WEALE'S

RUDIMENTARY

SERIES

45

LIMES AND MORTARS

PRICE 1/6

LONDON

LOCKWOOD & Co.

WEALE'S RUDIMENTARY, SCIENTIFIC, AND EDUCATIONAL SERIES.

The following are the Works already published in

CIVIL ENGINEERING, &c.

(*The Volumes are bound in limp cloth, except where otherwise stated.*)

CIVIL ENGINEERING, the Rudiments of; for the Use of Beginners, for Practical Engineers, and for the Army and Navy. By HENRY LAW, C.E. Including a Section on HYDRAULIC ENGINEERING, by GEORGE R. BURNELL, C.E. Illustrated with Plates and Diagrams. 5s.

... AND LANDS.

E. D. CHATTAWAY. 1s.

*** *With "Railway Construction," in one vol., 3s. 6d.*

EMBANKING LANDS FROM THE SEA, the Practice of. Treated as a Means of Profitable Employment for Capital. With Examples and Particulars of actual Embankments, and also Practical Remarks on the Repair of old Sea Walls. By JOHN WIGGINS, F.G.S. New Edition. 2s.

SUBTERRANEOUS SURVEYING, an Elementary and Practical Treatise on. By THOMAS FENWICK. Also the Method of Conducting Subterraneous Surveys without the use of the Magnetic Needle, and other modern Improvements. By THOMAS BAKER, C.E. Illustrated. 2s. 6d.

GAS-WORKS, and the Practice of Manufacturing and Distributing Coal Gas. By SAMUEL HUGHES, C.E. New Edition, revised by W. RICHARDS, C.E. Illustrated. 3s.

LOCKWOOD & CO., 7, STATIONERS' HALL COURT, E.C.

RUDIMENTARY TREATISE

ON

LIMES, CEMENTS, MORTARS,

CONCRETES,

MASTICS, PLASTERING, ETC.

BY GEORGE R. BURNELL, C.E.

"Legitimæ inquisitionis vera norma est, ut nihil veniat in practicam, cujus non fit etiam doctrina aliqua et theoria."—BACON.

Eighth Edition, with Appendices.

LONDON:
VIRTUE & CO., 26, IVY LANE,
PATERNOSTER ROW.
1869.

a. c.

s. c. lime
" cement
" mortar
" concrete

ADVERTISEMENT.

When the fifth edition of this treatise appeared in 1865, by way of making room for the closely-printed Appendix of Notes and the Index which were then added, not to increase the size of the volume "Notes on Concrete," by Lieut.-Col. Sir William Denison, Royal Engineers, and Governor of Madras, with remarks by Major-Gen. Sir William Reid, of the same branch of the service, were omitted. Both these gentlemen, whose great professional experience entitles any opinion of theirs to much respect, deprecate the use of concrete in situations exposed to the alternate action of water and air in a climate like ours, and adduce the decayed state of the river-walls at Woolwich and Chatham, as communicated by General Sir C. Pasley, R.E., resulting from severe frost and rapid thaw, as evidence in confirmation. On the other hand, the concrete blocks at Dover Harbour, and in the breakwater at Cherbourg, are shown to have answered perfectly. The *béton,* or rough rubble masonry, executed with cement or mortar by the Romans and during the middle ages, was, no doubt, very superior to our modern concrete, and though, on the whole, concrete has been found to answer admirably in some situations, in others it has failed as conspicuously. In Mr. Dobson's treatise on "Foundations and Concrete Work," which forms one of the volumes of this series, the reader will find an account of such *béton* works recently executed in the harbour of Algiers, which cannot fail to interest him.

These few words were necessary to account for re-inserting Sir William Denison's "Notes on Concrete," in the preliminary portion of the present volume, as some purchasers have expressed disappointment at their exclusion from the former edition.

August, 1867.

PREFACE.

The object the author of the following treatise has proposed to himself has been to put into as condensed a form as was consistent with the nature of the subject the knowledge and information dispersed through a numerous collection of authors who have treated thereupon. They are mostly in foreign languages; for it is much to be regretted that our own scientific authorities have not thought it worth their while to occupy themselves with this highly important branch of practical chemistry.

The author has endeavoured, as conscientiously as possible, to avoid any questionable theory, or to quote as practical results any cases of whose correctness reasonable doubts might be entertained. There are, it is true, some theories propounded, some practices recommended, which are in direct contradiction to those usually received in England. They have not, however, been so advanced, unless the long experience of the most distinguished foreign engineers has warranted him in believing that our own practice is based entirely upon prejudice. We are, whether for good or for evil, essentially a practical nation—we have a dislike to theory, almost to analysis—we examine reluctantly any habit we have long followed. As in politics, so we are even in building. Our forefathers made mortar in one way, as perfect as their knowledge admitted, and doubtlessly that way was all that was practically necessary to secure the results then sought for—so we continue without examination in the track they beat for us. Our requirements are, however, very different. Railroads, and the constructions they necessitate, have modified very materially the science of construction. In England, especially of late years, works have been executed which so immeasurably surpass in boldness anything which had been previously attempted, that we may be justified in expressing our surprise that so few attempts have been made to ascertain the real nature of the materials dealt with. Is it not to this neglect that we may attribute the numerous failures we read of?

Some of these failures have been so remarkable, and some recent business transactions have displayed so singular an inattention to the nature and properties of lime, that the author deems it his right to provoke a discussion upon the subject, trusting that abler heads and hands will complete what he has so imperfectly begun. This branch of chemical knowledge has been so entirely "revolutionised" of late, so much uncertainty still remains to overshadow it, that it would be worse than folly to make any assertion which would lead to a belief that even the very fundamental principles were not, even now, susceptible of modification. That which is to be desired above all things is to rouse the professions of engineers and architects from the apathy with which they treat such subjects as the one before us—the very alpha and omega of their business. There is, however, something so invidious in attacking openly a generally received opinion, as the author has done with respect to the mode of making mortar practised in this country, page 66 and subsequently, that he throws himself upon the consideration of his professional brethren, in the hope that they will excuse his boldness on the score of his sincere desire to advance the true interests of science.

At the same time the author would beg to protest very energetically against the "rule-of-thumb" methods which prevail in England in the manipulation of mortars. Architects and engineers, it is true, prescribe certain proportions of lime and sand to be employed; but in practice "the foreman of the pug-mill," as the labourers call the person entrusted with this work, is the only authority, and he mixes the ingredients precisely as it suits his fancy. In reality, mortar-making is a branch of practical chemistry—on a large scale, it is true—one which does not admit of the care and exactness of the laboratory. But the safety of a building often depends upon the perfection with which this operation is executed, and a certain amount of scientific acquirements is necessary to insure that perfection. For more than twenty-five years the author has been employed in building operations; but in the whole course of his experience he never saw in any construction, in England, a measure used to ascertain the proportions of the ingredients employed for making mortar.

We have seen of late years far too many accidents happen, too many absurdities committed, not to render it necessary to protest loudly against the carelessness with which the use of limes is regarded. One of the most important works executed of late years in London was built upon concrete made of stone lime, to which iron filings were added at a most tremendous and useless expense. Another large work was described in the specification to be executed with hydraulic lime; and the engineer allowed common Medway stone lime to be used, although it is very far from being what is properly called an hydraulic lime. We have known viaducts with piers 100 feet high executed with chalk lime; they have fallen, and been rebuilt with the hydraulic lime which only ought to have been employed; and we hear of pozzolana being used still in sea works. Surely, therefore, any examination of the nature of the materials to be used, which will hereafter prevent a repetition of such mistakes, must be of service.

The different scientific associations connected with building would confer a great boon upon the public if they would undertake a series of investigations upon the still undecided questions connected with the chemistry of their respective professions, and also if they would make a statistical statement of our mineral wealth, as far at least as building materials are concerned. We require a series of observations upon the geological and geographical distribution of the rocks able to furnish hydraulic limes. A synopsis of the building stones is also a desideratum; for the Parliamentary report upon the subject was very far indeed from being a satisfactory solution of its difficulties. Such an inquiry should be undertaken under the auspices of the united bodies of the engineers and architects.

CONTENTS.

LIST OF AUTHORS CONSULTED, AND OFTEN COPIED LITERALLY.

Vitruvius—De Architecturâ.
Plinius—Historia Naturalis.
St. Augustinus—Civitas Dei.
Philosophical Magazine.
Higgins on Calcareous Cements.
Knapp's Applied Chemistry (Translation).
Gmelin's Hand-Book of Chemistry.
Bischoff's Chemical and Theoretical Geology.
Quarterly Journal of Chemical Society.
Reports of Communications to Royal Institution.
Transactions of Royal Institute of British Architects.
Brande's Manual of Chemistry.
Ure's Dictionary of the Arts and Sciences.
Parnell's Applied Chemistry.
Pasley on Limes and Cements.
Smeaton's Account of Building Eddystone Lighthouse.
Godwin's Paper on Concretes. Trans. Brit. Arch.
Blondel—Cours d'Architecture.
Rondelet—L'Art de Bâtir.
Sganzin—Cours de Construction.
Vicat—Recherches sur la Chaux. Translated by Col. Smith, of the Madras Engineers.
Hassenfraz—L'Art de Calciner la Pierre Calcaire.
Treussart — Mémoires sur les Chaux et Ciments.
Claudel — Formules et Tables à l'Usage de l'Ingénieur.
Petot—Recherches sur la Chaufournerie.
Pelouze et Fremy — Abrégé de Chimie.
Dumas—La Chimie appliquée aux Arts.
Berthier—Traité des Essais par la Voie Sêche.
Encyclopédie Roret — L'Art du Chaufournier.
Les Annales des Mines.
Les Annales des Ponts et Chaussées.
Les Annales du Génie Militaire.
Les Comptes-Rendus de l'Académie des Sciences.
La Bibliothèque Universelle de Genève.
Les Annales de Chimie et de Physique.
Brard, Minéralogie appliquée aux Arts.
Kuhlman, Expériences Chimiques et Agronomiques.

NOTES ON CONCRETE.

BY LIEUT.-COL. SIR WILLIAM DENISON, ROYAL ENGINEERS.

The very general employment of the mixture of lime and gravel, commonly known by the name of concrete, in all foundations where, from the nature of the soil, precautions against partial settlements appear necessary, and the great probability of an extension of its use, in situations where the materials of which it is composed are easily and cheaply procured, must of course render it a subject of great interest to the engineer.

The paper which conveys information on this subject is an essay by Mr. G. Godwin. In this essay many instances are brought forward of the employment by the ancients of a mixture analogous to concrete, both for foundations and for walls. Several cases are also mentioned in which, of late years, it has been used advantageously for foundations by some of the most distinguished architects and civil engineers. In these latter instances, the proportion of the ingredients varies from one of lime and two of gravel, to one of lime and twelve of gravel; the lime being in most cases Dorking lime, and the gravel Thames ballast.* The proportion, however, most commonly used now, in and about London, is one of lime to seven of ballast, though, from experiments made at the building of the Westminster new Bridewell, it would appear that one of lime to eight of ballast made the most perfect concretion.

Concrete compounded solely of lime and screened stones will never assume a consistence at all equal to that of which sand forms a part. The north wing of Buckingham Palace affords an instance

* It is a question for consideration, whether a great variety of sizes in the materials used would not form the most solid as well as the hardest wall. The walls of the fortress of Ciudad Rodrigo, in Spain, are of concrete. The marks of the boards, which retained the semi-fluid matter in their construction, are everywhere perfectly visible; and besides sand and gravel there are everywhere large quantities of round boulder stones in the wall, from four to six inches in diameter, procured from the ground around the city, which is everywhere covered with them.—*Major-Gen. Sir W. Reid, R.E.*

of this. It was first erected on a mass of concrete composed of lime and stones, and when subsequent alterations made it necessary to take down the building, and remove the foundation, this was found not to have concreted into a mass.

Mr. Godwin states, as the result of several experiments, that two parts of stones and one of sand, with sufficient lime (dependent upon the quality of the material) to make good mortar with the latter, formed the best concrete. As the quality of the concrete depends therefore on the goodness of the mortar composed of the lime and sand, and as this must vary with the quality of the lime, no fixed proportions can of course be laid down which will suit every case. The proportions must be determined by experiment, but in no case should the quantity of sand be less than double that of the lime. The best mode of compounding the concrete is to thoroughly mix the lime, previously ground, with the ballast in a dry state; sufficient water being then thrown over it to effect a perfect mixture, it should be turned over at least twice with shovels, and then wheeled away instantly for use. In some cases, where a great quantity of concrete has to be used, it has been found advisable to employ a pug-mill to mix the ingredients; in every case it should be used hot.*

With regard to the quantity of water that should be employed in forming concrete, there is some difference of opinion; but as it is usually desirable that the mass should set as rapidly as possible, it is not advisable to use more water than is necessary to bring about a perfect mixture of the ingredients. A great change of bulk takes place in the ingredients of concrete when mixed together. A cubic yard of ballast, with the due proportion of lime and water, will not make a cubic yard of concrete. Mr. Godwin, from several experiments made with Thames ballast, concludes that the diminution is about one-fifth. To form a cubical yard therefore of concrete, the proportion of lime being one-eighth of the quantity of ballast, it requires about thirty cubic feet of ballast, and three and three-quarters cubic feet of ground lime, with sufficient water to effect the admixture.

An expansion takes place in the concrete during the slaking of the lime, of which an important use has been made in the underpinning of walls. The extent of this expansion has been found to

* It is stated that the setting of ordinary lime results from the absorption of carbonic acid gas from the atmosphere. That the limes of mortars become sooner or later carbonates is most certain, but there is no proof that this is the cause of their cohesion; indeed, there is every reason to doubt it. It is more probable that new attractive properties are acquired at the moment that hydrates of lime are formed from calcined lime and water, when in close union with silex, alumina, and some other substances, and that the properties first acquired at that time do not cease immediately, but continue, if undisturbed, for ages.—*Major-Gen. Sir W. Reid, R.E.*

amount to about three-eighths of an inch to every foot in height, and the size thus gained the concrete never loses.

The examples from which the above rules are deduced are principally of buildings erected in or about London; the lime used is chiefly from Dorking, and the ballast from the Thames. It is very desirable that a more extended collection of facts should be made, that the proportions of the materials, when other limes and gravels are used, should be stated, in order that some certain rules may be laid down by which the employment of concrete may be regulated under the various circumstances which continually present themselves in practice.

The Dorking and Halling limes are slightly hydraulic. Will common limes, such as chalk and common stone-lime, answer for forming foundations of concrete, where the soil, although damp, is not exposed to running water? Is it possible, even with hydraulic lime, to form a mass of concrete in running water? * If common lime will not answer, may it not be made efficient by a slight mixture of cement? These, and questions similar to these, are of great interest; and facts which elucidate them will be valuable contributions to the stock of knowledge on this subject.

Description of the Method adopted by Mr. Taylor, for Underpinning with Concrete the Storehouses in Chatham Dock-yard.

One of the large storehouses in Chatham dock-yard having for some time exhibited serious defects in its walls, the attention of the Admiralty was directed to it in the year 1834, and Mr. Taylor, the civil engineer and architect, was directed to report upon the best mode of obviating the evil.

Upon investigation, the foundation of the storehouse (a building 540 feet in length, and 50 in breadth) was found to be in a very bad state; the front wall, nearest the river, had originally been built upon piles, while the rear wall was laid upon an upper stratum of five or six inch plank, supported by two rows of transverse and

* As all *limes* are soluble, more or less, in fresh water, this seems very doubtful. Any attempt to check a spring, or stop the course of running water with fresh concrete, will certainly fail. An instance of this was seen at Chatham, in constructing a dock: in the floor of the dock were several springs, which, in spite of every attempt to check them with concrete, continually made their way to the surface, and in every case it was found that the lime had been washed away from the mass, leaving only the gravel and sand behind. Eventually it was found necessary to carry away the water in an iron pipe, and discharge it into the drain outside the dock. Mr. Godwin states, that the dock at Woolwich failed from using separate moulded masses of concrete, instead of employing it as one whole. In this case, had separate masses been used, and laid in cement, the work might have been carried on, though it might perhaps have failed eventually, from the solubility of the lime in fresh water affecting the blocks.—W. D.

longitudinal oak sleepers lying on the surface of the ground, which in this case was of a variable consistence, containing flints bedded in a sort of clay, quite pervious to the water, which at high tide rose some height upon the foundation. The sleepers and heads of the piles at the front of the building, thus exposed to alternate moisture and dryness, were in a state of rapid decay; in some places they were even reduced to a powder; and it was possible for a man to move under the walls in the space previously occupied by the timber. In the rear, the case was pretty much the same; the sleepers were universally in a state of decay, but in some places were much further advanced towards decomposition than in others.

The state of the storehouse requiring immediate attention, it was resolved to attempt to underpin the walls. This the patentee for the new description of concrete, or artificial stone, undertook to do, having adopted a plan proposed by Mr. Taylor, for forcing the soft concrete against the under part of the wall; and he proceeded to execute his contract in the following manner.

I must premise, that the storehouse was vaulted underneath, and that the piers, or cross walls, required as much underpinning as any other part of the building.

The walls were laid open to their bottom, both inside and outside the building; in the front, the heads of the piles and the sleepers were removed for a depth of about four feet below the bottom of the wall, and for lengths of about five feet at one time. In the rear, all the planks and sleepers were removed for the same distance. A mass of concrete, composed of one-eighth of Halling lime (reduced to a powder by grinding, and in a perfectly caustic state), and seven-eighths of Thames ballast, mixed up with so much boiling water as to reduce the whole to a pasty consistence, was then thrown from a height of about fifteen feet underneath the wall: it was allowed to project about a foot on each side, where it was confined by planks, and after being roughly levelled, it was well rammed, to give it as much consistence as possible. This mass was raised about three feet, or to within one foot of the bottom of the wall; it was then carefully levelled, and covered with half-inch slates. A kind of framework was then placed on the slates, consisting of two cross-plates of iron, placed perpendicularly to the direction of the wall, about one foot wide, and long enough to project about one foot on each side of the wall.

To these were fixed two frames parallel to the wall, about four feet long, each carrying two sockets for screws. Within these frames were placed two movable planks, long enough to pass just free between the cross-plates, and wide enough to fit nearly the space between the slates and the bottom of the wall. Upon these planks were sockets for the heads of the two screws, by which the planks were pushed forward, or withdrawn at pleasure.

When the apparatus was fixed, and the movable planks ready on both sides of the wall, about two barrowfuls of concrete, mixed as stated, were thrown in from above; the workmen below then commenced turning the screws on each side simultaneously, moving the two planks towards the centre of the wall, and forcing the concrete before them into all the vacant spaces, and against the bottom of the wall. When the plank was forced forward as far as it would go, by the strength of two men to each screw, the concrete was allowed to rest for about five or ten minutes, by which time it had set hard enough to stand by itself, and its expansion in the act of setting completed what the pressure of the screws might have left undone. The planks were then withdrawn, another charge thrown in on each side, and compressed as before, and this was continued till the whole space between the frames was filled with concrete. The screws were then removed, the boards and frames unbolted and taken out, and lastly, the side-plates were withdrawn, leaving an interval of about three-quarters of an inch between each mass of concrete, which space was afterwards filled in with grout.

The above description is given from notes taken at the time. The proportion of lime to gravel is as one to six; and such is the efficiency of the concrete in the mode in which it was applied, that no settlement has taken place since the work was completed.

Again, circumstances have caused me, since the foregoing was written, to pay particular attention to the application that has been made of late years of concrete, or artificial stone, to the various purposes of construction; and I shall now briefly state the experiments that I have made or witnessed on this subject, and the conclusions that may be fairly deduced from the results of these experiments.

The first experiment was made with the view of ascertaining whether a mass of concrete made with Aberthaw lime would resist the chemical action of water: for this purpose a small block, which had been prepared for nearly two years, was immersed for some time in distilled water, and upon applying the proper test to the water, it was found to have combined with a portion of the lime in the block. Having mentioned this circumstance to Sir M. Faraday, he suggested that it was probable the block contained a quantity of lime in an uncombined state; and recommended that it should be placed in a running stream for some time, in order to wash it thoroughly: this was accordingly done, by suspending the block for two months under a hulk in the river, after which, having again soaked it in distilled water for a week, hardly any trace of lime could be detected in the water by the application of the most delicate tests. This experiment then appears to prove that concrete, composed of proper materials (hydraulic lime and gravel), does not suffer by the chemical action of water. Experiment No. 2 was made in order to ascertain the strength of a block of concrete 2 ft. 6 in. long, 1 ft. 6 in. broad, and 1 ft. deep, which had been made for two years, and would have been used as a stretcher in the river wall at Woolwich. A shackle was placed round the centre of the block, and two others at the extremities, at the distance of $11\frac{1}{2}$ inches each from the centre: a force being applied to the two end shackles by means of the hydraulic press, the block broke in the centre, under a strain of 4 tons 11 cwt. I did not prosecute the experiment upon the strength of this material any further, having sent down some blocks to Gen. Sir C. Pasley, R.E., who had investigated the same subject, and the results of the experiments are as follows:—

Three stones, each 3 feet long, 18 inches wide, and 15 inches deep, were supported upon props 27 inches apart; weights being then applied to the centre of each, the first broke with 6,285 lbs., the second with 5,141 lbs., and the third with 2,930 lbs. This last had probably some flaw; taking therefore the mean of the two first only, the result will be 5,713 lbs.

A piece of York paving, $7\frac{1}{2}$ inches deep, 13 inches wide, and the same distance (27 inches) between the supports, broke with a weight of 13,512 lbs. The value of the constant *S*, in these two cases, deduced from the formula $S = \frac{l\,w}{4\,b\,d^2}$ will be for concrete 9·5, and for York paving 124·7, being about in the proportion of 1 to 13.

The experiments I have had the opportunity of witnessing, and which offer by far the most instructive results, have been the practical application of concrete to the construction of river walls at Woolwich and Chatham. In one instance, at Woolwich, it has been applied in mass, the wall having been constructed in the same manner as the Brighton sea-wall: in both the other instances at Woolwich and Chatham, the concrete was formed into blocks, which were allowed ample time to set and harden before they were built into the face of the wall.

At Woolwich the river-wall is for the most part founded upon piles; its height above the piles is about 24 feet, the thickness at bottom 9 feet, at top 5 feet, with a slope or batter in front of 3 feet in 22: the face of this wall is composed of the above-mentioned blocks, which are laid in cement, in courses 1 ft. 6 in. in height, the headers and stretchers in the course being each 2 ft. 6 in. long, the former having a bed of 2 feet, while the latter have only 1 foot; behind the facing the rough concrete is thrown in to complete the thickness of the wall and counter-forts. Both the blocks and the rough concrete are composed of lime and gravel, in the proportion of 1 to 7, and brought to the proper consistence with boiling water; but the blocks are, or ought to be, made with

Aberthaw lime, while Dorking lime is used for the rest of the work. The blocks are cast in moulds, and are submitted to pressure while setting: a coating of finer stuff is given to the face for the sake of appearance. The whole of the wall is built by tide work, and in the lower part therefore the backing of rough concrete has hardly time to set before it is covered by the tide; the water, however, in this instance, appears to affect the surface of the mass only, the interior, at the depth of a few inches, being generally speaking dry, and of a moderate degree of hardness when examined after the retirement of the tide.

During the summer the action of the water from day to day upon the facing of the river-wall was not perceptible; the surface still remained moderately hard; occasionally portions of the fine facing separated from the rest of the block, owing, it was said, sometimes to want of care in the original construction, sometimes to injuries caused by boats or vessels striking the wall: in these cases, however, a new facing of cement was applied, and before the winter the general appearance of the wall was to a certain extent satisfactory.

During the hard frost, however, evidences of failure began to show themselves; and as soon as the thaw allowed a thorough inspection of the face of the wall to be made, it was found that hardly a single block had escaped without some damage; in many instances the whole face had peeled off to the depth of half an inch; and at one spot, where a drain discharged itself into the river from a height of about six or eight feet, the back action of the water after its fall had worn away the lower courses to the depth of some inches: these were the evidences of the action of frost and water combined upon the best constructed wall at Woolwich. At Chatham they were of the same character, but the damage done to the wall was much greater.

The portion of river-wall at Woolwich which was built with rough concrete had been severely injured by the common action of the water before the frost; and the latter has only caused the destruction of the face to proceed with greater rapidity. Since the frost I have examined the walls of a school near Blackheath, which was built with concrete some years ago: I found that at the ground line, where the drip of the water had acted, the concrete was soft, and yielded easily to any force applied, while the walls above were very fairly hard, and seemed to have stood very well.

These then are the facts I have to submit; and I think they afford sufficient grounds for asserting, that in climates like ours, in situations exposed to the alternate action of water and air, concrete cannot be advantageously used as a building material, the apparent economy, caused by the cheapness of the material employed, being more than compensated for by the frequency of repairs. From the circumstance that at Chatham some of the blocks remain to a certain extent uninjured, whilst others close to them, and exposed to exactly the same action, are completely decomposed, one would be tempted to infer that proper caution had not been used in the selection of the lime of which the latter were composed; and that had Aberthaw lime been used throughout, the damage would not have been near so great. But even in this case, although the frost might not have produced so much effect upon the work, and should concrete be considered perfectly impervious to chemical action, yet the want of tenacity, or of power to resist a very trifling force, renders it peculiarly inapplicable to situations where, as in wharf-walls, it will be exposed to damage from the collision of vessels and floating bodies, in addition to the constant mechanical action of the water. Where, however, it is protected from these causes of destruction, as in foundations, its value is unquestionable; and even in the backing of retaining walls, revetments, &c., it may in many cases be advantageously applied, taking care to allow it time to set before any great pressure is thrown upon the wall. The specific gravity of concrete is from 120 to 130, about the same as that of brickwork.

W. DENISON, Lieut.-Col. R.E.

ON LIMES, CALCAREOUS CEMENTS,

MORTARS, STUCCOS, AND CONCRETES.

CHAPTER I.

CURSORY VIEW OF THE PROGRESS OF DISCOVERY IN THE SCIENCE CONNECTED WITH LIMES, ETC.

The use of some cementing material to bind together the small stones or other materials employed in the construction of walls, and also for the purpose of giving them a smooth surface adapted to receive polychromic or other decoration, dates from a very high antiquity. It is, however, probable that it was subsequently to the discovery of the art of brickmaking, that the ancients arrived at that of burning lime. Indeed, the use of moistened clay, which was found to have a certain ductility, and to harden also in drying, was likely to have preceded that of lime, as a cement; for the qualities and the mode of obtaining the latter were of a nature to require long study and great experience.

The Assyrians and Babylonians appear to have employed either moistened clay, or the bitumen so plentifully supplied by the springs in their country. Some doubt, however, exists as to whether these people did ever really use mortar. Captain Mignan sometimes talks of bricks which were cemented together with a coarse layer of lime. "At others," he says, that "between the brickwork at irregular distances a layer of white substance is perceptible, varying from $\frac{1}{4}$ in. to 1 in. in thickness, not unlike burnt gypsum or the sulphate of lime. From the peculiarly mollified state of the bricks I apprehend this white powder is nothing more than common earth, which has undergone this change by the influence of the air on the clay composing the bricks."

The Egyptians, however, used mortar in the construction of their pyramids; and Mr. Cresy has given an analysis of that employed in the construction of the pyramid of Cheops, which shows that they possessed nearly as much practical knowledge of the subject as we do at the present day. (*Theory and Practice of Engineering*, pages 717 and 718.)

Sir Gardner Wilkinson also mentions that the interiors of some of the pyramids were stuccoed, but he does not give any description by which we might even guess at the nature of the materials employed.

The Greeks, at a very early period of their civilization, used compositions, of which lime was the base, to cover the walls constructed of unburnt bricks. According to Plinius and Vitruvius, the palace of Crœsus, the Mausoleum, and the palace of Attalus were protected, or ornamented, in this manner. According to Strabo, the walls of Tyre were built of stone set with gypsum, a very common material apparently in Asia Minor, and the centre of the old Assyrian civilization.

In Italy the first people who employed mortar in their buildings were the Etruscans. Gori, in his *Museum Etruscum*, mentions that in the tombs found near their ancient cities, such as Iguvium, Clusium, Volterra, the constructions were made with mortar. Near Volterra also, in 1739, a cistern, entirely built and lined with that material, was discovered. A branch of this nation, known under the name of Tyrrhenians, were considered by the Greeks to have invented, or at least considerably improved, the art of masonry. The most ancient authors, such as Homer, Hesiod, Herodotus, and Thucydides, speak of them under that name, and call their walls by the word "tyrsis," instead of "teichos," the one used by the more modern authors. The word "tyrsis" is supposed to have had the same signification in the Etruscan language; and the towers erected for the purpose of fortification were also called "tyrseis" by the Greeks.

The Romans, as is well known, derived all their knowledge of the arts either from the Etruscans or the Greeks. They added little to the general stock of knowledge as to the use of limes, but Vitruvius is the first author upon the subject whose works have descended to us. The text of this remarkable man's work shows that the ancients, although they adopted a different scientific phraseology from that in fashion in the 18th century, knew as much of the laws regulating this branch of chemistry as the moderns of that time. For all practical purposes Vitruvius is even now as safe a guide as most of the authors who treated the subject subsequently; at least until we arrive at the researches of M. Vicat. (See *Vitruvius*, book ii., ch. 5.)

Plinius and St. Augustin treat occasionally about limes and cements; the former, principally to complain of the malpractices of the builders; the latter, to seek metaphysical comparisons. On the revival of literature, after the Cimmerian darkness of the middle ages, which it is now so much the fashion to admire, the authors who treated upon the art of building, such as Alberti, Palladio, Barbaro, Philibert de l'Orme, Scamozzi, Savot, Bullet, and Blondel, did little more than follow in the traces of Vitruvius. There was a difference of opinion, it is true, as to the quality of sand which it was most advisable to use: some new limes, some puzzolanos, terrass, and ashes, were employed to give to certain other limes the faculty of setting under water: but until about the middle of the last century no advance seems to have been made towards ascertaining the principles which regulate this branch of chemistry.

It is, indeed, worthy of remark, that the more useful arts appear to be carefully studied until the practical results they are capable of producing are ascertained: then the rules drawn from such results are received implicitly for a long period, and any attempt to ascertain the laws which regulate them is regarded as useless. We, the human race, appear to attain empirical knowledge quickly; scientific knowledge arrives at a much later period. So it was with limes: so it is with the casting and puddling of iron—a subject equally, if not more, interesting.

The first serious attempt made to ascertain the causes which gave some limes the power of setting under water, and which modified their rates of hardening, was made by the father of civil engineering in England, John Smeaton, in 1756. Being at that time engaged in the construction of the Eddystone Lighthouse, he found it necessary to have a cement capable of hardening at once in the water; he therefore began a series of experiments, which are detailed in his account of the building of that work; book iii., chap. 3. The results he arrived at were very remarkable, not only for their practical utility, but also as an illustration of the ease with which a very acute observer may stop short on this side of the attainment of a great truth. Smeaton found that the commonly received opinion that the hardest stones gave the best limes, was only true as far as regarded each quality considered by itself. That is to say, that of limes not fit to be used as "water cements," those made of the hardest stones were the best for certain uses in the air; but that whether obtained from the hardest marble, or the softest chalk, such limes were equally useless when employed under water. He found that all the limes which could set under water were obtained from the calcination of such limestones as contained a large portion of clay in their composition. His experiments led him to use, for the important work of the lighthouse, a cement compounded of blue lias lime from Aberthaw, and of puzzolano brought from Civita Vecchia, near Rome. Even at the present day it would be difficult to employ a better material than this, excepting that the price would ensure a preference to the Roman cement, then unknown. But Smeaton, after giving a table showing that all the water limes were obtained from limestones containing clay in chemical combination, in proportions varying from $\frac{3}{14}$ to $\frac{1}{17}$, goes on to say, "that it remains a curious question, which I must leave to the learned naturalist and chemist, why an intermediate mixture of clay in the composition of limestone of any kind, either hard or soft, should render it capable of setting in water in a manner no pure lime, I have yet seen, from any kind of stone whatsoever, has been capable of doing. It is easy to add clay in any proportion to a pure lime, but it produces no such effect: it is easy to add brick dust, either finely or coarsely powdered, to such lime in any proportion also; but this seems unattended with any other effect than what arises from other bodies become porous and spongy, and therefore absorbent of water as already hinted, and excepting what may reasonably be attributed to the irony particles that red brick-dust may contain. In short, I have as yet found no treatment of pure calcareous lime that rendered it more fit to set in water than it is by nature, except what is to be derived from the admixture of trass, puzzolano, and some ferruginous substance of a similar nature."

The stress Smeaton laid upon the presence of the ferruginous substance, led many chemists to attribute the hydraulicity of limes to the presence of the oxide of iron. Guyton de Morveau and Bergmann, finding the oxide of manganese in the hydraulic limes they analyzed, regarded it as producing the effect in question. Their researches were nearly contemporaneous with those of Smeaton. Thirty years afterwards, De Saussure observed that the lime of the Chamouni set under water, though entirely without manganese; and he, therefore, like Smeaton, attributed this faculty to the presence of clay. In 1813, Colets Descotils, on analyzing the compact marl of Senonches, which yields on calcination a lime capable of setting rapidly under water, found in it nearly one quarter of silex, which led him to the conclusion that the cause of the phenomenon consisted in the presence of a large quantity of siliceous matter, disseminated in very fine particles in the tissue of the stone itself.

To continue the quotation from Vicat: "The opinion of Descotils did not weaken or invalidate that of De Saussure, since clay contains generally more silex than alumina; and the two chemists agreed, moreover, in considering the oxide of manganese, if not as a useless element, at least as one which was not essential. This was the state of the question in 1813; and it was with the intention of putting an end to all doubts upon the subject that I decided at that epoch to proceed synthetically, and to compose hydraulic limes entirely, by burning different mixtures of common lime, slacked spontaneously, with clay: the success surpassed my hopes. All the clays, rich and soft to the touch, gave the same results; my experiments were repeated in Paris, in 1817, with the limes of Cleyes and of Champigny, and the clay from Vauvres; further experiments, by Mr. St. Leger, in England, and by M. Raucourt de Charleville, in Russia, confirmed the results previously obtained."

The subsequent researches of the most eminent chemists and engineers must be considered to have confirmed the theoretical opinion which guided Vicat in his experiments, with a few recent but important rectifications of detail.

Berthier, Dumas, Hassenfraz, Treussart, Thénard, Gay Lussac, Petôt, Sganzin, Girard, Parandier, Minard, Kuhlmann, in France—John of Berlin, and Fuchs of Munich—Pasley, Ansted, and Way, in our own country—as well as most of the scientific authors who have treated upon the subject throughout the globe—have arrived at nearly the same conclusions as Vicat with respect to the causes which influence the different actions of lime.

The following condensed statement of the usually received theory may, therefore, be taken as representing the actual state of this branch of chemical and engineering science.

CHAPTER II.

CHEMICAL THEORY OF THE ACTION OF LIMES, AND THEIR CLASSIFICATION.

Pure lime, or calcium, as regarded in chemistry, is a metallic oxide, having strong alkaline properties. It is caustic, and turns green the vegetable blues. Its specific gravity, according to Kirwan, is 2·3; according to Berzelius, its atomic weight is 20·5; according to Dumas, it is 20. It is very difficult of fusion, but greatly assists the fusion of other earthy bodies. At an ordinary temperature, pure water can dissolve $\frac{1}{772}$ of its own weight of lime; but, when boiling, it dissolves less. Dr. Dalton states that water at the following degrees of the centigrade scale will dissolve the following proportions of lime, and of its hydrate; viz.,

At 15° 5	centigrade	it dissolves	$\frac{1}{772}$	of lime, and	$\frac{1}{384}$	of the hydrate.
,, 50° 0	,,	,,	$\frac{1}{972}$	,,	$\frac{1}{729}$	,,
,, 100° 0	,,	,,	$\frac{1}{1270}$	,,	$\frac{1}{952}$	,,

The pure metallic base never occurs in nature, nor does pure lime, its protoxide. If the pure lime were exposed for a period, however short, it would absorb the water and carbonic acid gas of the atmosphere. We therefore find it in the state of the bi-carbonate, the carbonate and subcarbonate, of lime, in which it is very extensively diffused. The lime of commerce is obtained by the calcination of these carbonates, and the process consists in driving off by heat the carbonic acid gas which is in combination.

The minerals which contain the carbonate of lime, and which are designated under the generic name of "limestones," or "calcareous stones," are of very various natures. They are mostly composed of carbonate of lime, of magnesia, of oxide of iron, of manganese, of silica, and of alumina, combined in variable proportions; and they are also found with a mechanical admixture of clay (either bituminous or not), of quartzose sand, and of numerous other substances. The name of limestone is more especially applied to such of the above mixtures as contain at least one half of their weight of carbonate of lime. Mineralogists distinguish the subdivisions by the names of the "argillaceous, magnesian, sandy, ferruginous, bituminous, fetid," &c. These subdivisions, again, are often characterized by varieties of form and contexture, which are known specifically under the names of "lamellar, sacchroid, granular, compact, oolitic, chalky, pulverulent, pseudomorphic, concreted," &c., &c.

This nomenclature is important; for every description of limestone yields a lime of different quality, distinct in colour and weight, in its avidity for water, and especially in the degree of hardness it is capable of assuming when made into mortar. But the physical and mechanical nature of a stone are far from being certain guides as to the quality of the lime it can yield. A chemical analysis of a hand sample also frequently gives different results from those obtained in practice.

Experience alone should be the final guide of the engineer or of the builder.

The carbonate of lime occurs in nearly all the geological formations, but it is scarce in the primary ones. In the transition rocks it is more abundant; and it constitutes the great mass of the secondary and tertiary formations. It is worked largely, either for the purpose of obtaining building stones, or for burning for lime. The calcareous rocks of the primary formations, and of the early transition series, furnish the greater number of stones which are worked under the name of marbles. The secondary and tertiary calcareous rocks contain the mixtures of clay and other ingredients which render them the most adapted to furnish limes.

After a calcination sufficient to disengage the carbonic acid gas, the limestone will be found to have diminished considerably in weight, and the resulting material possesses the property of absorbing water, either with or without a disengagement of heat. It cracks and falls to pieces whilst thus combining with the water, or slacking, as the workmen call the process of passing into the state of a hydrate of lime.

The principal characteristics of the hydrate of lime are that it is white and pulverulent; much less caustic than quick lime. It parts easily with the first portions of its water of combination if exposed to fire, or even to mere friction; but it requires a very high degree of heat to cause it to part with the whole of the water. There is still a great degree of uncertainty as to the chemical action of the hydrates. Generally speaking, they are considered not to absorb oxygen; but Treussart supposes that they do so, and that they undergo important modifications in consequence. The quantity of water that limes solidify in passing to the state of hydrates, is also a question upon which much doubt exists amongst chemists. Berzelius supposed that the hydrates were formed of water and the metallic oxides, in such proportions as that the quantity of oxygen contained in the water should be equal to the oxygen contained in the oxide. Thus, the hydrate of lime absorbs carbonic acid gas from the air, or even (with the best limes) from water, if immersed therein; and after a period, varying with the nature of the limestones from which it is prepared, it solidifies with an imperfect crystallization. Whilst passing into this state, 100 parts of pure lime, which contain 28·16 parts of oxygen, Berzelius supposes to combine with 32·1 parts of water, which contain also 28·3 of oxygen. Thénard, however, does not admit this law to hold in all cases; and certainly some of Treussart's experiments would induce us to hesitate before we admit it. The hydrates, under the action of the voltaic pile, assume the same action as the oxides. Bodies capable of decomposing water, always acts upon them, even upon such as heat does not affect; acids also decompose the hydrates when these are produced from the oxides of mineral bases.

If, for the purposes of classification, we observe the phenomena which attend the slacking and hardening, or, to use the workman's phrase, the setting of lime, we find that they may be ranged in the following order. The lime in these experiments is supposed to be perfectly fresh, and is to be immersed in a small basket, in perfectly pure water, for the space of five or six seconds only. It is then to be allowed to dry, or at least the loose uncombined water is allowed to run off, and the contents of the basket are then emptied into a stone or iron mortar.

1. The lime hisses, crackles, swells, gives off a large quantity of very hot vapour, and falls into powder instantly: or,

2. The lime remains inert for a period of variable duration, but which does not exceed five or six minutes; after which the phenomena above described declare themselves energetically: or,

3. The lime, again, remains inert for five or six minutes, or the period of its inactivity may extend to a quarter of an hour. It then begins to give off vapour and to crack, without decrepitating to any great extent. The steam formed is less abundant, and the evolution of heat is less than in the two former cases: or,

4. The phenomena only commence an hour after the immersion of the lime, and sometimes even after a lapse of time still more considerable. The lime cracks, without decrepitation, it gives off little steam or heat: or,

5. The phenomena commence at epochs which are very variable, and in fact hardly perceptible; the heat given off is only distinguishable by the touch; the lime does not fall easily into powder, and at times it does not do so at all.

Before the effervescence has entirely disappeared, the slacking of the lime should be completed. As soon as the cracking and falling to pieces begin, water should be poured into the vase, not upon the lime, but by the side, so that it may flow freely to the bottom, from whence it would be absorbed by the portions of the lime in a sufficiently advanced state of chemical action to require it. The compost should be frequently stirred, and sufficient water should be added, taking care not to flood the lime, but merely to bring it to the consistence of a thick paste.

