Reinforced Concrete Terminal Warehouse—Baltimore and Ohio Railroad, New York
M. A. Long, Engineer *Turner Construction Company, Contractors*

Reinforced Concrete in Factory Construction

The Atlas Portland Cement Company
New York *Chicago*

Reinforced Concrete in Factory Construction

“Concrete *for* Permanence”

The Atlas Portland Cement Company
30 Broad Street, New York   Corn Exchange Bank Bldg., Chicago
Philadelphia   Boston   St. Louis   Minneapolis   Des Moines   Dayton   Savannah

Ninth Edition

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INTRODUCTION

REINFORCED concrete has provided for the manufacturer an entirely new building material. Indestructible, economical and fireproof, it offers under most conditions features of advantage over every other type of construction. The development has naturally been greatest in the larger centers of population, but it is extending rapidly to the remoter districts, and, indeed, wherever new buildings are contemplated.

This widespread interest demands an authoritative treatment, and The Atlas Portland Cement Company has embraced this opportunity to present to the manufacturer, and also to the architect and the engineer who are not concrete specialists, a brief treatise on reinforced concrete for factory construction, with a view of giving a comprehensive idea of the advantages and limitations of the material as adapted to the factory, and a demonstration of its value as illustrated in a variety of buildings in different localities.

The work has been prepared by a consulting engineer, Mr. Sanford E. Thompson, who is well qualified to treat the subject as an expert authority. The Atlas Portland Cement Company, occupying, as it does, a somewhat unique position among cement manufacturers, with its wide reputation for a thoroughly uniform and standard product, its selection by the United States government to furnish over 7,500,000 barrels for use in building the Panama Canal, and its immense production—over 50,000 barrels per day—commends the book to its readers with the hope that it may prove a fitting companion volume to the other publications of the company.

THE ATLAS PORTLAND CEMENT COMPANY.

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PREFACE TO NINTH EDITION

The ninth edition presents substantially the same subject matter covered in the preceding edition, but the text has been condensed by eliminating some of the purely descriptive parts.

Some new illustrations have been added to show the marked advance which has been made in improving the appearance of reinforced concrete industrial buildings. The modern concrete factory needs no apologies on the score of appearance when compared with factories of any other type of construction.

To the chapter on concrete aggregates has been added the recently developed Colorimetric Test for organic impurities in sand. The necessity for a simple, reliable test for determining the quality of sand for concrete has been long recognized by engineers. It is hoped that this test is one step toward this end.

The chapter on design and construction has been left practically unchanged. The basic principles and methods of design have remained unaltered since the text was written. Perhaps the most marked tendency has been the increased use of flat-slab floor construction, without girders and beams, one type of which was employed in the Winchester Repeating Arms Factory; described on page 43. The added head room and increase of light as well as simplicity of construction explain the increased adoption of this type of floor system.

SANFORD E. THOMPSON,
Maj. Ord. R. C., Washington, D. C.

May 22, 1918.

QUOTATION FROM PREFACE TO PREVIOUS EDITION

The second* edition aims to cover the developments in the field of reinforced concrete as applied to factory construction since the appearance in 1907 of the first edition.

As in the previous issue, details are presented of this type of construction and a careful description, with numerous illustrative drawings and photographs, is given of typical examples of concrete buildings selected from various sections of the country and erected by representative builders. Suggestions are thus offered to the factory owner who contemplates building in reinforced concrete, while at the same time the practical details may prove of value to architects, engineers and builders.

The chapter on Design and Construction has been rewritten, the chapter on Details of Construction has been revised and new articles have been added, describing in detail different types of factories that have been built of reinforced concrete during the interval that has elapsed since the issue of the first edition.

The large increase in the quantity of material has necessitated a rearrangement of the text and renumbering the pages.

The first chapter presents to the manufacturer a brief review of the qualities of reinforced concrete in comparison with other materials for factory buildings, and this is followed by a chapter giving in considerable detail the general principles of design with information in regard to methods of construction. Chapter III treats of the selection of the aggregates. These general chapters are followed by a number of articles describing in full some one shop, factory or warehouse of reinforced concrete, selected with a view of presenting a variety of the more usual types of factory and warehouse construction.

Chapter IV outlines with illustrations many of the styles and systems of reinforcement in common use in building construction, and briefly refers to examples of concrete block walls, surface finish, concrete pile foundations and tanks, each illustrated by photographs.

All illustrations, excepting a part of those in Chapter IV, have been prepared especially for this book. The half-tones are made from original photographs, and the designs from drawings furnished by the engineers and contractors, or reproduced in the office of the author from the original plans. In this way a number of details are shown which seldom appear in print. Care has been taken throughout to give complete measurements so that the figures may be used as a guide to new construction work.

The Atlas Portland Cement Company, and the undersigned, desire to express their appreciation of the courtesies extended by individuals and companies who have kindly furnished plans and data for incorporation into the descriptive chapters.

SANFORD E. THOMPSON,
Newton Highlands, Mass.

March 1, 1912.

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*1913 Reprint of Second Edition.

Hoboken Land & Improvement Company, Hoboken, N. J.
Charles Fall, Architect. Turner Construction Company, Contractors

CHAPTER I—FACTORY CONSTRUCTION

A manufacturer about to build a factory or warehouse must choose between several types of construction. In this selection the governing considerations are cost, safety, durability, and fire protection, while many minor factors enter into each individual case.

In this opening chapter the qualities of the different materials available for factories are discussed with special reference to the reinforced concrete.

Types of buildings for mills, factories, and warehouses may be classified as follows:

(1) Frame construction;
(2) Steel construction;
(3) Mill or slow burning construction;
(4) Reinforced concrete construction.

The first and cheapest type of frame construction may be neglected as unsuitable for permanent installation because of its lack of durability and its fire risk. Board walls, narrow floor joists, board floors and roofs, not only do not protect against fire, but in themselves afford fuel even when the contents of a factory are not combustible.

Steel construction with concrete or tile floors, provided the steel is itself protected from fire by concrete or tile, is efficient and durable, but its first cost alone will usually prohibit its use for the ordinary factory building.

Mill, or "slow burning" construction, as it is sometimes called to distinguish it from fireproof construction, consists of brick, stone, or concrete walls, with wooden columns, timber floor beams and thick plank floors, which, although not fireproof, are all so heavy as to retard the progress of a fire and thus afford a measure of protection.

Reinforced concrete for factories and warehouses, and also for office buildings, hotels, and apartment houses, as compared with steel is lower in cost, requires less time to build, and has a greater freedom from vibration.

As compared with slow burning construction, reinforced concrete gives greater fire protection, with less maintenance costs because of lower insurance rates, durability, freedom from repairs and renewals, and in many cases with even lower first cost.

COST.

As a fundamental principle in mill and factory construction, the cost must be such that the outlay for interest on construction, running expenses, and maintenance, shall be at the lowest possible minimum consistent with conservative design and the requirements of operation. A wooden building is cheap in first cost, and therefore in interest charges, but is expensive in insurance and repairs, while the risk of the loss in production after a fire, for which no insurance provides, may far counterbalance any theoretical saving.

As a general proposition, reinforced concrete is almost invariably the lowest priced fireproof material suitable for factory construction. The cost is nearly always lower than that for brick and tile, and with lumber at a high price it is frequently even lower than brick and timber, with the added advantage of durability and fire protection.

In comparing the cost of different building materials, one must bear in mind that the concrete portion of the building is only a part of the total cost. Since the cost of the finish and trim may equal or exceed that of the bare structure, even if the concrete itself cost, say, 10 per cent. more than brick and timber, the cost of the building complete may not be 5 per cent. greater than with timber interior. The lower insurance rates will partly offset this even if there is no other economical advantage for the fireproof structure.

The exact cost of a building in any case is governed by local conditions. In reinforced concrete the design, the loading for which it must be adapted, the price of cement, the cost of obtaining suitable sand and broken stone or gravel, the price of lumber for forms, the wages of the laborers and carpenters, are all factors entering into the estimate. Reinforced concrete is largely laid by common labor, so that high rates for skilled laborers affect it less than any of the other building materials.

SAFETY OF REINFORCED CONCRETE CONSTRUCTION.

It is as important for reinforced concrete buildings as for other types that the designer be competent, and that the builder be of undoubted experience and with a knowledge of the fundamental principles of this particular type of construction. By this it is not meant that the builder be an expert mathematician, but he should be able to recognize the necessity for placing the steel near the bottom surface of the beams and slabs, of accurately placing all the steel exactly as called for on the plans, uniform proportioning of the concrete, of breaking joints at the proper places, of laying beams and slabs as a monolithic floor system, and of determining the hardness of the concrete before removing forms and shores.

The safety of a well designed reinforced concrete building increases with age, the concrete constantly gaining in strength and the bond with the steel becoming stronger.

DURABILITY.

There is scarcely any class of manufacture which is not now being carried on in a reinforced concrete building. It is adaptable to any weight of loading, to high speed and heavy machinery, as well as to light machine tools, and to almost any style of design.

Recent scientific experiments, as well as actual experience, are favorable to the use of concrete under repeated and vibrating loads.

The use of concrete in brackets for supporting crane runs, as in the Bullock shop, pages 45 to 50, is an interesting example of severe application of loading. Several concrete buildings in San Francisco withstood the shock of the earthquake, while those around them of brick and stone and wood were destroyed.

While most materials tend to rust or decay with time, concrete under proper conditions continues to increase in strength for months or even for years.

Concrete expands and contracts with changes of temperature. Its co-efficient of expansion, that is, its expansion in a unit length for each degree of increase in temperature, is almost identical with steel, and on this account there is no tendency of the steel to separate from the concrete, and they act together under all conditions. As in building with other materials, provision must be made in long walls or other surfaces for the expansion and contraction due to temperature, by placing occasional expansion joints or by adding extra steel. In factories of ordinary size, no special provision need be made, as the regular steel reinforcement will prevent cracking.

Special precautions are necessary for laying concrete in sea water. A first class cement must be selected, rich proportions used—at least 1:2:4—a coarse sand, and well proportioned aggregate which will produce a dense impervious mass.

FIRE RESISTANCE.

Reinforced concrete ranks with the best fireproof materials, and it is this quality perhaps more than any other which is responsible for the enormous increase in its use for factories.

Intense heat injures the surface of the concrete, but it is so good a non-conductor that it provides ample protection for the steel reinforcement, and the interior of the mass is unaffected even in unusually severe fires.

For efficient fire protection in slabs, under ordinary conditions the lower surface of the steel rods should be at least $\frac{3}{4}$ inch above the bottom of the slab. In beams, girders and columns, a thickness of $1\frac{1}{2}$ to $2\frac{1}{2}$ inches of concrete outside of the steel, varying with the size and importance of the member, and the liability to severe treatment, is in general sufficient. In columns whose size is governed by the loads to be sustained, an excess of sectional area should be provided so that if, say, 1 inch of the surface is injured by fire, there will still be enough concrete to sustain any loads which may subsequently come upon it.

One of the advantages of concrete construction as a fireproof material is that the design may be adapted to the local conditions. For example, in an isolated machine shop where scarcely any inflammable materials are stored, it is a waste of money to provide a thick mass of concrete simply to resist fire. On the other hand, for a factory or warehouse storing a product capable of producing not merely a hot fire—a hot short fire will not damage seriously—but an intense heat of long duration, special provision may be made by using an excess area of concrete perhaps two or three inches thick.

Actual fires are the best test of a material. One of the most severe on record occurred in the Pacific Coast Borax Refinery described on pages 76 to 82, and the concrete there, as well as in the Baltimore and San Francisco fires, made an excellent record.

The best fire resistant materials for concrete are first-class Portland cement with quartz sand and broken trap rock. Limestone aggregate will not stand the heat so well as trap, while the particles of gravel are more easily loosened by extreme heat. Neither of these materials, however, if of good quality, need be rejected for building construction unless the demands are especially exacting and the liability to fire great. Cinders make a good aggregate for fire resistance, but the concrete made with them is not strong enough for reinforced concrete construction except in slabs of short span or in partition walls.

The fire resistance of concrete increases with age, as the water held in the pores is taken up chemically and is evaporated.

INSURANCE.

When reinforced concrete first came to the front for factories and warehouses, the insurance companies hesitated to assume such buildings as first-class risks. However, examination and tests have gradually convinced the most skeptical of their true fire resistance, until new structures of this material are sought after and given the lowest rates of insurance.

Mr. L. H. Kunhardt, Vice-President and Engineer of one of the oldest of the Factory Mutual Insurance Companies, which have for years played a leading part in the development of mill construction, and the science of fire protection engineering and consequent reduction of fire losses, presents in an appendix to this chapter (p.11) very instructive figures comparing the costs of insurance upon several types of factories for various classes of manufacture. Mr. Kunhardt also indicates the means by which concrete may be utilized in reducing even the present low rates of insurance upon buildings protected by efficient fire apparatus.

From the statements there given by so eminent an authority on mill insurance, we may conclude that a well-designed reinforced factory with continuous floors (1) offers security against disastrous fires and total loss of structure; (2) reduces danger to contents by preventing the spread of a fire; (3) prevents damage by water from story to story; (4) makes sprinklers unnecessary in buildings whose contents are not inflammable; (5) reduces danger of panic and loss of life among employees in case of fire.

STIFFNESS.

A reinforced concrete building really resembles a structure carved out of a single block or solid rock. It is monolithic throughout. The beams and girders are continuous from side to side and from end to end of the building, while even the floor slab itself forms a part of the beams, and the columns are also either coincident with them or else tied to them by their vertical steel rods.

All this accounts for the extraordinary stiffness and solidity of a reinforced concrete structure, and differentiates it from timber construction, where positive joints occur over every column; and even from steel construction, in which the deflection is greater.

FREEDOM FROM VIBRATION.

This solidity and entire lack of joints, and particularly the weight of the material, especially adapts it to both high speed and heavy machinery. The vibrations are deadened and absorbed in a way which is impossible in steel structures.

An interesting example of this fact is furnished in the Ketterlinus building described on pages 30 to 34, where the vibration and jar in the new concrete building are remarkably less than in the adjacent steel and tile structure carrying the same type of machinery.

VERSATILITY OF DESIGN.

Steel rods are set in the concrete, to provide tensile strength, in such quantity and location as is needed for special loading for which it is designed. Consequently, spans can be constructed of any reasonable length, either long or short, and column spacing may be adapted to the requirements of operation. Because of the weight of the concrete, which must itself be borne by the strength of the member, very long beam and girder spans are relatively more expensive than the more ordinary spans of 15 or 20 feet. Similarly, the cost of floor slabs per square foot increases appreciably with their span. These limitations are economical rather than theoretical, and every design should therefore be studied thoroughly to produce the best results at least cost, and to adapt the structure to the class of manufacture or storage for which it is intended.

The rule applies to reinforced concrete as well as to other structures, that the industrial portion of the plant, the arrangement of the machines, and of the transmission machinery, should be first designed and the structure adapted to give a minimum operating expense.

LIGHT.

A special feature of reinforced concrete construction is the possibility of building practically the entire wall of glass, so as to afford a maximum amount of light. Concrete is so strong that the columns can be made of small size and the windows carried by shallow beams. The window area may thus cover a very large percentage of the wall surface.

WATERTIGHTNESS.

In some classes of manufacture where water is freely used, as in paper and pulp mills, it is essential that the floors shall be tight so that water cannot fall upon the product on the floor below or onto the belting. In case of fire a watertight floor prevents damage from water to the machinery and materials in the stories below. A concrete floor with granolithic surface is practically impervious to water.

CLEANLINESS.

Concrete floors may be laid on a slight slope with a drain along the sides of the room so as to carry off all water and permit flushing with the hose. Concrete is vermin proof.

RAPIDITY OF CONSTRUCTION.

The speed with which a reinforced concrete building can be completed is due in a great measure to the fact that there need be no waiting for materials. Sand and stone are always available; Portland cement is now supplied by large mills with immense storage capacity; and steel rods are kept in stock, so that a building can be commenced as soon as the plans are completed and no delays need be incurred in ordering special shapes and awaiting their shipment from the mills.

In general under good superintendence the rate of progress of a reinforced concrete factory may be as fast as one-half story or even one story per week.

HANGING SHAFTING.

Provision may be made for shafting by placing bolts or sockets in the beams to connect with pillow blocks for special lines of shafting, or such connections may be made at regular intervals so that timbers or steel frames may be bolted and shafting, or tracks for conveying material, supported at any positions subsequently specified.

ROOF.

Naturally, the roof of a reinforced concrete building is of the same material, designed to carry the weight of roof covering and snow which may come upon it. It is advisable to cover with some one of the standard form of roofings.

If the building is erected with a view to adding one or more stories, it is well to build the roof of wood or light steel construction so that it may be readily taken down or raised. Often the roof slab is made of concrete sufficiently strong to afterward become a floor slab. When this is done, drainage is obtained by placing on the slab a temporary fill of cinder concrete, properly sloped.

TANKS.

The making of durable tanks is one of the problems in many factories. This is being solved in numerous cases by the use of reinforced concrete, designed with sufficient steel to resist the water pressure. In paper and pulp mills the adoption of concrete tanks is especially advisable because of the frequent repairs and renewals required in wood construction. Special attention should be given to the watertightness of concrete by grading all the aggregates and by care in placing.

LETTING THE CONTRACT

The contract for the construction of a reinforced concrete factory should be let only to responsible builders with practical experience in this class of work. A man who has simply laid concrete foundations is not competent to erect a factory building.

If day labor is employed, it must be under the direct superintendence of an engineer skilled in concrete construction.

The plan is frequently followed of requesting estimates from different contractors without specifying the requirements of the design. As a consequence, the man who dares to figure with the smallest factor of safety, and who thus would build the poorest and weakest structure, presents the lowest bid. Such a possibility may be precluded by having at least the general plans and specifications prepared in advance by a competent engineer or architect, so that the estimates may be compared with fairness.

Concrete building construction is frequently performed on the cost-plus-a-fixed-sum or cost-plus-a-percentage basis. These methods are apt to result in a somewhat higher cost for the structure than competitive bidding, although they offer less temptation to the builder.

Whatever plan is followed, one or more competent inspectors should be employed by the owners independent of the contractor to see that the work is properly performed in all its details.

GROWTH OF REINFORCED CONCRETE.

One of the first uses of reinforced concrete in building construction was in the house erected by W. E. Ward in 1872 at Port Chester, N. Y. Some twenty years earlier than this, in France, the first combinations of iron imbedded in concrete were made in a small way. However, not until the very end of the last century, since 1895, has concrete been employed commercially in the construction of buildings. Previous to this it had attained a wide use in foundations, and at this time its development was beginning for such structures as dams, sewers and subways.

Two principal reasons may be offered for this comparatively slow growth followed by such marvelous activity. In the first place, Portland cement manufacturers, beginning in Europe about the middle of the 19th century and in the United States about 1880, finally produced a grade of cement which, with the inspection necessary for all structural materials, could be depended upon to give uniform and thoroughly reliable results; furthermore, along with the perfection of the process of manufacture, the price gradually fell from the high cost per barrel in 1880 for imported cement, to a figure for domestic Portland cement of equally good, if not better, quality, at which concrete in plain form could compete with rough stone masonry, and with steel imbedded could compete with other building materials.

In the second place, theoretical studies and practical experiments have now produced rational and positive methods for computing the strength of concrete reinforced with steel so that absolute dependence can be placed upon it.

FIRE INSURANCE ON FACTORIES OF REINFORCED CONCRETE.

By L. H. Kunhardt, Vice-President, Boston Manufacturers' Mutual Fire Insurance Co.

In consideration of the question of insurance on reinforced concrete factories, the problem simply resolves itself into a determination of what the fire and water damage will be in the event of fire compared with that in other types of factory buildings. For this purpose concrete factories may be divided into two classes:

1st. Those having contents which are not inflammable or readily combustible. In this class, if wooden window frames and partitions, etc., have been eliminated, the building as a whole becomes practically proof against fire, provided there are no outside exposures, protection against which would require special precautions.

2nd. Those having contents which are more or less combustible, and which have in their construction small amounts of inflammable material such as wooden window frames and top floors. In this class the burning of contents is the cause of damage to the building, the extent of which is determined by the character of the contents.

Of the two, the latter class is the one ordinarily met, and with which the question of insurance cost is therefore usually concerned. The character of the occupancy, details of construction and conditions of various kinds inside and outside the factory, and in the various communities, have such direct bearing on rates that any statement as below of comparative cost must be extremely approximate, but perhaps of value as showing somewhat the relative costs. These in the following table are made upon the basis of a building without a standard fire equipment, which condition is, however, now rare in the case of first-class factories and warehouses, even if of fireproof construction.

CONCRETE FACTORIES VS. THOSE OF WOOD OR BRICK.

Approximate Yearly Cost of Insurance per $100. Exposures, None; Area Not Large; Good City Department; No Private Fire Apparatus Except Such as Pails and Standpipes.

	All Concrete		Brick Mill Construction or Open Joists		Wood Mill Construction or Open Joists		Add for Brick or Wood Buildings in Small Towns and Cities Without Best of Water and Fire Departments
	Bldg.	Contents	Bldg.	Contents	Bldg.	Contents	
General Storehouse..........	20c.	45c.	60c.	100c.	100c.	125c.	25c.
Wool Storehouse............	20c.	35c.	40c.	60c.	75c.	125c.	25c.
Office Building..............	15c.	35c.	45c.	75c.	100c.	150c.	25c.
Cotton Factory.............	40c.	100c.	150c.	250c.	200c.	300c.	50c.
Tannery....................	20c.	40c.	100c.	125c.	100c.	100c.	25c.
Shoe Factory...............	25c.	80c.	100c.	125c.	150c.	200c.	50c.
Woolen Mill................	30c.	80c.	100c.	125c.	150c.	200c.	50c.
Machine Shop..............	15c.	30c.	65c.	75c.	100c.	125c.	25c.
General Mercantile Building..	35c.	75c.	65c.	125c.	100c.	150c.	25c.

NOTE.—Table corrected to April 1, 1918.

NOTE.—These costs are based on the absence of automatic sprinklers and other private fire protective appliances of the usual completely equipped building. They are not schedule rates, but may be an approximation to actual costs under favorable conditions based on examples in various parts of the country.

NOTE.—The rates on Mill Construction are generally lower than those on joist construction, but the figures in columns 3, 4, 5 and 6 are a fair average between the two.

The foregoing table illustrates the gain by the use of the better type of construction, but in factory work it has long been recognized that there is a distinct hazard in the manufacturing operations and inflammable contents which is greater in degree than in other classes of property. The science of fire protection with automatic sprinklers and auxiliary apparatus has therefore attained such a degree of perfection that the brick or stone factory with heavy plank and timber floors is obtaining insurance at rates which are lower than those which are possible on any of the fireproof buildings without sprinklers. The real reason for this lies in the fact that the contents, including machinery, stock in process, and finished goods, constitute by far the larger part of the value of the plant, and these the building alone cannot be expected to protect when a fire occurs within, except in so far as the absence of combustible material in construction may assist in so doing. Fire protection is therefore needed for safety of contents, even if the building itself is practically fireproof.

As illustrating the value of fire protection, I would state that in the Boston Manufacturers' Mutual Fire Insurance Company, and others of the older of the Factory Mutual Companies, the average cost of insurance on the better class of protected factories has now for some years averaged, excluding interest, less than seven (7) cents on each one hundred dollars of risk taken, and on first-class warehouses connected with them, one-half this amount. These figures can be compared with the table as illustrating the gain by the installation of proper safeguards for preventing and extinguishing fire.

In these same protected factories and warehouses the actual fire and water loss is less than four (4) cents on each one hundred dollars of insurance, and, being so small, it would seem that they must be almost impossible of reduction, but nevertheless it is possible.

How can this be accomplished? This is the problem of the designer and builder of the concrete factory.

1st. By avoiding vertical openings through floors—a common fault in many factories with wooden floors. To be a perfect fire cut-off, a floor should be solid from wall to wall, with stairways, elevators and belts enclosed in vertical concrete or solid brick walls having fire doors.

2nd. By provision for making floors practically waterproof, that water may not cause damage on floors below that on which fire occurs. Scuppers of ample size to carry water from floors to outside are an essential part of the design. In the ordinary factory with wooden floors, loss from water is almost invariably excessive as compared with the loss by actual fire.

3rd. By making the buildings as incombustible as possible, thus reducing the amount of material upon which a fire may feed. Also by provision for sufficient thickness of fireproofing to thoroughly insulate all steel work, the fireproofing being sufficiently substantial that it may not scale off ceilings or columns at a fire or from other causes, thus allowing failure of steel work, by heating or deterioration. An owner is thus more secure if the fire protection or any parts of it fail at a critical moment.

4th. By judiciously limiting the area and values between vertical firewalls and by providing subdivision walls of substantial design which will withstand the attack of the severest fires.

5th. By good judgment as to the extent or amount of fire protection required in each individual case. While the value of the automatic sprinkler is recognized and the general rules specify its installation, the Factory Mutual Companies do not require it in the concrete building, except where there is sufficient inflammable material in the contents to furnish fuel for a fire. An essential feature of good factory construction includes not only consideration of the building, but protection adequate to its needs only.

The extent to which the above is faithfully carried out will eventually be the determining feature in the cost of insurance.

April 1, 1918.

CHAPTER II—DESIGN AND CONSTRUCTION

Concrete is an artificial stone, and if it contains no steel, that is, if it is not reinforced, it is brittle like stone. Just as stone can be used to support enormous loads, as in foundations, bridges and dams, provided it is so placed as to receive no tension or pull, so can concrete stand heavy loading in compression with no reinforcement.

Concrete, however, has the advantage of stone, because when built in place, steel, which is especially adapted for withstanding pull, may be introduced at just the right position in the beam or other member to take this pull. In an ordinary beam the upper surface is in compression and the lower surface in tension; the natural arrangement of materials is therefore to design the beam so that the upper part is composed of concrete, which takes the compression, while steel is embedded near the bottom to resist the pull or tension. The concrete by surrounding the steel protects it from rust and fire, and because concrete and steel expand and contract almost exactly alike when heated and cooled, they may be used thus in combination with no danger of separation from changes in temperature.

It is evident that to make a safe combination of concrete and steel it is necessary to know just how much load each can stand, and just where the steel must be located to take every bit of the tension which may occur in any part of the beam. While in a beam supported at the ends the pull is in the bottom and the principal steel must be as near to the bottom as is consistent with rust and fire protection, on the other hand, when the beam is built into a column or into another beam a load upon it produces also a pull at the top of the beam over its supports which tends to crack it there. Furthermore, there are other secondary stresses in the interior of the beam, partly shear or tendency to slide and partly tension or pull, which must be guarded against by locating steel rods in the proper places. Hence the necessity, because of the complication in the action of the stresses even in a single beam, that the designers have a knowledge of the principles of mechanics and the theories involved.

It is not the purpose of this book to dwell upon the theory of design, but instead to give practical principles of construction to supplement the theory which can be obtained readily from other sources.

CEMENT.

For all important concrete construction it is the practice to require that the Portland cement shall pass the Standard Specifications for Portland cement of the American Society for Testing Materials.

SAND.

Since it is impossible for even the most expert engineer to determine positively by inspection whether or not a sand is fit to be used in concrete, it is absolutely necessary that it should be tested for important work.

The difficulties are that the impurities, while affecting the chemical combination with the cement, may be so minute as to be impossible to distinguish by the eye.

An extremely small percentage of vegetable matter of certain kinds may delay the hardening of the cement so that at seven days there is practically no strength in the concrete or mortar.

SPECIFICATIONS FOR AGGREGATES.

The following specifications are of so general a character as to be applicable to nearly all kinds of concrete construction.

Fine Aggregates.*—The fine aggregate shall consist of sand, crushed stone or gravel screenings passing when dry a screen having ¼-inch diameter holes, or a screen having 4 meshes to the linear inch. It shall be clean, coarse and free from vegetable loam and other deleterious matter. Not more than 30 per cent by weight shall pass a sieve having 50 meshes per lineal inch. Mortars composed of 1 part Portland cement and 3 parts fine aggregate, by weight, when made into briquettes, shall show a tensile strength of at least 90 per cent of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand. To avoid the removal of any coating on the grains which may affect the strength, bank sands shall not be dried before being made into mortar, but shall contain natural moisture. The percentage of moisture may be determined upon a separate sample for correcting weight. From 10 to 40 per cent more water may be required in mixing bank or artificial sands than for standard Ottawa sand to produce the same consistency.

Coarse Aggregates.*—The coarse aggregate shall consist of inert material, such as crushed stone or gravel, which is retained on a screen having ¼-inch diameter holes. The particles shall be clean, hard, durable, and be free from all deleterious matter. Aggregates containing soft, flat or elongated particles should be excluded from reinforced concrete. A gradation of sizes of the particles is advantageous. The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete fully surrounding the reinforcement or filling all parts of the forms. Where concrete is used in mass the size of the coarse aggregate may be such as to pass a 3-inch ring. For reinforced concrete a size to pass a 1-inch ring or a smaller size may be used.

Gravel.*—The gravel shall be composed of clean pebbles free from sticks and other foreign matter and containing no clay or other material adhering to the pebbles in such quantity that it cannot be lightly brushed off with the hand or removed by dipping in water. It shall be screened to remove the sand which shall afterward be remixed with it in the required proportions.

Broken Stone.*‡—The broken or crushed stone shall consist of pieces of hard and durable rock, such as trap, limestone, granite, or conglomerate. The dust shall be removed by a sand screen, to be afterward, if desired, mixed with and used as a part of the sand, except that if the product of the crusher is delivered to the mixer so regularly that the amount of dust, as determined by frequently screening samples, is uniform, the screening may be omitted, and the average percentage of dust allowed for in measuring the sand.

Water.*—The water shall be free from oil, acid, strong alkalies, or vegetable matter.

REINFORCING STEEL

The steel reinforcement shall be free from excessive rust, scales, or coatings of any character, which tend to reduce or destroy the bond with the concrete. The steel shall conform to the requirements of the American Society for Testing Materials.

For temperature reinforcement steel of high elastic limit and deformed section is especially good.

PROPORTION OF MATERIALS.

In building construction, the proportions most generally adopted are 1 part cement to 2 parts sand to 4 parts broken stone or gravel (this being customarily indicated by the expression 1:2:4). One bag (4 bags to barrel) of Portland cement is considered as 1 cubic foot, thus proportions 1:2:4 mean one bag Portland cement, 2.0 cubic feet sand measured loose and 4.0 cubic feet of broken stone or gravel measured loose. Such concrete when made into cylinders 6 inches in diameter by 12 inches long must test 2,000 pounds per square inch at the age of 28 days.

On a small job, where tests cannot be made so economically, it is well to be conservative and require proportions 1:2:4. On the other hand, if an engineer is constantly present, it is often best not to definitely specify the relative amount of sand to stone, but to permit the proportion to vary with the material; thus, in laying the concrete if there is an excess of mortar the quantity of sand should be slightly reduced and the quantity of stone correspondingly increased, while if there is insufficient mortar to cover the stone and prevent stone pockets, the sand may be increased and the stone decreased. The proportion of cement to the sum of the parts of sand and stone may thus be kept constant.

CONSISTENCY.

For building construction and for other reinforced concrete work while it is necessary that the concrete shall be mixed wet enough to flow sluggishly around and thoroughly imbed the steel it must be no wetter than is required to attain this result. If mixed too dry, air voids will be left around the stone, and stone pockets will appear on the face of the concrete after removing the forms. If, on the other hand, too much water is added, the surface may have a similar appearance because of the water running away from the stone. Furthermore, and of greater importance than the mere appearance, an excess of water reduces the strength of the concrete maybe to two-thirds or less of its normal strength.

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*Paragraphs designated by an asterisk are quoted with permission from Taylor & Thompson's "Concrete, Plain and Reinforced." Second Edition.

‡The maximum size of stone for building construction is customarily limited to 1 inch or 1¼ inches, so that the concrete may be carefully placed around the steel and into the corners of the forms. In certain cases ½-inch or ¾-inch stone is specified, but the larger size is better, provided it can be properly placed.

PLACING.

Concrete shall be conveyed to place in such a manner that there shall be no distinct separation of the different ingredients, or in cases where such separation inadvertently occurs the concrete shall be remixed before placing. Each layer in which the concrete is placed shall be of such thickness that it can be incorporated with the one previously laid. Concrete shall be used so soon after mixing that it can be rammed or puddled in place as a plastic homogeneous mass. Any, which has set before placing, shall be rejected. When placing fresh concrete upon an old concrete surface, the latter shall be cleaned of all dirt and scum or laitance and thoroughly wet. Noticeable voids or stone pockets discovered when the forms are removed shall be immediately filled with mortar mixed in the same proportions as the mortar in the concrete. For horizontal joints in thin walls, or in walls to sustain water pressure, or in other important locations, a joint of neat cement paste shall be used.

If the concrete is conveyed by inclined chute or spout the angle of slope shall be 2 horizontal to 1 vertical.

SURFACES.

The proper treatment to give a pleasing appearance to exposed surfaces is one of the most difficult problems in concrete building construction. The surfaces of columns, beams and the under sides of floors can be made sufficiently smooth by careful spading, and by seeing to it that the mortar comes to the face and that the forms are tight enough to prevent the mortar running out.

The treatment of the outside surface is determined by the character of the structure. A fair surface, suitable for work which is not exposed to view, and even for sheds or other buildings where the appearance need not be regarded, may be obtained by using a very wet mixture of concrete and by careful spading, as described above.

When the character of building and its location is such as to warrant the obtaining of an excellent finish, this may be done by either dressing the surface after the forms are removed with a pointed hammer, by washing, or by rubbing with a block of carborundum or similar substance. These three methods, together with others, are described in detail and illustrated in the chapter on Details of Construction, and the methods adopted in different buildings are taken up in the descriptive chapters which follow.

FORMS.

†The lumber for the forms and the design of the forms shall be adapted to the structure and to the kind of surface required on the concrete. For exposed faces the surface next to the concrete shall be dressed. Forms shall be sufficiently tight to prevent loss of cement or mortar. They shall be thoroughly braced or tied together so that the pressure of the concrete or the movement of men, machinery or materials shall not throw them out of place. Forms shall be left in place until, in the judgment of the engineer, the concrete has attained sufficient strength to resist accidental thrusts and permanent strains which may come upon it. Forms shall be thoroughly cleaned before being used again.

The time for removal of forms is determined by the weather conditions and actual inspection of the concrete. The following approximate rules may be followed as a safe guide to the minimum time for the removal of forms.†

Walls in Mass Work.—One to three days, or until the concrete will bear pressure of the thumb without indentation.

Thin Walls.—In summer, two days; in cold weather, five days.

Slabs Up to Six Feet Span.—In summer, six days; in cold weather, two weeks.

Beams and Girders and Long Span Slabs. In summer, ten days or two weeks; in cold weather, three weeks to one month. If shores are left without disturbing them, the time of removal of the sheeting in summer may be reduced to one week.

Column Forms.—In summer, two days; in cold weather, four days, provided girders are shored to prevent appreciable weight reaching columns.

A very important exception to these rules applies to concrete which has been frozen after placing, or has been maintained at a temperature just above freezing. In such cases the forms must be left in place until after warm weather comes, and then until the concrete has thoroughly dried out and hardened.

FOUNDATIONS.

In a reinforced concrete building, the floor loads are carried by the slabs to the beams and girders, and thence to the columns, which concentrate the weight upon small areas of ground. The footing of each column must therefore be spread over a large enough area of ground so as not to overcompress the soil and cause appreciable settlement.

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†From paper on "Forms for Concrete Construction," by Sanford E. Thompson, before National Association of Cement Users, 1907.

*Mr. George B. Francis suggests the following loading for materials which can be clearly defined, at the same time calling attention to the necessity for varied and ample experience when fixing allowable pressures in any particular case:

Ledge rock, 36 tons per square foot.
Hard pan, 8 tons per square foot.
Gravel, 5 tons per square foot.
Clean sand, 4 tons per square foot.
Dry clay, 2 tons per square foot.
Wet clay, 2 tons per square foot.
Loam, 1 ton per square foot.

To illustrate the use of these rules: If a column 20 inches square carries a load from above of 80 tons, the footing over a soil of dry sand must cover an area of $^{80}/_{4} = 20$ square feet; that is, the footing must be about 4 feet 6 inches square.

Not only must the area be calculated to distribute the load over a proper area of soil, but the thickness of the footing must be computed so as to prevent the column punching or shearing through it, and a sufficient amount of reinforcing steel must be placed in the bottom of the concrete footing to prevent its buckling and breaking from the concentrated load of the column. The size of the rods is calculated from the bending moment produced by the upward pressure of the soil against the projection of the footing, which may be assumed to be a beam supported upon a line running through the center of the column. If, as is customary, the footing projects in both directions and the rods run in both directions, both projections may be taken into account as resisting the pressure.

In certain cases, where a very large footing is required, especially when the footing rests on piles, stirrups may be needed to resist shear or diagonal tension, as in an ordinary beam.

Proportions of concrete for reinforced footings may be 1:2½:5, i.e., one part Portland cement to 2½ parts sand to 5 parts broken stone or gravel, or the same proportions may be used as in the building above them.

Foundations in dry ground which do not require reinforcement and sustain only direct compression may be laid in proportions of 1:3:6 or 1:3:7. If laid under water the concrete should not be leaner than 1:2½:5, while for sea water construction a mixture at least as rich as 1:2:4 is advisable, with very careful testing of the cement and aggregates.

For a building with no basement, foundation walls between the columns are unnecessary. The walls may be started just below the surface of the ground, and each wall slab will form of itself a beam supported at each end by the column foundation. When a basement is included in the design, its wall is apt to act as a retaining wall to resist the pressure of earth, and it may be necessary to calculate the thickness and reinforcement required to resist the earth pressure. Frequently, the bottom of the wall is held by the basement floor, and the top by the first floor of the building. In this case it may be considered as a slab supported at the bottom and top, and the principal reinforcing rods should be vertical and placed about one inch from the interior face of the wall. If there is no support at the top, the footing may be enlarged by careful computation and a cantilever design made with the principal tension rods vertical, but near the exterior face of the wall; or the vertical slab may be supported at the ends by columns or buttresses of proper design, and the tension rods, computed to resist the earth pressure, run horizontally near the interior face.

For an ordinary cellar wall supported at bottom and top, a thickness of 8 inches, with ⅜-inch vertical rods about one foot apart will be strong enough to hold the earth, but it is best to actually compute the thickness and reinforcement for any given case. Even if the principal rods are vertical, occasional horizontal rods, spaced about 18 inches or 2 feet apart, should be placed in the wall to tie it together and prevent contraction cracks.

BASEMENT FLOOR.

The earth under a basement floor must be well drained. If necessary, drains of tile pipe or of screened gravel or stone may be placed in trenches just below the concrete, or the entire level may be covered with cinders or stone. If the basement is below tide water or ground water level, it is not safe to depend upon the concrete itself being water-tight, and a layer of waterproofing consisting of four to six layers of tarred paper, mopped on, may be spread on the concrete and carried up in continuous sheets on the walls to above water level, and the whole surface covered with another layer of concrete. In some cases it may be necessary to make the concrete

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*Taylor & Thompson's "Concrete, Plain and Reinforced," Second Edition, page 639.

extra thick, or to add reinforcement, to resist the upward pressure of the water.

For a basement floor in dry ground a 3-inch or 4-inch thickness of ordinary 1:3:5 concrete—that is, concrete composed of 1 part Portland cement to 3 parts sand to 5 parts broken stone or gravel—may be laid and the surface screeded to bring it to the required level. As it sets, this concrete should be troweled just as the wearing surface of a sidewalk is troweled, but without the mortar or granolithic finish which is customarily laid upon a walk. If the floor is to have a great deal of wear or trucking, the usual ¾-inch or 1-inch layer of 1:2 mortar may be laid upon the concrete before it has set, forming a part of the total thickness of 4 inches; but usually this is an unwarranted expense in a basement, as the plain concrete will give as good service.

It is well in any case to divide the floor into blocks, say 8 or 10 feet square, so that any shrinkage cracks will come in the joints. This is readily accomplished by laying alternate blocks, and then filling in the intermediate ones the next day.

DESIGN OF FLOOR SYSTEM.

LOADING.—In designing a reinforced concrete building, the first consideration is the loading which the various floors must sustain. In addition to the specified live or superimposed load the weight of the concrete itself must always be allowed for.

The various conditions met with in warehouse or factory construction may necessitate loadings varying from 75 to 1,000 pounds per square foot of floor area. As a guide to the selection of floor loads, the following values are suggested:

Office floors	75 pounds per square foot
Light running machinery,	75 to 150 pounds per square foot
Medium heavy machinery..	200 pounds per square foot
Heavy machinery	250 pounds per square foot
Storage of parts or finished products, depending upon actual calcuated loads,	150 to 1,000 pounds per square foot

When the loads are apt to occur only over a part of the floors, the slabs and beams are calculated for the full load, but a reduction of 15 per cent of the live load may be allowed in figuring the girders.

In the case of floors supporting machinery whose weight is slight but whose motions are great, a proper allowance should be made to take care of the resulting vibrations.

LAYOUT.—The arrangement of the floor beams, girders and columns depends upon so many considerations that special study is required in each case.

For heavy loads, say 250 pounds per square foot and over, bays 14 feet by 14 feet are generally the cheapest, while for light loads probably 18 feet by 18 feet is the most economical arrangement of bays.

In order to secure the most economical arrangement of beams and girders it is frequently necessary to make several comparative estimates with different spacings of these members.

