VITRIFIED BRICK FOR STREET PAVEMENTS

F. A. KUMMER

PRESENTED BY
THE EASTERN PAVING BRICK CO.
CATSKILL, N.Y.

VITRIFIED BRICK

FOR

STREET PAVEMENTS

A Description of its Manufacture and Some Notes on its Use

BY

FREDERIC A. KUMMER, C.E.

JUN. MEM. AM. SOC. C. E.

CATSKILL, N. Y.

THE EASTERN PAVING BRICK COMPANY

1899

PREFACE

In presenting this little work on the manufacture and use of vitrified paving brick, it is our desire to point out, concisely and clearly, the many advantages of such brick as a street paving material. Besides attempting to show how such brick are manufactured, as well as the extreme care required in their manufacture, we give some information as to the manner of laying brick pavements, which will be of use to those who desire to secure from this material the best results.

Vitrified brick has sometimes been condemned for street paving because the work of laying it has been improperly done, the brick itself being charged with a fault which was due to the manner in which it was laid. Poor foundation, lack of care in selecting the materials, and, most usual of all, improper or insufficient grouting of joints, invariably produce a poor street. If, as a result of such work, the brick itself is criticised, such criticism must be attributed to ignorance as to how a brick pavement ought to be laid. Vitrified brick, if laid so as to secure the best results, seldom wears out, provided, of course, that the brick itself is of thoroughly good quality. It will be seen, however, that the making of vitrified brick is an operation requiring a high degree of skill in order that the product may meet the exacting conditions under which it is to be used.

THE MANUFACTURE OF PAVING BRICK

AT THE

Plant of The Eastern Paving Brick Co.

The works of The Eastern Paving Brick Company are located at Catskill, on the Hudson River. Extensive docks give this company especial advantages for water transportation, and enable it to deliver its product conveniently and at small cost to all points available from tide-water. The land owned by the company, including its clay and shale banks, comprises about four hundred acres. The material is procured some ten miles from the works. It consists of low-grade iron-ore, shale, and clay. By efficiently combining these materials in the proper proportions a mixture is obtained which possesses the elements necessary to produce a tough, homogeneous vitrified brick, retaining its shape at very high temperatures and proving extremely durable in service. This company manufactures and ships about twenty-five million vitrified brick annually, which are sold in the Eastern towns and cities for street paving and sewer work. In order to manufacture this large number of brick, an investment of about five hundred thousand dollars has been made in real estate, buildings, kilns, machinery, docks and general equipment. To operate

this plant at its full capacity, machinery having a capacity of more than one thousand horse-power is required.

The selection of the materials and their analysis and proper combination require constant watchfulness, as much depends upon the care with which the ingredients are combined. In preparing the material for use, the following method is adopted: the shale and clay are brought to the works in hopper cars and conveyed upon an overhead trestle into the Storage Building. Here the cars are dumped, the shale and clay being kept separate in order that the former may first be run into the dry pans by means of conveyer belts. These dry pans consist of heavy rollers revolved in a pan having perforated plates at its outer diameter. The shale is here reduced to a fine powder, which falls through the perforations in the bottom of the pan at its outer edge, and is then taken up by the buckets of a lifting machine and carried into the second story of the Storage Building, where it is passed through fine screens, that portion which has been sufficiently pulverized being deposited in storage bins. It has then reached the consistency of fine dust. The coarser material returns again to the dry pans to be re-ground and screened as before. From these storage bins chutes convey the powdered shale to the Mixing Room, where the materials entering into the composition of the brick are weighed and measured by automatic devices. This arrangement secures an accurate proportioning of the ingredients, which produces a homogeneous and uniform product.

After being weighed and measured the material passes into the first of the mixing machines, called pug mills, where the shale and clay are thoroughly mixed while dry. It is then carried on conveyer belts into the Manufacturing Room, where it passes through other mixing machines in which a sufficient amount of water is added to combine the ingredients. This mixing is done under high pressure in order to insure the perfect blending of the component parts. The material then passes into the brick machines, which are operated upon the semi-dry process and are of the auger type, producing side-cut brick. Here it is again subjected to high pressure as it is forced through the steel dies of the machines. These dies are lubricated by steam. The clay issues from the dies in a solid column and is carried on conveyer belts through the cutting machines, where it is automatically cut up by wires into bricks of the size desired. This process produces what are known as wire-cut brick.

The bricks are then carried, still on belts, to the repressing machines. Here they are taken from the belts by hand and passed into the repressing machines, where they are subjected to heavy pressure, which rounds the corners and edges, making what is known as repressed or bevel-edged brick. Such of the brick as it is not desired to repress are allowed to pass along on the belts without being thrown into the repressing machines. The brick of both grades are finally placed upon small iron cars, upon tracks on each side of the

repressing machines, which connect with other tracks leading to the Drying Rooms. These rooms are located at the end of the Manufacturing Room, and the cars are run from one room to the other directly and conveniently without loss of time.

The heat for drying the brick is obtained from the kilns as they cool, by means of underground conduits leading from the front and back of each kiln to the Drying Rooms, circulation being secured by means of large blowers located on each side of the drying building. These blowers serve to draw the hot air gently and slowly from the kilns (mixing it with cool air, if necessary, to temper the heat) and deliver it to the Drying Rooms. While each kiln is being fired a temporary wall is built between it and the hot air conduit alongside. When it is desired to cool the kiln this wall is knocked away and circulation of the air is effected between the kilns and the Drying Rooms by means of the blowers.

In the Drying Room the brick are thoroughly dried before being placed in the kilns. It is necessary that the brick should be absolutely free from moisture, otherwise they would crack and split upon the application of heat in the kilns. After they are so dried, the cars containing them are carried on tracks out at the further end of the drying building, which comprises a series of long tunnels leading from the Manufacturing Room to the kilns. The cars are conveyed from these tunnels directly into the kilns, where the brick are stacked up preparatory to burning. There is

no re-handling of the brick from the time they are placed on cars in the Manufacturing Room until they reach the kilns.

