CHAPTER VI.

SIDEWALKS AND FOOTPATHS.

SIDEWALKS and other footpaths are usually paved with flagging-stone, bricks, wood in the form of planks or blocks, or some variety of concrete in which either bitumen or hydraulic cement is the binding material. Various kinds of artificial stone have been used for the same purpose. Most of the pavements above named are so well known as to need no mention here.

Concrete Footpaths.

Concrete footpaths should be laid upon a form of well compacted sand or fine gravel, or a mixture of sand, gravel and loam. The natural soil, if sufficiently porous to provide thorough sub-drainage, will answer.

It is not usual to attempt to guard entirely against the lifting effects of frost. but to provide for it by laying the concrete in squares or rectangles, each containing from twelve to sixteen superficial feet, which will yield to upheaval individually, like flagging stones, without breaking and without producing extensive disturbance in the general surface. When a case arises, however, where it is deemed necessary to prevent any movement whatever, it can be done by underlying the pavement with a bed of broken stone, or a mixture of broken stone and gravel, or with ordinary pit-gravel containing just enough of detritus and loam to bind it together

In high latitudes this bed should be one foot and upwards in thickness, and should be so thoroughly sub-drained that it will always be free from standing water. It is formed in the usual manner of making broken stone or gravel roads, already described, and finished off on top with a layer of sand or fine gravel about one inch in depth for the concrete to rest upon.

The concrete should not be less than 3½ and need rarely exceed 4 to 4½ inches in thickness. The upper surface to the depth of ½ inch should be composed of hydraulic cement and sand only. Portland cement is best for this top layer. For the rest any natural American cement of standard quality will answer. The following proportions are recommended for this bottom layer:

Rosendale or other American cement	1	measure.
Clean sharp sand	2½	"
Stone and gravel	5	"

It is mixed from time to time as required for use, and is compacted with an iron-shod rammer, in a single layer, to a thickness, less by half an inch than that of the required pavement.

As soon as this is done, and before the cement has had time to set, the surface is roughened by scratching, and the top layer composed of

1 volume of Portland cement, and
2 to 2½ volumes of clean fine sand,

is spread over it to a uniform thickness of about 1½ inches, and then compacted by rather light blows with an iron-shod rammer. By this means its thickness is diminished to half an inch. It is then smoothed off and polished with a mason's trowel, and covered up with hay, grass, sand, or other suitable material to protect it from the rays of the sun and prevent its drying too rapidly.

It should be kept damp and thus protected for at least ten days, and longer if circumstances will permit; and even after it is opened to travel, a layer of damp sand should be kept upon it for two or three weeks to prevent wear while tender.

At the end of one month from the date of laying, the Portland cement mixture forming the top surface will have attained nearly one-half its ultimate strength and hardness, and may then be subjected to use by foot passengers without injury.

The rammers for compacting the concrete should weigh from 15 to 20 pounds, those used on the surface layer from 10 to 12 pounds. They are made by attaching rectangular blocks of hard wood shod with iron, to wood handles about 3 feet long, and are plied in an upright position.

Certain precautions are necessary in mixing and ramming the materials, in order to secure the best results. Especial care should be taken to avoid the use of too much water in the manipulation. The mass of concrete, when ready for use, should appear quite incoherent and not wet and plastic, containing water, however, in such quantities that a thorough ramming, with repeated though not hard blows, will produce a thin film of moisture upon the surface under the rammer, without causing in the mass a gelatinous or quicksand motion.

The concrete may be prepared by hand, or in the concrete mixture Fig. 64. Equal care is essential in mixing and compacting the top layer of Portland cement and sand. The

mixing should be so thorough that each grain of sand will be entirely coated with a thin film of plastic cement, with very little excess of cement not thus disposed of.

A characteristic property of this mixture when properly and uniformly prepared, is that it does not assume a jelly like motion under the rammer. Excess of water must therefore be carefully avoided. The cement must be precisely such that the effect of each blow of the rammer will be distinct, local, and permanent, without disturbing the contiguous material compacted by previous blows. If it be too moist the mass will shake like wet clay; if it be too dry it will rise up around the rammer like sand. In either case the mass cannot be suitably compacted by ramming, and would therefore be comparatively weak and porous after setting.