Thus prepared, the lime should be left to itself until all the inert particles have had time to complete their action. The end of this is announced by the cooling of the mass, and it may last from two to three hours, or sometimes even more.

The limes should then be beaten up again, and water added, if necessary, until a paste be obtained as firm as possible, but at the same time preserving a certain degree of ductility. Its consistence should be equal to that of clay ready to be worked into pottery. A vase should then be taken and well filled with this paste; it should be marked and immersed in water, taking note of the day and hour of the immersion.

Careful observations made upon the limes thus treated show that they may be divided into the five following classes, characterized by the phenomena before described: namely, 1, the rich limes; 2, the poor limes; 3, the limes middlingly hydraulic; 4, the hydraulic limes; and, 5, the eminently hydraulic limes.

Smeaton and the bulk of the English engineers use the term *water* lime instead of *hydraulic;* but it appeared to me advisable, for the sake of uniformity of nomenclature, to preserve the one adopted throughout the Continent. It is, then, to be understood that wherever the term hydraulic lime occurs, it signifies the same as that of water lime, and means one which possesses the property of setting under water.

1. The *rich* limes are the purest metallic oxides of calcium we possess, and the purer the carbonate of

lime from which they are obtained, the more distinctly marked are the appearances from which they derive their name. These are, that they augment in volume to twice their original bulk, or even more than that, when slacked in the usual manner. If employed by themselves without any admixture of foreign substances, their consistency, even after many years of immersion, is the same as on the first day. If exposed to pure water frequently renewed, the very last particle would be taken up in solution by the water.

2. The *poor* limes are those which either do not augment in bulk at all, or only do so to a very trifling extent, when slacked. They do not harden under water more than the rich limes, and are acted upon by that agent in the same manner, excepting that they leave a small residuum without consistence.

3. The middlingly hydraulic limes set under water after from fifteen to twenty days' immersion, and continue to harden for some time afterwards; but the progress of their hardening diminishes after the sixth or eighth month; after a year their consistence is equal to that of dry soap. They dissolve, but with difficulty, in frequently renewed pure water. The change of bulk they undergo in slacking is the same as that of the poor limes, but never equal to that of the richer varieties.

4. The hydraulic limes set after from six to eight days' immersion, and continue to harden; the progress of this solidification may extend to twelve months, although the greater part of it is completed by the end of the first six. At this last epoch the lime is already of the consistence of the softer building stones, and the water in which it is immersed is no longer able to dis-

solve it, even when renewed. Its change in bulk in slacking is about the same as that of the poor limes.

5. The eminently hydraulic limes set within the third or fourth day of their immersion. After a month they are already quite hard, and capable of resisting the dissolvent action of running water. At the end of six months they are capable of being worked like the harder natural limestones, and present a fracture closely resembling that of the latter. Their change in bulk is invariably as small as that of the poor limes.

It is to be observed that all the qualities of lime, whether rich, poor, or hydraulic in any degree, assume indifferently every kind of colour. They may be either white, grey, yellow, buff, or red, without any corresponding change in their quality, as far at least as our present knowledge of the art of lime-burning will allow us to assert with any degree of certainty. We shall have occasion to revert to this question of the colour of limes when we treat of their calcination in a subsequent chapter.

CHAPTER III.

ON THE CHEMICAL NATURE AND GEOLOGICAL POSITION OF THE STONES WHICH FURNISH THE DIFFERENT SORTS OF LIME.

A CHEMICAL examination of the stones which furnish the different limes of the preceding classification, shows that the pure calcareous rocks, or such as contain only from 1 to 6 per cent. of silex, alumina, magnesia, iron, &c., either separately or in combination, give rich limes upon being burnt.

2. The limestones containing insoluble silica in the state of sand, magnesia, the oxides of iron and of manganese, in various respective proportions, but limited to between 15 to 30 per cent. of the whole mass, yield poor limes.

3. The limestones containing silica in combination with alumina (common clay), magnesia, and traces of the oxides of iron and of manganese, in various respective proportions, but within the limits of from 8 or 12 per cent. of the whole mass, yield moderately hydraulic limes.

4. When the above ingredients are present in the proportion of from 15 to 18 per cent., but the silica in its soluble form always predominating, the limestones yield an hydraulic lime.

5. When the limestones contain more than 20 and up to 30 per cent. of the above ingredients, but with the soluble silica in the proportion of at least one-half of them, the limestones yield eminently hydraulic limes.

The experiments upon which the above conclusions are based appear to show that limes owe their hydraulicity, or power of setting under water, to the presence of a certain quantity of clay, and sometimes, but rarely, to that of a certain quantity of pure soluble silica. It is supposed that during the calcination silicates of lime and alumina are formed, with an excess of lime; these in slacking absorb a quantity of water, and solidify in combining therewith; and the double salt being insoluble in water, the compound remains therein without decomposing, or at least it only yields the small proportion of lime which might have existed in excess in their combination.

In the actual state of our chemical knowledge it is impossible to say whether there exist any definite proportions either of silica alone, of silica and alumina, of silica or magnesia, &c., which are capable, when mixed with the same quantity of pure lime, of producing hydraulic limes of similar qualities. Indeed, the whole of this branch of chemistry, notwithstanding the important discoveries made in it of late years, is still very little understood. The action of the oxide of iron, for instance, quite escapes the attempts made to include it within any law. Berthier found that a mixture of 4 parts of chalk with 1 of ochre, containing 0·07 parts of oxide of iron, gave a very bad lime, one incapable of hardening under water. Yet we know that the Sheppy stone contains 0·086 of the same oxide, and the Boulogne cement stone contains as much as 0·15 ; both of these, as it is generally known, do set under water, not only with rapidity, but with a great degree of hardness. Treussart burnt a mixture of chalk and iron filings from a blacksmith's shop, of chalk with the black and the brown oxides of iron, at different degrees of calcination, of chalk and steel filings, but he only obtained rich limes without any degree of hydraulicity. Smeaton, however, had previously obtained different results, for he states that minion, a calcined iron ore, obtained from the outside of the nodules of the stone after the first roasting, communicated in a very great degree the power of setting under water to rich limes. He adds, in a note worthy of particular attention, that the "minion is supposed by Mr. Mitchell to be what falls from the outside of the iron stone, and therefore containing more clay."

The action of the magnesia seems also involved in the same obscurity. M. Parandier tried some experiments in which he mixed chalk with pure magnesia, but he only obtained very feebly hydraulic limes. Dumas states positively, that if more than 10 per cent. of magnesia be present, the limes begin to become poor; and that with 25 per cent. they become decidedly poor. Berthier, however, gives an analysis of the lime obtained from a mixture of the stone of Villefranche, near Paris, with dissolved silica, in the proportion of 5 of the stone to 1 of the silica, in which mixture the lime appears in the form of a carbonate, to the amount of 0·609

The carbonate of magnesium .	0·301
,, of iron . . .	0·030
,, of manganese . .	0·060
Total	1·000

The lime thus obtained became much harder under water than any even of the natural hydraulic limes. Again, when the magnesian limestones, found nearer Paris, are mixed with one-fifth of their bulk of soluble siliceous matter, they yield a lime still more energetic in its hydraulic properties than that above described, although the carbonate of magnesia is present in the proportion of 23 per cent.

Vicat, in an article inserted in "Les Annales des Ponts et Chaussées," upon the magnesian limestones, endeavoured to resume our knowledge of the subject; but his conclusions are far from satisfactory, and there still remains a doubt upon the action of the magnesia, which it were much to be desired that modern chemists should remove. He says, that "without clay, that is to say, without silica, limes cannot be decidedly hydraulic. The different combinations I have tried, by mixing pure chalk and magnesia, have only produced limes susceptible of setting in the commencement, without any ulterior progress; but this solidification, imperfect though it be, denotes in the magnesia certain hydraulic properties which the alumina itself does not possess. If, then, some portions of clay be present, it might happen that a triple-hydrate, of lime, of alumina, and of magnesia, might be formed, which should possess all the conditions of hardness and of progression which characterize the best hydraulic limes."

He further states that two species of limestones which were found to contain respectively, before burning, as follows—viz.,

Clay . . .	4·00	and	5·50
Carbonate of lime	42·50		52·00
,, of magnesia	53·50		42·50

yielded limes possessing the hydraulic character in an eminent degree. Parandier states that a stone composed of 58 parts of carbonate of lime, 11 of clay, and 31 of carbonate of magnesia, yields a very excellent hydraulic lime.

One law is, however, certain; namely, that no limestones are able to produce, in a commercially valuable form, hydraulic limes, unless silica be present in combination with alumina. All experiments, both analytical and synthetical, show that in the proportions cited in the beginning of this chapter, the silicate of alumina is capable of communicating the different qualities therein mentioned. It may, therefore, be regarded, practically, as the most efficient agent in producing the power of setting under water; and as being the one whose presence should be most sought for, and supplied, if wanting, whenever it is desired to obtain limes of that description.

Owing to the inconceivable negligence of the engineering profession in our country, we have no statistical account of the various hydraulic limes produced in England. It may, therefore, be interesting if we were to state the laws which appear to regulate the geological distribution of the rocks which supply them. The knowledge of these laws may prevent many useless researches, and save, perhaps, some injudicious outlay of capital.

It is known, to quote nearly the words of M. Parandier, that every stratified geological formation comprehends a series of beds, whose deposition corresponds with the various periods of existence of the marine basin in which they were formed, which marine basin must have had its hydrographical limits, its affluents, &c. In the first periods, immediately after the cataclysms and the great erosions (which, in disturbing the *status quo* of the preceding geological epoch, had given rise to the new order of things), the sedimentary deposits must principally have owed their origin to the matters held in suspension in the liquid. They must have taken the form, for the most part, and throughout the whole extent of the basin, of agglomerated rocks, sandstones, clays, &c., except in the isolated points of the affluents, in the great depressions of the bottom, and in the very deep waters, where the materials brought down by the currents could not arrive, and where the beds took a degree of compactness different from that which is to be found on the borders of the basin. By degrees the matters held in chemical suspension in the waters, and which were in the beginning mingled with those in mechanical suspension thus brought down, began to deposit, in greater relative proportions, as soon as the geological condition of the basin had resumed a normal state. At times recurrences of the great agitations of the strata were reproduced in the same geological epoch, but always during a shorter period, and with less intensity, the same phenomena.

Thus, in the lower divisions of the secondary strata, we find the marls, the siliceous sands, and clays, the calcareous marls, the ferruginous strata; then the limestones with all the different varieties of texture and composition; and, lastly, we find the magnesian limestones. The contact of certain formations either contemporaneous with, or posterior to, the formation of the different strata, often modifies these last. The presence of certain ingredients, and the secular action of the exterior agents, also often produce very remarkable modifications or alterations, and even some molecular transformations, which are very curious, changing even the chemical and physical properties of the rocks. But these phenomena have their particular laws, and their definite epochs of appearance: and we can calculate with a tolerable degree of certainty upon the extent of their action.

It is easily to be conceived, from what is stated above, that we should be able to predicate within certain limits the points at which the rocks are likely to contain the elements the most favourable to the attainment of the object in view in such researches as the one before us. The materials likely to furnish us the sands and clays fit to be converted into artificial puzzolanos, are generally to be met with at the bottom of the sedimentary formations. The limestones likely to yield hydraulic limes occur amongst the marly or argillaceous beds; or at the points where these last pass into the purer calcareous rocks, and which are marked by the intercallation of strata of limestone and clays. The upper members of all the series may be regarded as being too free from argillaceous matter to furnish anything but rich limes.

Amongst the secondary formations we find, for instance, that the lower chalk marl passes into the clays of the galt, or the upper green sand; and that it yields a lime which is often eminently hydraulic. In the green sand there are few solid calcareous rocks; there are few also in the lower members of the cretaceous formations below the green sand. Hydraulic limes are to be obtained from the beds of limestone intercallated between the marls of the Kimmeridge clay; in the Oxford clay at the passage between the upper and lower calcareous groups of this division of the sedimentary rocks; and in the Liassic series. (See Appendix A, page 121.)

A very important practical observation is to be made respecting the results of the calcination of the different limestones. It is, that those which are obtained from the stones containing much silica in the composition of the clay, swell in setting, and are likely to dislocate the masonry executed with them. Those, on the contrary, in which the alumina is in excess, are likely to shrink and to crack. The magnesian limestones, or dolomites, appear to be the least exposed to these inconveniences, and to retain without alteration their original bulk. The limes obtained from the Oxford clay generally swell; those from the chalk marl contract.

Another observation is, that the limestones which contain many fossils, are also exposed to the serious inconvenience of producing a lime exposed to the risk of slacking at various and uncertain periods. Whether it arise from the fact that the decomposition of the animal matter had previously affected the nature of the limestone in contact with it, or from that of the different action of the calcination upon the shells, we mostly find that the fossiliferous limestones contain black spots which do not slack at the same time as the rest of the lime, or which retain their avidity for water to a later period; and in either case they swell, and disintegrate the mass around them.

It were to be desired that a series of observations were made upon the different limestones throughout England, with a view to the classification of the limes they produce. To aid the formation of a set of tables of this kind, we subjoin a list of the headings under which the observations should be arranged.

Column 1. The number of the specimen.
" 2. The locality whence extracted.
" 3. The geological position and mineralogical name.
" 4. The geological constitution and importance of the beds and country on which the observations are made.
" 5. The physical characteristics of the stone.
" 6. The chemical analysis.
" 7. The mode of burning.
" 8. The properties of the matter burnt.
" 9. Observations on the slacking of the lime.
" 10. Observations on the trials of its hydraulicity.
" 11. General remarks.

The mode of analysis recommended by Berthier to ascertain whether a stone be, or be not, fit to be burnt for the purpose of obtaining an hydraulic lime, is as follows:—

"The stone should be powdered, and passed through a silk sieve; ten grammes of this dust are to be put into a capsule, and by degrees diluted muriatic acid is to be poured upon it, stirring it up continually with a glass or wooden rod; when the effervescence ceases, no more acid is to be added. The dissolution is then to be evaporated by a gentle heat until it is reduced to the state of a paste; it is then to be mixed with half a litre of water, and filtered; the clay will remain upon the filter. This substance is to be dried and weighed; the desiccation being made as perfect as possible. Lime water is then to be added to the remaining solution as long as any precipitation takes place from it. This precipitate must be collected as quickly as possible upon a filter; it is then desiccated and weighed. It is magnesia, often combined with iron and manganese." For all practical purposes the above mode of analysis is sufficiently accurate, and is sufficient to indicate all the details necessary to be known.

CHAPTER IV.

ON THE CALCINATION OF LIMESTONES.

The calcination of limestones may be effected in various manners; it is only necessary to observe certain conditions, which are very simple and easily attain-able. The carbonate of lime requires to be brought to a red heat, in order that the carbonic acid gas may be disengaged; and it must be maintained in a continued and uninterrupted manner at that heat, during several hours, in order that all the gas may escape. In general, the time necessary for the complete expulsion of the gas will be in proportion to the size of the pieces of stone operated upon; that is to say, it will be longer in proportion as the stones are bigger, denser, and drier: the operation will be shorter with limestone broken into small pieces, of a lighter nature, and moister. So well known is this last fact, that the lime-burners water the stone, if they are prevented from using it fresh from the quarry.

It is easy to conceive that the interior parts of large pieces of limestone can only receive the heat through an envelope of feebly conducting powers; and, moreover, that the carbonic acid gas has a certain pressure to overcome, in this case, before it can escape. The influence of the water may be explained in two manners: either it acts upon the carbonate of lime by entering into the formation of a temporary hydrate, and by replacing the carbonic acid for a very short space of time in the parts of the limestone first affected by the fire (for the hydrate itself, as we have already seen, is decomposed by heat); or, the water, being itself decomposed by the combustible employed, takes the form of different gases, of which the hydro-carbonate may be one. This, reacting upon the carbonic acid of the limestone, tends to convert it into an oxide of carbon; and thus facilitates its separation from the stone.

During the decomposition, a species of struggle is going on between two molecular forces: the one, which tends to make the carbonic acid take the gaseous form; the other, which retains it in combination. The latter force, like all those of the chemical affinities, increases as the operation proceeds. If, then, the temperature be not gradually augmented, the expansive power of the gas will be equilibriated by its affinity for the lime, and there would be no reason to determine a solution of the equilibrium. The intensity of the heat must therefore be gradually augmented; and, from these considerations, it becomes evident that the said intensity cannot be superseded by the length of exposure to its application.

In practice, whenever the nature of the limestone is such as to render its being broken into small fragments too expensive an operation, the lime-burners place the largest blocks in the centre, and in the positions where they are exposed to the greatest heat. Generally speaking, the temperature to be produced in a kiln is also, from the size of the stones, much greater than is necessary for the molecular decomposition. It is, in fact, a question of economy, whether the saving of the fuel compensate for the expense of breaking the stones into very small pieces.

In burning limestones, which yield either poor or hydraulic limes, it was formerly held that a chemical action is produced by means of which the clay, silex, magnesia, oxide of iron, &c., enter into combination with the lime, and by so doing facilitate the disengagement of the carbonic acid gas. They add, in fact, a new force to that of the heat, for as the lime has more affinity for them than it has for the carbonic acid, it seeks to quit its original state to enter into the new combination.

The presence of these ingredients in the limestone, therefore, facilitates calcination. But the action of the alumina, of the magnesia, and of the oxide of iron, either together or separately, seems to be confined within these limits. The addition of silica, even in very small doses, appears to determine a vitrification, which alters the nature of the lime very seriously. In all cases, therefore, where argillaceous limestones are used, it is necessary to exercise great care and attention in the regulation of the mode of calcination.

General Treussart, in his observations upon the burning of lime, says, "that all the limestones upon which he operated when of a blue colour became of an ochreous yellow if burnt in a slight degree. Upon augmenting the degree of heat, the colour passed successively to a deep yellow, to an ash-grey, and at last to a slate-coloured blue, when the heat was very intense." The mode in which he accounts for this blue colour is, by supposing that the iron has been reconverted into the state of a protoxide. Similar facts occur in brick burning, when the clay employed contains much oxide of iron, and is of a very dark colour. At a certain degree of the calcination, the iron they contain passes to the state of a red oxide, as in the bricks employed in London under the name of "place," or even "stock bricks;" if the heat be increased they become yellow, or straw colour, like the "pickings" and the malm paviours; then if the heat be further increased they become ash-grey, or blue, like the glazed headers of commerce. The iron, in this case, must have lost its oxygen to a great extent.

General Treussart appears inclined to differ from Vicat upon the question as to whether the colour of a lime may be taken as an approximate indication of its quality. According to the former, the best hydraulic limes, when properly burnt, are of a light straw colour. It is much to be desired that some such easy mode of distinguishing at once the degree of calcination were ascertained, for the qualities of the lime are very seriously affected by the heat it has been exposed to.

The importance of so determining the proper point at which to stop the calcination becomes more evident, when we consider that some of the hydraulic limes, if over-burnt, lose all their useful properties, and are, to use the workman's phrase, killed: if under-burnt, they are often poor, without any hydraulic powers. The purer limestones, or those which yield rich limes, present other phenomena equally inexplicable in the present state of our knowledge of the science. For instance: if chalk be burnt in such a manner as to drive off all the carbonic acid gas it contains, it yields a lime whose hydrate never solidifies under water, as we have already seen. If the calcination be stopped at a point below that necessary for the expulsion of the gas, the lime produced does not change in bulk by slacking, and it will be found to set under water almost as rapidly as the moderately hydraulic limes. If over-burnt, the resulting chalk-lime reassumes the power of hydraulicity, which it had lost at the point at which the gas was entirely disengaged. No consecutive series of observations has yet been made upon the action of limes in the different states of their calcination; but General Treussart states that those which have been over-burnt swell in setting; and some observations I have myself made upon the Portland cement (to be noticed hereafter) rather tend to confirm that assertion.

No invariable rule can be laid down as to the description of combustible to be employed. In our own country, the choice is practically limited to two sorts, coal or coke; and the only reason we can have to decide our preference must be based upon motives of economy. In some countries, Germany, Holland, the French Flanders, &c., peat is used very successfully when the kilns are constructed for the use of this combustible. In new countries, where wood abounds, it is largely used for lime-burning; but the kilns are, in such cases, made with hearths upon which the wood is burnt separately from the limestone; for the wood is not well adapted to what are called running kilns. The same objection also applies to the use of fresh coal; it often cakes, and runs; thus not only impeding the calcination, but also giving rise to great impurities in the lime. If any use of the produce of the distillation of the coal can be made, there is then an evident advantage in the employment of coke, for the gases which the latter gives off during combustion, arrive at once at their highest degree of temperature; whilst, with those from the coal in its natural state, the combustion is continued far beyond the surfaces of contact, and the temperature only arrives at its maximum at the end of this combustion. The quantity of smoke that escapes from the mouth of a kiln where coal is burnt, may be taken as an indication and a proof of the combustible wasted. But, as was said before, the determining motive in the choice of combustible must be found in local considerations of economy.

The limestone is sometimes burnt in large stacks in the open air, consisting of alternate layers of stone and of coal, similar, in fact, to the mode of burning bricks in clamps. The same care is required as with the latter, in well coating the sides with clay, so as to retain the heat as much as possible; and the heaps require the same attention to secure an equality of draught, so that the whole mass may be burnt alike. This method can, however, only be employed in the coal districts of any country, for the waste of combustible by the radiation of heat is enormous.

The forms of kilns usually employed may be classed as follows:—1. A rectangular straight prism. 2. A cylinder. 3. A cylinder surmounted by a truncated cone. 4. A reversed straight-sided cone, or funnel. 5. A cone of different diameters, or a form produced by the revolution of an ellipsoid.

The rectangular prisms are used in some parts of the continent for the purpose of burning at the same time both lime and bricks or tiles. The limestone occupies the lower half; the upper part is filled with the bricks or the tiles placed on edge.

The cylindrical kilns are principally used in situations where large quantities of lime are required within a short space of time. They are rarely constructed for definitive use; they are easily built, cheap, but not of long duration. An archway is first made to form the hearth; a round tower is then constructed upon this to form the kiln itself, which may be either in limestone, brick, or any material of those natures; the outside is rendered with clay, so as to effectually stop all the holes, and this envelope is maintained by a rough kind of hurdle, taking care to leave an opening in front of the hearth.

The kilns of the third form are constructed of more solid materials and in a more permanent manner. They serve only for the purpose of lime burning, without admixture of bricks. The largest stones are placed in the bottom of the kiln; the smaller pieces are placed in the straight cylindrical part at the top. These kilns are superior to the others before mentioned, inasmuch as the heat is reverberated from the sides, and cannot escape into the air without producing a useful effect.

These three forms of kilns are used principally for intermittent fires, and in cases where wood or rich flare coal is burnt. The two last-named forms are more especially employed when coke or poor coal is the combustible used. In the countries where peat is burnt, the kilns are constructed in the fifth form above described.

The inside of the kilns is generally built of fire bricks, or of such materials as resist the action of the fire, set in fire clay for a thickness of from 14 to 18 inches. The principle which should influence the choice of materials is, that they should be such as have the smallest conductive powers possible, and such as, when once heated, retain that state the longest.

When the kilns are worked by intermittent heat, either from wood or coal, the limestone charge rests upon arches, constructed of the large pieces to be burnt, laid dry. A small fire is lighted below these arches, and quite at the back; this is gradually increased towards the mouth as the draught increases. The opening is then regulated to secure the proper degree of combustion, and new combustible is added to maintain it to that point. The air, which enters by the fire door, carries the flame to all the parts of the arch, and gradually brings the whole mass of the limestone into a state of incandescence. It is to be observed, that some stones are exposed to the inconvenience of cracking, and of bursting with a loud explosion, by the application of heat. It is dangerous to use them in the construction of the arches; care must therefore be taken only to use such as are exempt from this inconvenience.

When the upper part of the kiln is of a smaller dimension than the lower, it often happens that the current of heated air, being impeded in its escape, returns, and drives the flame through the fire door. It is advisable, therefore, for this and for several other reasons connected with the draught of the kilns, to make the upper part in such a manner as to allow of the openings being enlarged or contracted, as the case may require. In some places the lime-burners, in filling the charge, introduce pieces of wood, placed vertically, in order to facilitate the circulation of the air and heat. These pieces are burnt at an early stage of the process, and they leave spaces which act as chimneys. It admits, however, of question, whether the circulation, being so much more active in these parts, does not produce an unequal calcination.

The degree of heat to be obtained varies, according to the density and the humidity of the limestone, from 15 to 30 degrees of Wedgewood's pyrometer. The length of time necessary for the perfect calcination can only be ascertained by experience. It depends not only upon the nature of the stone, and the quality of the combustible, but also upon the draught of the kiln, the state of the atmosphere, and the direction of the wind. Before the operation is completed in the lower portion, a gradual subsidence of the mass takes place; the stones which form the arches crack, the interstices diminish, and at length the charge sinks about one-sixth or one-fifth of its height. A very simple and effectual way of ascertaining whether the calcination is complete, is to drive a bar into the body of the charge. If it meet with a considerable resistance, or strike against the firm hard materials, it is a proof that the burning is not finished. But if, on the contrary, it penetrate easily, and only meet with a resistance similar to that which it would encounter in passing through a mass of gravel, the calcination may be regarded as complete. Another method of ascertaining whether this is really effected, consists in drawing a sample of the lime, upon which a direct essay is made; but this is liable to error, according to the position the piece may have occupied in the kiln.

Running kilns, or those in which the stone and coal, or coke, are mixed in alternate layers, are the most difficult to manage with certainty, although when established under favourable conditions they are the most economical. A mere change in the direction of the wind, a falling in of the inner parts of the kiln, an irregularity in the size of the pieces of limestone, are any of them causes sufficient to retard or accelerate the draught (by producing irregular movements in the descent of the materials), and thus give rise to either excessive or defective calcination. At times, a kiln will act perfectly for several weeks, then all of a sudden it will get out of order without any apparent reason. A mere change in the nature of the combustible will often produce so great a difference in the action as to defy all the calculations of the lime-burner. In fact, the use of running kilns is essentially a matter of practice, and as to their results, little can be predicted with certainty.

The most favourable conditions to ensure a successful result from this mode of burning seem to be, that the thickness of the charge of limestone do not exceed from 1 foot to 14 inches; that the charge do not pass the top of the kiln; and that the combustible be well and equally distributed throughout the mass. The man charged with the direction of the operation, must carefully watch the upper part of the furnace, and open fresh currents of air in the places where the gases in combustion do not pass. These may be ascertained by observing whether the stones are blackened by the smoke escaping through the top, for that evidently can only take place in the direction of the escape of the gases. Wherever, therefore, the stones remain unblackened, the kilnsman must pass a bar through them to open a new chimney.

The lime, whose calcination is complete, must be withdrawn with precaution, because a precipitate fall of the upper mass might derange the coal between the joints, and thus some of the layers might have an excess of coal, whilst others would be entirely without any. The upper parts of the charge must be well arranged after each withdrawal from the lower, the large unburnt pieces being thrown towards the centre, and proper currents of air formed through them. Generally speaking, the lime is extracted every morning and evening; on Sundays and holidays, precautions must be taken to render the action of the fire less rapid. It is usual to light the fire in this description of kiln as soon as the third course of limestone and combustible is filled in, in order to avoid the serious inconvenience of being obliged to empty the kiln, should the mass not get well into combustion.

Limes burnt in kilns adapted to periodical calcination have an advantage over those obtained from running kilns, inasmuch as they preserve better in the open air. This appears to arise from the fact of their cooling more gradually; indeed, it is preferable with the former kind to shut the fire door, and only to allow the heat to escape from the top of the kiln; this generally takes from six to eight hours after the complete extinction of the fire.

The combustion is carried on in the three first description of kilns on an average for three days and three nights; but of course the duration must vary according to the circumstances of each particular case. They usually require about 60 cubic feet of oak timber; 117 cubic feet of fir; about the same quantity of peat of the best quality; and 9 cubic feet of coal; to produce about 35 cubic feet of lime. The running kilns do not consume on the average more than 7 cubic feet of coal for the same quantity.

The calcination of limes is, however, a subject still very little understood, and it is impossible, therefore, to enunciate any principles of universal applicability. There are so many disturbing causes in operation; the difficulty of observation in all cases where large masses are in a state of simultaneous incandescence is so great; that it will be long before we shall be able to ascertain the chemical and electrical phenomena which take place during these operations, with sufficient certainty to enable us to derive any practical benefit from them. At present our best guide is experience, and a kilnsman who has watched the action of his own kiln for years, knows more upon the subject than the first theoretician in the world. There is one opinion, however, received among workmen which it may be advisable to contradict at once, notwithstanding its antiquity and the sanction it has received from Bernard de Palissy; namely, that if a calcination be interrupted, it can never be resumed. Messrs. Petot and Hassenfraz have both practically demonstrated that such is not the case. But Vicat and Minard appear to be of opinion tha: the limes thus obtained by a re-calcination, as well as the rich limes when under-burnt, exist in a state which possesses very peculiar properties, the laws of which are entirely unknown to us in the present state of the science.

Attempts have been made to employ the waste heat which escapes from the top of the running kilns, for the purpose of burning bricks or tiles, in a somewhat similar manner to that employed in the first description of kiln. The success of these attempts is, however, very doubtful; for if the bricks rest immediately upon the limestone they are liable to be distorted when this falls by the process of calcination, and it is an error to suppose that these articles require a less degree of heat than the lime itself. The only valuable or economical application of the heat, therefore, seems to consist in the drying the bricks, &c., gradually, before exposing them to a separate and distinct calcination.

In some countries the ashes which fall through the grates of the kilns are carefully collected and used as a water or hydraulic cement. They are found to be mixed with minute portions of lime which have fallen through the arches, and it is doubtlessly to their presence that we may attribute much of their useful action. Such cinders are usually sold at half the price of the lime. At Utrecht, and in Holland generally, oyster-shells are burnt in large quantities for the purpose of obtaining lime; but as the carbonate of lime they contain exists in a great state of purity, the lime is too rich to be employed without the admixture of trass or puzzolano.

Limestone generally loses by calcination 0·45 of its weight from the evaporation of the water and the disengagement of the carbonic acid gas. Its diminution in bulk is far from being as remarkable; and, moreover, the diminution varies with the nature of the stone, and the degree of subdivision in which it exists before and after calcination. It may be estimated as ranging between 0·1 and 0·2 of the original bulk. The difference in weight between the carbonate and the lime obtained from it, is also very uncertain; but the loss may be taken at about from 15 to 17 per cent. of the weight of the stone.

The general rules upon which limekilns should be constructed are as follows:—Firstly, the lining of the inside should be of fire bricks, because these materials resist the action of the fire better than any others; they preserve their form at high temperatures, and conduct the heat with greater difficulty. Secondly, the total height of the interior opening must be such that the degree of heat existing at the top be that absolutely required to calcine the stone placed there, in the cases where the calcination is periodical. This is found, generally speaking, to be attained when the height is to the largest diameter in the proportion of 2 to 1. Thirdly, when the calcination takes place in running kilns, this proportion may be beneficially increased until it arrives even at 5 to 1; the usual proportions vary between 3 and 4 to 1. Fourthly, in kilns in which the calcination is intermittent, the upper opening should be about one-third of the greatest diameter; the opening for the fire about one-fourth of the same dimension both in height and in width. In running kilns, the upper orifice should be five times the diameter of the lower one when these kilns are in the form of reversed cones; the dimension of the lower orifice is usually about 1 ft. 8 in. Fifthly, the thickness of the external walls is not invariable, the only rule to be observed is to make them as thick as possible, in order to retain the greatest quantity of heat. No mistaken motives of economy should be allowed to interfere in this case, for the saving obtained in the cost of the masonry would be very soon absorbed by the waste of fuel. As was said before, the fire-brick lining should be made from 14 to 18 inches in thickness.

It would appear from some remarkable facts observed during the execution of the later works of the Cherbourg Breakwater, and from experiments made by Messrs. Signorile and Vicat, that the nature of the fuel has at times a serious influence upon the quality of the lime exposed to its effects. If the fuel should contain much sulphur, it is possible that the sulphuric acid gas given off during its combustion may enter into combination with the lime, producing a mixture of sulphate of lime with the purer material. Now the sulphate of lime sets much more rapidly than, and with a different crystallization from that of, the carbonate of the same base; and it results from this that there is a confusion in the arrangement of the molecules of the mixed mass which does not allow of its assuming the same degree of hardness a more homogeneous material would do. Moreover, the sulphate of lime decomposes both in the open air and in sea water very rapidly, and if present in any considerable quantities it will infallibly cause the disintegration of any masonry into the execution of which it enters. Of course, the slower the process of calcination the greater will be the danger from the presence of any sulphur in the combustible; and it is for this reason that it is essential to the process of manufacturing Portland cement that the coke employed should have been carefully prepared.

CHAPTER V.

ON THE ARTIFICIAL HYDRAULIC LIMES.

Although the limestones which furnish hydraulic limes naturally are very plentifully distributed, circumstances may occur to render their employment too expensive. In such cases their want is supplied, at least upon the continent, by the use either of trass or of puzzolano (either natural or artificial), which are mixed with the rich limes, or by the use of artificial hydraulic limes. Vicat, the inventor of the system of making the latter employed near Paris, naturally recommends their use. General Treussart, with the jealousy which so strangely marks the two divisions of the engineering profession in France, the military and the civil, apparently for no other reason than because Vicat had so recommended the artificial hydraulics, gives the preference to the mixture of the trass, &c., with the rich limes. Experience has settled this question, however, in favour of Vicat's opinion; and unless the trass and puzzolanos are found in the most extraordinarily favourable conditions of economy, they are never used in the present day by engineers who have at all studied this branch of their profession.

Indeed, it must be evident that the chemical action produced upon the lime by the mechanical mixture of puzzolanos, can never be so perfect in its results as that which is called into activity during the process of calcination. Even if we leave out of account the effect of the heat in producing a more perfect chemical combination between the bases, there is always a danger attending the use of the subsequent mechanical mixtures. Either from carelessness, want of skill, or even in spite of the best intentions, it often happens that the combination is not perfect, and that the limes and puzzolanos are so mingled that there is excess of lime in one place, of puzzolano in another. Very serious failures have occurred from the use of these mixed materials in sea works, as we shall have occasion to notice hereafter. In the meantime, the experience of the best continental engineers has led them to prefer the use of the artificial hydraulic limes wherever natural ones are not to be met with.

There are two methods of preparing the artificial hydraulic limes. The first, which is the more perfect, but at the same time the more expensive, consists in mixing the slacked rich lime with a certain proportion of clay, and burning this compound. The lime in this case goes through a double calcination.

The second method consists in mixing, instead of the slacked lime, soft calcareous matters with the clays, such as chalk, or the tuffas of some of the other formations, and in reducing the whole to a paste by grinding them together in a mill. Being in both cases masters of the proportions of the different ingredients, it is easy to communicate the hydraulic properties in any degree of energy the works they are intended for may require.

Generally speaking twenty parts of dry clay are mixed with eighty parts of very pure rich lime, or with one hundred and forty parts of carbonate of lime; but if the lime or the carbonate contain already any clay in their composition, a smaller proportion would be necessary. It is impossible to say beforehand what the precise proportions should be, because the limestones and the clays of every locality differ in their nature. Of the latter, the finest and softest to the touch are the most preferable.

At Meudon, near Paris, some extensive lime works were erected under the directions of Vicat, by MM. Brian and St. Leger, for the manufacture of articial hydraulic limes from the chalk and clays of that country. The chalk was divided into pieces of the size of a fist previously to being ground. A large vertical mill, with two horses, crushed and mixed together, with a plentiful supply of water, the materials, which were introduced in the proportion of four of the chalk to one of the clay. The liquid mixture was run off into a series of five troughs placed at successive differences of level, and deposited in them the matter it held in suspension. A double set of these troughs was necessary, in order that one might be worked whilst the liquid was deposing in the other, and it was found that the shallower the troughs were in proportion to their surface, the more rapidly did the deposition take place.

As soon as the deposed matter became of sufficient consistence to support manipulation, it was made into small prisms with a mould. The prisms were then placed on a drying platform, and allowed to dry until they arrived at the state of freshly quarried limestone. They were then put into a kiln, and burnt by any of the modes we have already mentioned.

In England a somewhat similar process is followed in the manufacture of the Portland Cement, as it is very absurdly called. This is, in fact, nothing but an artificial hydraulic lime composed of the diluvial clay of the valleys of our principal rivers, mixed in definite proportions with the chalk of the same geological districts. These materials are very finely comminuted under mills, and with water; they are allowed to deposit, and are then desiccated and burnt. But here begins the difference, and the most delicate part of the manufacture. Instead of merely driving off the carbonic acid gas, the calcination is pushed to a point which produces vitrification in a very considerable portion of the contents of the kiln. The lime is, in fact, overburnt; and it often happens that it is irregularly so. Great care is therefore required in grinding the different products of the calcination, to secure a proper equality in their times of setting: for it is to be observed, that all the over-burnt limes, like the natural cements, slack with so much difficulty when in large masses, as to require to be broken up, or comminuted, before being used. There is also attached to the Portland cement the danger before alluded to of occasionally expanding in setting. It should, therefore, never be used, unless in positions where this action, which the manufacturers do not appear to be able to control, cannot be prejudicial to the solidity of the work. When carefully prepared it is invaluable for external plastering, because it does not allow of the formation of vegetation like the natural cements; but unless great care has been taken in its manufacture it should not be used for large masses of masonry.

There is a material sold in London under the name of Portland Cement, which is manufactured in the Midland Counties, principally in Warwickshire, and which requires to be used with even more caution than the material it is intended to represent. This artificial, and sometimes highly energetic, hydraulic lime is composed of ordinary blue lias lime, mixed in powder with definite proportions of clay, obtained from the intercalated beds of the same geological formation, and burnt in close retorts; the use of the retorts being to retain the colour. It must be evident that, inasmuch as both the clay and limestone strata of the blue lias differ in their mineralogical composition in a remarkable manner, and as the mixture of the materials obtained from their separate calcination takes place by a purely mechanical process, the probability that the resulting material will be of a variable quality must be increased to such a degree as to render it impossible to count upon its precise effects. The greatest practical danger attending the use of this (improperly called Portland) cement is, however, found in the fact, that the solidification does not take place with sufficient rapidity to allow of its being used under water in many cases where the real Portland cement would succeed, and for which that material is usually prescribed by our modern architects. A cement of equal value with, and possessing the same qualities as, this blue lias cement (as it ought to be called) would easily be formed by the mixture of grey stone lime, in powder, with pounded tiles or place bricks, in the proportions of from 15 to 20 per cent. of the latter, to from 80 to 85 per cent. of the lime; but, perhaps, the colour of this tile cement might be objectionable, inasmuch as it would be decidedly red. Both of these mixtures would also, it is to be observed, be useless in situations where they might be exposed to the effects of salt water: Portland cement, on the contrary, when well made, resists admirably, in such situations, if we may judge from so short an experience as eight or nine years'.

General Treussart's experiments upon artificial hydraulic limes would lead to the belief that their quality would be much improved if they were prepared with water in which the soda and potash of commerce were mixed. The proportions he recommends are five measures in volume of chalk to one of clay, for the paste to be burnt: the lime to be subsequently slacked with water in which the above ingredients had been dissolved in the proportions necessary to bring the solution to the degree of 5° of the acid gauge.

The subsequent researches of M. Kuhlmann decidedly confirm General Treussart's views upon this subject. Even so far back as May, 1841, M. Kuhlmann recorded the result of some experiments which induced him to propound the opinion, that in the cement stones the alkalies above mentioned, soda and potassa, served as carriers in the combination between the silica and the lime, and thus gave rise to the formation of silicates, which, when placed in contact with water, solidified it with a species of hydration similar to that of plaster. He cited, as a confirmation of his views, the fact, that, if a rich lime were burnt in contact with a dissolution of the silicate of potassa, it would become hydraulic. Subsequently M. Kuhlmann ascertained, by direct experiment, that it was possible to obtain an hydraulic lime of a superior quality by the calcination of a mixture of the rich lime and the alkaline silicate (both being very finely powdered) in the proportions of from 10 to 12 of the latter, to 100 of the former. It is essential that the respective materials be finely powdered and intimately mixed; for otherwise the reaction would be incomplete at the first moment of application, and an effect subsequent to the first solidification would soon produce a disintegration of the mass.

It has been ascertained that the artificial hydraulic limes do not attain, even under favourable circumstances, the same degree of hardness, the same power of resistance to compression, as the natural limes of the same class. Of the latter, those which are obtained from the closest grained and densest lime-stones, are the most resisting. They should, therefore, be used in preference to the artificial mixtures, unless very serious reasons of economy oppose themselves. The above objection to the want of hardness does not, however, appear to apply to some of the over-burnt limes, for the Portland cement attains a power of resistance to rupture either by extension or compression which is extremely remarkable. (See Appendix B, page 122.)

CHAPTER VI.

ON THE SLACKING OF LIMES.