The smallest amount of material is required with floor panels of short span and frequent floor beams to support them. However, the fact that the actual amount of material required for a certain floor construction is less than that required in another does not always mean that this floor construction is actually the cheapest. If, for example, the beams are closer together it must be remembered that the unit labor for the form work is increased, and also that of the steel labor.

The design of a complete floor system with reinforced concrete beams, girders, slabs and columns, is shown by the isometric view in Fig. 3 (p. 18). The columns are spaced 18 by 19 feet on centers and the floor is designed to support a live load of 250 pounds per square foot.

FLOOR SLABS.—The thickness and reinforcement of the floor slabs is determined by the distance between the beams, and by the loading which will come upon them. The most usual thicknesses are 3½ inches to 5 inches, with reinforcement calculated from the bending moment produced by the loads. An economical quantity of steel is apt to be from 0.8 per cent to 1 per cent of the sectional area of the slab above the steel.

A few rods are usually placed at right angles to the main bearing rods of the slab to assist in preventing contraction cracks, and these also add to the strength of the slab.

In a factory or warehouse, the most economical floor surface is generally a granolithic finish, consisting of a layer of 1:2 mortar about three-quarters inch thick, spread upon the surface of the concrete slab before it has begun to set, and troweled to a hard finish just like a concrete sidewalk.

Machines are readily bolted to the concrete by drilling small holes in the concrete at the proper points for the standards and grouting the lag screws in place, or else bolting them through the slab.

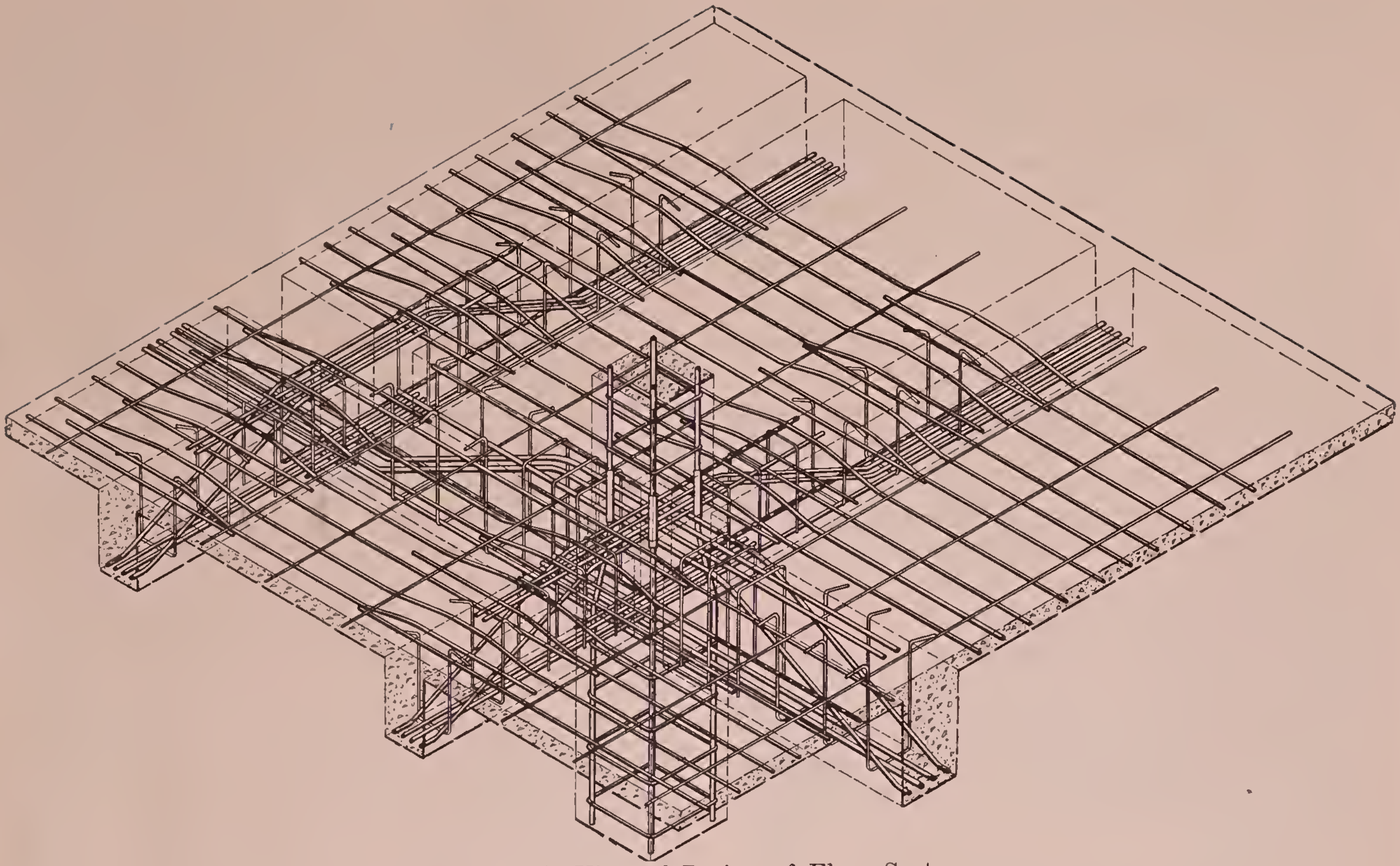

Fig. 3.—Isometric View of Design of Floor System.

If for any reason a wood floor is required, stringers may be laid upon the top of the concrete and spaces left between them or filled with cinders or with cinder concrete.

BEAMS AND GIRDERS.—As already indicated, the sizes and reinforcement of the beams and girders must be accurately computed by one who thoroughly understands the theories involved in reinforced concrete design. Even if tables are used the designer must have a knowledge of the mechanics and of the way in which the stresses act.

It is a simple matter to determine the amount of steel required in the bottom of the beam to sustain the pull due to a given loading but while this is an important determination it is by no means the only one.

The weak points in reinforced concrete structures are not usually due to insufficient steel for tension, but more often to an ignorance of other smaller details not less important. It is thus absolutely dangerous, and, in fact, criminal, for a novice to design or pass upon drawings for a reinforced concrete structure.

In beam and slab construction an effective bond must be provided at the junction of the beam and slab. When the principal slab reinforcement is parallel to the beam or girder, transverse bars should be placed in the top of the slab extending over the beam and well into the slab on each side.

Where the concrete in the web of beam and the slab is laid at one operation so that there can be no joint between them, the slab may be considered as an integral part of the beam, and the beam figured as a T section. In this case the effective width of slab considered shall not exceed one-fourth of the span length of the beam nor be greater than four times the thickness of the slab on either side of the edge of the web.

The design of reinforced concrete beams and girders involves the following studies:

(1) The bending moment due to the live and dead loads, this involving the selection of the proper formula for the computation.

(2) Dimensions of beams which will prevent an excessive compression of the concrete in the top and which will give the depth and width which is otherwise most economical.

(3) Number and size of rods to sustain tension in the bottom of the beam.

(4) Shear or diagonal tension in the concrete.

(5) Value of bent-up rods to resist shear or diagonal tension.

(6) Stirrups to supplement the bent-up rods in assisting to resist the shear or diagonal tension.

(7) Steel over the supports to take the tension due to negative bending moment.

(8) Concrete in compression at the bottom of the beam near the supports due to negative bending moment.

(9) Horizontal shear under flange of slab.

(10) Shear on vertical planes between beams and flanges.

(11) Distance apart of rods to resist splitting.

(12) Length of rods to prevent slipping.

(13) End connections at wall.

Although it is not the province of this book to go into the mathematical treatment of these various points, many of them are as yet so inadequately treated in literature on the subject that it will be advisable to touch upon them in a general way.

†BENDING MOMENT.—In the design of reinforced concrete beams and slabs as much variation may be obtained in the results by the selection of the bending moments as in the choosing of working stresses. When the beam or slab is designed as continuous over the supports it is absolutely necessary that the beam be really continuous both in design and in construction; that the stresses due to negative bending moment at the support be provided for, and that the steel be accurately placed. Under these conditions the following formulas are recommended as good practice:

Let $M =$ bending moment in foot pounds.

$w =$ load uniformly distributed in pounds per foot of length (both live and dead load).

$l =$ length of member between centers of support in feet.

To transform the bending moment to inch-pounds, multiply by 12.

For beams and slabs truly continuous and thoroughly reinforced over the supports,

$M = \frac{1}{12} wl^2$ at center and at support.

For beams and slabs partially continuous, as end spans, or for continuous members of 2 or 3 spans.

$M = \frac{1}{10} wl^2$ at center and adjoining support.

For beams and slabs simply supported at the ends and not continuous.

$$M = \frac{1}{8} wl^2.$$

The negative bending moments which exist at the support in continuous beams must be provided for by steel rods carried over the top of the support for tension and by a sufficient area of concrete and steel at the bottom of the beam near the support to take the compression. If the compression in the concrete at the bottom of the beam is excessive the beams must either be made deeper next to the support by forming a flat haunch or extra horizontal steel must be inserted. The tensile and compressive reinforcement over supports must extend sufficiently beyond the support to develop the requisite bond strength.

†REINFORCEMENT.—The tensile stress in mild steel must not exceed 16,000 pounds per square inch. For cold twisted steel, because of its higher elastic limit and its deformed surface which distributes any cracking, a higher stress of 18,000 pounds may be used. The compressive stress in reinforcing steel must not exceed 16,000 pounds per square inch nor more than 15 times the working compressive stress in the concrete.

†SPACING OF BARS.—The lateral spacing of parallel bars should not be less than two and one-half diameters, center to center, nor should the distance from the side of the beam to the center of the nearest bar be less than two diameters. The clear vertical spacing between two layers of bars should not be less than ½ inch.

†CONCRETE.—If the concrete is made of first-class materials mixed not leaner than 1 part cement to 2 parts sand to 4 parts stone, so as to have a compressive strength of at least 2,000 pounds per square inch at the age of 28 days, a value as high as 650 pounds per square inch for the extreme fiber compression in beams and slabs may be used with safety, provided the computation is based on what is termed the straight-line distribution of stress, and the ratio of the modulus of elasticity of steel to concrete is taken at 15.

†WORKING STRESSES IN BEAMS AND SLABS.—The following working stresses are for concrete composed of 1 part Portland cement, 2 parts sand and 4 parts broken stone or gravel and capable of developing an average compressive strength of 2000 pounds per square inch at 28 days:

a. Modulus of elasticity. The modulus shall be assumed as 1/15 that of steel; that is, a ratio of 15 shall be used.

b. Compression in extreme fiber. The extreme fiber stress in beams and slabs calculated for constant modulus of elasticity shall be 650 pounds

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†The values to be used in determining bending moments, allowable unit stresses, moduli of elasticity, etc., are usually definitely specified in the Building Codes and Regulations of the larger cities

per square inch. Adjacent to the support of continuous beams, stresses 15 per cent higher may be used.

c. Bearing. For compression on surface of concrete larger than loaded area 650 pounds per square inch.

d. Bond. The bonding stress between concrete and plain reinforcing bars shall be 80 pounds per square inch, and between concrete and deformed bars from 100 to 150 pounds per square inch, depending upon the character of the bar.

†SHEAR AND DIAGONAL TENSION.—The bending of a beam produces a tendency of the particles within the beam to pull apart. It is therefore necessary to study the vertical shear, the horizontal shear and the diagonal tension in a beam. When the maximum shearing stresses exceed the value allowed in tension for the concrete alone, web reinforcement must be provided to assist in carrying the diagonal tension stresses. This web reinforcement may consist of bent bars, or inclined or vertical members attached to or looped about the horizontal reinforcement. Where inclined members are used the connection to the horizontal reinforcement must be such as to insure against slip. Experiments prove that the bending up of the reinforcing bars in different adjoining planes increases the strength of the beam in shear to a very considerable extent, and that if the total shearing stress for 1:2:4 concrete does not exceed 120 pounds per square inch we are justified in assuming that the concrete carries one-third of the shear and the reinforcement the balance. The following allowable values for the maximum shearing stress should be used.*

a. For beams with horizontal bars only and without web reinforcement, calculated by the formula $v = \frac{V}{bjd}$, 40 pounds per square inch.

b. For beams thoroughly reinforced with web reinforcement, the value of the shearing stress being calculated according to the formula, 120 pounds per square inch, the web reinforcement shall be proportioned to resist two-thirds of the shearing stresses, as computed by the formula.

c. For punching shear, 120 pounds per square inch.

COLUMNS.

The most important of all the members of the building are the columns, for if a column fails the entire building is liable to go down.

Columns of short length, essentially piers, the length of which is not more than six times the least lateral dimension, may be built of plain concrete with no reinforcement, provided the loading is central. Columns longer than this should be reinforced for safety in construction and also to guard against the possibility of eccentric loading and the danger of sudden failure.

The ratio of the unsupported length of a column to its least width should be limited to 15.

The effective area of a column to use in figuring the compression should be less than the total area to allow a certain surface covering for fire protection. Where the contents of a building are especially inflammable this protective covering should be taken to a depth of 1½ inches on all surfaces, but if the contents are not of a particularly inflammable nature a decrease in the total diameter or width of a column of 1 to 2 inches is a fair allowance.

Columns may be reinforced by means of longitudinal rods, by bands or hoops, by bands or hoops together with longitudinal bars, or by structural shapes sufficiently rigid to act as columns themselves. Bands or hoops increase greatly the "toughness" of a column and its ultimate strength, but have little effect upon its behavior within the elastic limit. They do, however, tend to make the concrete a safer and more reliable material and should permit of a somewhat higher working stress.

The following are working stresses in the concrete for the several types of columns:

PLAIN COLUMNS.—Plain columns or piers whose length does not exceed 6 diameters, 25 per cent of the compressive strength of 28 days or 500 pounds per square inch on 2,000-pound concrete.

REINFORCED COLUMNS

a. Columns with longitudinal reinforcement only, the unit stress recommended for plain columns, plus the allowance for the value of the longitudinal steel.

b. For columns reinforced with not less than 1 per cent. and not more than 4 per cent. of longitudinal bars, and with bands, hoops, or spirals, as specified above, a stress of 700 pounds per square inch, provided the ratio of the un-

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*Taylor & Thompson, "Concrete, Plain and Reinforced," Third Edition, Page 39.

†The values to be used in determining bending moments, allowable unit stresses, moduli of elasticity, etc., are usually definitely specified in the Building Codes and Regulations of the larger cities.

supported length of the column to the diameter of the hooped core is not more than 100.

c. For the core of the structural steel column, 350 pounds per square inch.

In all cases, longitudinal steel is assumed to carry its proportion of stress in accordance with the ratio of modulus of elasticity of steel to modulus of elasticity of the concrete.

Bars composing longitudinal reinforcement shall be straight, and shall have sufficient lateral support to be securely held in place until the concrete has set.

Where bands or hoops are used the total amount of such reinforcement shall not be less than 1 per cent of the volume of the column enclosed. The clear spacing of such bands or hoops shall not be greater than one-fourth the diameter of the enclosed column. Adequate means must be provided to hold bands or hoops in place so as to form a column, the core of which shall be straight and well centered.

Bending stresses due to eccentric loads must be provided for by increasing the section and adjusting the steel until the maximum stress does not exceed the values above specified.

The compressive strength of concrete is approximately proportional to the amount of cement which it contains, so that increasing the proportion of cement is an effective method of strengthening the column to permit smaller section. By using proportions of 1:1:3 a safe working stress of 700 pounds per square inch may be adopted. If this is done the same mixture should be carried up through the floor so that there will be no weak places.

WALLS.

The walls of reinforced concrete factories are sometimes built up with the columns, but it is generally considered more economical to erect the skeleton structure and fill in the wall panels later, when columns forms are removed.

Slots in the columns are made by nailing a strip on the inside of the column forms. In this ways the panels are mortised into the columns.

Ordinary concrete walls require light reinforcement to prevent shrinkage and give them stiffness while setting. All that is required for, say, a 4-inch or 6-inch wall are ¼-inch bars spaced from 12 to 24 inches apart, according to the size and importance of the wall. At window and door openings a larger amount of reinforcement is of course necessary, and in these cases the amount of steel must be calculated just as though the lintels were reinforced concrete beams.

ROOFS.

Reinforced concrete roofs are designed like floors. A roof load commonly assumed in temperate climates, to provide for roof covering, snow and wind pressure, is 40 pounds per square foot, in addition to the weight of the concrete itself.

It is not safe to assume that the concrete roof of itself will be water-tight unless special provision is made in the construction. Although tanks and walls can readily be made to hold water, a roof is under extraordinarily disadvantageous conditions because of the rays of the sun. Usually, therefore, a tar and gravel or other form of roof covering must be provided.

CONSTRUCTION.

The details of construction are treated at length for individual buildings in the chapters which follow. Chapter XX also takes up many special points and treats as well of different methods of reinforcing.

A reinforced concrete building must have careful inspection while in process of erection, the special points to be observed being:

(1) Exact proportioning of materials.

(2) Mixing to a consistency only wet enough to flow sluggishly.

(3) Placing the concrete so as to prevent separation of ingredients.

(4) Placing concrete to avoid joints except where called for.

(5) Exact placing and imbedding of the reinforcement.

(6) Proper securing of the forms.

(7) Maintenance of the forms in position until the concrete is sufficiently strong.

CHAPTER III—CONCRETE AGGREGATES

The term "aggregate" includes not only the stone, but also the sand which is mixed with cement to form either concrete or mortar; in other words, it is the entire inert mineral material. This definition, now generally accepted, has replaced the one restricting the term to the coarse aggregate alone. It is the object of this chapter to enumerate the general principles which should be followed in the selection of sand and stone for mortar and concrete, and to describe briefly the method of testing aggregates and determining proportions which the author has found to give good results in practice.

At the outset it may be said that a concrete of fair quality, if rich enough in cement, can be made with nearly any kind of mineral aggregate, but there is, nevertheless, a wide variation in the results produced. For the fine aggregate, sand, broken stone, screenings, pulverized slag or the fine material from cinders may be used separately or in combination with each other. For the coarse aggregate, broken stone, gravel, screened gravel slag, crushed lava, shells, broken brick, or mixtures of any of these may be employed. However, the very fact of the adaptability of concrete to so wide a range of materials, every one of which really consists of a large class varying in size, shape and composition, tends to blind one to the economies which often may be affected and the improvement in quality which almost always will result by a careful selection and proportioning of the aggregates.

In many cases, especially where the cost of Portland cement is low, it may be cheaper to use whatever materials are nearest at hand, and insure the quality of the concrete or mortar by making it excessively rich in cement. If the structure is small and of little importance this course is properly followed, but, on the other hand, if a large amount of concrete is to be laid, and especially if the process is to be carried on in a factory, as in concrete block manufacture, it pays from the standpoints of both quality and economy, to use great care in the selection of the aggregates, as well as of the cement, and to provide means for maintaining uniformity.

To illustrate the variation which different aggregates may produce even when they are mixed with cement in the same proportions, the author has selected a few comparative tests of mortar and concrete.

EFFECT OF DIFFERENT AGGREGATES UPON THE STRENGTH OF MORTAR AND CONCRETE.

Tests by Mr. Rene Feret*, of France, with mortar made from different natural sands, show a surprising variation in strength, which is evidently due simply to the fineness of the sand of which the different specimens are composed. Selecting from his results proportions 1:2½ by weight—that is, 1 part cement to 2½ parts sand—and converting his results at the age of five months from French units to pounds per square inch, the average tensile strength of Portland cement mortar made with coarse sand is 421 pounds per square inch, with medium sand 368 pounds per square inch, and with fine sand 302 pounds per square inch. In the crushing strength, usually the most important consideration, the difference is even more marked. In round numbers at the age of five months the mortar of coarse sand gave 5,200 pounds per square inch; of the medium sand, 3,400 pounds per square inch, and of the fine sand 1,900 pounds per square inch. Note that the different sands were not artificially prepared, but were taken from the natural bank and correspond to those which every day are being used for concrete and mortar.

The effect of different mixtures of the same kind of material is shown by tests made by the author in 1905.† By varying the sizes of the particles of the aggregates, but using in all cases stone from the same ledge and the same proportion of cement to total aggregate by weight, namely, 1:9 (or approximately 1:3:6), it was found possible to make specimens the resulting strengths of some of which were two and a half times the strength of others.

GENERAL PRINCIPLES FOR SELECTING STONE.

The quality of concrete is affected by the hardness of the stone, the shape of the particles, the

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*Taylor & Thompson's "Concrete, Plain and Reinforced." page 136.

†Proceedings American Society of Civil Engineers, Vol. LIX, 1907.

maximum size of the particles and the relative sizes of the particles.

If broken stone is used, and there is an opportunity for choice, the best is that which is hard; with cubical fracture; with particles whose maximum size is as large as can be handled in the work; with the particles smaller than, say ¼ inch, screened out to be used as sand; and with the sizes of the remaining coarse stone varying from small to large, the coarsest predominating.

If gravel is used it must be clean. The maximum size of particles should be as large as can be handled in the work; grains below ¼ inch should be screened out to be used as sand, and the size of the stone should vary, with the coarsest predominating.

As already stated, the size of the coarsest particles of stone should be as large as can be handled in the work. This is because the strength of the concrete is thereby increased and a leaner mixture can be used than with small stone. In mass concrete the stones if too large are liable to separate from the mortar, and a practical maximum size is 2½ or 3 inches. In thin walls, floors and other reinforced construction a 1-inch maximum size is generally as large as can be easily worked between the steel. In some cases where the walls are very thin a ¾-inch maximum size is more convenient to handle.

It is a little more trouble but always best to screen out the sand from gravel or the fine material from crushed stone, and then remix it in the proportions required by the specifications, for otherwise the proportions will vary at different points, and one must use and pay for an excess of cement to balance the lack of uniformity.

If the gravel is used, it is absolutely essential that it shall be clean, because if clay or loam adheres to the particles the adhesion of the cement will be destroyed or weakened. Tests of the Boston Transit Commission give an average unit transverse strength of 605 pounds per square inch for concrete made with clean gravel as against 446 pounds per square inch when made with dirty gravel.

COMPARATIVE VALUES OF DIFFERENT STONE.

Different stones of the same class vary so widely in texture and strength that it is impossible to give their exact comparative values for concrete. A comparison by the author of a large number of tests of concrete made with different kinds of stone indicates that the value of a broken stone for concrete is largely governed by the actual strength of the stone itself, the hardest stone producing the strongest concrete. This forms a valuable guide for comparing different stones. Comparative tests indicate that different stones in order of their value for concrete are approximately as follows: (1) Trap, (2) granite, (3) gravel, (4) marble, (5) limestone, (6) slag, (7) sandstone, (8) slate, (9) shale, (10) cinders. Although, as stated above, the wide difference in the quality of the stone of any class makes accurate comparisons impossible—and this difficulty is increased by the fact that the proportions and age of the specimens affect their relative value—an approximate estimate drawn from actual tests gives the value for concrete of good quality sandstone as not more than three-fourths the value of trap, and the value of slate as less than half that of trap. Good cinders nearly equal slate and shale in the strength of concrete made with them.

The hardness of the stone grows in importance with the age of the concrete. Thus gravel concrete, because of the rounded surfaces, at the age of one month may be weaker than a concrete made with comparatively soft broken stone; but at the age of one year it may surpass in strength the broken stone concrete, because as the cement becomes hard there is greater tendency for the stones themselves to shear through, and the hardness of the gravel stones thus comes into play. Gravel makes a dense mixture, and if much cheaper than broken stone, can usually be substituted for it.

A flat grained material packs less closely and generally is inferior to stone of cubical fracture.

GENERAL PRINCIPLES FOR SELECTING SAND.

The only characteristic of sand which need be considered are the coarseness of its grains and its cleanness. These qualities affect the density of the mortar produced, and therefore the test of the volume of mortar, or "yield" determines which of two or more sands is best graded. The "yield" or "volumetric" test is considered by the author of greater value for quick results than all others put together. The methods of employing it are described farther along in the paper.

The best sand is that which produces the smallest volume of plastic mortar when mixed with cement in the required proportions by weight.

A high weight of sand and a corresponding low percentage of voids are indications of coarseness and good grading of particles; but because of the impossibility of establishing uniformity in weighing or measuring, they are merely general guides which cannot under any conditions be taken as positive indications of true relative values. The various characteristics of sand are separately considered in the following paragraphs:

WEIGHT OF SAND.—A heavy sand is generally denser, and therefore better than a light sand. However, this is not a positive sign of worth, because the difference in moisture may affect the weight by 20 per cent., and when weighed dry the results are not comparable for mortars since fine sand takes more water than coarse.

As an illustration of the variation in weight of natural sands having different moisture, the author found that the weight per cubic foot of Cowe Bay sand, which dry averaged 103 pounds, when placed out of doors and after a rain shoveled into a measure and weighed in exactly the same way (although it was allowed to drain for two days) averaged 83 pounds.

VOIDS IN SAND.—The voids, like the weight, are so variable in the same sand, because of different percentages of moisture and different methods of handling, that their determination is of but slight value. In the Cowe Bay sand just mentioned, the voids were 38 per cent in the sand, dry, and 52 per cent in the same sand, moist.

Because of such discrepancies, the author prefers to mix the sand with the cement and water, and determine the voids in the fresh mortar, as described later. This gives a true comparison of different sands, since with the same percentage of cement, the mortar having the lowest air plus water voids is the strongest.

COARSENESS OF SAND.—A coarse sand produces the densest, and, therefore, the strongest mortar or concrete. A sufficient quantity of fine grains is valuable to grade down and reduce the size of the voids, but in ordinary natural material, either sand or screenings, there will be found sufficient fine material for ordinary proportions, such as 1:1, 1:2, or 1:2½. For leaner proportions, such as 1:4 or 1:5, and sometimes 1:3, an addition of fine particles will be found advantageous to assist the cement in filling the voids. A dirty sand, that is, one containing fine clay or other mineral matter, up to say, 10 per cent, is actually found by tests to be better than a clean sand for lean mortars.

For water-tight work it is probable that a larger proportion of very fine grains may be employed than for the best results in strength. This is a question, however, which has not yet been thoroughly investigated.

Feret's rule for sand to produce the densest mortar is to proportion the coarse grains as double the fine, including the cement, with no grains of intermediate size. There is difficulty in an exact practical application of this rule, but it indicates the trend to be followed in seeking maximum density and strength.

CLEANNESS OF SAND.*—An excess of fine material or dirt, as has just been noted, weakens a mortar which is rich in cement. It may also seriously retard its setting. The author's attention was recently called to a concrete lining, one portion of which failed to set hard for several weeks, although the same cement was used as on adjacent portions of the work. The difficulty proved to be due entirely to the fact that the contractor substituted, in this place, a very fine sand, the regular material happening to run low.

SHARPNESS OF SAND.—Notice that the quality of sharpness has not been mentioned among the essential characteristics of sand. This omission was intentional. Many specifications still call for "sharp" sand, and yet the writer has never known a sand to be rejected simply because of its lack of sharpness. As a matter of fact, if two sands have the same sized grains, and contain an equal amount of dust, the one with rounded grains is apt to give a denser and stronger mortar than the sharp grained sand. A sand with a sharp "feel" is preferable to another, not to any extent because of its sharpness, but because the grittiness indicates a silicious sand which is apt to have no excess of fine material.

SAND VS. BROKEN STONE SCREENINGS.—Many comparative tests of sand and screenings have been made with contrary results. While frequently crusher screenings produce stronger mortar than ordinary sand, the author

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*The danger of vegetable impurities and the necessity for tensile tests referred to on page 13. See also page 26.

in an extensive series of tests has found the reverse to be true. This disagreement is probably due to the grading of the particles, although in certain cases the screenings may add to the strength because of hydraulicity of the dust when mixed with cement.

TESTING SAND.

Previous paragraphs show the defects in the more common methods of examining sand.

Tests made by the author in 1903 proved the value of the principles of the density of mortars laid down by Feret, and in the winter of that year similar plans for testing aggregates were introduced by Mr. William B. Fuller and the author at Jerome Park Reservoir, New York City. The object of the test is to determine which of two or more sands will produce the denser, and therefore the stronger, mortar in any given proportions.

The different results in strength which Mr. Feret found with coarse, medium and fine sand respectively have already been given, these relative strengths in compression being respectively 5,200, 3,400 and 1,900 pounds, with proportions 1:2½ by weight in each case. An examination of the tests shows that the strongest mortar was also densest; that is, the smallest volume or yield of mortar was produced with a given weight of aggregate.

The mortar of medium sand occupied a volume 7½ per cent in excess of the volume of the mortar with coarse sand; and the mortar of fine sand, a volume 17 per cent in excess of the mortar with coarse sand.

Following these principles, two sands may be compared and the better one selected by determining which produces the smallest volume of mortar with the given proportions by weight. Using the method described below, the author has been able to increase the strength of a mortar about 40 per cent by merely changing the sizes of grains of the aggregate.

The method of making the test is as follows: If the proportions of the cement to sand are by volume, they must be reduced to weight proportions; for example, if a sand weighs 83 pounds per cubic foot moist, and the moisture found by drying a small sample of it at 212° Fahr. is 4 per cent, which corresponds to about 3 pounds in the cubic foot, the weight of dry sand in the cubic foot will be $83 - 3 = 80$. If the proportions by volume are 1:3, that is, one cubic foot dry cement to 3 cubic feet of moist sand, and if we assume the weight of the cement as 100 pounds per cubic foot, the proportions by weight will be 100 pounds cement to $3 \times 80 = 240$ pounds of sand, which correspond to proportions 1:2 4/10 by weight.

A convenient measure for the mortar is a glass graduate, about 1½ inches in diameter, graduated to 250 cubic centimeters. A convenient weight of cement plus sand, for a test, is 350 grams. For weighing, the author employs Harvard Trip scales, which weigh with fair accuracy to one-tenth of a gram. The sand is dried and mixed with cement, in the calculated proportions, in a shallow pan about 10 inches in diameter and 1 inch deep. The mixing is conveniently done with a 4-inch pointing trowel. The dry mixed material is formed into a circle, as in mixing cement for briquets, and sufficient water added to make a mortar of plastic consistency, similar to that used in laying brick masonry. After mixing five minutes, the mortar is introduced about 20 c.c. at a time into the graduate, and to expel any air bubbles, is lightly tamped with a round stick with a flat end. The mortar is allowed to settle in the grduate for one or two hours until the level becomes constant, when the surplus water is poured off, and the volume of the mortar in cubic centimeters is read. For greater exactness, a correction may be introduced for mortar remaining on pan and trowel. The other sands, which are to be compared with this one, are then mixed with cement in the same proportions by dry weight, and sufficient water added to give the same consistency. The percentage of water required will vary with the different aggregates, the finer sand requiring the more water. After testing all the mortars, the sand which produces the strongest mortar is immediately located as that in the mortar of lowest volume. By systematic trials, the best mixture of two or more sands may also be found.

In some cases a correction must be introduced for the specific gravity of the sand; for example, ordinary bank sand has an average specific gravity of 2.65, but if this is to be compared with broken stone screenings having a specific gravity of, say, 2.80, the proportions of the two must be made slightly different. For these particular specific gravities, proportions 1:3, by weight, with sand, correspond in absolute volume to proportions 1:3 2/10, by weight, of the screenings.

In making these tests, it is also important to notice the character of the mortar as it is being mixed. It should work smooth under the trowel and be practically free from air bubbles.

TESTING SANDS FOR ORGANIC IMPURITIES

The Colorimetric Test for Sand, developed by the Structural Materials Research Laboratory,* Lewis Institute, Chicago, is for the purpose of determining the amount of organic impurities in sand. It is not intended as a test for the grading or granulometric composition of the sand.

The following is an extract from the Circular of the Lewis Institute describing the test, of which only the Field Test is given here:

"A sample of sand is digested at ordinary temperature in a solution of sodium hydroxide (NaOH). If the sand contains certain organic materials, thought to be largely of a humus nature, the filtered solution resulting from this treatment will be found to be of a color ranging from light yellow up through the reds to that which appears almost black. The depth of color has been found to furnish a measure of the effect of the impurities on the strength of mortars made from such sands. The depth of color may be measured by comparison with proper color standards."

"Two methods of procedure have been developed: (1) For Field Tests; (2) For Laboratory Tests.

"METHOD FOR FIELD TESTS.

"Fill a 12-oz. graduated prescription bottle to the 4½-oz. mark with the sand to be tested. Add a 3 per cent solution of sodium hydroxide until the volume of the sand and solution, after shaking, amounts to 7 oz. Shake thoroughly and let stand over night. Observe the color of the clear supernatant liquid.

"In approximate field tests it is not necessary to make comparison with color standards. If the clear supernatant liquid is colorless, or has a light yellow color, the sand may be considered satisfactory is so far as organic impurities are concerned. On the other hand, if a dark-colored solution, ranging from dark reds to black, is obtained the sand should be rejected or used only after it has been subjected to the usual mortar strength tests.

"Field tests made in this way are not expected to give quantitative results, but will be found useful in:

"(1) Prospecting for sand supplies;

"(2) Checking the quality of sand received on the job;

"(3) Preliminary examination of sands in the laboratory.

"An approximate volumetric determination of the silt in sand can be made by measuring or estimating the thickness of the layer of fine material which settles on top of the sand. The per cent of silt by volume has been found to vary from 1 to 2 times the per cent by weight."

TESTING CONCRETE AGGREGATES.

For concrete in any given proportions, the best sizes of stone and of sand may be determined by similar methods to those described for testing sand mortars, although larger quantities of materials must be used and the measure must be strong to withstand the light ramming which is necessary. A short length of cast iron pipe, closed at one end, may be used for this.

The aggregates, which mixed with cement in the required proportions produce the smallest volume of concrete, are usually the best, although, as already indicated, the shape of the particles and their hardness must also be taken into consideration.

PROPORTIONING CONCRETE.

A general principle of practical use in determining the relative proportions of two or more aggregates in a concrete is that, the weight of material and the percentage of cement remaining the same, the mixture producing the smallest volume of concrete is the best.

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*Under the auspices of Committee C-9 of the American Society for Testing Materials.

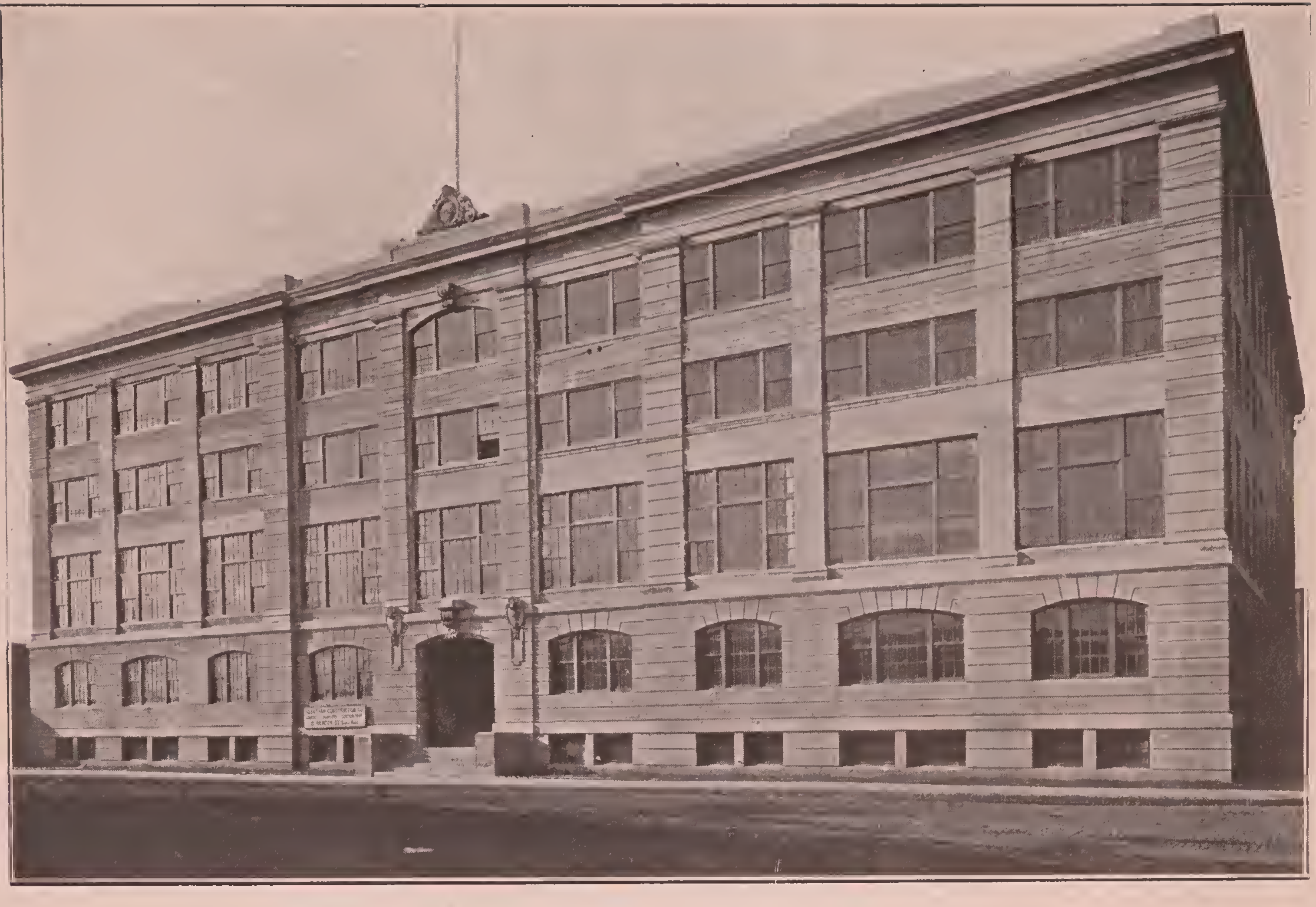


Fig. 4.—Carter's Ink Factory, Cambridge, Mass. Densmore & LeClear, Boston, Architects; Aberthaw Construction Co., Boston, Contractors.

PLANT OF CARTER'S INK COMPANY

The new plant of the Carter's Ink Company, Cambridge, Mass., located on a lot facing the Charles River, is an illustration of the architectural possibilities of reinforced concrete in factory construction. A large majority of concrete factories have been built with no regard whatever to appearance, when with a comparatively small increase in cost it is possible to produce an artistic structure. In the present case the location of the plant on the future Charles River parkway demanded a careful architectural treatment.

Reinforced concrete was chosen on account of its adaptability to architectural design, its economy for the loads required, its fireproof qualities, rapidity of erection, and freedom from vibration.

The plant includes a main building for the manufacture and storage of the company's products, an external toilet room and stairway tower, a power house, and a glass storage building.

The main building (shown in Fig. 4) is an L-shaped structure, four stories high, with a maximum length of 186 feet, a height of 78 feet and an average width of 64 feet. The one-story power house is also of reinforced concrete, 69 feet long and 41 feet wide. The glass storage building, 83 feet long and 61 feet wide, is a one-story frame structure with exterior walls of plaster on wire-lath and concrete floor.

EXTERIOR DESIGN.

In order to gain an architectural effect in keeping with the prominent location of the building, the front and sides were designed with recessed window arches, and variations in window grouping, and trimmed with cast ornamental work and a cornice of quite elaborate design. Winchester gravel was used in the concrete panels and piers, the face being hand picked with smooth draft lines on the various panels to give the proper contrast between the component parts of the front and sides.

REINFORCED CONCRETE DESIGN.

The company's work imposed heavy floor loads and somewhat longer spans than usual in mill construction. The total dead and live loads used in the design were: Basement, 200 pounds per square foot; first floor, storage division, 485 pounds; offices, 150 pounds; lavatory and locker rooms, 125 pounds; second floor, 240 pounds; third and fourth floors, 355 pounds; fourth mezzanine, 320 pounds.

In general, Johnson corrugated bar girder frames were used for reinforcement, the tensile stress allowed being 16,000 pounds per square inch.

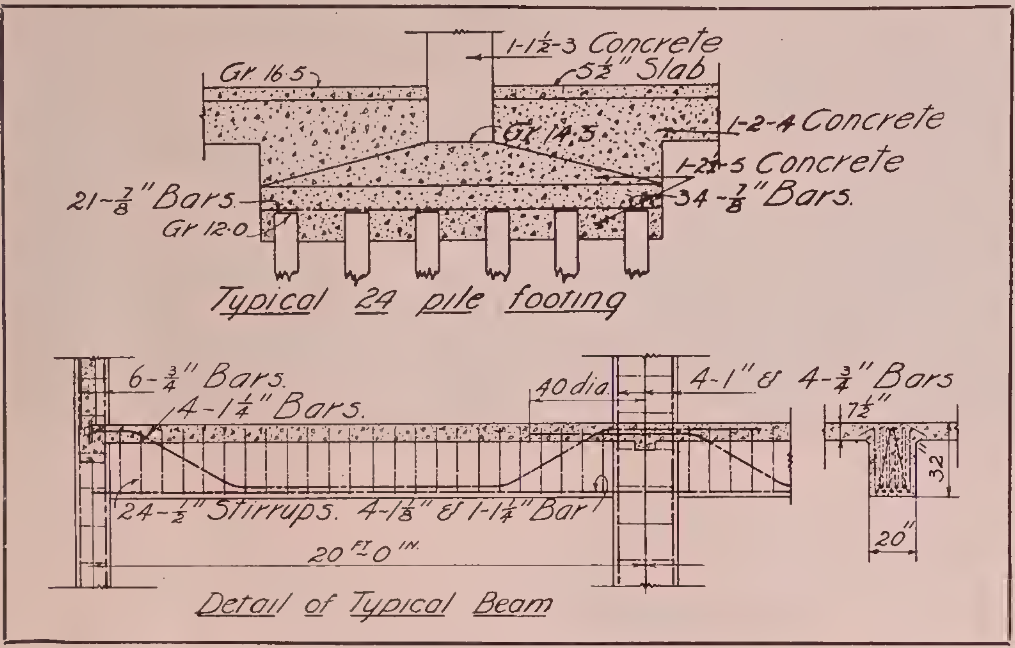


Fig. 5.—Details of Typical Girder and Main Column Footings.