The stacking of the brick in the kilns must be carefully done. Sand is placed between them to prevent them from sticking together when subjected to great heat. After the kiln is filled with its charge of 150,000 brick, it is walled and sealed up at both ends. Fires are then kindled in the ovens on each side. The kilns are what are known as down-draft kilns, because the heat from the ovens passes upward into the dome of the kiln and then down through the entire mass of brick into underground flues leading to smoke-stacks at the side. The process of burning is gradual and covers a period of some ten days. The greatest care is necessary to produce gradually the degree of heat desired. The burning must be regular and gradual, the heat being increased slowly to the maximum temperature. The temperature is steadily augmented for a period of five days until the maximum temperature is reached, when it is maintained as nearly constant as possible for five more days, to enable the heat to penetrate throughout the mass of brick. The firing is then discontinued and the kiln is allowed to cool slowly. After the brick are burned and cooled sufficiently, the kiln is opened.

After being removed from the kilns the brick are carefully sorted, and any which from their location in the kiln may have been under-burned or over-burned are separated from the others. These latter brick are used for building purposes, sidewalks, etc., and only the best selected brick are sold for street paving.

COMPOSITION OF CATSKILL PAVING BRICK.

The term vitrified brick as applied to paving brick is in one sense a misnomer. Paving brick are not completely vitrified. Were they so, they would be brittle, glassy, and entirely too hard for street paving. They are partially vitrified, however, and it is necessary that the ingredients be so selected that this partial vitrification may be readily accomplished without employing a temperature so high as to impair the shape of the brick. The composition of such brick is about as follows: 65 to 70 per cent. of silica, 18 to 20 per cent. of alumina, 10 to 12 per cent. of oxide of iron, 3 to 4 per cent. of lime, and a small percentage of the alkalies which are found in most native clays. The composition of course varies with the different makes of brick. The superior results which the Catskill brick have shown in service and in tests are due to the fact that the materials used are capable of being perfectly blended. The silica and alumina shown in the analysis are necessary to form the skeleton of the brick. The iron, lime, and alkalies are fluxed, and the iron, melting at a lower temperature than the silica and alumina, fills the interstices between their particles, thereby cementing the mass together. If an excessive proportion of iron be used, it will prevent the particles of

silica from touching each other, thereby causing the brick to lose their shape, stick together, and become warped and cracked. This may be illustrated by comparing the process of making brick to the process of making mortar. The mason mixes a sufficient amount of lime with sand in order to fill up the interstices; he then applies water to the mixture of sand and lime, and fills the smaller interstices which remain after the lime is incorporated in the mass of silica; he then adds still more water, until finally he prevents any of the particles of silica from touching each other, when he is enabled to handle the mortar with his trowel or hoe with ease. So soon as the water evaporates from the pile of mortar, the mason will discover that it has hardened and that he can no longer handle it with his trowel. He must then add more water in order to prepare the mortar for use. An insufficient amount of iron in the brick results in incomplete filling of the interstices, just as when there is too small an amount of water in the mortar. On the other hand, an excessive amount of iron causes the brick to lose their shape, just as an increased amount of water in the mortar makes it possible to handle it with the trowel easily.

Tests of Catskill brick show results about as follows:

TESTS OF CATSKILL PAVING BRICK MADE AT THE LABORATORY OF LATHBURY & SPACKMAN, IN PHILADELPHIA, IN ACCORDANCE WITH THE REQUIREMENTS OF THE SPECIFICATIONS OF THE NATIONAL BRICK MANUFACTURERS ASSOCIATION.

	Catskill shale paving bricks from Hunter Avenue and Colby Street (Albany, N. Y.), May 25, 1898.
Average size in inches	8.625×4.00× 2.50
Average weight in pounds	7.071
Average area of top surface, square inches,	21.56
Average volume of one brick, cubic inches,	86.25
Average specific gravity	2.41

Absorption of water, average of 5:

Weight in pounds, after drying 48 hours	28.25
Weight in pounds after immersion 48 hours	28.92
Weight in pounds of water absorbed	0.67
Percentage of water absorbed	2.37

Cross breaking strength, bricks on edge. Centre load between supports 6 *inches apart:*

First	8,640 lbs.
Second	9,390
Third	9,800
Fourth	9,900
Fifth	10,940
Sixth	11,080
Seventh	11,380
Eighth	12,550
Ninth	13,080
Tenth	13,920
Average strength in pounds	11,077 ± 1,611
Modulus of rupture	2,492

Impact tests (two), 28-inch rattler, 20 inches long, making 30 revolutions per minute.

	(1)	(2)
Weight before tests, pounds	156.20	153.71
Weight after 300 revolutions	148.59	147.14
Weight after 1,800 revolutions	133.37	130.53
Loss in pounds after 300 revolutions	7.61	6.57
Loss in pounds after 1,800 revolutions	22.83	23.18
Loss in per cent. after 300 revolutions	4.87	4.27
Loss in per cent. after 1,800 revolutions	14.62	15.08

Average per cent. loss after 1,800 revolutions.... 14.85

Owing to the superior quality of these brick they have come to be extensively used in the Eastern cities. The following figures compiled from the records of the company show where their brick have been laid and in what quantities during the past few years:

STATEMENT OF CATSKILL BRICK IN USE IN THE FOLLOWING PLACES.

New York (State):

Albany	196,589.7	square	yards.
Brooklyn	77,303	"	"
Mount Vernon	35,541	"	"
New York	12,000	"	"
Patchogue, L. I.	14,693	"	"
Tarrytown	3,100	"	"
Johnstown	6,100	"	"
Catskill	1,600	"	"
Troy	26,890	"	"
Jamaica, L. I.	55,000	"	"

Ilion	136	square yards.
Port Chester	4,350	" "
Poughkeepsie	5,800	" "
Glens Falls	7,168	" "
New Rochelle (railroad tracks)	32,150	" "
Schenectady	21,373	" "
Groton	230	" "
Water Filter at Albany	1,820,318	brick.
Water Reservoir at Poughkeepsie	252,400	"
New Jersey:		
Newark	19,665	square yards.
Perth Amboy	1,000	" "
West Orange	150	" "
Jersey City	5,740	" "
Massachusetts:		
Holyoke	13,800	square yards.
Fitchburg	2,140	" "
Connecticut:		
Waterbury	700	square yards.
Stamford	7,800	" "
Norwalk	4,500	" "
South Norwalk	2,900	" "
Vermont:		
Burlington	3,600	square yards.
Montpelier	200	" "
Rhode Island:		
Newport	1,100	square yards.
West Indies:		
Kingston, Jamaica	15,000	square yards.

