The Belgian Pavement.

The Belgian pavement, so named from its common use in Belgium, is made with blocks of stone that are nearly cubical in form, split as nearly as possible to square angles, with little if any dressing. The trap rock, which forms the palisades of the Hudson river, is extensively used for this purpose.

The following is one of the common forms of specification for this pavement; each block to measure on the face or upper surface not less than five inches nor more than seven inches in length; nor less than five inches nor more than six inches in breadth; in depth not less than six inches nor more than seven inches; nor shall the difference between the base and the top surface of any *stone* exceed one inch in either direction.

The sub-soil or other matter, other than clean sand, is to

lozenge-shaped divisions, presenting the edges diagonally to the wheel tires. The stone over the centre of each panel is to have 2 holes for a lewis, that it may be lifted out for a commencement of removing the stones to get access to the panel below. *This stone* should be set *only in clean sand;* all the rest of the stones are covered with sand that must be well washed into the joints, and there consolidated by thin grouting of hydraulic cement run freely into the sand and left to harden between the stones.

Fifth. I do claim as new and of my own invention the constructing a concrete foundation in panels or sections (to give access to pipes or conduits below) by the application and combination therewith of frames formed of any suitable material, with a thinner edge upward to allow the concrete mass to be lifted out when needed, substantially as described, when this is combined with a paved road-way of any kind laid thereon as described.

be excavated and removed to a depth of thirteen inches below the top surface of the new pavement when fully rammed, forming the proper arch or grade beneath the proposed pavement. Upon this foundation, clean, coarse sand or gravel is to be filled and thoroughly compacted by ramming or rolling to the proper depth to receive the paving stones, which are then to be laid in close contact, in even courses, transversely to the line of the street. When so laid, the pavement shall be thoroughly rammed to the grade and to the proper arch or crown, after which the surface is to be covered with one inch in depth of clean, coarse sand, and all interstices filled in solid with sand.

The blocks shall not be laid more than fifteen feet in advance of the rammers. When the road bed is not of firm and compact soil, the thickness of the sand foundation must be increased to 10 or 12 inches or more, and in soft, compressible, or swampy soils a concrete foundation should be resorted to. Indeed a solid and unyielding foundation is more necessary under a Belgian pavement, than under the larger blocks used in the Russ and Guidet methods.

The market price of Belgian paving blocks, whether of trap rock or granite, fluctuates with the price of labor, from $35 to $60 per thousand in New York city; so that the cost of the finished pavement laid upon six inches of concrete, will vary from about $3.60 to $4.50 per square yard, exclusive of profit to the contractor.

In setting the stones in a sand form it is important that they should all receive an equal amount of ramming, to prevent unequal settlement subsequently; and, if set in mortar on a concrete, rubble, or cobble foundation, they should not be walked upon or otherwise disturbed for some hours after

they have been settled to their place, so that the mortar will have time to set, and the street should not be opened to traffic for some days, or until the mortar has attained sufficient strength to resist crushing.

Wooden Pavements.

Wooden pavements made with blocks of wood—generally yellow or white pine—set on the end of the grain, although they have been extensively tried in the United States and elsewhere, within the last fifteen years, are unfit for streets subjected to heavy traffic. They are slippery in wet weather, and are of course very perishable, from their inability to resist either the wear and tear of traffic, or the course of ordinary decay. Various devices have been resorted to in order to lessen these objections and render these pavements safe and reasonably durable, such as setting them with wide open joints across the street so as to give the horses a good foothold; Kyanizing, Burnettizing or creosoting the wood to prevent decay; and underlaying them with an elastic foundation of boards or planks, to enable the blocks to resist the crushing and wearing effects of heavily loaded vehicles.*

* One of the most efficacious methods of preserving wood from decay, as well as from the attacks of land and marine insects, consists in impregnating it, by either the Bethell or the Seely process with the dead oil—containing carbolic acid (C_{12} H_6 O_2) or cresylic acid (C_{14} H $(^1_1)$) obtained in the distillation of coal tar. "By the Bethell process the timber is placed in an air-tight cylinder of boiler iron, which is then exhausted of air to the point indicated by 20° on the Bourdon vacuum gauge. At this point the creosote is admitted into the cylinder at a temperature of about 120° Fah., at once filling it to within an inch or two of the top. A pressure of about 150 pounds per square inch is then applied, and maintained for from five to eight hours, depending on the size of the pieces of timber under treatment. The creosote oil is then drawn off and the timber removed."