There are three methods of slacking lime, with respect to the relative merits of which chemists are even now at issue. The object to be obtained is to reduce the quick lime into a pasty hydrate, as unctuous as possible, and one which has absorbed the greatest possible quantity of water without having taken up too much, and thereby lost a proper consistence. As we have already seen that every separate variety of limestone produces a lime of a different chemical composition, it would in all probability be found that it would be dangerous to decide, before making experiments upon each of them, the mode of slacking which would be the most advantageous. The three methods are either by immersion or maceration; or, by sprinkling with small quantities of water; or, by allowing the lime to slack spontaneously by absorbing the moisture of the atmosphere. The circumstances which render it advisable to employ either the one or the other of these methods, may be stated as follows.

All the rich limes, as we have already seen, are capable of being slacked by immersion; they keep in a plastic state under water, and they even gain by being allowed to remain therein, for all the core becomes thus slacked. Plinius states that the Romans were so convinced of the truth of this, that the ancient laws forbade the use of lime unless it had been slacked for three years; and that it was owing to this regulation that their works were not disfigured by cracks or crevices. Alberti mentions, in the 11th chapter of the second book, that he discovered once, in an old trough, some lime which had been left there 500 years, as he was led to believe, by many indications around it; and that this lime was as soft and as fit to be used as at first.

But when the limes are hydraulic in their action, or when they harden rapidly, if reduced to the state of hydrates, it is important not to slack them before they are absolutely required; moreover, it is equally important not to mix them with too much water, for this always interferes more or less with the crystallization in setting, and gives rise to other phenomena alluded to hereafter. Vicat recommends that the slow-slacking limes (such, in fact, as are all the hydraulic ones) should be reduced to a powder before they are worked up into a paste for the making of mortar; that an imperfect slacking be commenced, in fact, before the lime is to be used. General Treussart, and all practical men, however, agree in considering this course not only as doubtful, but even as positively injurious. There are, it is true, in all limes, particles which slack with more difficulty than the rest; and if these particles be introduced into the mortar, as they expand in slacking, they are likely to disintegrate the other portions of the work into which they enter. It is possible that this inconvenience is obviated by the imperfect slacking Vicat recommends; but it is also evident that the hydration and the absorption of carbonic acid gas must also be going on, and that the lime is losing some of the concretionary force it should exercise in place. Treussart asserts, and with justice, that all limes of an hydraulic character require to be used fresh from the kiln; that the workman's notion that the lime is killed by time is substantially correct; and that the only precaution to be taken to ensure a perfect slacking should be to grind the fresh lime immediately before using it. Vicat, it is true, insists much upon the lime being slacked and immediately put into close casks; but that is only a mode of palliating the inconvenience. It is singular, however, that Smeaton followed precisely the system Vicat recommends in transporting across the country the lime used for the Eddystone lighthouse. Hassenfraz, and many other writers upon the subject, appear to agree with Vicat; but experience is certainly against the conclusions to which they arrive.

The hydraulic limes, then, it may be asserted, require to be slacked by one or the other of the modes described, as either by sprinkling them with small quantities of water, or by spontaneous absorption whilst in their freshest state. Wherever it can be done economically, the former mode should be employed, the lime being previously ground. Should the position or the extent of the work to be executed not justify the expense of a mill for grinding the lime, the second may be employed.

The rich limes augment in slacking about two-fifths in weight, and even as much as 3·52 of their original volume, or even more; they absorb about one-third of their volume of water before passing to powder, and one-half before the powder becomes moist. The powder has already a very considerable augmentation upon the bulk of the lime itself, sometimes to the extent of double its original volume. To pass into a paste fit for mortar, the powder will again absorb about 1½ time its own bulk of water; and it is then about 3½ to 4 times the bulk of the lime. The hydraulic limes absorb considerably less water, and only increase in bulk from 1¾ to 2½ times their original volume.

There are still some unexplained phenomena in the action of the hydrates, which are worthy of attracting the attention of the scientific world. For instance: even though the lime be reduced to the state of a paste, it nevertheless retains the power of absorbing water during a long interval of time. And we have already seen that although it has so great an affinity for the water, yet it parts with it very easily upon the application of heat or friction. It is this latter faculty that the workmen bring into action when, as they say, they chafe up again a mortar which has been made for some time. With the hydraulic limes this practice is bad, and should never be allowed; for the solidification of a mortar once interrupted, it is often put a stop to for ever. The same inconvenience does not appear to be attached to the re-working of the rich limes.

Many distinguished philosophers are disposed, in the actual state of our chemical knowledge, to attribute the various phenomena connected with the setting of lime to the changes it undergoes during the process of hydration, and to assign to the various ingredients which are ordinarily found in connection with that base little more than a mechanical action. It is considered by these persons, in fact, that the solidification of limes only takes place by the absorption of the water of crystallization; and that although subsequently the carbonic acid gas combining with the hydrate of lime may greatly increase its hardness, this gas plays but an insignificant part in the early part of the solidification. It would, indeed, be impossible to present sufficient doses of carbonic acid gas to the quick setting limes within the period they usually require for the completion of that process, at least under ordinary circumstances; and the singular manner in which some quick setting limes and cements throw off the excess of water mixed with them, beyond that required for the purposes of hydration, appears to confirm these opinions. Moreover, it is questionable whether, according to the laws of chemical equivalents, any of the supposed combinations between the lime, the silica, or the other bases, could take place under the circumstances which usually attend the application of building materials; and it has been observed that the simple immersion of chalk in a solution of alum, previously to calcination, communicates to it after going through the kiln hydraulic properties, feeble, it is true, and of no commercial value, but still distinctly perceptible. In this case the alum will be found to have been volatilized in the kiln, for no trace of it is to be discovered in the caustic lime; the effect it produces would, therefore, appear to be confined to the production of some molecular change in the lime during the calcination which is favourable to the subsequent process of hydration. Possibly the different circumstances under which the latent caloric of the water of crystallization is given off by the various classes of limes, may have a connection with the solidification of the latter. At any rate it is to be observed that the limes which give off the greatest heat and with the greatest rapidity, after the process of slacking, are precisely those which harden under the most unsatisfactory conditions, even if they harden at all. Mr. Way's unpublished researches in this highly interesting, but still obscure, department of chemistry, have thrown great doubts upon the opinions usually received with respect to it. Unfortunately his views are not yet sufficiently developed to allow of their being referred to in more than a cursory manner.

With the very moderately hydraulic limes used in London, no great precautions are necessary in slacking the lime, nor does the operation require much time. The usual mode of throwing water over the lime, and then covering the latter with sand to retain the vapour given off, answers sufficiently well for buildings in the air, and in which the common Dorking or Halling limes are used. If the blue lias lime be used, however, it is necessary to begin the slacking about 24 hours before it is made into mortar, in order that the more inactive parts may be called into action.

When the lime has been thus reduced to the state of a hydrate, it is converted into mortar, for the purposes of masonry, by the additions of sand. The carbonic acid gas of the atmosphere is slowly absorbed by the hydrates, and they finally resume the crystalline form of the carbonate of lime, by arranging themselves around the bodies with which they are in contact. This process goes on from the outside towards the centre, and with a rapidity varying with the nature not only of the lime itself, but also with that of the sand; for the chemical nature of the latter has nearly as much influence upon the progress of the crystallization as its mechanical structure. It is not found that the carbonization of the lime ever attains the same degree as that which exists in the limestone; and we may, therefore, assert that almost all mortars are in a constantly increasing state of induration, if that operation has ever commenced. This same fact also renders the recalcination of lime more easy than the original operation; the carbonic acid gas has not entered into such intimate union, in the second case, as when the mixture had taken place naturally. The thickness of the comparatively perfectly carbonated film upon the hydraulic limes is, at the end of the first year, about $\frac{1}{4}$th of an inch; about $\frac{1}{8}$th upon the rich limes. The further annual progress goes on in a decreasing ratio; for it is evident that the increasing thickness of the film must oppose an increasing resistance to the transmission of the gas necessary to produce the desired effect.

Some curious facts might be mentioned, not only to show the influence of a large body of masonry in retarding the solidification of the mortar in the interior, but also of the danger of using the rich limes in cases where such masses are necessary. Amongst them we may mention a fact cited by General Treussart, who had occasion to demolish, in the year 1822, one of the bastions erected by Vauban, in the citadel of Strasbourg, in the year 1666. In the interior the lime, after these 156 years, was found to be as soft as though it were the first day on which it had been made. Dr. John mentions that, in demolishing a pillar, nine feet in diameter, in the church of St. Peter at Berlin, which had been erected 80 years, the mortar was found to be perfectly soft in the interior. In both cases the lime used had been prepared from pure limestone.

Pure water absorbs or takes up all the soluble and uncrystallized portions of the hydrates of lime. In all instances, therefore, in which it is required to build in water, or to expose the constructions to the action of that fluid, it is necessary to employ such limes only as solidify almost instantaneously. Many cases have occurred in which works executed with the rich limes have failed, from the fact of all the mortar having been carried away: amongst others, the locks constructed for the improvement of the navigation of La Vilaine, which fell in from the cause above mentioned.

CHAPTER VII.

ON THE SANDS AND OTHER INGREDIENTS USED IN CONJUNCTION WITH LIME TO MAKE MORTAR.

These ingredients are of several natures, and they exercise very different and very important effects upon the qualities of the respective combinations into which they enter. They are, 1, the sands, properly so called, whether fluvial or pit sand; 2, the clays, either in their natural or their burnt state; 3, the puzzolanos, trass, or other volcanic productions; and, 4, the produce of artificial calcination, such as cinders, slag of furnaces, or scoriæ.

1. Sands are derived originally from the decomposition of the older rocks, either by the action of running water, or by the spontaneous decomposition of the rocks themselves. They are technically distinguished from dust, by the fact that they sink at once to the bottom of water, without leaving any sensible quantity in suspension. The decomposition of the rocks often gives rise to a kind of agglutinating substance, which accompanies the sand, and binds it together. But this only takes place in the positions where the sand is found "in situ;" washed by the rains and the running

waters, it soon parts with such heterogeneous particles, and it arrives in a comparatively pure state into the bed of the principal rivers. This purity is lost as the rivers approach their embouchures; for, in the first place, the diminished velocity of the current causes the heavier particles to subside before arriving there; the waters then only carry down the light earthy particles, and the decaying vegetable matters which may fall into them, thus giving rise to the formation of clay deposits. The constituent parts of the sand represent faithfully the rocks from whence they are derived; thus the granitic rocks produce a sand, the principal ingredients of which are quartz, feldspar, and mica; the volcanic rocks are represented by sands in which lava, obsidian, &c., appear; the flat, soft-grained sands arise from the disintegration of the schistose rocks; the calcareous rocks, as might naturally be expected from their soft nature, are those which are the least represented in the series, unless in the case of the siliceous sands, arising from the comminution of the flints so plentiful in some of the secondary formations.

The partial and secondary revolutions of the globe have given rise to immense formations of sand in places where rivers have long ceased to flow. The sand extracted thencefrom is known under the name of "pit sand," to distinguish it from that borne down by the rivers, called "river sand," and from the "virgin sand," which remains in the places where formed, without in any way suffering the action of water. Pit sand generally is of a sharper and more angular grain than river sand; but in all other respects its composition is identical, excepting that it is occasionally stained by ochres.

The generally received opinion that the sand should be perfectly free from all earthy matters, is only true to a certain extent. There exists a species of sand in very large masses in some parts of France, where it forms even entire hills, consisting of comminuted chalk in irregular grains, very unequal in size, and mingled with a clay sometimes yellow, red, brown, or even white, in proportions varying from a quarter to three quarters of the total volume. It is known under the name of "arènes," and is largely used in conjunction with rich limes for river and water works. Some of the decomposed grauwacké rocks also yield an argillaceous sand, composed of quartz, schiste, feldspar, and particles of mica agglutinated by a species of clay, which is very valuable, whether used in its natural state, or calcined to make artificial puzzolanos, like the arènes. The granitic rocks of Devonshire, some parts of Brittany and of the extreme north-west of Spain, all of which are characterized by a remarkable excess of feldspar, yield a sand of great value for building purposes, especially when the mortars composed of it are not immediately exposed to the effects of running water. In all probability, the potassa present in the decomposed and decomposing feldspar may influence the setting of the limes mixed with the sands thus obtained.

2. The clays are rarely used in their natural state in combination with lime, unless it be to give a certain degree of consistence to mud walls or pisé work. When burnt, they act somewhat in the manner of puzzolanos; and for all cases in which the mortars thus made are not exposed to the action of sea water, they appear to answer very well. The Romans were perfectly aware of the practical value of this process; for

many of their works, which have survived to the present day, especially the aqueducts, were executed with a mortar containing pounded bricks or tiles.

M. Raffineau de Lille made a very important essay of the artificial cements obtained from pounded bricks in some works he executed, in fresh water, near Calais. There it answered as well as the ancient Romans had found it to have done. He called the attention of Vicat to the question, and that eminent engineer, after a laborious series of experiments, arrived at the conviction that the action of the burnt clay was in every respect analogous to that of the natural puzzolanos. Berthier had previously shown that the latter materials consisted principally of the silicate of alumina mixed with a very small proportion of lime and iron; and as Vicat found the clays to differ in their composition only in the fact of their being hydro-silicates of alumina with nearly the same foreign ingredients, he thought that all that was necessary to render the clays as useful for hydraulic purposes as the puzzolanos, would be to drive off the water of combination. His experiments led him also to believe that a low degree of heat produced the best results, provided that it were managed in such a way as to allow the free access of the air to all parts of the matter in incandescence.

General Treussart applied similar artificial puzzolanos on a large scale at Strasbourg. Other essays were made at Algiers, the Fort Boyard in the Ile de Ré, at Brest, and at Cherbourg. At Strasbourg no accident has occurred; but in all the cases where the cements thus prepared were exposed to the action of sea-water, they appeared to set very satisfactorily at first—the favourable appearances lasted even for three or four years, but at the expiration of that time all these cements fell to powder.

Some very important lessons are to be derived from these failures. Firstly, they demonstrated clearly that the greatest possible care must be taken to ensure a perfect mixture of the ingredients of these cements, for the molecules of the silicate of alumina cannot enter into combination, if they do ever combine, with the lime unless they be mixed with it in a state of very minute division. *A priori*, then, we may assert that it is preferable to mix the clay with the carbonate, or the subcarbonate, before calcination. Secondly, it would appear that there must be a specific difference between the puzzolanos produced by the slow action of volcanic heat upon the various ingredients, and that produced by an artificial calcination, even should there not be a difference in the chemical constitution of the respective substances.

Vicat studied the causes of these failures, and was led by them to some conclusions which may probably explain, not only the disintegration of the limes, but also the destruction of some of the building-stones, by sea-water. He found in the sea-water a very considerable portion of hydrochloride of magnesia, and he proceeded to experiment upon its action upon the hydrates and imperfect carbonates of lime. He found that in a simple solution of the hydrochloride, the particles which were already in a state of perfect carbonization remained intact; but that the particles which were simply in the state of hydrates passed into that of a soluble hydrochloride, and that the magnesia was introduced into the mass and disseminated throughout the whole tissue. It there quickly passed to the state of a carbonate, with the greater facility when any carbonic acid gas was present. From this Vicat was led to think that the imperfectly carbonated parts of the cements, whose failure led to the investigation, must have taken up the magnesia from the sea-water, and passed to hydro-carbonates of lime and magnesia, similar to the dolomites, whose formation may perhaps be accounted for in like manner. This would of course be accompanied by a mode of crystallization different from that of the ordinary carbonate of lime, leading, doubtlessly, to the disintegration of the whole mass.

The engineer charged with the direction of the works at Rochefort told me that, besides taking up the magnesia, and passing to the state of a carbonate of lime and magnesia, the mortars at Fort Boyard contained crystals of sulphate of lime. Now, as the sea-water does contain a considerable portion of the sulphate of magnesia, it is possible that the lime may have absorbed the sulphuric acid thus presented, and given rise to the new combination, which in its turn must have contributed to destroy the cohesion of the whole body, for the tendency of the sulphate of lime in crystallizing is known to be expansive.

The practical lesson to be drawn from these researches would be, never to employ the artificial puzzolanos, in the present state of our knowledge of this branch of chemistry, for any works of importance where water charged with salts is likely to affect them. It also shows how much care should be taken before employing new compounds in works of importance; for we see that in these cases no symptom of decay manifested itself during the first three or four years. Such want of precaution is the more culpable in England, where we possess natural cements of such undoubted excellence, and where it would be so easy to procure the best hydraulic limes.

3. The puzzolano is a volcanic substance of a pulverulent character, and a violet red colour, which was first employed in the fabrication of mortars by the Romans. It was then, according to Vitruvius, found in the vicinity of Puzzoli, near Baia, and not far from Vesuvius. Subsequently a similar material has been found in the Vivarais, a theatre of extinct volcanic action in the centre of France; near Edinburgh; at a village called Brohl, near Andernach on the Rhine, where it is worked under the name of trass or terrass; and in almost all the localities marked either by the present or past action of subterranean fires. Its aspect varies, however, very much; sometimes it is in a state of powder, at others in coarse grains; often in the form of pumice, scoria, or of tuffa or small rubble-stone. Its colour is often brown, or yellow, or grey, or black, even in the same locality.

The Tripoli, and the sandstones and limestones altered by contact with the rocks of eruption, also frequently take the character of puzzolanos, and may be classed, therefore, as pseudo-volcanic products of a similar category. But the conditions under which they were exposed to the heat of the volcanic rocks, and under which they gradually cooled, have necessarily modified their chemical and mechanical nature.

The puzzolanos are principally composed of silica and alumina, with a little lime in combination, mixed with potash, soda, magnesia, and oxide of iron. The iron appears to be in a peculiar state of magnetism; for although in very feeble proportions, it is capable of affecting the needle.

Berthier gives the following analysis of the puzzolano of Civita Vecchia and of the trass of Andernach:—

	Trass.	Puzzolano.
Silica	0·570	0·445
Alumina . . .	0·120	0·150
Lime	0·026	0·088
Magnesia . . .	0·010	0·047
Oxide of iron. . .	0·050	0·120
Potash	0·070	0·014
Soda	0·010	0·040
Water	0·096	0·092
	0·952	0·996

Essays have also been made with the basaltic and trass rocks in the same manner as with the puzzolanos, and the result has been found to be the same. The difficulty of breaking or pounding them, however, is a very serious objection to their economical employment. Indeed, the manner of action of these various volcanic productions is still so much involved in obscurity that it is a matter of great doubt whether the lavas are highly to be recommended. If the action be principally chemical, of course, when well ground, they are likely to produce the same effect as their congeners; although all this class of substances vary within very wide limits in their chemical composition. If it be merely mechanical, and arise only from their porosity and the facility with which they absorb and combine with the water, their density is a very serious objection. Vicat is of opinion that basalt should be burnt so as to produce a vitrification before it is employed.

Whatever be the cause of the peculiar action of the basaltic rocks, it is evident that the effect produced by the mixture of the puzzolanos and trass is eminently useful in rendering the richest limes fit for every description of works executed in either sea or fresh water. Smeaton used them in the Eddystone Lighthouse with the blue lias lime. Since then, and previously, even as far back as the time of Vitruvius, they had and have been employed in conjunction with limes obtained from chalk and crystalline limestone with perfect success. The essential difference in these cases is, that less is required when hydraulic limes are used, than when they are mixed with the rich limes. The latter will bear at the same time a large quantity of sand or gravel, the former only a very small quantity. The results, if the proportions be well regulated, are the same; the determination of the sort of lime must, therefore, be entirely guided by motives of economy.

4. The term "slag" is usually applied to the vitrified earths which are left in furnaces, either for glass or iron, after the purer products are withdrawn. "Scoriæ" are the lighter, more porous, and less perfectly vitrified earths, which arise principally from the puddling and refining of iron; the term is also applied to the less compact portions of the slag. Cinders are the earthy residues from the combustion of woods, peat, coal, or other combustibles.

The slags and scoriæ differ very considerably in their chemical nature, partly from the constitution of the minerals from which they are obtained, partly from the different action of the furnaces from whence they are produced. They principally consist of silica, with a feeble proportion of alumina, lime, magnesia, and very large proportions of the oxides of iron and manganese.

Hassenfraz and Berthier give the following analysis of these materials—namely,

Place.	State.	Substance.	Silica.	Alumina.	Lime.	Magnesia.	Oxides of	
							Iron.	Manganese.
Allevard .	Black	Slag .	49	4	10	2·4	21	11
St. Hélène	Bad .	„	71	2·5	7	3	4	8
Breteuil .	Black	„	47	11	23	..	7	..
Kaiserlautern	„	„	49	15	30	..	13	..
Mont Blanc	„	Scoriæ	23	1	2	1	45	24
„	„	„	18	1	14	1	61	9
„	„	„	9	1	10	8	56	3
Rives . .	„	„	29	..	18	2	44	4

On comparing these results with those obtained from the analysis of the puzzolano and trass, we perceive at once a very remarkable difference in the proportion of the ingredients, as we also find that the scoriæ and the slag differ from one another. The slag, when the furnaces are well managed, contains but little iron; the scoriæ contain so much that they are at the present day almost invariably worked over again in the most economically managed iron works, producing, it is true, very inferior iron.

When ground into powder, the scoriæ and slags, which contain a large proportion of the mineral oxides, make very good mortars if mixed with middlingly or perfectly hydraulic limes. With the former it is not advisable to use them in positions where the mortars would be exposed to the action of running water; with the latter they may be used to replace sand, sometimes with advantage. (See Appendix C, page 125.)

Coal cinders, according to Weigleb, Dolomieu, and Panzerberg, contain usually 44 parts of silica, 17 of alumina, 5 of lime, and 34 of oxide of iron. When properly mixed, they appear to render the rich limes moderately hydraulic. Great care requires to be exercised in their manipulation to proportion the quantity of water used, for they absorb it with such avidity that, unless there be a large quantity present, they abstract it from the hydrate of lime, and render the crystallization of the latter imperfect. Workmen characterise this action by saying that the lime becomes short; in fact, its coherent powers are much diminished. If, however, the necessary precautions be taken, coal cinders may be usefully employed for works out of the water.

Wood cinders are often objectionable in consequence of the excess of alkali they contain: if this be removed by washing, they may occasionally be useful in the absence of other materials capable of communicating hydraulic properties. Peat ashes have never been tried in any scientific manner; but there does not appear to be any reason why they should not be as useful as those of wood.

In page 36 we already noticed the use of the clinkers which fall through the fire-bars of the limekilns. Their hydraulic properties appear to arise from the mixture of the lime in a very minute state with the silicate of alumina of the cinders. In Belgium they are very largely and very successfully used for canal and river works under the name of "cendrée de Tournay."

Vicat classes the different materials named and described above still further, according to the energy of their action upon the limes with which they are mixed. He calls "very energetic" any substance which, after being mingled with lime slacked in the usual manner, and brought to the consistence of a stiff paste, produces a mortar capable of setting from the first to the third day; of acquiring after the lapse of twelve months a degree of hardness equal to that of a good brick; and of giving a dry powder if sawn with a tooth saw after that time.

"Simply energetic," any substance which will determine the setting from the fourth to the eighth day; and which is capable of acquiring after twelve months the consistence of a soft stone, and of giving a damp powder under the tooth saw.

"Slightly energetic," when the setting only takes place between the tenth and the twentieth day; the consistency of hard soap would be acquired after twelve months, and the mortar would then clog the tooth saw.

"Inert," when the materials, if mixed with rich limes, exert no influence upon their action under water. In all these cases the mortars are to be immersed immediately. It is, moreover, to be observed that the degree of hardness attained is the only invariable characteristic, for the time of setting varies very considerably.

Having established these differences, Vicat ranges the common sands amongst the materials he classifies as "inert." The arènes and grauwacké rocks yield materials which are but slightly energetic. The puzzolanos, whether natural or artificial, are classed occasionally as being simply energetic or very energetic, as the case may be. Experience, however, shows that the artificial puzzolanos should only be ranged in the first class.

These different actions appear to be owing to the affinity of the several materials for the lime. Vicat found, in fact, that, if treated by acids and by lime water, they were distinguished from one another as follows:—the inert materials resisted the action of acids, unless when calcareous sand was operated upon, and were totally without influence, even upon boiling lime water. The slightly energetic materials yielded in a trifling degree to the acids, and took up a small proportion of the lime from the lime water. The energetic, and very energetic, materials were powerfully affected by the acids, and took up a very notable portion of the lime in solution.

The same author gives, as the result of forty years' experience, the following tables of the materials it is advisable to mix together to obtain the best results in the respective cases mentioned. He supposes that the architect or engineer has under hand the four descriptions of lime, and the different substances to be mixed with them; and that in the first case he desires to obtain a mortar capable of attaining a great degree of hardness under water, under ground, or in places where there is a constant humidity; in the second case, where it is desired to obtain a mortar able to set rapidly in the open air, to resist rain, and the changes of the weather. He recommends, then, to mix with

CASE THE FIRST.

Rich limes.	Moderately hydraulic.	Hydraulic.	Eminently hydraulic.
The very energetic puzzolanos, either natural or artificial.	The simply energetic puzzolanos. The very energetic ditto, mixed with half sand or other inert matter. The energetic arènes, or grauwacké rocks.	The slightly energetic puzzolanos. The energetic ditto, with half sand or inert matters. The slightly energetic arènes, &c.	The inert matters such as sand, &c. Slag, scoriæ, &c.

CASE THE SECOND

Rich limes.	Moderately hydraulic.	Hydraulic.	Eminently hydraulic.
No ingredient can attain the object.	No ingredient can perfectly attain the object.	Any description of sand; pounded quartz. Dust of pounded limestone and other inert matters.	Any description of sand; pounded quartz. Dust of pounded limestone and other inert matters.

General Treussart, however, does not agree with Vicat in supposing that the chalk, or rather the rich limes, cannot be rendered capable of setting by the mixture of puzzolanos; and, indeed, the experience of almost all builders would lead us to believe that Vicat has, in this case, been carried away by the love of theory. Gauthey, in his work upon the construction of bridges, however, seems rather to lean to Vicat's opinion; which is confirmed, it must be added, by the experience of the engineers of Toulon and Marseilles.

CHAPTER VIII.

ON THE MAKING OF MORTARS.

The making of mortar comprehends the slacking of the lime and the mixture of the ingredients worked up with it. As we have already seen, both the former process and the nature of the latter differ, according to the nature of the lime to be dealt with. It is, however, a universal rule, in contradiction to the slovenly practice of London builders, that all limes, of what nature soever, should be reduced to a paste before being mixed with the other ingredients.

People who have not studied the action of the hydrates in a scientific and consecutive manner, oppose the introduction of the previous manipulation of the lime on the score of the extra expense, and on the pretence that the lime loses in strength thereby. As to the objection of the expense, that must of course be estimated by the importance of the works. The second objection is to be met by observing that the rich limes require to be for a long time exposed to the air to enable them to take up the carbonic acid gas; and that, therefore, so far from losing, they gain by exposure; and, moreover, the hydraulic limes being very difficult to slack, it is necessary that all their particles should be put in contact with the water. If the lime be not previously reduced into the state of a perfect hydrate, it is always exposed to blister, and to disintegrate, in a manner depending upon the comminution of its particles before being employed: for it is evident that if the lime be ground, the more inactive particles are in a more favourable condition for the absorption of the water.

The degree of consistence of this paste should vary with the nature of the extraneous materials. It should be stiff whenever it is intended to form a gange for substances whose particles are hard and palpable, and which are capable of preserving sensible distances from one another. It should be more liquid when the substances to be mixed with it are pulverulent, of impalpable and fine grains, presenting an homogeneous appearance, and in which it is impossible to distinguish the separate elements, such as the puzzolanos, &c. To secure a proper state of the hydrate, it is of very great importance, however, not to use too much water in slacking the lime. So much should be used, and only so much, as is necessary to cause the quick lime to fall to powder. It is also equally important not to mix up into the state of paste more lime than is immediately required to be used; for although, upon being reworked, the hydrates, which had began to solidify, give off the water they had rendered latent as it were, yet a portion of their force must evidently be lost by their doing so in proportion to the degree of advancement of the process.

In France, whenever great care is required in the fabrication of the mortars, the lime is worked up into a paste in a mill, consisting of two vertical stones working in a trough. The lime, after going through this operation, is then mingled with the sand in a pug-mill, or by hand, upon a floor. If the dimensions of the construction should be such as to justify the expense, it should be made a necessary condition that mechanical means be employed, for even with the greatest possible care the mixture by hand is never perfectly effected.

The quantities of sand to be used vary, as might be expected, according to the nature of the limes, and also of the sand itself. Within certain limits, if the limes do not gain by the mixture, at least their effect is not sensibly diminished. Thus we find that, for the rich limes, the resistance is rather increased if the sand be in the proportions varying from 50 to 240 per cent. of the paste measured in bulk in the state of a firm paste. Beyond that point the resistance decreases.

The resistance of hydraulic limes increases, if the sand be mixed in the proportion of 50 to 180 per cent.

of the paste; from thence it decreases. The much greater proportion of sand the rich limes are able to support, may perhaps account for the partiality of the builders in their favour.

If it be required to mix common lime and puzzolanos, the best proportions, according to General Treussart, are 1 of lime in powder to $2\frac{1}{2}$ of puzzolano; 1 of lime to 2 of trass; or 1 of lime to 1 of sand, and 1 of puzzolano or trass.

The best hydraulic limes, as we have seen, lose much of their qualities if long exposed to the air; it is therefore advisable to work them only for the time absolutely necessary to ensure, firstly, their perfect reduction to the state of hydrates; and, secondly, the intimate mixture of the lime and sand. The rich limes, however, as we have before said, inasmuch as they absorb the carbonic acid gas with difficulty, gain by being exposed for a longer period to the contact of the atmosphere. As far as such a proceeding is consistent with economy, it is advisable, then, to protract the operation of their manipulation as much as possible; it is even advisable to work up large quantities of such mortar beforehand, rendering it fit for use by a second manipulation.

Some of Vicat's experiments show that all limes lose two-fifths of their strength if mixed with too much water. It is then better to wet the materials to be used, and to employ a stiff mortar, than to follow the course usually adopted by masons and bricklayers of using very soft fluid mortar. The system of grouting is more than questionable in its results; the lime suspended in it is nearly destroyed, the extra quantity of water is but an addition to the difficulties of setting opposed to the mortar already in place.

There are conditions of the atmospheric state which affect the goodness of the mortars, about whose action the best authorities are not decided. For instance, those made in summer are always worse than those made in winter. It has been supposed by some that this fact is accounted for by the too rapid desiccation of the mortar; and Vicat even asserts that they lose four-fifths of their strength if allowed to dry very rapidly. He recommends, in consequence, that the masonry be watered during the summer months, in all constructions of importance, to guard against this danger. Probably the hydrates are not in a favourable condition to absorb the carbonic acid gas, if they be allowed to dry rapidly; the presence of the water being necessary for the combination of the lime and the carbon.

The freedom of the water from carbonic acid gas in solution is also a necessary condition of the successful use of the hydraulic limes. Their success depends, to a certain extent, upon the slow, gradual manner in which they take up that gas from the atmosphere, and crystallize about the nuclei offered to their action. Some engineers prescribe that the water should be deprived of such impurities by boiling, and although the precaution be rather exaggerated, it is certainly of a useful tendency.

As the lime reduced into a paste does but fill up the voids of the materials it is mixed with, there is necessarily a very considerable diminution of bulk upon the quantities of the respective substances taken separately. The exact amount of this diminution varies, of course, with the limes or sand employed; but as a general rule it may be taken at about three-fourths of their collective volumes. To state this in a convenient formula; if a = the bulk of the lime, b = the bulk of the sand; then $(a+b) \times 0{\cdot}75$ = the bulk of the mortar they will produce.

The position in which a mortar of any description is to be used, also modifies the proportions of sand which it is desirable to mix with it. Underground, in the water, and in damp positions, less sand should be employed than in the open air, where it is exposed to the changes of the atmosphere.

It is often a matter of importance to know the powers of resistance of mortars; but, as they differ within a very large range, it is not easy to state them very precisely. The best experiments, however, show that we may safely calculate, for all practical purposes, upon a resistance of 14 ℔s. avoirdupois per inch superficial, to a force acting in a direction to tear asunder by an effort of longitudinal traction; of 42 ℔s. to a crushing force; and of $5\frac{1}{4}$ ℔s. per inch superficial to a force tending to make the particles slide upon one another. It would not be safe to expose new works to greater efforts than those which could be included within the above limits.

CHAPTER IX.

ON CONCRETES.

The term "concrete" is usually applied to a species of rough masonry of small materials, consisting of gravel or broken stone mixed with a lime, either previously worked into a mortar or not, as the nature of the lime may require. It is principally used for the purpose of distributing the weight of a large heavy construction over the greatest surface possible; or for the backing of coursed masonry, in cases where walls are required of great thickness. Properly speaking, it would be better to apply the word "concrete" to this sort of masonry, when executed in the manner usually adopted in our country, by slacking the lime upon and in immediate contact with the gravel. When the lime has been previously worked into a paste, the French word "beton" might be applied, for the sake of distinguishing the two processes.

The use of this beton, or concrete, is very ancient, for it is known to have been employed by the Romans; and Smeaton expressly states that he derived the idea of using it, as a backing for river works, from an inspection of the ruins of Corfe Castle, in Dorsetshire. In the middle ages it was very commonly used, as may be proved by an inspection of the ruins of feudal fortifications. General Pasley was, therefore, mistaken in awarding the merit of the introduction of this system to Sir Robert Smirke.

Of course, the quality of a concrete must depend upon the nature of the materials to be employed. The situations in which it is to be used are mostly those in which there is a great amount of humidity, and in which from the facts that, firstly, the concrete is in large masses; and secondly, that it is covered up as soon as executed, it is necessary to employ only such materials as are susceptible of a rapid setting and continued progression in their powers of resistance. In the former parts of this treatise, we have seen that the limes which unite the above conditions are the hydraulic limes, obtained either from the argillaceous, or the magnesio-argillaceous, carbonates of limes. In their absence, some ingredients of the nature of the puzzolanos, burnt clay, slag, or cinders must be used. But it should always be borne in mind, that these mixtures are but very imperfect imitations of the natural productions; they should never be used if the hydraulic limes can be obtained, even at an increased price; and, as was before said of the hydraulic limes, those obtained from the calcination of the limestone itself are preferable to those made artificially.

In almost every work upon the art of construction, we meet with descriptions of modes of making concrete. It is, however, very discouraging to observe that, in spite of all that may be said, the majority of architects and engineers treat the subject with such utter indifference that the old imperfect systems are still retained, and the conduct of these works is left almost invariably to some rule-of-thumb workman, who only knows that he has been accustomed to make concrete in a certain manner, without knowing any one of the principles which regulate the action of the materials he works with. We thus find that the greater part of the concrete made in and near London, where the building art ought to be the most advanced, is made simply by turning over the ground stone lime—a very moderately hydraulic one, by the way—amongst the gravel. It is then put into barrows, and shot down from a stage. Such a mode of proceeding is rapid and economical; but it is eminently unscientific, leading, doubtlessly, to the waste of material we so often witness, for the practice is to make the concrete about one-third thicker than would be at all necessary if the process of making it were more perfect. Unfortunately, in England, we do everything in such a desperate hurry, especially since railroads have been constructed, that we cannot afford the time necessary for a perfect execution of the works. Failures are consequently frequent, the waste of materials enormous; and, of course, between the two, the expense is out of all proportion to what it ought to be.

It cannot be too often repeated that the first condition necessary to obtain a good concrete, or beton, is that the lime be brought to the state of a perfect hydrate before being mixed with the nuclæi which it is intended to surround. It should, therefore, be reduced to the state of a thick paste, and made into a mortar before it is mingled with the gravel. Instead of being thrown down from a height, and left to arrange itself as it best may, it should be wheeled in on a level, and beaten with a rammer; for we find that, when thrown thus from a height, the materials separate, and the bottom parts of a thick bed of concrete are without their proper proportion of lime. The advantage of making the lime into a mortar previously is, that it fills in a much more perfect manner the intervals of the gravel or stones; and, in fact, renders the concrete what it is meant to be, an imperfect species of rubble masonry.

For water-works required to set rapidly, an excellent concrete may be made by a mixture of hydraulic limes, puzzolanos, and sand. The proportions found to yield the best results are given by Treussart, as follows: viz.,

30 parts of hydraulic lime, very energetic, measured in bulk, and before being slacked.
30 „ of trass of Andernach.
30 „ of sand.
20 „ of gravel.
40 „ of broken stone, a hard limestone.

The above proportions diminished one-fifth in volume after manipulation: the mortar was made first, the stones and gravel added thereto. When the puzzolano of Italy is used, the proportions, for the same description of work, become (measured in bulk, as before)—

33 parts of energetic hydraulic lime, measured before slacking.
45 „ of puzzolano.
22 „ of sand.
60 „ of broken stone and gravel.

The first of these concretes should be employed immediately it is made; the second requires to be exposed about twelve hours before it is put in place.

When burnt clay or pounded bricks are used, the proportions should be the same as with the trass; but, as we have seen before, the use of this material is not to be recommended in the sea water. If rich limes be used instead of hydraulic, the dose of the natural or artificial puzzolanos must be increased, and that of the stone and gravel diminished.

In positions where sufficient time can be allowed for a concrete or beton to set, (if made simply of lime, sand, and gravel,) the expense of the puzzolanos should be avoided. A very excellent concrete for either sea or river works is made by a mixture of a mortar made of three parts of fine sand to one of hydraulic lime unslacked, with equal quantities of gravel or broken stone: the proportions of the last may often be augmented to $1\frac{1}{2}$ to 1 of the mortar without inconvenience. No water should be mixed with the mortar and gravel during their manipulation; the mortar itself, if possible, should be prepared in a pug-mill, and mixed with the gravel by being frequently turned over on a platform.

Every precaution should be taken to prevent the different ingredients from being mingled with clay or other earths.

The concrete thus made should be spread in layers from 10 in. to 1 ft. in thickness, and well rammed, until the mortar begins to flush up at the top. A course once commenced should never be allowed to be interrupted until completed throughout the whole of its length. When the work is executed in water, other precautions require to be taken, not only for the purpose of compressing the concrete, but also to prevent the lime from being washed away. These must, of course, vary with the circumstances of each particular case; but we must always remember that works of this kind, executed under water, are far inferior to those executed in the open air.

When works are left to the care of mere workmen, as they too often are with ourselves, a very absurd mode of making concrete is often adopted where there is much water to be contended with. The lime is mixed with the gravel, without being previously slacked, and left to absorb the water necessary for its passing to a hydrate how it may. Such a course is unphilosophical and dangerous in the highest degree, and cannot too carefully be guarded against. In fact, the object to be attained, of securing a carbonate of lime by the equal and regular action of the hydrate, is thereby rendered impossible. It is much more than probable that many of the particles of lime can in these cases only obtain the water necessary for their solidification by absorption from the others around them. They must begin their action after the others have ceased; and as the process of crystallization in all cases requires a new molecular arrangement, often accompanied by an expansion, there is little reason to doubt that if the lime be in large quantities, it must disintegrate the mass.

Vicat executed the beton for the bridge of Souillac on the Dordogne in the following proportions in volume:—

26 parts of hydraulic lime in paste.
39 „ of granitic sand.
66 „ of gravel.

This mixture diminished in volume in the proportion of 1·31 to 1·00. But the diminution in volume differs of course with the limes, or the sands used in the different localities.

Broken limestone appears to add very much to the qualities of concretes, betons, and mortars. Very probably this may be attributed to the affinity between the molecules of the already formed carbonate of lime, and that which is in process of formation; the new crystals may group themselves more easily about bodies whose form is similar to the one they are themselves to assume. Or possibly there may be a tendency in the chemical elements to arrive at a state of equilibrium; and the carbonate of lime may, therefore, be supposed to part with a certain portion of its carbonic acid gas.

Many attempts have been made to produce with concrete a species of artificial blocks—amongst others, by Mr. Ranger. These do not appear to have answered in practice; but we may safely assert that, if the mortars had been properly mixed in the first place, and if the concrete, when in the mould, had been properly rammed, and then allowed to dry very gradually, there is no reason why the attempts to make artificial stone should fail. One great cause of failure of this kind of artificial stone always has been, that the blocks are exposed too soon after fabrication. They dry rapidly, unevenly, and consequently crack in every possible direction, and thus offer great facilities for the action of the frost upon any water they may contain.

The resistance of beton or concrete should never be regarded as being superior to those already given for limes, if the superstructure be commenced upon them immediately. In both cases the resistances are found to increase with comparative rapidity during the first six or seven months. It would be advisable, therefore, to leave concretes undisturbed during that space of time if it were possible.

At Cherbourg Breakwater and at Dover Pier, Portland cement has latterly been largely and successfully used for the purpose of making immense artificial blocks. At Cherbourg the blocks are constructed upon the sheltered side of the Breakwater, with coursed rubble stone bedded in a mortar of granitic sand and Portland cement, and they are subsequently floated upon rafts over the positions where they are to be immerged. At Dover the cement was used to make a species of concrete, which was poured into a mould and allowed to harden before being placed in the body of the masonry in the ordinary way. (See Appendix D, page 126.)

CHAPTER X.

ON CEMENTS.

A PECULIAR class of the argillaceous limestones yields on calcination a species of lime capable of setting under water with considerable rapidity, of acquiring a great degree of hardness within a very short space of time, and of being employed without the admixture of any foreign substance. The name of "cements" has been (somewhat absurdly) conferred in an especial manner upon this class of materials, although, properly speaking, the word is generic, and should include all substances capable of cementing together small materials.