Extract from the Annual Report of the City Engineer of Albany, N. Y., for the year ending January 1, 1899, showing the great increase in the use of vitrified brick, and the decrease in the use of other paving materials. Of the total area of brick paving, 196,589 square yards is laid with Catskill brick.

AREA OF PAVEMENT LAID EACH YEAR FROM 1885 TO 1898.

YEAR.	Cobble-stones removed.	Cobble-stones.	Granite.	Stone blocks not granite.	Vitrified brick.	Sheet asphalt.	Macadam.	TOTAL.
	Sq. yards.	Sq. yards.	Sq. yards.	Sq. yards.	Sq. yards.	Sq. yards.	Sq. yards.	Sq. yards.
1885 and previous thereto	.....	866,838.0	197,407.9	29,116.0	.....	.....	26,405.0	1,119,766.9
1886	42,403.3	7,197.6	28,969.8	.....	.....	.....	.....	36,167.4
1887	10,504.9	2,754.8	41,184.3	792.9	.....	.....	.....	44,731.1
1888	47,435.3	16,637.0	42,914.5	.....	.....	.....	2,208.0	61,759.5
1889	33,237.6	3,560.8	38,359.5	.....	.....	9,640.4	9,710.4	61,271.1
1890	32,107.6	2,127.3	38,069.0	.....	.....	55,669.4	.....	95,865.7
1891	68,727.0	1,459.1	15,154.2	.....	.....	81,056.4	.....	100,669.7
1892	6,212.5	2,194.5	5,548.6	.....	.....	8,799.8	.....	16,942.9
1893	17,802.1	.....	14,996.4	.....	.....	5,755.5	.....	20,751.9
1894	7,058.0	.....	6,636.8	.....	2,463.6	.....	.....	9,100.4
1895	42,491.0	.....	36,990.7	.....	11,365.2	.....	.....	48,355.9
1896	87,635.8	.....	26,729.2	.....	72,851.0	.....	16,547.7	116,127.9
1897	55,109.0	.....	3,208.7	.....	76,214.7	*211.5	.....	79,423.4
1898	38,308.0	.....	771.2	.....	65,882.8	.....	.....	66,654.0
Totals	489,032.1	902,769.1	496,940.8	29,908.9	228,777.3	161,133.0	54,871.1	1,877,587.8
Deduct cobble-stones removed	.....	489,032.1	.....					489,032.1
Cobble-stones remaining	.....	413,737.0	Total area of paved streets	.....				1,388,555.7

* Granite covered with asphalt, to be deducted from granite area.

PAVING MATERIALS.

The question of properly paving streets is one which has not until recently received that careful attention and study on the part of engineers and municipal authorities which the interests involved demand. It is a question of more than ordinary importance, involving the health, comfort, and safety of the community, as well as considerations of durability, and of economy, both as to first cost and as to maintenance.

It may be stated as a general proposition that the first requisite to a street pavement is that it afford a safe and agreeable roadway for horses and vehicles. By an agreeable roadway we mean not only one which is pleasant to those driving over it, but also one which facilitates the traction of loaded vehicles as much as possible without being slippery or unsafe. A further consideration to be borne in mind is that the pavement be so constructed as to be durable. Having conserved these two requirements, we have gone a long way toward solving the problem of a satisfactory pavement.

There are also certain other considerations which, while they are of less importance, nevertheless largely enter into the selection of a paving material. The pavement should be as nearly noiseless as possible; it should be sufficiently low in cost to warrant its use, and it should be so laid that sections may be removed when necessary without great cost and without

impairing the value of the surrounding pavement. It should further be of such a nature that it will not absorb liquids, gases, or street filth. It is also of great importance that pavements be so constructed that, while sufficiently hard and rigid to enable them to sustain the heaviest loads, they will at the same time not be so hard as to injure the feet of horses.

A street pavement is made up of several component parts, each having its own function. The foundation gives to the pavement the strength and rigidity necessary to withstand heavy loads and the continual impact of traffic. Upon this should be placed a properly cushioned bearing surface which does not primarily support the loads, but serves to transmit the weight of these loads to the foundation. This bearing surface must be smooth and lasting. Unless, however, the pressure be properly distributed over the sub-grade, by the foundation, the best paving materials are of little value.

Bearing in mind, then, that the function of the foundation is to transmit the weight of passing loads to the ground beneath, and that of the pavement proper to receive these loads and properly transmit them to the foundation, at the same time affording a safe, smooth, and durable pavement, we are led to the consideration of the question: what material will best answer this purpose? The opinion is wide-spread among engineers and others interested in street paving—and this opinion is rapidly becoming more general—that vitrified brick most nearly fulfils these requisites. (See

table on page 15.) Before outlining the reasons for this it may be well to state briefly wherein such brick differs from the common building brick. This difference results first from its having been subjected to a temperature sufficiently high to produce what is called vitrification, and, secondly, from the fact that it is composed of ingredients which make the process of vitrification possible. Ordinary building brick, being made of clay which does not contain these ingredients, will crumble if subjected to the heat required to effect the process of vitrification. Vitrified brick, if well made, are hard without being brittle; tough and able to resist impact without splitting, chipping, or crumbling; so dense that they absorb only a small percentage of moisture and hence are not affected by the frost; and are homogeneous in quality so that they will wear smoothly and evenly over their entire surface. Such brick can only be produced by the most careful manipulation of the ingredients and by the exercise of a high degree of skill and judgment in the burning. Many so-called vitrified brick, which through lack of proper care in the manufacture are not suitable for paving streets, have been placed in the market, to the great detriment of paving brick in general.