The Seely process, in brief, consists (1) in subjecting the wood to a temperature above the boiling point of water, and below 300° Fah., while immersed in a bath of creosote oil, for a sufficient length of time to expel the moisture. When the water is thus expelled the pores contain only steam; and then (2) the hot oil is quickly replaced by a bath of cold oil, by means of which change the steam in the pores of the wood is condensed, and a vacuum formed into which the oil is forced by atmospheric pressure and capillary attraction. The dead oil referred to above contains only a small percentage of the two acids named. It is claimed that either of them applied in a pure unadulterated state to the surface of a piece of timber, like a paint, will thoroughly permeate the entire piece, even if it be one foot or more in thickness, and will effectually prevent decay, a question which has not yet been satisfactorily determined. The process is now on trial.

The usual sizes for the wooden blocks are from 3 to 4 inches in width, 8 to 14 inches in length across the street, and 6 to 8 inches in depth.

The ordinary requirements for the Nicolson pavement are that the block shall be of sound yellow or white pine, free from sap, of rectangular form, and not less than 3 nor more than 4 inches wide, not less than 6 nor more than 14 inches long, and 6 inches deep, the grain of the wood being in the direction of the depth. The blocks for paving the side gutters are to be sawed to a bevel, so as to form a suitable channel way of uniform cross section about six inches outside the line of curb-stones, to carry off the surface water.

In preparing the foundation, the subsoil and all material other than clean sand, is excavated to a depth of 9 inches below the top surface of the new pavement, and parallel thereto. Upon this road-bed clean sand is filled in to the required

depth and a close flooring of common pine boards 1 inch thick is laid thereon, lengthwise with the line of the street, the ends resting on similar boards laid transversely from curb to curb. The flooring boards are thoroughly tarred on both sides with hot coal tar, brought to a proper consistency by boiling with pitch, so as to be tough and not brittle when cool.

Upon this flooring the blocks are set on end in parallel courses running across the street, the lower end of each block having been previously dipped to half its height in hot coal tar prepared as above directed. The joints which run parallel with the line of street are close, and not continuous.

The transverse courses are separated from each other $\frac{3}{4}$ of an inch, by batons of common pine one inch wide and $\frac{3}{4}$ of an inch thick, laid end to end at the base of the blocks, the whole being secured and made firm by nails driven through each baton and block with the flooring boards.

The spaces above the batons between the courses of blocks is then filled with a kind of concrete composed of clean roofing gravel and hot coal tar, thoroughly mixed and compactly rammed in with suitable iron-shod rammers.

Finally the surface of the pavement, as fast as it is finished, is thoroughly coated with hot coal tar, prepared as specified, and immediately covered with fine sand and gravel, mixed in equal proportions and laid on not less than one inch in thickness.

A section of this pavement taken parallel to the line of street is shown in Fig. 52.

A modification of this method consists in making the blocks square and all of the same dimensions on top (about

4 in. by 4 in.), one half of them being 3 or 4 inches less in depth than the rest, and then setting them on the prepared foundation in continuous courses closely in contact both across and lengthwise of the street, alternating the deep and shallow blocks with each other in both directions, thus forming a series of cells about 4 inches square and 3 to 4

FIG. 52.

inches deep, arrayed like the dark squares on a chess board. Fig. 53. These cells are filled with coarse gravel and prepared coal tar or asphaltum, and the whole pavement is coated over with the coal tar preparation and a layer of fine sand. When the flooring of boards is omitted, it is sometimes the practice to underlie the block with a coat of lime

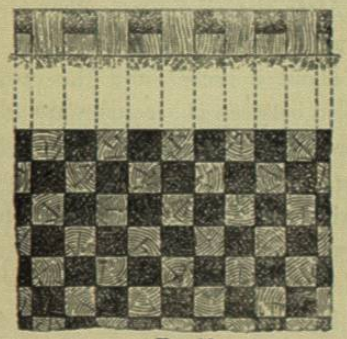

FIG. 53.

or cement mortar, or with a layer of thick paper covered with coal tar, in order to exclude the moisture from below.