The first discoverer of this kind of cement was Mr. Parker, of London, who in the year 1796 took out a patent for the manufacture of what he called Roman cement, from the septaria nodules of the London clay formation, found in the Island of Sheppy. His process consisted in calcining the stone, previously broken into small fragments, to a point equal to the commencement of vitrification, and then reducing it to powder by some mechanical operation. Parker appears to have thought that a very high degree of heat was necessary to the success of the operation; but we shall have occasion to observe hereafter that the point of calcination has not the same influence on these cements which it has upon the ordinary limes.

Subsequently Mr. Frost discovered that the septaria of Harwich, on the coast of Essex, produced a cement of the same nature. Mr. Atkinson introduced another made from the nodules of the argillaceous limestones of the secondary formations of Yorkshire. On the coast of France a similar material was found in 1802, at Boulogne. M. Lacordaire discovered it also at Pouilly, in the ancient province of Burgundy; MM. Lamé and Clayperon found it in Russia. It occurs in the Isle of Wight, in the Bay of Weymouth, and doubtlessly is to be met with in all the marl beds intercalated between the principal stages of the limestone formations, and very frequently in the tertiary clays, in the form of detached nodules, of a dark-coloured argillaceous limestone traversed by veins filled with calcareous spar. The colour is sometimes blue, especially when the nodules are obtained from the lias; sometimes brown, or a deep red, in the tertiary formations, owing to the presence of the oxide of iron in very considerable quantities.

The mineralogical composition of the stones from which the cement is made differs very much; but the characteristic type may be said to consist of above 30 and below 60 per cent. of clay and other extraneous matter in combination with the carbonate of lime. The Sheppy stone usually contains 55 parts of lime, 38 of clay, and 7 of iron; the Yorkshire stone contains 34 parts of clay, 62 of carbonate of lime, and 4 per cent. of iron; the Harwich stone contains 47 parts of clay, 49 of carbonate of lime, and 3 of oxide of iron. But the most careful analyses made by Berthier are as follows. The stones experimented upon were—column 1, the Sheppy stone; column 2, the septaria of the coast near Boulogne; column 3, a stone from Matala in Sweden; column 4, a stone from the neighbourhood of Argenteuil, near Paris.

Carbonate of lime	0·690	0·639	0·661	0·651
Magnesia	0·002	...	...	0·019
Oxide of iron	0·037	0·075	0·022	0·060
„ manganese	0·012	...	...	0·070
Silica	0·180	0·150	0·295 (Silica, Alumina, Water together)	0·140
Alumina	0·066	0·048		0·060
Water	0·013	0·066		0·060
	1·000	0·978	0·978	1·060
Waste or error	...	0·022	0·022	0·060 deduct.
Total	1·000	1·000	1·000	1·000

The cement stones are burnt in conical kilns with running fires, and, in England at least, with coke or coal. The mode of burning requires a considerable degree of attention, for experience has demonstrated that Parker was mistaken in supposing that a commencement of vitrification was necessary. On the contrary, the practice of manufacturers at the present day is rather to under-burn the cement, with the object of economizing the expense of grinding. This material differs in this respect also from the ordinary limes, that the precise point of calcination does not appear to affect its qualities.

Before being burnt, the stone is of a fine close grain, of a peculiar pasty appearance; the surfaces of fracture are rather greasy to the touch, and somewhat warmer than the surface of the stone. Examined with the microscope it exhibits many sparkling points, which may be either crystals of carbonate of lime, or of some of the other constituents. It sticks easily to the tongue; it does not strike fire; its dust, when scraped with the point of a knife, is a greyish white for the most part, especially when derived from the blue lias formation. It effervesces with nitrous acid, and gives off nitrous acid gas. During calcination the cement stone loses about one-third of its weight, and the colour becomes of a brown tinge, differing with the stones from which the cement is obtained. When burnt it becomes soft to the touch, and leaves upon the fingers a very fine dust; and it sticks very decidedly to the tongue.

When withdrawn from the kiln in blocks, the cement absorbs water with so much difficulty that General Pasley was almost justified in stating that it could not do so. As he remarks, "it might be preserved in this state for a long time in a dry room; but calcined cement being of no use until it is pulverized, this is always done at the mill of the manufacturer, to save the necessity of every purchaser providing himself with an apparatus for grinding it." It is usually put into casks well closed when thus ground, and may in that state be preserved for a very long time; but contact with the atmosphere rapidly deteriorates its quality. The cement powder absorbs humidity and carbonic acid gas from the atmosphere; it then passes gradually into the state of a subcarbonate; but a second burning, carried to a lower degree than that employed for the first calcination, restores its useful properties.

It is to be observed, and the fact is of sufficient importance to warrant repetition, that though all cements and limes tend to reassume a state of carbonization similar to that in which they existed in the stones from whence they were extracted, they only do so to a very imperfect degree. The proverb that lime at a hundred years is but a child, is perfectly true. Cements, on the contrary, harden very rapidly; but we have no instances of their acquiring the strength of the original stone.

M. Petot mentions that, in his experiments upon the calcination of the cement stones, he found that when it had been carried to the point of driving off all the carbonic acid gas, the powder it gave was perfectly inert. This should be borne in mind in making any new experiments on this class of limestones; and at any rate it constitutes a very remarkable difference between it and those which produce the common lime. The same distinguished engineer also found that cement *mortar* was capable of being revived after the lapse of a considerable time. We may remark, in passing, that his researches form the best text-book upon the subject of the calcination both of limes and cements.

There does not appear to be any definite rule in the London trade respecting the size of the casks, or the nature of the means by which the cement is transported. This is of little importance as long as it is intended to use it in the immediate neighbourhood of the source of supply. When, however, the cement has to be transported to a great distance, it should never be packed in barrels of more than 6 cwt. each, and the greatest precautions should be adopted to prevent the contact of the atmosphere in any manner whatever.

The specific gravity of the natural stone is usually about 2·16; that of the calcined stone in block is about 1·58; that of the powder, very loosely packed, is about 0·85 to 1·00. The best cement is, however, that which is the lightest, and it should be ground very fine. The size of the sieve required to be used by the French engineers is No. 2 of their wire gauge, and 185 meshes to the square of 4 inches of a side; which seems a very reasonable dimension.

The use of these natural cements requires a great degree of skill and attention on the part of the workman. If it be not brought to a proper consistence—if too much or too little water be used—if it be not immediately employed as soon as made—it solidifies unequally, cracks, and adheres badly to the materials The care requisite for its successful application constitutes, in fact, the great objection to the use of cement. It is always dangerous to be obliged to rely on the skill or integrity of workmen, who either do not understand the necessity of taking pains with their work, or who, from being paid by the piece, have an interest in slurring it over.

A small quantity of water only is necessary to work up cements to their greatest point of resistance, which General Treussart found to be the most successfully attained when the water was employed in the proportion of one-third of the cement in volume. It is necessary to beat up the cement very frequently; indeed, the more it is turned over before the setting commences, the harder it becomes. No more should be prepared than can be immediately employed, for without this precaution it will set in a very short time.

The time of setting varies with the nature of the water used, and the quantity of sand present. With sea-water the time is longer than with fresh, and the sand retards the process of setting considerably. When the cement is new, however, the time of setting, if it be used pure, should never exceed half an hour, a quarter of an hour being the normal period. It often happens, however, that the best cement will harden in an interval not exceeding five or six minutes; under water the interval becomes one hour at most. When mixed with sand in proportions varying from $\frac{1}{2}$ to 1, $1\frac{1}{2}$, and 2, to 1 of cement, the time of setting becomes from 1 h. 2 min. to 1 h. 18 min. in the air; under water the time becomes proportionally longer. It may even, under sea-water, and if the mixture be also made therewith, extend, for the mixtures with large proportions of sand, to 24 hours.

Pure cement has much greater powers of resistance than when it is mixed with sand in any proportion whatever—in this again differing from the limes. The resistance to rupture after about 20 days' exposure to the air, is about 54 lbs. per inch square when the cement is used pure; if the sand be in the proportion of $\frac{1}{2}$ to 1 of cement, the same resistance falls to 37 lbs.; if it be in equal proportions, it falls to 27 lbs. Doubtlessly, these resistances are less than we often meet with, but it is not safe in practice to count upon a greater strength than they indicate. Rondelet's rule, that the resistance to crushing is three times that offered to traction, does not seem to be quite correct in this case, for it would make the resistance of pure cement only equal to 162 lbs. per inch superficial; but, again, it would not be safe to take a higher degree of strength as the basis of any series of calculations for practical purposes. Moreover, the permanent load in any large works should never be more than one-sixth of that required to produce rupture; and, if small materials be employed, the resistance should be calculated at only one-fifteenth of that indicated by theoretical conclusions of the above nature.

Cement adheres very strongly to iron, to granite, and to bricks, in a proportion following an inverse direction to the manner in which they have been just named. When re-burnt, after having lost its strength by exposure to the air, the resistance is not more than one-fourth of that of the fresh cement from the stone.

The resistance to an effort tending to make stones slide upon their beds when joined by pure cement, may be considered equal to 9 lbs. per square inch upon the average; but it often arrives at 18 lbs. per inch.

From these considerations, it would appear that the best mode of using the natural cements is to employ them without sand in all works under water, or where a great crushing weight is to be brought upon them at once. For foundations in damp situations, where rapidity of execution is desired, they may be mixed with 2 parts of sand to 3 of cement; the same proportions are suitable for cornices, or coatings exposed to the weather. 3 parts of sand to 2 of cement make a good mixture for perpendicular faces; but care must be taken that the cement be used so as not to allow of the formation of fissures, or the frost will destroy it.

Many of the failures of the coatings executed upon brickwork are to be attributed to the neglect of proper precautions against the action of the atmosphere. It is important that the brickwork to be covered be thoroughly dry before the coating is added, or the expansion of the water it contains will blow off the latter. The cheap and disgraceful system of colouring, instead of painting, also leads to many failures in the employment of this very useful class of materials.

In England, owing to the cheapness of the so-called Roman cement, whether specifically distinguished as Atkinson's, the Medina, or merely called Roman, almost all the works executed in water at the present day are executed with it. But there are reasons to make us doubt whether we do not in this case adopt a system which is at least open to objection. Cement is so convenient, that engineers and architects neglect to study the qualities of lime; and some very unfortunate accidents have arisen from that neglect. For instance; the author has seen, in one of the government dockyards, the whole of the backing of a graving dock executed in cement, when there were large works in the immediate vicinity for the manufacture of the blue lias lime—a most shameful waste of the money of the nation. All the profession may recollect a sad accident, which cost the lives of several men, and which arose from building columns in cement on bases in mortar. With respect to these cases we may observe that Roman cement is a most admirable material where great rapidity of setting is required; but it should only be used under such circumstances, for good hydraulic limes in time attain a degree of resistance sufficiently great for all practical purposes, and at a much less expense. To use a hard, quick-setting material upon a yielding base, is a degree of ignorance totally unaccountable on the part of any professional man of average discernment. In fine, the uses of these cements are many and various; we, in our country, are rather inclined to abuse them.

There are many sorts of artificial cement employed which are obtained either from the over-calcination of the hydraulic limes (all of them possessing the faculty of acquiring a more rapid setting, and a greater degree of hardness when so burnt), such as the Portland cement before mentioned; or from the mixture of burnt clays with the rich limes. In some parts of the continent, where the natural cement stones do not exist, the latter are much used, and they yield a very tolerable substitute for the articles they replace. They are not exposed to the inconvenience which attends the over-calcined limes, of swelling in setting; but they are far from attaining the hardness of either the natural cements or the overburnt artificial ones. Their use is principally confined to a mixture with the slow-setting limes when they are employed in damp situations, and in these cases they succeed remarkably well. The cess-pools and water tanks throughout the interior of Normandy are lined with a mortar made in this manner, and they resist perfectly; but this description of cement is never used if the natural cements can be obtained at a reasonable price.

It is to be observed, that although the Portland cement is occasionally exposed to the before-mentioned inconvenience of expanding whilst setting, it has other qualities of a very remarkable nature. It becomes, in equal times, after the first setting (which, by the way, is very irregular), much harder than the Roman cements. It will admit of a much larger quantity of sand for every purpose; and, moreover, as it does not absorb the humidity of the atmosphere with the same facility it consequently resists the action of frost more successfully, and is less exposed to discoloration by the formation of vegetation.

In some parts of France, especially in the ancient Lorraine, limestone beds are worked which yield a species of lime intermediate between the Roman cements and the eminently hydraulic limes. The best of these occur at Flavigny, and Richard Menil, near Nancy, where they are principally used for making floors of one piece, and of a smooth uniform surface. The colour of the stone is of a darkish brown, of a great tenacity, and very compact; its specific gravity is 2·62. The lime it produces is of a yellowish grey, and it sets very rapidly in water. Mixed with the clean gravel of the Moselle, in the proportions of $4\frac{1}{2}$ to 1 of cement, the volume of the mixture diminishes one-fourth; it is then spread upon the form prepared to receive it, and well beaten. There must be many beds of such limestone in our own country, as in the neighbourhood of Rugby, Bath, Aberdare, &c.; and, if they were properly sought for, they might add materially to our facilities for building. We require a careful geological survey of England to ascertain the riches we possess of this nature. A commencement was made by the parliamentary commission for the choice of the building stones for the Houses of Parliament; but it did not extend its inquiries to the other branches of this very important part of practical science.

CHAPTER XI.

ON THE VARIOUS CEMENTS COMPOSED OF NUMEROUS EXTRANEOUS INGREDIENTS.

There exists also an infinite number of processes for making cements able to harden under water, and to acquire a great degree of resistance. Their success is of course very various; nor can it well be otherwise, for as all these mixtures depend for their success upon the care and skill observed in their manipulation, they must be exposed to all the accidents which attend the processes of human industry. The following are some of the artificial cements alluded to; but the list might be extended indefinitely without including all the varieties.

They may be separated into two grand divisions, the bituminous and the oleaginous. Both of the classes are of constant use in the arts of building; and they furnish materials of very great importance, either for the coating of works for ornamental purposes, or for protecting them against the action of water.

The bituminous cements are used either for the purpose of supplying the absence of large flagging for street paving, or for covering the extrados of arches, in order to prevent the percolation of water from the upper structure. In many situations they are very successful, when employed for street paving; but, generally speaking, we in England have no occasion for such substitutes for stone. Such is not the case in France, however; and it might be economical to use these cements in some of our own inland towns, where the cost of land carriage renders the stone flagging very expensive. For covering arches, these cements are, moreover, very much to be recommended. In all new masonry, with whatever care executed, there are always movements which fissure the coatings executed in limes or natural cements. These again are subject to unequal shrinkage and contractions, which produce crevices; and, from these united causes, it is very rare to find that such coatings are impermeable. The bituminous cements are more elastic; it often happens in their case that small crevices solder themselves, so to speak; and, if any serious repairs are required to be done, it is much easier to execute them than it is when the works are executed with limes.

The best bituminous cements are obtained from the natural asphalt, which is met with in large quantities on the shores of the Dead Sea; in Albania; in Trinidad; at Lobsann and Bekelbronn, in the department of the "Bas Rhin;" in the department of the Puy de Dôme; near Seyssel, in the department of the "Ain;" at Gaugeac, in that of the Landes; and would, in all probability, be found near Castleton, in Derbyshire, if carefully sought for.

There are two sorts used in commerce, the pure and the impure. The first does not contain extraneous matter in any great degree; the second contains a variable proportion of carbonate of lime, and is, therefore, better adapted to such works as are exposed to the effects of the sun. The purer asphalt melts in such positions, but it is better adapted for subterranean works.

The best bitumen, or asphalt, for the words are very illogically confounded in commerce, is free from water. Its specific gravity is 1·10 to 1·15 at the ordinary temperature; it is solid, but highly ductile, for it draws easily into threads; its fracture is black, slightly brilliant. Put into warm water, it should float upon the surface, and in that operation it should not deposit any sand. It dissolves completely in the oil of petroleum and the essence of turpentine; and the dissolution, which should be of a bistre or dark-brown colour, after being filtered, should not be found to have contained more than seven per cent. of earthy matters. In commerce, much fraud takes place by mixing coal tar and pitch; but these materials, though very valuable by themselves, destroy the superior qualities of the mineral asphalts. It is also highly important to secure the purity of the asphalt from sulphur, or the sulphates of iron. Even so small a proportion as 0·5 (or $\frac{1}{2}$) per cent. would materially diminish its value.

When the asphalt is to be used, the solid bituminous stone is thrown into a quantity of mineral pitch, in a state of ebullition; for if it were put into the caldron alone, it would calcine without melting. If any sand or earthy impurities be present, they should be removed at this stage of the process. The calcareous matters are mixed with the melting bitumen in proportions varying with its nature; and the mixture is applied by means of large spatules, or trowels. Colonel Emy found the following proportions to be the best for the asphalt of Gaugeac, and they may be taken with tolerable safety, as being the most suitable for all the members of this class of cements, when used as a coating for arches.

$2\frac{1}{8}$ pints (wine measure) of pure mineral pitch.

11 ℔s. avoirdupois of Gaugeac bitumen.

17 pints of powdered stone dust, wood ashes, or minion.

It is advisable to lay this cement upon a bed of concrete, or mortar; and as much as possible in slabs of 2 ft. 6 in. to 3 ft. in width. It should be evenly spread and compressed by a trowel, well rubbed and reduced to a uniform close surface. When all the bubbles have been expelled, a fine sand is sprinkled over the surface, and worked in with the trowel, observing never to fill the crevices formed by the air-bubbles with sand, but only with asphalt.

The thickness necessary for coating any arches is not more than from three-fifths to half an inch; the quantity of the cement thus employed to cover a yard square is about $4\frac{1}{2}$ ℔s.

For street paving, it is absolutely necessary to employ under the asphalt a bed of concrete of hydraulic lime and gravel; the upper surface being rendered smooth by a coating of hydraulic mortar. The thickness of the asphalt should be increased to three-fifths of an inch; and it is advisable to add a small quantity of pure quick lime to the bitumen in ebullition, to prevent the asphalt from becoming soft under the influence of the sun's heat. The surface upon which the asphalt is to be employed should be perfectly dry; and it should be applied as hot as possible. All the natural asphalts are not of the same quality in so far as their elasticity is concerned. If, therefore, any of them are found to be too brittle, that defect should be remedied by mixing a quantity of the mineral pitch or petroleum; but on no account by the mixture of coal tar or vegetable pitch.

The coal tars, or vegetable pitch, although they be not so desirable as the natural bitumens for building purposes, may in many cases become very valuable substitutes for them. They are not so supple, the stone powder to be mingled with them requires to be prepared with greater care; and it would appear that they are not so durable as the natural productions of a corresponding class. But they make very good coatings for vaults, or for walls exposed to the dampness of the earth; and many situations occur in which their use must be more economical than that of the materials they are to replace. For foot pavings, however, they do not answer at all.

The mode of using them is to mix powdered calcareous stone, in variable proportions, with the pitch or tar in a state of ebullition. Care must be taken that the stone be thoroughly dry; for if it were wet, it would render the cement porous, from the effect of the vapour trying to escape. The burning, or degree of heat, must also be so regulated that the stone be not converted into quick lime, which takes place with comparative facility owing to its highly comminuted state. The proportions of powder are from 6 to 7 of the pitch in volume, but these require to be ascertained by direct experiment in every distinct case. All the other details of the use of these cements are precisely the same as in the case of the natural asphalts, excepting that it is advisable to use them in greater thicknesses.

The cements used for mosaic works are sometimes of the bituminous character. As applied on the continent, they are of three sorts. The first, which serves to set the large tesseræ in forming floors, is composed of pitch mixed with a black earth; the second, which serves to set stones of middling dimensions, is made of the calcareous stone of Tivoli, and of oil; it is properly an oleaginous cement; the third, which is used for the more delicate mosaics of pieces of glass, is made of lime, pounded bricks, gum andragan, and the white of eggs. The French plumbers unite the glazed pottery tubes they employ for the distribution of water, with a hot cement made of resin, wax, and lime; or with a cold cement composed of quick lime, cheese, milk, and the white of eggs. The list of these mixtures is, as we observed before, interminable; but their use is not of sufficient importance to require a detailed notice.

The oleaginous cements were formerly very much used in London under the name of mastic, for the purpose of the ornamental decorations of the Quadrant, and of King William Street in the City. They produce a very fine, close-grained, even surface, and if painted in the beginning, and repainted every three or four years, they retain their beauty for a very long period. Their use has, however, very much diminished of late, owing to the expense, and the difficulty of the manipulation. Indeed, there are no reasons which should induce us to prefer these materials to the hydraulic cements obtained from the septaria, in face of the great difference in their prices.

The best mastics used are known in commerce under the names of Hamelin's mastic, in England; and the mastic de Dhil, in France. The composition of both is kept secret; but the main principle of their fabrication consists in the mixture of pounded brickdust, or well-burnt clay, or stone, with litharge, the red protoxide of lead, and with perhaps some extraneous matters. As the proprietors of these processes object to their being rendered public, we content ourselves with calling attention to them, and observing, that they are the best of this class of artificial cements. Many substitutes have been invented for them, which have been more or less successful; the following being amongst the most remarkable.

A litharge mastic is made by mingling 93 parts of burnt clay, pulverized, with 7 parts of litharge ground to a very fine powder. It is mixed up for use with a sufficient quantity of very pure linseed oil, to reduce it to the consistence of plaster in a similar state; it is applied like plaster, after the surface has been previously wetted with a sponge filled with oil. This mastic was invented by the Baron Thénard, and it has answered tolerably well.

At La Rochelle, the officers of the engineers used, in 1826, a mastic which very closely resembled the mastic de Dhil.

It was composed of

14 parts in volume of siliceous sand.

14 parts of pulverized calcareous stone.

$\frac{1}{14}$ in weight of litharge (of the united weights of the sand and stone).

$\frac{1}{7}$ of the total weight of linseed oil.

These powders were previously well dried in an oven, for it was found that the affinity of the mixture for the oil depended upon the state of desiccation of the matters, and upon the commencement of a calcination which appeared to be produced. The mastic thus produced was mixed with oil in the usual manner, and the surfaces upon which it was applied were previously soaked with oil.

In Paris the military engineers sometimes use a mastic of nearly a similar composition, which is made of 6 parts in weight of cement, 1 of white lead, 1 of litharge, 3 of linseed oil, and $\frac{1}{2}$ of a richer oil, perhaps an animal oil. At times the cement made from burnt clay is used, at others the natural cement; it has been found also that in some positions the white lead might be advantageously replaced by a similar quantity of puzzolano.

Vauban recommended a kind of mastic which appears to have answered very well for the lining of cisterns and such works. He took 5 or 6 parts in volume of rich lime, which had been slacked in linseed oil, and he mixed these with 2 parts of good cement passed through a very fine sieve. The mixture was beaten up for about half a day; it was laid aside for a night, and beaten up again during half an hour on the next day. It was then laid on the work to be covered in coats of from $\frac{1}{8}$th to $\frac{1}{6}$th of an inch at a time, the joints being first well raked out and cleaned. After three or four days, a second, and subsequently a third and a fourth coat were added, the lower one being well scored to form a key to the last one to be applied. This is the simplest, and experience has shown it to be one of the best methods of making mastic; but we may repeat that such compositions are but elaborate modes of supplying the places of materials which exist already in the more convenient form of the natural cements. (See Appendix E, page 129.)

CHAPTER XII.

ON PLASTERING.

The modes of "rendering" the insides of dwellings vary in different countries with the materials most commonly found. Wherever the sulphate of lime occurs in large quantities, it is the material exclusively employed; when it becomes too dear, a combination of lime with sundry other materials is substituted for it; or cement, either natural or artificial, is used.

The sulphate of lime is met with in large formations known under the commercial name of gypsum. It is to be found, in England, at Alston, in Cumberland; at Shotover Hill, in Oxfordshire; and a variety of the fibrous gypsum occurs in Derbyshire and in Cheshire. In the neighbourhood of Paris, it is met with at Montmartre, Belleville, Charonne, Ménilmontant, le Mont Valérien, Triel, Meulan, and Vaux. It is worked in the departments of the Soane and Loire, of the Rhône, of the Marne, the Seine and Oise, and of the Landes; in the Alps and the Lower Pyrénées; it is also found near Marseilles, Grenoble, Mont Blanc, and Mont Cenis; in Tuscany, Savoy, Spain, and Switzerland. An anhydrous variety is worked at Bergamo, and Milan, which comes from the neighbourhood of Vulpino. In Germany there are also beds of it largely worked for the purpose of dressing the artificial meadows; and large quantities are also extracted for the same purpose in the British colonies of North America, which are exported principally to the United States. It may be said geologically to occur either in contemporary strata of great thickness (as near Paris) in the tertiary formations; or in the iridescent marls (*les marnes irisées*) of La Meuse, or the Aveyron; or in masses of a subsequent date in the different secondary rocks. These last masses are constantly in contact with the igneous rocks, and they are very frequently associated with the dolomites, rock-salt, bitumen, and sulphur in a distinct form.

The sulphate of lime is insipid, or of a slightly bitter flavour; it is colourless and indecomposable by heat. It is soluble in water, whether hot or cold, 1000 parts of water at any temperature between 10° and 100° of the centigrade scale dissolving 3 parts of plaster. Its specific gravity is 2·31; it contains in its natural state 20·9 per cent. of water of crystallization, which is given off at a temperature less than 200° of the centigrade scale (392° Fahrenheit).

The gypsum from the best quarries is nearly as hard as the calcareous stones; after its water of crystallization is driven off, it becomes pulverulent and like flour. If fresh water be presented to it in this state, it combines with the normal quantity of water, and reassumes the form of a hydrate, which it had lost by the burning, crystallizing around the materials presented to it, and recovering its original density and strength to a very great degree. It is this property which has led to its use in buildings: when the plaster is burnt it is dehydrated; when gauged, or worked up, the precise quantity of water it had lost is restored to it.

The plaster is "got" from the quarries (either underground or open) by picks and wedges; sometimes with gunpowder. The greater number of the quarries round Paris are underground; and at Montmartre, nearly the whole hill is thus dug out. The stone is broken up into small blocks, about the size necessary for rubble masonry, before being carried to the kilns.

The burning of the plaster stone at Paris, and throughout the continent, is managed in a very slovenly way. The kilns consist simply of three sides of a square enclosed by brick walls, covered with a rough tiled roof, in which spaces are left to allow the escape of the steam. Under this sort of shed (for that is a more correct name than that of a kiln), the plaster is arranged by constructing, firstly, a series of vaults of the largest stones, filling in the haunches as the arches are carried up. Upon these the remaining stones are piled, paying attention only to the fact that the larger ones should be near the fireplace formed by the vaults. These are subsequently filled with faggots, or other firewood, which is then lighted. The flames rise through the spaces left in the stones; they ascend gradually through the mass, and distribute, as equally as may be, the heat in their passage.

The time of burning necessarily depends upon the quantity operated upon at once; but care must be taken that it be not continued so long as to over-calcine the particles in immediate contact with the fire. As was before said, a degree of heat equal to 200° of the centigrade scale is sufficient to drive off the water; if exposed to a greater heat, the sulphate of lime appears to lose its power of combining with the water necessary for the process of reassuming the form of a hydrous sulphate. The system of calcination adopted abroad, as might naturally be expected, leads to a great waste of raw material, owing to the very slovenly way in which it is executed. As much as one-fifth is wasted in many of the kilns.

Some of the London manufacturers adopt a mode of preparing the plaster, which obviates not only this inconvenience, but also that attending the use of coal, which discolours the plaster very much. It consists of a kiln so arranged that the fuel is never in immediate contact with the stone; but the chimney from the fireplace passes round and round the kiln, and communicates its heat during the whole of its passage, rendering the interior, in fact, an oven. The plaster in this case is burnt continuously.

A system has also been proposed lately in France which appears theoretically superior even to this process. It is founded on the fact that steam at a very great degree of heat becomes a gas, very greedy of water, and able to absorb it from any body it may be put into contact with. A jet of steam, heated above 400° Fahrenheit, is in this system projected upon the plaster stone, which has been broken very small comparatively; it takes up immediately all the water present, and leaves the plaster in the state of a pure anhydrous sulphate of lime, without waste or discoloration. The difficulty of this process lies in making the chamber in which it is carried on, and all the machinery, sufficiently strong to resist the action of so very elastic a gas as steam at that temperature. But the problem has been solved for the drying of gunpowder by a similar use of very high-pressure steam; there can, then, be no insuperable difficulty in the case of the plaster.

The stone which yields the best description of plaster, without any exception, is that found near Paris. Generally speaking, its superior hardness, and rapidity of setting, are attributed to the presence of a small quantity of carbonate of lime, which is supposed to be converted into a pure lime by calcination. But, as Guy Lussac observed, this cannot be the real explanation, for the degree of calcination of the plaster is never sufficiently high to affect the carbonate. The degree of hardness of the plaster must then depend entirely upon that of the stone from whence it is obtained; and we generally find, in fact, that such is the case—the hardest stones produce the hardest plaster.

A simple manner of ascertaining the quality of a plaster stone is to put into a vase a certain quantity of it in a state of powder, and to pour thereon one half in volume of nitric acid, diluted in three times its own weight of water. This is allowed to repose, and after several hours, the liquid is to be decanted very gently. The deposit is to be washed with pure water several times, being allowed to rest between each of the operations. As soon as the water is pure and tasteless, the mixture or deposit is to be taken out, spread upon a sheet of paper, and dried. Weighed in this state, the loss it has sustained represents the quantity of carbonate of lime present in the stone submitted to the analysis.

After the calcination, the plaster is reduced to powder, either by hand or in a mill; in this state it absorbs the humidity of the atmosphere with great avidity, and requires to be covered up very carefully, directly it is crushed, to secure it from contact therewith. There is also, from this same reason, a considerable danger in transporting plaster in its manufactured state for any great distance.

When mixed with water, a species of confused crystallization takes place, and the water in combining with the plaster gives off a considerable portion of its latent heat. An augmentation of volume takes place, which is supposed to be owing to the efforts of the crystals to arrange themselves symmetrically. Unless great attention be paid to this action of the plaster, it is likely to compromise seriously the solidity of the work. Sometimes it is obviated by mingling with the plaster substances which may allow the movement of the crystals to take place, without affecting the colour of the mass.

Plaster is far from having permanently the tenacity of mortar, which property in the latter, unlike plaster, as it is well known, increases with time. Rondelet found that if two bricks were joined together by means of this material, they united with one-third more force in the commencement than if they had been joined with lime; but that they subsequently lost their force of adherence. A very useful application of plaster was made by Smeaton in the construction of the Eddystone Lighthouse, where he covered the fresh cement joints with it, to give them the time necessary to harden.

In England, where plaster is both bad and expensive, its use is confined to the more costly descriptions of decoration. In France, however, it is largely used for the construction of walls, both internal and external, as well as for rendering them afterwards. If proper precautions be taken to cover the surfaces exposed to the weather, and if it be painted as soon as dry, the plaster is eminently useful in such positions; and replaces very advantageously the natural cements for all common purposes. But it is utterly incapable of resisting the action of water.

As the proprietors of the French quarries of gypsum have recently made vigorous efforts to introduce that material into our country, and as from its superior qualities it will eventually force itself into general use, if burnt near the place of consumption, some instructions are added as to the manner of employing it which is generally adopted in Paris and the environs.

The coarser kinds of plaster are used for the ordinary works, such as the rendering of walls and partitions; the finer qualities are reserved for the ceilings, cornices, and other decorative works. A difference is to be observed in the quantity of water to be mixed, according to the position and nature of the work to be executed. Thus, for walls, the plaster must be gauged stiff for the first coats, and more fluid for the setting coat. For cornices worked out in the solid, the core is made of stiffly gauged plaster, which is floated with finer material, and lastly finished off with plaster laid on by hand about the consistence of cream. Practice only can ascertain the precise degree of stiffness to be given, especially as every burning yields a different quality.

When walls are to be rendered in plaster, they require to be first jointed, and then wetted with a broom. The surface is then covered with a coat of thinly gauged stuff laid on with a broom, or at least worked with the trowel in such a manner as to leave sufficient hold for the next coat. This is gauged stiff, and is laid on with the trowel; it is floated with a rule, but the face is finished with a hand trowel. Owing to this, and to the fact that the plaster sets too rapidly to allow of great pains being taken with the floating, the surfaces are never so even, nor are the angles so square and true, as with the common system adopted in England. But this mathematical nicety is not really of importance in ordinary works, whilst the rapidity with which the plaster dries constitutes a real and very important recommendation in its favour.

The partitions in Paris are generally made solid, so as to prevent sound from passing through them. They are executed with quarters of oak or of fir, according to the nature of the building. Upon the quarters, laths are nailed every 4 in. apart, and the interior is filled in with plaster rubble. This is made even and flush with the laths, and the whole is then rendered like an ordinary wall.

The ceilings are sometimes executed with close laths, but the usual plan is to nail them about 3 to 3½ in. from centre to centre. A sort of flat centering is put under them, and what are called "augets" are then formed between in plaster, which finish about flush with the under side of the laths, and return up the joists to nearly their total height, forming a sort of channel, which the workmen often finish by drawing a bottle along the sides. The minimum thickness in this case should be about 1 inch; the ceiling itself is added underneath; the floors are either of wood, or of tiles upon a bed of plaster formed above the joists. The better description of such floors and ceilings are often made, however, with laths spaced 4″ from centre to centre; the space between ceiling and floor is then filled up with light plaster rubble, and the upper and under surfaces are rendered to receive the ceiling and the tiles. Ceilings executed in either of these two last-named manners, cost 1½ time those executed either with laths or flat "augets."

In countries like our own, and in Belgium and the French Flanders, where the price of plaster is very high, it is replaced by the use of a mixture of lime and sand, to which cows' or calves' hair is added. This mixture is then applied upon close lathing for ceilings and partitions, and in the usual manner upon walls.

The lime generally used for this purpose is the chalk lime, which is slacked with a great deal of water, and runs from an upper basin in the state of a cream into a lower one, where the excess of water is allowed to evaporate. A grating should be placed at the entry of the passage between the two basins, to keep back the core, or any unslacked particles the upper one might contain. The lime run in this manner is made into a mortar with a very fine sand, and the hair is then added. For the first coats coarse hair will be most desirable; for the finishing coats it should be finer.

In well-finished works two coats are given, which are distinguished by the names of the "rendering" and the "floating." A third coat is then added called the setting coat, which is made of the pure lime as it is run from the basin. Ceilings are afterwards covered with a very light coat of plaster, gauged thin, and laid on with a trowel. Such plastering is very cheap; and if proper attention be paid to its execution so as to avoid blisters from the use of unslacked lime; to fill the cracks which frequently take place in the thicker coats, from the unequal contraction of the lime in setting; and to allow a proper interval for the whole plastering to dry before the painting, or subsequent decoration to be added, is applied; the lime and hair may be safely admitted as a substitute for the natural plaster. The greater rapidity with which the latter dries, the much superior manner in which it takes colour, and the degree of hardness it attains, will, however, secure it the preference, unless very weighty considerations of economy oppose its employment.
siderations of economy opposes its employment. (See Westmacott's Appendix F, page 105.)

One great use of the sulphate of lime dehydrized, or of the common plaster is for the purpose of top-dresssing upon the lucerne, trefoil, sanfoin, and other artificial grasses. This method of using it prevails to a very great extent throughout France and the United States; but it is comparatively unknown in England. Some experiments appear to have been already made, but with the English plaster stone in its unburnt state. They did not succeed; it may be owing to the difference of the two stones, or because, as the raw gypsum was used, in so very wet a climate as ours, its useful action was too rapidly exhausted. It would also appear that the gypsum was used as a manure (for which purpose it is comparatively valueless) instead of being simply employed as a top-dressing. In the north-west of France the farmers use the plaster in equal quantities with the seed sown, or 4 cwt. per acre. It is sprinkled gently over the grass crops, and the best time for employing it is immediately before a shower of rain. This dressing requires to be renewed every year, and consequently is rather expensive; but the results it produces are startling, so great is the difference in the weight of the grass crops. The objection on the score of expense ought now to be obviated; for with the facilities offered by the French Railway Companies, the plaster stone could be obtained in England at a sufficiently low rate to enable manufacturers to supply the plaster itself at a price which would bring it within the reach of farmers.

The London manufacturers appear to have been running a race lately in bringing out new combinations of plaster, the result of which only appears to be, that they obtain artificially and expensively what would be nearly as well obtained by the use of the French plaster stone. Amongst the best of these inventions is, without exception, the Keene's cement, which is capable of being worked to a very hard and beautiful surface, so hard, indeed, as to be well adapted for floors or skirtings. It is obtained by soaking the plaster in alum water after a first calcination; it is then put a second time into the kiln, reburnt, and ground. The Keene's cement is, in fact, a very beautiful plaster. Why the name of cement should be given is, however, a mystery, unless we explain it on the ground that the manufacturers wish to keep up their charter of applying names without rhyme or reason.

The Parian cement is also composed of a plaster base, the gypsum being mixed with borax (the borate of soda) in powder, and the mixture is calcined, and is subsequently ground. The result is a very beautiful material; but it is liable to the same objection as the Keene's cement, namely, the expense.

There are numerous other mixtures of the same nature in which the plaster is mixed with one or more of the salts. They can hardly be yet considered as inventions which have fallen into the domain of publicity; any detailed description might, therefore, be considered as an interference with the rights of the proprietors. (See Appendix G, page 131.)

CHAPTER XIII.

ON STUCCOS.

The name "stucco" is given to a species of plastering which is subsequently worked to resemble marble. It is generally made of lime mixed with calcareous powder, chalk, plaster, and different other substances, in such a manner as to obtain in a short time a solid surface, which may be coloured, painted, and polished with sufficient perfection to allow of its being used instead of the more precious marbles. It is employed in architecture to cover columns, pilasters, walls, plinths; to form mouldings, bas-reliefs, and other analogous objects of decoration.

Stucco is also sometimes used to protect exterior surfaces exposed to the air or to humidity; but in this case such materials only should be used as are capable of resisting the action of water. As the materials for making stuccos do not exist everywhere in the same manner, their composition must differ in every locality. The principal object is to obtain a material which is capable of acquiring a great degree of hardness, and which is able to receive a polish. To obtain these results, one of the most important conditions is, that the different ingredients be reduced to the greatest possible degree of fineness, and that they possess the power of rapidly solidifying.

There are two species of stuccos: those made of limes, and those made of plaster. Of the former it is evident that the best must be those which are classed under the name of cements; but their disagreeable colour prevents their being used, at least for ornamental decoration. They serve, however, to form the foundations on which the more elegant preparations are applied, whenever any danger is to be feared from humidity.

The Italians usually execute their stuccos in three coats; the first is a very coarse one, and forms merely what we would call the "rendering." The materials of the second are much finer, and they contain a larger proportion of lime; the surface being thus brought up to a very even, close grain. The last coat of stucco is made of rich lime which has been slacked, and run through a very fine sieve, and is usually allowed to stand from four to five months before being used, in order that every particle of it may be reduced to a hydrate. If the lime cannot be kept for so great a length of time, the slacking may be perfected by beating it up very frequently. When great perfection is required, it is usual to mingle pounded white Carrara marble, or even gypsum or alabaster; but the latter are only used in situations which are entirely protected from the action of the atmosphere. The powdered marble and the lime in the form of a very damp paste are mixed, in equal quantities, until the whole is perfectly homogeneous. Vitruvius even recommends that the trituration with a trowel be continued, so long as any portion of the mixture adheres to the iron, before it be applied. This preparation is then laid very carefully upon the even surface of the second coat of plaster, and well worked with the trowel until the face becomes perfectly polished. It forms a very good imitation of marble of a uniform colour.

The different colours are obtained by mixing with the lime such metallic oxides as the case may require; thus, to obtain blues, two measures of marble powder, one of lime, and a half measure of the oxide, or even the carbonate of copper, are mixed together.

To obtain greens, a quantity of the green enamel is used with a larger proportion of marble powder; but the mixture is worked up with lime water. Pearl greys are made by mingling ashes with the marble. Browns, by mingling ashes and cement in proportions varying with the tones desired to be obtained. Blacks are made by using forge ashes containing numerous particles of iron. Calcined ochres are used to make the reds, as is also litharge, or the red oxide of lead; the yellow oxide of lead serves to give that colour. The mixtures thus obtained are subsequently laid on in patches; and the excellence of the work consists in the taste with which they are employed to imitate the effects of the natural marbles, so as to give either the blending or the distinct opposition of colours to be met with therein.

When plaster is used instead of lime, it is gauged with lukewarm water in which size has been dissolved, or fish glue, or gum arabic, in order to fill up the pores, to give it more consistence, and to render it susceptible of receiving a better polish. This kind of stucco is the one more especially employed when it is required to produce details of great delicacy and perfection. If it be required to produce divers tints with this material, the colours should be dissolved in the size water before it is used for gauging the plaster.

The polishing should never be commenced until the whole of the stucco is perfectly dry. To hasten the desiccation a linen may be applied frequently to the face to absorb the moisture which may have worked through; but no friction should be allowed until the whole is perfectly dry. The surface is then rubbed with a very fine-grained grit stone, washing and cleaning it with a sponge in the same manner as a real marble; it is then rubbed with a linen containing moistened tripoli powder and chalk; and the whole is finished by a rubber of felt imbibed with oil and very fine tripoli powder, which is quite at the end changed for a rubber containing nothing but oil. The thickness of the coat of stucco varies from between one-sixth to one-eighth of an inch, for internal works.