As regards the foothold afforded to horses by brick pavements, it may be claimed, without fear of contradiction, that brick, especially on grades, affords a better foothold and involves less danger of slipping than either asphalt or granite block, particularly after the latter has been subjected to traffic for considerable time and has

become polished and rounded. The reason for this is, in the first place, that the rounded edges of repressed brick and the joints between them afford a series of parallel grooves, two and a half inches apart (being the thickness of the brick), which extend laterally across the street and afford an opportunity for the calks of the horses' shoes to secure a hold. This effect is not obtained with asphalt or asphalt block, and, while it is obtained with granite block when first laid, the latter soon becomes polished, and is then even more slippery than asphalt. On the contrary, no matter how much a brick pavement wears, the surface does not become polished. Swan Street, in Albany, N. Y., is an instance of a heavy grade laid with brick. This is about a nine per cent. grade, and at the top is located one of the large engine-houses of the Albany Fire Department. The engine drivers have found, in getting their heavy machines up and down this grade in all weathers, that the slipping is noticeably less than upon any other kind of pavement in similar use in that city.

Greater ease in traction is one of the chief advantages of a brick pavement. Even on slight grades, horses experience difficulty in pulling loads of any weight, unless their foothold is sure. This ease of traction is the same in very warm weather as in cold weather, because changes of temperature do not affect brick. It is well known that the softening of asphalt in hot weather makes traction, especially in the case of heavily loaded vehicles, extremely difficult. We have all, doubtless, seen cases where the wheels of wagons

have cut into the hot asphalt surface to a considerable depth. Such a pavement also becomes injurious to horses in very warm weather on account of its tendency to hold the heat. Similar results are found in wet weather, when difficulty of traction is caused by the insecure foothold which horses obtain, and in cold weather the asphalt becomes so hard that it polishes almost like granite block and becomes exceedingly slippery. These facts are well known to all who are familiar with asphalt pavements.

In small towns where the roads are built of macadam or other similar material, brick will be found of the highest value for paving the gutters along the sides of the roadways. Many towns and villages have adopted brick for this purpose and find it in every way superior to cobble-stones or to Belgian block. It not only affords a smoother surface for running water, but makes a handsomer finish to the street. At the same time its cost is as low as and in many cases considerably lower than second-hand Belgian block, and is not much higher than that of ordinary cobble-stone.

As a material for use between the tracks of street railroads, even where cheaper material may be employed in the street itself, brick has no equal. A well-constructed brick pavement, with pitch joints to provide against the vibration of the ties, makes a smoother and better finished track and costs less to lay and to maintain than any good material known. It presents none of the objectionable features found in asphalt or Belgian block.

THE SELECTION OF PAVING BRICK.

Leaving out of consideration the quality of the brick, the first question to be decided is that of size. Occasionally brick for street paving is made no larger than ordinary building brick, 2 in. by 3 in. by 8 in. Others again are 2 1-2 in. by 4 in. by 8 1-2 in., the size varying up to a block 3 in. by 4 in. by 9 in., or even 4 in. by 5 in. by 12 in. Again, the question is between fire-clay brick, shale brick, or a brick which is a combination of the two; and, as these bricks differ widely in color, many persons make this a consideration in determining the kind of brick to be selected. That a brick is said to be vitrified, or that it has been specially burned for street paving, does not necessarily make it suitable for this purpose. Some brick, especially those which are most thoroughly vitrified, are too hard to be used in a street; and, while such brick may show good results in tests on account of their hardness, they are so brittle that they chip and crack readily under the impact of horses' feet. Again, the desirability of a square-edged brick, or one which has been repressed and has rounded or bevelled edges, must be considered.

It is generally conceded that a brick 2 1-2 in. by 4 in. by 8 1-2 in. is most satisfactory for general paving work. This size has been adopted by the National Brick Manufacturers' Association as the standard. Smaller brick do not look well and are troublesome to handle; at the same time they involve a needless

number of joints to be filled with cement. The cement is not so durable as the brick and therefore the durability of the pavement as a whole is reduced. This might seem to be an argument in favor of paving blocks of the largest size, but, in burning such blocks, it has been found very difficult to insure thorough vitrification. A paving brick, of the standard size mentioned, may be thoroughly vitrified, giving it a homogeneous and uniform texture, while a paving block, on account of its greater size, is often found to be soft at the centre. By this vitrification we mean the partial vitrification which is desirable in paving brick. Experience in the manufacture of vitrified brick has shown that not more than eighty per cent. of the product of the kilns in the manufacture of vitrified brick is suitable for use in street paving. The remaining twenty per cent. is, however, merchantable, inasmuch as brick of the size mentioned above are readily salable for other purposes than street paving. This makes it for the manufacturer's interest to cull his brick carefully. In the case of block the culled material is not readily salable for other purposes and hence there might be a tendency to cull such brick less rigidly.

The form of paving brick in most general use is the bevel-edge or repressed brick. This bevelling of the edges makes a round shoulder which does not chip off, a fault sometimes found with square-edged brick. At the same time, there are many advocates of the brick with square edges who believe that, if the joints between the brick are thoroughly filled to the top with

hard Portland-cement grout, the cement will sustain the square corner of the brick and prevent its chipping off. This is probably true early in the life of the pavement; but, after the brick begins to wear down, the corners generally become chipped or ground off into the rounded form which the bevel-edge brick has when laid. The joint between the bricks which is secured by the rounding of the corners is desirable, providing a foothold for horses, as above stated. The lugs or other projections sometimes employed are not necessary, as an ample joint may be secured without them. There are some, however, who prefer the lugs, owing to the greater regularity obtained in the joints.

LAYING THE BRICK.

FOUNDATION.

The first thing to be considered in laying a street with brick is the foundation, and this is of the utmost importance. After the street has been reduced to grade, the earth should be thoroughly rolled and tamped until the surface of the road-bed is firm, hard, and compact. If any depressions occur under the rolling they should be properly filled in with sand or other suitable material and re-rolled. If the character of the ground renders it necessary, an efficient method for draining the soil under the foundation should be adopted. Upon this hard-rolled surface is to be laid the foundation, which is to support the paving surface.