By the Stowe method the blocks rest directly upon a form of clean well compacted sand or gravel, which may be from

4 to 6 inches in thickness only, if the road bed be hard and firm.

In soft spongy or clayey soils the sand foundation should be of greater thickness, though seldom exceeding 8 to 10 inches. The sand foundation should be carefully graded so as to be parallel to the finished street surface.

The blocks are set in courses transversely across the street

FIG. 54.

so as to break joints lengthwise of the street, the courses being separated from each other one inch, by a continuous course of wooden wedges placed close together edge to edge, and extending from curb to curb. These wedges are set in the first instance with their tops flush with the top surface of the blocks. After the whole pavement shall have been well rammed so as to give each block a firm bed, the wedges are driven down about 3 inches, and the open joints thus formed above them between the courses are filled in with a concrete composed of hot coal tar and fine roofing sand and gravel. (See Fig. 54.) The surface of the pavement may then be coated with coal tar prepared by boiling with pitch, and finished off with a thin layer of sand.

A modification of this general method of forming the pavement by setting single blocks of wood in courses slightly separated from each other, has been practiced to some extent without very satisfactory results. It consists in forming the blocks into sections or compound blocks, each containing from 12 to 15 single blocks breaking joints with each other in one direction, and held together with wooden

tree-nails, passing entirely through the section from side to side, and striking each full block twice. Each section has a triangular groove running horizontally around its four sides, for the reception of strong wooden keys. The sections are set in contact, breaking joints, upon a foundation of sand or a flooring of boards, and thus mutually support each other and are prevented from tilting by the keys inserted horizontally between them.

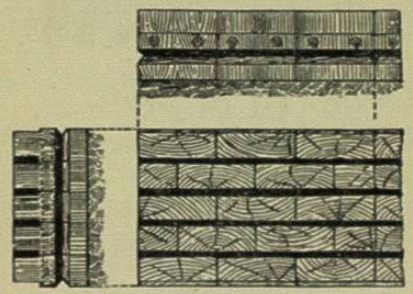

FIG. 55.

Deep grooves are cut in the upper face of each section so as to form continuous grooves across the finished pavement. These are filled with cement concrete, a mixture of coal-tar, sand and gravel, or other suitable material. Their principal object is to give a secure foothold for draught animals. One of the compound blocks is shown in Fig. 55. They are brought upon the street in readiness for laying.

Another method is to set the blocks on a base of cast-iron formed into cells on top, into which the blocks, previously dipped in hot asphaltum, or otherwise properly prepared, are inserted to about half their depth, each block having a shoulder around it which bears upon the top of the iron partition separating the cells.

The cast-iron base is formed in sections, of convenient area for removal in places where necessary, each section being screwed to those adjacent to it by iron clamps or staples as seen in Fig. 56 at *a*, and by pins as seen at *b*; or they may be held together by dove-tail projections fitting into corresponding recesses. The blocks fit together so as to form close joints on top, a channel being cut in each, so as

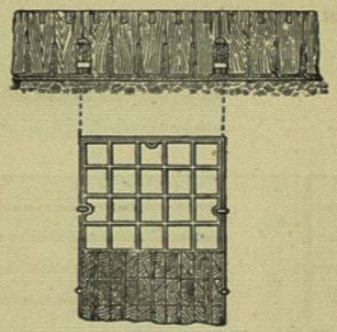

Fig. 56.

to form continuous channels, across the street, to give the horses a foothold. All the blocks are brought to the required form by machinery.*

* The author is indebted to E. S. Chesbrough, Esq., City Engineer of the city of Chicago, for the following interesting report on the wooden pavements in that city:

"It is true that wooden pavements have been more successful here than in any other important city. The reason is owing far more, I think, to local circumstances than to any peculiarity in the kinds of pavements used. Our city is on a very flat site, underlaid by a moist soil. Our streets are generally wide, and our traffic, instead of being principally on two or three main thoroughfares, is greatly diffused. When it is added we have the cheapest important lumber market in the country, you can easily see why wooden pavements should be more favored with us than they are elsewhere. Besides these considerations I should mention that our wooden pavements, while in good condition, are much more agreeable to drive over, than any other kind it is practicable to put down here, except the asphalt, which is much more costly.