Fig. 6.—Interior of Basement, Carter's Ink Factory.

The concrete for the slabs and girders was mixed in the proportions of 1 part Atlas Portland Cement to 2 parts sand to 4 parts broken stone passing a 1-inch mesh, while the column mixture was 1:1½:3. In the beams and slabs a fibre stress of 600 pounds per square inch was allowed, and the columns were figured on the basis of 600 pounds per square inch in compression.

All curtain walls, and also the basement retaining wall, were 1:2½:5 mixture with an addition of 1 part hydrated lime to 10 parts of cement, to make it more water-tight.

A typical first-floor girder is shown in detail in Fig. 5. These girders have 20-foot spans and are spaced 10 feet 6 inches on centers. They are 20 inches wide and 32 inches deep, reinforced with five 1¼-inch and four 1⅛-inch bars. Four of the 1¼-inch bars are bent up at the quarter points and carried over the support. Each girder has twenty-four ½-inch V stirrups spaced as shown.

The floor slabs are 7½ inches thick, reinforced with ⅝-inch bars spaced 5¾ inches apart.

The photograph in Fig. 6 of the interior of the basement shows the columns and floor system.

The columns throughout are reinforced with four 1-inch and two ¾-inch bars, with ¼-inch hoops 12 inches on centers.

Fig. 7 shows the form work and reinforcement in place for the second-floor construction.

FOUNDATIONS.

The foundation soil is filled land on clay, silt and streaks of sand, and about 200 spruce piles averaging 20 feet in length and 10 inches in diameter at the top were required to carry the buildings. Each pile was figured to carry ten tons.

The footings for the main

columns, of which a typical design is shown in Fig. 5, are of the spread type, each resting upon 24 piles placed 24 inches apart on centers and in rows, 30 inches apart. In general the foundations are of the cut pyramid form and heavily reinforced.

The basement curtain walls are carried from footing to footing, being reinforced as girders with horizontal bars to carry their own load and also with vertical bars to act as retaining walls.

Fig. 7.—View of Carter's Ink Factory During Construction.

COST.

The total cost of the plant was about $160,000. The forms for the columns cost 18 cents per square foot of surface and for the floors 11 cents per square foot of superficial surface. The concrete for the beams and floor slabs cost $6.20 per cubic yard and for the columns $7.25 per cubic yard, while the reinforcing steel cost $41 per ton in place.

KETTERLINUS BUILDING, PHILADELPHIA

The plant of the Ketterlinus Lithographic Manufacturing Company is located in Philadelphia at the northwest corner of Fourth and Arch Streets, and the reinforced concrete portion of the structure built in 1906 represents a type of building adapted to city manufacturing establishments limited to a comparatively small ground area. The building illustrated on a following page as Fig. 9 is eight stories high besides the basement, and its dimensions are 80 by 67 feet. The architects and engineers were Ballinger & Perrot, of Philadelphia, and they also supervised the erection, which was done by day labor with no general contractor.

This new building adjoins and forms a part of the old plant of the Ketterlinus Company, which is of steel frame construction, fireproofed with terra cotta.

In both buildings heavy machinery is now running, and many large printing presses are at work on the third, fourth and fifth floors. Because of the proximity of the old and new types of construction the advantages of the reinforced concrete, from the point of view of the manufacturer, are particularly evident. In the building of steel and terra cotta construction the vibration from the machinery is noticeable as soon as one enters, while on the other hand, in the new structure the concrete, because of its greater mass and inertia, absorbs the vibrations, and it is difficult to appreciate the speed and power of the machines. As a result, too, of this reduction in the vibration the noise of the machinery is effectually deadened.

The building is designed for a working load of 400 pounds per square foot. The concrete for practically the whole of the work was proportioned 1:2½:5, equivalent by actual measurement to one barrel (4 bags) Atlas Portland cement to 9½ cubic feet of sand to 19 cubic feet broken stone, the basis of proportioning is in a barrel of 3.8 cubic feet. The sand was well graded coarse material, frequently termed in the region of Philadelphia "Jersey gravel"; the stone was trap rock broken to a size at which all the particles would pass a one-inch ring excepting the stone in the concrete immediately surrounding the steel, which was of a size to pass through a half-inch ring.

To harmonize with the old adjoining building of which it forms a part, the exterior walls are faced with brick with terra cotta trimmings.

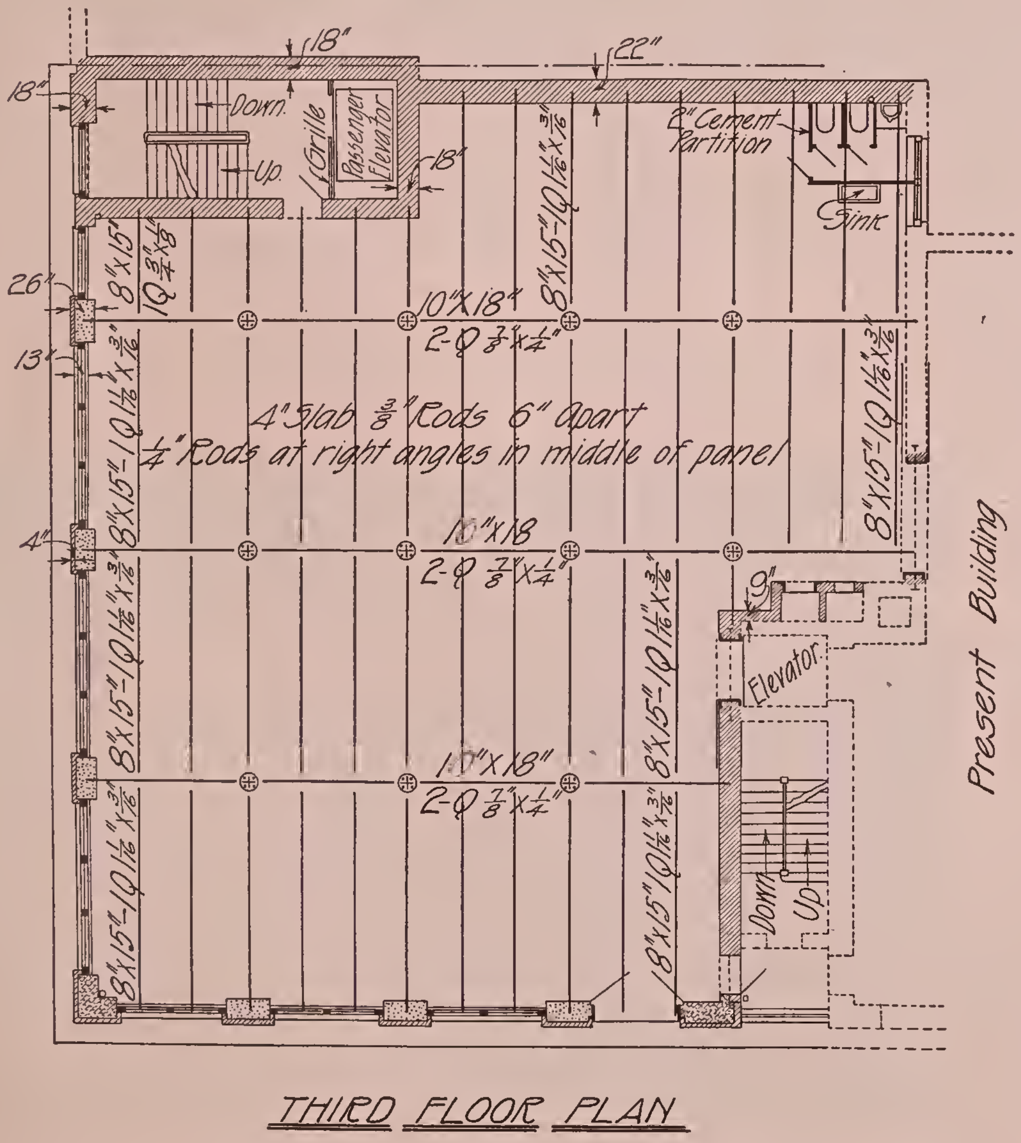


Fig. 8.—Typical Floor and Roof Plans of the Ketterlinus Building.

DESIGN.

Several features in the design of the Ketterlinus building are of unusual interest. The columns below the fifth floor, instead of being the usual solid concrete construction with four or more round rods for reinforcement, are essentially steel columns surrounded by concrete. The beams and girders are reinforced with the unit frame system in which the steel is all put together in the shop and brought to the job ready to place in the form. The saw-tooth roof is also a novel feature for reinforced concrete.

The columns are spaced 13 feet 6 inches apart in one direction and 19 feet 2 inches in the other. The girders follow the shorter span, and the bays are divided into three panels by the cross beams, as shown in Fig. 8.

COLUMNS.

One of the problems in concrete building construction where the loads are heavy or the building is several stories high, is to build the columns small enough to satisfy the requirements of the occupants and owners without overloading the concrete. Its solution is especially difficult in a city building where the land area is so valuable that every square inch of floor space is at a premium, and where there must be more stories than are economical under other conditions. Moreover, the building laws of many cities require more conservative loading than might be warranted if it were certain that the conditions of construction were in all cases the best.

In a number of recent instances the difficulty has been met by the use of composite columns, a combination of concrete and structural steel, and this is the plan followed by the designers of the Ketterlinus building. Full details of the column construction are presented in Fig. 10.

The interior columns in the building up to the fifth floor are 23 inches in diameter. In the basement and the four lower stories, the core of the column is formed of steel plates and angle irons riveted together in the form of a cross. Around this cross 1/8 inch wire ties were placed every 12 inches and looped around four vertical round rods which increased the reinforcement. In the basement, for example, the center steel is made up of a plate 18 inches wide and 5/8 inch thick with two plates of similar thickness but 8 inches wide at right angles to it, and four angle irons 6 by 6 by 5/8 inch all riveted together. The four round rods, which complete the so-called "Star" reinforcement, are 1 1/8 inch diameter.

The columns in the three stories nearest the top are designed to carry the full dead and live loads of floors and roof. In each lower story the columns are designed to carry the full dead load

Fig. 9.—The Ketterlinus Building. (*See p.* 30).
Architects and Engineers, Ballinger & Perrot of Philadelphia.

and a smaller proportion of the full live load than can be carried by the floor construction, this live load factor being reduced proportionately to the number of floors carried; for example, the basement columns were calculated on a basis of carrying on the steel cores alone three-fourths the live load plus the full dead load with a factor of safety of 4.

The steel is designed to bear the computed load without exceeding a maximum compression of 16,000 pounds per square inch. The compressive strength of the concrete in these columns is not considered, though almost sufficient to carry the dead load.

The weight of the girders is borne in part by brackets of steel riveted to the angle irons and partly by the concrete knees or enlargements of the columns which run out obliquely from the columns and which are reinforced on each side by two ½-inch rods.

Above the fourth story the columns are of the same diameter but with the more ordinary reinforcement of four round rods.

FLOOR SYSTEM

Each girder was designed as an independent beam supported at the ends by the enlargement of the columns and the steel brackets. The area of the reinforcing steel was calculated in the usual way, but instead of placing each rod separately in the form, girder frames were made from quadruple or twin webbed bars, which were cut, bent to shape and stirrups fastened thereto in the shop. The girder frame reinforcement was brought to the building in the form of a truss, and the work of placing consisted simply of setting this truss in the form upon cast steel sockets, each having a ¾-inch threaded stud projecting upward through the frame. A nut screwed down on this stud over the frame holds it rigidly in position. Every rod and every member could not help but be in exactly the right location in the beam. This girder frame and socket were the invention of Emile G. Perrot, one of the firm of architects who designed the building, the object being to insure the exact amount and arrangement of tension and shear members in the exact location as designed, and to afford opportunity for inspection of the steel in position before the pouring of the concrete.

In the various plans the letter "Q" is entered as a part of the description of the reinforcement. This stands for the word "Quadruple" and indicates a group of four rods held at intervals by

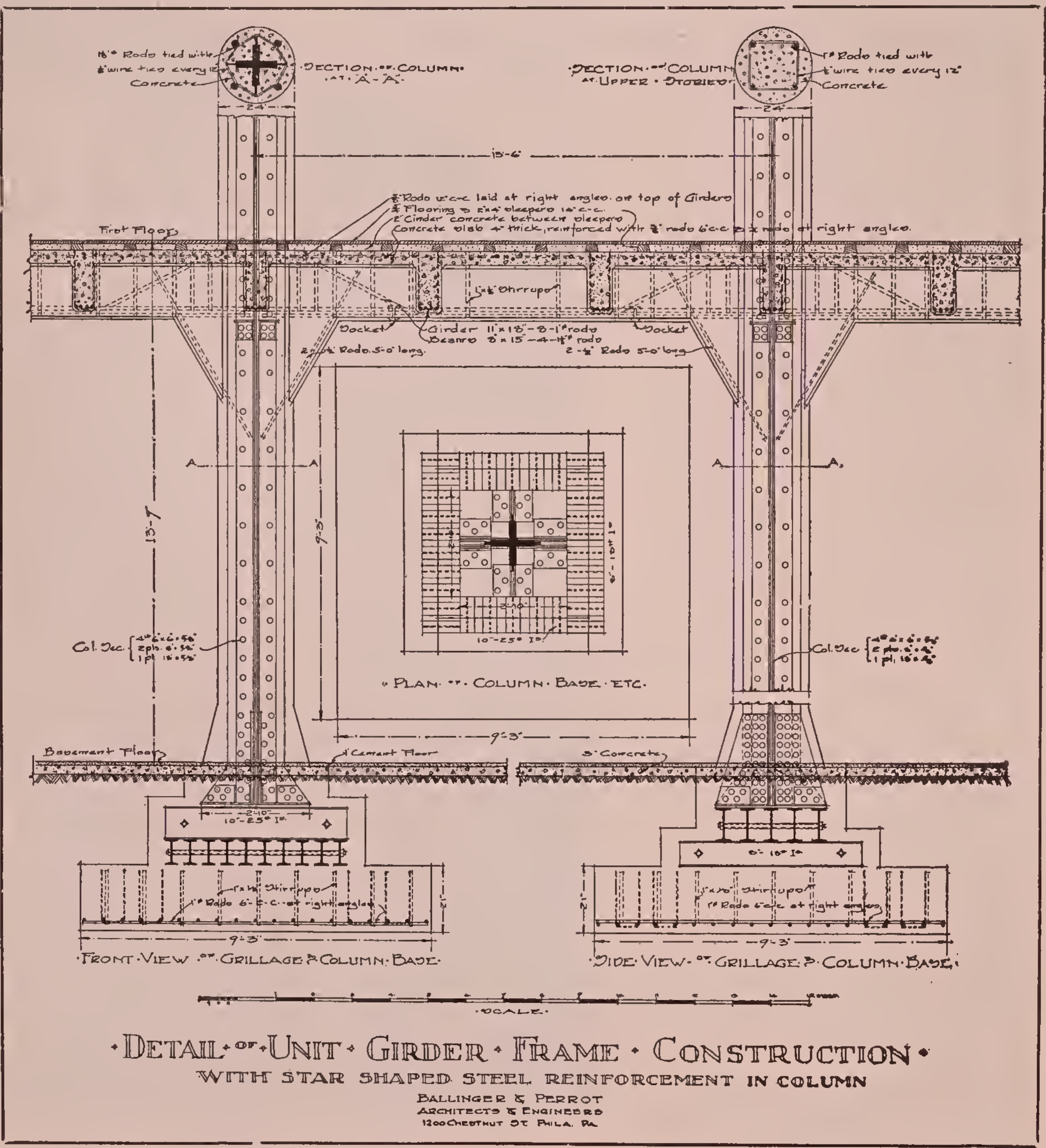


Fig. 10.—Details of Columns and Girders.

special sockets.

The rods are rolled in sets of four, connected by a web, and this web is sheared and bent down in 2-inch lengths at intervals of 3 inches to give greater grip in the concrete. These 2-inch lengths are bent back over stirrups, where they occur, to clinch them in position on the frame. The outside bars are also cut loose at each end and bent upward to reinforce the top of the beam near the supports. The sockets (Fig. 10.) are shaped so that they support the rods 1½ inches above the bottom the beam or girder, and are held in place by a ¾-inch bolt passing up through the bottom of the wood mold. These threaded sockets afterward are used for securing shafting, hangers or other fixtures.

In the various dimensions of beams on the plan, the width and depth is given first, followed by "1 Q" or "2 Q" (the latter meaning 8 rods), then the diameter of rod, and finally the thickness of the web forming a part of the rods. Thus 10″x18″-2Q⅞″x¼″ means that the beam is 10 inches wide by 18 inches deep, reinforced with two groups of four rods ⅞ inch diameter, connected longitudinally by webs ¼ inch thick. The depth of the beams and girders is given from the under side of the slab instead of from the top of the slab, the more usual form. The area of cross-section of each of such "Q" bars is about 3 square inches.

The slabs are of usual construction, being 4 inches thick and reinforced for the net span of 3 feet 10 inches with 3-inch No. 10 expanded metal, this mesh having been substituted instead of ⅜-inch rods spaced 6 inches apart and occasional ¼-inch rods running in the other direction, as originally shown on the drawings, at an increase of about one per cent of the cost of the building.

The wearing surface is a 1¼-inch maple wood floor on 2 by 4-inch sleepers 16 inches apart. The sleepers are placed on the concrete slab and cinder concrete in proportions 1:3:7 filled in between them.

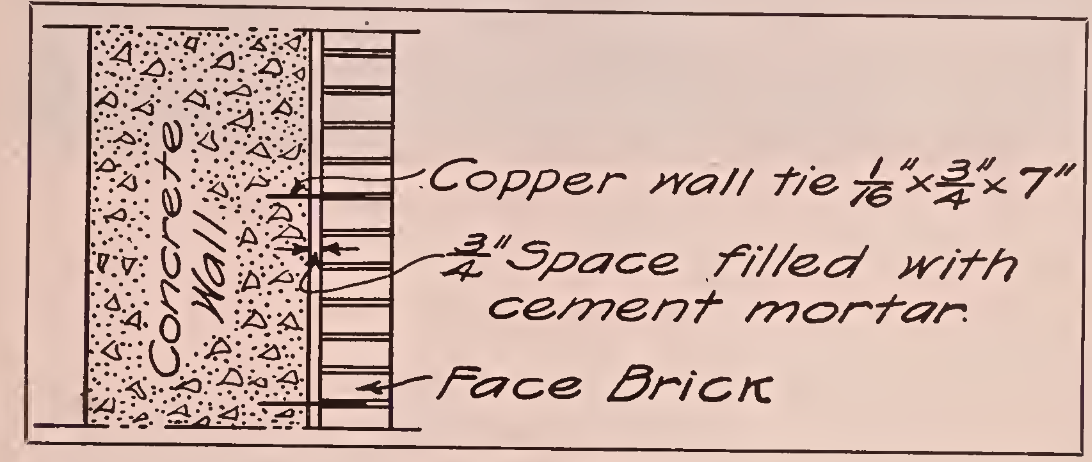


Fig. 11—Brick Wall Ties.

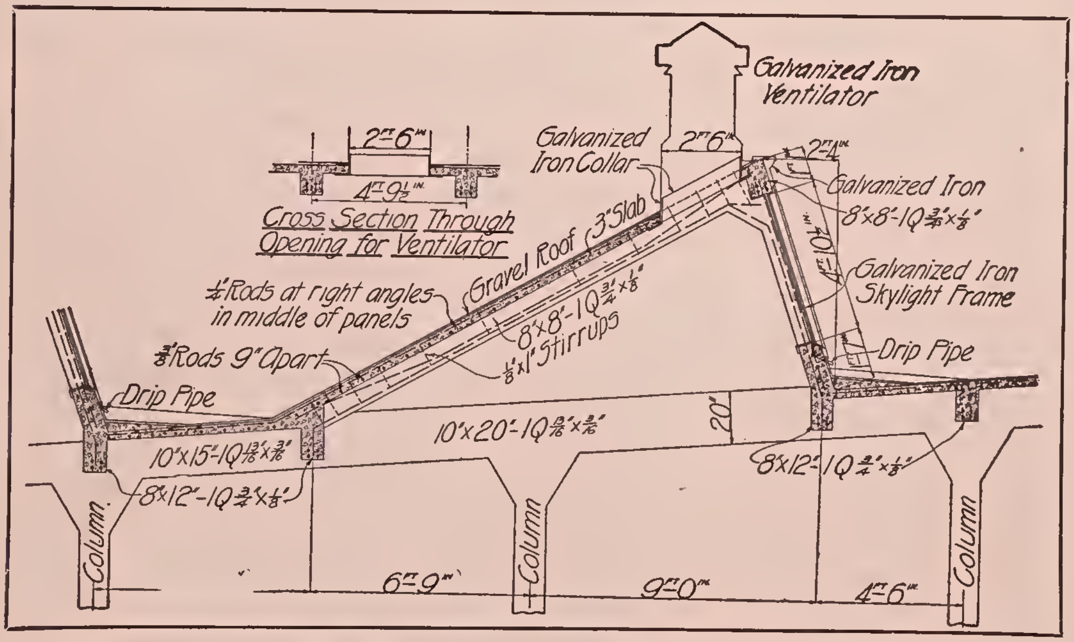


Fig. 12—Cross Section Detail of Saw-Tooth Roof.

WALLS.

The walls are essentially reinforced concrete columns, veneered on the outside with 4 inches of brickwork and separating the windows. The window lintels are of concrete faced with terra cotta to match the red sandstone of the older building adjoining and anchored to the concrete. The lintels form reinforced concrete beams and support a brick wall 13 inches thick, which is run up to the bottom of the terra cotta window sills.

The method of connecting the brick with the concrete of the columns is shown in Fig. 11, copper wall ties 1⁄16 by ¾ by 7 inches being set in the concrete at intervals, and, after the removal of the forms, bent out and laid into the joint of the face brick, which is separated from the concrete

Fig. 13—Interior of Ketterlinus Building, Showing 20-Ton Lithographic Press.

by a ¾-inch mortar joint for purposes of alignment.

ROOF.

The general design of the saw-toothed roof appears on the full cross-section, Fig. 12. In Fig. 12 the details are illustrated. Inclined girders extend across the building, and above these project the sawteeth, which rest upon concrete beams running into the girders. Saw-tooth construction in reinforced concrete is, of course, expensive, because of the irregularities of the forms, but with the aid of the unit reinforcing system, which accurately locates the steel, the design is satisfactorily worked out.

As in the other plans, the letter "Q" indicates a quadruple bar whose web thickness is designated by the final fraction in the dimensions. In the roof, instead of the four bars being on one plane and rolled all together with a single web, they are arranged in pairs, with a web connecting the two bars of each pair.

COST.

The concrete portion of the building cost $27,000. This sum included the form work and steel reinforcement, except the column cores and grillage beams, which cost $5,500 additional. The total cost of the structure, including the inside finish, amounted to nearly $90,000.

The unit girder construction is somewhat more expensive than the ordinary system of bending and placing separate rods, but the result is a sure location for every member, with no danger of a rod being left out or placed so high as to lose a large part of its efficiency. In this particular building the cost of the unit girder reinforcement was 4 cents per pound after bending ready to place.

INSURANCE.

It is of interest to observe that the building is insured by the Associated Mutual Insurance Companies, and at the time of completion was the only building in the congested portion of Philadelphia which was insured by them.

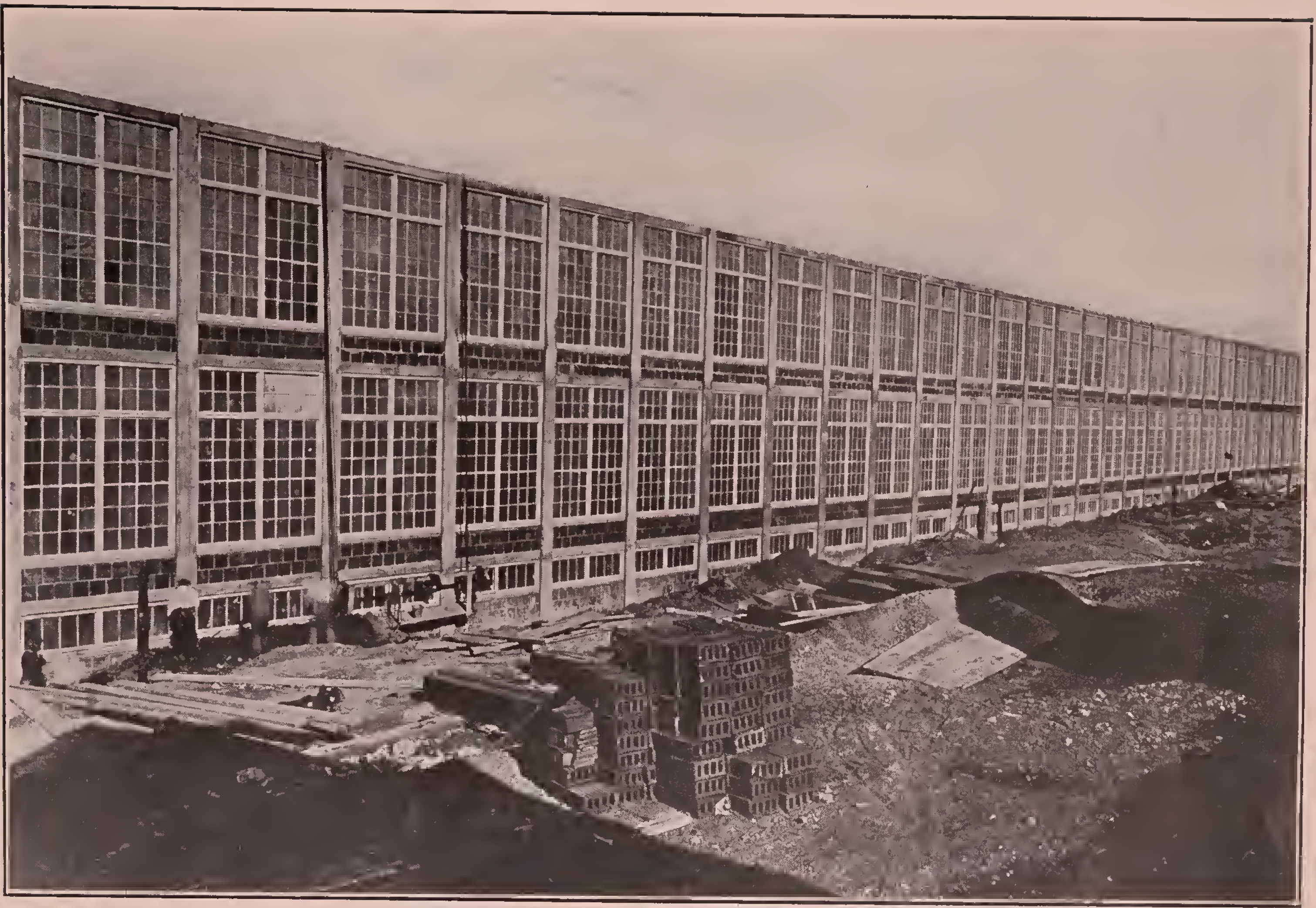


Fig. 14.—Exterior of Spinning Mill, Maverick Cotton Mills, East Boston, Mass. Engineers and Architects, Lockwood, Greene & Co. of Boston.

MAVERICK COTTON MILLS

The Maverick Mills, located at East Boston, Mass., were the first textile mills of large size in the United States to be built entirely of reinforced concrete. While ultimately the mills will operate 250,000 spindles, the initial installation is about one-quarter of this, and consists of a 51,200-spindle mill, 550 feet long, 130 feet wide, two stories in height, a 340 by 231 feet weave shed, one story high; a 30 by 40 feet two-story detached office building and a 91 by 62 feet power house adjoining the weave shed.

The problem of installing the textile machinery on the concrete floors proved to be comparatively simple of solution, and it was found that the equipment could be set up fully as cheaply and with scarcely any more trouble than in a mill with wooden floors. This is partly due to the fact that the absence of vibration and the greater friction between the bases of the machines and the concrete floor almost precluded any tendency for the machines to "creep," which allowed a material reduction in the number of floor bolts. In the case of the spinning frames, for example, instead of the 22 floor bolts usually needed, but six were required, and by using an air drill and expansion bolts these six could be placed almost as rapidly as six lag screws in a wooden floor.

The exterior of the spinning mill is shown by the photograph in Fig. 14.

The plant was designed by Lockwood, Greene & Co., Engineers and Architects, of Boston, Mass., and was built under their supervision according to the Hennebique System of reinforced concrete by the Hennebique Construction Company of New York.

Reinforced concrete was used throughout the entire plant, the concrete being mixed in the proportions of 1:2:4. The stresses assumed in computing the sizes of the various members were 650 pounds per square inch extreme fibre stress on the concrete, and 16,000 pounds per square inch tension in the steel, the ratio of the modulus of steel to that of concrete being taken as 15.

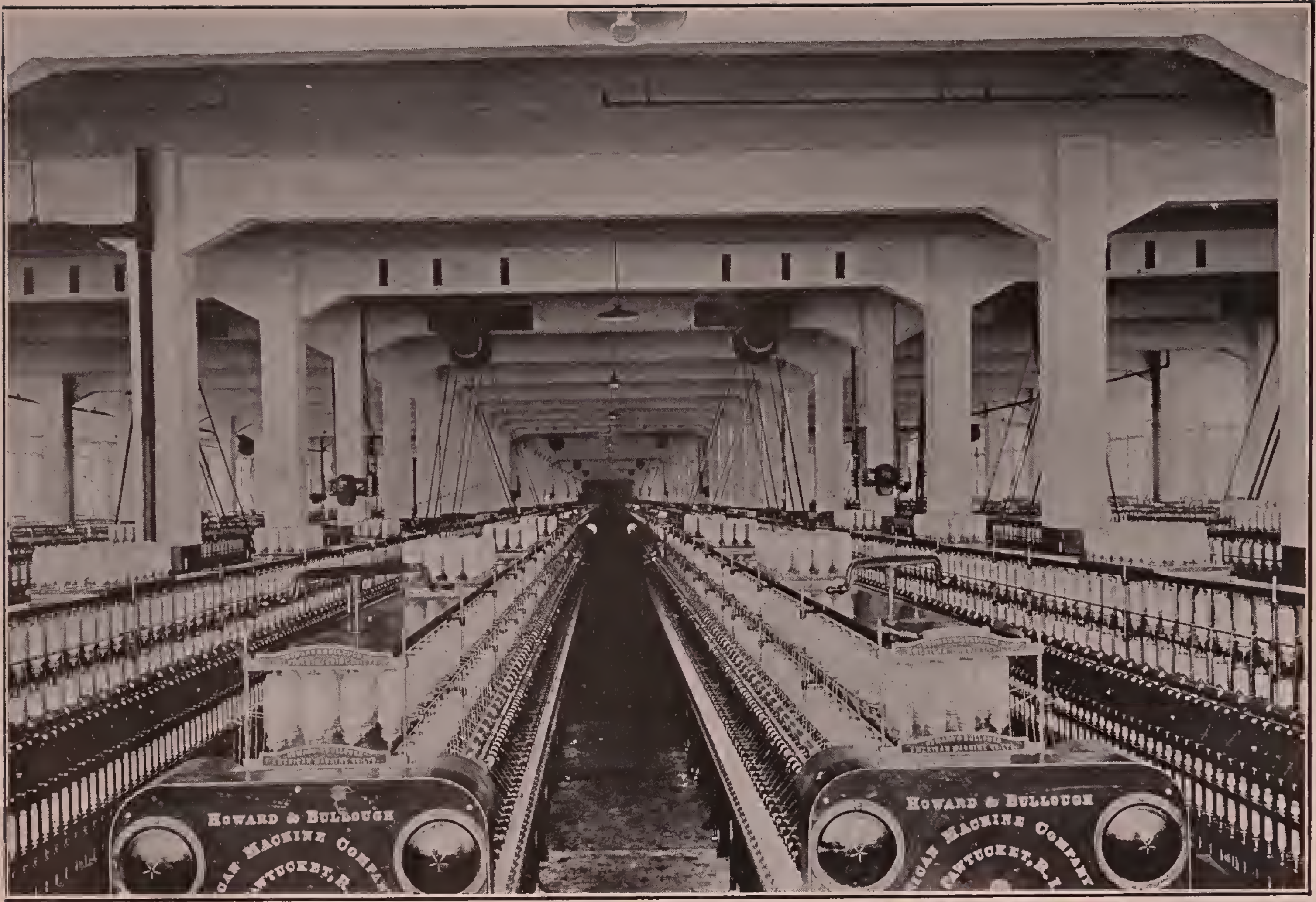


Fig. 15—Interior View of Spinning Mill, Maverick Cotton Mills.

SPINNING MILL.

In the spinning mill, which was designed to carry a live load of 75 pounds per square foot, the columns are spaced in rows 25 feet apart transversely and 10 feet 8 inches longitudinally. The story heights are 16 feet. The floor system consists of reinforced concrete girders spanning the 25 feet transversely from column to column and carrying a 4½-inch floor slab of 10 feet 8 inches span.

Fig. 16 shows the detailed design of a typical girder. These girders were designed as fully continuous, the bending moment at both the center and over the supports being taken as $\frac{1}{12} wl^2$. In order to provide for the excess compression in the concrete at the bottom of the girder at the support, caused by the continuous action, the girders were made deeper next to the support by forming a flat haunch as shown in Fig. 16. The girders are reinforced with two 1¼-inch and two 1⅛-inch round rods, the 1⅛-inch rods being bent up near the quarter points and carried horizontally over the supports into the adjacent bay.

The stirrups, which are flat steel ⅛ inch by ¾ inch, were bent in the form of a U and were placed as shown in Fig. 16. Near the support the stirrups were inverted because, in a continuous beam in the part near the support subjected to negative bending moment, the diagonal tension acts in the opposite direction to that in the part subjected to positive bending moment.

The floor slabs, which are 4½ inches thick, were also calculated with a moment of $\frac{1}{12} wl^2$ and are reinforced with ⅜-inch rods, 6 inches on centers. Cross reinforcing consisting of three ⅜-inch rods at right angles to the main reinforcing is provided in each bay to prevent shrinkage and temperature cracks and to stiffen the floor.

The floors are finished with a 1-inch granolithic surface, composed of 1 part cement to 1 part sand to 1 part ¼-inch stone, laid before the concrete below it had set, so as to form one homogeneous slab.

All columns supporting the first floor are 18 inches square, those on the second 16 inches square, and those running to the roof 14 inches square. The reinforcing for these columns consists of four ⅝-inch rods bound with ⅛-inch by ¾-inch hoops spaced 12 inches on centers.

The photograph in Fig. 15 illustrates the interior of the mill, and is especially interesting in showing the heavy motors and shafting attached directly to the concrete above.

WEAVE SHED.

In the weave shed, which is only one story high with a basement, the columns are spaced 26 feet on centers longitudinally and 21 feet 4 inches transversely, every other column being carried through the first floor to support the roof construction.

The floor, which is similar in design to that of the mill described above, was designed for a live load of 100 pounds per square foot.

A particularly interesting feature in the design of the weave shed is the saw-tooth roof construction shown in detail in Fig 17 and by the photograph in Fig. 19 of the interior of the building.

The inclined girders were designed as simply supported and were proportioned so as to have sufficient stiffness to obviate the necessity of horizontal tie rods from bay to bay.

The total rise of the saw-tooth is 9 feet 10 inches from the top of the column to the peak of the roof.

All the saw-tooth sashes are fixed and are double glazed. A wooden stool is bolted to the concrete sill and and at the top a wooden blocking piece is attached continuously to the edge of the roof slab. The sash fits underneath this blocking piece and is attached to it by clamps and screws. The drip is taken care of by a beveled

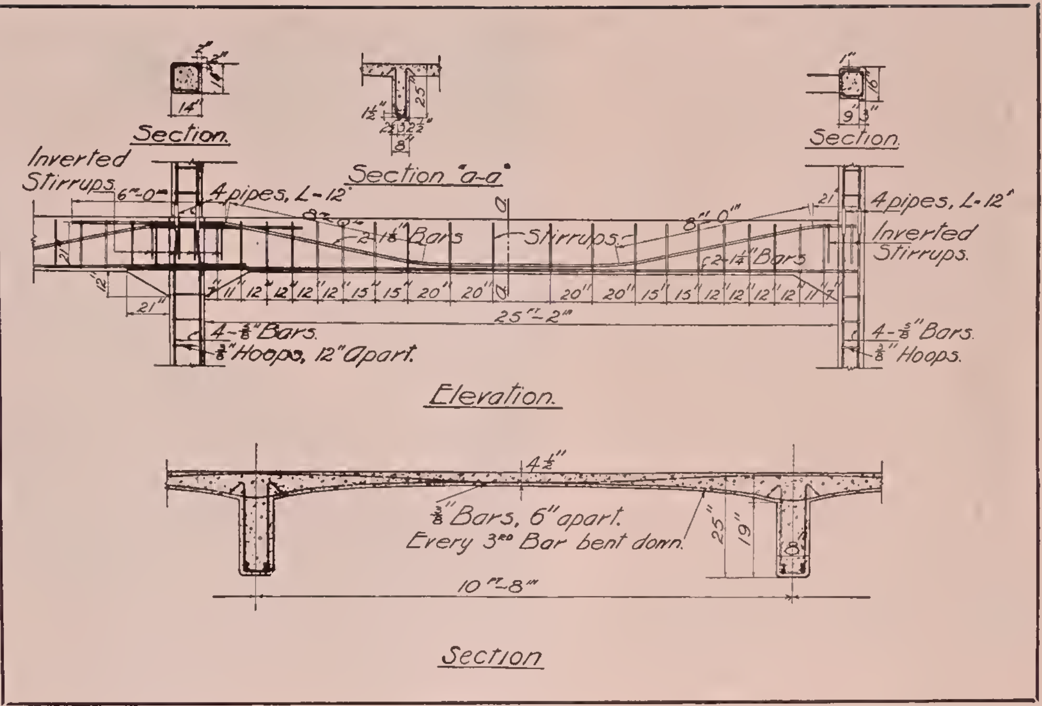


Fig. 16—Details of Typical Beam, Slab and Column.

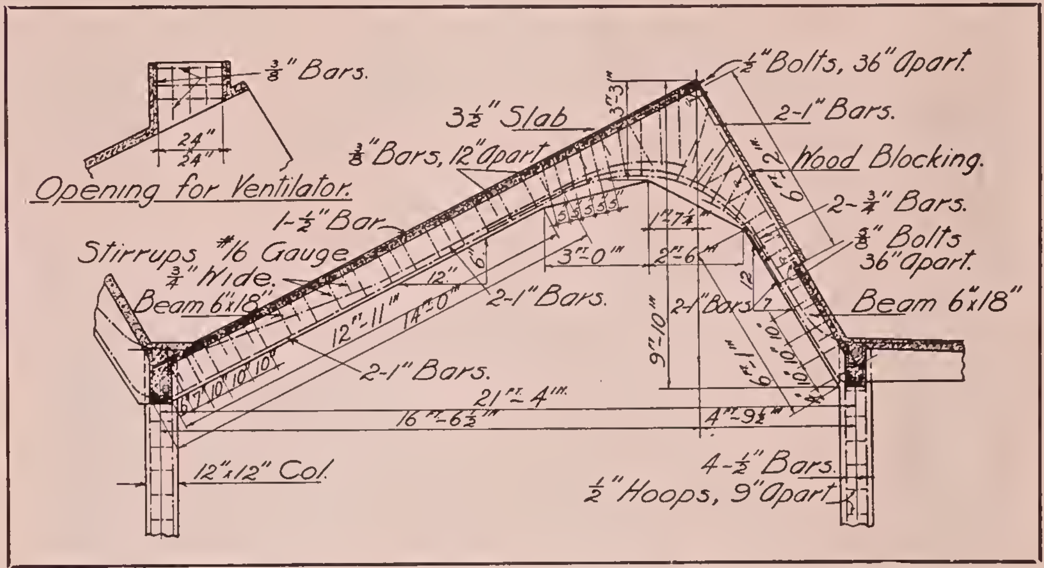


Fig. 17—Cross Section Detail of Saw-Tooth Roof.

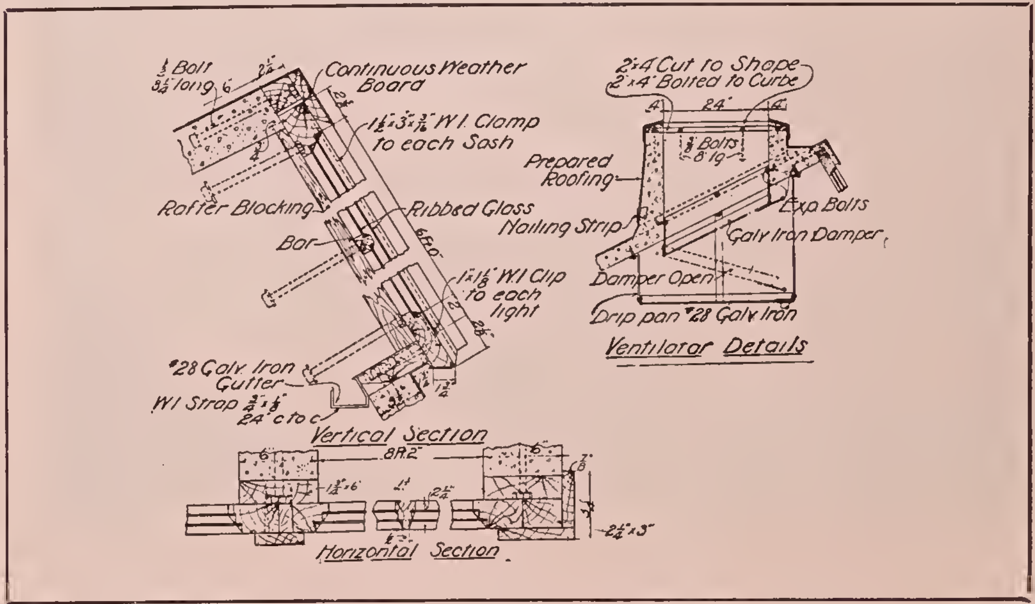


Fig. 18—Details of Saw-Tooth Sashes, Maverick Cotton Mills.

facia board placed over the top of the blocking piece and the top rail of the sash.