This generally consists of a layer of concrete from four to six inches deep. In some cases a very durable pavement may be formed by laying the brick upon a bed of thoroughly rolled sand. In other cases broken stone, cinders, etc., may be used. A sand foundation in localities where the underlying soil is hard, clean sand, containing little or no loam, is proving highly satisfactory in many cities along the southern coast as well as in the West. Miles of streets have been laid upon the sand-bed, the same being thoroughly wet and rolled until it becomes as solid as a floor. Upon this the brick is laid without any other joints than those of clean, sharp sand, and such a pavement, with the sand foundation confined between the curbs, needs only careful maintenance, at a slight cost, to make it thoroughly durable and satisfactory. This pavement, however, can only be recommended for light traffic and where the draining of the sub-grade can be depended upon. The general practice, particularly in the North and East, is to use concrete foundation, owing to the character of the soil, and the heavy traffic to be sustained. The concrete for this purpose is generally composed of one part hydraulic cement, two parts clean, sharp sand, and five or six parts broken stone. The cement and sand are mixed dry and then made into mortar, after which broken stone, thoroughly wet, is mixed in. This foundation is spread evenly over the surface and thoroughly rammed. It should be protected from the sun while drying by being moistened or covered with a layer of sand. The sand cush-

ion and the brick should not be placed upon it until after it has dried for a considerable time, from one to two weeks if possible, although in many cases only forty-eight hours is allowed for drying. The greatest care should be taken to insure good material and proper workmanship in constructing the foundation. If this is not well done it will produce faults in the pavement which can only be remedied at great expense.

The sand cushion is a layer of sand which is generally placed on top of the concrete to form a bed for the brick. Practice regarding the depth of this layer of sand varies considerably. In some cases it is only 1 1-2 inches deep, varying from this up to 2 1-2 and even 3 inches. A cushion of this character is very desirable, inasmuch as it not only forms a perfectly true and even surface upon which to place the brick, but it also acts as a cushion and makes the pavement less hard and rigid than would be the case were the brick set directly upon the concrete. Upon the sand cushion the brick are laid on edge, joints being properly broken. The sand cushion, forming the bed on which the brick are laid, is wet, smoothed, and brought to the proper crown in the centre of the street by means of wooden templates, properly trussed, mounted on wheels or shoes which bear on the upper surface of the curb. Advancing the template along the street levels and trues the sand-bed to its proper shape. The brick are then placed on edge, broken joints being formed by placing half brick at the curb, the brick at the curb line being placed loosely against the curb, so that when

the pavement is rolled the brick have room to spread and settle into the sand-bed. This obviates the danger of forming an arch leaving a hollow space under the brick, between the bricks and the concrete. Such a hollow space will result in the rumbling noise sometimes heard upon improperly laid brick streets. The rolling of the brick before grouting is generally done with a heavy cylinder roller weighing about one ton to each foot of its length. Rolling should be continued until all brick are properly embedded in the sand cushion.

THE JOINTS.

There is some diversity of opinion as to the best material to be used for the joints between the brick in street paving. The three materials most commonly used are clean, sharp sand, paving cement (being a combination of asphalt, pitch and other ingredients) and Portland-cement grout, composed of the best grade of Portland cement and clean, fine, sharp sand, the finer the better. Each material has some advantages, and each must be properly used in order that satisfactory results may be obtained. A street poorly grouted with Portland cement is considerably worse than one which is not grouted at all but which has its joints filled with clean, sharp, dry sand. It is to be particularly noted that in brick paving, aside from the quality of the brick, the joints are the most important factor in the life of the pavement. As soon as a number of brick in a street settle below those immediately

surrounding them because of badly made joints, the tendency of traffic over such a spot is to grind off the exposed edges of the brick, and in a little while a depression in the street is formed where the brick are badly broken or chipped, making it appear to the ordinary observer that the fault was in the brick. The same brick, if the joints had been good, would have worn indefinitely.

Portland-cement grout makes a very satisfactory joint when properly applied, and, by giving a good support to the edges of the brick, reduces the danger of chipping to a minimum. We cannot lay too much stress upon the proper application of the cement joint. As usually applied, the cement is mixed with clean, very fine, sharp sand, and water, and when reduced to the consistency of ordinary thin grout, is generally flooded upon the pavement from the mixing-box and swept into the joints between the brick with brooms. This method is very undesirable. It will be found that in many cases the sand, especially where it is not as fine as it should be, gets away from the cement while the grout is being spread over the street, resulting in joints which are some all sand, some all cement, and none properly made. Much the more satisfactory way is to pour the joints, the grout thoroughly mixed being dipped out of the mixing-box with pails, the mixture being constantly stirred until it is all dipped out of the box. This method of pouring the joints secures an even and well-filled joint which will add very greatly to the life of the pavement. The sand and

cement should be carefully mixed and should remain uniform. If coarse sand is used it separates from the cement during the operation of filling the joints and chokes up the joint with wet sand and very little cement, while other joints will be filled with cement and little or no sand. As a consequence, those joints which are choked up are not filled to the bottom, the coarse sand not having the consistency to run down between the brick to the sand cushion. Thus no bond is formed between the bricks and they soon separate from each other under traffic, and the pavement shows great wear at these points. It is easy to see, in going over a street, where the grouting has been well done and where improperly done. Portions of the pavement, sometimes as small as one square yard, or less, with little or no cement in the joints, and showing great wear, are evidences of improper grouting.

Joints are sometimes made by mixing the sand and cement dry and heating them. The mixture is then broomed into the joints until they are filled, after which the pavement is wet down, forming the bond after the sand and cement are in place. The ordinary method, however, of pouring the grout, gives thoroughly satisfactory results when carefully done.

The paving-cement joint is somewhat more expensive than that made with Portland cement. In places where the pavement is subjected to great vibration, such as in railroad streets and adjoining railroad tracks, it preserves the integrity of the pavement better. This is because the paving-cement joint is

elastic and allows a certain amount of play between the individual bricks without destroying the joint between them. The usual composition, which is used at a temperature of 300 degrees Fahrenheit, consists of 20 parts of refined asphalt, 3 parts of residuum oil, and 100 parts of coal tar obtained from the direct distillation of coal tar, generally known at the works as No. 4. The joints should be as completely filled with this material as possible, and to effect this it must be used only when very hot. Engineers frequently insist upon the paving cement being poured into the joints from a pot having a spout; but a much better joint is obtained by pouring the material over the street from coal hods and brooming it into the joints with wire brooms. To do this successfully a heating tank on wheels is necessary, holding about ten barrels. This tank should be kept hot all day. One man is necessary to feed the fire and draw out the mixture from a spigot into coal hods. Another man carries the hods from the heating tank to a third, who pours the hot material over the street. The latter starts to pour in the centre of the street, working backward toward the curb and pouring a strip about two feet in width. A fourth man with a wire broom follows immediately after him sweeping the surplus material toward the pourer and in the direction of the curb. This method, when properly employed, leaves the entire surface of the street covered with a very thin coating of the pitch. Upon this a light coating of sand is at once spread. This sand being placed on the hot pitch be-

comes thoroughly mixed with it, and the traffic over the street soon grinds all appearance of the pitch from the surface of the brick, leaving the street smooth and clean.