Scagliola is made by a process of a similar nature to the one thus executed, with perhaps some slight differences in the manner of setting up and drying the coat of plastering which forms its base. There are a greater number of small pieces, splinters, "scagliole" of marble in the best descriptions of this work, and it is from them that the process derives its name.

MM. Darcet and Thénard applied to the interior of the dome of the Panthéon in Paris an encaustic, for the purpose of rendering the stone fit to receive the paintings executed by M. Gros, which answered remarkably well for the plaster under similar circumstances. The surfaces to be covered were firstly dried by large braziers for the purpose of driving out the moisture in the stone, and removing all the air contained in the parts exposed to the heat, so that the stone might be rendered more absorbent, and that the encaustic might penetrate further into it. A mixture of 1 part of yellow wax, and 3 parts of oil, in which $\frac{1}{10}$th of the whole weight of litharge had been mixed before melting, was then applied at a temperature of 212° Fahr. It was laid on with a brush, in frequent coats, until in fact the stone was so thoroughly impregnated with it that it could absorb no more. The pictures above-mentioned have resisted very well for more than twenty years in an exposed position.

Should the above mixture be too expensive, another, consisting of 1 part of oil, containing $\frac{1}{10}$th of its weight of litharge, and of 2 or 3 parts of rosin, may be substituted. This mixture should be allowed to cool, and be remelted before it is applied; the walls being previously well dried, and the encaustic laid on in five or six coats. Plastering which has been thus treated becomes sufficiently hard to resist the nail in a very short time; and it is effectually protected against any changes of the atmosphere. The action of these oleaginous substances is merely to fill the pores of the plaster, and thus to prevent the action of the moisture. They do not appear to enter into any chemical combination.

CHAPTER XIV.

ON THE SALTPETREING OF LIMES, CEMENTS, AND PLASTERS.

A VERY interesting—and at present, unfortunately, a very little understood—class of phenomena takes place when the materials we have considered are exposed to certain conditions. We find that in damp positions, in new works, walls are often covered with a crystalline substance of a white fleecy appearance, and of a slightly acid flavour, which works its way through any ordinary coat of paint; and, as it absorbs the humidity of the atmosphere in efflorescing, it renders the walls damp on the surface, and carries off the paint in large patches. This process is called by workmen saltpetreing, and is in fact the production of saltpetre from the materials employed in the construction of the walls. The very disagreeable effect it produces upon decorations, either internal or external, renders the research of its cause extremely interesting to the architect or the builder; moreover, its action upon the durability of stone is such, that the study of this singular chemical phenomenon interests the engineer to an equal extent.

Saltpetre is, properly speaking, a nitrate of potassa; but, although it is regarded as the sole cause of the appearances we now examine, it is far from being the only substance produced in the particular instances; for the nitrate of soda and the chloride of potassium are often to be met with in connection with the saltpetre itself.

Very few chemists appear to pay attention to the fact that nearly all limestones contain a certain quantity of soda and potassa; or at least in the analyses we meet with in chemical works no mention is made of their presence. General Treussart was, perhaps, the first to publish any hint upon the subject, when he stated that the artificial cements differed from those obtained from the septaria nodules, inasmuch as the latter contained a small dose of one or the other of those metallic oxides. But his discovery appears to have led no further than to securing a better method of making the articles he sought, and its influence upon the solution of the question before us was quite neglected.

The ancient chemists believed that the production of the saltpetre was to be explained by the combination of the nitrogen present in the walls (arising from a previous combination of the oxygen of the atmosphere with the azote supplied by the decomposition of the animal matters contained in the building materials) with the metallic oxides they might contain. This theory remained unquestioned until M. Longchamp proposed another by which he sought the explanation of the phenomenon of the production of the nitrogen, by supposing that the carbonates of lime and of magnesia, taken in a proper degree of comminution, and properly wetted, could absorb air, condense it, and transform it into nitric acid in the course of time; or rather bring it to that state, after condensation, which would cause it to enter into combination with the lime and magnesia, giving rise to the formation of the nitrates of those two substances, and so much the more readily enable it to combine with the potassium, especially if it were present in the form of a carbonate.

Under all circumstances, the presence of powerful bases, such as the chalk and magnesia, or the potassium, appears to be necessary, and they require to be in a highly comminuted state. Lime in the form of chalk, or a highly porous limestone, is favourable to the action of the nitrogen. Marbles, and the densest class of limestones, nitrify with great difficulty, hardly at all; and the limes made from them enjoy a corresponding immunity from this inconvenience. Thouvenel appears to believe that these bases only nitrify when in the state of carbonates; but the extraordinary facility with which the sulphates of lime give rise to the formation of the saltpetre is not of a nature to persuade us of the universality of the law. And, indeed, there are some cases to be noticed hereafter, in which it would appear that, so far from its being necessary that the lime be a carbonate, the nitrification ceases when it becomes so in an eminent degree, or is at least much retarded.

Whichever theory we adopt to account for the presence of the nitrogen, there appear to be certain conditions which facilitate the production of the saltpetre. Firstly, a degree of humidity, about equal to that of garden earth, is very favourable to it. At 32° of Fahrenheit, the nitrification does not take place; between 60° and 70° it is the most abundant. In Sweden, light is considered rather to retard it, and an exposition towards the north is always sought for; but that does not appear so much to be owing to the absence of strong sunshine, as to the evaporating effects of the north winds, which are eagerly desired in the artificial nitre factories. Light, in fact, would rather appear to be without influence in its action than otherwise. The most favourable conditions for the formation of the nitre, indeed, are united in cellars, and other underground constructions; and it was from them that the French chemists, during the war, extracted the saltpetre necessary for their gunpowder manufactures; especially from the demolition of cellars executed with plaster instead of mortar. The richest of these materials contain sometimes as much as from 5 to 7 per cent. of saltpetre.

The nitrification takes place very freely when sea water and sea sand have been used, so much as to render them totally unfit for works requiring any perfection of execution. Dumas asserts that there is a very considerable quantity of nitre in the sea salt; if so, it may explain the injurious action of the sea water. Brande, it is true, does not mention nitre as being present in the sea salt; but he states that the earthy muriates are so in the proportions of between 5 and 28 per thousand, the sulphates between 6 and 32½ per thousand. The efflorescence upon works executed with sea water is, however, very distinctly and decidedly a nitrate of soda; and, as it occurs in much greater abundance wherever it is used, notwithstanding Brande's silence, we may safely assume, that some portion at least of the nitre is furnished by it.

It seems hardly reasonable, in fact, to attribute the presence of the nitre entirely to the decomposition of the animal matters contained in the building materials. These in many cases are submitted at times to such a degree of heat as would arrest the process of decomposition; but, in the case of bricks, we find the nitrification to take place almost immediately upon their being exposed to the air. It is difficult, also, to explain in this manner the constant formation of new crystals of the nitrate of potassa, which goes on in the caves of Ceylon, and of La Roche Guyon, in France. In the artificial nitre works, it is true that the nitre is obtained by mixing calcareous earths with decaying animal matter; but the latter requires to be present in such large proportions, that we hesitate before we can receive it as being the only source from whence the materials used in building derive the quantities necessary. We are forced to seek the explanation of the phenomenon in the action of the chemical bases upon the constituent elements of the atmosphere. It is known, says Dumas, that the azote and the oxygen combine together under the form of nitric acid, by the aid of the electric fluid, and under the influence of water. The presence of such energetic bases as lime and magnesia may, perhaps, be equivalent to that of the electricity; especially as the porosity of the materials enables them to act upon smaller quantities at a time.

The practical bearings of this interesting chemical question, upon the professions of the engineer and architect, are as follows:—

Firstly. Sea water, or sea sand, should never be used in making up mortar, or plaster, which is likely to require painting, or any sort of decoration, such as papering, stuccoing, &c. For outside works, the use of sea sand which has been well washed in fresh water, and exposed for at least six months, may be admitted, but it is still likely to cause a nitrification; and as the conditions of temperature internally are more favourable to that action than externally, it is most likely to manifest itself in that direction. There is always a danger attending the use of sea sand; if it can be replaced, it should therefore be so, even at an increased expense.

For such works as sea walls, lock chambers, quay walls, &c., it is not of so much importance that the nitrification be avoided, provided always that the stones used be of such a nature as to resist the destructive tendency of the process. Many of the oolites are not so able to resist, such as the Portland stone, the Caen, and the Bath stone. They should not, then, either be used in conjunction with mortar made with either sea sand or sea water; nor should they, in any case, be exposed to the latter. The purer crystalline limestones, and the granites, resist this cause of chemical decomposition much better, and should be employed in such positions in preference. It is, however, to be observed that there are some kinds of oolite, such as the Ranville stone, near Caen, the Roach beds of the Portland, which are as little affected by the sea water as the stones just mentioned.

Secondly. When it is absolutely necessary to use such materials as we know to be exposed to the inconvenience of nitrification, it is advisable to take early precautions with the view of preventing the action of the atmosphere upon the chemical ingredients. We see that in whatever manner the bases absorb the nitrogen, whether from the decomposition of the animal matter, or from the condensation of the gases, that the absorption could not take place unless the atmosphere were in contact with the internal structure. If, then, we protect the interior in some manner by a coat of paint, or an encaustic, for instance, we shall probably stop the action of the nitrification. It is thus, doubtlessly, that we may account for the fact that if the Roman cement be painted as soon as it is dry, it does not assume the action in question; but if it be left for any length of time unpainted, it becomes useless to attempt to execute such work. The atmosphere has entered the pores of the cement; the nitrates will cause any coat of paint to fall off.

Such a precaution can, however, only be successful when the body of the work is not of a nature to furnish its own nitrogen, if such an expression be allowable; or when it is in such positions, and of such dimensions, as not to derive it from any other quarter. If, for instance, a wall be built of bricks made from the alluvial mud of the embouchures of rivers, no precautions can prevent the saltpetre from forming. Engineers or architects, then, who have any decorative works to execute in places where such materials only are used, must detach them from the walls. If the wall be thin and the coat of encaustic penetrate very deeply into the plastering, it may happen that the saltpetreing may take place entirely on the outside; but this is a mere chance, that is to say, it is an action we can neither explain nor control; one, therefore, no prudent man would calculate upon. In very thick walls we often find that the saltpetreing does not take place on both sides, only on the weather (or exposed) side. Possibly this may be explained by supposing that the limes in the interior have had time to become more perfect carbonates before the air can have found its way through the pores.

But if the process once begin with such thick walls it never leaves off, at least within any reasonable time.

The workmen in London have a practice which may some day serve as a guide to more scientific examinations upon the subject. It consists, whenever they use Portland stone in elevation, in covering it with a wash made of pounded stone-dust and sand, which is rubbed off upon cleaning down the work. This very simple precaution serves temporarily to protect the stone against the formation of the saltpetre. But it is to be observed that the precaution alluded to is not effectual to stop the process of the saltpetreing, otherwise than temporarily, although it diminishes its force afterwards. The process is resumed, but in a weaker degree, as soon as the coating is removed. The most reasonable mode of accounting for the action of this wash is by supposing that it affords a protection to the stone, by closing up its pores, during the time it is passing from the state of a subcarbonate to a perfect carbonate of lime, or from a protocarbonate to a percarbonate; for a very distinct change takes place in the chemical nature of limestones of every description upon exposure.

These precautions are unfortunately very doubtful in their results; at every moment we are exposed to see the materials which contain soda and potassa take up the action of saltpetreing. Many noble frescos have perished in this manner; many of the finest buildings have been ruined by the decomposition it superinduces in the stones of which they are built. The study of the mode of its action becomes therefore highly important; but it is to be feared that it will continue to be treated with the neglect which has hitherto been the lot of the whole science of chemistry applied to the arts of building.

It happens, unfortunately, that very few architects or engineers are chemists; few chemists are aware of the nature of the questions it concerns us so deeply to have solved. M. Kuhlman's researches upon the subject immediately before us—viz., the nitrification of building materials—are, it is true, of the greatest interest, and have done much to elucidate the more obscure parts of its theory; but neither he, nor the various French or German chemists, nor our own countrymen who have lately devoted so much time and attention to the phenomena connected with the use of lime, have succeeded in overcoming the practical difficulties which are superinduced by the nitrification. Subsequently to the Exhibition of 1851, the whole of this branch of applied chemistry has been brought more distinctly under the notice of the scientific world; and it is to be hoped that shortly the obscurity in which it is still involved will be dispelled. In the meantime, however, professional men, architects, and engineers would do well to study for themselves, with more attention than it is to be feared they usually do, the practical applications of the important materials to which it has thus been attempted to call attention.

GEORGE R. BURNELL.

APPENDIX A. (Page 22.)

In England, where the "rule of thumb" prevails so extensively, it is the general practice to receive the blue lias lime as a good and a satisfactory hydraulic lime in all cases, and without any regard to the positions in the series that the beds of that formation may occupy. It is, however, necessary to remark, that every bed of the blue lias limestone contains a different proportion of the silicate of alumina, in combination with the carbonate of lime; and that, therefore, the powers of setting under water must be very different in the limes obtained from them. Even at the base of the Liasic series, the differences that occur are as great as between about 8 per cent. of the silicate of alumina and 90 per cent. of carbonate of lime, and 64 per cent. of the former ingredient to 34 per cent. of the latter. The first of these would yield only a moderately hydraulic lime; the latter would yield, on the contrary, a most energetic cement, if burnt and ground. The peculiar properties of the blue lias limes have been established upon the results that have followed the conversion of the middle beds of the series, which contain from 16 to 20 per cent. of the silicate of alumina. It would be, of course, easy to distinguish the best qualities of blue lias lime, as in fact it is easy to predicate the nature of any description of that material. Thus the lumps of burnt limestone should be rather large, and they should present on all sides a conchoidal fracture; the lime should swell but little in slacking, and it should not give out much heat, nor yield to the effect of the water before about two to five minutes. A lime of this description requires to be slacked before being mixed with the sand, for use in a building; but as the London builders have a fancy for the employment of lime "hot," as they call it, it is safer to employ the blue lias lime, after being ground. The best descriptions of blue lias lime that enter into the consumption of the London market, are obtained from Warwickshire, Leicestershire, Dorsetshire, the neighbourhood of Bath, Aberdare, Rugby, &c.; but they are all of them of very variable composition, and they require to be used with great precaution; at least until the precise nature of the beds has been ascertained.

APPENDIX B. (Page 45.)

Since this book was written time has enabled experience to pronounce upon many of the processes and the materials that are employed in the preparation of limes and cements; and amongst these it has decidedly settled the question as to the superior qualities of the Portland cement, both as regards durability and as to the powers of resistance that it may attain in comparison with the natural cements, or the best hydraulic limes. There have not been introduced, in the process of preparing the Portland cement, any modifications; or have the rules observed with regard to the burning of the mixture of the chalk and clay, of which the cement is composed, been in any way altered, excepting, of course, some trifling modifications which have borne upon the working details of the fabrication. The use of the cement has, however, spread greatly; it is employed in enormous quantities, both for hydraulic works and for those that are not exposed to the peculiar danger that attends the use of the cements, or artificial hydraulic limes, in sea or ordinary river water; it is employed, in fact, wherever the conditions of the buildings are such as to require great powers of resistance to external forces; and in all these cases it has been found to be far superior to the natural materials of the same class; so much so, in fact, as to have entirely superseded their use, wherever the freight, or the conditions under which the natural cement stones or hydraulic limes occur, allow anything like an equality of price. It therefore appears to be necessary to enter more into the theory and practice of the manufacture of the Portland cement than had previously been done in the earlier editions of this work.

The Portland cement, as manufactured in the neighbourhood of London, is made by a mixture of the chalk and clay of the alluvial formations of the lower parts of the Thames and Medway; the chalk being derived from the upper members of that formation, or from the chalk with flints, and the mud being principally derived from the deposition of the tidal waters that have swept along the shores that are bounded by the chalk cliffs. These ingredients are ground with a great quantity of water under edge rollers, and they escape through species of sieves in the requisite proportions, to flow off into large backs or reservoirs, where they part with a great proportion of the water used for their levigation. Of cours there can be little certainty as to the proportions of the chalk anc clay that are thus mixed, as they may, both of them, vary mucb in their chemical composition; but as a general rule the manufacturers endeavour to secure a mixture in which the carbonate o lime should be present in about the proportions of 60 per cent. or the whole mass, the silicate of alumina in the proportion of 34 per cent., and the rest would be composed of various ingredients that are found in the alluvial mud. After the mixture has been allowed to settle in the backs, it is dug out in the plastic state, and is then submitted to a species of dessication; it is put into the kilns in the state of a hard paste, and is there subject to a great heat, such as is capable of producing a pyrogenic compound of the silicate of alumina and lime. As was said in the text, great care is required in the management of the kilns, in order to secure, as nearly as possible, an equal degree of calcination in all the materials that enter into the charge; but the principle that the manufacturers aim at in this operation, is to give, as much as possible, a uniform degree of heat to every particle of the mixture, as they are thus enabled to calculate upon the setting qualities and the various physical conditions of the cements. There are three qualities that frequently characterise the products of a kiln—the under burnt, the properly burnt, and the over burnt; and it is upon the judicious mixture of these that the success of the operation of the burning must depend. The Portland cement is ground under millstones, placed so as to revolve horizontally, and it escapes from these stones through a sieve, to be spread out on a floor, where a species of cooling and of air slacking is allowed to take place, which is found to be very beneficial to the future stability of the works into the composition of which the cement enters. The specific gravity of the Portland cement, ground in this manner, may be taken at about 1·200, water being 1·000, and it is believed that this weight is a favourable condition; in fact, the consumers of Portland cement seek this quality of weight to such an extent that an ingenious system of fraud, which consists of mixing that article with the slag of the iron works, has lately been practised to a considerable extent.

The cement, after being ground, is passed through a sieve that has 46 holes to the square inch, and is packed in casks which are kept carefully water-tight. The usual conditions of setting that are imposed by hydraulic engineers are, that when gauged neat—that is, without the mixture of any sand—the cement shall set, in the open air, within the space of not less than two hours, so that it should be able to support the weight of a Vicat's needle, loaded with the weight of $3\frac{1}{4}$ lbs.: the cement that sets in less time than the above is rejected in all cases where the engineers attach importance to the quality of this material. Blocks of the cement mixed with sand, in the proportion of 6 of cement to 10 of sharp sea sand, carefully sifted, are prepared for trial by the authorities of the Cherbourg breakwater, and they are immersed in sea water that is kept cool, and is renewed every day for the space of 120 hours; the size of the blocks is made 8 inches long, by 4 inches wide, by $1\frac{6}{10}$ of an inch in thickness, and two nicks, or depressions, forming collars, are made in the middle of the blocks, which reduce the section of them to the square of $1\frac{6}{10}$ inch on a side; the test weight, that is rigorously enforced for these blocks, is 56 lbs. per inch superficial of the sectional area, or about 144 lbs.

on the total surface. The Metropolitan Board of Works, however, impose the resistance of 500 lbs. on the $1\frac{1}{2}$ square inch *seven* days after being made in an iron mould; but in this case the neck is cast, not cut out, and the blocks are immersed in soft, not in salt, water. Both of these conditions seem to be necessary for securing the best qualities of Portland cement.

Of course the attainment of these conditions involves a great deal of expense, and there cannot be a doubt but that great economy would result from the use of a natural material that would present the same composition as the chalk and clay, that are mixed with so much labour, and dried at so great an outlay. The attention of manufacturers has long been turned to this point, and the makers of blue lias lime have, amongst others, tried to introduce the method of burning that lime to a high point, and mixing it with the burnt clay associated with the limestone in the same formation. But there appear to be difficulties attending the composition of this mixture that entail great risks in the use of the resulting material; and the mixture of chalk and clay, before burning, has been found hitherto to be the most adapted to secure the degree of hardness, the weight, and the time of setting required. So that the blue lias cements, the Boulogne cements, &c., have generally failed to satisfy the requirements of hydraulic engineers; though they may answer tolerably well for the ordinary processes of building. The same thing may, it is believed by the author, be asserted with respect to the cement made by Colonel Scott, of the Royal Engineers, that seems to be well adapted to obtaining a cheap substitute for Portland cement, provided the peculiar hydraulic properties of the latter are not called into play; but which would in all probability fail, if exposed to the continuous action of moisture, especially when charged with the salts of the ocean.

The Scott's cement is made, in fact, by exposing the fresh burnt lime, heated to redness, to the fumes of sulphur that is burnt in pots under the grate. In this manner a description of sub-sulphate of lime is formed, that has the properties of setting with great rapidity and hardness, but which the author believes would be found to yield to the effects of the chlorides that are contained in the sea water, if not also to the long continued action of the causes of decay in the cement if used in open air. Scott's cement appears to be an admirable material for the execution of brickwork that is to be protected from the damp by a coating of cement, or for the execution of the internal rendering coats of buildings, that require to be quickly dry; but there is little about the process of making these cements that should warrant the belief that they can acquire any hydraulic properties by it; on the contrary, the formation of the sulphate of lime is a permanent source of danger to the stability of the resulting compounds when they are required to set under sea water, as we have had occasion to remark with respect to the artificial cements that were used at La Rochelle, and other places on the French coast. Colonel Scott's process contributes, at any rate, to the rapidity of setting, and to the hardness of the moderately hydraulic limes. It is questionable whether it would produce a great effect upon the more energetic materials of that class; and it would certainly do harm if applied to the calcination of the natural or the artificial cements. Such as it is, however, Colonel Scott has the merit of having placed at the command of the builder a valuable process for improving the ordinary limes of the country, for all the purposes of internal decoration, or for the execution of works that are usually performed in limes of the qualities that are known under the names of chalk or of grey-stone limes. The use of Scott's cement for the purpose of making concrete will be noticed hereafter more in detail, when the applications of that material, which has been sadly neglected of late, are considered.

APPENDIX C. (Page 62.)

The peculiar properties of the scoriæ of iron forges seem to have inspired the manufacturers of that metal with the idea that they might derive a profit from this refuse of their manufacture, by its application to the preparation of cements and hydraulic limes for concrete, or for the execution of the rubble masonry inserted under the foundations of public buildings. At least, attempts have been made lately to introduce the scoriæ of iron furnaces and of the puddling mills, with the view either of increasing the resistance of the limes and cements, or of increasing their weight, in case they should not be of the precise character that is required of the limes in question in this respect. But it appears that, in all the cases hitherto tried, the scoriæ contain the silicate of alumina, and the iron, in the form that might be converted into the mixture of the lime and sand, in an entirely inert state; and thus, that their presence does but add to the difficulty that attends the setting of the limes and cements with which they are associated, by interposing a fresh substance that would hinder the completion of the induration. Perhaps the introduction of this substance, which must be heavy in the ground state, may be of service in cases where it is desired to increase the weight of the cement or lime used; but this can be only by reason of the mechanical mixture of an ingredient that would itself be quite indifferent to the processes going on around it, and it cannot add anything to the qualities of the other materials to which it is presented. The same remark may be extended to the whole class of the so-called metallic cements; they contain, in fact, those materials that might be of service, generally speaking, in that state that renders them unfit for entering into fresh combinations, especially when they are derived from processes of manufacture that require the intervention of great heat. The effect of this heat seems to be to render the combinations of the alumina, potass, iron, &c., stable, and such as cannot be broken up for the formation of new compounds with the lime with which they are associated.

APPENDIX D. (Page 78.)

There has been a considerable amount of interest attached of late to the attempts made by M. Coignet to introduce what he calls the *béton agglomeré,* and by Colonel Scott, of the Royal Engineers, to introduce the use of concrete made by his cements and shingle, for the purposes of building; and the results that these two gentlemen have attained are sufficiently remarkable to merit our attention on the present occasion. Colonel Scott has executed in this manner the shells of buildings that are formed of a waggon-head shape, and that are fourteen feet at least in their clear span, and he used for the purpose a mixture of one part of his cement to ten parts of sand; the walls that had to carry the roof, that was made in the same material, being only nine inches thick. M. Coignet has executed many thousand francs' worth of work in the *béton agglomeré* in the sewers of Paris; he has built entirely in that material the church of Vesniet, near Paris, and he has applied it to the execution of railway and common bridges of fifty feet span, at least; so that it can no longer be considered that the experiment is upon trial. In fact, the results that have been attained at the Dover, Alderney, Cherbourg, Marseilles, Algiers, &c., works, had long since proved that concrete was susceptible of being used in building operations like any ordinary stone, and all that M. Coignet has done in this case has been to demonstrate the fact in a striking manner.

The difference between M. Coignet's system and Colonel Scott's, consists in the former gentleman employing every description of lime in the preparation of the *béton,* which he takes every precaution to have slacked with just the proper quantity of water to ensure the hydration of the lime, and then carefully to triturate the mass, and to compress the ingredients in moulds by a system of ramming. The best materials that are thus produced are composed of a mixture of the slow-setting artificial cements, with a good hydraulic lime and a proper proportion of sand; and great skill is required in so apportioning the lime and cement, that the powers of the resulting mass should present everywhere the same powers of resistance to the weights or forces they may have to resist. Of course, there can be no difficulty in varying the proportions of the lime and cement to produce this result, though M. Coignet neglected this precaution in the building of Vesniet church; nor can there be any difficulty in observing the precautions that are required to provide for the contraction and expansion of the masonry in a monolithic bridge, such as that gentleman has executed. Well and judiciously used, there can be no reason why Coignet's agglomerated *béton* should not be employed for the execution of ordinary descriptions of masonry; or, indeed, why that description of works should not be performed with any description of common *béton* (using that word in the sense of a mixture of lime, sand, and shingle) rammed in a mould.

The same thing may be said of Colonel Scott's concrete, and, indeed, of any other description of that material; but it seems to be better in all cases to mix the lime or cement with sand first, to bring it into the state of mortar, and then to present to it the materials round which it is intended to crystallise. Colonel Scott has, however, had sufficient influence with the War Office to persuade them to make an application on a large scale of this concrete, made in the usual manner, to the huts and stables of the camp at Aldershot, hitherto with markedly successful results, both with regard to the durability and the economy of the constructions to which this system is applied. The theory is, that a masonry so prepared, being a rough rubble masonry without any bond, ought to be executed of the thickness of one-third more than ordinary brickwork; but this must in all cases be regulated by the weight that is brought upon the bearing section, and the weights given in the text, page 71, ought in no instance to be exceeded, in the early days of the experiment at any rate. The failure of Mr. Ranger, and of many others, in their attempts to employ concrete as a material of construction, can, therefore, only be considered as proving that they did not understand the theory of limes; yet the College of Surgeons, and the shops in Pall Mall, that Mr. Ranger executed, stand to this day as a proof that, when well prepared, the concrete made in ordinary style is capable of supporting the action of the London atmosphere successfully. Concrete might be very advantageously employed in the backing of quay or river walls, or in the execution of rubble masonry for the purposes that Colonel Scott has applied his cement to. The quay walls of Havre are, in fact, backed with a kind of masonry of this description; and a remarkably large and successful instance of the use of concrete, made in part with Portland cement, exists in the facings and backings of the basins of the Victoria Docks, London, executed under the directions of Mr. G. P. Bidder, C.E. The different descriptions of limes and cements used in England would, no doubt, require to be treated in a different manner than they are usually done, in order to secure the equality of their setting; but it is precisely to the attainment of this condition that the efforts of the people employing those materials ought to be directed. Well selected blue lias lime, or grey-stone lime, mixed with pounded brick dust, would do as well for the execution of concrete, for the ordinary conditions of exposure to the weather, as even the cements of Colonel Scott, or any other manufacturer. For exposure in sea water there appear to be some causes at work that would render necessary the employment of Portland or Roman cement; but even in this case the success of the application of the concrete blocks at Dover Harbour and the Cherbourg breakwater, shows that the resources which that material offers to engineers and architects are neglected, either in consequence of ignorance of the theory of limes, or of want of boldness in trying experiments on the part of the professional men, more than in consequence of the nature of the material. The admirable manner in which the works of concrete executed by Roman and mediæval architects have stood the effects of time, must always excite our surprise that the use of that material should have been so long neglected, and the building arts deprived of the advantages it offers for the execution of monolithic structures, or those made by the agglomeration of small materials.

There has been a great deal of attention also called of late to the invention of Mr. Ransome, which was noticed in the original edition of this work, and which has subsequently received considerable improvements at his hands. This invention consists, as most persons interested in these matters are aware, of a mixture of the silicate of soda with sand, so as to produce a material susceptible of being moulded, which is then immersed in a bath of the chloride of calcium, and subsequently washed thoroughly, so as to remove the salts that would effloresce upon the surface of the material. The theory upon which this process is based is perfect, and the double decomposition of the silicate of soda and the chloride of calcium, is such as must produce the silicate of lime, that would act as the cementing material to the sand, leaving the chloride of sodium to be washed off; but this salt is accompanied with other impurities which are eliminated in the process of conversion, and the greatest care is required to ensure the freedom of the mixture from the effects of such foreign ingredients. Mr. Ransome has hitherto succeeded in effectually destroying the appearance of the salt; but the danger of the manufacture from this cause will always attend it, and thus render it a process that will be entirely a matter of confidence between the employer and the manufacturer. In Mr. Ransome's hands, or in those of the people that he may bring up, there can be little ground for hesitation in the use of this material for all the purposes of internal decoration, or even for external decoration in cases where the salt has been effectually withdrawn; in careless hands there must be considerable danger of the efflorescence of salts, which may compromise the painted decoration that may be applied to the material so produced. As the colour of the mixture can be regulated to any tone by the intervention of the metallic oxides, there is, perhaps, little danger to be feared from this source; but there would always remain a considerable amount of doubt as to the application of the patent concrete stone, on the score of the disagreeable effects produced by the efflorescence of the salts. The bath of the chloride of calcium, in which the mixture of sand and silicate of soda is immersed, it may be important to add, is kept at a point of ebullition by means of the passage of a steam-pipe through it; the washing out the salt is effected by a stream of cold water; the mixture of the silicate of soda and the sand is effected by the use of a pug-mill.

APPENDIX E. (Page 96.)

The kind of rendering that is so much used in India under the name of *Chunam*, appears to merit a passing notice on the present occasion. There are some principles brought into play in the setting of this form of lime that are indirectly connected with the action of the oleaginous cements, so that it may be as well to dwell upon them.

There are several kinds of this *chunam*, according to the locality where it is employed, and to the uses to which it is proposed to be applied. In the interior of the country it is said to be prepared most usually from *kunkar* nodules—calcareous concretionary masses, from the size of a bean to blocks of some hundreds weight, which are found imbedded *parsemé* in almost every portion of the alluvial soil of the great plains of India. These nodules consist mainly of carbonate of lime, mixed with a little clay in impalpable powder. This, when burned, is mixed with coarse or fine siliceous sand, and tempered thoroughly with water, to which most generally (but not always) a coarse syrup or molasses from the native sugar is added in small quantity. The only real use of the molasses appears to be to retard the too rapid drying of the fresh laid *chunam* in the torrid climate of India. On the sea coast shells are burned, and mixed with sand, which is treated in the same manner. The practice is to boil with the syrup, called locally *jaggree*, some description of fruits, but these do not appear to have much influence on the setting of the lime; and immediately upon application, is added a portion of short tow, if it be desired to employ the chunam as a stucco. The kind that is habitually used as a material for rendering walls is obtained by the calcination of the purest limestone, or shells. That is beaten up with *jaggree*, mixed with water; and this kind of chunam becomes very hard, so as to bear, in fact, a polish. In the patient hands of the Hindoo labourers the use of this material, no doubt, produces excellent results; but as the whole process of manufacture employed in the preparation of chunam is, in fact, founded upon the retardation of the setting and the careful manipulation of the material in place, there can be little reason to regard this application as anything more than a local one, that is to be accounted for by the want of limestone in mass over great areas, and by the low price of labour, in India.

APPENDIX F. (Page 105.)

A discovery, by a Mr. Westmacott, has lately formed the object of a patent, and it has been taken up by a house in London of some considerable influence, with a view to augmenting the resistance of the rendering coats that are executed in lime, by the mixture of pounded limestone with that material, and sand. This is, in fact, nothing more than the application of the principle mentioned in the text, p. 77, where the tendency of the lime to crystallise around a gangue of the same nature as itself, is referred to, and the inference is drawn that the presentation of the crystallised forms of carbonate of lime would be favourable to the solidification of the mass " of concretes, *bétons*, or mortars." It is to be observed that Mr. Westmacott mixes with the chalk lime that he employs, considerable quantities of pounded chalk, or of some other equally common description of stone that has a base of carbonate of lime, and thus he obtains a mixture that is capable of setting with greater rapidity, and consequently with less chance of discolouration of the surface; but here all the advantage of Mr. Westmacott's process ceases. The mixture of the pounded limestone does but add to the strength of the resulting material, inasmuch as it presents to that body a substance that is already "*set*," and that is capable of assisting in the process of the conversion of the hydrate of lime into the carbonate of that base; but this must be at the expense of the power to carry sand, and the whole economy of the process must depend upon the relative values of the sand, or of the pounded limestones in the precise localities where the materials are employed. The advantage of the process is simply that which would follow from the improvement which would be effected in the conditions of the crystallisation of the lime; it in nowise alters those conditions, or introduces a new principle, of what manner soever.

APPENDIX G. (Page 107.)

The patents by which Keene's cement and the Parian cement were protected have lately lapsed by time, and the consequence has been that the lime-burners, being at liberty to apply the processes on which they are founded, have been stimulated by the competition of the trade to improve the manufacture of one of these articles. Hence the manufacture of the Keene's cement, in particular, has been very much advanced, and the use of that material now can be safely recommended wherever it may be necessary to employ a hard cement, which it would be necessary to paint immediately after its application. The principal objection to the use of this material was, that its liability to the efflorescence of the salts, that threw off the paint and left large blotches on the walls; this has been remedied by neutralising the acid with which the sulphate of lime is treated. It does not appear that the manufacture of the Parian or Martin's cements has been sensibly improved of late, and the use of these plasters, as they ought to be called, is therefore attended with the same amount of risk that they were previously exposed to, which was far less than was the case with Keene's cement; yet the improvement of the latter has enabled that material to be substituted very largely for its rivals. There are some curious conditions attending the use of Keene's cement with respect to the rendering coat that is laid upon the wall, which yet require to be experimentally settled. It would succeed admirably wherever it is desired to have a hard and non-absorbent surface for walls, as in the case of hospitals, or for skirtings, floors, angle staves, &c., or wherever it is necessary to paint the surface at once. The specific gravity of the Keene's cement is very low, a bushel of it only weighing about 70 or 75 lbs. at the utmost; whereas Portland cement weighs from 100 to 110 lbs. per bushel.

INDEX.

THE END.

JAMES S. VIRTUE, PRINTER, CITY ROAD, LONDON.

PRIZE MEDAL, INTERNATIONAL EXHIBITION. 1862
was awarded to the Publishers of
"Weale's Series."

7, *Stationers' Hall Court,*
September, 1871.

NEW LIST
OF
WEALE'S
RUDIMENTARY, SCIENTIFIC, EDUCATIONAL, AND CLASSICAL SERIES,

OF WORKS SUITABLE FOR

Engineers, Architects, Builders, Artisans, and Students generally, as well as to those interested in Workmen's Libraries, Free Libraries, Literary and Scientific Institutions, Colleges, Schools, Science Classes, &c., &c.

***** THE ENTIRE SERIES IS FREELY ILLUSTRATED WHERE REQUISITE.**

(*The Volumes contained in this List are bound in limp cloth, except where otherwise stated.*)

AGRICULTURE.

66. CLAY LANDS AND LOAMY SOILS, by J. Donaldson. 1*s.*

140. SOILS, MANURES, AND CROPS, by R. Scott Burn. 2*s.*

141. FARMING, AND FARMING ECONOMY, Historical and Practical, by R. Scott Burn. 3*s.*

142. CATTLE, SHEEP, AND HORSES, by R. Scott Burn. 2*s.* 6*d.*

145. MANAGEMENT OF THE DAIRY—PIGS—POULTRY, by R. Scott Burn. With Notes on the Diseases of Stock, by a Veterinary Surgeon. 2*s.*

146. UTILISATION OF TOWN SEWAGE—IRRIGATION—RECLAMATION OF WASTE LAND, by R. Scott Burn. 2*s.* 6*d.*
Nos. 140, 141, 142, 145, *and* 146 *bound in* 2 *vols., cloth boards*, 14*s.*

ARCHITECTURE AND BUILDING.

16. ARCHITECTURE, Orders of, by W. H. Leeds. 1*s.* 6*d.* } In 1 vol., 2*s.* 6*d.*
17. ——————— Styles of, by T. Talbot Bury. 1*s.* 6*d.* }
18. ——————— Principles of Design, by E. L. Garbett. 2*s.*
Nos. 16, 17, *and* 18 *in* 1 *vol. cloth boards*, 5*s.* 6*d.*

22. BUILDING, the Art of, by E. Dobson. 1*s.* 6*d.*

23. BRICK AND TILE MAKING, by E. Dobson. 3*s.*

25. MASONRY AND STONE-CUTTING, by E. Dobson. New Edition, with Appendix on the Preservation of Stone. 2*s.* 6*d.*

30. DRAINAGE AND SEWAGE OF TOWNS AND BUILDINGS, by G. D. Dempsey. 2*s.*
With No. 29 (*See page* 4), *Drainage of Districts and Lands*, 3*s.*

35. BLASTING AND QUARRYING OF STONE, &c., by Field-Marshal Sir J. F. Burgoyne. 1*s.* 6*d.*

36. DICTIONARY OF TECHNICAL TERMS used by Architects, Builders, Engineers, Surveyors, &c. New Edition, revised and enlarged by Robert Hunt, F.G.S. [*In preparation.*

42. COTTAGE BUILDING, by C. B. Allen. 1*s.*

44. FOUNDATIONS AND CONCRETE WORKS, by E. Dobson. 1*s.* 6*d.*

45. LIMES, CEMENTS, MORTARS, CONCRETE, MASTICS, &c., by G. R. Burnell, C.E. 1*s.* 6*d.*

57. WARMING AND VENTILATION, by C. Tomlinson, F.R.S. 3*s.*

83**. DOOR LOCKS AND IRON SAFES, by Tomlinson. 2*s.* 6*d.*

111. ARCHES, PIERS, AND BUTTRESSES, by W. Bland. 1*s.* 6*d.*

116. ACOUSTICS OF PUBLIC BUILDINGS, by T. R. Smith. 1*s.* 6*d.*

123. CARPENTRY AND JOINERY, founded on Robison and Tredgold. 1*s.* 6*d.*

123*. ILLUSTRATIVE PLATES to the preceding. 4to. 4*s.* 6*d.*

124. ROOFS FOR PUBLIC AND PRIVATE BUILDINGS, founded on Robison, Price, and Tredgold. 1*s.* 6*d.*

127. ARCHITECTURAL MODELLING IN PAPER, Practical Instructions, by T. A. Richardson, Architect. 1*s.* 6*d.*

128. VITRUVIUS'S ARCHITECTURE, by J. Gwilt, Plates. 5*s.*

130. GRECIAN ARCHITECTURE, Principles of Beauty in, by the Earl of Aberdeen. 1*s.*
Nos. 128 *and* 130 *in* 1 *vol. cloth boards*, 7*s.*

132. ERECTION OF DWELLING-HOUSES, with Specifications, Quantities of Materials, &c., by S. H. Brooks, 27 Plates. 2*s.* 6*d.*

156. QUANTITIES AND MEASUREMENTS. With Rules for Abstracting, &c. By A. C. Beaton. 1*s.* 6*d.*

ARITHMETIC AND MATHEMATICS.