"As the property holders on each side of a street are assessed the cost of paving it, except at intersections with other streets, it is very natural they should have something to say with regard to the kind of pavement to be put down; in fact the City Council has of late allowed them to make private contracts, the work however to be subject to the supervision of the Board of Public Works. As a consequence of this state of things, and also of the rival claims of patentees, we have tried various kinds of pavement during the last twenty years; no kind has lasted any better than the Nicolson. There has not been time enough yet to determine whether some of the newer kinds will last as long or not.

"Of the kinds of pavement laid here the following includes all it would be of any practical value to describe, viz.:

"1st. The Nicolson, which you are familiar with.

"2d. Bastard Nicolson, differing from the real in the absence of wooden strips in the bottom of the joints between the blocks, which are filled with gravel.

"3d. The Stowe, which is without any flooring under the blocks. These are kept apart with thin pieces of wood, wedge-shaped at the end, and driven into the sand below. The upper parts of the joints between the blocks are filled like those of the Nicolson.

"4th. The Greeley, which differs from the Nicolson simply in the joint between the blocks, which is filled entirely with the wooden strips, leaving no room for gravel.

"5th. The unpatented, which is without flooring under the blocks

Brick Pavements.

Among the many attempts that have been made to combine bitumen and other hydro-carbons, including even ordinary coal tar, with other substances for street pavements, the hydro-carbonized brick pavement introduced by Messrs.

Caduc and De Valins, of San Fancisco, California, deserves notice. The bricks are prepared by heating them in a boiler-iron tank set in brick work with a furnace underneath, and containing a sufficient quantity of the liquid hydro-carbon to allow for evaporation, and secure a thorough satura-

has no strips between them, and dispenses with tar. It is the most used here now.

"Some portions of wooden pavements here have lasted in tolerably good condition for nine years. When properly laid on wide streets they may be relied upon to keep in good condition about seven years but some fail in less time, especially where there is much traffic and vehicles are compelled to go in ruts, as for instance, through the nar row arch-ways of our river tunnels, in which the wooden pavements keep in good order only two or three years. The traffic through these is not to be compared with that on Broadway, or Fulton St., New York.

"Gravel, Macadam, Cobble, and Limestone block pavements have all been used here, but none of them compare favorably with the best of similar kinds used in eastern cities. The cobble has been entirely discontinued. The Macadam is but little used. The stone is very disagreeable as compared with wood, and no new streets have been paved with it for years. The first wooden pavements of this city were laid in 1856.

"Our streets are under the care of the Superintendent of Public Works. Mr. I. K. Thompson, the former one, now a member of the Board, and Mr. Geo. W. Wilson, the present one, have kindly given me their views on this subject. They are both satisfied that the reason some wooden pavements last so much shorter time than others, is owing to a less degree of care or skill, in the selection of the blocks. This is of course, when they are subjected to like usage. They also think white oak is more durable than pine used in this way. The unpatented costs about $1.40 per square yard, including 4 inches of ballast blocks 8 inches in depth. The blocks are now laid diagonally across the streets, and are considered more durable laid this way."

tion of the bricks. The heat is applied with an intensity and duration sufficient to reduce the liquid material to a consistency that will withstand high atmospheric temperatures without softening. A tank 12ft. long, 4 to 5ft. wide, and 3ft. deep is a suitable size, and the time required for a thorough saturation of the bricks about 24 hours. It is claimed that, thus treated, the bricks will sustain great weight without crushing, and will resist abrasion and wear when subjected to ordinary street traffic, but no satisfactory evidence on these points, based upon their practical use, has been obtained. The description furnished by the inventors does not specify the kind of hydro-carbon required to give the best results.

The prepared bricks are set in a layer of sand about 2 inches thick, spread upon the road bed after the latter has been properly adjusted to a surface parallel with that of the finished pavement. The road bed and sand should be thoroughly compacted by ramming or rolling.