SPECIFICATIONS FOR LAYING BRICK.

We give below a set of specifications which may prove of value to those contemplating brick paving work.

FOUNDATION.

Sand.

The sand, wherever mentioned in these specifications, except for grouting and filling the joints of the brick pavement and sidewalks and for covering the same, or for the sand cushion for the brick pavement, shall be clean and moderately coarse, of the best quality, and shall be free from loam and refuse matter. For the sand cushion for the brick pavement, the sand must be screened until entirely free from pebbles exceeding one-quarter (1-4) inch in size. For grouting and filling the joints of the brick pavement and sidewalks, and for covering the same, the sand shall be clean and sharp and of the best quality. At least eighty per cent. (80%) by weight of the first-named sand shall be retained by a screen having fifty (50) meshes to the lineal inch, so that not more than three per cent. (3%) by

weight shall be lost upon washing. The second-named sand shall be capable of passing a fifty (50) mesh per lineal inch screen, but not less than fifty per cent. (50%) by weight shall be retained by a screen having one hundred and twenty (120) meshes per lineal inch.

Depth of Concrete.

After the surface of the carriage-way shall have been brought to the proper sub-grade and shall have been properly rolled so as to be smooth and practically firm and dry, hydraulic-cement concrete, made as hereinafter specified, shall be placed upon it to a depth of six (6) inches.

Concrete.

The concrete used as a foundation for the pavement and which is provided for in the contractor's bid, shall be composed of one (1) part of fresh-ground American hydraulic cement, of the best quality, eighty (80) pounds weight of such cement being taken as equal to one cubic foot in volume, two (2) parts of clean, sharp sand and four (4) parts of broken stone, or of broken bricks, the pieces of which shall in no case be too large to pass through a two-inch ring. The proportions of sand, cement, and stone as above described, are to be determined by measurement. The cement and sand shall be first thoroughly mixed dry; then water shall be added by degrees and without flooding the mortar, in sufficient quantity to form a stiff mortar; the broken stone, previously thoroughly wet, shall next be added

and the mass worked and turned over until the broken stone presents surfaces everywhere covered with mortar. The broken stone must be free from dust and dirt, but must not have the small-sized pieces screened out; it must be passed through a screen or separator, and all such stone as will not pass through the two (2) inch holes must be discarded and must not be brought on the street. The use of broken cobble-stones will only be permitted where it is found possible to break them into pieces of such size as to absolutely fulfil the requirements of this section of the specifications.

The cement shall be capable of resisting a tensile strain of sixty (60) pounds per square inch after thirty minutes' exposure to the air and twenty-four hours' immersion in water, and shall also be guaranteed by the makers to have such strength as has been hereinbefore required in these specifications; it must be of a well-known brand and one that is approved by the City Engineer. The use of concrete that has been mixed longer than one hour will not be allowed. All mixing must be done on tight platforms.

Concrete shall not be placed on the street unless the curbs are previously set and until the bottom has been trimmed to exact shape. The depth of the concrete shall be regulated by flat iron bars twenty-four (24) inches long, one-quarter (1-4) inch thick, and one and one-half (1 1-2) inches wide, which shall be driven to a firm bearing and have the top of concrete marked thereon with chalk, or preferably by means of adjustable iron rings with clamping screws.

The concrete shall be placed in proper position and there rammed with heavy rammers until it is thoroughly compacted and has a clear mortar surface, which surface, when left, shall be six (6) inches above the top of the sub-grade heretofore specified, and in exact conformity with the drawing of the cross-section of the street prepared by the City Engineer.

At least twenty-four (24) hours shall be allowed for the concrete to set before the pavement is laid. When connection is made with any layer, set, or partially set, the edge of such layer must be broken down and shall be free from dust and properly wet, so as to make the junction fresh and close. No driving with horses must be permitted upon the surface of the concrete at any time nor under any circumstances. Careful driving will be allowed upon planks placed on the concrete, but not until thirty-six (36) hours after the concrete is laid. Sand may be brought on the concrete in wheelbarrows, wheeled on planks laid for that purpose. The concrete must be protected from frost by means of sand or planks laid thereon, if the weather is cold. All concrete injured by frost must be taken up and replaced with new concrete.

Sand Cushion.

Upon the top of the concrete thus prepared and previously cleared from all loose stones and rubbish, shall be placed clean sand, free from loam, sufficient to form five and one-half (5 1-2) inches in depth in connection with the brickwork. Particular care must be taken

that the sand be wet at the time the bricks are laid. This sand, as hereinbefore specified, when used as a one and one-half inch cushion for the brick pavement, must be screened, and free from pebbles of more than one-quarter inch in diameter, and must be kept free from stones and rubbish after having been spread on the concrete.

Brick Pavement.

The pavement is to be of repressed, vitrified paving bricks of the best quality. The bricks are to be of uniform size and quality throughout the entire work. They must not be less than two and one-quarter (2 1-4) inches wide across their upper and lower faces; not less than four (4) inches deep; and not less than eight (8) inches long, except where half bricks are necessary to fill out lines of pavement. The bricks must be of uniform size and of the same manufacture throughout the entire street.

All paving bricks must be homogeneous and compact in structure, free from loose lumps of uncrushed clay, from laminations caused in the process of manufacture, or from fire cracks or checks of more than superficial character or extent. All bricks so distorted in burning as to lie unevenly in the pavement shall be rejected. Bricks that are improperly annealed will not be accepted.

Tests.

All bricks shall be free from lime and magnesia in the form of pebbles and shall show no signs of cracking or

spawling, on remaining in water ninety-six (96) hours. They shall be subjected to the standard test for abrasion, as recommended by the convention of the National Brick Manufacturers' Association, held at Buffalo, N. Y., in February, 1897, and under such test shall not sustain a loss in weight of more than twenty (20) per cent.