32. MATHEMATICAL INSTRUMENTS, THEIR CONSTRUCTION, USE, &c., by J. F. Heather. Original Edition in 1 vol. 1*s.* 6*d.*

*** *In ordering the above, be careful to say "Original Edition," to distinguish it from the Enlarged Edition in 3 vols., advertised on page 4 as in preparation.*

60. LAND AND ENGINEERING SURVEYING, by T. Baker. 2*s.*
61*. READY RECKONER for the Admeasurement and Valuation of Land, by A. Arman. 1*s.* 6*d.*
76. GEOMETRY, DESCRIPTIVE, with a Theory of Shadows and Perspective, and a Description of the Principles and Practice of Isometrical Projection, by J. F. Heather. 2*s.*
83. COMMERCIAL BOOK-KEEPING, by James Haddon. 1*s.*
84. ARITHMETIC, with numerous Examples, by J. R. Young. 1*s.* 6*d.*
84*. KEY TO THE ABOVE, by J. R. Young. 1*s.* 6*d.*
85. EQUATIONAL ARITHMETIC: including Tables for the Calculation of Simple Interest, with Logarithms for Compound Interest, and Annuities, by W. Hipsley. 1*s.*
85*. SUPPLEMENT TO THE ABOVE, 1*s.*

85 *and* 85* *in* 1 *vol.*, 2*s.*

86. ALGEBRA, by J. Haddon. 2*s.*
86*. KEY AND COMPANION to the above, by J. R. Young. 1*s.* 6*d.*
88. THE ELEMENTS OF EUCLID, with Additional Propositions, and Essay on Logic, by H. Law. 2*s.*
90. ANALYTICAL GEOMETRY AND CONIC SECTIONS, by J. Hann. Entirely New Edition, improved and re-written by J. R. Young. [*In preparation.*
91. PLANE TRIGONOMETRY, by J. Hann. 1*s.*
92. SPHERICAL TRIGONOMETRY, by J. Hann. 1*s.*

Nos. 91 *and* 92 *in* 1 *vol.*, 2*s.*

93. MENSURATION, by T. Baker. 1*s.* 6*d.*
94. MATHEMATICAL TABLES, LOGARITHMS, with Tables of Natural Sines, Cosines, and Tangents, by H. Law, C.E. 2*s.* 6*d.*
101. DIFFERENTIAL CALCULUS, by W. S. B. Woolhouse. 1*s.*
101*. WEIGHTS, MEASURES, AND MONEYS OF ALL NATIONS; with the Principles which determine the Rate of Exchange, by W. S. B. Woolhouse. 1*s.* 6*d.*
102. INTEGRAL CALCULUS, RUDIMENTS, by H. Cox, B.A. 1*s.*
103. INTEGRAL CALCULUS, Examples on, by J. Hann. 1*s.*
104. DIFFERENTIAL CALCULUS, Examples, by J. Haddon. 1*s.*
105. ALGEBRA, GEOMETRY, and TRIGONOMETRY, in Easy Mnemonical Lessons, by the Rev. T. P. Kirkman. 1*s.* 6*d.*
117. SUBTERRANEOUS SURVEYING, AND THE MAGNETIC VARIATION OF THE NEEDLE, by T. Fenwick, with Additions by T. Baker. 2*s.* 6*d.*

131. READY-RECKONER FOR MILLERS, FARMERS, AND MERCHANTS, showing the Value of any Quantity of Corn, with the Approximate Values of Mill-stones & Mill Work. 1*s.*

136. RUDIMENTARY ARITHMETIC, by J. Haddon, edited by A. Arman. 1*s.* 6*d.*

137. KEY TO THE ABOVE, by A. Arman. 1*s.* 6*d.*

147. STEPPING STONE TO ARITHMETIC, by A. Arman. 1*s.*

148. KEY TO THE ABOVE, by A. Arman. 1*s.*

158. THE SLIDE RULE, AND HOW TO USE IT. With Slide Rule in a pocket of cover. 3*s.*

168. DRAWING AND MEASURING INSTRUMENTS. Including—Instruments employed in Geometrical and Mechanical Drawing, the Construction, Copying, and Measurement of Maps, Plans, &c., by J. F. HEATHER, M.A. 1*s.* 6*d.* [*Now ready.*

169. OPTICAL INSTRUMENTS, more especially Telescopes, Microscopes, and Apparatus for producing copies of Maps and Plans by Photography, by J. F. HEATHER, M.A. 1*s.* 6*d.* [*Now ready.*

170. SURVEYING AND ASTRONOMICAL INSTRUMENTS. Including—Instruments Used for Determining the Geometrical Features of a portion of Ground, and in Astronomical Observations, by J. F. HEATHER, M.A. 1*s.* 6*d.* [*Now ready.*

*** *The above three volumes form an enlargement of the Author's original work, "Mathematical Instruments," the Tenth Edition of which* (*No.* 32) *is still on sale, price* 1*s.* 6*d.*

*** *New Volumes in preparation :—*

PRACTICAL PLANE GEOMETRY: Giving the Simplest Modes of Constructing Figures contained in one Plane, by J. F. HEATHER, M.A.

PROJECTION, Orthographic, Topographic, and Perspective: giving the various modes of Delineating Solid Forms by Constructions on a Single Plane Surface, by J. F. HEATHER, M.A.

*** *The above two volumes, with the Author's work already in the Series, "Descriptive Geometry," will form a complete Elementary Course of Mathematical Drawing.*

CIVIL ENGINEERING.

13. CIVIL ENGINEERING, by H. Law and G. R. Burnell. Fifth Edition, with Additions. 5*s.*

29. DRAINAGE OF DISTRICTS AND LANDS, by G. D. Dempsey. 1*s.* 6*d.*
With No. 30 (*See page* 2), *Drainage and Sewage of Towns*, 3*s.*

31. WELL-SINKING, BORING, AND PUMP WORK, by J. G. Swindell, revised by G. R. Burnell. 1*s.*
43. TUBULAR AND IRON GIRDER BRIDGES, including the Britannia and Conway Bridges, by G. D. Dempsey. 1*s.* 6*d.*
46. ROAD-MAKING AND MAINTENANCE OF MACADAMISED ROADS, by Field-Marshal Sir J. F. Burgoyne. 1*s.* 6*d.*
47. LIGHTHOUSES, their Construction and Illumination, by Alan Stevenson. 3*s.*
62. RAILWAY CONSTRUCTION, by Sir M. Stephenson. With Additions by E. Nugent, C.E. 2*s.* 6*d.*
62*. RAILWAY CAPITAL AND DIVIDENDS, with Statistics of Working, by E. D. Chattaway. 1*s.*
No. 62 *and* 62* *in* 1 *vol.*, 3*s.* 6*d.*
80*. EMBANKING LANDS FROM THE SEA, by J. Wiggins. 2*s.*
82**. GAS WORKS, and the PRACTICE of MANUFACTURING and DISTRIBUTING COAL GAS, by S. Hughes. 3*s.*
82***. WATER-WORKS FOR THE SUPPLY OF CITIES AND TOWNS, by S. Hughes, C.E. 3*s.*
118. CIVIL ENGINEERING OF NORTH AMERICA, by D. Stevenson. 3*s.*
120. HYDRAULIC ENGINEERING, by G. R. Burnell. 3*s.*
121. RIVERS AND TORRENTS, with the Method of Regulating their Course and Channels, Navigable Canals, &c., from the Italian of Paul Frisi. 2*s.* 6*d.*

EMIGRATION.

154. GENERAL HINTS TO EMIGRANTS. 2*s.*
157. EMIGRANT'S GUIDE TO NATAL, by R. J. Mann, M.D. 2*s.*
159. EMIGRANT'S GUIDE TO NEW SOUTH WALES, WESTERN AUSTRALIA, SOUTH AUSTRALIA, VICTORIA, AND QUEENSLAND, by James Baird, B.A. 2*s.* 6*d.*
160. EMIGRANT'S GUIDE TO TASMANIA AND NEW ZEALAND, by James Baird, B.A. 2*s.* [*Ready.*

FINE ARTS.

20. PERSPECTIVE, by George Pyne. 2*s.*
27. PAINTING; or, A GRAMMAR OF COLOURING, by G. Field. 2*s.*
40. GLASS STAINING, by Dr. M. A. Gessert, with an Appendix on the Art of Enamel Painting, &c. 1*s.*
41. PAINTING ON GLASS, from the German of Fromberg. 1*s.*
69. MUSIC, Treatise on, by C. C. Spencer. 2*s.*
71. THE ART OF PLAYING THE PIANOFORTE, by C. C. Spencer. 1*s.*

LEGAL TREATISES.

50. LAW OF CONTRACTS FOR WORKS AND SERVICES, by David Gibbons. 1*s.* 6*d.*
107. THE COUNTY COURT GUIDE, by a Barrister. 1*s.* 6*d.*
108. METROPOLIS LOCAL MANAGEMENT ACTS. 1*s.* 6*d.*
108*. METROPOLIS LOCAL MANAGEMENT AMENDMENT ACT, 1862; with Notes and Index. 1*s.*
Nos. 108 *and* 108* *in* 1 *vol.*, 2*s.* 6*d.*
109. NUISANCES REMOVAL AND DISEASES PREVENTION AMENDMENT ACT. 1*s.*
110. RECENT LEGISLATIVE ACTS applying to Contractors, Merchants, and Tradesmen. 1*s.*
151. THE LAW OF FRIENDLY, PROVIDENT, BUILDING, AND LOAN SOCIETIES, by N. White. 1*s.*
163. THE LAW OF PATENTS FOR INVENTIONS, by F. W. Campin, Barrister. 2*s.*

MECHANICS & MECHANICAL ENGINEERING.

6. MECHANICS, by Charles Tomlinson. 1*s.* 6*d.*
12. PNEUMATICS, by Charles Tomlinson. New Edition. 1*s.* 6*d.*
33. CRANES AND MACHINERY FOR RAISING HEAVY BODIES, the Art of Constructing, by J. Glynn. 1*s.*
34. STEAM ENGINE, by Dr. Lardner. 1*s.*
59. STEAM BOILERS, their Construction and Management, by R. Armstrong. With Additions by R. Mallet. 1*s.* 6*d.*
63. AGRICULTURAL ENGINEERING, BUILDINGS, MOTIVE POWERS, FIELD MACHINES, MACHINERY AND IMPLEMENTS, by G. H. Andrews, C.E. 3*s.*
67. CLOCKS, WATCHES, AND BELLS, by E. B. Denison. New Edition, with Appendix. 3*s.* 6*d.*
Appendix (*to the* 4*th and* 5*th Editions*) *separately*, 1*s.*
77*. ECONOMY OF FUEL, by T. S. Prideaux. 1*s.* 6*d.*
78*. THE LOCOMOTIVE ENGINE, by G. D. Dempsey. 1*s.* 6*d.*
79*. ILLUSTRATIONS TO THE ABOVE. 4to. 4*s.* 6*d.*
80. MARINE ENGINES, AND STEAM VESSELS, AND THE SCREW, by Robert Murray, C.E., Engineer Surveyor to the Board of Trade. Fifth Edition, revised and augmented, with a Glossary of Technical Terms, with their equivalents in French, German, and Spanish. 3*s.*
82. WATER POWER, as applied to Mills, &c., by J. Glynn. 2*s.*
97. STATICS AND DYNAMICS, by T. Baker. New Edition. 1*s.* 6*d.*
98. MECHANISM AND MACHINE TOOLS, by T. Baker; and TOOLS AND MACHINERY, by J. Nasmyth. 2*s.* 6*d.*
113*. MEMOIR ON SWORDS, by Col. Marey, translated by Lieut.-Col. H. H. Maxwell. 1*s.*

114. MACHINERY, Construction and Working, by C. D. Abel. 1*s.* 6*d.*
115. PLATES TO THE ABOVE. 4to. 7*s.* 6*d.*
125. COMBUSTION OF COAL, AND THE PREVENTION OF SMOKE, by C. Wye Williams, M.I.C.E. 3*s.*
139. STEAM ENGINE, Mathematical Theory of, by T. Baker. 1*s.*
155. ENGINEER'S GUIDE TO THE ROYAL AND MERCANTILE NAVIES, by a Practical Engineer. Revised by D. F. McCarthy. 3*s.*
162. THE BRASSFOUNDER'S MANUAL, by W. Graham. 2*s.* 6*d.*
164. MODERN WORKSHOP PRACTICE. By J. G. Winton. 3*s.*
165. IRON AND HEAT, Exhibiting the Principles concerned in the Construction of Iron Beams, Pillars, and Bridge Girders, and the Action of Heat in the Smelting Furnace, by James Armour, C.E. Woodcuts. 2*s.* 6*d.* [*Now ready.*
166. POWER IN MOTION: Horse Power, Motion, Toothed Wheel Gearing, Long and Short Driving Bands, Angular Forces, &c., by James Armour, C.E. With 73 Diagrams. 2*s.* 6*d.* [*Now ready.*
167. A TREATISE ON THE CONSTRUCTION OF IRON BRIDGES, GIRDERS, ROOFS, AND OTHER STRUCTURES, by Francis Campin, C.E. With numerous Illustrations. 2*s.* [*Ready.*
171. THE WORKMAN'S MANUAL OF ENGINEERING DRAWING, by John Maxton, Instructor in Engineering Drawing, Royal School of Naval Architecture & Marine Engineering, South Kensington. Plates & Diagrams. 3*s.* 6*d.* [*Ready.*
172. MINING TOOLS. For the Use of Mine Managers, Agents, Mining Students, &c., by William Morgans, Lecturer on Mining at the Bristol School of Mines. 12mo. 2*s.* 6*d.* [*Ready.*
172*. ATLAS OF PLATES to the above, containing 200 Illustrations. 4to. 4*s.* 6*d.* [*Ready.*

TREATISE ON THE METALLURGY OF IRON; containing Outlines of the History of Iron Manufacture, Methods of Assay, and Analysis of Iron Ores, Processes of Manufacture of Iron and Steel, &c., by H. Bauerman, F.G.S., A.R.S.M. Second Edition, revised and enlarged. Numerous Woodcuts. [*In the Press.*

NAVIGATION AND SHIP-BUILDING.

51. NAVAL ARCHITECTURE, by J. Peake. 3*s.*
53*. SHIPS FOR OCEAN AND RIVER SERVICE, Construction of, by Captain H. A. Sommerfeldt. 1*s.*
53**. ATLAS OF 15 PLATES TO THE ABOVE, Drawn for Practice. 4to. 7*s.* 6*d.*
54. MASTING, MAST-MAKING, and RIGGING OF SHIPS, by R. Kipping. 1*s.* 6*d.*

54*. IRON SHIP-BUILDING, by J. Grantham. Fifth Edition, with Supplement. 4*s.*

54**. ATLAS OF 40 PLATES to illustrate the preceding. 4to. 38*s.*

55. NAVIGATION; the Sailor's Sea Book: How to Keep the Log and Work it off, Law of Storms, &c., by J. Greenwood. 2*s.*

83 *bis*. SHIPS AND BOATS, Form of, by W. Bland. 1*s.* 6*d.*

99. NAUTICAL ASTRONOMY AND NAVIGATION, by J. R. Young. 2*s.*

100*. NAVIGATION TABLES, for Use with the above. 1*s.* 6*d.*

106. SHIPS' ANCHORS for all SERVICES, by G. Cotsell. 1*s.* 6*d.*

149. SAILS AND SAIL-MAKING, by R. Kipping, N.A. 2*s.* 6*d.*

PHYSICAL AND CHEMICAL SCIENCE.

1. CHEMISTRY, by Prof. Fownes. With Appendix on Agricultural Chemistry. New Edition, with Index. 1*s.*

2. NATURAL PHILOSOPHY, by Charles Tomlinson. 1*s.*

3. GEOLOGY, by Major-Gen. Portlock. New Edition. 1*s.* 6*d.*

4. MINERALOGY, by A. Ramsay, Jun. 3*s.*

7. ELECTRICITY, by Sir W. S. Harris. 1*s.* 6*d.*

7*. GALVANISM, ANIMAL AND VOLTAIC ELECTRICITY, by Sir W. S. Harris. 1*s.* 6*d.*

8. MAGNETISM, by Sir W. S. Harris. 3*s.* 6*d.*

Nos. 7, 7*, *and* 8 *in* 1 *vol. cloth boards*, 7*s.* 6*d.*

11. HISTORY AND PROGRESS OF THE ELECTRIC TELEGRAPH, by Robert Sabine, C.E., F.S.A. 3*s.*

72. RECENT AND FOSSIL SHELLS (A Manual of the Mollusca), by S. P. Woodward. With Appendix by Ralph Tate, F.G.S. 6*s.* 6*d.*; in cloth boards, 7*s.* 6*d.* Appendix separately, 1*s*,

79**. PHOTOGRAPHY, the Stereoscope, &c., from the French of D. Van Monckhoven, by W. H. Thornthwaite. 1*s.* 6*d.*

96. ASTRONOMY, by the Rev. R. Main. New and Enlarged Edition, with an Appendix on "Spectrum Analysis." 1*s.* 6*d.*

133. METALLURGY OF COPPER, by Dr. R. H. Lamborn. 2*s.*

134. METALLURGY OF SILVER AND LEAD, by Lamborn. 2*s.*

135. ELECTRO-METALLURGY, by A. Watt. 2*s.*

138. HANDBOOK OF THE TELEGRAPH, by R. Bond. New and enlarged Edition. 1*s.* 6*d.*

143. EXPERIMENTAL ESSAYS—On the Motion of Camphor and Modern Theory of Dew, by C. Tomlinson. 1*s.*

161. QUESTIONS ON MAGNETISM, ELECTRICITY, AND PRACTICAL TELEGRAPHY, by W. McGregor. 1*s.* 6*d.*

173. PHYSICAL GEOLOGY (partly based on Portlock's "Rudiments of Geology"), by Ralph Tate, A.L.S., &c. 2*s.* [*Now ready.*

174. HISTORICAL GEOLOGY (partly based on Portlock's "Rudiments of Geology"), by Ralph Tate, A.L.S., &c. 2*s.* 6*d.* [*Now ready.*

MISCELLANEOUS TREATISES.

12. DOMESTIC MEDICINE, by Dr. Ralph Gooding. 2*s.*
112*. THE MANAGEMENT OF HEALTH, by James Baird. 1*s.*
113. USE OF FIELD ARTILLERY ON SERVICE, by Taubert, translated by Lieut.-Col. H. H. Maxwell. 1*s.* 6*d.*
150. LOGIC, PURE AND APPLIED, by S. H. Emmens. 1*s.* 6*d.*
152. PRACTICAL HINTS FOR INVESTING MONEY: with an Explanation of the Mode of Transacting Business on the Stock Exchange, by Francis Playford, Sworn Broker. 1*s.*
153. LOCKE ON THE CONDUCT OF THE HUMAN UNDERSTANDING, Selections from, by S. H. Emmens. 2*s.*

NEW SERIES OF EDUCATIONAL WORKS.

1. ENGLAND, History of, by W. D. Hamilton. 5*s.*; cloth boards, 6*s.* (Also in 5 parts, price 1*s.* each.)
5. GREECE, History of, by W. D. Hamilton and E. Levien, M.A. 2*s.* 6*d.*; cloth boards, 3*s.* 6*d.*
7. ROME, History of, by E. Levien, M.A. 2*s.* 6*d.*; cloth boards, 3*s.* 6*d.*
9. CHRONOLOGY OF HISTORY, LITERATURE, ART, and Progress, from the earliest period to the present time. 2*s.* 6*d.*; cloth boards, 3*s.* 6*d.*
11. ENGLISH GRAMMAR, by Hyde Clarke, D.C.L. 1*s.*
11*. HANDBOOK OF COMPARATIVE PHILOLOGY, by Hyde Clarke, D.C.L. 1*s.*
12. ENGLISH DICTIONARY, containing above 100,000 words, by Hyde Clarke, D.C.L. 3*s.* 6*d.*; cloth boards, 4*s.* 6*d.*
——————, with Grammar. Cloth bds. 5*s.* 6*d.*
14. GREEK GRAMMAR, by H. C. Hamilton. 1*s.*
15. ——— DICTIONARY, by H. R. Hamilton. Vol. 1. Greek—English. 2*s.*
17. —————— Vol. 2. English—Greek. 2*s.*
——— Complete in 1 vol. 4*s.*; cloth boards, 5*s.*
——————, with Grammar. Cloth boards, 6*s.*
19. LATIN GRAMMAR, by T. Goodwin, M.A. 1*s.*
20. ——— DICTIONARY, by T. Goodwin, M.A. Vol. 1. Latin—English. 2*s.*
22. —————— Vol. 2. English—Latin. 1*s.* 6*d.*
——— Complete in 1 vol. 3*s.* 6*d.*; cloth boards, 4*s.* 6*d.*
——————, with Grammar. Cloth bds. 5*s.* 6*d.*
24. FRENCH GRAMMAR, by G. L. Strauss. 1*s.*

25. FRENCH DICTIONARY, by A. Elwes. Vol. 1. French—English. 1*s.*
26. ——— Vol. 2. English—French. 1*s.* 6*d.*
——— Complete in 1 vol. 2*s.* 6*d.*; cloth boards, 3*s.* 6*d.*
———, with Grammar. Cloth bds. 4*s.* 6*d.*
27. ITALIAN GRAMMAR, by A. Elwes. 1*s.*
28. ——— TRIGLOT DICTIONARY, by A. Elwes. Vol. 1. Italian—English—French. 2*s.*
30. ——— Vol. 2. English—French—Italian. 2*s.*
32. ——— Vol. 3. French—Italian—English. 2*s.*
——— Complete in 1 vol. Cloth boards, 7*s.* 6*d.*
———, with Grammar. Cloth bds. 8*s.* 6*d.*
34. SPANISH GRAMMAR, by A. Elwes. 1*s.*
35. ——— ENGLISH AND ENGLISH—SPANISH DICTIONARY, by A. Elwes. 4*s.*; cloth boards, 5*s.*
———, with Grammar. Cloth boards, 6*s.*
39. GERMAN GRAMMAR, by G. L. Strauss. 1*s.*
40. ——— READER, from best Authors. 1*s.*
41. ——— TRIGLOT DICTIONARY, by N. E. S. A. Hamilton. Vol. 1. English—German—French. 1*s.*
42. ——— Vol. 2. German—French—English. 1*s.*
43. ——— Vol. 3. French—German—English. 1*s.*
——— Complete in 1 vol. 3*s.*; cloth boards, 4*s.*
———, with Grammar. Cloth boards, 5*s.*
44. HEBREW DICTIONARY, by Dr. Bresslau. Vol. 1. Hebrew—English. 6*s.*
———, with Grammar. 7*s.*
46. ——— Vol. 2. English—Hebrew. 3*s.*
———Complete, with Grammar, in 2 vols. Cloth boards, 12*s.*
46*. ——— GRAMMAR, by Dr. Bresslau. 1*s.*
47. FRENCH AND ENGLISH PHRASE BOOK. 1*s.*
48. COMPOSITION AND PUNCTUATION, by J. Brenan. 1*s.*
49. DERIVATIVE SPELLING BOOK, by J. Rowbotham. 1*s.* 6*d.*
50. DATES AND EVENTS. A Tabular View of English History, with Tabular Geography, by Edgar H. Rand. [*In Preparation.*

THE SCHOOL MANAGERS' SERIES
OF
READING BOOKS,

Adapted to the Requirements of the New Code of 1871.

Edited by the Rev. A. R. GRANT, Rector of Hitcham, and Honorary Canon of Ely; formerly H.M. Inspector of Schools.

	s. d.		s. d.
FIRST STANDARD . . .	0 3	FOURTH STANDARD . . .	0 10
SECOND „	0 6	FIFTH „ . . .	1 0
THIRD „	0 8	SIXTH „ . . .	1 2

GREEK AND LATIN CLASSICS,

WITH EXPLANATORY NOTES IN ENGLISH.

LATIN SERIES.

1. A NEW LATIN DELECTUS, with Vocabularies and Notes, by H. Young . . . . 1*s.*
2. CÆSAR. De Bello Gallico; Notes by H. Young . . 2*s.*
3. CORNELIUS NEPOS; Notes by H. Young . . . 1*s.*
4. VIRGIL. The Georgics, Bucolics, and Doubtful Poems; Notes by W. Rushton, M.A., and H. Young . 1*s.* 6*d.*
5. VIRGIL. Æneid; Notes by H. Young . . . 2*s.*
6. HORACE. Odes, Epodes, and Carmen Seculare, by H. Young 1*s.*
7. HORACE. Satires and Epistles, by W. B. Smith, M.A. 1*s.* 6*d.*
8. SALLUST. Catiline and Jugurthine War; Notes by W. M. Donne, B.A. . . . . 1*s.* 6*d.*
9. TERENCE. Andria and Heautontimorumenos; Notes by the Rev. J. Davies, M.A. . . . . . . 1*s.* 6*d.*
10. TERENCE. Adelphi, Hecyra, and Phormio; Notes by the Rev. J. Davies, M.A. . . . . 2*s.*
11. TERENCE. Eunuchus, by Rev. J. Davies, M.A. . 1*s.* 6*d.*
    Nos. 9, 10, *and* 11 *in* 1 *vol. cloth boards*, 6*s.*
12. CICERO. Oratio Pro Sexto Roscio Amerino. Edited, with Notes, &c., by J. Davies, M.A. (*Now ready.*) . . 1*s.*
14. CICERO. De Amicitia, de Senectute, and Brutus; Notes by the Rev. W. B. Smith, M.A. . . . . . . 2*s.*
16. LIVY. Books i., ii., by H. Young . . . . 1*s.* 6*d.*
16*. LIVY. Books iii., iv., v., by H. Young . . . 1*s.* 6*d.*
17. LIVY. Books xxi., xxii., by W. B. Smith, M.A. . 1*s.* 6*d.*
19. CATULLUS, TIBULLUS, OVID, and PROPERTIUS, Selections from, by W. Bodham Donne . . . . 2*s.*
20. SUETONIUS and the later Latin Writers, Selections from, by W. Bodham Donne . . . . 2*s.*
21. THE SATIRES OF JUVENAL, by T. H. S. Escott, M.A., of Queen's College, Oxford . . . . . . 1*s.* 6*d.*

GREEK SERIES.

WITH EXPLANATORY NOTES IN ENGLISH.

1. A NEW GREEK DELECTUS, by H. Young . 1*s.*
2. XENOPHON. Anabasis, i. ii. iii., by H. Young . . 1*s.*
3. XENOPHON. Anabasis, iv. v. vi. vii., by H. Young . 1*s.*
4. LUCIAN. Select Dialogues, by H. Young . . . 1*s.*
5. HOMER. Iliad, i. to vi., by T. H. L. Leary, D.C.L. 1*s.* 6*d.*
6. HOMER. Iliad, vii. to xii., by T. H. L. Leary, D.C.L. 1*s.* 6*d.*
7. HOMER. Iliad, xiii. to xviii., by T. H. L. Leary, D.C.L. 1*s.* 6*d.*
8. HOMER. Iliad, xix. to xxiv., by T. H. L. Leary, D.C.L. 1*s.* 6*d.*
9. HOMER. Odyssey, i. to vi., by T. H. L. Leary, D.C.L. 1*s.* 6*d.*
10. HOMER. Odyssey, vii. to xii., by T. H. L. Leary, D.C.L. 1*s.* 6*d.*
11. HOMER. Odyssey, xiii. to xviii., by T. H. L. Leary, D.C.L. 1*s.* 6*d.*
12. HOMER. Odyssey, xix. to xxiv.; and Hymns, by T. H. L. Leary, D.C.L. . . . . 2*s.*
13. PLATO. Apologia, Crito, and Phædo, by J. Davies, M.A. 2*s.*
14. HERODOTUS, Books i. ii., by T. H. L. Leary, D.C.L. 1*s.* 6*d.*
15. HERODOTUS, Books iii. iv., by T. H. L. Leary, D.C.L. 1*s.* 6*d.*
16. HERODOTUS, Books v. vi. vii., by T. H. L. Leary, D.C.L. 1*s.* 6*d.*
17. HERODOTUS, Books viii. ix., and Index, by T. H. L. Leary, D.C.L. . . . . 1*s.* 6*d.*
18. SOPHOCLES. Œdipus Tyrannus, by H. Young . . 1*s.*
20. SOPHOCLES. Antigone, by J. Milner, B.A. . . . 2*s.*
23. EURIPIDES. Hecuba and Medea, by W. B. Smith, M.A. 1*s.* 6*d.*
26. EURIPIDES. Alcestis, by J. Milner, B.A. . . . 1*s.*
30. ÆSCHYLUS. Prometheus Vinctus, by J. Davies, M.A. . 1*s.*
32. ÆSCHYLUS. Septem contra Thebas, by J. Davies, M.A. 1*s.*
40. ARISTOPHANES. Acharnenses, by C. S. D. Townshend, M.A. . . . . 1*s.* 6*d.*
41. THUCYDIDES. Peloponnesian War. Book i., by H. Young 1*s.*
42. XENOPHON. Panegyric on Agesilaus, by Ll. F. W. Jewitt 1*s.* 6*d.*

LONDON, *August*, 1871.

A Catalogue

OF

NEW & STANDARD WORKS

IN

ENGINEERING, ARCHITECTURE, AGRICULTURE, MATHEMATICS, MECHANICS, SCIENCE, &c. &c.

PUBLISHED BY

LOCKWOOD & CO.,

7, STATIONERS'-HALL COURT, LUDGATE HILL, E.C.

ENGINEERING, SURVEYING, &c.

Humber's New Work on Water-Supply.

A COMPREHENSIVE TREATISE on the WATER-SUPPLY of CITIES and TOWNS. By WILLIAM HUMBER, Assoc. Inst. C.E., and M. Inst. M.E. Author of "Cast and Wrought Iron Bridge Construction," &c. &c. This work, it is expected, will contain about 50 Double Plates, and upwards of 300 pages of Text. Imp. 4to, half bound in morocco. [*In the press.*

*** *In accumulating information for this volume, the Author has been very liberally assisted by several professional friends, who have made this department of engineering their special study. He has thus been in a position to prepare a work which, within the limits of a single volume, will supply the reader with the most complete and reliable information upon all subjects, theoretical and practical, connected with water supply. Through the kindness of Messrs. Anderson, Bateman, Hawksley, Homersham, Baldwin Latham, Lawson, Milne, Quick, Rawlinson, Simpson, and others, several works, constructed and in course of construction, from the designs of these gentlemen, will be fully illustrated and described.*

AMONGST OTHER IMPORTANT SUBJECTS THE FOLLOWING WILL BE TREATED IN THE TEXT:—

Historical Sketch of the means that have been proposed and adopted for the Supply of Water.—Water and the Foreign Matter usually associated with it.—Rainfall and Evaporation.—Springs and Subterranean Lakes.—Hydraulics.—The Selection of Sites for Water Works.—Wells.—Reservoirs.—Filtration and Filter Beds.—Reservoir and Filter Bed Appendages.—Pumps and Appendages.—Pumping Machinery.—Culverts and Conduits, Aqueducts, Syphons, &c.—Distribution of Water.—Water Meters and general House Fittings.—Cost of Works for the Supply of Water.—Constant and Intermittent Supply.—Suggestions for preparing Plans, &c. &c., together with a Description of the numerous Works illustrated, viz:—Aberdeen, Bideford, Cockermouth, Dublin, Glasgow, Loch Katrine, Liverpool, Manchester, Rotherham, Sunderland, and several others; with copies of the Contract, Drawings, and Specification in each case.

Humber's Modern Engineering. First Series.

A RECORD of the PROGRESS of MODERN ENGINEERING, 1863. Comprising Civil, Mechanical, Marine, Hydraulic, Railway, Bridge, and other Engineering Works, &c. By WILLIAM HUMBER, Assoc. Inst. C.E., &c. Imp. 4to, with 36 Double Plates, drawn to a large scale, and Photographic Portrait of John Hawkshaw, C.E., F.R.S., &c. Price 3*l.* 3*s.* half morocco.

List of the Plates.

NAME AND DESCRIPTION.	PLATES.	NAME OF ENGINEER.
Victoria Station and Roof—L. B. & S. C. Rail.	1 to 8	Mr. R. Jacomb Hood, C.E.
Southport Pier	9 and 10	Mr. James Brunlees, C.E.
Victoria Station and Roof—L. C. & D. & G. W. Railways	11 to 15A	Mr. John Fowler, C.E.
Roof of Cremorne Music Hall	16	Mr. William Humber, C.E.
Bridge over G. N. Railway	17	Mr. Joseph Cubitt, C.E.
Roof of Station—Dutch Rhenish Railway	18 and 19	Mr. Euschedi, C.E.
Bridge over the Thames—West London Extension Railway	20 to 24	Mr. William Baker, C.E.
Armour Plates	25	Mr. James Chalmers, C.E.
Suspension Bridge, Thames	26 to 29	Mr. Peter W. Barlow, C.E.
The Allen Engine	30	Mr. G. T. Porter, M.E.
Suspension Bridge, Avon	31 to 33	Mr. John Hawkshaw, C.E. and W. H. Barlow, C.E.
Underground Railway	34 to 36	Mr. John Fowler, C.E.

With copious Descriptive Letterpress, Specifications, &c.

"Handsomely lithographed and printed. It will find favour with many who desire to preserve in a permanent form copies of the plans and specifications prepared for the guidance of the contractors for many important engineering works."—*Engineer.*

Humber's Modern Engineering. Second Series.

A RECORD of the PROGRESS of MODERN ENGINEERING, 1864; with Photographic Portrait of Robert Stephenson, C.E., M.P., F.R.S., &c. Price 3*l.* 3*s.* half morocco.

List of the Plates.

NAME AND DESCRIPTION.	PLATES.	NAME OF ENGINEER.
Birkenhead Docks, Low Water Basin	1 to 15	Mr. G. F. Lyster, C.E.
Charing Cross Station Roof—C. C. Railway.	16 to 18	Mr. Hawkshaw, C.E.
Digswell Viaduct—Great Northern Railway.	19	Mr. J. Cubitt, C.E.
Robbery Wood Viaduct—Great N. Railway.	20	Mr. J. Cubitt, C.E.
Iron Permanent Way	20*a*	——
Clydach Viaduct—Merthyr, Tredegar, and Abergavenny Railway	21	Mr. Gardner, C.E.
Ebbw Viaduct ditto ditto ditto	22	Mr. Gardner, C.E.
College Wood Viaduct—Cornwall Railway	23	Mr. Brunel.
Dublin Winter Palace Roof	24 to 26	Messrs. Ordish & Le Feuvre.
Bridge over the Thames—L. C. & D. Railw.	27 to 32	Mr. J. Cubitt, C.E.
Albert Harbour, Greenock	33 to 36	Messrs. Bell & Miller.

With copious Descriptive Letterpress, Specifications, &c.

"A *resumé* of all the more interesting and important works lately completed in Great Britain; and containing, as it does, carefully executed drawings, with full working details, will be found a valuable accessory to the profession at large."—*Engineer.*

"Mr. Humber has done the profession good and true service, by the fine collection of examples he has here brought before the profession and the public."—*Practical Mechanic's Journal.*

Humber's Modern Engineering. Third Series.

A RECORD of the PROGRESS of MODERN ENGINEERING, 1865. Imp. 4to, with 40 Double Plates, drawn to a large scale, and Photographic Portrait of J. R. M'Clean, Esq., late President of the Institution of Civil Engineers. Price 3*l.* 3*s.* half morocco.

List of Plates and Diagrams.

MAIN DRAINAGE, METROPOLIS.

NORTH SIDE.

Map showing Interception of Sewers.
Middle Level Sewer. Sewer under Regent's Canal.
Middle Level Sewer. Junction with Fleet Ditch.
Outfall Sewer. Bridge over River Lea. Elevation.
Outfall Sewer. Bridge over River Lea. Details.
Outfall Sewer. Bridge over River Lea. Details.
Outfall Sewer. Bridges over Marsh Lane, North Woolwich Railway, and Bow and Barking Railway Junction.
Outfall Sewer. Bridge over Bow and Barking Railway. Elevation.
Outfall Sewer. Bridge over Bow and Barking Railway. Details.
Outfall Sewer. Bridge over Bow and Barking Railway. Details.
Outfall Sewer. Bridge over East London Waterworks' Feeder. Elevation.
Outfall Sewer. Bridge over East London Waterworks' Feeder. Details.
Outfall Sewer. Reservoir. Plan.
Outfall Sewer. Reservoir. Section.
Outfall Sewer. Tumbling Bay and Outlet.
Outfall Sewer. Penstocks.

SOUTH SIDE.

Outfall Sewer. Bermondsey Branch.
Outfall Sewer. Bermondsey Branch.
Outfall Sewer. Reservoir and Outlet. Plan.

MAIN DRAINAGE, METROPOLIS, *continued*—

Outfall Sewer. Reservoir and Outlet. Details.
Outfall Sewer. Reservoir and Outlet. Details.
Outfall Sewer. Reservoir and Outlet. Details.
Outfall Sewer. Filth Hoist.
Sections of Sewers (North and South Sides).

THAMES EMBANKMENT.

Section of River Wall.
Steam-boat Pier, Westminster. Elevation.
Steam-boat Pier, Westminster. Details.
Landing Stairs between Charing Cross and Waterloo Bridges.
York Gate. Front Elevation.
York Gate. Side Elevation and Details.
Overflow and Outlet at Savoy Street Sewer. Details.
Overflow and Outlet at Savoy Street Sewer. Penstock.
Overflow and Outlet at Savoy Street Sewer. Penstock.
Steam-boat Pier, Waterloo Bridge. Elevation.
Steam-boat Pier, Waterloo Bridge. Details.
Steam-boat Pier, Waterloo Bridge. Details.
Junction of Sewers. Plans and Sections.
Gullies. Plans and Sections.
Rolling Stock.
Granite and Iron Forts.

With copious Descriptive Letterpress, Specifications, &c.

Opinions of the Press.

"Mr. Humber's works—especially his annual 'Record,' with which so many of our readers are now familiar—fill a void occupied by no other branch of literature. . . . . The drawings have a constantly increasing value, and whoever desires to possess clear representations of the two great works carried out by our Metropolitan Board will obtain Mr. Humber's last volume."—*Engineering.*

"No engineer, architect, or contractor should fail to preserve these records of works which, for magnitude, have not their parallel in the present day, no student in the profession but should carefully study the details of these great works, which he may be one day called upon to imitate."—*Mechanics' Magazine.*

"A work highly creditable to the industry of its author. . . . The volume is quite an encyclopædia for the study of the student who desires to master the subject of municipal drainage on its scale of greatest development."—*Practical Mechanic's Journal.*

Humber's Modern Engineering. Fourth Series.

A RECORD of the PROGRESS of MODERN ENGINEERING, 1866. Imp. 4to, with 36 Double Plates, drawn to a large scale, and Photographic Portrait of John Fowler, Esq., President of the Institution of Civil Engineers. Price 3*l.* 3*s.* half-morocco.

List of the Plates and Diagrams.

NAME AND DESCRIPTION.	PLATES.	NAME OF ENGINEER.
Abbey Mills Pumping Station, Main Drainage, Metropolis	1 to 4	Mr. Bazalgette, C.E.
Barrow Docks	5 to 9	Messrs. M'Clean & Stillman, C.E.
Manquis Viaduct, Santiago and Valparaiso Railway	10, 11	Mr. W. Loyd, C.E.
Adams' Locomotive, St. Helen's Canal Railw.	12, 13	Mr. H. Cross, C.E.
Cannon Street Station Roof, Charing Cross Railway	14 to 16	Mr. J. Hawkshaw, C.E.
Road Bridge over the River Moka	17, 18	Mr. H. Wakefield, C.E.
Telegraphic Apparatus for Mesopotamia	19	Mr. Siemens, C.E.
Viaduct over the River Wye, Midland Railw.	20 to 22	Mr. W. H. Barlow, C.E.
St. Germans Viaduct, Cornwall Railway	23, 24	Mr. Brunel, C.E.
Wrought-Iron Cylinder for Diving Bell	25	Mr. J. Coode, C.E.
Millwall Docks	26 to 31	Messrs. J. Fowler, C.E., and William Wilson, C.E.
Milroy's Patent Excavator	32	Mr. Milroy, C.E.
Metropolitan District Railway	33 to 38	Mr. J. Fowler, Engineer-in-Chief, and Mr. T. M. Johnson, C.E.
Harbours, Ports, and Breakwaters	A to C	

The Letterpress comprises—

A concluding article on Harbours, Ports, and Breakwaters, with Illustrations and detailed descriptions of the Breakwater at Cherbourg, and other important modern works; an article on the Telegraph Lines of Mesopotamia; a full description of the Wrought-iron Diving Cylinder for Ceylon, the circumstances under which it was used, and the means of working it; full description of the Millwall Docks; &c., &c., &c.

Opinions of the Press.

"Mr. Humber's 'Record of Modern Engineering' is a work of peculiar value, as well to those who design as to those who study the art of engineering construction. It embodies a vast amount of practical information in the form of full descriptions and working drawings of all the most recent and noteworthy engineering works. The plates are excellently lithographed, and the present volume of the 'Record' is not a whit behind its predecessors."—*Mechanics' Magazine.*

"We gladly welcome another year's issue of this valuable publication from the able pen of Mr. Humber. The accuracy and general excellence of this work are well known, while its usefulness in giving the measurements and details of some of the latest examples of engineering, as carried out by the most eminent men in the profession, cannot be too highly prized."—*Artizan.*

"The volume forms a valuable companion to those which have preceded it, and cannot fail to prove a most important addition to every engineering library."—*Mining Journal.*

"No one of Mr. Humber's volumes was bad; all were worth their cost, from the mass of plates from well-executed drawings which they contained. In this respect, perhaps, this last volume is the most valuable that the author has produced."—*Practical Mechanics' Journal.*

Humber's Great Work on Bridge Construction.

A COMPLETE and PRACTICAL TREATISE on CAST and WROUGHT-IRON BRIDGE CONSTRUCTION, including Iron Foundations. In Three Parts—Theoretical, Practical, and Descriptive. By WILLIAM HUMBER, Assoc. Inst. C.E., and M. Inst. M.E. Third Edition, revised and much improved, with 115 Double Plates (20 of which now first appear in this edition), and numerous additions to the Text. In 2 vols. imp. 4to., price 6*l.* 16*s.* 6*d.* half-bound in morocco. [*Recently published.*

"A very valuable contribution to the standard literature of civil engineering. In addition to elevations, plans, and sections, large scale details are given, which very much enhance the instructive worth of these illustrations. No engineer would willingly be without so valuable a fund of information."—*Civil Engineer and Architect's Journal.*

"The First or Theoretical Part contains mathematical investigations of the principles involved in the various forms now adopted in bridge construction. These investigations are exceedingly complete, having evidently been very carefully considered and worked out to the utmost extent that can be desired by the practical man. The tables are of a very useful character, containing the results of the most recent experiments, and amongst them are some valuable tables of the weight and cost of cast and wrought-iron structures actually erected. The volume of text is amply illustrated by numerous woodcuts, plates, and diagrams; and the plates in the second volume do great credit to both draughtsmen and engravers. In conclusion, we have great pleasure in cordially recommending this work to our readers."—*Artizan.*

"Mr. Humber's stately volumes lately issued—in which the most important bridges erected during the last five years, under the direction of the late Mr. Brunel, Sir W. Cubitt, Mr. Hawkshaw, Mr. Page, Mr. Fowler, Mr. Hemans, and others among our most eminent engineers, are drawn and specified in great detail."—*Engineer.*

Weale's Engineer's Pocket-Book.