The Portland cement and sand may be mixed together by hand on a mortar bed, but that process, to obtain thorough and uniform manipulation, would be tedious and expensive. A better method would be by a cubical box of somewhat smaller dimensions than the concrete mixer referred to above. A kind of trituration, or a grinding and rubbing process of mixing gives the best results. This may be easily and inexpensively secured by putting in the box, with the cement, sand, and water, several smooth rounded pebbles weighing 6 to 8 pounds each. After the batch is emptied out upon the platform, these are taken out for further use.*

* The writer's previous publications, viz., "Limes, Hydraulic Cements and Mortars," and "Béton Aggloméré and other Artificial Stones," give full details on this branch of the subject. They are published by D. Van Nostrand New York City.

When silicious hydraulic lime, like that of Teil, France, can be procured at moderate cost, it can be used with advantage to replace one-third to one-half of the Portland cement, care being taken to so adjust the proportions that the volume of paste produced by mixing and tempering the cement and lime together, shall exceed by about 25 per cent the volume of voids in the sand, as ascertained by the water test.

In laying concrete footpaths in squares or rectangles, the material is spread and rammed between stout planks set and firmly maintained on edge, with their upper edge coincident with the surface of the path, every alternate square being omitted in the first instance, to be subsequently filled in,—say on the following day—after those first formed have become sufficiently hard to sustain without injury, the ramming of the fresh concrete against them. To prevent adhesion between the squares, the edge against which the new material is placed may be covered with whitewash, or a coat of oil. A strip of felt, muslin, or card board interposed between the squares will answer the same purpose, although this device is covered by the Schillinger patent.

One advantage of this kind of footpath, over that formed in a continuous layer, is that the squares can be taken up to get at water and gas pipes, and then replaced without injury. In some cases it may be advantageous to mould the squares under sheds, and then lay them like common flagging-stones, after they have become sufficiently strong to bear handling and transportation. Three weeks will generally suffice for this purpose. It will be found unadvisable to make them larger than three to three and a half feet square.

The Schillinger pavement for footpaths, which is patented

in respect to the method of preventing adhesion between the squares, is formed substantially after the manner above described, with this important exception and defect, that the top layer, which receives all the wear, instead of being mixed with very little water and compacted by ramming, is applied in a plastic condition as a coat of mortar. It is therefore comparatively deficient in hardness, compressive strength and the power of resisting frost. Its want of compressive strength, in particular, was fully proved by experiments in 1871, recorded in the volume on "Béton Aggloméré and Other Artificial Stones," from which the table page 214 is taken. It shows in a marked manner the superior strength of a mixture that can be compacted by ramming; as well as the superiority of Portland to Rosendale cement.

The surface layer of the concrete pavement above described, resembles in all essential respects the artificial stone to which the name béton aggloméré has been given in France, sometimes known as béton Coignet, from M. Francois Coignet of Paris, who first introduced it. In France, however, the silicious hydraulic lime of Teil replaces the Portland cement to a large extent, some of the strongest samples of the stone having been made with 1 measure of this lime (slaked and in powder) ¾ of a measure of dry Boulogne Portland cement, and 4 measures of sand. The compressive strength of this mixture, when 21 months old, was reported by Mr. P. Michelot, ingénieur-in-chief des Ponts et Chaussée to be 7176 lbs. per square inch for one specimen, and 7405 lbs. for another. The specimens were rectangular blocks 3¼ inches deep, 3 inches long and 2¼ inches wide.

Proportion of Sand and Cement by Measure (dry).	How Mixed.	Crushing strength of Blocks in gross tons.
Rosendale cement, no sand......	Not plastic.	6.25
do. do. do.	Plastic.	0.90
Portland cement, no sand.......	Not plastic.	24.55
do. do. do.	Plastic.	22.32
Rosendale cement, 1. Sand, 1.2	Not plastic.	2.67
do. do. do.	Plastic.	0.45
Portland cement, 1. Sand, 1.7	Not plastic.	24.10
do. do. do.	Plastic.	8.92
Rosendale cement, 1. Sand, 1.8	Not plastic.	1.00
do. do. do.	Plastic.	0.53
Portland cement, 1. Sand, 2.55	Not plastic.	12.50
do. do. do.	Plastic.	8.47
Rosendale cement, 1. Sand, 2.35	Not plastic.	1.34
do. do. do.	Plastic.	Went to pieces in water.
Portland cement 1. Sand, 3.4	Not plastic.	8.00
do. do. do.	Plastic.	6.25
Rosendale cement, 1. Sand, 3.5	Not plastic.	0.45
do. do. do.	Plastic.	Went to pieces in water.
Portland cement, 1. Sand, .5	Not plastic.	4.46
do. do. do.	Plastic.	2.23
Rosendale cement, 1. Sand, 4.7	Not plastic.	0.40
do. do. do.	Plastic.	Went to pieces in water.