They shall have a specific gravity of not less than two and three-tenths (2 3-10).

They shall absorb not more than five (5) per cent. of water when dried at boiling heat of water for forty-eight (48) hours and afterward immersed for forty-eight (48) hours in water. This test is to be made on bricks that have previously been subjected to the abrasion test.

They shall show a modulus of rupture of not less than two thousand (2,000) pounds per square inch when tested in full size on their edge, or as laid in the pavement, the same to be computed by the formula $R = \frac{3\,l\,w}{2\,b\,d_2}$; in which formula R is the modulus of rupture, l the length between supports (equal to 6), b and d the breadth and depth, all in inches, and w the load, in pounds, producing rupture.

All bricks tested shall show an average equal to the limits named above, or, where limits are not named, the results of the tests shall be satisfactory to the City Engineer, but a variation in individual specimens of not to exceed fifteen (15) per cent. of the above limits will be allowed. Bricks not hitherto successfully used

at other places will not be accepted without a chemical analysis, certified to by some competent chemist of reputation, which analysis shall show a chemical composition not differing materially from that of other paving brick in successful use. All bricks shall have a proper shrinkage and shall not differ materially in size from the accepted samples of the same make, unless such change is due to a change of die, such change to be acceptable to the City Engineer; nor shall they differ greatly in color from the natural color of the well-burned brick of its class and manufacture. These qualities shall be compared with the brick deposited and referred to at the time of letting or with others afterward substituted by the consent of both parties to this agreement.

The bricks will be carefully inspected after they are brought on the line of the work, and all lots of brick which do not conform in quality and dimensions to these specifications will be rejected, and must then be immediately removed from the line of the work. Where the piles of bricks are mostly of good quality, but contain numerous inferior bricks, the contractor will be required to furnish such laborers as may be necessary to aid the inspector in the examination and culling of the bricks; and in case the contractor shall neglect or refuse so to do, such laborers as in the opinion of the Street Commissioner shall be necessary will be employed by the said Commissioner and the expense thus incurred by him will be deducted from and paid out of any money that may become due to the contractor under this agreement.

Proper care must be taken to exclude all poor bricks. After the bricks are laid and before they are grouted the contractor must remove all inferior bricks that have escaped previous culling, including all those marked by the inspector as condemned.

After fifty thousand (50,000) bricks, or such lesser number as may suffice to pave the entire street, are brought on the ground, the City Engineer shall select not less than sixty (60) bricks of apparently average quality, which bricks must be packed up for shipment, and sent to such laboratory as the said City Engineer shall specify, at the expense of the contractor, to be tested in the manner hereinbefore described; and if the samples so selected fail under the prescribed tests, the entire amount of brick shall be rejected and shall be immediately removed from the street. No brick must be used on the street until the receipt of a satisfactory record of tests prescribed. Where a brick of known make has already been tested, as herein specified, and found satisfactory for other streets, the City Engineer may, at his discretion, allow such brick to be used without special tests, reserving, however, the right at any time during the progress of the work to reject any lot of fifty thousand (50,000) bricks where the bricks do not conform to the requirements hereinbefore specified, or to any three of such five requirements, or to the second requirement alone.

Paving.

The bricks are to be laid on edge at right angles to the line of the street, except at intersecting streets,

where they are to be laid at such angle and in such manner as the City Engineer may direct. Each alternate course is to be commenced with a half brick. No half bricks or bats are to be used except at the ends of courses. All longitudinal joints are to be broken with a lap of at least three (3) inches. The joints are to be made tight by hammering the courses together frequently and by shoving the bricks together, lengthwise, by aid of a crowbar, before the closures are made at the ends of the course. The bricks are to be laid by skilled workmen, who shall stand on the bricks already laid, and in no case shall the bed of sand in front of the pavement be disturbed or walked on after having been smoothed over and brought to the exact crown and grade. A template shall be used for striking the sand cushion to the exact shape of the crown of the street. This template shall be made in accordance with the plans and directions of the City Engineer; it shall be kept whole, true to shape and in good condition; it shall rest on the curbs and be drawn forward immediately before the bricks are laid. The street is to be swept clean before rolling. As soon as practicable, and not to exceed three days after the bricks are laid, they are to be rolled to a proper surface with a roller weighing not less than five (5) tons. Sand is not to be put on the pavement until after grouting. After the brick pavement has been properly rolled to the correct finished surface and grade, the joints are to be filled with cement grout.

Grouting.

Grouting is to be of Portland cement of first quality and of a brand acceptable to the City Engineer, and of such fineness that ninety (90) per cent. will pass through a sieve of 10,000 meshes per square inch. When mixed neat and exposed one day in air and six days in water, it shall withstand a tensile strain of not less than 450 pounds per square inch. A pure thin Portland-cement grout formed of one part of cement to one part of fine, sharp, yellow sand, is to be first poured over the pavement, being dipped from a portable grout-box, care being taken that it passes into the joints and completely fills them. This operation is to be immediately followed up with a thicker grout in the same proportions of cement and sand, but with just water enough to enable it to run, which shall be brushed into the joints with a street-sweeper's bass broom, with rubber scraper attached. The pavement is to remain undisturbed in this condition until inspected, then to be completely covered with sand, after which the street is to remain closed for not less than ten (10) days, and for a longer period if practicable. Before the final acceptance of the work, or at such later date as the Street Commissioner shall determine, the contractor is to thoroughly sweep the street and remove all sweepings. The object of the sand covering is to prevent the grout from drying out too fast, hence it must be sprinkled from time to time in dry and windy weather. If from any cause the grout becomes washed

out of the joints, or does not fill them entirely, at all places, the contractor must, before the acceptance of his work, thoroughly clean out, wet, and regrout all such imperfect joints, and barricade the work from all traffic for six days thereafter. During the period of the five years' maintenance of the pavement all open or imperfect joints must in like manner be cleaned out, regrouted and barricaded.

SPECIFICATIONS FOR A STANDARD METHOD OF CONDUCTING THE RATTLER TEST FOR PAVING BRICK.