THE ENGINEER'S, ARCHITECT'S, and CONTRACTOR'S POCKET-BOOK (LOCKWOOD & CO.'S; formerly WEALE'S). Published Annually. In roan tuck, gilt edges, with 10 Copper-Plates and numerous Woodcuts. Price 6*s.*

" A vast amount of really valuable matter condensed into the small dimensions of a book which is, in reality, what it professes to be—a pocket-book. . . . . We cordially recommend the book to the notice of the managers of coal and other mines; to them it will prove a handy book of reference on a variety of subjects more or less intimately connected with their profession. It might also be placed with advantage in the hands of the subordinate officers in collieries."—*Colliery Guardian.*

"The assignment of the late Mr. Weale's '*Engineer's Pocket-Book*' to Messrs. Lockwood & Co. has by no means lowered the standard value of the work. It is too well known among those for whom it is specially intended, to need more from us than the observation that this continuation of Mr. Weale's series of Pocket Books well sustains the reputation the work has so long enjoyed. Every branch of engineering is treated of, and facts, figures, and data of every kind abound."—*Mechanics' Mag.*

"It contains a large amount of information peculiarly valuable to those for whose use it is compiled. We cordially commend it to the engineering and architectural professions generally."—*Mining Journal.*

Iron Bridges, Girders, Roofs, &c.

THE APPLICATION OF IRON TO THE CONSTRUCTION OF BRIDGES, GIRDERS, ROOFS, and other Works. By FRANCIS CAMPIN, C.E. With numerous Illustrations. 12mo, cloth boards, 3*s.* [*Just published.*

Barlow on the Strength of Materials, enlarged.

A TREATISE ON THE STRENGTH OF MATERIALS, with Rules for application in Architecture, the Construction of Suspension Bridges, Railways, &c.; and an Appendix on the Power of Locomotive Engines, and the effect of Inclined Planes and gradients. By PETER BARLOW, F.R.S., Mem. Inst. of France; of the Imp. and Royal Academies of St. Petersburgh and Brussels; of the Amer. Soc. Arts; and Hon. Mem. Inst. Civil Engineers. A New and considerably Enlarged Edition, revised by his Sons, P. W. BARLOW, F.R.S., Mem. Inst. C.E., and W. H. BARLOW, F.R.S., Mem. of Council Inst. C.E., to which are added a Summary of Experiments by EATON HODGKINSON, F.R.S., WILLIAM FAIRBAIRN, F.R.S., and DAVID KIRKALDY; an Essay (with Illustrations) on the effect produced by passing Weights over Elastic Bars, by the Rev. ROBERT WILLIS, M.A., F.R.S. And Formulæ for Calculating Girders, &c. The whole arranged and edited by WILLIAM HUMBER, Assoc. Inst. C.E., and Mem. Inst. M.E., Author of "A Complete and Practical Treatise on Cast and Wrought-Iron Bridge Construction," &c. &c. Demy 8vo, 400 pp., with 19 large Plates, and numerous woodcuts, price 18*s*. cloth.

Opinions of the Press.

"This edition has undergone considerable improvement, and has been brought down to the present date. It is one of the first books of reference in existence."—*Artizan.*

"Although issued as the sixth edition, the volume under consideration is worthy of being regarded, for all practical purposes, as an entirely new work . . . the book is undoubtedly worthy of the highest commendation, and of an honourable place in the library of every engineer."—*Mining Journal.*

"An increased value has been given to this very valuable work by the addition of a large amount of information, which cannot prove otherwise than highly useful to those who require to consult it. . . . . The arrangement and editing of this mass of information has been undertaken by Mr. Humber, who has most ably fulfilled a task requiring special care and ability to render it a success, which this edition most certainly is. He has given the finishing touch to the volume by introducing into it an interesting memoir of Professor Barlow, which tribute of respect, we are sure, will be appreciated by the members of the engineering profession."—*Mechanics' Magazine.*

"A book which no engineer of any kind can afford to be without. In its present form its former value is much increased."—*Colliery Guardian.*

"The best book on the subject which has yet appeared. . . . . We know of no work that so completely fulfils its mission. . . . . As a scientific work of the first class, it deserves a foremost place on the bookshelves of every civil engineer and practical mechanic."—*English Mechanic.*

"There is not a pupil in an engineering school, an apprentice in an engineer's or architect's office, or a competent clerk of works, who will not recognise in the scientific volume newly given to circulation, an old and valued friend. . . So far as the strength of timber is concerned, there is no greater authority than Barlow."—*Building News.*

"It is scarcely necessary for us to make any comment upon the first portion of the new volume. . . . . Valuable alike to the student, tyro, and experienced practitioner, it will always rank in future, as it has hitherto done, as the standard treatise upon this particular subject."—*Engineer.*

"The present edition offers some important advantages over previous ones. The additions are both extensive and valuable, comprising experiments by Hodgkinson on the strength of cast-iron; extracts from papers on the transverse strength of beams by W. H. Barlow; an article on the strength of columns; experiments by Fairbairn, on iron and steel plates, on the behaviour of girders subjected to the vibration of a changing load, and on various cast and wrought-iron beams; experiments by Kirkaldy, on wrought-iron and steel bars, and a short appendix of formulæ for ready application in computing the strains on bridges."—*Engineering.*

Strains, Formulæ & Diagrams for Calculation of.

A HANDY BOOK for the CALCULATION of STRAINS in GIRDERS and SIMILAR STRUCTURES, and their STRENGTH; consisting of Formulæ and Corresponding Diagrams, with numerous Details for Practical Application, &c. By WILLIAM HUMBER, Assoc. Inst. C.E., &c. Fcap. 8vo, with nearly 100 Woodcuts and 3 Plates, price 7*s.* 6*d.* cloth.

"To supply a universally recognised want of simple formulæ, applicable to the varied problems to be met with in ordinary practice, Mr. Humber, whose works on modern engineering afford sufficient evidence of his qualifications for the task, has compiled his 'Handy Book.' The arrangement of the matter in this little volume is as convenient as it well could be. . . . The system of employing diagrams as a substitute for complex computations is one justly coming into great favour, and in that respect Mr. Humber's volume is fully up to the times."—*Engineering.*

"The formulæ are neatly expressed, and the diagrams good."—*Athenæum.*

"That a necessity existed for the book is evident, we think; that Mr. Humber has achieved his design is equally evident. . . . We heartily commend the really *handy* book to our engineer and architect readers."—*English Mechanic.*

Strains.

THE STRAINS ON STRUCTURES OF IRONWORK; with Practical Remarks on Iron Construction. By F. W. SHEILDS, M. Inst. C.E. Second Edition, with 5 plates. Royal 8vo, 5*s.* cloth.

CONTENTS.—Introductory Remarks; Beams Loaded at Centre; Beams Loaded at unequal distances between supports; Beams uniformly Loaded; Girders with triangular bracing Loaded at centre; Ditto, Loaded at unequal distances between supports; Ditto, uniformly Loaded; Calculation of the Strains on Girders with triangular Basings; Cantilevers; Continuous Girders; Lattice Girders; Girders with Vertical Struts and Diagonal Ties; Calculation of the Strains on Ditto; Bow and String Girders; Girders of a form not belonging to any regular figure; Plate Girders; Apportionments of Material to Strain; Comparison of different Girders; Proportion of Length to Depth of Girders; Character of the Work; Iron Roofs.

Construction of Iron Beams, Pillars, &c.

IRON AND HEAT, Exhibiting the Principles concerned in the Construction of Iron Beams, Pillars, and Bridge Girders, and the Action of Heat in the Smelting Furnace. By JAMES ARMOUR, C.E. Woodcuts, 12mo, cloth boards, 3*s.* 6*d.*; cloth limp, 2*s.* 6*d.* [*Just published.*

Power in Motion.

POWER IN MOTION: Horse Power, Motion, Toothed Wheel Gearing, Long and Short Driving Bands, Angular Forces, &c. By JAMES ARMOUR, C.E. With 73 Diagrams. 12mo, cloth boards, 3*s.* 6*d.* [*This day.*

Trigonometrical Surveying.

AN OUTLINE OF THE METHOD OF CONDUCTING A TRIGONOMETRICAL SURVEY, for the Formation of Geographical and Topographical Maps and Plans, Military Reconnaissance, Levelling, &c., with the most useful Problems in Geodesy and Practical Astronomy, and Formulæ and Tables for Facilitating their Calculation. By MAJOR-GENERAL FROME, R.E., Inspector-General of Fortifications, &c. Third Edition, revised and improved. With 10 Plates and 113 Woodcuts. Royal 8vo, 12*s.* cloth.

Hydraulics.

HYDRAULIC TABLES, CO-EFFICIENTS, and FORMULÆ for finding the Discharge of Water from Orifices, Notches, Weirs, Pipes, and Rivers. By JOHN NEVILLE, Civil Engineer, M.R.I.A. Second Edition, with extensive Additions, New Formulæ, Tables, and General Information on Rain-fall, Catchment-Basins, Drainage, Sewerage, Water Supply for Towns and Mill Power. With numerous Woodcuts, 8vo, 16*s.* cloth.

*** This work contains a vast number of different hydraulic formulæ, and the most extensive and accurate tables yet published for finding the mean velocity of discharge from triangular, quadrilateral, and circular orifices, pipes, and rivers; with experimental results and co-efficients; effects of friction; of the velocity of approach; and of curves, bends, contractions, and expansions; the best form of channel; the drainage effects of long and short weirs, and weir-basins; extent of back-water from weirs; contracted channels; catchment-basins; hydrostatic and hydraulic pressure; water-power, &c. &c.

Levelling.

A TREATISE on the PRINCIPLES and PRACTICE of LEVELLING; showing its Application to Purposes of Railway and Civil Engineering, in the Construction of Roads; with Mr. TELFORD'S Rules for the same. By FREDERICK W. SIMMS, F.G.S., M. Inst. C.E. Fifth Edition, very carefully revised, with the addition of Mr. LAW'S Practical Examples for Setting out Railway Curves, and Mr. TRAUTWINE'S Field Practice of Laying out Circular Curves. With 7 Plates and numerous Woodcuts. 8vo, 8*s.* 6*d.* cloth. *** TRAUTWINE on Curves, separate, price 5*s.*

"One of the most important text-books for the general surveyor, and there is scarcely a question connected with levelling for which a solution would be sought but that would be satisfactorily answered by consulting the volume."—*Mining Journal.*

"The text-book on levelling in most of our engineering schools and colleges."—*Engineer.*

"The publishers have rendered a substantial service to the profession, especially to the younger members, by bringing out the present edition of Mr. Simms's useful work."—*Engineering.*

Tunnelling.

PRACTICAL TUNNELLING; explaining in Detail the Setting out of the Works; Shaft Sinking and Heading Driving; Ranging the Lines and Levelling Under-Ground; Sub-Excavating, Timbering, and the construction of the Brickwork of Tunnels; with the Amount of Labour required for, and the Cost of the various Portions of the Work. By FREDK. W. SIMMS, F.R.A.S., F.G.S., M. Inst. C.E., Author of "A Treatise on the Principles and Practice of Levelling," &c. &c. Second Edition, revised by W. DAVIS HASKOLL, Civil Engineer, Author of "The Engineer's Field-Book," &c. &c. With 16 large folding Plates and numerous Woodcuts. Imperial 8vo, 1*l.* 1*s.* cloth.

Strength of Cast Iron, &c.

A PRACTICAL ESSAY on the STRENGTH of CAST IRON and OTHER METALS ; intended for the Assistance of Engineers, Iron-Masters, Millwrights, Architects, Founders, Smiths, and others engaged in the Construction of Machines, Buildings, &c. ; containing Practical Rules, Tables, and Examples, founded on a series of New Experiments ; with an Extensive Table of the Properties of Materials. By the late THOMAS TREDGOLD, Mem. Inst. C.E., Author of "Elementary Principles of Carpentry," "History of the Steam-Engine," &c. Fifth Edition, much improved. Edited by EATON HODGKINSON, F.R.S. ; to which are added EXPERIMENTAL RESEARCHES on the STRENGTH and OTHER PROPERTIES of CAST IRON ; with the Development of New Principles, Calculations Deduced from them, and Inquiries Applicable to Rigid and Tenacious Bodies generally. By the EDITOR. The whole Illustrated with 9 Engravings and numerous Woodcuts. 8vo, 12*s*. cloth.

*** HODGKINSON'S EXPERIMENTAL RESEARCHES ON THE STRENGTH AND OTHER PROPERTIES OF CAST IRON may be had separately. With Engravings and Woodcuts. 8vo, price 6*s*. cloth.

The High-Pressure Steam Engine.

THE HIGH-PRESSURE STEAM ENGINE ; an Exposition of its Comparative Merits, and an Essay towards an Improved System of Construction, adapted especially to secure Safety and Economy. By Dr. ERNST ALBAN, Practical Machine Maker, Plau, Mecklenberg. Translated from the German, with Notes, by Dr. POLE, F.R.S., M. Inst. C.E., &c. &c. With 28 fine Plates, 8vo, 16*s*. 6*d*. cloth.

"A work like this, which goes thoroughly into the examination of the high-pressure engine, the boiler, and its appendages, &c., is exceedingly useful, and deserves a place in every scientific library."—*Steam Shipping Chronicle.*

Tables of Curves.

TABLES OF TANGENTIAL ANGLES and MULTIPLES for setting out Curves from 5 to 200 Radius. By ALEXANDER BEAZELEY, M. Inst. C.E. Printed on 48 Cards, and sold in a cloth box, waistcoat-pocket size, price 3*s*. 6*d*.

"Each table is printed on a small card, which, being placed on the theodolite, leaves the hands free to manipulate the instrument—no small advantage as regards the rapidity of work. They are clearly printed, and compactly fitted into a small case for the pocket—an arrangement that will recommend them to all practical men."—*Engineer.*

"Very handy : a man may know that all his day's work must fall on two of these cards, which he puts into his own card-case, and leaves the rest behind."—*Athenæum.*

Laying Out Curves.

THE FIELD PRACTICE of LAYING OUT CIRCULAR CURVES for RAILROADS. By JOHN C. TRAUTWINE, C.E., of the United States (extracted from SIMMS'S Work on Levelling). 8vo, 5*s*. sewed.

Estimate and Price Book.

THE CIVIL ENGINEER'S AND CONTRACTOR'S ESTIMATE AND PRICE BOOK for Home or Foreign Service: in reference to Roads, Railways, Tramways, Docks, Harbours, Forts, Fortifications, Bridges, Aqueducts, Tunnels, Sewers, Waterworks, Gasworks, Stations, Barracks, Warehouses, &c. &c. &c. With Specifications for Permanent Way, Telegraph Materials, Plant, Maintenance, and Working of a Railway; and a Priced List of Machinery, Plant, Tools, &c., required in the execution of Public Works. By W. DAVIS HASKOLL, C.E. Plates and numerous Woodcuts. Published annually. Demy 8vo, cloth, 6*s*.

As furnishing a variety of data on every conceivable want to civil engineers and contractors, this book has ever stood perhaps unrivalled."—*Architect*, Jan. 21, 1871.

"The care with which the particulars are arranged reflects credit upon the author, each subject being divided into tables under their own special heads, so that no difficulty arises in finding the exact thing one wants. The value of the work to the student and the experienced contractor is inestimable."—*Mechanic's Mag.*, Feb. 3.

"Mr. Haskoll has bestowed very great care upon the preparation of his estimates and prices, and the work is one which appears to us to be in every way deserving of confidence."—*Builder's Weekly Reporter*, Jan. 27, 1871.

Surveying (Land and Marine).

LAND AND MARINE SURVEYING, in Reference to the Preparation of Plans for Roads and Railways, Canals, Rivers, Towns' Water Supplies, Docks and Harbours; with Description and Use of Surveying Instruments. By W. DAVIS HASKOLL, C.E., Author of "The Engineer's Field Book," "Examples of Bridge and Viaduct Construction," &c. Demy 8vo, price 12*s*. 6*d*. cloth, with 14 folding Plates, and numerous Woodcuts.

"'Land and Marine Surveying' is a most useful and well arranged book for the aid of a student. . . . . We can strongly recommend it as a carefully-written and valuable text-book."—*Builder*, July 14, 1868.

"He only who is master of his subject can present it in such a way as to make it intelligible to the meanest capacity. It is in this that Mr. Haskoll excels. He has knowledge and experience, and can so give expression to it as to make any matter on which he writes, clear to the youngest pupil in a surveyor's office. . . . . The work will be found a useful one to men of experience, for there are few such who will not get some good ideas from it; but it is indispensable to the young practitioner."—*Colliery Guardian*, May 9, 1868.

"A volume which cannot fail to prove of the utmost practical utility. . . . . It is one which may be safely recommended to all students who aspire to become clean and expert surveyors; and from the exhaustive manner in which Mr. Haskoll has placed his long experience at the disposal of his readers, there will henceforth be no excuse for the complaint that young practitioners are at a disadvantage, through the neglect of their seniors to point out the importance of minute details, since they can readily supply the deficiency by the study of the volume now under consideration."—*Mining Journal*, May 5, 1868.

Engineering Fieldwork.

THE PRACTICE OF ENGINEERING FIELDWORK, applied to Land and Hydraulic, Hydrographic, and Submarine Surveying and Levelling. Second Edition, revised, with considerable additions, and a Supplementary Volume on WATER-WORKS, SEWERS, SEWAGE, and IRRIGATION. By W. DAVIS HASKOLL, C.E. Numerous folding Plates. Demy 8vo, 2 vols. in one, cloth boards, 1*l*. 1*s*. (published at 2*l*. 4*s*.)

Fire Engineering.

FIRES, FIRE-ENGINES, AND FIRE BRIGADES. With a History of Manual and Steam Fire-Engines, their Construction, Use, and Management; Remarks on Fire-Proof Buildings, and the Preservation of Life from Fire; Statistics of the Fire Appliances in English Towns; Foreign Fire Systems; Hints for the formation of, and Rules for, Fire Brigades; and an Account of American Steam Fire-Engines. By CHARLES F. T. YOUNG, C.E., Author of "The Economy of Steam Power on Common Roads," &c. With numerous Illustrations, Diagrams, &c., handsomely printed, 544 pp., demy 8vo, price 1*l.* 4*s.* cloth.

"A large well-filled and useful book upon a subject which possesses a wide and increasing public interest. . . . . To such of our readers as are interested in the subject of fires and fire apparatus we can most heartily commend this book. . . . . It is really the only English work we now have upon the subject."—*Engineering.*

"Mr. Young has proved by his present work that he is a good engineer, and possessed of sufficient literary energy to produce a very readable and interesting volume." —*Engineer.*

"A volume which must be regarded as the text-book of its subject, and which in point of interest and intrinsic value is second to no contribution to a special department of history with which we are acquainted. 'Fires, Fire-Engines, and Fire Brigades' is the production of an earnest and diligent writer who comes to the task he has undertaken with a thorough love of it, and a firm determination to do it justice. . . . . The style of the work is admirable. . . . . It has the surpassing merit of being thoroughly reliable."—*Insurance Record.*

"Great credit is unquestionably due to Mr. Young for having brought before the public the results of his exploration in this hitherto untrodden field. We strongly recommend the book to the notice of all who are in any way interested in fires, fire-engines, or fire-brigades."—*Mechanics' Magazine.*

Manual of Mining Tools.

MINING TOOLS. For the use of Mine Managers, Agents, Mining Students, &c. By WILLIAM MORGANS, Lecturer on Practical Mining at the Bristol School of Mines. 12mo. With an Atlas of Plates, containing 200 Illustrations. 4to. [*Just ready.*

Earthwork, Measurement and Calculation of.

A MANUAL on EARTHWORK. By ALEX. J. S. GRAHAM, C.E., Resident Engineer, Forest of Dean Central Railway. With numerous Diagrams. 18mo, 2*s.* 6*d.* cloth.

"We can cordially recommend the work to the notice of our readers."—*Building News.*

"As a really handy book for reference, we know of no work equal to it; and the railway engineers and others employed in the measurement and calculation of earthwork will find a great amount of practical information very admirably arranged, and available for general or rough estimates, as well as for the more exact calculations required in the engineers' contractor's offices."—*Artizan.*

"The object of this little book is an investigation of all the principles requisite for the measurement and calculation of earthworks, and a consideration of the data necessary for such operations. The author has evidently bestowed much care in effecting this object, and points out with much clearness the results of his own observations, derived from practical experience. The subjects treated of are accompanied by well-executed diagrams and instructive examples."—*Army and Navy Gazette.*

Field-Book for Engineers.

THE ENGINEER'S, MINING SURVEYOR'S, and CONTRACTOR'S FIELD-BOOK. By W. DAVIS HASKOLL, Civil Engineer. Second Edition, much enlarged, consisting of a Series of Tables, with Rules, Explanations of Systems, and Use of Theodolite for Traverse Surveying and Plotting the Work with minute accuracy by means of Straight Edge and Set Square only; Levelling with the Theodolite, Casting out and Reducing Levels to Datum, and Plotting Sections in the ordinary manner; Setting out Curves with the Theodolite by Tangential Angles and Multiples with Right and Left-hand Readings of the Instrument; Setting out Curves without Theodolite on the System of Tangential Angles by Sets of Tangents and Offsets; and Earthwork Tables to 80 feet deep calculated for every 6 inches in depth. With numerous wood-cuts, 12mo, price 12*s.* cloth.

"A very useful work for the practical engineer and surveyor. Every person engaged in engineering field operations will estimate the importance of such a work and the amount of valuable time which will be saved by reference to a set of reliable tables prepared with the accuracy and fulness of those given in this volume."—*Railway News.*

"The book is very handy, and the author might have added that the separate tables of sines and tangents to every minute will make it useful for many other purposes, the genuine traverse tables existing all the same."—*Athenæum.*

"The work forms a handsome pocket volume, and cannot fail, from its portability and utility, to be extensively patronised by the engineering profession."—*Mining Journal.*

"We know of no better field-book of reference or collection of tables than that Mr. Haskoll has given."—*Artizan.*

"A series of tables likely to be very useful to many civil engineers."—*Building News.*

"A very useful book of tables for expediting field-work operations. . . . The present edition has been much enlarged."—*Mechanics' Magazine.*

"We strongly recommend this second edition of Mr. Haskoll's 'Field Book' to all classes of surveyors."—*Colliery Guardian.*

Railway Engineering.

THE PRACTICAL RAILWAY ENGINEER. A concise Description of the Engineering and Mechanical Operations and Structures which are combined in the Formation of Railways for Public Traffic; embracing an Account of the Principal Works executed in the Construction of Railways; with Facts, Figures, and Data, intended to assist the Civil Engineer in designing and executing the important details required. By G. DRYSDALE DEMPSEY, C.E. Fourth Edition, revised and greatly extended. With 71 double quarto Plates, 72 Woodcuts, and Portrait of GEORGE STEPHENSON. One large vol. 4to, 2*l.* 12*s.* 6*d.* cloth.

Harbours.

THE DESIGN and CONSTRUCTION of HARBOURS. By THOMAS STEVENSON, F.R.S.E., M.I.C.E. Reprinted and enlarged from the Article "Harbours," in the Eighth Edition of "The Encyclopædia Britannica." With 10 Plates and numerous Cuts. 8vo, 10*s.* 6*d.* cloth.

Bridge Construction in Masonry, Timber, and Iron.

EXAMPLES OF BRIDGE AND VIADUCT CONSTRUCTION OF MASONRY, TIMBER, AND IRON; consisting of 46 Plates from the Contract Drawings or Admeasurement of select Works. By W. DAVIS HASKOLL, C.E. Second Edition, with the addition of 554 Estimates, and the Practice of Setting out Works, illustrated with 6 pages of Diagrams. Imp. 4to, price *2l. 12s. 6d.* half-morocco.

"One of the very few works extant descending to the level of ordinary routine, and treating on the common every-day practice of the railway engineer. . . . A work of the present nature by a man of Mr. Haskoll's experience, must prove invaluable to hundreds. The tables of estimates appended to this edition will considerably enhance its value."—*Engineering.*

"We must express our cordial approbation of the work just issued by Mr. Haskoll. . . . . Besides examples of the best and most economical forms of bridge construction, the author has compiled a series of estimates which cannot fail to be of service to the practical man. . . . The examples of bridges are selected from those of the most notable construction on the different lines of the kingdom, and their details may consequently be safely followed."—*Railway News.*

"A very valuable volume, and may be added usefully to the library of every young engineer."—*Builder.*

"An excellent selection of examples, very carefully drawn to useful scales of proportion."—*Artizan.*

Mathematical and Drawing Instruments.

A TREATISE ON THE PRINCIPAL MATHEMATICAL AND DRAWING INSTRUMENTS employed by the Engineer, Architect, and Surveyor. By FREDERICK W. SIMMS, F.G.S., M. Inst. C.E., Author of "Practical Tunnelling," &c. &c. Third Edition, with a Description of the Theodolite, together with Instructions in Field Work, compiled for the use of Students on commencing practice. With numerous Cuts. 12mo, price *3s. 6d.* cloth.

Oblique Arches.

A PRACTICAL TREATISE ON THE CONSTRUCTION of OBLIQUE ARCHES. By JOHN HART. Third Edition, with Plates. Imperial 8vo, price *8s.* cloth.

*** *The small remaining stock of this work, which has been unobtainable for some time, has just been purchased by* LOCKWOOD & CO.

Oblique Bridges.

A PRACTICAL and THEORETICAL ESSAY on OBLIQUE BRIDGES, with 13 large folding Plates. By GEO. WATSON BUCK, M. Inst. C.E. Second Edition, corrected by W. H. BARLOW, M. Inst. C.E. Imperial 8vo, *12s.* cloth.

"The standard text-book for all engineers regarding skew arches, is Mr. Buck's treatise, and it would be impossible to consult a better."—*Engineer.*

"A very complete treatise on the subject, re-edited by Mr. Barlow, who has added to it a method of making the requisite calculations without the use of trigonometrical formulæ."—*Builder.*

WATER POWER, as applied to Mills, &c. By J. GLYNN. 2*s.*

ENGINEER'S GUIDE TO THE ROYAL AND MERCANTILE NAVIES. By a PRACTICAL ENGINEER. Revised by D. F. McCARTHY.

ARCHITECTURE, &c.

Construction.

THE SCIENCE of BUILDING: an Elementary Treatise on the Principles of Construction. Especially adapted to the Requirements of Architectural Students. By E. WYNDHAM TARN, M.A., Architect. Illustrated with 47 Wood Engravings. Demy 8vo, price 8*s.* 6*d.* cloth. [*Recently published.*

"A very valuable book, which we strongly recommend to all students."—*Builder.*

"A modest and valuable book of reference for the student. . . . The formulæ will be found perfectly intelligible and available by the class for whom they are intended."—*Athenæum.*

"While Mr. Tarn's valuable little volume is quite sufficiently scientific to answer the purposes intended, it is written in a style that will deservedly make it popular. The diagrams are numerous and exceedingly well executed, and the treatise does credit alike to the author and the publisher."—*Engineer*, Feb. 17, 1871.

"No architectural student should be without this hand-book of constructional knowledge."—*Architect.*

"The book is very far from being a mere compilation; it is an able digest of information which is only to be found scattered through various works, and contains more really original writing than many putting forth far stronger claims to originality. . . . . Mr. Tarn has done his work exceedingly well, and he has produced a book which ought to earn him the thanks of all architectural students."—*Engineering.*

Beaton's Pocket Estimator.

THE POCKET ESTIMATOR FOR THE BUILDING TRADES, being an easy method of estimating the various parts of a Building collectively, more especially applied to Carpenters' and Joiners' work, priced according to the present value of material and labour. By A. C. BEATON, Author of 'Quantities and Measurements.' Numerous Woodcuts. [*In the Press.*

Villa Architecture.

A HANDY BOOK of VILLA ARCHITECTURE; being a Series of Designs for Villa Residences in various Styles. With Detailed Specifications and Estimates. By C. WICKES, Architect, Author of "The Spires and Towers of the Mediæval Churches of England," &c. First Series, consisting of 30 Plates; Second Series, 31 Plates. Complete in 1 vol., 4to, price 2*l.* 10*s.* half morocco. Either Series separate, price 1*l.* 7*s.* each, half morocco.

"The whole of the designs bear evidence of their being the work of an artistic architect, and they will prove very valuable and suggestive to architects, students, and amateurs."—*Building News.*

The Architect's Guide.

THE ARCHITECT'S GUIDE; or, Office and Pocket Companion for Engineers, Architects, Land and Building Surveyors, Contractors, Builders, Clerks of Works, &c. By W. DAVIS HASKOLL, C.E., R. W. BILLINGS, Architect, F. ROGERS, and P. THOMPSON. With numerous Experiments by G. RENNIE, C.E., &c. Woodcuts, 12mo, cloth, price 3*s.* 6*d.*

Vitruvius' Architecture.

THE ARCHITECTURE OF MARCUS VITRUVIUS POLLIO. Translated by JOSEPH GWILT, F.S.A., F.R.A.S. Numerous Plates. 12mo, cloth limp, price 5*s.*

The Young Architect's Book.

HINTS TO YOUNG ARCHITECTS; comprising Advice to those who, while yet at school, are destined to the Profession; to such as, having passed their pupilage, are about to travel; and to those who, having completed their education, are about to practise. By GEORGE WIGHTWICK, Architect, Author of "The Palace of Architecture," &c. &c. Second Edition. With numerous Woodcuts. 8vo, 7*s*., extra cloth.

Drawing for Builders and Students.

PRACTICAL RULES ON DRAWING for the OPERATIVE BUILDER and YOUNG STUDENT in ARCHITECTURE. By GEORGE PYNE, Author of a "Rudimentary Treatise on Perspective for Beginners." With 14 Plates, 4to, 7*s*. 6*d*., boards.

CONTENTS.—I. Practical Rules on Drawing—Outlines. II. Ditto—the Grecian and Roman Orders. III. Practical Rules on Drawing—Perspective. IV. Practical Rules on Light and Shade. V. Practical Rules on Colour, &c. &c.

Drawing for Engineers, &c.

THE WORKMAN'S MANUAL OF ENGINEERING DRAWING. By JOHN MAXTON, Instructor in Engineering Drawing, South Kensington. With upwards of 300 Plates and Diagrams. 12mo, cloth, strongly bound, 4*s*. 6*d*. [*This day.*

Cottages, Villas, and Country Houses.

DESIGNS and EXAMPLES of COTTAGES, VILLAS, and COUNTRY HOUSES; being the Studies of several eminent Architects and Builders; consisting of Plans, Elevations, and Perspective Views; with approximate Estimates of the Cost of each. In 4to, with 67 plates, price 1*l*. 1*s*., cloth.

Weale's Builder's and Contractor's Price Book.

THE BUILDER'S AND CONTRACTOR'S PRICE BOOK (LOCKWOOD & CO.'S, formerly WEALE'S). Published Annually. Containing Prices for Work in all branches of the Building Trade, with Items numbered for easy reference, and an Appendix of Tables, Notes, and Memoranda, arranged to afford detailed information, commonly required in preparing Estimates, &c. Originally Edited by the late GEO. R. BURNELL, C.E., &c. 12mo, 4*s*., cloth.

"A multitudinous variety of useful information for builders and contractors. . . . . With its aid the prices for all work connected with the building trade may be estimated."—*Building News.*

"Carefully revised, admirably arranged, and clearly printed, it offers at a glance a ready method of preparing an estimate or specification upon a basis that is unquestionable. A reliable book of reference in the event of a dispute between employer and employed."—*Engineer.*

"Well done and reliable. It is the duty of a just critic to point out where any improvement can be made in any work, but Mr. Burnell has anticipated all objections in his clearly-printed book. We therefore recommend it to all branches of the profession."—*English Mechanic.*

"Mr. Burnell has omitted nothing from this work that could tend to render it valuable to the builder or contractor."—*Mechanic's Magazine.*

Handbook of Specifications.

THE HANDBOOK OF SPECIFICATIONS; or, Practical Guide to the Architect, Engineer, Surveyor, and Builder, in drawing up Specifications and Contracts for Works and Constructions. Illustrated by Precedents of Buildings actually executed by eminent Architects and Engineers. Preceded by a Preliminary Essay, and Skeletons of Specifications and Contracts, &c., &c., and explained by numerous Lithograph Plates and Woodcuts. By Professor THOMAS L. DONALDSON, President of the Royal Institute of British Architects, Professor of Architecture and Construction, University College, London, M.I.B.A., Member of the various European Academies of the Fine Arts. With A REVIEW OF THE LAW OF CONTRACTS, and of the Responsibilities of Architects, Engineers, and Builders. By W. CUNNINGHAM GLEN, Barrister-at-Law, of the Middle Temple. 2 vols., 8vo, with upwards of 1100 pp. of text, and 33 Lithographic Plates, cloth, *2l. 2s.* (Published at *4l.*)

"In these two volumes of 1,100 pages (together), forty-four specifications of executed works are given, including the specifications for parts of the new Houses of Parliament, by Sir Charles Barry, and for the new Royal Exchange, by Mr. Tite, M.P. The latter, in particular, is a very complete and remarkable document. It embodies, to a great extent, as Mr. Donaldson mentions, 'the bill of quantities, with the description of the works,' and occupies more than 100 printed pages.

"Amongst the other known buildings, the specifications of which are given, are the Wiltshire Lunatic Asylum (Wyatt and Brandon); Tothill Fields Prison (R. Abraham); the City Prison, Holloway (Bunning); the High School, Edinburgh (Hamilton); Clothworkers' Hall, London (Angel); Wellington College, Sandhurst (J. Shaw); Houses in Grosvenor Square, and elsewhere; St. George's Church, Doncaster (Scott); several works of smaller size by the Author, including Messrs. Shaw's Warehouse in Fetter Lane, a very successful elevation; the Newcastle-upon-Tyne Railway Station (J. Dobson); new Westminster Bridge (Page); the High Level Bridge, Newcastle (R. Stephenson); various works on the Great Northern Railway (Brydone); and one French specification for Houses in the Rue de Rivoli, Paris (MM. Armand, Hittorff, Pellechet, and Rohault de Fleury, architects). The last is a very elaborate composition, occupying seventy pages. The majority of the specifications have illustrations in the shape of elevations and plans.

"We are most glad to have the present work. It is valuable as a record, and more valuable still as a book of precedents.

"About 140 pages of the second volume are appropriated to an exposition of the law in relation to the legal liabilities of engineers, architects, contractors, and builders, by Mr. W. Cunningham Glen, Barrister-at-law; intended rather for those persons than for the legal practitioner. Suffice it, in conclusion, to say in words what our readers will have gathered for themselves from the particulars we have given, that Donaldson's Handbook of Specifications must be bought by all architects."—*Builder.*

Mechanical Engineering.

A PRACTICAL TREATISE ON MECHANICAL ENGINEERING: comprising Metallurgy, Moulding, Casting, Forging, Tools, Workshop Machinery, Mechanical Manipulation, Manufacture of the Steam Engine, &c. &c. With an Appendix on the Analysis of Iron and Iron Ore, and Glossary of Terms. By FRANCIS CAMPIN, C.E. Illustrated with 91 Woodcuts and 28 Plates of Slotting, Shaping, Drilling, Punching, Shearing, and Riveting Machines—Blast, Refining, and Reverberatory Furnaces—Steam Engines, Governors, Boilers, Locomotives, &c. Demy 8vo, cloth, price *12s.*

Grantham's Iron Ship-Building, enlarged.

ON IRON SHIP-BUILDING; with Practical Examples and Details. Fifth Edition. Imp. 4to, boards, enlarged from 24 to 40 Plates (21 quite new), including the latest Examples. Together with separate Text, 12mo, cloth limp, also considerably enlarged, By JOHN GRANTHAM, M. Inst. C.E., &c. Price 2*l.* 2*s.* complete.

Description of Plates.

1. Hollow and Bar Keels, Stem and Stern Posts.
2. Side Frames, Floorings, and Bilge [Pieces.
3. Floorings *continued*—Keelsons, Deck Beams, Gunwales, and Stringers.
4. Gunwales *continued*—Lower Decks, and Orlop Beams.
4*a*. Gunwales and Deck Beam Iron.
5. Angle-Iron, T Iron, Z Iron, Bulb Iron, as Rolled for Building.
6. Rivets, shown in section, natural size; Flush and Lapped Joints, with Single and Double Riveting.
7. Plating, three plans; Bulkheads and Modes of Securing them.
8. Iron Masts, with Longitudinal and Transverse Sections.
9. Sliding Keel, Water Ballast, Moulding the Frames in Iron Ship Building, Levelling Plates.
10. Longitudinal Section, and Half-breadth Deck Plan of Large Vessels on a reduced Scale.
11. Midship Sections of Three Vessels.
12. *Large Vessel*, showing Details—*Fore End* in Section, and End View, with Stern Post, Crutches, &c.
13. *Large Vessel*, showing Details—*After End* in Section, with End View, Stern Frame for Screw, and Rudder.
14. *Large Vessel*, showing Details—*Midship Section*, half breadth.
15. *Machines* for Punching and Shearing Plates and Angle-Iron, and for Bending Plates; Rivet Hearth.
15*a*. Beam-Bending Machine, Independent Shearing, Punching and Angle-Iron Machine.
15*b*. Double Lever Punching and Shearing Machine, arranged for cutting Angle and T Iron, with Dividing Table and Engine.
16. *Machines.*—Garforth's Riveting Machine, Drilling and Counter-Sinking Machine.
16*a*. Plate Planing Machine.
17. *Air Furnace* for Heating Plates and Angle-Iron: Various Tools used in Riveting and Plating.
18. *Gunwale*; Keel and Flooring; Plan for Sheathing with Copper.
18*a*. Grantham's Improved Plan of Sheathing Iron Ships with Copper.
19. Illustrations of the Magnetic Condition of various Iron Ships.
20. Gray's Floating Compass and Binnacle, with Adjusting Magnets, &c.
21. Corroded Iron Bolt in Frame of Wooden Ship; Jointing Plates.
22–4. *Great Eastern*—Longitudinal Sections and Half-breadth Plans—Midship Section, with Details—Section in Engine Room, and Paddle Boxes.
25-6. Paddle Steam Vessel of Steel.
27. *Scarbrough*—Paddle Vessel of Steel.
28–9. Proposed Passenger Steamer.
30. *Persian*—Iron Screw Steamer.
31. Midship Section of H.M. Steam Frigate, *Warrior*.
32. Midship Section of H.M. Steam Frigate, *Hercules*.
33. Stem, Stern, and Rudder of H.M. Steam Frigate, *Bellerophon*.
34. Midship Section of H.M. Troop Ship, *Serapis*.
35. Iron Floating Dock.

"An enlarged edition of an elaborately illustrated work."—*Builder*, July 11, 1868.

"This edition of Mr. Grantham's work has been enlarged and improved, both with respect to the text and the engravings being brought down to the present period . . . The practical operations required in producing a ship are described and illustrated with care and precision."—*Mechanics' Magazine*, July 17, 1868.

"A thoroughly practical work, and every question of the many in relation to iron shipping which admit of diversity of opinion, or have various and conflicting personal interests attached to them, is treated with sober and impartial wisdom and good sense. . . . . As good a volume for the instruction of the pupil or student of iron naval architecture as can be found in any language."—*Practical Mechanic's Journal*, August, 1868.

"A very elaborate work. . . . It forms a most valuable addition to the history of iron shipbuilding, while its having been prepared by one who has made the subject his study for many years, and whose qualifications have been repeatedly recognised, will recommend it as one of practical utility to all interested in shipbuilding."—*Army and Navy Gazette*, July 11, 1868.

CARPENTRY, TIMBER, &c.

Tredgold's Carpentry, new & enlarged Edition.

THE ELEMENTARY PRINCIPLES OF CARPENTRY: a Treatise on the Pressure and Equilibrium of Timber Framing, the Resistance of Timber, and the Construction of Floors, Arches, Bridges, Roofs, Uniting Iron and Stone with Timber, &c. To which is added an Essay on the Nature and Properties of Timber, &c., with Descriptions of the Kinds of Wood used in Building; also numerous Tables of the Scantlings of Timber for different purposes, the Specific Gravities of Materials, &c. By THOMAS TREDGOLD, C.E. Edited by PETER BARLOW, F.R.S. Fifth Edition, corrected and enlarged. With 64 Plates (11 of which now first appear in this edition), Portrait of the Author, and several Woodcuts. In 1 vol., 4to, published at *2l. 2s.*, reduced to *1l. 5s.*, cloth.