The table gives the compressive strength of blocks 3½ inches wide, 5½ inches long, and 3 inches thick, the area under pressure being 19¼ square inches. Some of the blocks were made with little water and compacted by ramming, others with plastic, rather over-stiff mason's mortar, firmly pressed into the moulds with a trowel. The Portland cement was made at Boulogne, France. The blocks were 7 days old, having been kept in water 6 days.

Asphalt Footpaths.

Asphalt sidewalks may be laid after either of the two methods described for pavements for carriage ways, but the thickness of the foundation, if of concrete, need not generally exceed 3 to 4 inches, and that of the asphalt covering may be restricted to from ⅜ to ½ or at most ¾ of an inch.

In compact clayey soils the foundation should rest upon a lay of sand or gravel, 4 to 5 inches in thickness, to secure sub-drainage, and guard against upheaval by frost. The various patented pavements containing coal tar, resin, pitch, etc., will generally answer as a foundation for the asphalt layer.

Asphalt in the form of Bituminous Mastic is also used for paving sidewalks. This mastic may be prepared by heating together, in a covered iron boiler, mineral tar either natural or manufactured, (see page 173 and 182) and certain calcareous, silicious, or earthy substances previously reduced to powder, and it differs from the mixture used for paving carriage ways only in containing a little more of the mineral tar.

The bituminous mastics of Seyssel or Val de Travers are prepared by mixing the bituminous limestone from those localities, previously pulverized by grinding or by roasting, with the mineral tar derived from the impregnated sandstone. In the Seyssel limestone 7 to 8 per cent of tar must generally be added, while that from Val de Travers will seldom require more than 4 to 5 per cent of tar. The tar required for a given quantity of mastic is first heated in the iron boiler, until the liquid begins to emit a whitish vapor. The powdered stone is then added little by little, care being taken not to add it in quantities large enough to cause a sudden lowering of the temperature. The emission of a yellowish or brownish vapor indicates too high a degree of heat, when the fire must be reduced and the mass stirred rapidly, to prevent injury to the mastic by scorching.

For convenience of handling, the mastic is moulded into blocks measuring about 20 inches by 12 inches by 6 inches. When used it is broken up into small fragments and remelted, 2 to 3 per cent of mineral tar being then added to compensate for loss at the second heating.

The pulverization of the bituminous limestone preparatory to its incorporation with the mineral tar may be effected by either grinding or roasting.

For grinding it is simply broken up into pieces about the size of a hen's egg and then passed through any ordinary mill. The grinding can best be conducted in cold dry weather, as the stone is then less liable to cake in the mill.

For roasting, the stone is first broken up as for grinding, and then gently heated in a covered iron vessel, accompanied by constant stirring with an iron instrument, which causes the fragments to disintegrate and fall into a partially coherent powder.

Bituminous mastic is suitable for paving sidewalks,

cellars, areas, markets, and for covering walls and arches to exclude water, and prevent leakage.

It is extensively used in fortifications for covering the arches of gun-casemates and powder magazines before the earth covering is put on. When employed for pavements it should be laid upon a concrete foundation of sufficient thickness to support, without settlement or other disturbance, the greatest weight likely to come upon it. This thickness will therefore depend upon the character of the underlying soil, but will rarely exceed 3 inches. The thickness of the mastic covering is usually ⅝ to ¾ of an inch. It is applied by spreading it while hot and plastic, with a wooden trowel or spatula, great care being taken to form a water-tight junction between contiguous strips. Before applying the mastic upon hydraulic concrete the latter should be covered with a very thin slipped coat of common lime mortar; just enough to make it smooth.