Interior condensation is handled by a galvanized iron gutter supported on wrought-iron straps screwed to the stool, thence discharging into a 2-inch pipe running the width of the building in each bay. The drawing in Fig. 18 gives the detail design of the saw-tooth sashes.

Three-ply asbestos asphalt built-up roofing was used, this roofing being brought over the peak of the saw-tooth and down over the facia board.

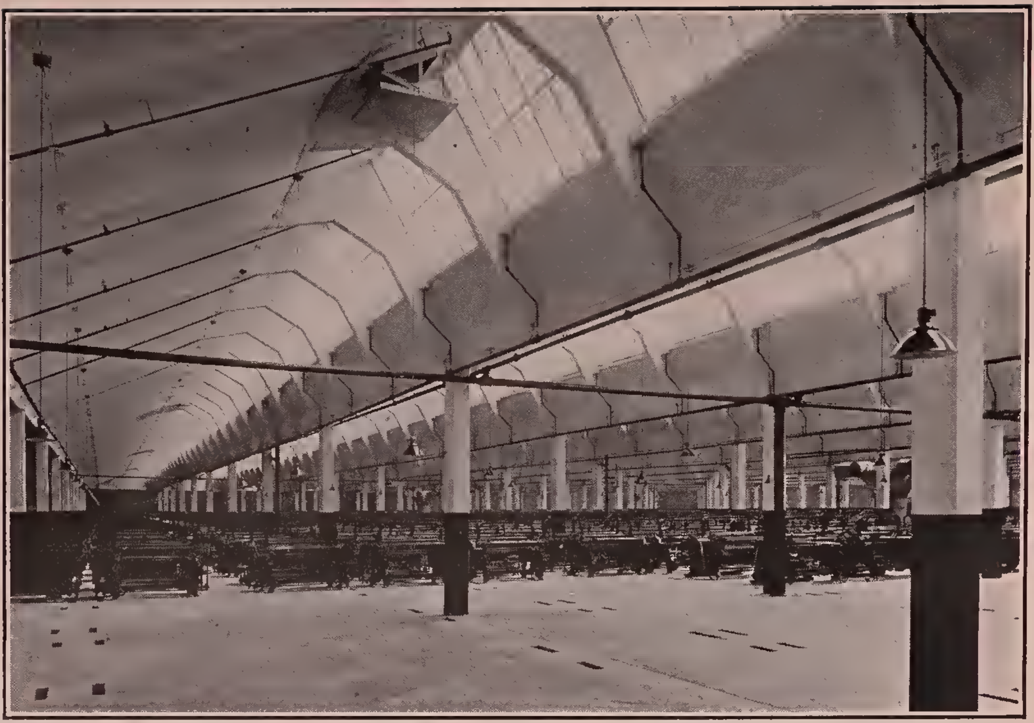


Fig. 19—Interior View of Weave Shed, Maverick Cotton Mills.

POWER HOUSE.

The power house, also of reinforced concrete construction, is divided into two parts by a longitudinal wall, one part being a boiler room one story high and the other a basement and one story turbine room.

The foundations of the boiler room are formed of wooden piles capped with reinforced concrete beams, while the engine-room foundation consists of a 22-inch reinforced concrete mattress.

REINFORCED CONCRETE STORAGE WAREHOUSE, LYNN, MASS.

The Lynn Storage Warehouse, at Lynn, Mass., is built for the storage of general merchandise and furniture, reinforced concrete having been selected as the most economical fireproof construction. To provide for the variable character of its contents, the several floors are designed to sustain different loading; the three lower floors are each planned for the rather heavy loading of 250 pounds per square foot, while on the fourth floor 200 pounds per square foot of loading is to be allowed, and on the fifth and sixth floors 150 pounds. A possible weight of 50 pounds per square foot is provided for in the roof design.

The building shown in Fig. 20 is six stories high besides the basement, being 50 feet wide by 165 feet long. Although not strictly speaking a factory building, the design is typical of first-class factory construction.

An interesting feature of the layout is the omission of the first floor in the corner of the building near the large elevator, in order to provide sufficient head room for teams to drive in and deposit their load upon the elevator, or else, if preferred, to drive directly onto the elevator, which is 11x12 feet in area, so that the wagon and horses can be elevated to the floor where the goods are to be placed and hauled to the proper point.

A full cross-section of the warehouse, showing the dimensions of the members and the general scheme of design, is shown in Fig. 21.

FLOOR CONSTRUCTION.

Round rods are used for reinforcement of the beams, girders and columns, while expanded metal forms the slab reinforcement.

The designs were carefully worked up by the Eastern Expanded Metal Company and checked by Mr. Worcester as consulting engineer. The sectional view (Fig. 21) illustrates the general scheme of reinforcing. Complete details of a typical girder, beam and slab, designed to safely sustain 150 pounds per square foot of the floor load in addition to the weight of the concrete, are drawn in Fig. 22. The slab, as indicated, is 6 feet in width from center to center of beam or 5 feet 3 inches in net span. The beams are 17 feet 9 inches from center to center of girders or 17 feet net span. The girders are 12

Fig. 20—Lynn Storage Warehouse.

The Designer of the Reinforced Concrete and also the Builder Was the Eastern Expanded Metal Company of Boston, Mr. J. R. Worcester Being Consulting Engineer. The Architect Was Mr. D. A. Sanborn of Lynn.

feet between centers of columns or 10½ feet net span.

The expanded metal reinforcement is placed near the bottom of the slab in the center of its span, and rises up to the top of the slab over the beams to provide for negative bending moment. The metal used is 3-inch mesh, No. 10 gage, this being equal to a cross-section of 0.175 square inches per foot of width of slab, or 0.5 per cent of the cross-section of the slab area above the steel.

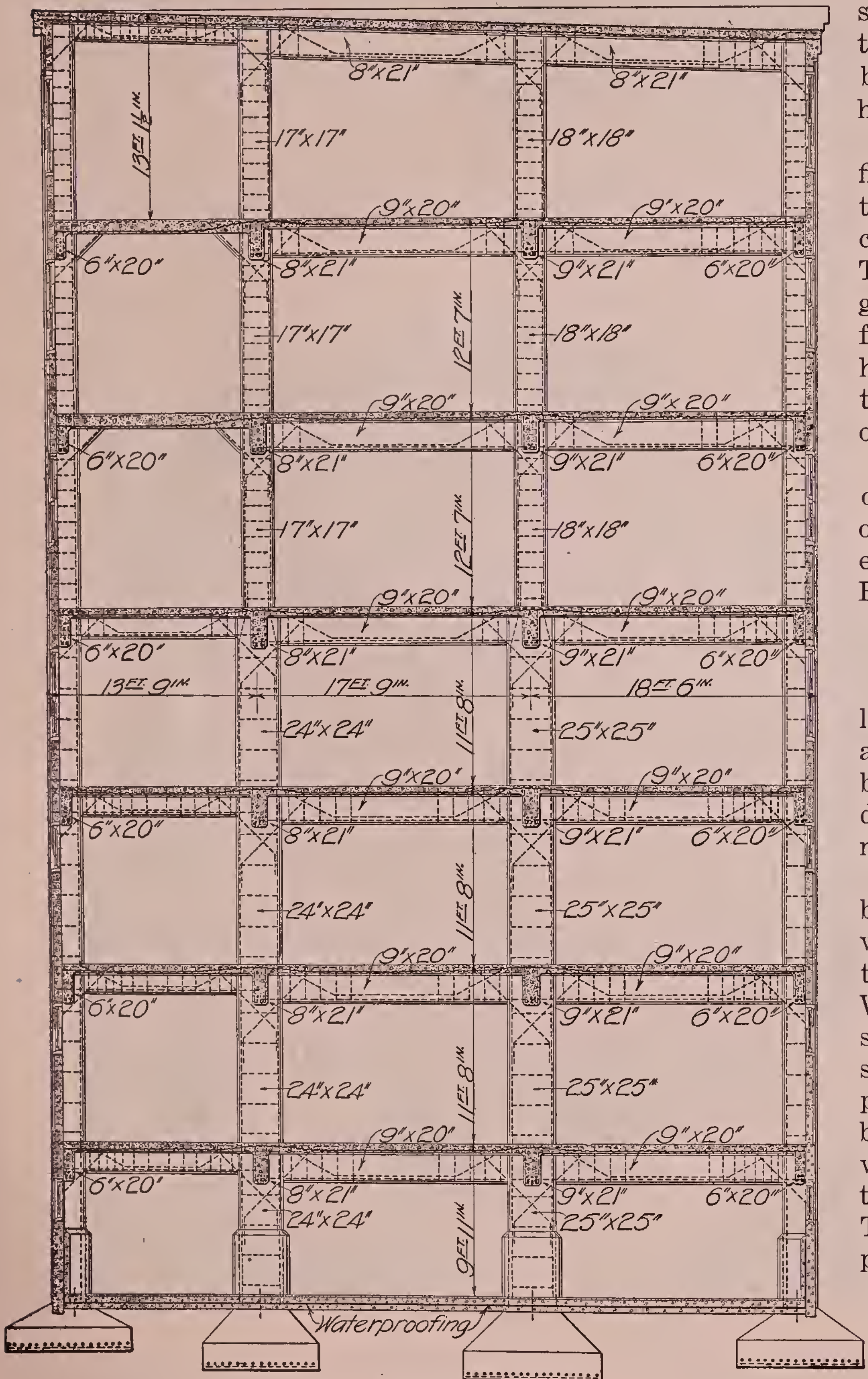


Fig. 21—Cross Section Through Lynn Storage Warehouse.

In the beams three 1-inch rods are imbedded, one of them bent up at the quarter points and running horizontally over the supports so as to lap by the rod from the next bay, thus giving two-thirds as much reinforcement over the supports as in the center of the beam. The stirrups are flat steel ¼ inch by 1 inch. Notice from Fig. 21 that in the three lower stories, where the loading is heavier, there are five stirrups in each end of the beam instead of two. The beams in these lower stories are made the same size, 9 inches by 20 inches, in order to use the same forms throughout the building, but the reinforcement is heavier.

The typical girders in Fig. 22 have five ⅞-inch rods at the center, two of them bent up and running on an incline from the center of the span. The incline starts at the center of the girder instead of one-quarter way from each end, because the girder having its greatest load at the center, the shear is nearly uniform throughout the entire span.

Instead of the more usual practice of forming the wall girders as a part of the wall, they are built independently of the wall slab, as indicated in Fig. 21.

FLOOR SPECIFICATIONS.

There are several points of particular interest in the floor specifications, and without copying them entire a brief outline is worth noting, as the data are quite full and the requirements conservative.

The slabs are calculated with a bending moment $\frac{1}{10}$ WL in cases where three or more slabs are continuous, while for the wall slabs $\frac{1}{8}$ WL is employed. The working strength of the concrete in compression is limited in the slabs to 500 pounds per square inch if computed by the parabolic method of stress, which is equal to about 600 pounds by the more usual straight line method. The slab steel is limited to 16,000 pounds per square inch in tension, the ratio of the modulus of steel to that of concrete being taken as 15. At right angles to the length of the span $\frac{1}{10}$ square inch of steel is re-

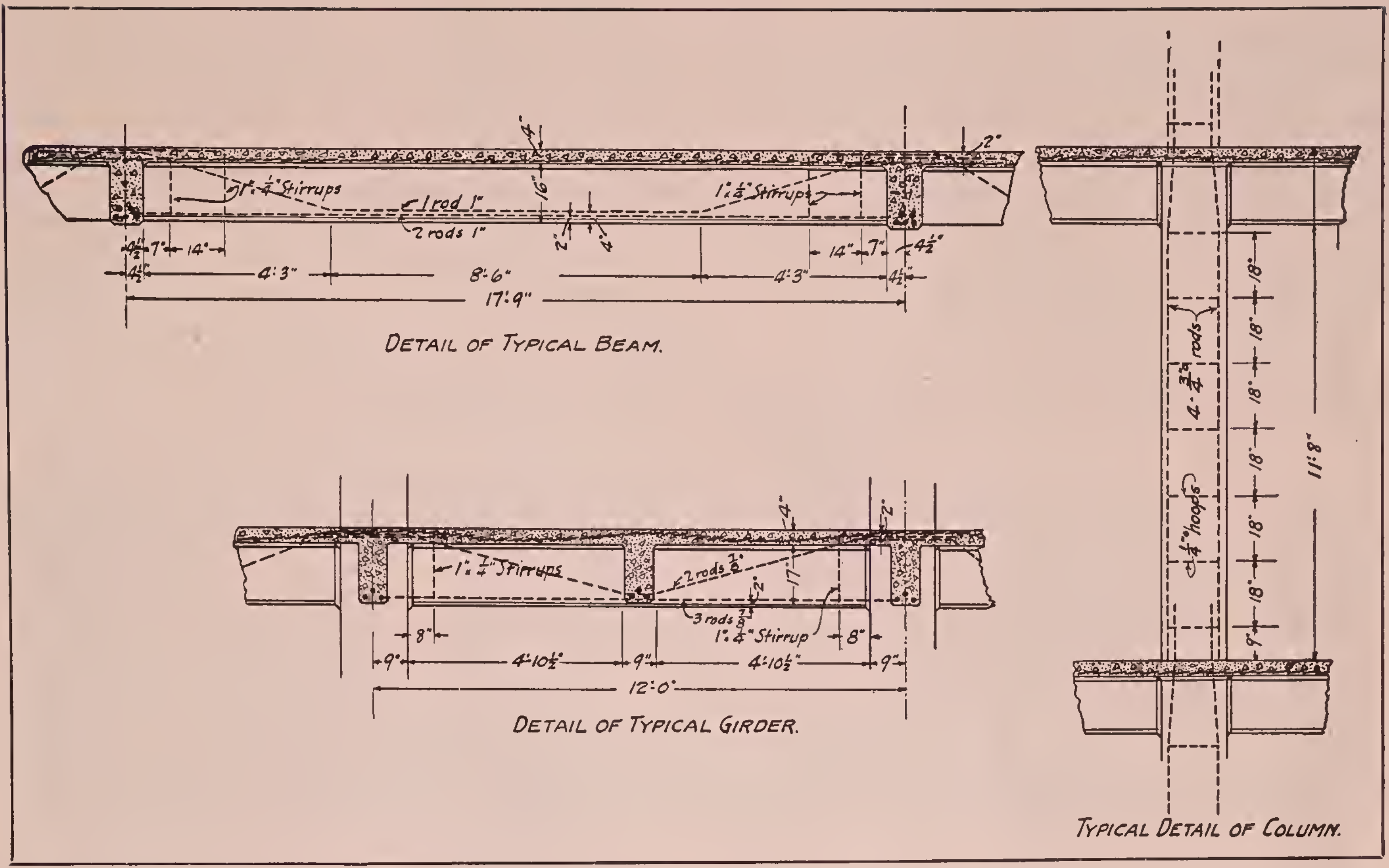


Fig. 22—Details of Typical Beam, Girder and Column.

quired per foot of length of slab, which with the 4-inch slab is equivalent to about 0.25 per cent. A thickness of ¾ inch of concrete is required below the metal in the slabs.

The bending moment in the beams and girders is considered as ⅛ WL. The beams are considered as T-beams in computing their strength, and it is specified that the width of the flange shall not exceed one-third the span, and that the average compression in the flange shall not exceed two-thirds of the extreme fiber stress.

The vertical shear in the concrete in beams which are not reinforced for shear is limited to one-tenth the extreme compressive working stress in the concrete, and it is assumed that this vertical shear is distributed over a section whose area is the width of the stem, that is, the width of the beam multiplied by the distance from the center of the steel to the center of the slab, the latter being considered as approximately the center of compression. In any case even when the beam is reinforced for shear the unit shear stress is limited to three-tenths of the extreme compressive unit fiber stress. Thus, if the allowable compressive fiber stress is 500 pounds per square inch, the shear in beams not reinforced for shear must not exceed 50 pounds, and in any case the section must be large enough so that even if reinforced there is sufficient area of concrete to keep the total stress within a limit of 150 pounds per square inch.

When all of the shear cannot be taken by the concrete, the vertical component of the diagonal bent-up tension rods is figured to take it, and, in addition, if necessary vertical or diagonal stirrups are introduced.

The specifications required for the coarse material of the aggregate trap stone ranging in size of particles from ¼ inch to 1¼ inches. The proportions for the floor system are 1:2½:5, or by exact volume one barrel (4 bags) cement to 10 cubic feet sand to 20 cubic feet stone.

COLUMNS.

The columns are spaced 12 feet apart lengthwise of the building and 17 feet 9 inches on centers across the building. The interior columns supporting the lower floors are 24 by 24 inches and 25 by 25 inches (the larger size supporting the greater spans), and in the three upper stories the sizes are reduced to 17 by 17 inches and 18 by 18 inches. This arrangement was used to avoid remaking the column forms, this saving, in the opinion of the builders, being enough to more than offset the slight excess of concrete required.

The columns are outlined in Fig. 22 and also quite distinctly in the general cross-section in Fig. 21. In the latter the diagonal rods will be noticed at the head of each column running into the beams and providing diagonal reinforcement against wind pressure. The building is so high in proportion to its width that this reinforcement was considered advisable.

The ordinary reinforcement of the columns is four ¾-inch vertical rods, with occasional hoops ¼ inch in diameter. In the wall columns, which are oblong in plan and which because of their location are subjected to a greater wind pressure, four larger vertical rods are inserted. The rods are of such length as to project above the next floor level, and the next set rests upon this floor so as to lap and transfer the stresses.

The columns are laid with a richer concrete than other parts of the building, being mixed in proportions 1:1½:3. The compressive stress allowed is 700 pounds per square inch figured on the area of the column, or 600 pounds per square inch on the concrete if the steel is computed to take a proportion of the compression.

Fig. 23—Loading Buildings, Winchester Repeating Arms Company.

WINCHESTER REPEATING ARMS FACTORY

The new loading buildings of the Winchester Repeating Arms Company, located on their property between Winchester Avenue and Sheffield Avenue, in New Haven, Conn., are especially interesting because of the heavy loads actually carried and the fact that flat-slab or girderless floors, sometimes called the mushroom system, were adopted instead of the ordinary plan of short-span slabs, supported by beams and girders.

In this flat-slab construction, which is illustrated by the photograph of the interior of the building in Fig. 26 and by the details of design in Fig. 24, no beams are used, the floor being of uniform thickness throughout and the loads transmitted from the floor slab direct to columns with flared capitals. The absence of the beams that tend to cut down the head room, obstruct light, gather dust, and interfere with the convenient arrangement of the shafting and pulley supports, goes far to make this for many purposes an ideal form of factory construction.

The loading buildings are duplicates with the exception of a steel-frame plaster-walled storage room on the roof of one, and they are connected by a corridor opening off the elevator well and toilet rooms that serve both buildings. Each building is 300 feet long, 60 feet wide, two stories high and designed with sufficient strength to provide for two additional stories in the future.

The photograph in Fig. 23 shows the completed buildings.

DESIGN.

The second and future third-story floors were designed to carry a live load of 250 pounds per square foot over the entire area, while the other floors throughout the buildings, including stairs, landings, platforms, etc., were designed for a live load of 10 pounds per square foot.

The columns are spaced 20 feet by 24 feet on centers.

All floor slabs are 10 inches thick and reinforced by bands or sets of ¾-inch round rods

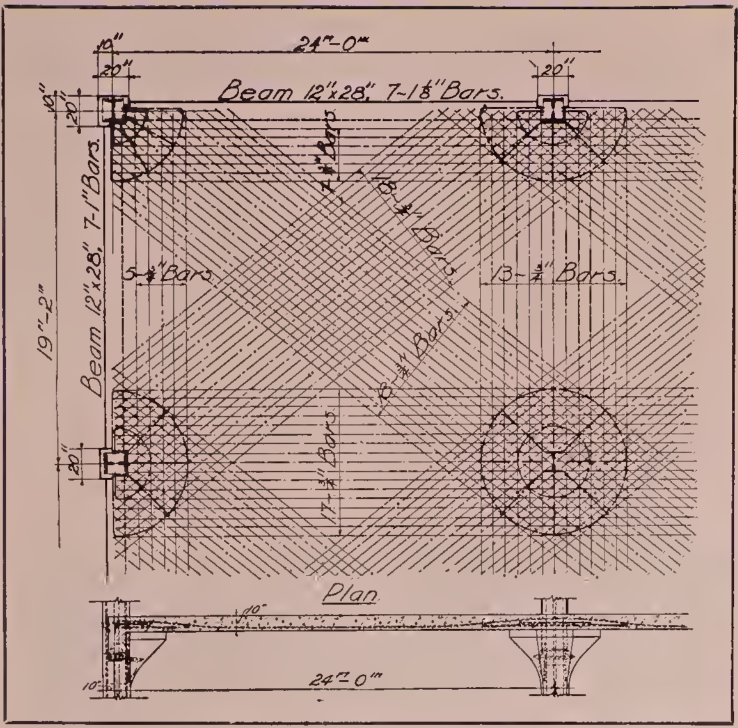


Fig. 24—Plan Showing Floor Reinforcement, Winchester Repeating Arms Loading Building.

Fig. 26—Interior of Leading Building, Winchester Repeating Arms Company

running in four directions radially from the column heads. The spacing of these rods, together with the arrangement of the radial bars, is shown by the partial second-floor plan in Fig. 24.

The end panels are supported by reinforced concrete beams running between the exterior columns. These beams, a typical one of which is shown in detail by Fig. 25, also carry the brick panel beneath the windows.

In calculating the strength of the flat slab and of the wall beams the ratio of the modulus of elasticity of steel to that of concrete was taken as 15, the concrete was figured at 625 pounds per square inch fiber stress and the steel in tension at 14,000 pounds per square inch.

The columns, shown in detail by Fig. 25, are composed of structural steel plate and angle columns incased in concrete. This structural steel work, designed to carry the entire live and dead loads of the floors above, together with the weight of the columns themselves, was computed on the basis of Gordon's formula, which gave a stress of approximately 12,000 pounds per square inch. Fig. 25 shows the details of the flared column heads and the arrangement of the radial bars and circular hoops which support the slab reinforcement.

Throughout the entire work the concrete was mixed in the proportions of 1 part Atlas Portland Cement to 2 parts sand to 4 parts broken stone.

In the first story the finished floors are of 1⅛-inch tongued and grooved maple flooring laid on 3 by 6-inch spruce planks bedded on "Tar-Rok." The second story finished floors consist of 1⅛-inch tongued and grooved spruce plank secured to 3 by 3-inch spruce screeds placed 20 inches on centers and embedded in 3 inches of cinder concrete fill.

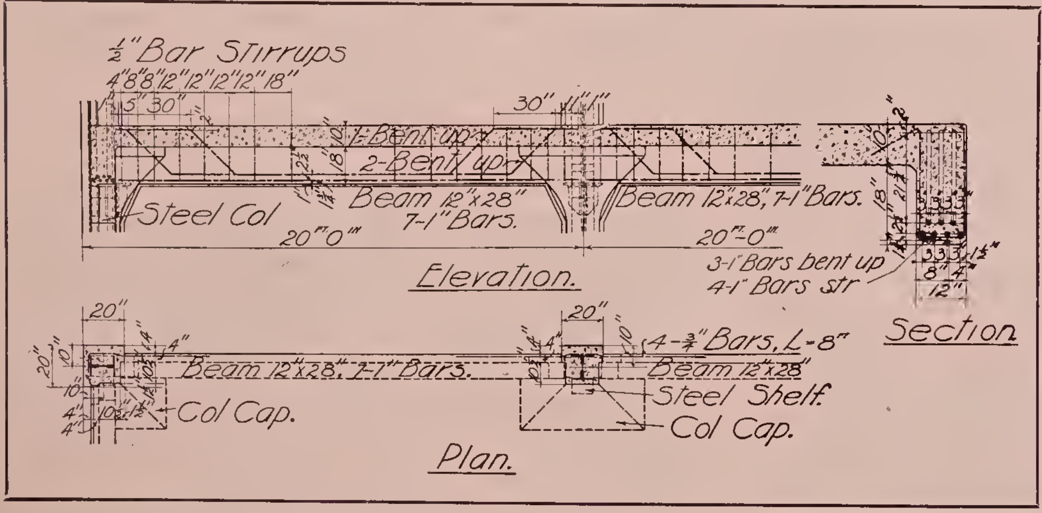


Fig. 25—Details of Typical Wall Beams.

COST.

The total cost of the building, including excavation, was about $150,000. The cost of the concrete in place was $6.00 per cubic yard. The forms cost 12¼ cents per square foot and the reinforcing steel $45 per ton in place.

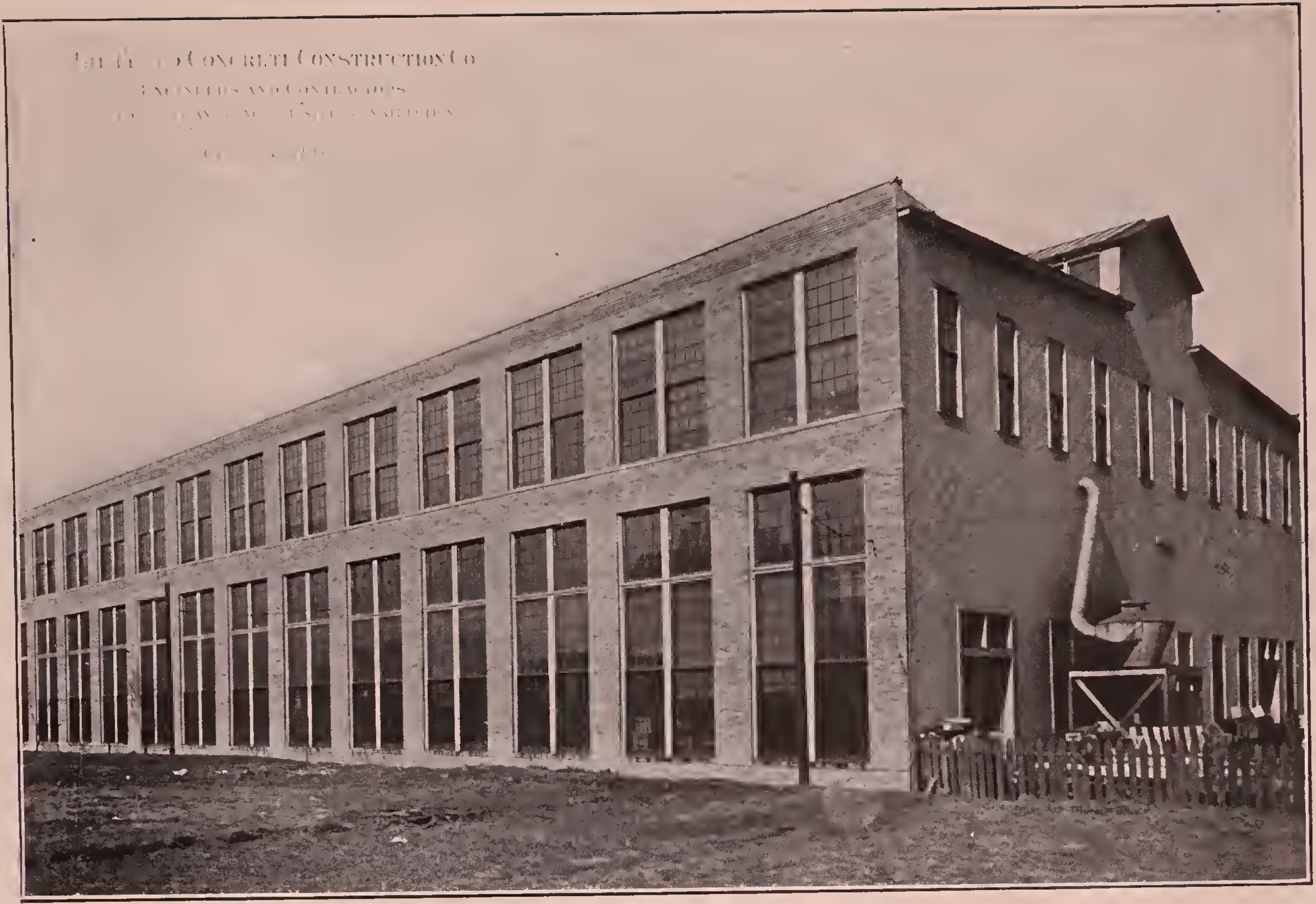


Fig. 27—Bullock Electric Machine Shop. Ferro-Concrete Construction Company, Contractors.

BULLOCK ELECTRIC MACHINE SHOP

A novel feature of the reinforced concrete machine shop of the Bullock Electric Company, at Norwood, Ohio, a branch of the Allis-Chalmers Company, is the supporting of 10-ton cranes upon concrete brackets which form a part of the concrete column. It is customary even in reinforced concrete shops to place the crane runs upon steel columns independent of the rest of the structure, but we have here an example of the transmission of the load directly from the runways, which are steel plate girders, to the reinforced concrete columns. The machine shop, illustrated in Fig. 27, was only fifty-eight and a half days in building and has been in successful and continuous operation since its completion.

The building under consideration is an extension to Shop No. 3, which is of the regular type of steel frame with brick walls. The extension was first designed in similar steel construction, but an alternate proposal to substitute reinforced concrete made by the Ferro-Concrete Construction Company, of Cincinnati, was adopted at substantially the same cost.

Twisted steel was used for reinforcement. The proportions of the concrete were 1:2:4 throughout, using 4 bags Atlas Portland cement to 8 cubic feet of good coarse sand to 16 cubic feet of broken stone, which was the run of the crusher, screened through 1¼-inch screen.

The floors consist of three longitudinal bays running the entire length of the building, a distance of 256 feet. The total width is 107 feet 7½ inches, thus allowing the two outer bays to be each 42 feet 11½ inches and the inside bay 21 feet 8½ inches. In the other direction, that is, lengthwise of the building, the columns are 16 feet apart on centers. The long open floor spaces afford ample room for the machine tools and the handling and distributing of the parts and the finished machines. A view of the shop in operation is photographed in Fig. 30.

The height of the first story, 27 feet in the clear from the floor to the ceiling and 23 feet in the clear to the bottom of the girders, provides the head room necessary for the 10-ton cranes which are located in the outside bays,

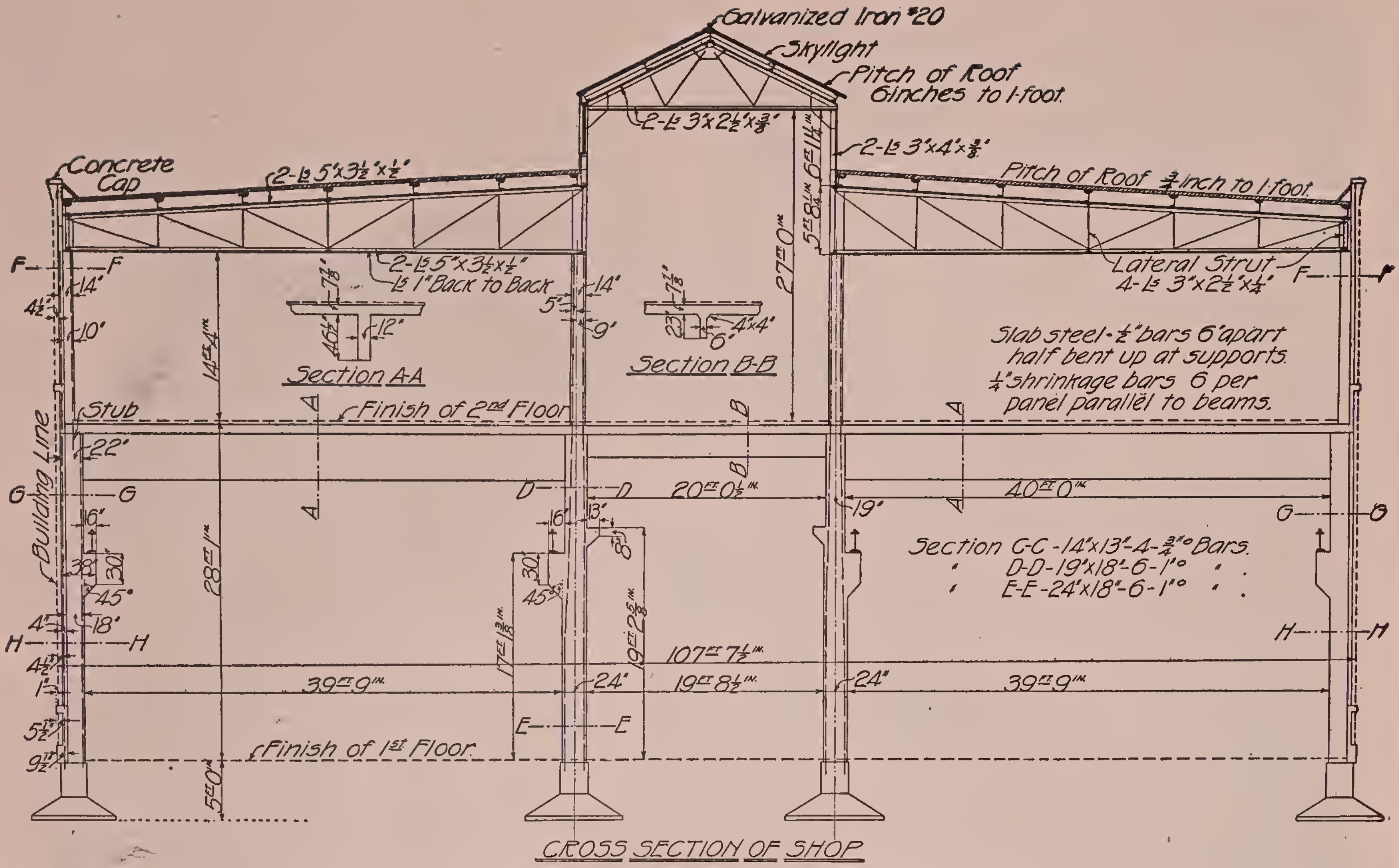


Fig. 28—Cross-Section of the Bullock Machine Shop.

and also permits very large high windows.

The center bay is designed so that another crane may be installed there when required, but for the present its place is occupied by an intermediate floor. This floor is of light steel I-beam and wood construction, resting upon channel irons running across between the two rows of columns. The channels are bolted at the ends to the concrete columns and their weight also supported by straps suspended from the crane brackets. Had the floor been intended for permanent use it would have been built of reinforced concrete, but the difficulty and expense of tearing down a floor of concrete when the space was needed for the crane made this impracticable.

DESIGN.

The general design of the building is shown in the cross-section in Fig. 28.

The lower story is devoted to the manufacture of the heavier part of the electric machinery and in the assembling of dynamos. In the upper story are the lighter machine tools for the making of the smaller parts. The roof is of 2-inch plank upon steel trusses (see Fig. 28), being built in this way instead of in reinforced concrete so that it can be raised and a third story added when needed. One end of the building, as shown in the photograph of the completed shop, Fig. 27, is also of temporary construction, so that it can be lengthened without tearing down a brick and concrete wall.

COLUMNS.

Footings of the interior are shown in Fig. 29. These illustrate a typical reinforced concrete footing with two layers of rods at right angles to each other in the bottom. In this case the rods are ¾-inch diameter, while in the footings for the wall columns, which are not shown in our drawings, ½-inch rods fulfil the requirements. The rods in each layer are shorter than the dimensions of the footing in the interior columns (Fig. 29), being 6 feet 8 inches long and placed with one end 2 inches from the edge of the footing and the other end 18 inches from the opposite edge, the alternate rods being staggered to allow for the decrease in the bending moment from the column toward the edges of the footing. As the footing is square, while the column is oblong, 10 bars run in one direction, while 12 bars are placed in the other layer to provide for the greater bending moment.

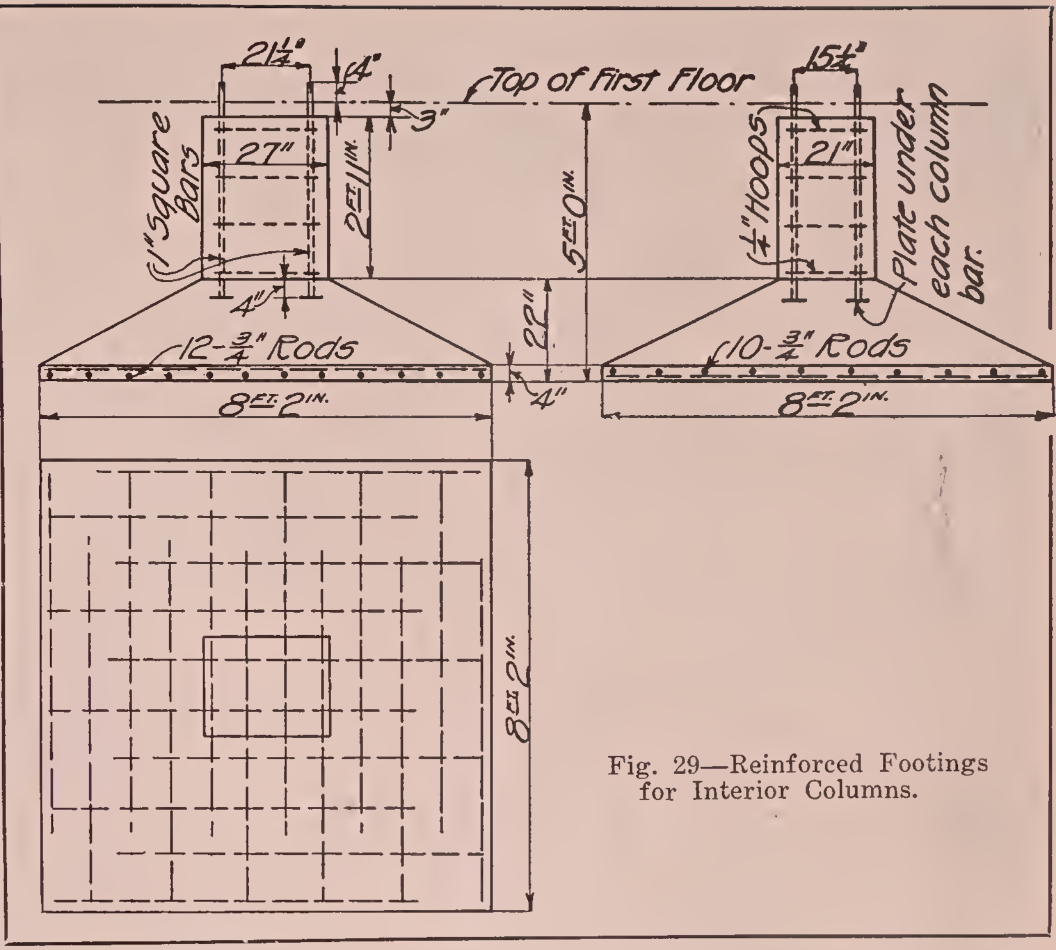


Fig. 29—Reinforced Footings for Interior Columns.

The footings really extend up to within 3 inches of the first floor level, the short vertical section of 2 feet 11 inches being built at the same time as the footing proper in order that the first floor can be laid entire and the first story columns started above it. These short vertical lengths are reinforced with six 1-inch rods which extend 4 inches down into the main part of the footing and project 7 inches above the concrete so as to pass through the floor and connect with the column above. These vertical rods rest upon steel plates 3 inches square, which distribute the compression from the steel to the concrete. Four ¼-inch horizontal hoops are placed around the vertical rods. The columns above the first floor are of slightly smaller dimensions, as shown by the offsets in Fig. 28. Thus, the portion below the first floor is 21 by 27 inches, which reduces to 18 by 24 inches with a further reduction above the crane brackets. The reinforcement in the columns in the first story is the same as below the floor, six 1-inch rods butting upon the ends of the rods below and connected with them by a short pipe sleeve. One-quarter-inch hoops were spaced double, every 12 inches.

The wall columns have footings similar to those of the interior columns, except of smaller dimensions and lighter reinforcement. The base is 7 feet 4 inches, reinforced with sixteen ½-inch rods in each layer. Below the first floor the column is 20 inches by 26 inches, reinforced simply with a ⅜-inch rod in each corner and four ¼-inch horizontal hoops.

Above the first floor the exterior columns are of T-shaped cross-section, as described in the paragraphs which follow, the column proper being 14 by 22 inches in the first story and 12 by 14 inches in the second story.

CRANE BRACKETS.

The brackets, shown in Fig. 28, which support the cranes, are of particular interest. To provide for the shear, it was considered advisable to loop the reinforcing rods into the bracket, running them out horizontally and then bending them down on an incline back into the column. The steel I-beams supporting the track for the crane rest directly upon these brackets and run the full length of the building.

FLOOR SYSTEM.