The bricks may be set in a single layer, on edge or on end, with continuous joints running across the street, and breaking joints in the other direction. They are firmly settled to their places by ramming, and hot coal-tar or asphaltum is poured into the joints to cement them together, and render the pavement impervious to water. The surface is finished with a coating of the same material laid on hot, and then top-dressed with a layer of fine gravel or coarse sand. When two layers are used, the bottom one may be of unprepared bricks laid flatwise, with the joints filled in with sand, and then covered with a coat of hot coal-tar or asphaltum. The top layer may be set on edge or on end, and finished off as in the case of a single layer.

On steep grade the surface layer may be set with open half-inch joints running across the street, filled in with a mixture of hot tar and gravel.

The durability of this pavement has yet to be proved.

Asphalt Pavements.

Within the last twenty-five years bitumen, in some of its many forms, has been employed to a considerable extent, as the binding material or matrix for road and street coverings laid in continuous sheets without joints. They are all comprised under the general head of asphalt pavements. The city of Paris took the lead in this innovation upon the former methods of paving with stone, the reasons assigned for the change being, (1) the want of connection and homogeneity, in the elements of which the stone paving is composed, (2) the incessant noise produced by them, (3) the imperfect surface drainage which they secure, by reason of which the foul waters are not carried off but filter into the joints, and (4) the ease with which they can be displaced, and used for the construction of barricades, breastworks and rifle pits in time of civil war.

Varieties of Bitumen.

There are several varieties of bitumen which pass insensibly into each other, from *naphtha* the most fluid, to *petroleum* and *mineral tar*, which are less so, thence to *maltha* which is more or less cohesive, and thence to *asphaltum* which is generally solid. The softer kinds gradually harden in time by the evaporation of the volatile parts.

They are hydro-carbons, accompanied in the solid and viscous kinds with various oxygenated carburets of hydrogen.

The fluid varieties are generally solvents, to a greater or less extent, of those that are solid or less fluid.

The forms of bitumen most extensively employed for pavements are *mineral tar ; asphalt rock,* which is an amorphous carbonate of lime impregnated with mineral tar, and known in commerce as *bituminous limestone ; asphaltum ;* heavy *petroleum oils* like those from West Virginia, or others not volatile under 212° Fah., or the residuum of refined petroleum containing no water, and so refined as not to be volatile at 212° Fah.

Mineral Tar.

The principal sources of the natural mineral tar of commerce are in France, at Bastenne (Landes) and at Pyrimont Seyssel (Ain), and in Switzerland at Val de Travers, in the canton of Neuchatel. At Bastenne as well as at Gaujac, in the south of France, it flows from several springs mixed with water. The Bastenne mines are nearly exhausted, and no shipments of mineral tar to foreign ports are now made from that locality. This tar is also found impregnating quartzy sandstone, from which it is separated by boiling. At Seyssel both sandstone and limestone are impregnated with it. By boiling the sandstone in water the tar rises to the surface, or adheres to the sides of the vessel. The sandstone seldom yields more than 10 per cent of tar, the average of the mines falling considerably below that proportion. At the ordinary temperature mineral tar should not be either brittle or liquid, but viscous and ductile, so that it will freely elongate into threads when drawn out, and not break unless drawn very thin.

Bituminous Limestone.

This limestone, known also as *asphalt rock*, occurs in both Seyssel and Val de Travers. The stone is of a liver brown color, irregular in fracture, massive, and has a specific gravity of 2.114, water being 1.000. It contains from 5 to 15 per cent, and sometimes 20 per cent, of the mineral tar above described; is tough and difficult to break with a hammer, being to some extent malleable. It can be cut easily with a sharp knife, or scratched and abraded with the finger nail.

Asphaltum.

Asphaltum is a variety of bitumen generally found in a solid state. At ordinary temperature it is brittle, and too hard to be impressed with the finger nail. It is black or brownish in color, opaque, slightly translucent at the edge of a new fracture, of smooth fracture, and has little odor unless rubbed or heated. It melts easily, burns with very little if any residue, and is very inflammable.