As bituminous mastic contains more of the mineral tar or asphaltic cement than the mixture for street pavements heretofore described, it is softer than that mixture, at the same temperature, and is never used for paving carriage ways, or where it will be subjected to the continued tread of heavy animals. It is doubtful whether it is as good even for sidewalks, as asphalt applied in the usual way by ramming.

Where sidewalks have vaults beneath them, it is important that the percolation of water from the top as well as from the side walls next the street should be prevented. When the vaults are covered with arches, a layer of bituminous mastic, and even of some of the best coal tar preparations, properly laid over the arches before the earth filling is put on will prevent leakage from the top.

Another method is to keep the arches so low that a monolithic bed of cement concrete, rather rich in good cement mortar, and not less than 4 to 5 inches in thickness over the crowns of the arches, can be put over the entire width occupied by the vaults and the side wall next the street, the top surface of the concrete being finished with a coat of rich cement mortar, at the proper height and slope to receive the pavement.

Another method still is to omit the arches altogether, and span the entire width of the sidewalk with stone platforms 8 to 10 inches in thickness, of which the outer edges take the place of the curb stones, and the top surfaces that of the side-walk pavement. These platforms fit closely together at the edges, which are calked to render them water tight, and they may rest upon intermediate piers or columns, wherever danger is apprehended of their inability to support the greatest weight which may be placed upon or moved over them.

The vault wall next the street, if properly constructed of rich cement concrete in a monolith 15 to 18 inches thick, will exclude the water perfectly. If of brick laid in bituminous mastic, with all the vertical joints compactly filled with the same material, it will also be water tight if only 12 inches in thickness. But if the bricks are laid in cement or lime mortar, the exterior face of the wall should be coated with bituminous mastic, throughout its entire height, special care being taken to secure a perfect junction between this surface and the roof surface. The filling directly against this wall should be coarse sand or gravel, so that any water from the side gutter will promptly run off.

Brick Footpaths.

Brick pavements, if laid with carefully selected hard-burnt brick, make very good footpaths for streets devoted mainly to residences, or where there is very little loading or unloading heavy goods at the curb. The bricks should be laid on their edges, with their longest dimensions directly or diagonally across the walk, upon a form of well compacted gravel or coarse sand, or preferably upon a foundation of creosoted boards firmly bedded with a uniform bearing on the sand, to the required inclination. The boards prevent the unequal settlement, almost certain to ensue if they are omitted, in consequence of the narrow bearing surface of the bricks.

Flagging Stone Footpaths.

Flagging stones laid upon a form of sand or gravel, or directly upon the natural soil when light and porous, form, probably, of all the materials above mentioned, the best sidewalk pavement, and, all things considered, give the most general satisfaction, where they can be procured of good quality and at reasonable cost. The North (Hudson) River blue stone flagging has for many years been in extensive demand for this purpose, in cities and towns of the Atlantic States, north of the Carolinas, located upon water routes. It is strong, hard, and durable, does not polish and become slippery under wear, and resists frost and does not break from upheaval by it, unless unusually broad and thin. The quarries yield slabs of any required thickness and superficial area.

Broken Stone and Gravel Footpaths.

A very good footpath, suitable for parks, and for the sidewalks of country roads and suburban streets, can be made with broken stone or gravel, or with a mixture of the two, applied in substantially the same manner and to about half the thickness described in Chapter III, for the construction of road coverings.

After the footpath bed has been excavated to the required width and depth, it should be compacted by a garden roller or by ramming, unless the soil be sufficiently firm without it.

If the soil be wet and clayey, or if it be at all infested with springs, a tile drain of 1½ to 2 inches bore should be laid below the reach of frost, under the centre of footpaths, other than sidewalks, and the trench filling above it should be a sandy or gravelly mixture that will allow the water to percolate freely through it. The subdrainage of sidewalks is presumed to be suitably provided for in connection with that of the roadway.

The lower layer of material to the depth of 4 or 5 inches may be small rubble, or field cobble stone, or the refuse of quarries, and of inferior quality. After it is put in place a roller or rammer may be passed over it, and the interstices partially filled up by breaking off the projecting fragments with a hammer; or the required evenness may be secured by a second thin layer of smaller stones. A surface of suitable gravel, 2 inches in thickness, applied in two layers, with the necessary raking, sprinkling, and rolling, completes the walk. The surface layer should be of small screened gravel, when practicable.