The floor of the first story was laid directly upon the ground after filling in around the columns and thoroughly puddling the earth. This floor is of 1:2:4 concrete with sleepers upon it and a 2-inch oak floor.

The second floor is supported in the two bays by girders about 40 feet long in the clear, 12 inches wide and 54½ inches deep from top of slab. In the bottom of the girder, to take the tension, are ten 1-inch square twisted rods and. to provide for the negative bending moment, five 1-inch rods were placed at the top of the beams over the supports. The shear or diagonal tension is provided for by these bent-up rods, together with sixteen ½-inch and ten ¼-inch U bars. The reinforcement was rigidly located before the concrete was poured, so that it could not be displaced.

In the central bay the net span is about 20 feet and the girders are smaller, being 6 by 31

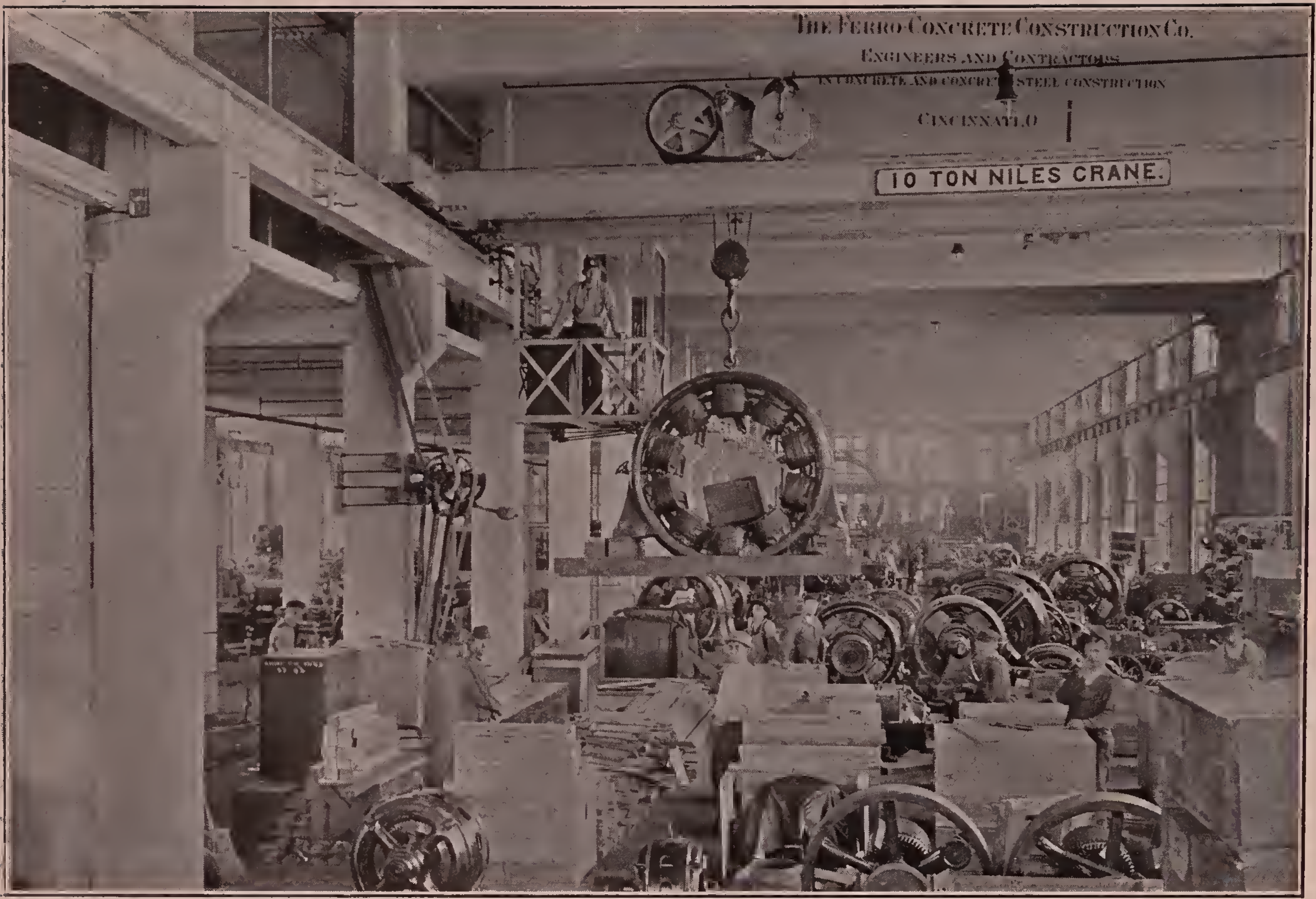


Fig. 30—Bullock Electric Company Machine Shop in Operation.

inches. The thickness of the slab is included in the depth of the girders in both cases, since the concrete for the girders and slabs was poured at one operation.

The girders extend across the building from column to column, and are thus 16 feet apart on centers, giving a net span for the concrete floor slab of 15 feet in the outside bays and 15 feet 6 inches in the middle bay. The slabs, which are designed by a load of 225 pounds per square foot, are 7⅞ inches thick, reinforced with ½-inch bars spaced 6 inches on centers. In addition ¼-inch rods about 2 feet apart run across the building parallel to the girders to prevent contraction cracks.

The wearing surface of the floor is ⅞-inch maple flooring upon 3 by 4-inch sleepers spaced 16 feet apart on centers and filled between with cinder concrete.

WALLS.

The window area comprises a large percentage of the wall surface, the openings in the concrete being 12 feet 2 inches wide and in the lower story 23 feet 8 inches. The walls, 4 inches in thickness, were carried up at the same time as the columns, thus forming with them T-sections. Below and above the windows, the wall was also 4 inches thick, with water table and sills.

Each vertical section of wall was reinforced with two ½-inch square bars in the first story and two ¼-inch bars in the second story. Horizontal loops of ¼-inch wire were also placed about 2 feet apart. Above the windows the walls were reinforced with three horizontal rods and with vertical rods spaced about 3 feet apart.

In order that the exterior of the new building should harmonize with the older shops in the same plant, the walls were surfaced with a single thickness of light-colored pressed brick. These were tied to the wall by the wires which were used in keeping the forms together. These ties were No. 8 galvanized iron wire about 12 inches long, which projected from the concrete about 6 inches. They were spaced every 18 inches horizontally and every six courses of brick vertically. The projecting ends were turned in a hook by the brick-layer and bedded in the mortar joints just like regular brick anchors.

Fig. 31—Factory of Hunter Illuminated Car Sign Company.

FACTORY OF HUNTER ILLUMINATED CAR SIGN COMPANY

The factory building of the Hunter Illuminated Car Sign Company, at Flushing, L. I., is built with walls of hollow tile.

The hollow tile used in the construction are called "Tilecrete" and are manufactured under the "Pauly Process." By this process the concrete, composed of Portland cement and carefully selected aggregates and mixed to the consistency of grout, is poured into molds surrounded by a steam jacket. Enough water is evaporated from the concrete by the heat to permit the withdrawal of the tile within a few minutes, although enough water is left to thoroughly harden the tile. The finished product has the density and uniformity of wet mixed concrete and is very true and uniform in shape and size.

While the tile itself is remarkably cheap, it is in erection that the greatest economies are obtained, as the large size of the tile enables a given volume of wall to be erected with fewer units than with any other materials. Experience has demonstrated that a mason can easily lay 400 10-inch tiles per day, thus erecting eight times as much wall as would be possible with brick.

DESIGN.

The building is 80 feet long and 75 feet wide, two stories in height with a one-story office addition 21 by 31 feet. The side walls of the main building are 22 feet high and the gable walls 31 feet high.

The floors are of wood, the first floor being supported on Lally columns and the roof on wooden posts. The sills and lintels are all of reinforced concrete built in place.

The partial plan and sections in Fig. 32 show the details of design.

CONSTRUCTION.

After the footings were put in the foundation walls were built up of concrete hollow tile 12 by 16 by 12 inches, pointed and filled with concrete, so as to form a 16-inch solid wall without the use of wooden forms. The main walls were then carried up in 8-inch hollow tile broken out in pilas-

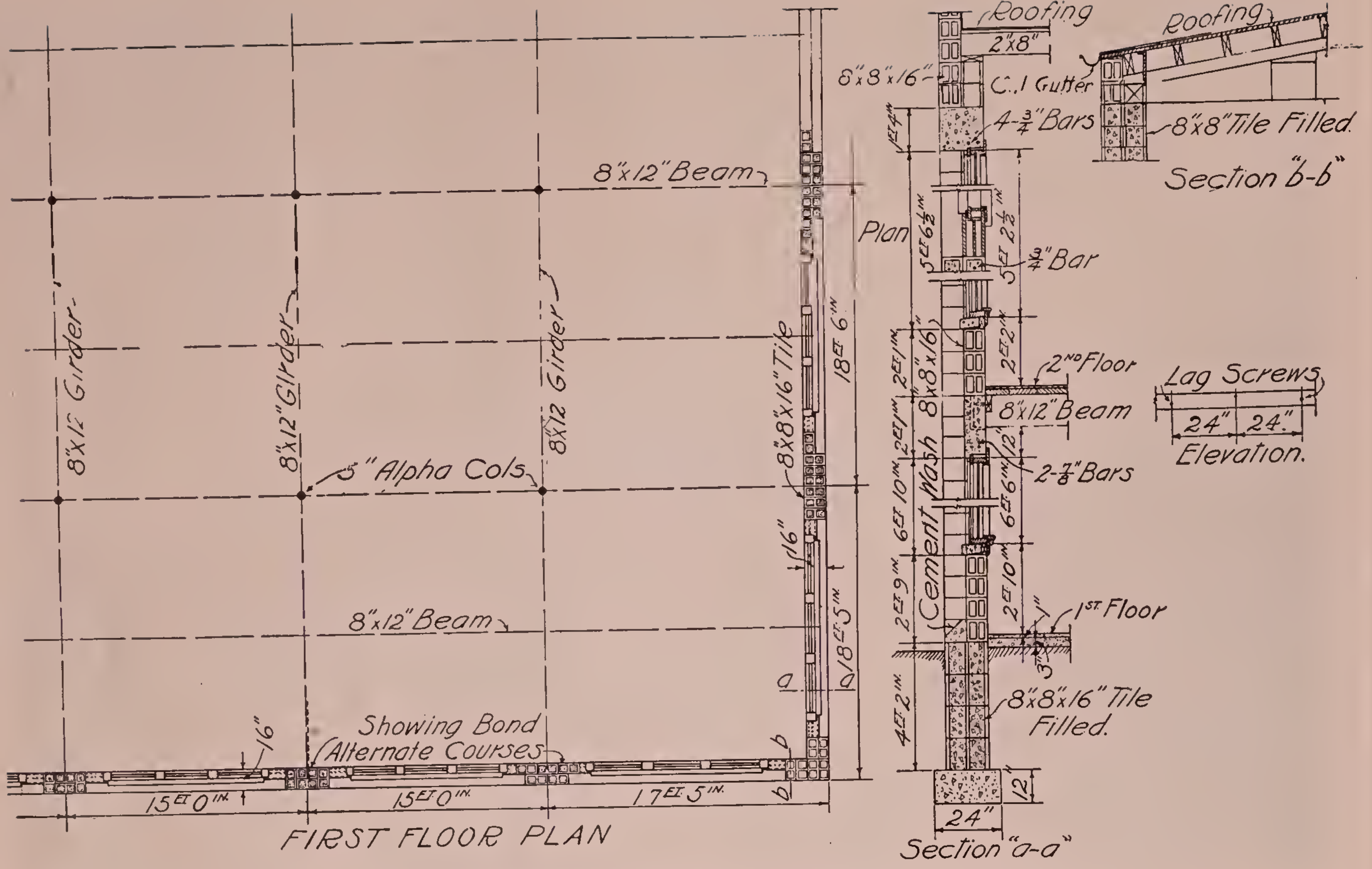


Fig. 32—Partial Plan and Cross Section of Hunter Factory.

ters on the side walls 15 feet on centers and on the gable walls 18 feet 6 inches on centers.

The pilasters thus are 16 inches by 32 inches and in order to form columns were filled solid with concrete and reinforced with ¾-inch steel rods.

After the building was completed the tile were carefully pointed on both sides of the wall and the faces cleaned down, so that at a short distance away the work has the appearance of dimension stone.

COST.

The building cost complete, including heating and plumbing, about $10,000 or approximately 75 cents per square foot of floor space.

Fig. 33—Wholesale Merchants' Warehouse, Nashville.

WHOLESALE MERCHANTS' WAREHOUSE

The immense reinforced concrete warehouse at Nashville, Tenn., illustrated above, is the result of a scheme of co-operation of a number of the most prominent merchants of that city. They previously had conducted their business in various individual warehouses in the business section of the city and some distance from the railroad. To better their condition the idea was conceived of forming the Wholesale Merchants' Warehouse Company to erect a fireproof building alongside of the tracks, and thus save the large expense of hauling and at the same time obtain greatly reduced insurance rates.

Insurance on the stock carried by the merchants in the old type of frame buildings ranged from \$1.80 to \$2.20 per hundred, while in the new fireproof, reinforced concrete structure the rates were reduced to \$0.40 per hundred.

LAYOUT.

The general plan is a framing of longitudinal beams with no girders and the division of the floors into compartments for the different firms. The interior columns are spaced 12 feet apart in one direction and 16 feet 7½ inches in the other. In general, the beams run lengthwise of the building from column to column, with no supporting girders, while cross-beams are placed at intervals to tie the building together and to support the partitions.

These cross-beams and their partitions are not spaced uniformly, but at different distances apart, so as to afford a merchant a choice of several sizes of rooms, each of which extends the full depth of the building. For example, the spacing of the partitions is three bays in a large number of cases, while in one portion of the building the spacing is one and a half bays; in another, two bays; and in still another four bays. The widths of the compartments thus vary from about 24 feet to 66 feet, with a uniform depth of about 130 feet.

The beam design is somewhat different than usual along the front and rear of the building. Here the cross span is 18 feet instead of 12 feet, and short cross girders are introduced, each of which supports a floor beam at its center. The

Fig. 34—Interior of Wholesale Merchants' Warehouse.

projecting girders at the rear of the building, that is, at the top of the plan in the figure, support the roof over the loading platform in the basement.

In order to take advantage of the full width of the lot, and yet not encroach upon the loading platform with the basement columns, the rear wall of the building from the first floor up to the roof is supported by the ends of the floor girders which project at each story about 30 inches, thus acting as cantilevers.

Because of the variety in the weights of the goods to be stored, the floors were designed for different loadings. The first floor was calculated for 350 pounds loading per square foot of surface, the second floor for 300 pounds and the third and fourth floors for 250 pounds. The roof was figured for a snow load of 40 pounds per square foot. These figures in each case represent live loads, and do not include the weight of the concrete itself.

BEAMS AND SLABS.

Details of the construction of a typical beam and slab are drawn in Fig. 35 (p. 53). These are designed for the first story to support a floor load of 350 pounds per square foot in addition to the weight of the reinforced concrete itself.

Inspection of the plans shows that three of the six bars in the beam are bent up on an incline and run across over the supports, lapping there a distance of one-quarter of the span length. Several $\frac{3}{16}$-inch round stirrups are also provided to assist in taking the shear. The dimensions of the beams, 12 by 20 inches for the longitudinal beams of which the details are shown, and 10 by 16 inches for the cross-beams supporting the partitions, are given in the customary way, measuring the depth from the top of the slab to the bottom of the beam, and assuming, of course, that the standard practice is followed of placing the concrete in the beams and slabs at one time, so as to form a monolithic T-section. The rods in the bottom of the beam are placed in two layers, so as to bring them far enough apart to prevent the concrete splitting between them.

It will be noticed in the floor sketches that $\frac{1}{2}$-inch bars 5 inches apart, to form the reinforcement for the slab, are placed in the bottom of the slab at the center of its span, but that all run up toward the supporting beam, and thus in the longitudinal section of the beam at the top of the diagram, these rods which are shown by so many dots, are close to the upper surface. This plan is somewhat easier to follow than where rods are alternately horizontal and bent up, and it is preferable to the latter because the negative bending moment at the ends of a continuous slab is at least as great as the positive moment in the center, so that fully as much reinforcement is required to take the pull at the top of the slab over the supports as is necessary in the bottom at the middle of the span.

The roof is of concrete of lighter design, and the slab, which is 3 inches thick, is laid on a slope of ¼ inch per foot and is covered with tar and gravel roofing.

COLUMNS.

Although the floor loads are heavy, the columns are only 19 inches square in the basement and less than this in the stories above because the spacing between them is comparatively small. The general type of reinforcement is four ⅝-inch vertical bars near the corners with 3/16-inch horizontal loops at intervals of 5 to 12 inches, varying with the dimensions of the columns. In the first story ¾-inch vertical bars were used with loops 4 inches apart.

The columns are designed for a loading of 750 pounds per square inch, a seemingly high stress for the proportions of cement to aggregate used, 1:2¼:4½, but in making the calculations no account is taken of the area of concrete outside of the steel loops nor of the strength of the vertical steel, so that the loading is really conservative.

COAL TRESTLE.

Comparatively few designs of reinforced concrete coal trestles have been published, and the trestle erected in connection with this building is therefore shown in considerable detail. Its elevation is given in Fig. 33 (p. 51), and the details in Fig. 36.

COST.

The entire cost of the building was about $357,000, including finish, of which $192,000 was for the reinforced concrete and the excavation. The cost of the construction plant, which is included, was $19,000, an unusually large amount.

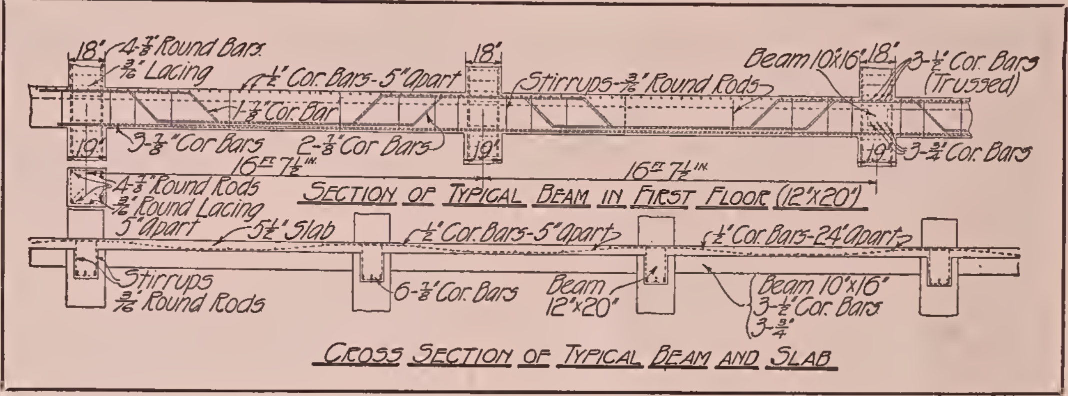
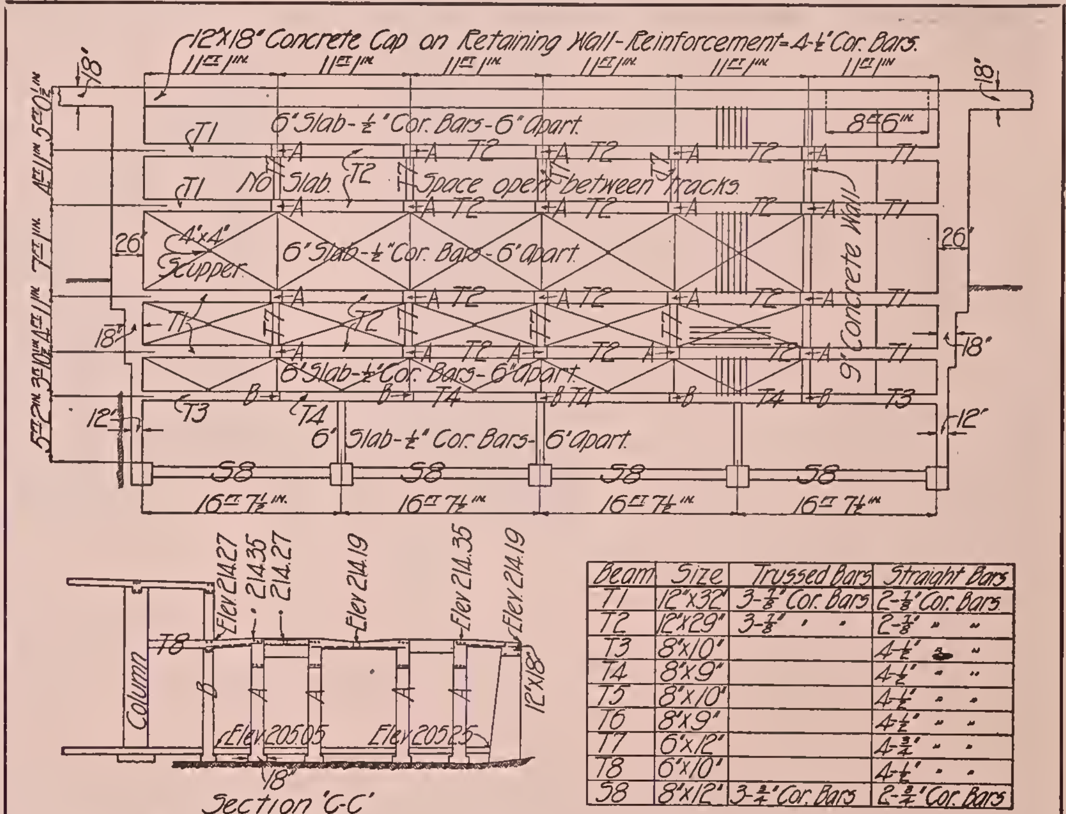


Fig 35—Details of Reinforcement of Typical Beam and Slab. (See p. 52.)



Beam	Size	Trussed Bars	Straight Bars
T1	12"x32"	3-⅞" Cor. Bars	2-⅞" Cor. Bars
T2	12"x29"	3-⅞" " "	2-⅞" " "
T3	8"x10"		4-½" " "
T4	8"x9"		4-½" " "
T5	8"x10"		4-½" " "
T6	8"x9"		4-½" " "
T7	6"x12"		4-¾" " "
T8	6"x10"		4-½" " "
S8	8"x12"	3-¾" Cor. Bars	2-¾" Cor. Bars

Fig. 36—Details of Coal Trestle.

Fig. 38—Plant of Boston Woven Hose and Rubber Company. The plant was designed by Mr. John O. DeWolf, Architect and Engineer, of Boston, Mass., with Mr. Edward A. Tucker, Boston, Mass., as Concrete Engineer, and Mr. Sanford E. Thompson, Boston, Mass., as Consulting Engineer, the Contractor being Benjamin Fox, of Boston, Mass.

PLANT OF BOSTON WOVEN HOSE AND RUBBER COMPANY

The plant of the Boston Woven Hose & Rubber Company, located in Cambridge, Mass., includes a hose manufacturing building and two warehouses of reinforced concrete covering approximately 220,000 square feet of floor space.

An interesting feature in connection with these buildings is the speed with which they were erected, the work being started on July 19 and completed ready for occupancy by the middle of October, only thirteen weeks being required. Such a record would have been absolutely impossible with any other type of construction than reinforced concrete.

DESIGN.

The hose building is 322 feet long by 60 feet wide, with four stories each 15 feet high from top of floor to top of floor. A single row of columns spaced 10 feet 4 inches on centers runs through the center of the building. The floor system is made up of reinforced concrete girders spanning across the building 30 feet from the interior columns to wall pilasters and carrying a 5-inch floor slab.

The photograph in Fig. 39 (p. 55) shows the interior of this building.

The floors were designed for a live load of 150 pounds per square foot.

The girders are 18 inches wide and 28 inches deep and are reinforced with seven 1-inch bars, five of these being bent up and three being carried horizontally over the supports into the adjacent bay. The floor slab is reinforced with ½-inch bars, 7 inches on centers, with two out of every three bars bent up and staggered so that exactly as much steel is carried in the top of the slab over the supports as in the bottom of the slab in the middle of the span.

The method of arranging the ducts for the blower system of heating is of special interest, these ducts being carried up inside the wall pilasters, so as to do away with all unsightly or cumbersome heating equipment.


Fig. 39—Interior View of Hose Building.


Fig. 40—Hoisting Concrete Pile Into Driving Position.

In order to provide for the excess compression in the concrete at the bottom of the girder at the support, the girders were made deeper next to the columns by forming a flat haunch.

The concrete for the floor construction was mixed in the proportions of 1 part Atlas Portland Cement to 2½ parts sand to 5 parts broken stone of size to pass a ¾-inch ring, while for the columns and pilasters a mixture of 1:1½:3 was used.

The stresses assumed in computing the sizes of the various members were 500 pounds per square inch extreme fiber stress in the members of the floor system, and 600 pounds per square inch direct compression in the concrete, this stress being permissible because of the rich proportions used, and 16,000 pounds per square inch tension in the steel. Corrugated bars were used throughout the buildings.

All floors were finished with a 1-inch granolithic surface mixed in the proportions of 1 part cement to 2 parts sand and placed within three hours after the under slab, so as to form one homogeneous slab.

The roof surfaces were covered with three-ply tar and gravel roofing laid directly on the concrete, the roof pitch being ½ inch to a foot.

In the warehouses the second and fourth floors are designed for a live load of 200 pounds per square foot, and the third floor for a live load of 300 pounds per square foot. For these loadings it was found more economical to use two rows of columns instead of a single row—otherwise the construction is substantially the same as in the hose building.

Fig. 41 is a cross section of one of the warehouses and shows the details of design and construction for the floor system, columns, walls and footings.

REINFORCED CONCRETE PILES.

The power house is carried on reinforced concrete piles, which were formed in horizontal molds above ground and then driven. Fig. 102 (p. 90) gives the design of a typical pile and the photograph in Fig. 40 shows one of the piles being lifted into position for driving.

The piles taper from 14 inches at the top to 9 inches at the point and are reinforced with four ⅞-inch bars connected at intervals, as shown, with ½-inch warping bars. The concrete was mixed by hand in proportions 1:2:4, using ¾-inch trap rock. A 1½-inch galvanized iron pipe was cast in the center of the pile for a water jet.

The piles average about 30 feet long and were driven at the age of thirty to forty days. The hammer weighed 4,700 pounds and the blows were cushioned by a head consisting of a plate iron collar 16 inches square on the inside and 3 feet in height, encasing an oak block 16 by 16 by 18 inches to the bottom of which six thicknesses of rope and four layers of rubber belting were nailed. The usual drop was 3 feet, but in some cases this was increased to 10 feet without injuring the pile.

The average cost of the piles driven was $1.63 per linear foot of pile.

CONSTRUCTION.

The construction plant consisted of a 1½-yard Ransome mixer with a Ransome hoist in a tower. The concrete was conveyed in Ransome carts and barrows. All forms were made on the ground and hoisted into place by a derrick, which also lifted the steel reinforcement from the ground to its destination. The forms were used over four times on each building.

The total cost of buildings was about $270,000.

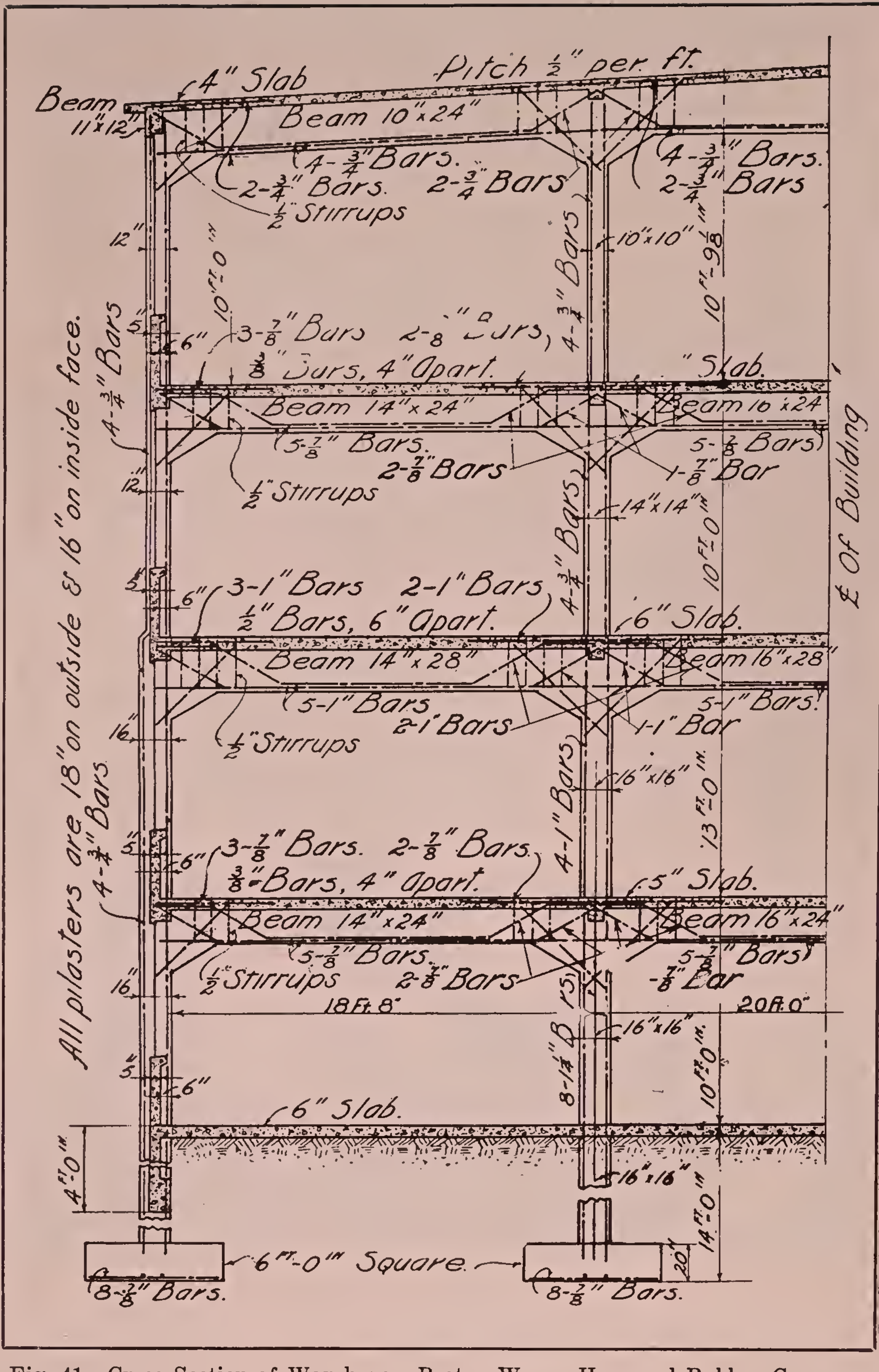


Fig. 41—Cross Section of Warehouse, Boston Woven Hose and Rubber Company.

Fig. 42—Bush Model Factory No. 2. The builder of this concrete factory was the Turner Construction Company. Mr. E. P. Goodrich, formerly chief engineer for the Bush Terminal Company, prepared the structural design and Mr. William Higginson was the architect.

BUSH MODEL FACTORY No. 2

The plant of the Bush Terminal Company, located in South Brooklyn on the east shore of New York Bay on Thirty-sixth Street, between Second and Third Avenues, will cover when completed an immense area and comprise some hundred and fifty warehouses and factories. Many of the more recent of these buildings are of reinforced concrete construction, the factory selected from this group for description being 75 ft. wide by 599 ft. long, and six stories high above the basement. Several features of the design are of unusual types.

The Terminal Company owns some 160 acres of land with nearly three-quarters of a mile of water front. A number of piers, each one-quarter of a mile in length, with wide docks between, permit the largest ocean steamers to discharge and load without interference. The large warehouses, 50 by 150 feet, and from four to seven stories high, provide the steamship lines renting these Bush piers with unusual facilities for both the storage and the trans-shipment of freight.

In addition to this storage and shipping business handled by the piers and warehouses, a plan is already being carried out to erect eighteen fireproof factories or loft buildings, their floor space to be rented for manufacturing purposes. The first of these factories, built in 1905, and the second, called the Bush Model Factory No. 2, built in 1906, offer unusually attractive features because of the excellent facilities afforded. The details of the latter, which is shown complete in Fig. 42, form the subject of this chapter.

DESIGN.

Instead of the usual system of beams, girders and slabs, the floors consist essentially of heavy girders directly supporting ribbed slabs, designed so that the under surface presents a corrugated or ribbed appearance, the purpose being to use for the necessarily long spans a minimum

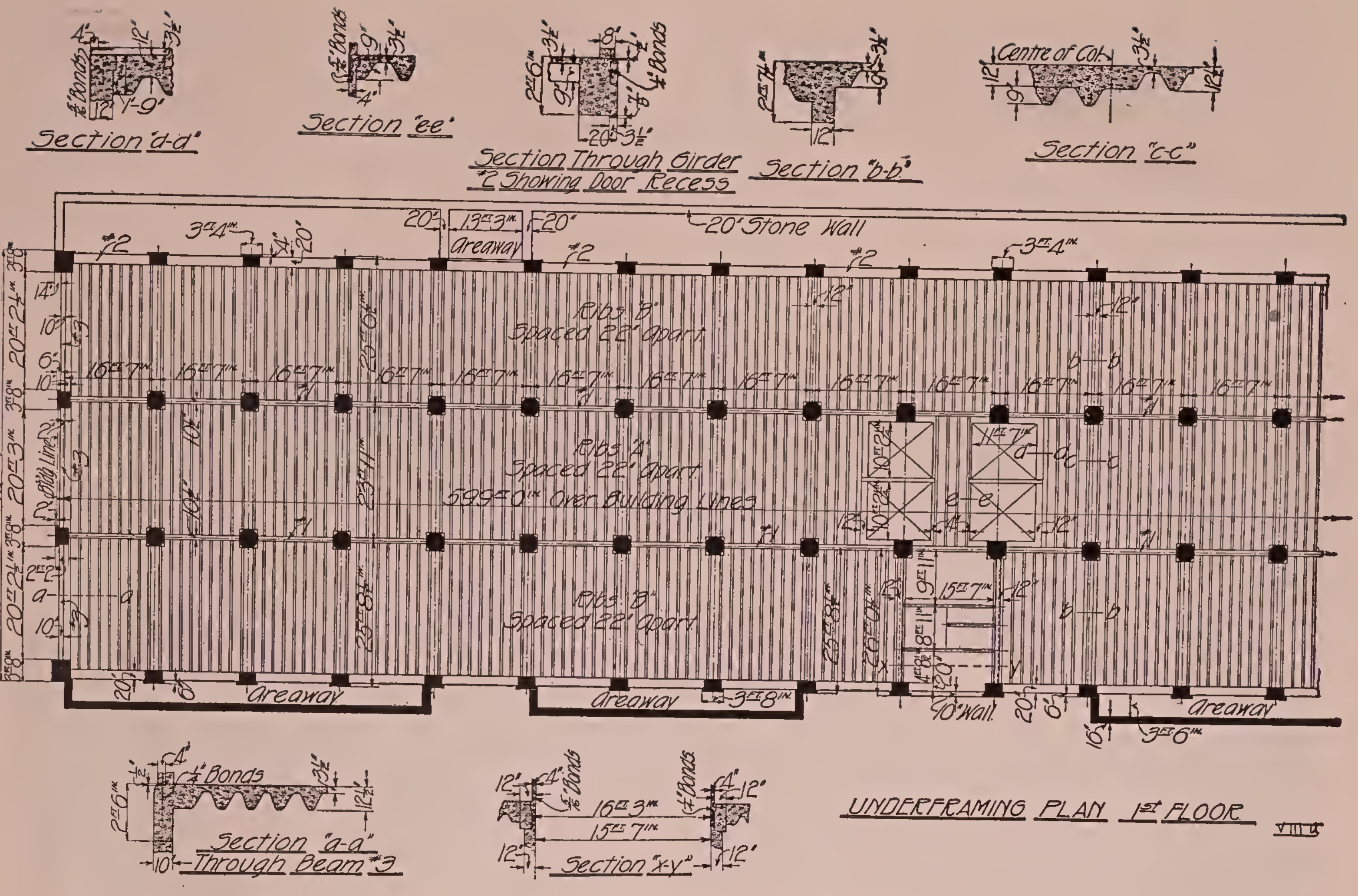


Fig. 43—General Floor Plan of Bush Factory No. 2.

quantity of concrete placed most effectively to take the loads upon it.

An idea of the general plan of the structure is gained from Fig. 43. In order to present it on a fairly large scale, only one end of the building, a length of about 225 feet in a total of 599 feet, is shown.

The sectional elevation may be seen in Fig. 44.

Two lines of columns 16 ft. 7 in. on centers divide the factory into aisles about 24 ft. in width, thus giving exceptionally good floor space for either storage or manufacturing. Heavy girders run lengthwise of the building from column to column, while spanning the distance between these two lines or girders and the walls is the ribbed floor system.

Two groups of four elevators each are located one-quarter way from each end of the building, and in adjoining bays on each side of both groups of elevators are the stair wells. The first floor plan, Fig. 43, shows the stairs to the basement only on one side of the elevators, but an additional flight is provided for the stories above. Except for the location of the stairs, the floor system of the different stories is identical, thus simplifying the design and permitting the use of the same forms throughout.

The roof is surrounded by a fire wall 3 feet 6 inches high. A series of skylights over the center aisle afford additional light to the top story.

Round rods formed into trusses on the ground and raised to place ready to drop into the forms provide the reinforcement. The proportions of the concrete used throughout were one part Portland cement, 2 parts sand, 4 parts stone, being equivalent in actual volume to one barrel (4 bags) cement, 7.2 cubic feet of sand, and 14.4 cubic feet of broken stone. The aggregate consisted of sand excavated by dredges from Cowe Bay, and washed gravel of a size passing a ¾-inch sieve.

COLUMNS.

The column footings are supported by wooden piles, and the area of the footing is so large in proportion to the size of the columns as to require a special design of heavy horizontal rods and vertical stirrups.

In Factory No. 1 the interior columns are cyl-

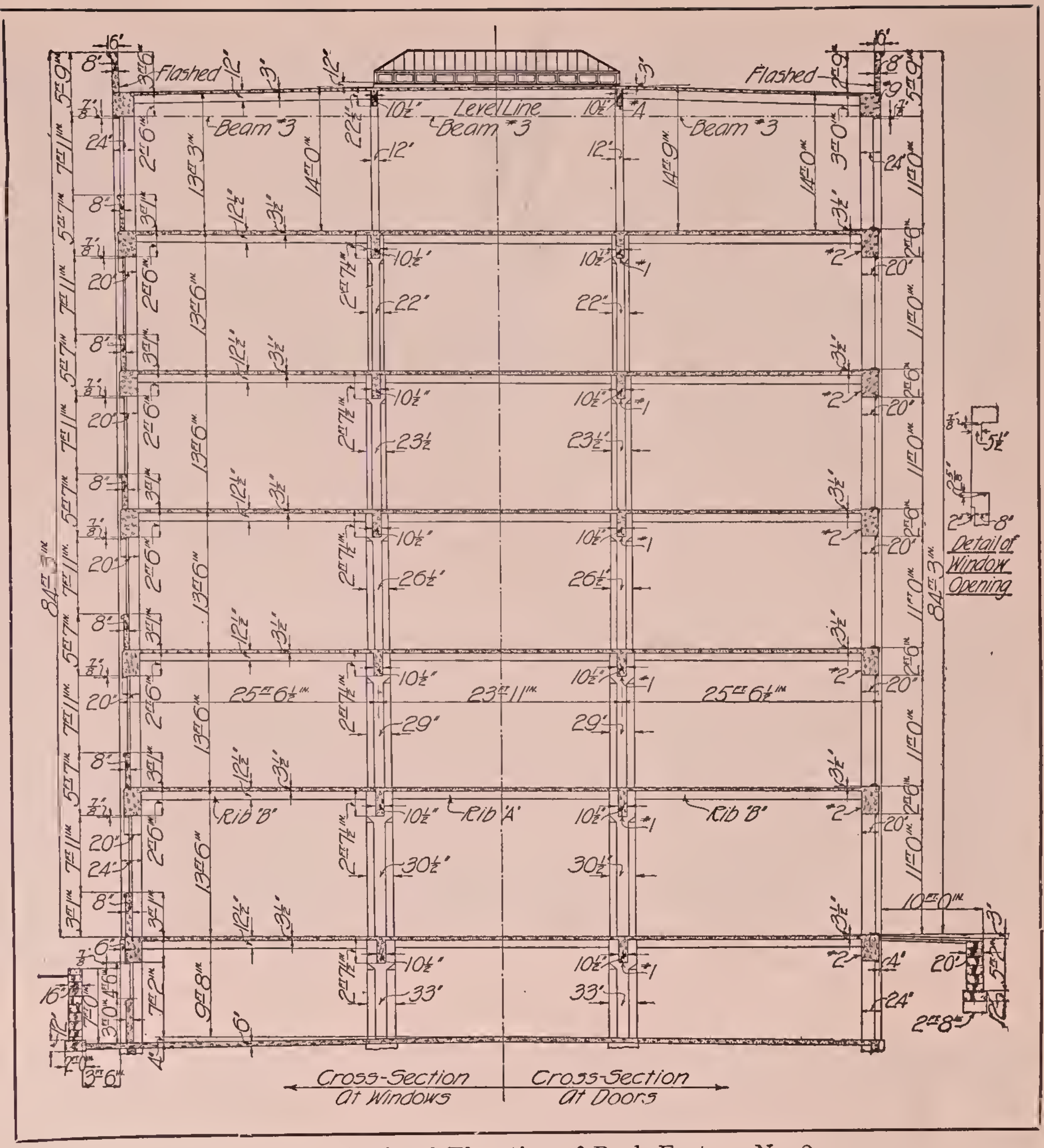


Fig. 44—Sectional Elevation of Bush Factory No. 2.

indrical and composed of an outside shell of cinder concrete 2½ inches thick. These cinder concrete cylinders were prepared in advance in 2-foot lengths in a zinc mold, with spiral hooping and expanded metal forming the inner surface. After hardening, they were set one upon another in the building, and filled with concrete.