The following from the Report of the Commission on Standard Specifications for testing paving brick, appointed by the National Brick Manufacturers' Association, will be of value in testing paving brick:

I. Dimensions of the Machine:—The standard machine shall be twenty-eight (28) inches in diameter and twenty (20) inches in length, measured inside the rattling chamber. Other machines may be used varying in diameter between twenty-six (26) and thirty (30) inches, and in length from eighteen (18) to twenty-four (24) inches; but if this is done, a record of it must be attached to official report. Long rattlers may be cut up into sections of suitable length by the insertion of iron diaphragms at the proper points.

II. Construction of the Machine:—The barrel should be supported on trunnions at either end; in no case shall a shaft pass through the rattling chamber. The cross section of the barrel shall be a regular polygon, having fourteen (14) sides. The heads and staves shall be composed of gray cast-iron, not chilled or case hardened. There shall be a space of one-fourth of an inch between the staves for the escape of dust and small pieces of waste. Other machines may be used having from twelve (12) to sixteen (16) staves; but if this is done, a record of it must be attached to the official report of the test.

III. Composition of the Charge:—All tests must be executed on charges composed of one kind of material at a time. No test shall be considered official where two or more different bricks or materials have been used to compose a charge.

IV. Quantity of the Charge:—The quantity of the charge shall be estimated by its bulk and not its weight. The bulk of the standard charge shall be equal to fifteen (15) per cent. of the cubic contents of the rattling chamber, and the number of whole brick whose united volume comes nearest to this amount shall constitute a charge.

V. Revolutions of the Charge:—The number of revolutions for a standard test shall be eighteen hundred (1,800), and the speed of rotation shall be thirty (30) per minute. The belt power shall be sufficient to rotate the rattler at the same speed, whether charged or empty. Other speeds of rotation between 24 and 36

revolutions per minute may be used; but if this is done, a record of it must be attached to the official report.

VI. Condition of the Charge:—The bricks composing a charge shall be dry and clean, and as nearly as may be possible in the condition in which they are drawn from the kiln.

VII. Calculation of the Results:—The loss shall be calculated in per cents. of the weight of the dry brick composing the charge, and no result shall be considered as official unless it is the average of two distinct and complete tests, made on separate charges of brick.

SPECIFICATIONS FOR STANDARD METHOD OF COMPUTING ABSORPTION TEST FOR PAVING BRICK.

I. The number of bricks for a standard test shall be five (5).

II. The test must be conducted on rattled bricks. If none such are available, the whole bricks must be broken in halves before treatment.

III. Dry the bricks for forty-eight (48) hours at a temperature ranging from 230 to 250 degrees F. before weighing for the initial dry weight.

IV. Soak for forty-eight (48) hours, completely immersed in pure water.

V. After soaking, and before weighing, the bricks must be wiped dry from surplus water.

VI. The differences in weight must be determined on scales sensitive to one gram.

VII. The increase weight due to water absorbed shall be calculated in per cents. of the initial dry weight.

Resolved: That in the opinion of the commission, any paving brick which will satisfy the requirements of reasonable mechanical tests will not absorb sufficient water to prove injurious to it in service. We therefore recommend that the absorption test be abandoned as unnecessary, if not actually misleading.

SPECIFICATIONS FOR THE STANDARD METHOD OF MAKING CROSS BREAKING TESTS OF PAVING BRICK.

I. Support the brick on edge, or as laid in the pavement, on hardened steel knife-edges rounded longitudinally to a radius of twelve (12) inches and transversely to a radius of one-eighth inch, and bolted in position so as to secure a span of six (6) inches.

II. Apply the load to the middle of the top face through a hardened steel knife-edge, straight longitudinally and rounded transversely to a radius of one-sixteenth inch.

III. Apply the load at a uniform rate of increase till fracture ensues.

IV. Compute the modulus of rupture by the formula,

$f = \frac{3\,w\,l}{2\,b\,d_2}$; in which

f = modulus of rupture in pounds per square inch.

w = total breaking load of pounds.

l = length of span in inches = 6.

b = breadth of brick in inches.

d = depth of brick in inches.

V. Samples for test must be free from all visible irregularities of surface or deformities of shape, and their upper and lower faces must be practically parallel.

VI. Not less than ten (10) bricks shall be broken, and the average of all be taken for a standard test.

SPECIFICATIONS FOR THE STANDARD METHOD OF MAKING CRUSHING TESTS OF PAVING BRICK.

I. The crushing test should be made on half bricks, loaded edgewise, or as they are laid in the street. If the machine used is unable to crush a full half brick, the area may be reduced by chipping off, keeping the form of the piece to be tested as nearly prismatic as possible. A machine of at least 100,000 pounds capacity should be used, and the specimens should not be reduced below four (4) square inches of area in cross section at right angles to direction of load.

II. The upper and lower surfaces should preferably

be ground to true and parallel planes. If this is not done, they should be bedded in plaster of Paris while in the testing machine, which should be allowed to harden ten minutes under the weight of the crushing planes only, before the load is applied.

III. The load should be applied at a uniform rate of increase to the point of rupture.

IV. Not less than an average obtained from five tests on five different bricks shall constitute a standard test.

The following resolution was adopted:

Whereas, from the experimental work done so far by this commission, or by others so far as is known to us, in the application of the cross breaking and crushing tests to paving bricks, it is not possible to show any close relationship between the qualities necessary for a good paving material and high structural strength as indicated by either of these tests.

Resolved: That for this reason the commission recommends that these tests shall be considered as purely optional in the examination of paving material, and not necessary as a proof of excellence.

A HINT REGARDING THE GROUTING.

Owing to the fact that brick pavements laid on well-prepared foundations of first-class material throughout have in some instances shown poor results, it would be well to note that the only cause for such results will

be found in the improper or insufficient grouting of the joints. Wherever brick pavements properly laid with brick of good quality have been found to show wear quickly it may be laid to this cause and to this cause alone, and it would be well for all engineers engaged in preparing specifications for brick paving work, or in superintending such work, to lay special stress upon the care with which such specifications are prepared, especially as regards the method of preparing the grout for the joints and applying the same. As regards the actual carrying out of the work, it is well worth while to take extra precautions to insure the complete filling of the joints with the grouting material, as well as to see that said material shall be properly mixed when it enters and fills the joints, and not separated so that some joints are filled with sand and some with neat cement.