It is found floating on the Dead Sea, and in many places in Europe. Many localities in Mexico supply it, and it abounds in the islands of Barbadoes, Trinidad, and Cuba, and in Ritchie county, West Virginia, and in New Brunswick, Dominion of Canada. They all yield, by distillation, an inflammable gas; a kind of bituminous oil; a tarry substance like coal tar; and a species of coke. They are all too brittle when cold, and too soft when exposed to the direct rays of a summer's sun, to be employed in their natural state, as the cementing substance of street pavements. A suitable solvent to render it fit for such use, has been found in the heavy petroleum oils, or the residuum of refined petroleum,

not volatile at 212° Fah., already mentioned. The result of the combination, which should take place in an iron boiler at a temperature of about 470° Fah., is a manufactured bituminous cement exactly resembling in composition, quality, and appearance, the natural mineral tar obtained from the mines of Bastenne, of Gaujac, or from the sandstone of Seyssel.

This variety of bitumen, known as mineral tar, or bituminous or asphaltic cement, whether furnished by nature in a nearly pure state, or formed by the combination of other natural bitumens, under the general law that the more fluid kinds are solvents of those that are solid or less fluid, is the best and only suitable cementing substance, or binding medium, for asphalt pavements yet discovered. Like all the bitumens it owes its property of hardness and toughness under varying temperatures, to the presence in suitable proportions of the compounds called petroline and asphaltine, too much of the former making the asphaltic cement too soft in warm weather, while an excess of the latter renders it too brittle in winter. Hence the percentage of heavy petroleum oil necessary to be added in order to convert into a good bituminous cement, any particular variety of asphaltum, depends upon the proportion of petroline and asphaltine which the latter already contains, and this proportion varies greatly in different localities.

No asphaltic cement is suitable for all climates, and even the natural mineral tar from Seyssel, though well adapted for use upon the streets of Paris, requires to be mixed with a harder asphalt, to enable it to withstand exposure to the sun in the United States.

Bituminous Limestone (Asphalt) Pavements.

A capital distinction must be made between pavements of asphalt hereafter described, made either with natural asphalt rock, or with the refined asphaltum as a cement, combined with suitable calcareous powder, and all or nearly all of those attempted imitations of it, produced by mixing crude mineral tar, or manufactured tar, with one or more pulverized minerals or earths. And more especially must we exclude from the category of asphalt pavements, all those patented street coverings composed of wood-tar, coal-tar, pitch, rosin, etc., mixed with either sand, gravel, ashes, scoria, sulphur, lime, etc., or with two or more or all of them. Some of them will produce a tolerably fair sidewalk, but they are totally unfit for the surface of a carriage way. Some of the best of them will answer for carriage way foundations.

The natural asphalt rock, like that from Seyssel or Val de Travers, or other localities in the Jurassic region, in order to be suitable for paving carriage ways, should contain about 11 or 12 per cent of bitumen (mineral tar) and 88 or 89 per cent of amorphous carbonate of lime. Inasmuch, however, as some of these limestones contain more, and others less than 11 or 12 per cent of the tar, it is frequently necessary and always practicable to obtain a mixture of the requisite degree of richness in bitumen, by combining those of different qualities together, or, if none but a rock poor in bitumen is procurable, the same result may be obtained by adding mineral tar to it.

The rock should be of the fine-grained variety, of tolerably close texture, and composed of pure carbonate of lime

so uniformly and homogeneously impregnated with the bitumen, that a cut made with a sharp knife will show neither pure white nor jet black spots, but be of a brownish liver color, mottled with grey.

When asphalt rock of this character is heated to a temperature of 200° to 212° Fah., the bitumen becomes soft, the grains of limestone separate from each other, and the mass crumbles into a partially coherent powder. If this powder, while still hot, be powerfully compressed by ramming, tamping, or rolling, the molecules will again unite, and the mass when cold will assume all the essential qualities of the original rock, but in a superior degree, as regards toughness, hardness and incompressibility. This is the whole theory of asphalt road coverings, as applied to the street pavements in Paris and elsewhere.

Foundations for Asphalt Pavements.

The pavement foundation should be preferably, cement, concrete, or rubble stones filled in with concrete made after the same formula, and laid in the same manner and to the same thickness, heretofore described for a pavement of stone blocks; or it may be six to eight inches of suitably compacted broken stone; or an old broken stone road carefully cleaned by scraping and sweeping, and then covered to an even surface with a coat of mortar; or an old cobble, or stone block pavement, with the joints raked out to a depth of about one inch, and then cleaned off and coated with mortar. Even a badly worn pavement of coal-tar concrete, or other kindred mixtures, may be the foundation, under suitable precautions. The mortar used for surfacing the foundation may be composed of one volume of common lime

paste, one volume of the paste of Rosendale or other equivalent cement, and seven to eight volumes of coarse sharp sand. If standard Portland cement be used, the volume of lime paste may be doubled, and the volume of sand increased one-half, producing a mortar containing cement paste one, lime paste two, and sand ten to twelve.