In Factory No. 2 the columns are octagonal in shape, and composed wholly of gravel concrete. Just below the girders the section was made square (see Fig. 46, p. 61), these square caps being the same size on all the stories so as to avoid altering the rib and girder molds.

The columns were spirally reinforced with round high carbon steel ⅜ to ½ inch in diameter, the pitch varying in the different stories. The loading upon the columns was graduated from 500 pounds per square inch of their section for the upper floor to 1,000 pounds per square inch in the basement. This, however, assumed full loads on all the floors at the same time, which would not ordinarily occur, so that the columns in the lower stories are liable to be stressed much less than the nominal figures. The spiral hooping is computed to assist in bearing the load.

FLOOR SYSTEM.

The general scheme of design has been referred to in paragraphs above. Longitudinal girders of 13 feet 4 inches net span, supported by columns 16 feet 7 inches on centers, carry the ribbed slabs which run across the building with a net span of about 23 feet.

The details of design of the beams and ribbed slabs are drawn in Fig. 45. The ribs are V-shaped in cross-section, as shown in Sections aa and bb. Two 1-inch round rods, one bent up at the points determined by moment diagram, and the other extending horizontally to the girders, provide for the tension and ½-inch stirrups are bent around and wired on to the horizontal rods. Ribs A, which are shown in the diagram, connect the two girders, while ribs B, which run from the girders to each wall, are similar in design, except that the upper rod cannot project beyond the support, and is therefore anchored by bending it with a quarter turn around another rod which runs at right angles to it in the wall.

The steel is designed for a maximum pull of

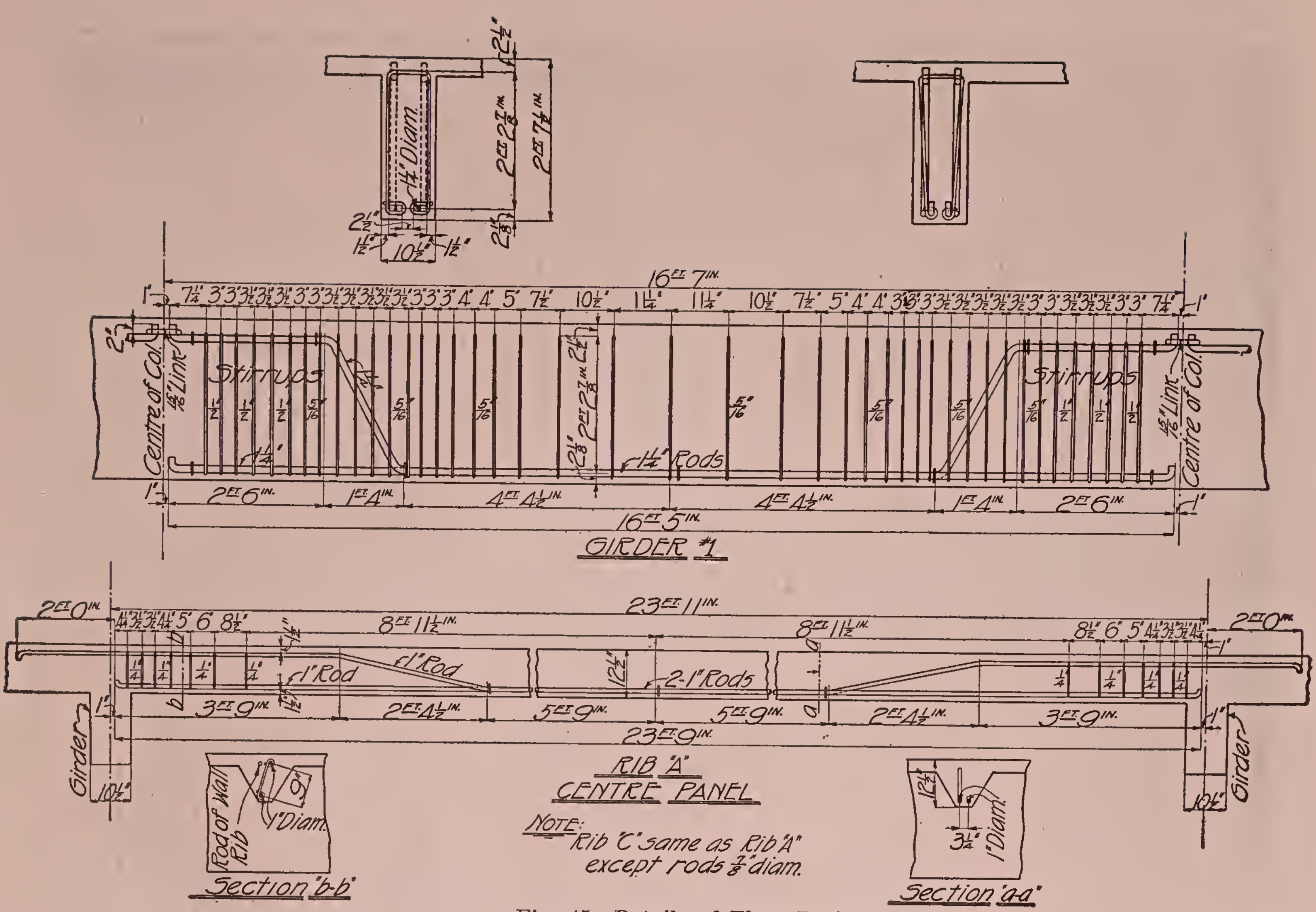


Fig. 45—Details of Floor Design.

16,000 pounds per square inch when the full allowed load is on the floor, and stirrups are provided wherever the shear exceeds 50 pounds per square inch. The floors are designed for a loading of 200 pounds per square foot besides the dead weight of the concrete.

The design of the principal girders is also shown in Fig. 45. The stirrups are close together at the ends of the girders where the shear is the greatest and each stirrup is looped around the tension rods, then passes up on each side of the girder and across, as shown in the sections. The stirrups are ½-inch in diameter near the end of the beam, then at the points where the large rods are inclined and thus take a portion of the shear, the size is reduced to 5/16 inch, and this is continued to the center of the beam, the spacing gradually becoming wider as the shear decreases. The tensional reinforcement in the girders consists of four 1¼-inch rods, two of which are bent up just beyond the one-quarter points, and extend nearly to the center of the column, where each is connected with the reinforcement in the next girder by an oval link of 15/16-inch round steel (see figure above).

In the bays around the elevators, the rib forms were dropped 8½ inches, so as to make the slabs between the ribs 12 inches thick, as shown in Section CC, Fig. 43.

No reinforcement was placed longitudinally of the building at right angles to the ribs. In the floors first laid with the V-shaped rib, slight shrinkage cracks occurred between the ribs and parallel to them. These, however, did not open or indicate any structural weakness, and they were eliminated by more thorough rodding of the surface.

The underside of the floor construction, and also the columns, are shown in the photograph, Fig. 46 (p. 61).

CONSTRUCTION.

Two mixing plants were located in the basement of the building near the two elevator shafts. The arrangement of the entire plant was according to the Ransome design. Each mixer was located on a platform about 3 feet above the floor level, and the raw material sup-

Fig. 46—View of Interior of Bush Model Factory No. 2

plied to it by wheelbarrows.

The building was completed in seventy-four working days, the average progress being 10.4 days per story. During this time 16,000 cubic yards of concrete were placed and 950 tons of steel. The usual gang consisted of 80 carpenters and 180 laborers.

The photograph shown in Fig. 47, shows the general layout of the forms, the girder forms extending lengthwise of the view with the ribs at right angles to them. The rib forms, which are approximately triangular, rest directly upon the sides of the girder molds, and narrow pieces of plank are dropped between them to form the bottom of the rib.

The total cost of the building complete was approximately $450,000. It has automatic sprinklers, steam heat, ample toilet rooms, heavy freight elevators, wire glass windows in metal frames, standard automatic fire doors, hardwood floors, and so forth, to make a really model factory.

Since the completion of this factory, numerous other model buildings of concrete have been built for this same concern.

Fig. 47—View Illustrating Form Construction for Bush Terminal Factory. See Fig. 42 for Finish View.

Fig. 48—Packard Motor Car Factory.

PACKARD MOTOR CAR FACTORY

The Packard Motor Car Company at Detroit, Michigan, turned out 700 automobiles in 1905. The demand for these cars necessitated an enlargement of the plant, and in the spring of 1906, after careful consideration of the various types of construction, it was decided to build the new factory of reinforced concrete. The building illustrated in Fig. 48 is the result.

Plans were drawn at once by Mr. Albert Kahn, architect, and the contract was let to the Concrete Steel and Tile Construction Company, of Detroit, the Trussed Concrete Steel Company acting as engineers.

The structure, as is shown on the plans, is long and narrow, and in the form of an L, so that all parts of the floor are well lighted. It is proposed at some future time to extend the building by carrying out another wing. At present there are two stories, and the roof is designed as a floor with a temporary covering, as described below, so that another story can be added at a later date. The first floor is laid right on the ground—there is no basement.

The building is designed to provide very large floor area without interference of columns. A single row of columns runs through the center of the factory, and these are 32 feet apart on centers, a distance slightly greater than the space between the line of columns and the walls on each side.

Although a motor car appears to be a heavy machine in itself, the parts are comparatively light, and by placing the heavier machinery on the ground floor, it was possible to allow a floor load of only 100 pounds per square foot, in addition to the dead load or weight of the structure itself. In certain parts of the floor, this load is increased, around the elevators especial care being taken to give an excess of strength. This comparatively light live load together with the type of floor construction selected, a combination of tile and concrete, permitted the rather unusually long spans.

The general plan, Fig. 49, shows the layout

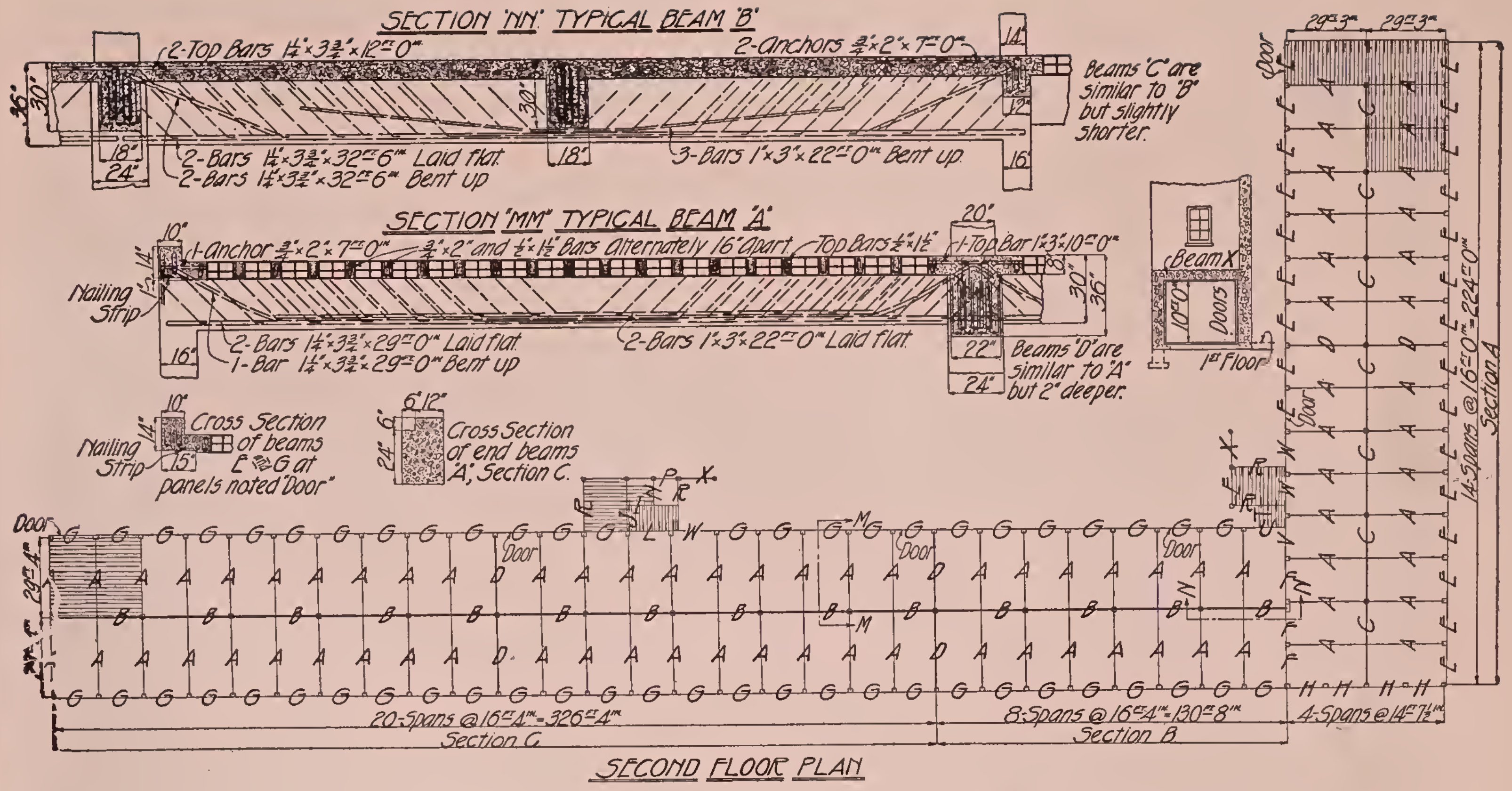


Fig. 49—Floor Plan and Beam Details in Packard Factory

on the floor, with an outline of the location of the beams, girders and columns.

FLOOR SYSTEM.

The first floor is built directly upon the ground. The top soil was removed and the surface thoroughly tamped, then covered with 6 inches of cinders rammed hard to receive the concrete. On top of this porous layer, a 5-inch thickness of concrete in proportions 1 part cement and 2 parts sand to 5 parts broken limestone was spread, and covered with a 1-inch mortar surface, laid before the concrete below had set, in proportions 2 parts cement to 3 parts sand, and thoroughly troweled with a steel trowel to a smooth surface. This was divided into sections as it was being laid to provide contraction joints.

In the floor above, the wide spacing of the columns, already mentioned, necessitated beams and girders of unusual length, and consequently of unusual width and depth. The girders (see Fig. 49) are 30 feet 8 inches in net length between columns, or 32 feet 8 inches on centers, and measures 22 inches wide by 36 inches deep from top to slab. Each girder supports one beam at the center of its span, the alternate beams running directly into the columns. The reinforcement, which consists of Kahn trussed bars,* is very clearly seen in section NN in the figure. The girder selected, as shown on the plan below it, is taken at the intersection of the two wings of the building, and the column at the right is therefore narrower than the left-hand support, the latter illustrating the typical columns in the building.

The floor system, as already mentioned, is designed for a load of 100 pounds per square foot in addition to the weight of the concrete and steel. The design is figured so that this loading will not produce a tension in the steel exceeding 16,000 pounds per square inch, and will keep the compression in the concrete everywhere within the limit of 500 pounds per square inch.* The proportions of the concrete are one part Atlas Portland cement, 2 parts sand, 4 parts broken limestone, the exact measurements being one barrel (4 bags) cement to 7.56 cubic feet sand to 15.10 cubic feet stone.

The shear or diagonal tension is provided for by bending some of the tension rods and also by the bent-up portion of the individual bars.

The beams, of which a typical section, MM, is also shown in Fig. 49, are 27 feet 1 inch net span between girder and wall column. The general construction is similar to the girder shown above it and labeled beam "B" except that fewer bars are bent up because the shear is less. The

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*See Illustration, Fig. 49.

*Figured by the parabolic formula, or nearly 600 pounds by the straight-line formula.

section of the typical beams is 30 inches deep and 18 inches in width.

A somewhat peculiar slab section is shown in the upper portion of section MM. This is made up of sections of tile and concrete placed alternately. The floor slab is 14 feet 6 inches net span between beams, and consists essentially of a series of concrete beams 8 inches deep by 4 inches in width spaced 16 inches apart on centers and reinforced with Kahn trussed bars. These little beams run directly into the upper surface of the regular beams, labeled "A" on the plan, and are supported by them.

Between these little beams hollow tile is laid, the method of construction being to first place the tile upon the level panel form, then set the reinforcing metal in position between the rows of tile, and pour the concrete. The object of the insertion of tile is to lighten the floor slab, and thus reduce the weight upon the beams and girders by occupying space which must otherwise be solid concrete. It also permits very simple form construction, consisting chiefly of a large surface readily built and removed.

After hardening, the under surfaces of the floors are plastered with 2 inches of Portland cement mortar to hide the tile and form the ceiling. On top of the floor slab, a 2-inch wearing surface of cement mortar finish is also laid to make the finished floor.

The beams around the elevators are specially constructed to sustain a weight of 8,000 pounds live or superimposed load, plus 8,000 pounds from the counterweights, plus 4,000 pounds, the weight of the elevators loaded.

The original specifications called for a roofing designed to carry 40 pounds per square foot, but it was afterward decided to build this as a floor of the same construction as the second floor so that another story could be added when required. On top of the level surface thus formed a layer of cinders was spread and shaped so as to pitch to stumps; a 1-inch layer of mortar was laid on the cinders, and upon this tar and gravel roofing.

COLUMNS.

The interior columns are in general 24 inches square and designed for a safe loading which produces a compressive stress in them not exceeding 450 pounds per square inch. The concrete was made in proportions one part Portland cement to 1½ parts sand and 2 parts stone, and reinforced with Kahn trussed bars.

The wall columns are similar in design, but smaller in section and spaced 16 feet 4 inches apart on centers, so that all the cross beams run directly into them. A longitudinal beam at each floor line connects these wall columns and also supports the brickwork, which is built up to the level of the window sills.

Fig. 51—Concrete and Tile Floor Under Construction.

Fig. 52—Interior View of Packard Factory Completed.

Fig. 53—Interior View of Syracuse Cold Storage Company's Warehouse.

WAREHOUSE OF SYRACUSE COLD STORAGE COMPANY

The warehouse of the Syracuse Cold Storage Company, Syracuse, N. Y., illustrates the application and the economy of factory-made unit-concrete floors.

The warehouse is a six-story and basement building approximately 78 feet square. While it was originally designed for mill construction, alternate bids were taken using both a monolith concrete design and a structural steel frame incased in concrete with separately molded floor sections. This last type of construction was found to be cheaper than either of the others and consequently was adopted.

The photograph in Fig. 53 is an interior view of the completed structure.

DESIGN.

With the exception of the top floor the building was designed to carry a live load of 300 pounds per square foot. The columns were spaced 15 feet 3 inches on centers both ways. The structural steel frame, which consisted of plate and angle columns carrying Bethlehem girder beams, was designed to carry the entire live and dead loads, the concrete encasing the columns and girders being considered only as fireproofing.

The separately molded floor sections, details of which are shown in Fig. 54, rested on the lower flange of the I-beams, reinforcement being provided for ties over the top flanges. The connections were filled with field concrete placed after the members were in position.

CONSTRUCTION.

The concrete floor sections were delivered both by rail and by team from the plant at which they were manufactured, three miles distant. The concrete members were unloaded by a boom attached to the steel columns. They were distributed about the building and set in place, as shown in Fig. 55, by chain hoists on portable I-beam trolleys.

The top flange of one beam in each panel was coped to allow the beams to enter, and they

Detailed Cost of Syracuse Cold Storage Company's Warehouse

Building 78 ft. x 78 ft., steel frame fireproofed, having basement, six storage floors and concrete roof. Floors designed for 375 lbs. per sq. ft. total load. Total area of floors, 40,432 sq. ft.; volume, 424,480 cu. ft.

	Classification of Work	Quantities	Cost	Total Cost	Cost per Yd.	Cost per Lb.	Cost per Sq. Ft.	Cost per Cu. Ft.
Concrete Floors	Concrete materials in floors: cement at $1.40 bbl., stone at $1.10 ton	373 yds.	$1,156.30	......	$3.10	....	.028	....
	Reinforcing steel in floors, f.o.b. shop	105,810	1,454.40	......	....	.014	.036	....
	Labor fabricating reinforcement	....	317.43	......	....	.003	.008	....
	Labor making floor sections and roof	....	2,605.69	......	....	....	.064	....
	Labor erecting members	....	1,650.10	......	....	....	.040	....
	Hauling and freight on members from factory (2 miles)	....	382.57	......	....	....	.008	....
	Power, erection tools and supplies	....	217.40	......	....	....	.005	....
	Fixed factory charges, including power, interest and depreciation	....	500.00	......	....	....	.012	....
	Total for floors in place, not including pointing or grouting	....	.....	$8,283.89	....	....	.250	.0195
Structural Frame and Fireproofing	Structural steel erected	250,000	$7,050.00	......	....	.028	....	....
	Materials for concreting floors and fireproofing steel	....	244.84	......	....	....	....	....
	Labor pointing and concreting floors and fireproofing steel	....	1,149.00	......	....	....	....	....
	Lumber for forms used in fireproofing steel	....	150.00	......	....	....	....	....
	Freight, delivery and cartage on field materials	....	50.00	......	....	....	....	....
	Tools, power and supplies	....	100.00	......	....	....	....	....
	Total for frame and fireproofing	....	.....	$8,743.84	....	....	.216	.0206
	Engineering and superintendence	....	$798.53	......	....	....	.019	.001
	Total for floors, frame and fireproofing	....	.....	$17,826.26	....	....	.44	.041
General	Brick curtain walls, stairs, trim, felt and gravel roof, and all other work to complete superstructure	....	$6,904.76	......	....	....	.17	.016
	Total cost of superstructure	....	.....	$24,731.02	....	....	.61	.057

Fig. 56

were slid into position on the lower flange, wedged up, pointed underneath, the projecting reinforcement tied over the top flanges and the spaces between the ends and edges grouted in solid.

After the separately molded members were in place they were covered with a 2-inch granolithic wearing surface.

COST.

The table in Fig. 56 gives the detailed cost of the warehouse. As shown by this table the separately molded floor sections cost 20½ cents per square foot in place, the steel frame and fireproofing 21½ cents per square foot and the cost of engineering and superintendence about 2 cents per square foot. This gives a total of only 44 cents per square foot or 4 cents per cubic foot of volume for frame and floor. These costs, of course, as well as the others in this book, are on the basis of labor and material before the Great War.

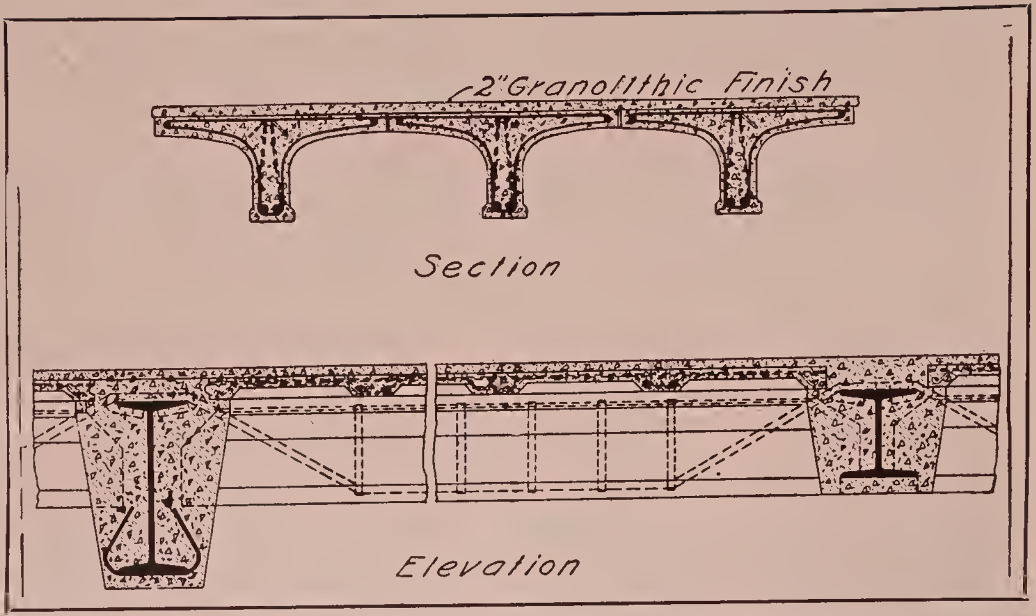

Fig. 54—Details of Separately Moulded Floor Sections.

Fig. 55—Method of Handling Separately Moulded Floor Section.

Fig. 57—Blacksmith and Boiler Shop of The Atlas Portland Cement Co. at Northampton, Pa.

BLACKSMITH AND BOILER SHOP OF THE ATLAS PORTLAND CEMENT COMPANY

At the plant of The Atlas Portland Cement Company, in Northampton, Pa., concrete is used extensively in construction, not only in foundations and for the cement storehouses, but also for the floors and walls of the newer buildings.

In 1906 a new blacksmith and boiler shop was built with a 10-ton crane extending from wall to wall and running upon reinforced concrete arched beams. The building was designed by the company's engineer and built by day labor. It is shown complete in Fig. 57.

DESIGN.

The shop is 309 feet 9 inches long, 55 feet 6 inches wide and 31 feet 2 inches high to the bottom of the roof trusses, this height being necessary for the traveling of the crane.

The walls consist of piers 14 feet on centers, with wall panels and windows between them. These piers are made of heavy section (see Fig. 59) to support the crane, and for this purpose they project into the building 23 inches as far up as the crane runway, and at the top are connected with arches which are laid at the same time and form a part of the wall. The arches are reinforced with five ¾-inch rods spaced 5 inches apart. The crane run is shown in Fig. 59. An 8-inch by 10-inch yellow pine timber is bolted directly to the concrete beam, and upon this rests the track. The walls between the piers, which are dovetailed into them, as shown, are 9 inches thick. This is somewhat excessive, but the extra quantity of concrete may be justified by the low cost of materials and the lean proportions of the concrete, which are 1 part cement to 4 parts sand to 5 parts gravel. There is no reinforcement in the wall panels except directly above the windows.

A cross-section of the shop with its steel roof trusses is shown in Fig. 59.

CONSTRUCTION.

Somewhat unusual methods of construction were employed. The piers were first run up to the

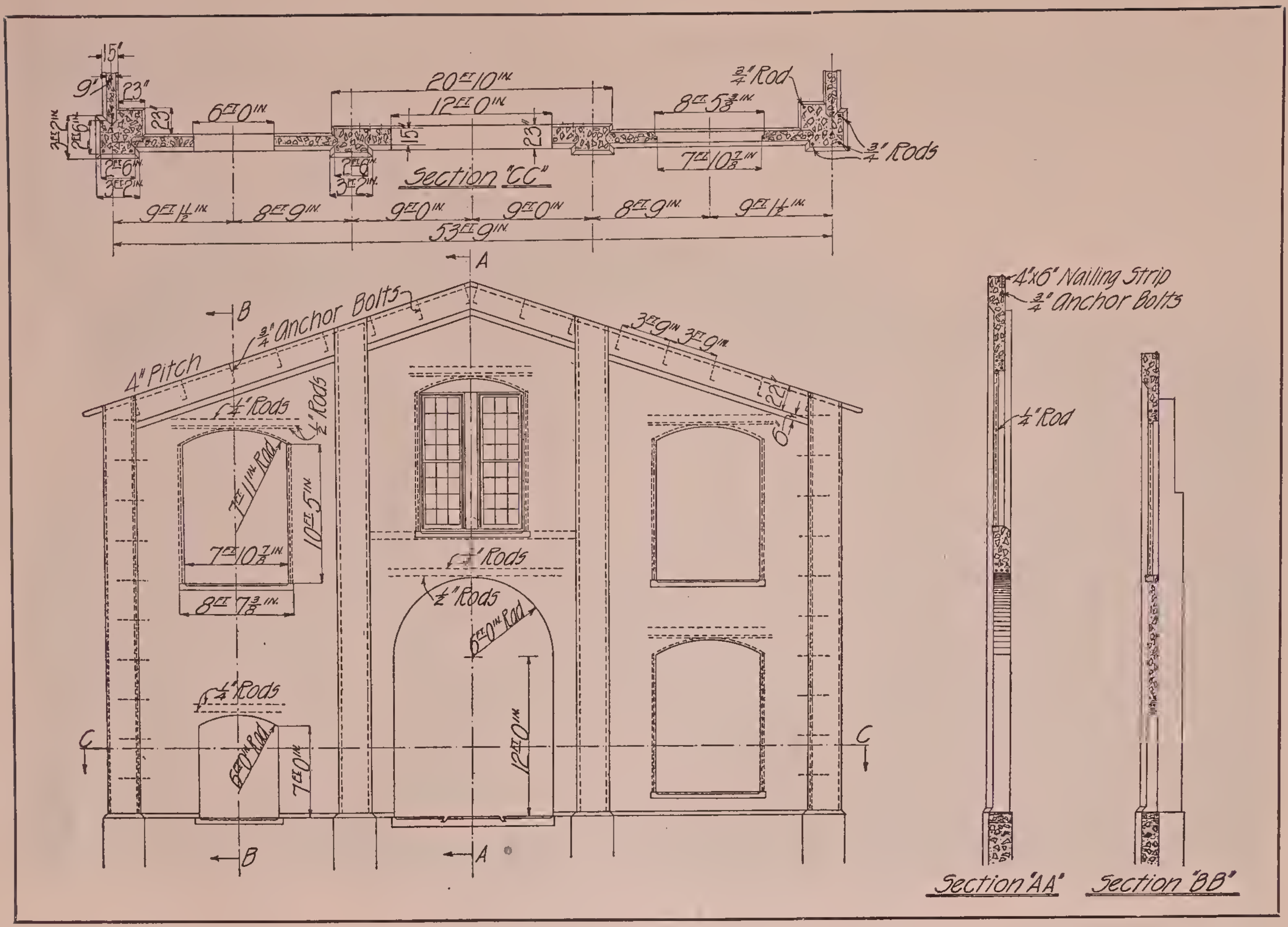

Fig. 58—East Wall of Blacksmith and Boiler Shop of the Atlas Portland Cement Company

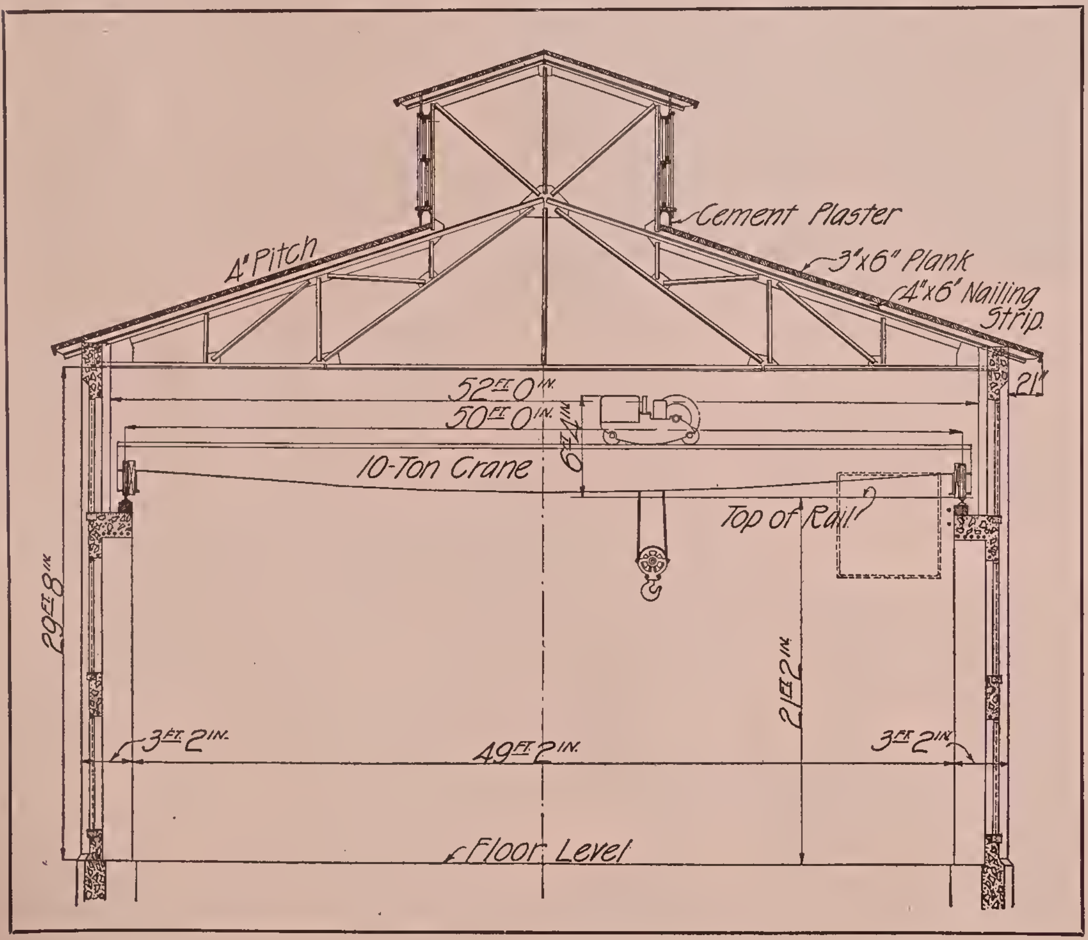

Fig. 59—Cross Section of Blacksmith and Boiler Shop of the Atlas Portland Cement Company

full height of the building, as illustrated in the photograph, Fig. 60. Then the panel forms were placed, as in Fig. 61, and the concrete poured between them.

The window frames had been set in advance, so that the openings were formed in each wall panel as it was poured. The only tie rods which were inserted to connect the piers and the wall panels were at the corners of the building, where ½-inch horizontal rods 2½ feet long were placed every 3 feet in height.

Above the foundations of the shop, 792 cubic yards of concrete were required, with only 5,570 pounds of steel. In the foundation 460 cubic yards were laid in addition. The concrete was mixed by hand, and the usual gang consisted of 2 foremen, 17 men mixing, 4 men hoisting, 4 men placing, and 6 carpenters. The wages for the laborers ranged from $1.20 to $1.50 per day, with a $2 rate for the carpenters. The total cost of the concrete in the foundations and walls was $29,328, which is equivalent to only $4.93 per cubic yard of concrete, an exceptionally low price. The cheapness of labor partially accounts for the low cost. Ordinarily, in building construction with thinner walls and higher material and labor costs, the unit price per cubic yard will be greatly in excess of this figure.


Fig. 60—Wall Piers for The Atlas Portland Cement Company Building.

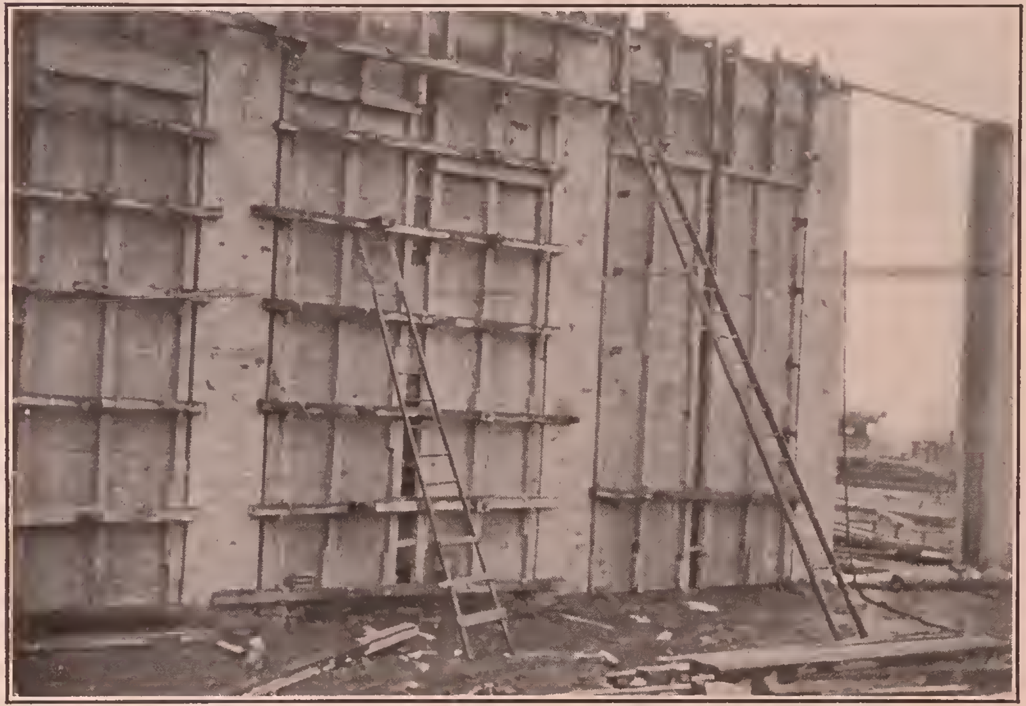
Fig. 61—Panel Wall Forms for The Atlas Portland Cement Company Building.

The forms, of hemlock lumber, costing $25 per thousand, were dressed only on the side next to the concrete. About 19,000 feet of lumber was used at a cost of $485, the labor on forms being about $5,500. Although the forms were used ten times, the Engineer estimates the salvage for another similar job to be about 60 per cent, as the lumber was but slightly injured.

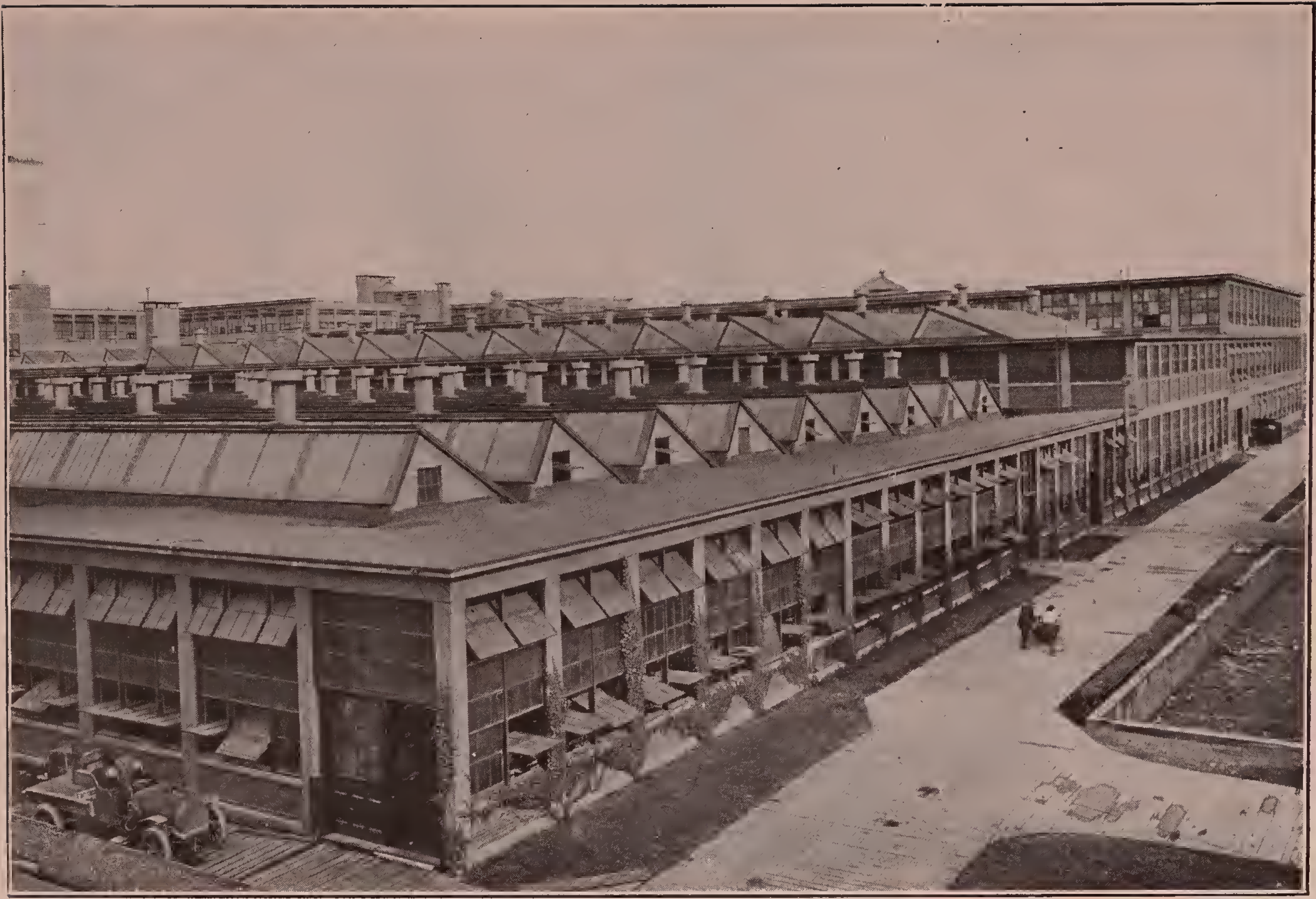

Fig. 62—Exterior of Manufacturing, Assembly and Body Buildings, Pierce-Arrow Motor Car Factory

PIERCE-ARROW MOTOR CAR FACTORY

When the Pierce-Arrow Motor Car Co. of Buffalo, N. Y., was confronted with the necessity of more extensive and complete manufacturing facilities they decided to build a manufacturing plant complete in every detail; a plant that by its perfect system of light, heat and ventilation, its safety and freedom from decay, and its fireproofness, would attract and hold the best and most desirable skilled workmen.