"'Tredgold's Carpentry' ought to be in every architect's and every builder's library, and those who do not already possess it ought to avail themselves of the new issue."—*Builder*, April 9, 1870.

A work whose monumental excellence must commend it wherever skilful carpentry is concerned. The Author's principles are rather confirmed than impaired by time, and, as now presented, combine the surest base with the most interesting display of progressive science. The additional plates are of great intrinsic value."—*Building News*, Feb. 25, 1870.

"'Tredgold's Carpentry' has ever held a high position, and the issue of the fifth edition, in a still more improved and enlarged form, will give satisfaction to a very large number of artisans who desire to raise themselves in their business, and who seek to do so by displaying a greater amount of knowledge and intelligence than their fellow-workmen. It is as complete a work as need be desired. To the superior workman the volume will prove invaluable; it contains treatises written in language which he will readily comprehend."—*Mining Journal*, Feb. 12, 1870.

Grandy's Timber Tables.

THE TIMBER IMPORTER'S, TIMBER MERCHANT'S, and BUILDER'S STANDARD GUIDE. By RICHARD E. GRANDY. Comprising:—An Analysis of Deal Standards, Home and Foreign, with comparative Values and Tabular Arrangements for Fixing Nett Landed Cost on Baltic and North American Deals, including all intermediate Expenses, Freight, Insurance, Duty, &c., &c.; together with Copious Information for the Retailer and Builder. 12mo, price *7s. 6d.* cloth.

"Everything it pretends to be: built up gradually, it leads one from a forest to a trenail, and throws in, as a makeweight, a host of material concerning bricks, columns, cisterns, &c.—all that the class to whom it appeals requires."—*English Mechanic.*

"The only difficulty we have is as to what is NOT in its pages. What we have tested of the contents, taken at random, is invariably correct."—*Illustrated Builder's Journal.*

Tables for Packing-Case Makers.

PACKING-CASE TABLES; showing the number of Superficial Feet in Boxes or Packing-Cases, from six inches square and upwards. Compiled by WILLIAM RICHARDSON, Accountant. Oblong 4to, cloth, price *3s. 6d.*

"Will save much labour and calculation to packing-case makers and those who use packing-cases."—*Grocer.* "Invaluable labour-saving tables."—*Ironmonger.*

Nicholson's Carpenter's Guide.

THE CARPENTER'S NEW GUIDE; or, BOOK of LINES for CARPENTERS: comprising all the Elementary Principles essential for acquiring a knowledge of Carpentry. Founded on the late PETER NICHOLSON's standard work. A new Edition, revised by ARTHUR ASHPITEL, F.S.A., together with Practical Rules on Drawing, by GEORGE PYNE. With 74 Plates, 4to, *1l. 1s.* cloth.

Dowsing's Timber Merchant's Companion.

THE TIMBER MERCHANT'S AND BUILDER'S COMPANION; containing New and Copious Tables of the Reduced Weight and Measurement of Deals and Battens, of all sizes, from One to a Thousand Pieces, and the relative Price that each size bears per Lineal Foot to any given Price per Petersburgh Standard Hundred; the Price per Cube Foot of Square Timber to any given Price per Load of 50 Feet; the proportionate Value of Deals and Battens by the Standard, to Square Timber by the Load of 50 Feet; the readiest mode of ascertaining the Price of Scantling per Lineal Foot of any size, to any given Figure per Cube Foot. Also a variety of other valuable information. By WILLIAM DOWSING, Timber Merchant. Second Edition. Crown 8vo, *3s.* cloth.

"Everything is as concise and clear as it can possibly be made. There can be no doubt that every timber merchant and builder ought to possess it, because such possession would, with use, unquestionably save a very great deal of time, and, moreover, ensure perfect accuracy in calculations. There is also another class besides these who ought to possess it; we mean all persons engaged in carrying wood, where it is requisite to ascertain its weight. Mr. Dowsing's tables provide an easy means of doing this. Indeed every person who has to do with wood ought to have it."—*Hull Advertiser.*

MECHANICS, &c.

Mechanic's Workshop Companion.

THE OPERATIVE MECHANIC'S WORKSHOP COMPANION, and THE SCIENTIFIC GENTLEMAN'S PRACTICAL ASSISTANT; comprising a great variety of the most useful Rules in Mechanical Science; with numerous Tables of Practical Data and Calculated Results. By W. TEMPLETON, Author of "The Engineer's, Millwright's, and Machinist's Practical Assistant." Tenth Edition, with Mechanical Tables for Operative Smiths, Millwrights, Engineers, &c.; together with several Useful and Practical Rules in Hydraulics and Hydrodynamics, a variety of Experimental Results, and an Extensive Table of Powers and Roots. 11 Plates. 12mo, *5s.* bound. [*Just published.*

"As a text-book of reference, in which mechanical and commercial demands are judiciously met, TEMPLETON'S COMPANION stands unrivalled."—*Mechanics' Magazine.*

"Admirably adapted to the wants of a very large class. It has met with great success in the engineering workshop, as we can testify; and there are a great many men who, in a great measure, owe their rise in life to this little work."—*Building News.*

Engineer's Assistant.

THE ENGINEER'S, MILLWRIGHT'S, and MACHINIST'S PRACTICAL ASSISTANT; comprising a Collection of Useful Tables, Rules, and Data. Compiled and Arranged, with Original Matter, by W. TEMPLETON. 4th Edition. 18mo, 2*s.* 6*d.* cloth.

"So much varied information compressed into so small a space, and published at a price which places it within the reach of the humblest mechanic, cannot fail to command the sale which it deserves. With the utmost confidence we commend this book to the attention of our readers."—*Mechanics' Magazine.*

"Every mechanic should become the possessor of the volume, and a more suitable present to an apprentice to any of the mechanical trades could not possibly be made." —*Building News.*

Designing, Measuring, and Valuing.

THE STUDENT'S GUIDE to the PRACTICE of MEASURING, and VALUING ARTIFICERS' WORKS; containing Directions for taking Dimensions, Abstracting the same, and bringing the Quantities into Bill, with Tables of Constants, and copious Memoranda for the Valuation of Labour and Materials in the respective Trades of Bricklayer and Slater, Carpenter and Joiner, Painter and Glazier, Paperhanger, &c. With 43 Plates and Woodcuts. Originally edited by EDWARD DOBSON, Architect. New Edition, re-written, with Additions on Mensuration and Construction, and several useful Tables for facilitating Calculations and Measurements. By E. WYNDHAM TARN, M.A., Architect. 8vo, 10*s.* 6*d.* cloth. [*Just published.*

"This useful book should be in every architect's and builder's office. It contains a vast amount of information absolutely necessary to be known."—*The Irish Builder.*

"The book is well worthy the attention of the student in architecture and surveying, as by the careful study of it his progress in his profession will be much facilitated."—*Mining Journal*, Feb. 11, 1871.

"We have failed to discover anything connected with the building trade, from excavating foundations to bell-hanging, that is not fully treated upon in this valuable work."—*The Artizan*, March, 1871.

"Mr. Tarn has well performed the task imposed upon him, and has made many further and valuable additions, embodying a large amount of information relating to the technicalities and modes of construction employed in the several branches of the building trade. . . . . . From the extent of the information which the volume embodies, and the care taken to secure accuracy in every detail, it cannot fail to prove of the highest value to students, whether training in the offices of provincial surveyors, or in those of London practitioners."—*Colliery Guardian*, February 10th, 1871.

"Altogether the book is one which well fulfils the promise of its title-page, and we can thoroughly recommend it to the class for whose use it has been compiled. Mr. Tarn's additions and revisions have much increased the usefulness of the work, and have especially augmented its value to students. Finally, it is only just to the publishers to add that the book has been got up in excellent style, the typography being bold and clear, and the plates very well executed."—*Engineering*, March 24, 1871.

Superficial Measurement.

THE TRADESMAN'S GUIDE TO SUPERFICIAL MEASUREMENT. Tables calculated from 1 to 200 inches in length, by 1 to 108 inches in breadth. For the use of Architects, Surveyors, Engineers, Timber Merchants, Builders, &c. By JAMES HAWKINGS. Fcp. 3*s.* 6*d.* cloth.

MATHEMATICS, &c.

Gregory's Practical Mathematics.

MATHEMATICS for PRACTICAL MEN; being a Commonplace Book of Pure and Mixed Mathematics. Designed chiefly for the Use of Civil Engineers, Architects, and Surveyors. Part I. PURE MATHEMATICS—comprising Arithmetic, Algebra, Geometry, Mensuration, Trigonometry, Conic Sections, Properties of Curves. Part II. MIXED MATHEMATICS—comprising Mechanics in general, Statics, Dynamics, Hydrostatics, Hydrodynamics, Pneumatics, Mechanical Agents, Strength of Materials. With an Appendix of copious Logarithmic and other Tables. By OLINTHUS GREGORY, LL.D., F.R.A.S. Enlarged by HENRY LAW, C.E. 4th Edition, carefully revised and corrected by J. R. YOUNG, formerly Professor of Mathematics, Belfast College; Author of "A Course of Mathematics," &c. With 13 Plates. Medium 8vo, 1*l.* 1*s.* cloth.

"As a standard work on mathematics it has not been excelled."—*Artizan.*

"The engineer or architect will here find ready to his hand, rules for solving nearly every mathematical difficulty that may arise in his practice. As a moderate acquaintance with arithmetic, algebra, and elementary geometry is absolutely necessary to the proper understanding of the most useful portions of this book, the author very wisely has devoted the first three chapters to those subjects, so that the most ignorant may be enabled to master the whole of the book, without aid from any other. The rules are in all cases explained by means of examples, in which every step of the process is clearly worked out."—*Builder.*

"One of the most serviceable books to the practical mechanics of the country. . . The edition of 1847 was fortunately entrusted to the able hands of Mr. Law, who revised it thoroughly, re-wrote many chapters, and added several sections to those which had been rendered imperfect by advanced knowledge. On examining the various and many improvements which he introduced into the work, they seem almost like a new structure on an old plan, or rather like the restoration of an old ruin, not only to its former substance, but to an extent which meets the larger requirements of modern times. . . . . In the edition just brought out, the work has again been revised by Professor Young. He has modernised the notation throughout, introduced a few paragraphs here and there, and corrected the numerous typographical errors which have escaped the eyes of the former Editor. The book is now as complete as it is possible to make it. . . . . We have carried our notice of this book to a greater length than the space allowed us justified, but the experiments it contains are so interesting, and the method of describing them so clear, that we may be excused for overstepping our limit. It is an instructive book for the student, and a Textbook for him who having once mastered the subjects it treats of, needs occasionally to refresh his memory upon them."—*Building News.*

The Metric System.

A SERIES OF METRIC TABLES, in which the British Standard Measures and Weights are compared with those of the Metric System at present in use on the Continent. By C. H. DOWLING, C. E. 8vo, 10*s.* 6*d.* strongly bound.

"Mr. Dowling's Tables, which are well put together, come just in time as a ready reckoner for the conversion of one system into the other."—*Athenæum.*

"Their accuracy has been certified by Professor Airy, the Astronomer Royal."—*Builder.*

"Resolution 8.—That advantage will be derived from the recent publication of Metric Tables, by C. H. Dowling, C.E."—*Report of Section F, British Association, Bath.*

Inwood's Tables, greatly enlarged and improved.

TABLES FOR THE PURCHASING of ESTATES, Freehold, Copyhold, or Leasehold; Annuities, Advowsons, &c., and for the Renewing of Leases held under Cathedral Churches, Colleges, or other corporate bodies; for Terms of Years certain, and for Lives; also for Valuing Reversionary Estates, Deferred Annuities, Next Presentations, &c., together with Smart's Five Tables of Compound Interest, and an Extension of the same to lower and Intermediate Rates. By WILLIAM INWOOD, Architect. The 18th edition, with considerable additions, and new and valuable Tables of Logarithms for the more Difficult Computations of the Interest of Money, Discount, Annuities, &c., by M. FÉDOR THOMAN, of the Société Crédit Mobilier of Paris. 12mo, 8*s*. cloth.

*** *This edition (the 18th) differs in many important particulars from former ones. The changes consist,* first, *in a more convenient and systematic arrangement of the original Tables, and in the removal of certain numerical errors which a very careful revision of the whole has enabled the present editor to discover; and* secondly, *in the extension of practical utility conferred on the work by the introduction of Tables now inserted for the first time. This new and important matter is all so much actually added to* INWOOD'S TABLES; *nothing has been abstracted from the original collection: so that those who have been long in the habit of consulting* INWOOD *for any special professional purpose will, as heretofore, find the information sought still in its pages.*

"Those interested in the purchase and sale of estates, and in the adjustment of compensation cases, as well as in transactions in annuities, life insurances, &c., will find the present edition of eminent service."—*Engineering.*

Geometry for the Architect, Engineer, &c.

PRACTICAL GEOMETRY, for the Architect, Engineer, and Mechanic; giving Rules for the Delineation and Application of various Geometrical Lines, Figures and Curves. By E. W. TARN, M.A., Architect, Author of "The Science of Building," &c. With Illustrations. Demy 8vo. [*In the press.*

Compound Interest and Annuities.

THEORY of COMPOUND INTEREST and ANNUITIES; with Tables of Logarithms for the more Difficult Computations of Interest, Discount, Annuities, &c., in all their Applications and Uses for Mercantile and State Purposes. With an elaborate Introduction. By FÉDOR THOMAN, of the Société Crédit Mobilier, Paris. 12mo, cloth, 5*s*.

"A very powerful work, and the Author has a very remarkable command of his subject."—*Professor A. de Morgan.*

"No banker, merchant, tradesman, or man of business, ought to be without Mr. Thoman's truly 'handy-book.'"—*Review.*

"The author of this 'handy-book' deserves our thanks."—*Insurance Gazette.*

"We recommend it to the notice of actuaries and accountants."—*Athenæum.*

SCIENCE AND ART.

The Military Sciences.

AIDE-MÉMOIRE to the MILITARY SCIENCES. Framed from Contributions of Officers and others connected with the different Services. Originally edited by a Committee of the Corps of Royal Engineers. Second Edition, most carefully revised by an Officer of the Corps, with many additions; containing nearly 350 Engravings and many hundred Woodcuts. 3 vols. royal 8vo, extra cloth boards, and lettered, price 4*l.* 10*s.*

"A compendious encyclopædia of military knowledge, to which we are greatly indebted."—*Edinburgh Review.*

"The most comprehensive work of reference to the military and collateral sciences. Among the list of contributors, some seventy-seven in number, will be found names of the highest distinction in the services. . . . The work claims and possesses the great merit that by far the larger portion of its subjects have been treated originally by the practical men who have been its contributors."—*Volunteer Service Gazette.*

Field Fortification.

A TREATISE on FIELD FORTIFICATION, the ATTACK of FORTRESSES, MILITARY, MINING, and RECONNOITRING. By Colonel I. S. MACAULAY, late Professor of Fortification in the Royal Military Academy, Woolwich. Sixth Edition, crown 8vo, cloth, with separate Atlas of 12 Plates, sewed, price 12*s.* complete.

Dye-Wares and Colours.

THE MANUAL of COLOURS and DYE-WARES: their Properties, Applications, Valuation, Impurities, and Sophistications. For the Use of Dyers, Printers, Dry Salters, Brokers, &c. By J. W. SLATER. Post 8vo, cloth, price 7*s.* 6*d.* [*Recently published.*

"Essentially a manual for practical men, and precisely such a book as practical men will appreciate."—*Scientific Review.*

"A complete encyclopædia of the *materia tinctoria*: The information given respecting each article is full and precise, and the methods of determining the value of articles such as these, so liable to sophistication, are given with clearness, and are practical as well as valuable."—*Chemist and Druggist.*

Electricity.

A MANUAL of ELECTRICITY; including Galvanism, Magnetism, Diamagnetism, Electro-Dynamics, Magno-Electricity, and the Electric Telegraph. By HENRY M. NOAD, Ph.D., F.C.S., Lecturer on Chemistry at St. George's Hospital. Fourth Edition, entirely rewritten. Illustrated by 500 Woodcuts. 8vo, 1*l.* 4*s.* cloth.

"This publication fully bears out its title of 'Manual.' It discusses in a satisfactory manner electricity, frictional and voltaic, thermo-electricity, and electro-physiology." —*Athenæum.*

"The commendations already bestowed in the pages of the *Lancet* on the former editions of this work are more than ever merited by the present. The accounts given of electricity and galvanism are not only complete in a scientific sense, but, which is a rarer thing, are popular and interesting."—*Lancet.*

Text-Book of Electricity.

THE STUDENT'S TEXT-BOOK OF ELECTRICITY: including Magnetism, Voltaic Electricity, Electro-Magnetism, Diamagnetism, Magneto-Electricity, Thermo-Electricity, and Electric Telegraphy. Being a Condensed Résumé of the Theory and Application of Electrical Science, including its latest Practical Developments, particularly as relating to Aërial and Submarine Telegraphy. By HENRY M. NOAD, Ph.D., Lecturer on Chemistry at St. George's Hospital. Post 8vo, 400 Illustrations, 12*s.* 6*d.* cloth.

"We can recommend Dr. Noad's book for clear style, great range of subject, a good index, and a plethora of woodcuts. Such collections as the present are indispensable." —*Athenæum.*

"A most elaborate compilation of the facts of electricity and magnetism, and of the theories which have been advanced concerning them."—*Popular Science Review.*

"Clear, compendious, compact, well illustrated, and well printed, this is an excellent manual."—*Lancet.*

"We can strongly recommend the work, as an admirable text-book, to every student —beginner or advanced—of electricity."—*Engineering.*

"The most complete manual on the subject of electricity to be met with."—*Observer.*

"Nothing of value has been passed over, and nothing given but what will lead to a correct, and even an exact, knowledge of the present state of electrical science."—*Mechanics' Magazine.*

"We know of no book on electricity containing so much information on experimental facts as this does, for the size of it, and no book of any size that contains so complete a range of facts."—*English Mechanic.*

Rudimentary Magnetism.

RUDIMENTARY MAGNETISM: being a concise exposition of the general principles of Magnetical Science, and the purposes to which it has been applied. By Sir W. SNOW HARRIS, F.R.S. New and enlarged Edition, with considerable additions by Dr. NOAD, Ph.D. Numerous Woodcuts. 12mo. [*In the press.*

Chemical Analysis.

THE COMMERCIAL HANDBOOK of CHEMICAL ANALYSIS; or Practical Instructions for the determination of the Intrinsic or Commercial Value of Substances used in Manufactures, in Trades, and in the Arts. By A. NORMANDY, Author of "Practical Introduction to Rose's Chemistry," and Editor of Rose's "Treatise of Chemical Analysis." Illustrated with Woodcuts. Second and cheaper Edition, post 8vo, 9*s.* cloth.

"We recommend this book to the careful perusal of every one; it may be truly affirmed to be of universal interest, and we strongly recommend it to our readers as a guide, alike indispensable to the housewife as to the pharmaceutical practitioner."—*Medical Times.*

"The very best work on the subject the English press has yet produced."—*Mechanics' Magazine.*

Practical Philosophy.

A SYNOPSIS of PRACTICAL PHILOSOPHY. By the Rev. JOHN CARR, M.A., late Fellow of Trin. Coll., Cambridge. Second Edition. 18mo, 5*s.* cloth.

Science and Art.

THE YEAR-BOOK of FACTS in SCIENCE and ART; exhibiting the most important Improvements and Discoveries of the Past Year in Mechanics and the Useful Arts, Natural Philosophy, Electricity, Chemistry, Zoology and Botany, Geology and Mineralogy, Meteorology and Astronomy. By JOHN TIMBS, F.S.A., Author of "Curiosities of Science," "Things not Generally Known," &c. With Steel Portrait and Vignette. Fcap. 5*s*. cloth.

*** *This work, published annually, records the proceedings of the principal scientific societies, and is indispensable to all who wish to possess a faithful record of the latest novelties in science and the arts.*

The back Volumes, from 1861 to 1870, each containing a Steel Portrait, and an extra Volume for 1862, with Photograph, may still be had, price 5*s*. each.

"Persons who wish for a concise annual summary of important scientific events will find their desire in the 'Year Book of Facts.'"—*Athenæum.*

"The standard work of its class. Mr. Timbs's 'Year Book' is always full of suggestive and interesting matter, and is an excellent *résumé* of the year's progress in the sciences and the arts."—*Builder.*

"A correct exponent of scientific progress . . . . a record of abiding interest. If anyone wishes to know what progress science has made, or what has been done in any branch of art during the past year, he has only to turn to Mr. Timbs's pages, and is sure to obtain the required information."—*Mechanics' Magazine.*

"An invaluable compendium of scientific progress for which the public are indebted to the untiring energy of Mr. Timbs."—*Atlas.*

"There is not a more useful or more interesting compilation than the 'Year Book of Facts.' . . . The discrimination with which Mr. Timbs selects his facts, and the admirable manner in which he condenses into a comparatively short space all the salient features of the matters which he places on record, are deserving of great praise."—*Railway News.*

Science and Scripture.

SCIENCE ELUCIDATIVE OF SCRIPTURE, AND NOT ANTAGONISTIC TO IT; being a Series of Essays on—1. Alleged Discrepancies; 2. The Theory of the Geologists and Figure of the Earth; 3. The Mosaic Cosmogony; 4. Miracles in general—Views of Hume and Powell; 5. The Miracle of Joshua—Views of Dr. Colenso: The Supernaturally Impossible; 6. The Age of the Fixed Stars—their Distances and Masses. By Professor J. R. YOUNG, Author of "A Course of Elementary Mathematics," &c. &c. Fcap. 8vo, price 5*s*. cloth lettered.

"Professor Young's examination of the early verses of Genesis, in connection with modern scientific hypotheses, is excellent."—*English Churchman.*

"Distinguished by the true spirit of scientific inquiry, by great knowledge, by keen logical ability, and by a style peculiarly clear, easy, and energetic."—*Nonconformist.*

"No one can rise from its perusal without being impressed with a sense of the singular weakness of modern scepticism."—*Baptist Magazine.*

"The author has displayed considerable learning and critical acumen in combating the objections alluded to. . . . . The volume is one of considerable value, inasmuch as it contains much sound thought, and is calculated to assist the reader to discriminate truth from error, at least so far as a finite mind is able to separate them. The work, therefore, must be considered to be a valuable contribution to controversial theological literature."—*City Press.*

Geology and Genesis Harmonised.

THE TWIN RECORDS of CREATION; or, Geology and Genesis, their Perfect Harmony and Wonderful Concord. By GEORGE W. VICTOR LE VAUX. With numerous Illustrations. Fcap. 8vo, price 5*s.* cloth.

"We can recommend Mr. Le Vaux as an able and interesting guide to a popular appreciation of geological science."—*Spectator.*

"The author combines an unbounded admiration of science with an unbounded admiration of the Written Record. The two impulses are balanced to a nicety; and the consequence is, that difficulties, which to minds less evenly poised, would be serious, find immediate solutions of the happiest kinds."—*London Review.*

"A most instructive and readable book. We welcome this volume as aiding in a most important discussion, and commend it to those interested in the subject."—*Evangelical Magazine.*

"Vigorously written, reverent in spirit, stored with instructive geological facts, and designed to show that there is no discrepancy or inconsistency between the Word and the works of the Creator. The future of Nature, in connexion with the glorious destiny of man, is vividly conceived."—*Watchman.*

"No real difficulty is shirked, and no sophistry is left unexposed."—*The Rock.*

Geology, Physical.

PHYSICAL GEOLOGY. (Partly based on Major-General Portlock's Rudiments of Geology.) By RALPH TATE, A.L.S., F.G.S. Numerous Woodcuts. 12mo. [*Just ready.*

Geology, Historical.

HISTORICAL GEOLOGY. (Partly based on Major-General Portlock's Rudiments of Geology.) By RALPH TATE, A.L.S., F.G.S. Numerous Woodcuts. 12mo. [*Just ready.*

Wood-Carving.

INSTRUCTIONS in WOOD-CARVING, for Amateurs; with Hints on Design. By A LADY. In emblematic wrapper, handsomely printed, with Ten large Plates, price 2*s.* 6*d.*

"The handicraft of the wood-carver, so well as a book can impart it, may be learnt from 'A Lady's' publication."—*Athenæum.*

"A real *practical guide.* It is very complete."—*Literary Churchman.*

"The directions given are plain and easily understood, and it forms a very good introduction to the practical part of the carver's art."—*English Mechanic.*

Popular Work on Painting.

PAINTING POPULARLY EXPLAINED; with Historical Sketches of the Progress of the Art. By THOMAS JOHN GULLICK, Painter, and JOHN TIMBS, F.S.A. Second Edition, revised and enlarged. With Frontispiece and Vignette. In small 8vo, 6*s.* cloth.

*** This Work has been adopted as a Prize-book in the Schools of Art at South Kensington.

"A work that may be advantageously consulted. Much may be learned, even by those who fancy they do not require to be taught, from the careful perusal of this unpretending but comprehensive treatise."—*Art Journal.*

"A valuable book, which supplies a want. It contains a large amount of original matter, agreeably conveyed, and will be found of value, as well by the young artist seeking information as by the general reader. We give a cordial welcome to the book, and augur for it an increasing reputation."—*Builder.*

"This volume is one that we can heartily recommend to all who are desirous of understanding what they admire in a good painting."—*Daily News.*

Delamotte's Works on Illumination & Alphabets.

A PRIMER OF THE ART OF ILLUMINATION; for the use of Beginners: with a Rudimentary Treatise on the Art, Practical Directions for its Exercise, and numerous Examples taken from Illuminated MSS., printed in Gold and Colours. By F. DELAMOTTE. Small 4to, price 9*s*. Elegantly bound, cloth antique.

"A handy book, beautifully illustrated; the text of which is well written, and calculated to be useful. . . . The examples of ancient MSS. recommended to the student, which, with much good sense, the author chooses from collections accessible to all, are selected with judgment and knowledge, as well as taste."—*Athenæum.*

ORNAMENTAL ALPHABETS, ANCIENT and MEDIÆVAL; from the Eighth Century, with Numerals; including Gothic, Church-Text, large and small, German, Italian, Arabesque, Initials for Illumination, Monograms, Crosses, &c. &c., for the use of Architectural and Engineering Draughtsmen, Missal Painters, Masons, Decorative Painters, Lithographers, Engravers, Carvers, &c. &c. &c. Collected and engraved by F. DELAMOTTE, and printed in Colours. Royal 8vo, oblong, price 4*s*. cloth.

"A well-known engraver and draughtsman has enrolled in this useful book the result of many years' study and research. For those who insert enamelled sentences round gilded chalices, who blazon shop legends over shop-doors, who letter church walls with pithy sentences from the Decalogue, this book will be useful."—*Athenæum.*

EXAMPLES OF MODERN ALPHABETS, PLAIN and ORNAMENTAL; including German, Old English, Saxon, Italic, Perspective, Greek, Hebrew, Court Hand, Engrossing, Tuscan, Riband, Gothic, Rustic, and Arabesque; with several Original Designs, and an Analysis of the Roman and Old English Alphabets, large and small, and Numerals, for the use of Draughtsmen, Surveyors, Masons, Decorative Painters, Lithographers, Engravers, Carvers, &c. Collected and engraved by F. DELAMOTTE, and printed in Colours. Royal 8vo, oblong, price 4*s*. cloth.

"To artists of all classes, but more especially to architects and engravers, this very handsome book will be invaluable. There is comprised in it every possible shape into which the letters of the alphabet and numerals can be formed, and the talent which has been expended in the conception of the various plain and ornamental letters is wonderful."—*Standard.*

MEDIÆVAL ALPHABETS AND INITIALS FOR ILLUMINATORS. By F. DELAMOTTE, Illuminator, Designer, and Engraver on Wood. Containing 21 Plates, and Illuminated Title, printed in Gold and Colours. With an Introduction by J. WILLIS BROOKS. Small 4to, 6*s*. cloth gilt.

"A volume in which the letters of the alphabet come forth glorified in gilding and all the colours of the prism interwoven and intertwined and intermingled, sometimes with a sort of rainbow arabesque. A poem emblazoned in these characters would be only comparable to one of those delicious love letters symbolized in a bunch of flowers well selected and cleverly arranged."—*Sun.*

THE EMBROIDERER'S BOOK OF DESIGN; containing Initials, Emblems, Cyphers, Monograms, Ornamental Borders, Ecclesiastical Devices, Mediæval and Modern Alphabets, and National Emblems. Collected and engraved by F. DELAMOTTE, and printed in Colours. Oblong royal 8vo, 2*s*. 6*d*. in ornamental boards.

AGRICULTURE, &c.

Youatt and Burn's Complete Grazier.

THE COMPLETE GRAZIER, and FARMER'S and CATTLE-BREEDER'S ASSISTANT. A Compendium of Husbandry. By WILLIAM YOUATT, ESQ., V.S. 11th Edition, enlarged by ROBERT SCOTT BURN, Author of "The Lessons of My Farm," &c. One large 8vo volume, 784 pp. with 215 Illustrations. 1*l.* 1*s.* half-bd.

CONTENTS.

On the Breeding, Rearing, Fattening, and General Management of Neat Cattle.—Introductory View of the different Breeds of Neat Cattle in Great Britain.—Comparative View of the different Breeds of Neat Cattle.—General Observations on Buying and Stocking a Farm with Cattle.—The Bull.—The Cow.—Treatment and Rearing of Calves.—Feeding of Calves for Veal.—Steers and Draught Oxen.—Grazing Cattle.—Summer Soiling Cattle.—Winter Box and Stall-feeding Cattle.—Artificial Food for Cattle.—Preparation of Food.—Sale of Cattle.

On the Economy and Management of the Dairy.—Milch Kine.—Pasture and other Food best calculated for Cows, as it regards their Milk.—Situation and Buildings proper for a Dairy, and the proper Dairy Utensils.—Management of Milk and Cream, and the Making and Preservation of Butter.—Making and Preservation of Cheese.—Produce of a Dairy.

On the Breeding, Rearing, and Management of Farm-horses.—Introductory and Comparative View of the different Breeds of Farm-horses.—Breeding Horses, Cart Stallions and Mares.—Rearing and Training of Colts.—Age, Qualifications, and Sale of Horses.—Maintenance and Labour of Farm-horses.—Comparative Merits of Draught Oxen and Horses.—Asses and Mules.

On the Breeding, Rearing, and Fattening of Sheep.—Introductory and Comparative View of the different Breeds.—Merino, or Spanish Sheep.—Breeding and Management of Sheep.—Treatment and Rearing of House-lambs, Feeding of Sheep, Folding Sheep, Shearing of Sheep, &c.

On the Breeding, Rearing, and Fattening of Swine.—Introductory and Comparative View of the different Breeds of Swine.—Breeding and Rearing of Pigs.—Feeding and Fattening of Swine.—Curing Pork and Bacon.

On the Diseases of Cattle.—Diseases Incident to Cattle.—Diseases of Calves.—Diseases of Horses.—Diseases of Sheep.—Diseases of Lambs.—Diseases Incident to Swine.—Breeding and Rearing of Domestic Fowls, Pigeons, &c.—Palmipedes, or Web-footed kinds.—Diseases of Fowls.

On Farm Offices and Implements of Husbandry.—The Farm-house, the Farm-yard, and its Offices.—Construction of Ponds.—Farm Cottages.—Farm Implements.—Steam Cultivation.—Sowing Machines, and Manure Distributors.—Steam Engines, Thrashing Machines, Corn-dressing Machines, Mills, Bruising Machines.

On the Culture and Management of Grass Land.—Size and Shape of Fields.—Fences.—Pasture Land.—Meadow Land.—Culture of Grass Land.—Hay-making.—Stacking Hay.—Impediments to the Scythe and the Eradication of Weeds.—Paring and Burning.—Draining. Irrigation.—Warping.

On the Cultivation and Application of Grasses, Pulse, and Roots.—Natural Grasses usually cultivated.—Artificial Grasses or Green Crops.—Grain and Pulse commonly cultivated for their Seeds, for their Straw, or for Green Forage.—Vegetables best calculated for Animal Food.—Qualities and Comparative Value of some Grasses and Roots as Food for Cattle.

On Manures in General, and their Application to Grass Land.—Vegetable Manures.—Animal Manures.—Fossil and Mineral Manures.—Liquid or Fluid Manures.—Composts.—Preservation of Manures.—Application of Manures.—Flemish System of Manuring.—Farm Accounts, and Tables for Calculating Labour by the Acre, Rood, &c., and by the Day, Week, Month, &c.—Monthly Calendar of Work to be done throughout the Year.—Observations on the Weather.—INDEX.

"The standard, and text-book, with the farmer and grazier."—*Farmer's Magazine.*

"A valuable repertory of intelligence for all who make agriculture a pursuit, and especially for those who aim at keeping pace with the improvements of the age."—*Bell's Messenger.*

"A treatise which will remain a standard work on the subject as long as British agriculture endures."—*Mark Lane Express.*

Scott Burn's Introduction to Farming.

THE LESSONS of MY FARM: a Book for Amateur Agriculturists, being an Introduction to Farm Practice, in the Culture of Crops, the Feeding of Cattle, Management of the Dairy, Poultry, and Pigs, and in the Keeping of Farm-work Records. By ROBERT SCOTT BURN, Editor of "The Year-Book of Agricultural Facts," &c. With numerous Illustrations. Fcp. 6*s*. cloth.

"A most complete introduction to the whole round of farming practice."—*John Bull.*

"There are many hints in it which even old farmers need not be ashamed to accept."—*Morning Herald.*

Tables for Land Valuers.

THE LAND VALUER'S BEST ASSISTANT: being Tables, on a very much improved Plan, for Calculating the Value of Estates. To which are added, Tables for reducing Scotch, Irish, and Provincial Customary Acres to Statute Measure; also, Tables of Square Measure, and of the various Dimensions of an Acre in Perches and Yards, by which the Contents of any Plot of Ground may be ascertained without the expense of a regular Survey; &c. By R. HUDSON, Civil Engineer. New Edition, with Additions and Corrections, price 4*s*. strongly bound.

"This new edition includes tables for ascertaining the value of leases for any term of years; and for showing how to lay out plots of ground of certain acres in forms, square, round, &c., with valuable rules for ascertaining the probable worth of standing timber to any amount; and is of incalculable value to the country gentleman and professional man."—*Farmer's Journal.*

The Laws of Mines and Mining Companies.

A PRACTICAL TREATISE on the LAW RELATING to MINES and MINING COMPANIES. By WHITTON ARUNDELL, Attorney-at-Law. Crown 8vo. 4*s*. cloth.

Auctioneer's Assistant.

THE APPRAISER, AUCTIONEER, BROKER, HOUSE AND ESTATE AGENT, AND VALUER'S POCKET ASSISTANT, for the Valuation for Purchase, Sale, or Renewal of Leases, Annuities, and Reversions, and of property generally; with prices for Inventories, &c. By JOHN WHEELER, Valuer, &c. Third Edition, enlarged, by C. NORRIS. Royal 32mo, strongly bound, price 5*s*. [*Just published.*

"A neat and concise book of reference, containing an admirable and clearly-arranged list of prices for inventories, and a very practical guide to determine the value of furniture, &c."—*Standard*, June 27, 1871.

The Civil Service Book-keeping.

BOOK-KEEPING NO MYSTERY: its Principles popularly explained, and the Theory of Double Entry analysed; for the use of Young Men commencing Business, Examination Candidates, and Students generally. By an EXPERIENCED BOOK-KEEPER, late of H.M. Civil Service. Second Edition. Fcp. 8vo. price 2*s*. cloth.

"A book which brings the so-called mysteries within the comprehension of the simplest capacity."—*Sunday Times.*

"It is clear and concise, and exactly such a text-book as students require."—*Quarterly Journal of Education.*

"No Englishman ought to be without this book."

EVERY MAN'S OWN LAWYER; a Handy-Book of the Principles of Law and Equity. By A BARRISTER. 8th Edition, carefully revised, including a Summary of the New Bankruptcy Laws, the Fraudulent Debtors Act, the Reported Cases of the Courts of Law and Equity, &c. With Notes and References to the Authorities. 12mo, price 6*s.* 8*d.* (saved at every consultation), strongly bound.

Comprising the Rights and Wrongs of Individuals, Mercantile and Commercial Law, Criminal Law, Parish Law, County Court Law, Game and Fishery Laws, Poor Men's Lawsuits.

THE LAWS OF

BANKRUPTCY.	MORTGAGES.
BILLS OF EXCHANGE.	SETTLEMENTS.
CONTRACTS AND AGREEMENTS.	STOCK EXCHANGE PRACTICE.
COPYRIGHT.	TRADE MARKS AND PATENTS.
DOWER AND DIVORCE.	TRESPASS, NUISANCES, ETC.
ELECTIONS AND REGISTRATION.	TRANSFER OF LAND, ETC.
INSURANCE.	WARRANTY.
LIBEL AND SLANDER.	WILLS AND AGREEMENTS, ETC.

Also Law for

Landlord and Tenant.	Clergymen, Churchwardens.
Master and Servant.	Medical Practitioners, &c.
Workmen and Apprentices.	Bankers.
Heirs, Devisees, and Legatees.	Farmers.
Husband and Wife.	Contractors.
Executors and Trustees.	Stock and Share Brokers.
Guardian and Ward.	Sportsmen and Gamekeepers.
Married Women and Infants.	Farriers and Horse-Dealers.
Partners and Agents.	Auctioneers, House-Agents.
Lender and Borrower.	Innkeepers, &c.
Debtor and Creditor.	Pawnbrokers.
Purchaser and Vendor.	Surveyors.
Companies and Associations.	Railways and Carriers.
Friendly Societies.	&c. &c.

"*No Englishman ought to be without this book* . . . any person perfectly uninformed on legal matters, who may require sound information on unknown law points, will, by reference to this book, acquire the necessary information; and thus on many occasions save the expense and loss of time of a visit to a lawyer."—*Engineer*, Jan. 28, 1870.

"It is a complete code of English Law, written in plain language which all can understand . . . should be in the hands of every business man, and all who wish to abolish lawyers' bills."—*Weekly Times*, March 6, 1870.

"With the volume before us in hand, a man may, in nine cases out of ten, decide his own course of action, learn how to proceed for redress of wrongs, or recovery of rights, and save his pocket from the dreaded consultation fees and the incalculable bills of costs."—*Civil Service Gazette*, May 23, 1868.

"We have found it highly satisfactory as a work of authority and reference, and a handy-book of information. There is abundance of cheap and safe law in this work for all who want it."—*Rock*, May 26, 1868.

"A useful and concise epitome of the law, compiled with considerable care."—*Law Magazine.*

"What it professes to be—a complete epitome of the laws of this country, thoroughly intelligible to non-professional readers. The book is a handy one to have in readiness when some knotty point requires ready solution."—*Bell's Life.*

Bradbury, Evans, & Co., Printers, Whitefriars, London.

MECHANICAL ENGINEERING, &c.

MECHANICS, Rudimentary Treatise on; being a concise Exposition of the General Principles of Mechanical Science, and their Applications. By C. Tomlinson. Illustrated. 1s. 6d.

PNEUMATICS, for the Use of Beginners. By Charles Tomlinson. Illustrated. 1s. 6d.

CRANES, the Construction of, and other Machinery for Raising Heavy Bodies for the Erection of Buildings, and for Hoisting Goods. By Joseph Glynn, F.R.S., &c. Illustrated. 1s.

THE STEAM ENGINE, a Rudimentary Treatise on. By Dr Lardner. Illustrated. 1s.

THE STEAM ENGINE, a Treatise on the Mathematical Theory of, with Rules at length, and Examples for the use of Practical Men. By T. Baker, C.E. Illustrated. 1s.

STEAM BOILERS: their Construction and Management. By R. Armstrong, C.E. Illustrated. 1s. 6d.

AGRICULTURAL ENGINEERING: Farm Buildings, Motive Power, Field Machines, Machinery, and Implements. By G. H. Andrews, C.E. Illustrated. 3s.

CLOCKS, WATCHES, AND BELLS. By Edmund Beckett Denison, LL.D., &c. &c. Fifth Edition, with Appendix and additional Illustrations. 3s. 6d.

*** *The Appendix to the Fourth and Fifth Editions, separately,* 1s.

THE ECONOMY OF FUEL, particularly with reference to Reverberatory Furnaces for the Manufacture of Iron, and to Steam Boilers. By T. Symes Prideaux. 1s. 6d.

MARINE ENGINES AND STEAM VESSELS, a Treatise on. Together with Practical Remarks on the Screw and Propelling Power, as used in the Royal and Merchant Navy. By Robert Murray, C.E., Engineer-Surveyor to the Board of Trade. Fifth Edition, revised and enlarged. Illustrated. 3s.

THE POWER OF WATER, as applied to drive Flour Mills, and to give motion to Turbines and other Hydrostatic Engines. By J. Glynn, F.R.S., &c. New Edition, Illustrated. 2s.

STATICS AND DYNAMICS, the Principles and Practice of; embracing a clear development of Hydrostatics, Hydrodynamics, and Pneumatics, with Central Forces and Super-Elevation of Exterior Rail. By T. Baker, C.E. 1s. 6d.

SWORDS, AND OTHER ARMS used for Cutting and Thrusting, Memoir on. By Colonel Marey. Translated by Colonel H. H. Maxwell. With Notes and Plates. 1s.

WEALE'S

RUDIMENTARY

SERIES

LONDON

LOCKWOOD & Co