If a new foundation has to be prepared, it should be of good cement concrete, and for streets subjected to heavy traffic not less than 6 inches thick if upon firm and compact soils, and rarely more than 9 or 10 inches if the road bed be wet, spongy, or clayey. It should be compacted to an even surface parallel to that of the new pavement, so that the latter can be applied in a sheet of uniform thickness.

Heating the Asphalt.

The asphalt rock, previously pulverized by grinding, is brought to a uniform temperature of 250° to 260° Fah., in iron heaters, and in this condition is conveyed in wheel-barrows with sheet iron bodies to the place where it is to be used. If the heaters be arranged upon wheels so as to be portable, they can be kept in close proximity to the point of application, in which case the hot material may be taken out with long handled shovels, and deposited directly upon the foundation in its proper place, but it will generally be found convenient to convey it in wheel-barrows.

The material is not in fit condition for use until all the moisture has been driven from it, and it should not be applied upon a cement-concrete foundation until the latter has had some days to set, nor in any case upon any kind of foundation until its surface has become perfectly dry. If laid upon a damp surface the heat vaporizes the moisture,

and the steam, escaping through the powder, prevents a thorough and complete cohesion of the particles, and renders the pavement imperfect. When it is impossible or inconvenient to wait for the surface of the foundation to become dry, a first coating of asphalt, one-fourth of an inch thick, may be applied, to be followed when hard by the final covering. By this precaution the injurious effects of the steam created by the hot powder, will be avoided. For this lower coat the asphalt may be of poorer quality.

Applying the Asphalt.

The hot powder having been carefully spread upon the foundation with an iron rake, to a depth exceeding by two-fifths the ultimate thickness required, is then compacted by

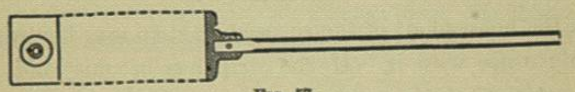

Fig. 57.

ramming with iron pestles, kept sufficiently hot in portable furnaces to prevent a too rapid cooling of the asphalt. The ramming should first be done cautiously with light blows,

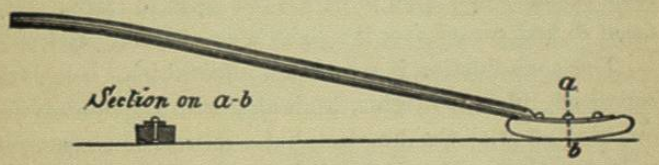

Fig. 58.

gradually increasing in energy, special care being taken at the junction of the hot powder with that previously laid. The finished pavement should be smooth and even, with from 1¼ to 2 inches thickness of asphalt, except upon streets

where the traffic is very heavy, when the thickness may advantageously be from 2½ to 3 inches. The iron rammer, Fig. 57, may be circular, square, or rectangular on the face, and should weigh from 14 to 16 pounds. After the rammers, hot smoothing irons, Fig. 58, are passed over the surface, in order to give it a high degree of finish.

It is usual to lay this pavement in transverse strips from curb to curb, or from gutter to gutter, of a uniform width of 4 to 6 feet, care being taken to cut the outer edge of each strip to a rebate while it is yet soft as shown in Fig. 59, so

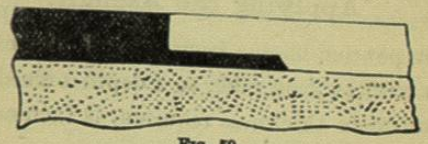

FIG. 59.

that the hot asphalt of the succeeding strip may lap over and firmly unite with it. If the strip has become cold, from interruption of the work or other cause, some of the hot asphaltic cement should be applied to the rebate with a brush, in order to insure a close and powerful cohesion in the joint. In two or three hours after the work is done the road is sufficiently hard to be thrown open to traffic. It is usual to first spread over it a light layer of loamy sand.