After a careful study of the various types of construction, reinforced concrete was selected. The satisfaction this material has given the owners is shown by the fact that during the wonderful development of the past four years, when the plant was increased from its original size of 325,000 square feet of floor space to its present area of 780,000 square feet, all the buildings have been constructed entirely of reinforced concrete.

A block plan of the factory is shown in Fig. 63 (p. 73). The entire plant is laid out with the idea of attaining the highest degree of factory economy. With this in view the buildings were arranged so that the materials in process of manufacture are gradually conveyed toward the Assembly Building, thus eliminating all confusion and unnecessary handling.

MANUFACTURING BUILDING.

The Manufacturing Building is a one-story structure, 205 feet by 401 feet, covered over its entire area with a sawtooth roof. The extremely careful work and accurate inspection necessary in turning out the small pieces that go into the mechanism of an automobile require the greatest possible amount of light. The sawtooth skylights and the exceptionally large windows made possible through the use of reinforced concrete have solved this problem admirably.

The photograph, Fig. 62, shows the exterior of the Manufacturing Building with the Assembly and Body Buildings beyond.

ASSEMBLY BUILDING.

The Assembly Building, 122 feet by 401 feet in dimensions, is the most interesting of the plant from a structural standpoint. Fig. 65 (p. 74) shows the interior. Two three-ton cranes travel the entire length of the building, and in order to give these a large area of action, the building is divided by a single row of columns down the center. This necessitated roof girders spanning 61 feet and measuring 16 inches wide by 93 inches deep. These were reinforced with Kahn bars having a sectional area of 18 square inches. The crane girders, that is, the beams upon which the crane runs, span 25 feet from column to column and are of reinforced concrete, the rails for the traveller being fastened directly to the concrete by ⅝-inch bolts bedded in the concrete.

BODY BUILDING.

The body Building, an exterior view of which is shown in Fig. 64, is a four-story structure, 751 feet long and 140 feet wide, built with two wings 60 feet wide and a 40-foot open court between them. It contains two large freight elevators, capable of handling the largest type of touring car, one smaller elevator and three reinforced concrete stairways, each enclosed in isolated brick towers projecting out into the court.

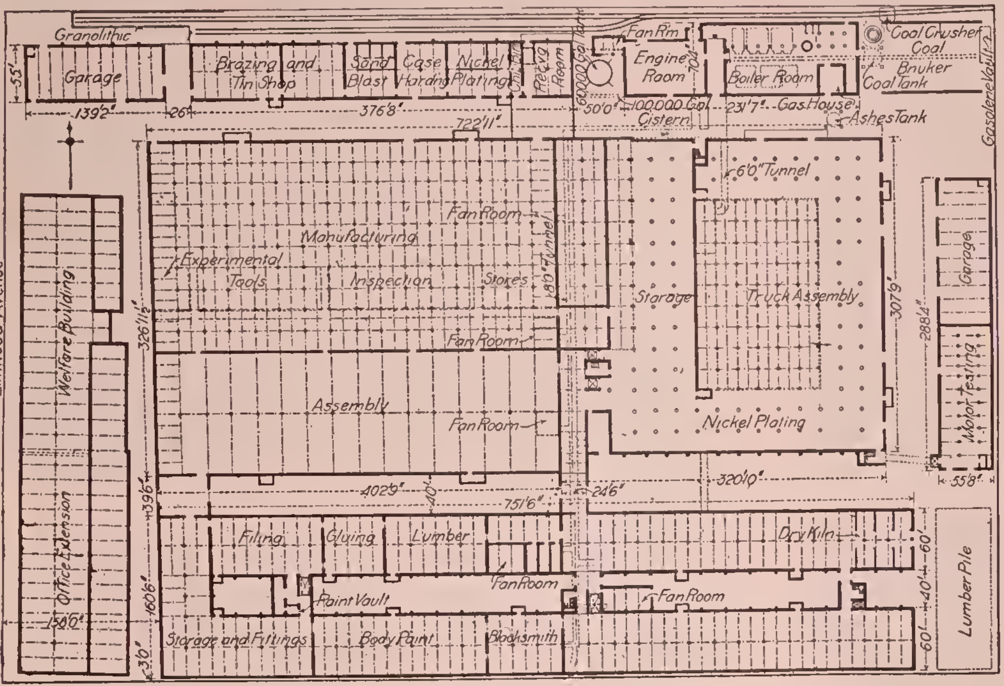

Fig. 63—Block Plan of Pierce-Arrow Motor Car Factory.

Fig. 64—Exterior Elevation of Pierce-Arrow Body Building

The beam and girder type of construction was used throughout the building, a single row of columns 25 feet on centers running through the center of the building.

Fig. 67, illustrating the interior of the Wood-Working Room, is of particular interest as showing clearly the method of attaching the heavy motors direct to the ceiling and of suspending the shaft hangers, sprinkler pipes and electric-light fixtures from the concrete slab.

STORAGE AND NICKEL-PLATING BUILDING.

A different type of design is followed in the Storage and Nickel-Plating Buildings, where the mushroom or girderless-floor construction is used. Fig. 66 is an interior view of the second floor of the Storage Building, and illustrates the value of the flat-slab construction in storage buildings, allowing as it does complete utilization of all the space from floor to ceiling, without interference from beams or girders.

GARAGE.

The Garage is a one-story building, 55 feet wide and 139 feet long, with a monitor running its entire length. Fig. 68 shows the interior. In or-

Fig. 65—Interior of Pierce-Arrow Assembly Building.

Fig. 66—Interior of Pierce-Arrow Storage Building.

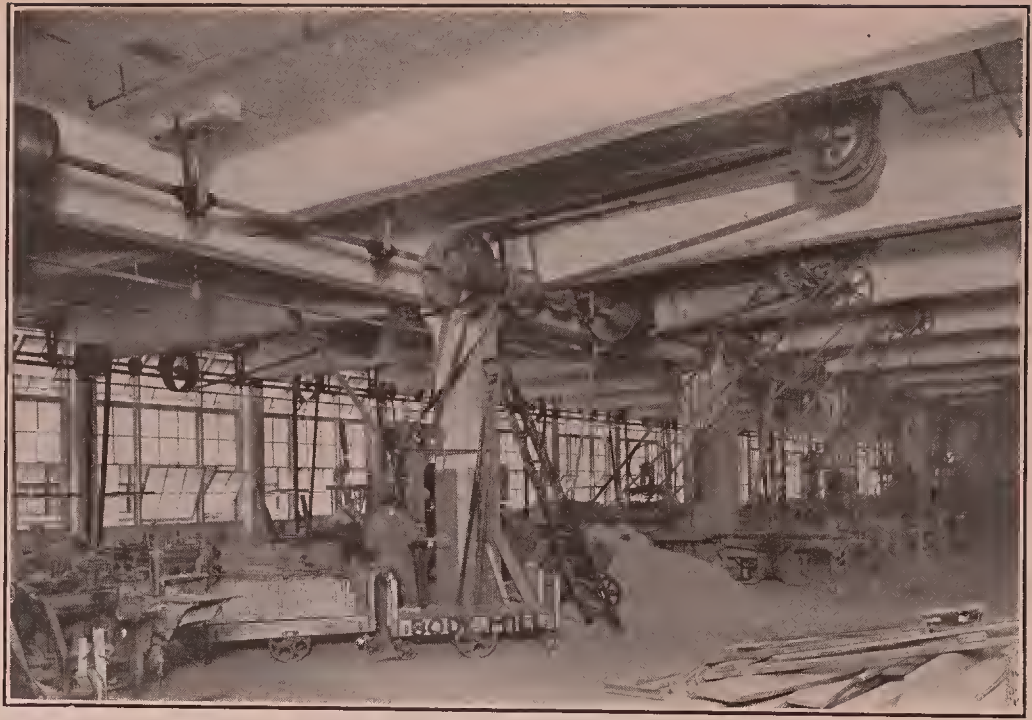

Fig. 67—Interior View of Wood Working Room in Body Building.

Fig. 68—Interior of Garage.

der to have a large unobstructed floor space, in which to move automobiles around easily, no interior columns were used in the building and the roof girders spanned 55 feet so as to leave the entire floor clear. These girders are 16 inches wide and 56 inches deep at center of the building, sloping with roof to 40 inches deep at wall columns.

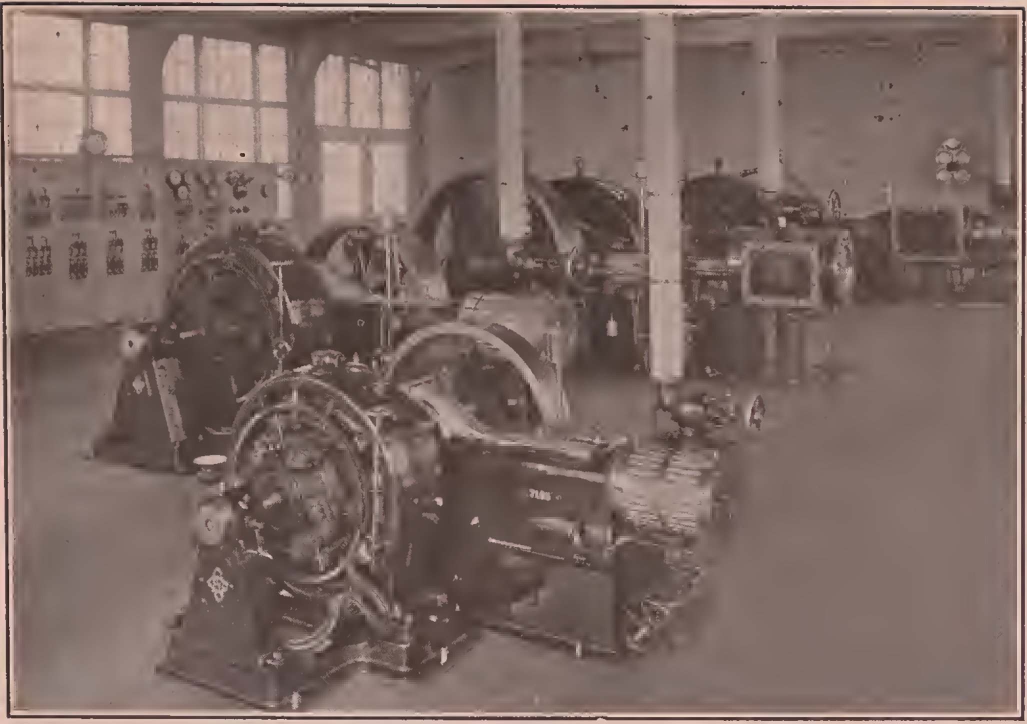

Fig. 69—Interior View of Pierce-Arrow Engine Room.

THE POWER HOUSE is a one-story structure, 55 feet wide and 194 feet long, with no interior columns, the regular roof and monitor roof being carried by reinforced concrete girders spanning 55 feet, see Fig. 69.

Fig. 70—Pacific Coast Borax Refinery. Designed and Built by Ernest L. Ransome, of Ransome & Smith Co.

PACIFIC COAST BORAX REFINERY

The distinction of being the designer and builder of the first two reinforced concrete factory buildings in the world undoubtedly belongs to Mr. Ernest L. Ransome, of the Ransome & Smith Company. Of these the Pacific Coast Borax Refinery at Bayonne, N. J., a few miles from Jersey City, deserves special attention not only as one of the earliest examples of this type of construction, but for its notable record in passing through a terrific fire without structural injury. Moreover, the fact that it was not erected until 1897-8 serves to emphasize the marvelous growth in reinforced concrete construction.

The time is so recent and reinforced concrete buildings are now so common that it is difficult to appreciate the boldness of the conception to construct a 4-story building, to sustain actual working loads of 400 pounds per square foot besides heavy machinery even on the top floor, out of a material until recently used almost exclusively for foundations, and considered capable of resisting only compressive loads. Of course, the principle of steel reinforcement in concrete had been understood for a number of years previous to 1897. In fact, a house of reinforced concrete was built in Port Chester, N. Y., as early as 1871, and a few other similar structures appeared between this date and 1897. But with the exception of the factory at Alameda, Cal., also designed and built by Mr. Ransome, the Pacific Coast Borax Building appears to be, as above intimated, the first attempt at concrete factory construction.

While it is not claimed that the design of this factory is in all respects typical of the up-to-date concrete factory building as now erected by the Ransome & Smith Company and other contractors, many of its features and the methods employed in its construction are well worth consideration.

As built to-day, double walls are not regarded as essential for factories, but instead the wall surface is usually taken entirely by windows separated by concrete columns which support the floors above. In the floor system, slabs of longer span with correspondingly heavier beams are now more common, while expansion joints

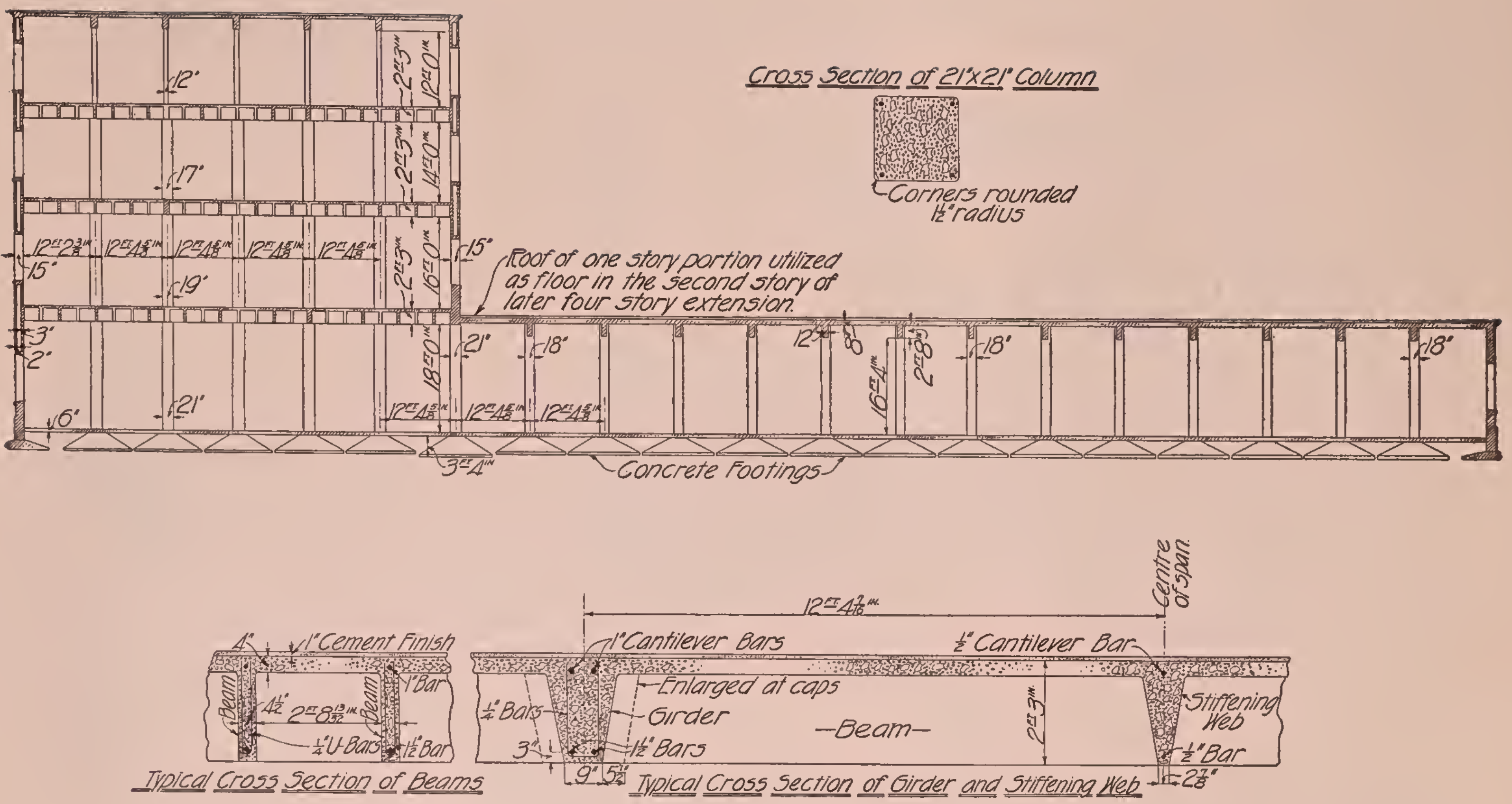

Fig. 71—Cross Section of Pacific Coast Borax Refinery.

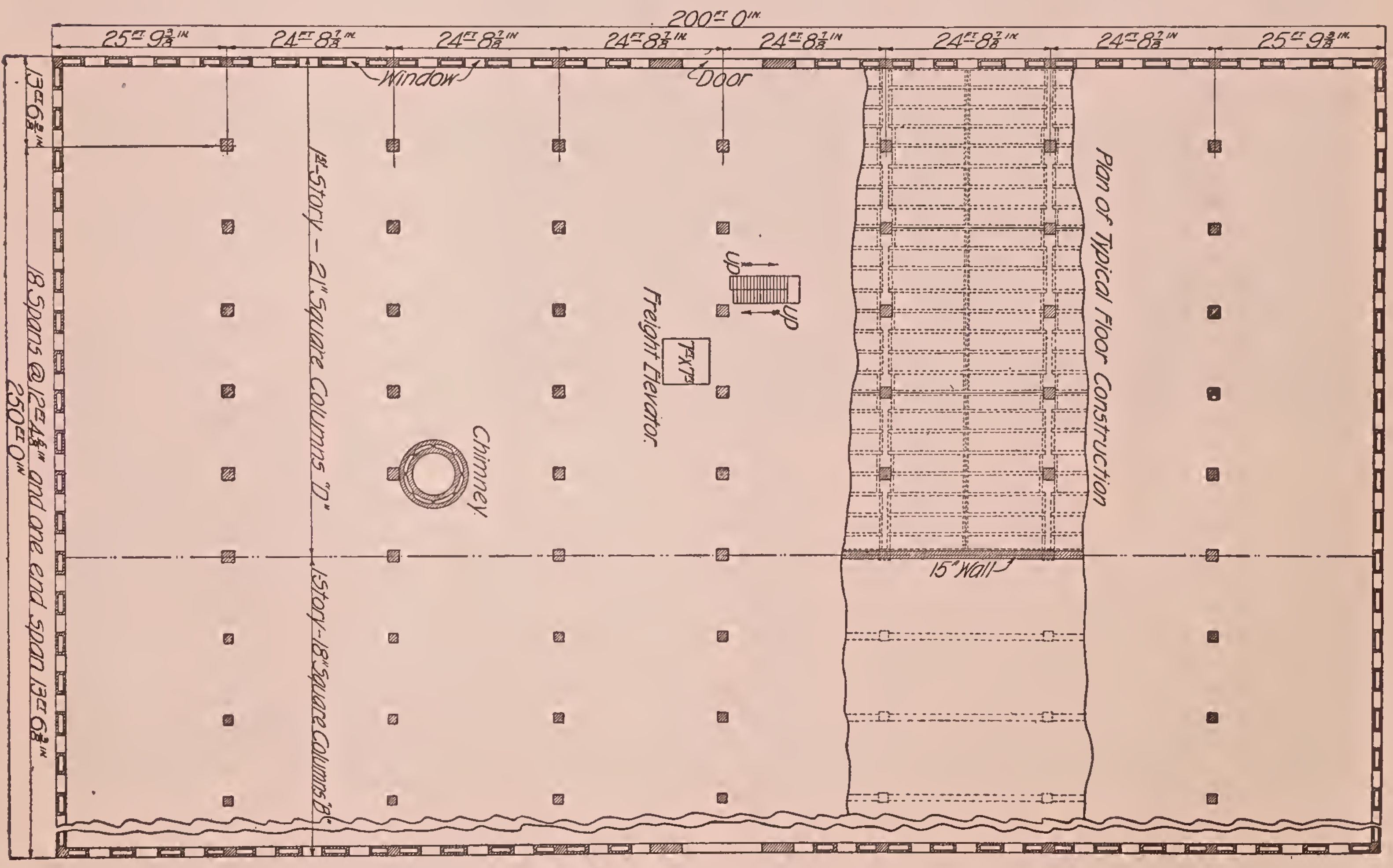

Fig. 72—Plan of First Story of Pacific Coast Borax Refinery.

in floors are not usually specified unless the building covers an extremely large area.

DESIGN.

The main building is 200 feet long by 75 feet wide, and four stories high, rising 70 feet above the ground. Connected with this and forming a part of it is a section which was built first only one story high, and then after the fire carried up to the full four stories, as shown in Fig. 70. The area of ground covered by the combined buildings is 50,000 square feet.

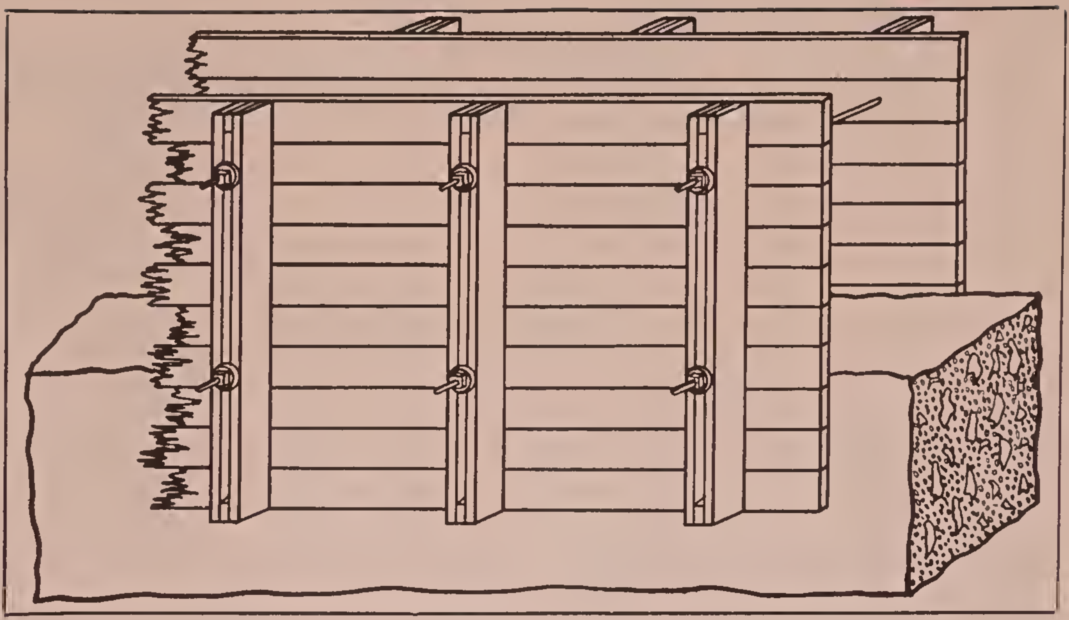

Fig. 73—Type of Wall Molds.

The plan of the first story is shown in Fig. 72, the junction between the four-story and the one-story portion being indicated by the dot and dash line AA. In order to show the plan on a large scale, the first floor of the four-story building is drawn in full and a part of the one-story portion is omitted as indicated by the irregular lines BB.

The bays in general are 24 ft. 8⅞ inches by 12 ft. 4⅝ inches; the columns in the first story are 21 inches square, in the second story 19 inches, in the third story 17 inches, and in the fourth story 12 inches. They are computed by a maximum compression of 500 pounds per square inch.

The sectional elevation in Fig. 71 shows the columns and also the column footings which are reinforced in the bottom with horizontal rods. The footings were designed so that the compression upon the soil, which is of a marshy character, should not exceed 2,500 pounds per square foot.

Fig. 71 also illustrates the construction of the floor system, and, taken in connection with a plan of a portion of the second floor in Fig. 72, gives a good idea of the type of design. Girders connect the columns which are 12 ft. 4⅝ inches on centers. Between the girders and at right angles to them, run the concrete floor beams about 3 feet apart and so thin and deep that they resemble timber joists in appearance. As these beams are nearly 25 feet long in the clear, a stiffening web crosses them in the middle, designed to serve the same purpose as bridgeing in wooden floor joist construction. that is, to assist in preventing tendency to buckle under heavy loads. The girders are of rather peculiar construction, being made thicker in the panels next to the columns so as to save expense in forms. (See Fig. 71.)

Originally, the columns in the fourth story of the main building and also the roof were of wood, while the one-story part was of similar construction. After the fire the wood was all replaced by concrete, as shown in the plans. The roofs were then built as reinforced slabs of 12 ft. 4⅝ inches span from centre to centre of the beams, the latter being 24 ft. 8⅞ inches long between column centres. Still later the roof of the low part formed the floor for the second story when this portion of the building was raised to full height, shown in the finished photograph, Fig. 70.

The reinforcement of the beams and girders and stiffeners of the principal floors is shown at the lower part of the diagram, Fig. 71. The slabs were built of such short span that they received no reinforcement, the depth being 4 inches in addition to the 1-inch cement finish.

The floors with the beams and girders were laid as separate panels about 24 feet square, a vertical contraction being carried down through the beams on a line with alternate columns; that is, every eighth beam was built double. As stated above, it is not now customary to insert contraction joints except on extraordinarily large surfaces, the contraction being provided for instead by the steel reinforcement in the beams and slabs.

The exterior walls were finished by picking the surface with a sharp tool which removed the outside skin of cement so as to show the stone and mortar between and resemble pean hammered masonry. A part of this work was done by hand and part with pneumatic hammers. Although a pneumatic hammer averaged about 400 square feet in ten hours, while by hand 100 to 150 square feet was a fair day's work for a man, the actual cost with the power tool was but slightly less than by hand because of the higher grade of men required, the extra men for shifting air pipes, etc., and the wear and tear on the tools.

The surface was also divided into blocks by wood moldings nailed to the inside of the form. The stairs are also of reinforced concrete.

Fig. 74—Photograph of Cast Iron Melted by the Fire

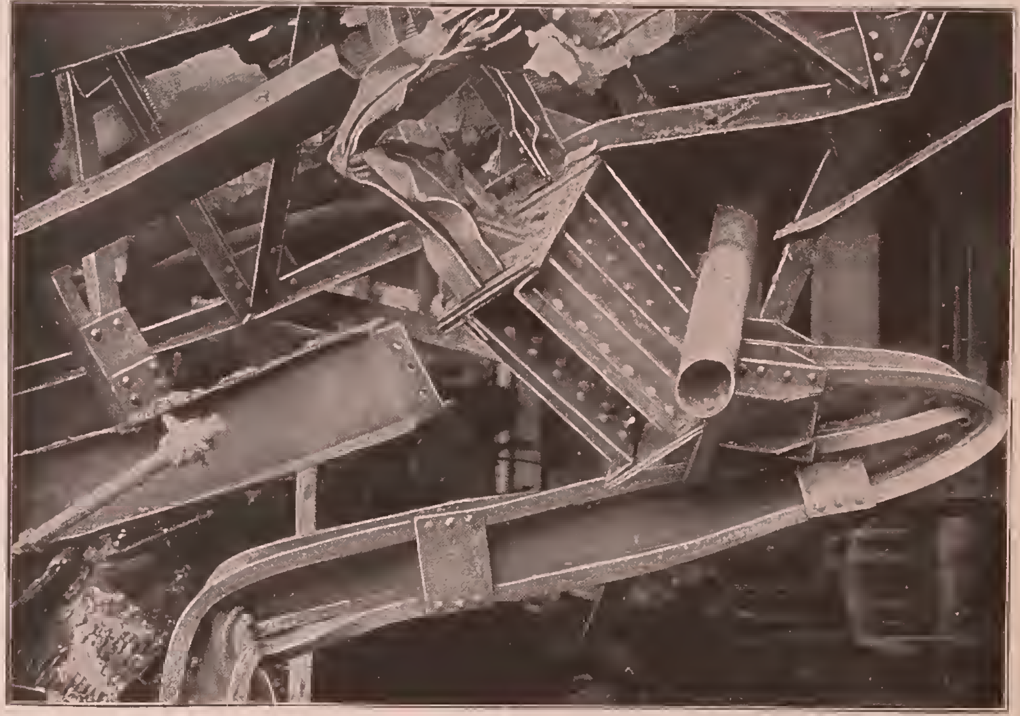

Fig. 75—Effect of Fire Upon Steel Tank House

CONSTRUCTION.

Construction was begun late in the fall of 1897 and completed in October, 1898. The usual time per story was 40 to 50 days, whereas now such a building would be put up by the same builders at the rate of a story in one or two weeks.

The column forms were built in the usual way with vertical boards paneled together, and held with clamps surrounding them. The wall forms were 7/8-inch dressed boards, designed in general like Fig. 73.

These forms, patented by Mr. Ransome in 1885, are still extensively used in wall construction. The special feature is the vertical standard made of two 1 by 6-inch boards on edge with a slot between, through which pass the bolts. By loosening the nut, the plank behind the standards may be loosened and the standards raised. The walls were built in sections 4 feet high with central cores to form the hollow walls.

White pine was used for forms, and the salvage on the lumber probably did not amount to more than 10 per cent, although by present methods the builders usually figure about 30 per cent.

The total cost of the building was in the neighborhood of $100,000.

THE FIRE

Some four years after completion, in the spring of 1902, the Refinery was subjected to one of the most severe fires to which a manufacturing building is liable. Although the building itself is of concrete, it contained a large amount of wood in the form of partitions, window frames and bins, in addition to the wooden roof, and at the time of the fire one room happened to be completely filled with empty wooden casks which pro-

Fig. 76—View of Refinery After the Fire.

Fig. 77—View of Refinery, Including New and Old Structures.

vided yet more fuel for the flames. Some of the material used in the manufacturing process was also extremely inflammable.

To illustrate the heat of the fire, an insurance man called attention to the fact that the plank roof was entirely gone, with no charred wood remaining, the brass in the dynamos was melted, and at least in one case a piece of cast iron was fused into a misshapen mass. A photograph of the melted cast iron is shown in Fig. 74.

This fusing of the iron is especially remarkable since cast iron melts at the high temperature of about 2200° Fahr. The piece appears to be a portion of a pulley which was probably located near an opening in the floor through which there was a tremendous draft of flame.

The chief structural damage to the building at the time of the fire was caused by the fall of an iron tank which was located on the wooden roof and supported by timbers from the fourth floor. This weight coming suddenly upon the floor broke the slab and two or three of the floor beams, but did not pass through to the floor below, being caught by the damaged floor.

In several places throughout the building the concrete had been split off by the fire to a depth of 1/4 to 1 inch, and on one of the exterior walls a few cracks showed over a doorway. The total cost of repairs, including the portion of the floor broken by the tank, was in the neighborhood of $1,000. The broken beams were repaired by inserting new concrete in the central portion and supporting it by bolts run down through the ends of the beams which still remained in place.

As a result of the fire the structure was completely gutted, nothing remaining but the reinforced concrete and a mass of charred roof, with the machinery, shafting, dynamos, etc., melted or twisted out of shape. A photograph taken directly after the disaster before any repairs were made is given in Fig. 76. This photograph also presents a very good view of the Refinery itself with the main building and the one-story addition.

In contrast with the durability of the reinforced concrete under the action of the fire is a steel tank house adjoining the building. This was built with steel columns and roof girders, and the effect of the heat upon the steel structure is graphically shown in Fig. 75, page 79.

A photograph of the Refinery, taken in 1907 and shown as Fig. 77, presents one view of the buildings, showing in the foreground the new part also built by Ransome & Smith and the older structure in the background.

CHAPTER IV—DETAILS OF CONSTRUCTION

To provide better adhesion or bond between the steel and concrete than is given by round or square rods, many types of deformed bars have been invented, and those most commonly used in the United States are illustrated in the pages which follow. Views are also shown of a number of systems of assembling the steel or arranging the reinforcement for application to special conditions.

In addition to this digest of systems of reinforcement, a number of photographs are presented of details of construction most commonly met with in reinforced concrete buildings. In this connection are shown photographs of concrete block walls, surface finish for concrete walls, concrete piles, and concrete tanks.

SYSTEMS OF REINFORCEMENT.

RANSOME TWISTED BARS.—One of the oldest types of reinforcing steel is the square twisted bar illustrated in Fig. 78, invented by Mr. E. L. Ransome, of the Ransome & Smith Co., and used as long ago as 1894.

Twisted bars may be purchased ready to use, or on a large job may be twisted on the work. The number of twists per linear foot depends upon the diameter; thus, for ¼-inch bars there may be five twists per foot, and for 1-inch bars one twist per foot.

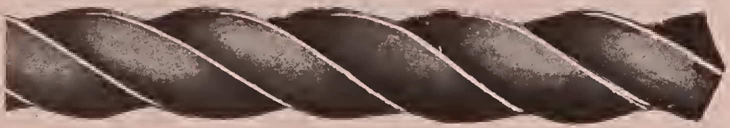

Fig. 78—Ransome Twisted Bar.

In computing cross-section area of steel in reinforced concrete, the twisted bars are figured as square bars of the dimension before twisting. Twisted bars are employed in the Pacific Coast Borax Refinery and the Bullock Electric Company shop, described on pages 76 to 81 and 45 to 48.

THACHER BAR.—The Thacher bar, Fig. 79, was designed and patented by Mr. Edwin Thacher, of the Concrete Steel Engineering Company. Round bars are rerolled to the shape indicated.

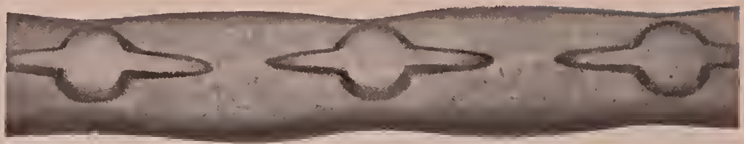

Fig. 79—Thacher Bar.

CORRUGATED BARS.—The corrugated bar, Figs. 80 and 81, is the invention of Mr. A. L. Johnson, of the Corrugated Bar Company. These bars are made in both square and round shapes and are rolled from billet stock, medium or high carbon steel. This company has devised a machine fabricated beam and girder unit frame called Corr-Bar Units, Fig. 82, which is self-centering and collapsible. The normal size and net sections of both the round and square corrugated bars are given in the following table:

Fig. 80—Corrugated Square Bar.

Fig. 81—Corrugated Round Bar.

AREAS AND WEIGHTS OF CORRUGATED BARS.
STANDARD SIZES

Corrugated Squares	Size in inches.......	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼
	Net area in square inches....	.06	.14	.25	.39	.56	.76	1.00	1.26	1.55
	Weight per foot in pounds...	.22	.49	.86	1.35	1.94	2.64	3.43	4.34	5.35
Corrugated Rounds	Size in inches	⅜	½	9/16	⅝	¾	⅞	1	1⅛	1¼
	Net area in square inches....	.11	.19	.25	.30	.44	.60	.78	.99	1.22
	Weight per foot in pounds...	.38	.66	.86	1.05	1.52	2.06	2.69	3.41	4.21

DIAMOND BAR.—The diamond bar, Fig. 83, is one of the most recent types of rolled bar and the invention of Mr. William Mueser, of the Concrete Steel Engineering Company. The sizes correspond to those of square bars, as shown in the following table:


Fig. 82—Corr-Bar Units.


Fig. 83—Diamond Bar.

Areas and Weights of Diamond Bars

Size	¼ in.	⅜ in.	½ in.	⅝ in.
Area in square inches	.0625	.1046	.25	.39
Weight per foot	.213	.478	.85	1.33

Size	¾ in.	⅞ in.	1 in.	1¼ in.
Area in square inches	.56	.76	1.00	1.56
Weight per foot	1.91	2.60	3.40	5.31

KAHN TRUSSED BAR.—The Kahn trussed bar, Fig. 84, invented by Mr. Julius Kahn, of the Trussed Concrete Steel Company, is rolled with flanges, which are bent up, as shown in the figure, to resist the shear in the beam. The Kahn bar is employed in the Packard building, described on pages 62-64.

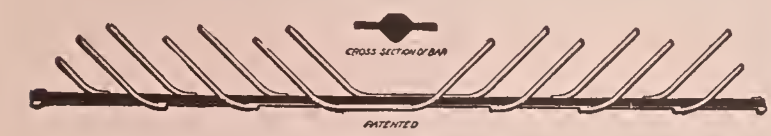

Fig. 84—Kahn Trussed Bar.

RIB BAR.—The rib bar, another product of the Trussed Concrete Steel Company, is rolled with four longitudinal ribs connected at frequent intervals by cross ribs, so as to form cup depressions between them designed to grip the concrete.

Areas of cross-section of cup bars are made to correspond to square bars of the same nominal size.

HAVEMEYER BARS.—The Havemeyer bar, Fig. 85, is the invention of Mr. J. F. Havemeyer, of the Concrete Steel Company. It is rolled in both square and round shapes. The square bar has a series of projections and depressions in conjunction with the plain square section of the bar, the projections on the sides equaling the depressions on the corners. The round bar has projections staggered on alternate faces. Both the round and the square bars have the same net sectional area and the same gross weight as plain bars of the same nominal size.


Fig. 85—Havemeyer Bar.

EXPANDED METAL.—One of the oldest forms of sheet reinforcement is expanded metal invented by Mr. John T. Golding.

Sheet steel is slit in a special machine and then pulled out or expanded so as to form a diamond mesh.

EXPANDED METAL MESHES

Designation			Section in Square Inches per Foot of Width	Weight per Square Feet in Pounds
Mesh	Gage (Stubs)	Strand—Standard or Extra		
½ in.	No. 18	Standard	.209	.74
¾ in.	No. 13	Standard	.225	.80
1½ in.	No. 12	Standard	.207	.70
2 in.	No. 12	Standard	.166	.56
3 in.	No. 16	Standard	.083	.28
3 in.	No. 10	Light	.148	.50
3 in.	No. 10	Standard	.178	.60
3 in.	No. 10	Heavy	.267	.90
3 in.	No. 10	Extra Heavy	.356	1.20

LATHING

Designation	Gage, United States Standard	Size of Sheets	Sheets in a Bundle	Square Yards in a Bundle	Weight per Square Yard
A	24	18 x96	9	12	4⅛
Special B	27	20¼x96	9	13½	2¾
Diamond No. 24	24	22½x96	9	15	3
Diamond No. 26	26	24 x96	9	16	2¾
Emco No. 24	24	27 x96	9	18	3
Emco No. 27	27	27 x96	9	18	2¼

CLINTON WELDED WIRE.—Clinton welded wire fabric, made by the Clinton Wire Cloth Company, is manufactured in different sizes of mesh and different gages of wire. As commonly made, the longitudinal strands are of larger diameter and closer spacing than the cross strands, the latter being chiefly to prevent construction cracks in the concrete. The wires are electrically welded at every intersection.

The fabric is furnished in diameters of wire ranging from $\frac{1}{10}$ inch to $\frac{3}{10}$ inch, and with spacing between the strands from 2 inches up to 20 inches.

The laying of the fabric in the Decauville garage, New York, is illustrated in Fig. 86.

Fig. 86—Laying Clinton Welded Wire in Decauville Garage, New York.

TRIANGLE MESH REINFORCEMENT.—Triangle mesh steel-wire reinforcement, Fig. 87, manufactured by the American Steel and Wire Company, is made with both single and stranded longitudinal or tension members. That with the single-wire longitudinal is made with one wire varying in size from a No. 12 gage up to and including a $\frac{1}{2}$-inch diameter, and that with the stranded longitudinal is composed of two or three wires varying from No. 12 gage up to and including No. 4 wires stranded or twisted together with a long lay. These longitudinals, either solid or stranded, are always spaced 4 inches on centers, sizes being varied to obtain desired cross-sectional area of steel per foot of width.

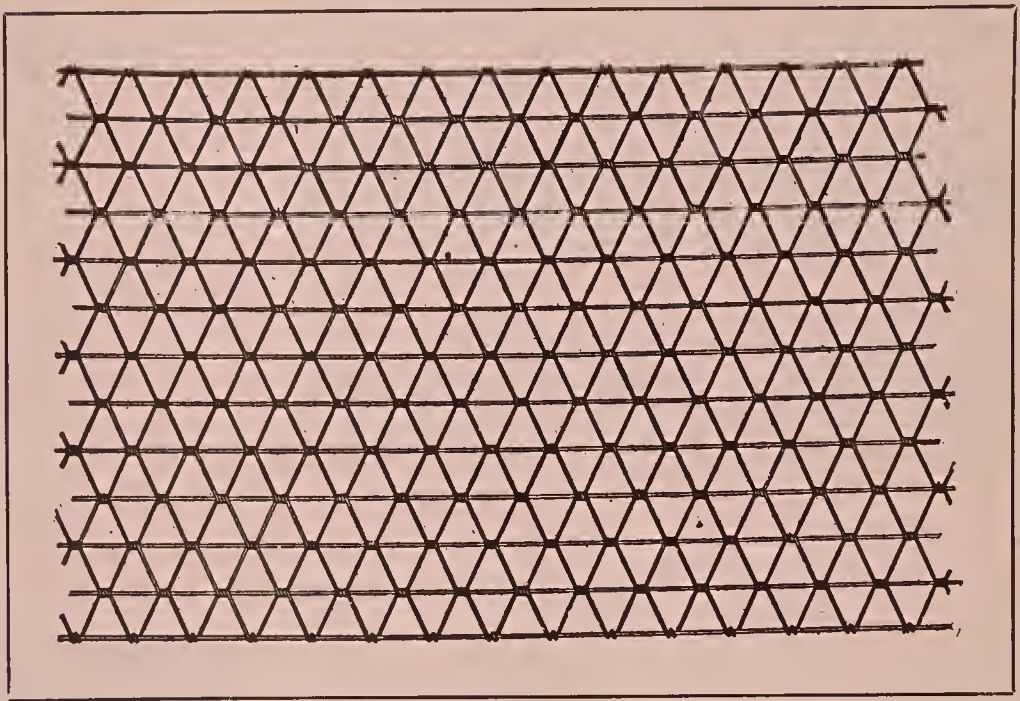

Fig. 87—Triangle Mesh Reinforcement.