The consolidation is sometimes effected with heavy iron rollers of different weights, beginning with the lightest and finishing off with the heaviest, but a roller containing only a single cylinder, if sufficiently heavy to be effective, is apt to cause the soft asphalt to rise up in front of it, and even to tear it asunder as the temperature becomes lower. Two or three rollers, placed close together in the same frame, one behind the other, would be less objectionable.

The method of consolidation with rammers is believed to be the best, all things considered.

It is important that the surface should be evenly finished to the required grade, and be free from elevations and depressions. If otherwise the wear will be more severe, in consequence of the shocks and blows created whenever a wheel rises and falls upon the uneven surface. Moreover, rainwater and all noxious fluids should drain off freely, which they could not do from a rough pavement, and as the asphalt is impervious to water, they would stand in pools until cleaned off or removed by evaporations.

There can, of course, be no vertical absorption from rains, through such a covering. There will also be no lateral absorption if suitable drainage has been provided. The road bed will therefore remain dry at all seasons of the year, and no upheavals from frost need ever be apprehended.

Asphalt Pavements without Bituminous Limestone.

When it is desired to construct an asphalt pavement, without using the bituminous limestone from the Jurassic region which, as already described, contains both the matrix or binding material, and the body cemented together, and which after disintegration by heat, or by grinding, is capable of being re-united under a new form, and especially in the form of a monolithic sheet suitable for street coverings, there are three essential points demanding consideration, viz :

First. To obtain a suitable bituminous or asphaltic cement.

Second. To obtain a solid material in the form of

powder, fit to replace the amorphous carbonate of lime of the natural asphalt rock.

Third. To combine these two in such manner that they will answer the purpose of a pavement. These points will be briefly considered in their regular order.

The Asphaltic Cement.

First. The imported mineral tar, after proper treatment to adapt it to our climate, by adding a small quantity of refined asphaltum, is a good asphaltic cement. When, however, it is desired to manufacture a suitable cement from the crude materials, the variety of bitumen known as asphaltum or asphalt is employed as the basis.

The asphalts from different localities differ very much in the proportion of asphaltine and petroline which they contain. Too much asphaltine renders the cement brittle in cold weather, while it will become too soft in summer if it contains an undue quantity of petroline. No natural asphalt, whether liquid or solid, has yet been found suitable for all climates and seasons, and it is necessary to mix two or more together, in order to arrive at satisfactory results, having first ascertained the standard quality of each.

The asphalts in common use in this country are derived from deposits found in the islands of Cuba and Trinidad; from Ritchie county, West Virginia, and from the province of New Brunswick. The two last named, known respectively as Grahamite and Albertite, are pure asphalts, containing little if any foreign impurities, while the others contain from 20 to 30 per cent of deleterious refuse matter, which has to be separated by a careful process of refining. They all differ in the amount of asphaltine which they contain,

there being the most in Grahamite and Albertite, less in the Cuban, and least in that from Trinidad. There is a liquid asphalt or mineral tar, brought from the isthmus of Tehuantepec, which contains less asphalt than the Trinidad. It contains about 2 per cent of sulphur and a large proportion of water, as received in the market, from which it has to be separated by refining.

These natural asphalts, having each been brought by refining to a standard point of specific gravity and purity, may be used separately, or two or more of them may be mixed together, as the basis of the asphaltic cement. It will be necessary in using only the solid asphaltums to add, at a suitable temperature—say from 250° to 300° Fahrenheit—a small per centage of the proper solvent, such as the heavy oils or "still bottoms," produced in the process of refining crude petroleum, in order to render the cement fit for pavements, and enable it to withstand the changes of temperature in the locality where it is to be used. The precise quantity of heavy oil that it would be necessary to add to any one asphalt, would not be likely to suit another, or the mixture of two or more of them. Chemical research and experiment can alone determine this point. A liquid bitumen containing asphaltine and petroline in the requisite proportions to produce the desired result may replace the still bottoms.

A serious impediment to the successful use of asphalt for pavements in this country, is the condition in which they are shipped from the island of Trinidad and other localities where the deposits are found.

The operation of refining—improperly so called—at the mines, is very imperfectly done, so that variable and some-