Fig. 88—Hy-Rib

HY-RIB.—Hy-rib, illustrated in Fig. 88, and made by the Trussed Concrete Steel Company, consists of a steel sheathing with deep stiffening ribs for concrete and plaster work. It is a combined unit of reinforcement for centering studs and lath.

TRUSSIT.—Trussit is formed by expanded metal or herringbone lath bent to V-shape section, as shown in Fig. 89. It is a self-centering reinforcement for light concrete roofs erected without forms, solid partitions, without studding, curtain walls, fences, etc. It is manufactured by the General Fireproofing Company.

FERROINCLAVE.—Ferroinclave, invented by Mr. Alexander E. Brown, of the Brown Hoisting Machinery Company, is sheet metal bent as in Fig. 90, and spread over or plastered with mortar to form a sheet 1⅜ inches thick.

CUMMINGS SYSTEM.—A number of reinforcement details have been presented by Mr. Robert A. Cummings, as illustrated in Fig. 91.

In the illustration at the top of the diagram is shown the Cummings method of forming the bent-up bars and attaching them to the tension bars. In general the plan is to provide tension bars with ends specially anchored, while securely attached to them are small rods horizontal in the middle of the beam or girder, or bent up, as indicated, to pass across the top of the beam and form inclined inverted U bars or stirrups. The "Supporting Chairs," placed at the point of the bending up of the rods, are also drawn. For the slab steel another type of supporting chair is employed, as illustrated in the detail sketch.

HERRINGBONE GIRDER BAR AND FRAME.—The herringbone bar made by the General Fireproofing Company consists of a main tension member of either square or twisted lug bars to which looped stirrups are rigidly attached. The bar is shipped from the shop completely assembled, so that the only work required in the field is the bending of the stirrups to the proper angle. When a girder frame is desired, it may be easily formed by inserting a properly bent bar through the loops and wiring it to shear members.

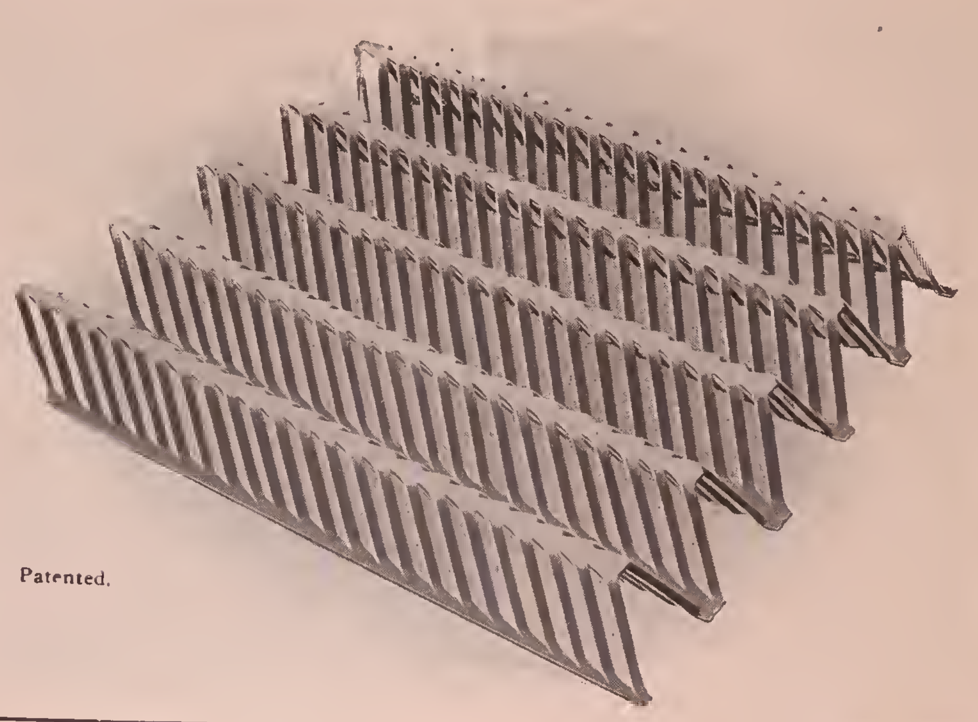

Fig. 89—Trussit.

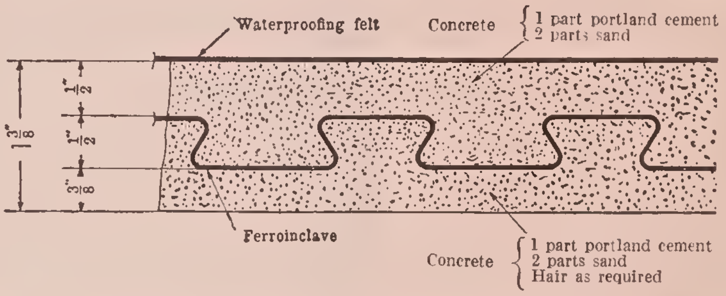

Fig. 90—Placing of Ferroinclave Roof.

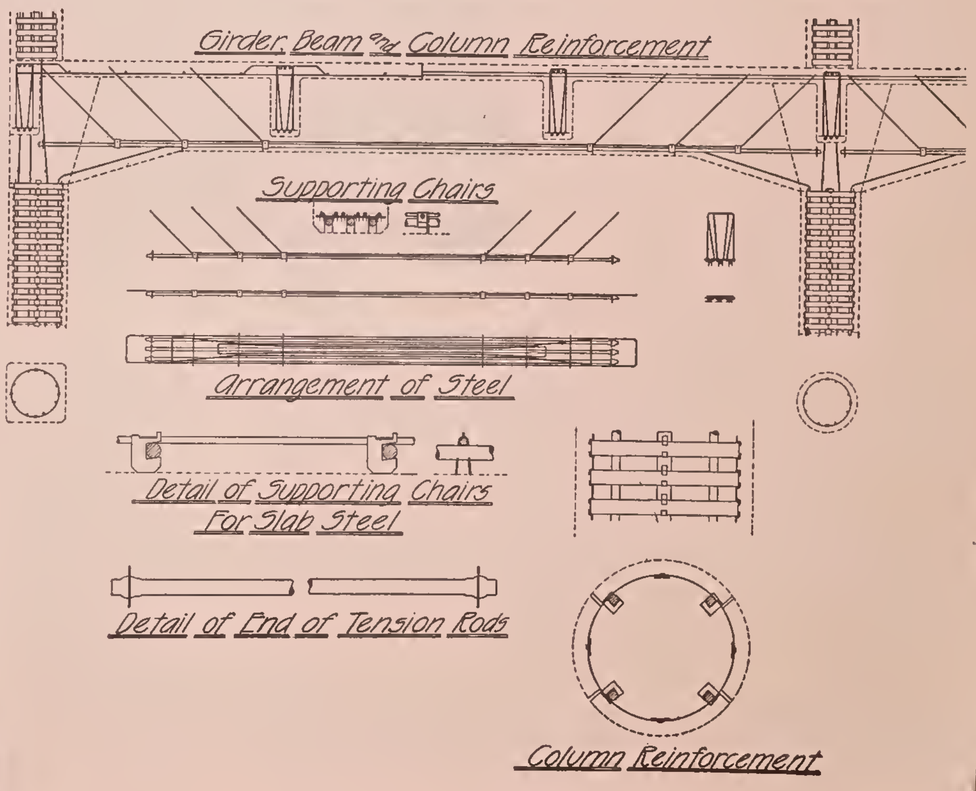

Fig. 91—Details of Cummings System.

CONCRETE BLOCK WALLS.

Frequently concrete blocks are cheaper for factory walls than solid concrete, because no forms are required. However, if used in combination with reinforced concrete interior construction or with steel beams, they must be securely connected to them with ties, and the compressive strength of the blocks carefully figured to see that there is sufficient area of concrete to carry the weight.

In the warehouse at Nashville, pages 51-53, concrete blocks are utilized for partitions.

An example of a concrete block exterior with a reinforced concrete interior construction is shown in Fig. 93. This illustrates the Salem Laundry Building, Salem, Mass., of which Ballinger & Perrot were architects, and Simpson Brothers Corporation, builders. This has a reinforced concrete floor system and interior columns of solid concrete. The exterior columns are hollow blocks with reinforcing rods running through the openings in them and surrounded by mortar of the same proportions as the block themselves, so as to form solid piers.

Fig. 93—Concrete Block Walls, Salem Laundry.

Fig. 94—Photograph of Spatter Dash Finish of Lynn Storage Warehouse.

CONCRETE TILE.

Concrete tiles are being used for partitions and floors the same way that terra-cotta tiles are employed. They are also coming into extensive use for the exterior walls of dwelling houses. They lay very true and even, and for the better class of buildings are plastered.

One of the best patented processes for making concrete tile consists in pouring the wet concrete of the consistency of grout into a mold and then, by means of a steam jacket, which forms a part of the mold, the water is evaporated from the concrete, so as to permit the withdrawal of the tiles from the molds within a few minutes. The product is thus as dense and uniform as wet mixed concrete and yet very true in shape and size. Plastering adheres better than to most other forms of concrete.

The factory of the Hunter Illuminated Car Sign Company, described on pages 49 to 50, is built of concrete hollow tile or, as it is termed, "Tilecrete," manufactured, as described in the last paragraph, under the Pauly Process. In this building the tiles are laid up with mortar without any plastering on the surface.

SURFACE FINISH.

One of the most striking developments in re-

Fig. 95—Tooling the Surface of Friedenwald Building Walls.

Fig. 96—Photograph of Tooled Surface.

inforced concrete industrial buildings has been the constant improvement in architectural design and in the exterior and interior finish. While in factory construction the appearance of the building is usually of less consequence than in the case of office or public buildings, the effect should be pleasing to the eye.

Plastering on solid concrete or on concrete blocks is unsatisfactory in climates where the temperature in the winter months falls below freezing. A very thin skin of cement may be plastered on by a skilled mechanic, but this is apt to appear streaked and prove unsatisfactory over a large surface. If the surface is broken by moldings or joints this plan can be used with fair results.

A variation of this method is to float the concrete surfaces with a sand-cement grout applied as soon as forms are removed. This is only valuable where the forms can be removed in one or two days after pouring. When this can be done the 1:1 grout is rubbed into the surface with a wood float. This is not a plastering method, but really is a rub finish; the grout serving to fill up the pores of the concrete. When concrete is too hard to be treated in this manner, satisfactory results may be obtained by using a carborundum brick instead of a float.

Another style of finish is obtained by removing the wall forms within twenty-four hours and immediately washing the surface. To do this satisfactorily the concrete cannot be laid very wet, or the water will run down over the completed surface. A similar effect is obtained with acid treatment.

Another type of finish, which tests of several years in New England have shown to be satisfactory if properly applied, is the slap-dash, illustrated in Fig. 94 (p. 86), which is a view of the wall of the Lynn storage warehouse built by the Eastern Expanded Metal Company, and described on pages 39 to 42. The wall is first plastered with cement mortar, and after drying the slap-dash is thrown on.

An excellent finish, although a somewhat expensive one, is obtained by removing the surface skin of cement which forms against the molds by dressing it with a pointed hammer of a pneumatic tool. This method is illustrated in Fig. 95 (above), and a photograph of the same wall, taken at close range, is shown in Fig. 96.

CONCRETE PILE FOUNDATIONS.

In certain cases concrete piles are an economical substitute for wood piles or deep pier foundations. Where the loading is excessive or the durability of a wood pile is doubtful the use of concrete piles is an economy. Wood piles rot and deteriorate unless there is sufficient water to keep them constantly wet. In sea water, wood piles are rapidly attacked by teredo worms, although this trouble does not often apply to factory foundations.

Two kinds of concrete piles are used: The cast-in-place pile and the pre-cast driven pile. In the first a hole is made in the ground by one method or another and the concrete cast in. In the second the pile is cast above the ground and afterward jetted or driven to position. Local conditions and considerations determine which type is used. Four types of patented reinforced concrete piles are illustrated in the following figures:

The Simplex pile, manufactured by the Simplex Concrete Piling Company, is constructed by driving a hollow shell with a point to the full depth and filling the hole with concrete as the shell is withdrawn. The different processes used in driving this pile are shown in Fig. 97.

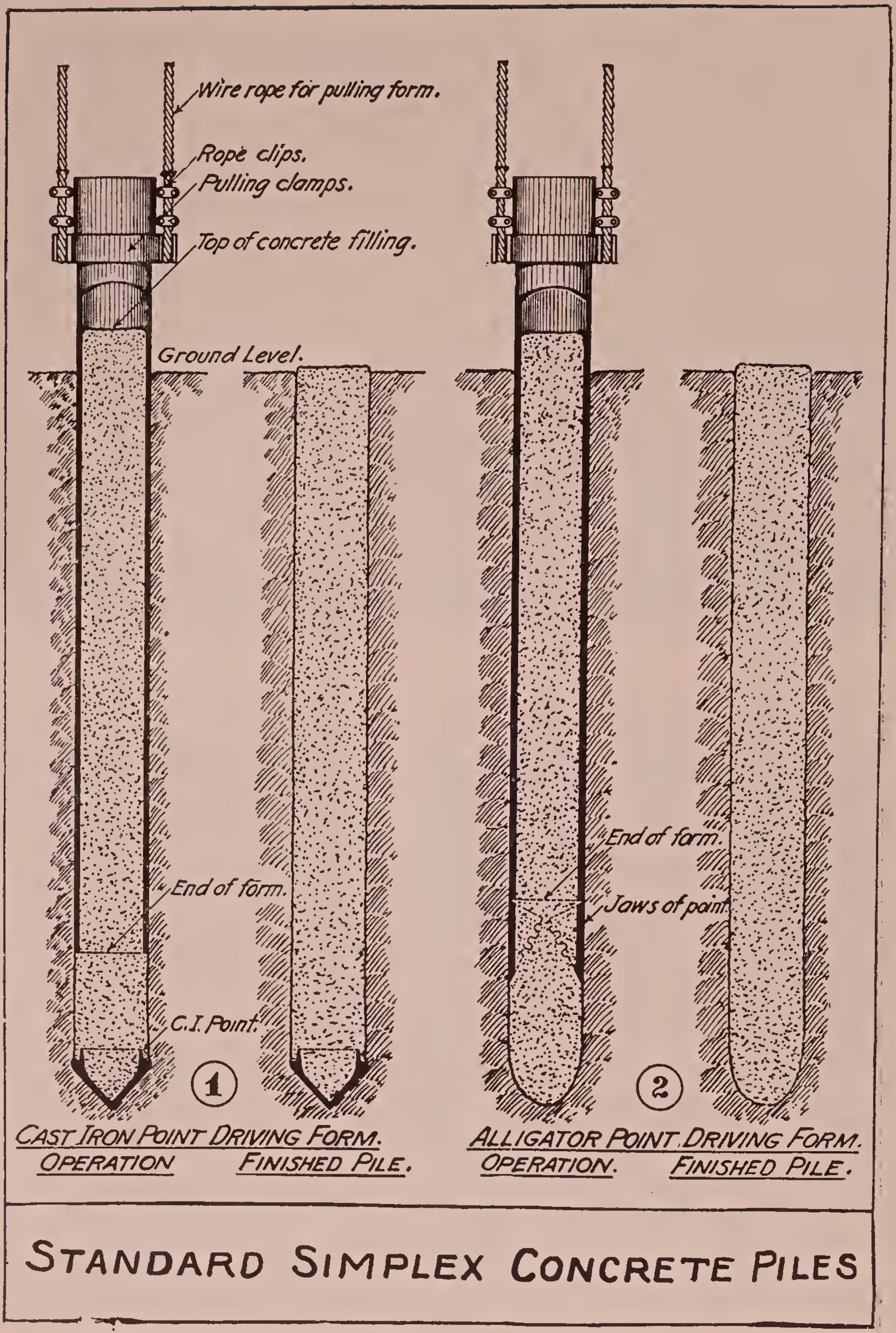

Fig. 97—Simplex Pile.

The Raymond pile of the Raymond Concrete Pile Co. is formed as follows: A collapsible mandrel or core is expanded. This expanded core is encased in a sectional, spirally reinforced sheet steel shell. The combined core and shell is driven to sufficient penetration. The core is then collapsed and withdrawn from the shell. The shell—which remains in the ground—is then carefully inspected. Concrete is now poured into the shell. (See Fig. 98.)

The corrugated pile, patented by Frank B. Gilbreth, Fig. 99 (p. 89), is cast on the ground and driven by a pile-driver with the aid of a water jet. The illustration shows a corrugated pile in process of driving for the foundation of the warehouse for Mr. John Williams, at West Twenty-seventh Street, New York City.

The pedestal pile patented by the MacArthur Concrete Pile and Foundation Company, Fig. 100 (p. 89), has an enlarged base providing a greater bearing. It is formed by first driving a core and cylindrical casing to the required depth. The core is then removed and a charge of concrete dumped to the bottom of the casing, the core then being used as a rammer to compress this

Fig. 98—Raymond Pile.

Fig. 99—Gilbreth Corrugated Pile.

Fig. 100—MacArthur Pedestal Pile.

Fig. 101—Hennebique Compressed Pile—See page 88.

concrete into the surrounding soil until the base is about 3 feet in diameter, after which the casing is filled to the top with wet concrete. After the pile is formed the cylindrical casing is withdrawn from the ground.

The compressed pile of the Hennebique Construction Company, Fig. 101 (above), is formed by dropping a heavy steel-pointed weight so as to compress the soil laterally and vertically and then filling the resulting cavity with concrete. The concrete is tamped with a rammer, the final result being a supporting column larger at the base than at the top.

DRIVEN PILES.—In cases where too many boulders are not liable to be encountered, piles are built upon the ground, reinforced with steel rods, and, after setting for at least a month, are driven with a pile driver. The corrugated pile, illustrated on page 89 (Fig. 99) and described on page 88, is a special form of driven pile.

Where the foundation materials allow it, precast piles are often driven by a combination of water-jetting and driving with a hammer. The water jet makes it possible to sink the pile to almost its final position and then with a few blows from the hammer to settle it into place.

If the pile is to be jetted down the jet pipe is usually cast in the center of the pile, with the open end at the point of the pile.

The piles used under the power house of the Boston Woven Hose and Rubber Company, and shown in Fig. 102 illustrate this type of driven pile and show the jet pipe in place.

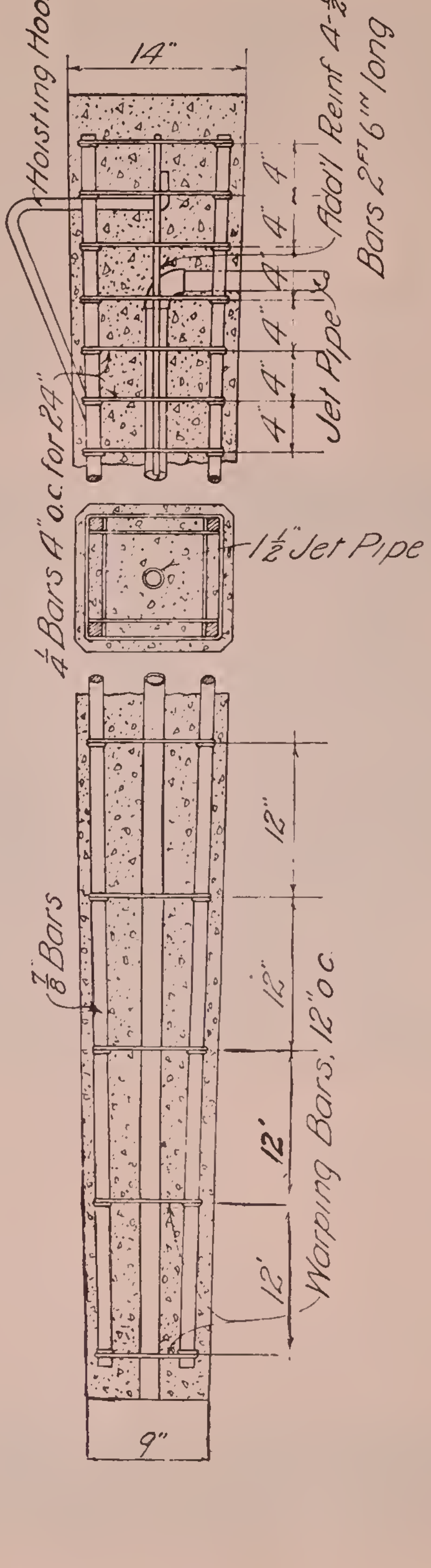

Fig. 102—Detail of Reinforced Concrete Pile, Boston Woven Hose & Rubber Co.

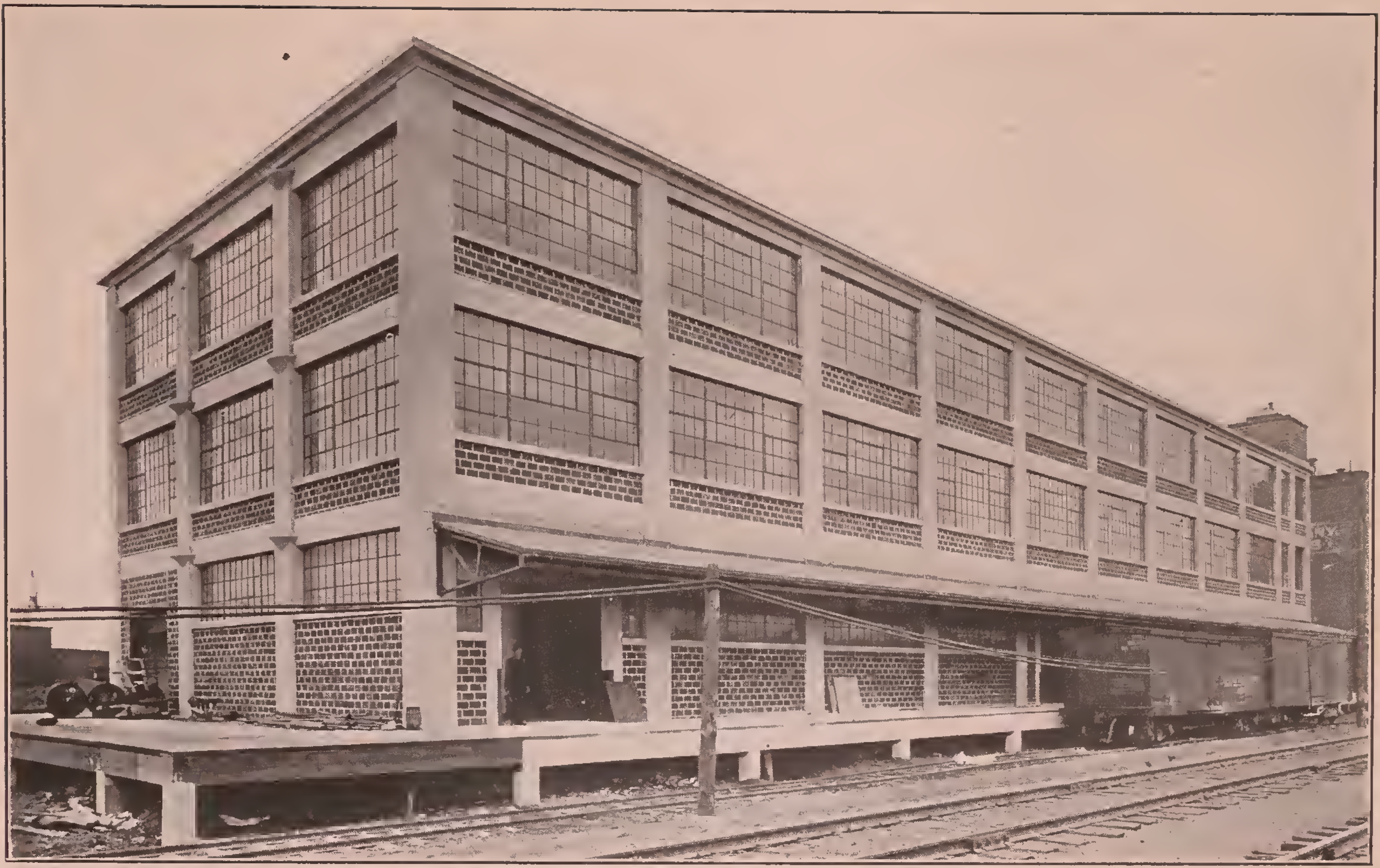

Figure 103—Revere Rubber Company, Chelsea, Mass. Lockwood, Greene & Company, Architects & Engineers.
Aberthaw Construction Company, Contractors

Fig. 104—Carpentry Shop, National Cash Register Co., Dayton, Ohio.
The General Fireproofing Co., Designers of Reinforcement; Expanded Metal Fireproofing Co., Contractors.

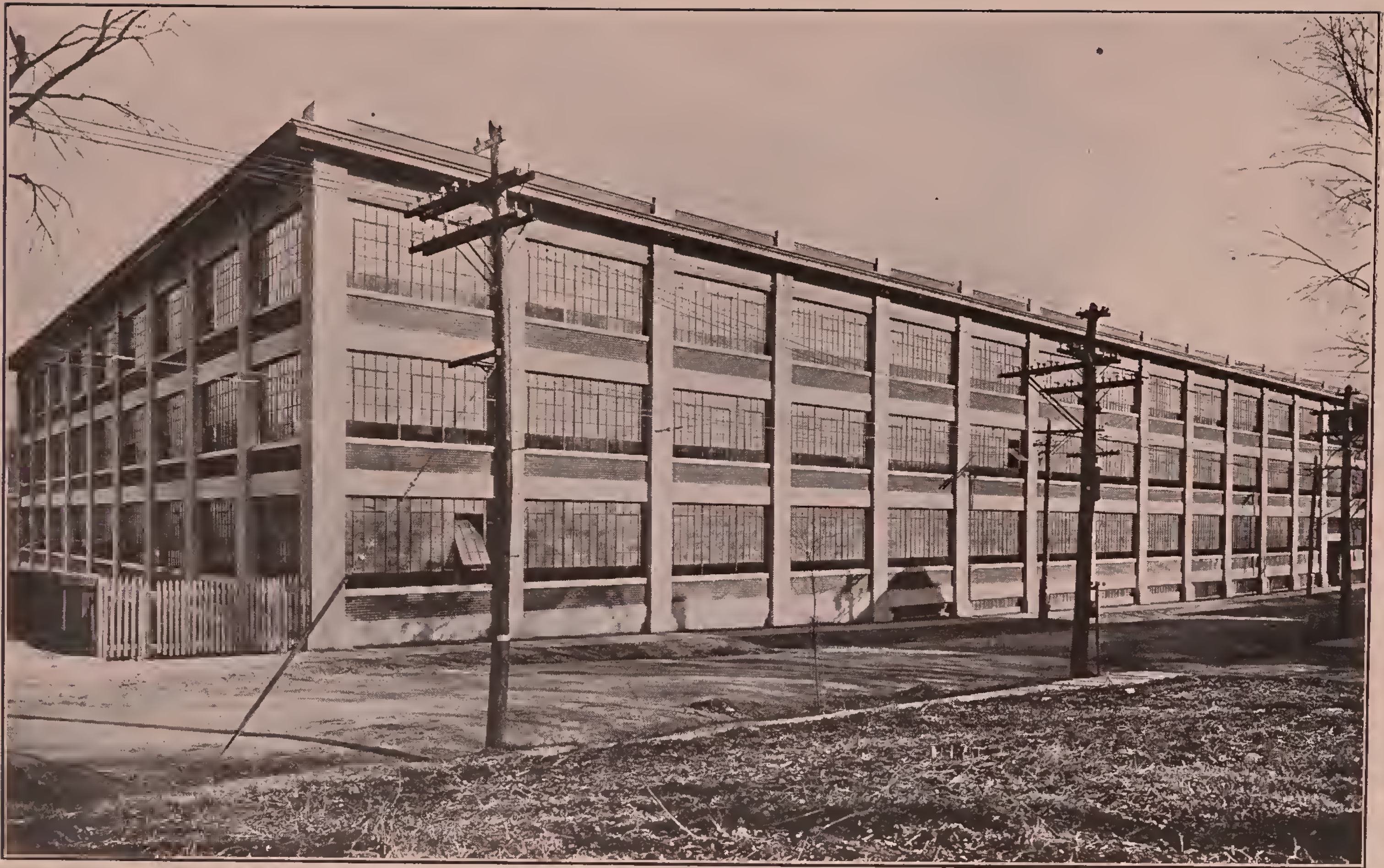

Figure 105—Goodell-Pratt Company, Greenfield, Mass. J. R. Worcester & Company, Architects & Engineers. Aberthaw Construction Company, Contractors

Figure 106—General Electric Company Building No. 26, Fort Wayne, Ind. Harris & Richards, Architects. Wells Bros., Contractors

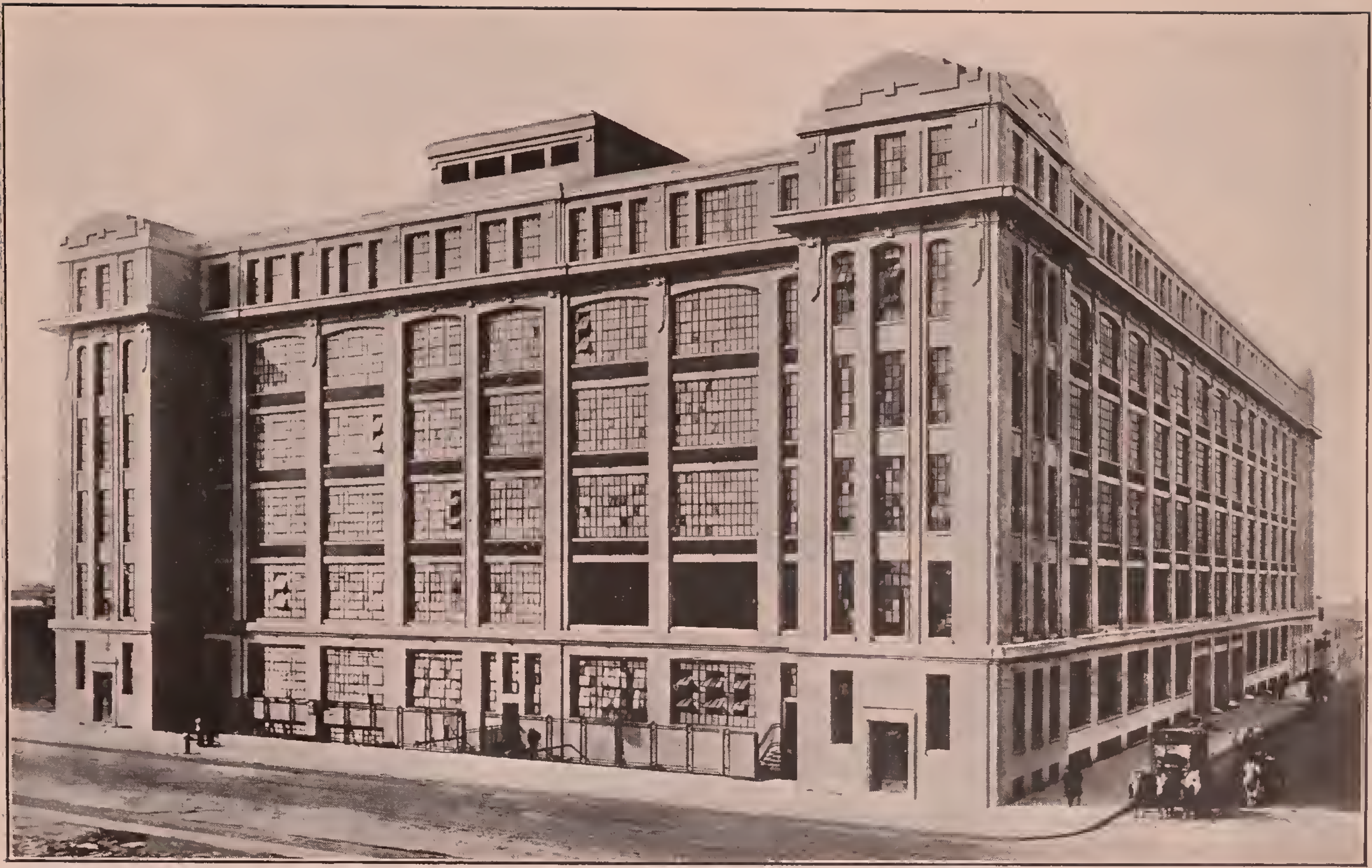

Figure 107—American Can Company, Brooklyn, N. Y. N. M. Loney, Engineer. Turner Construction Company, Contractors

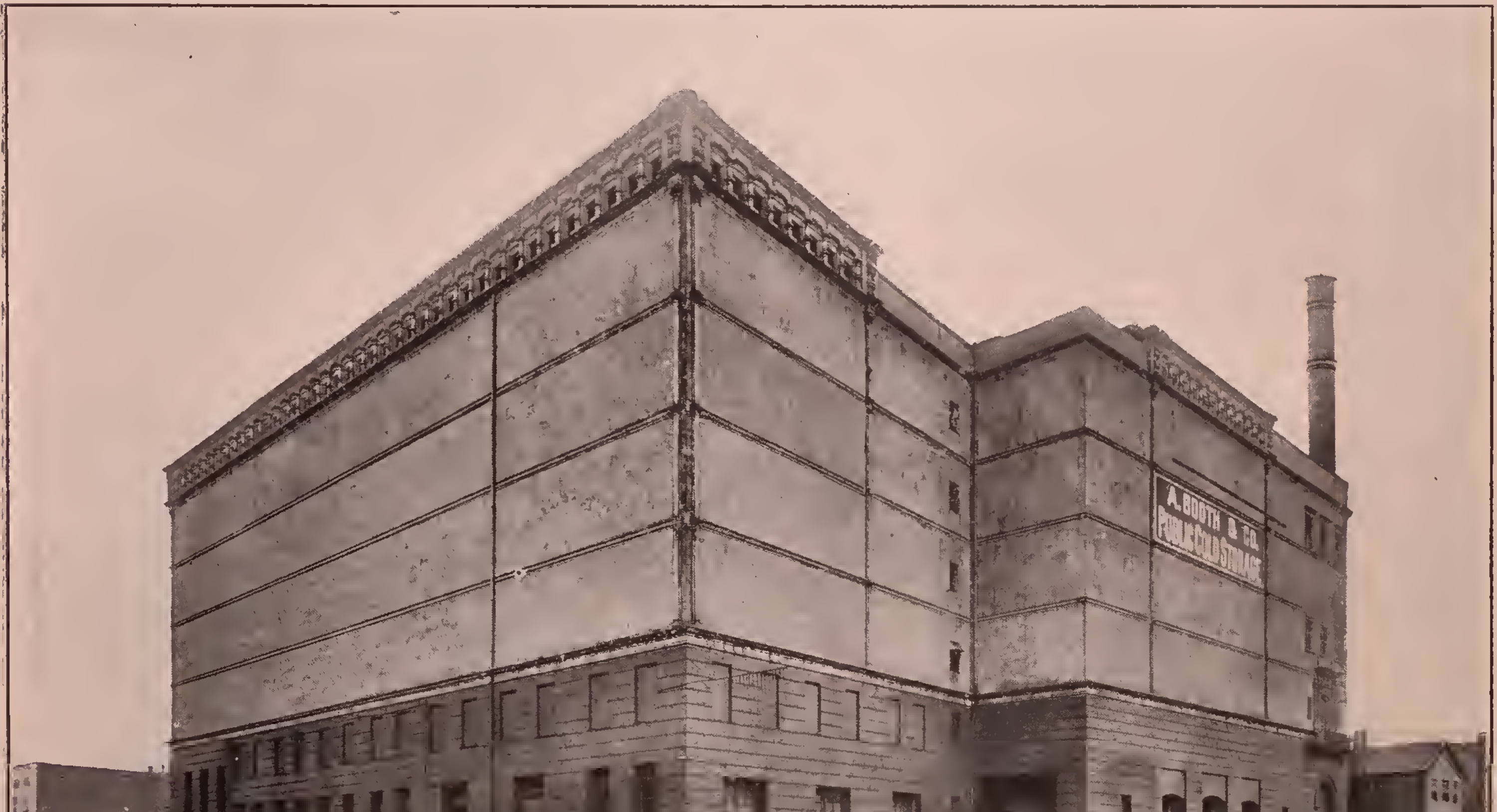

Fig. 108—A. Booth & Company, Detroit, Mich. John Scott & Company, Architects. Concrete Steel & Tile Construction Company, Contractors

INDUSTRIAL PLANT ROADWAYS

In addition to its use in the buildings of the plant, concrete has been put to efficient use in the construction of plant roadways. The necessity of a hard durable road leading to the plant and connecting its buildings is apparent. Every industrial organization must be planned to run 365 days—and even nights—in the year in time of necessity, and its output must not be held down by poor roadways and transportation.

Roadways that are always rutty and dusty and in wet or frosty weather almost impassable are not only wasting money, but often actually reduce the plant output through delays in receiving and delivering materials.

The phenomenal success of concrete for highways has caused the adoption of similar construction for plant roadways. The fact that concrete offers a roadway that is hard and usable every day regardless of weather makes it the ideal material for the purpose. In addition, concrete roadways are not dusty; can be cleaned by flushing with a hose; and, above all, require no extensive maintenance with its attendant vexatious obstructions to the operation of the plant.

CONSTRUCTION DETAILS.

The plant roadway of concrete is constructed in exactly the same way as a concrete country highway. The concrete is proportioned 1 part Portland cement to 2 parts sand to 3 parts broken stone. A very flat crown may be used owing to the superior drainage qualities of concrete. This crown is made a maximum of $\frac{1}{50}$ of the width of road or a minimum of $\frac{1}{100}$ the width. The thickness of roadway at sides ordinarily is 6 inches.

Where a plant roadway has a building at each edge it is convenient to dish the surface so as to allow rain-water to drain down the center. Concrete allows this to be done, and thus removes one of the chief causes of unsatisfactory service in a cinder, dirt or gravel road.

PLANTS USING CONCRETE ROADWAYS

A partial list of prominent corporations at whose plants concrete roadways have been built follows:

S. S. White Dental Supply Co., Princess Bay, N. Y.
Harrison Brothers & Co., Inc., Philadelphia.
Studebaker Corporation, Detroit, Mich.
American Can Company, Hackensack, N. J.
Atlantic, Pacific & Gulf Co., Brooklyn, N. Y.
E. I. du Pont de Nemours & Co., Hopewell, Va.
E. I. du Pont de Nemours & Co., Harrisburg, Pa.
Allis-Chalmers Co., West Allis, Wis.
General Chemical Co., Edgewater, N. J.
Henry Bower Chemical Mfg. Co., Philadelphia.
American Dyewood Co., Chester, Pa.
The Hess-Bright Mfg. Co., Philadelphia, Pa.
Sherwin Williams Paint Co., Chicago.
Continental Can Company, Chicago.
Russel Wheel & Foundry Co., Detroit, Mich.

Full specifications for concrete roads and alleys may be obtained by addressing The Atlas Portland Cement Co., 30 Broad St., New York, or Corn Exchange Bank Bldg., Chicago.

Old, Inefficient Roadway. New Concrete Roadway.

Harrison Brothers & Co., Inc., Plant at Philadelphia, Pa. Atlas Portland Cement Used Exclusively.
E. C. Thompson, Plant Supt.; J. R. A. Hagermans, Field Engineer; Henry E. Baton, Contractor

Another View of Harrison Brothers & Co., Inc., Plant at Philadelphia, Showing Concrete Roadway

Part of the System of Concrete Driveways and Walks at the General Chemical Co. Plant, Edgewater, N. J.

IN presenting this book to you, we are of the full belief that it will be of real value. Below we show a comparative statement of relative values. These facts are all clearly brought out in the preceding pages. The question in your mind resolves itself into, whether you—as a prospective builder, architect, or engineer—want a building.

Firstly of:
- Reinforced Concrete Construction, with
    - Lowest final cost (all classes considered)
    - Lowest insurance rate (all classes considered)
    - Lower initial cost than steel construction
    - Perfect Rigidity
    - No depreciation, or repairs
    - Unexcelled sanitary qualities
    - Maximum Lighting
    - Absolute Fireproofness

Secondly:
- Steel Cage, Fireproofed, with—
    - Highest initial and final cost (all classes considered)
    - Medium insurance rate (all classes considered)
    - Noticeable vibration
    - Fair lighting
    - Only *fire resistive* qualities

Thirdly:
- Slow Burning, or Mill Construction, with—
    - Low initial cost (all classes considered)
    - High insurance rate (all classes considered)
    - Vibration
    - Marked depreciation
    - Lighting difficulties
    - No resistance to fire

When you have decided by elimination, in favor of Reinforced Concrete, take into consideration the recognized merit, the indisputable quality standard of

ATLAS PORTLAND CEMENT

Reinforced Concrete Factory—The Carter's Ink Company, Cambridge, Mass.
Densmore & LeClear, Architects *Aberthaw Construction Co., Contractors*

THE ATLAS PORTLAND CEMENT CO.
PORTLAND
ATLAS
CEMENT
TRADE MARK
NEW YORK, N.Y.

"The Standard by which all
other makes are measured"