For park walks the transverse form of the surface should be convex, and the sides of the walk, where no paved side gutters are used, should be sufficiently high to discharge

the surface water upon the adjacent turf. In some cases it will suffice to take up the sod on either side of the walk for a width of 2½ to 3 feet, and reset it in the form of a shallow trench, called a sod-gutter, provided with suitable outlets—covered or open drains—at the lowest levels, for carrying off the surface water.

If it be found that the surface water is not promptly conveyed away by these means, or if it injures the sod by wearing it into gullies, the walks must be provided with paved gutters, on one or both sides, as circumstances may require. A neat and durable gutter may be formed of small cobble stones, such as can usually be found in gravel pits.

Where an area embraced by a system of park walks is not susceptible of easy and sightly surface drainage, one or more main covered drains should be constructed, with a sufficient number of branches to collect the water from grated silt-basins located in the depressions of the side gutters. The location and size of these drains, will be governed by the configuration of the ground, the kind of soil, and other circumstances of a special and local character.

The extensive use of hydraulic cement concrete recommended in this volume renders it proper that some general directions for its fabrication should be given for the information of those not familiar with its properties. The following is condensed from the fifth edition of the writer's work on "Limes, Hydraulic Cements, and Mortars."*

Hand-made Concrete.

Each batch of mortar or concrete should correspond to one cask of the cement. In mixing it by hand labor, four

* D. Van Nostrand, Publisher, 23 Murray Street, New York.

men constitute a gang for measuring out and mixing the ingredients, who proceed to the several steps of the process in the following order :

First. The sand is spread upon the platform in a rectangular layer about two inches in thickness.

Second. The dry cement is spread equally all over the sand. If lime be used as one of the ingredients, it should first be slaked to a powder by sprinkling, and then mixed with the dry cement, before the latter is spread over the sand.

Third. The men place themselves, shovel in hand, two on each side of the rectangle, at the angles, facing inwards. Furrows of the width of a shovel, are then turned outward along the ends of the rectangle, until the whole bed is turned. The two men on one side then find themselves together, and opposite the two on the other side, having, of course, left a vacant space transversely through the middle, of double the width of a shovel. They then move quickly to the ends of the wide furrow and turn successive furrows inward, when the bed occupies the same space that it did previous to the first turning. The turning is executed by successively thrusting the shovel under the material, and turning it over about one angle as a pivot. Each shovel thus moves to the middle of the bed, where it is met by the one opposite, when each man moves back to the side, in dragging the edge of the shovel over the furrow he has just turned.

Fourth. A basin is formed by drawing all the material to the outer edge of the bed.

Fifth. The water is poured into the basin thus formed.

Sixth. The material is thrown back upon the water, absorbing it, when the bed occupies the same space that it did in the beginning.

Seventh. The bed is turned twice, by the process above described. If required for mason's use, the mortar is heaped up, to be carried when and where required. If for concrete (the mortar occupying the rectangular space as at first).

Eighth. The coarse materials (whether broken stone, bricks, gravel, shells, or a mixture of two or more or all of them) are spread equally over the bed.

Ninth. A bucket full of water more or less (depending on the quantity of stone, their absorbing power, and the temperature of the air) is sprinkled over the bed.

Tenth. The bed is turned once as before, and then heaped up for use. The act of heaping up, when done with care, has the effect of a second turning.

The time consumed in making a batch of concrete, composed of one barrel of cement, two and a half to three barrels of sand, and five or six barrels of the coarse materials, is from twenty-five to twenty-eight minutes. An experienced gang of first-rate laborers can do it in a little over twenty minutes. If lime be added, the amount of sand and coarse materials, and the time required for mixing are proportionally increased.

Mill-made Concrete.

Mill-made concrete possesses sufficient superiority over that manipulated by hand, to justify the expense of providing suitable power and machinery, when operations of considerable magnitude are to be carried on. The more thorough manipulation secured by machinery, enables a smaller proportion of the cementing substance to be used, and effects a saving in the cost of both materials and labor.

The Cubical Concrete Mixer.

This mixer, Fig. 64, consists of a cubical box made of hard-wood plank or boiler iron, measuring about four feet on each edge in the interior, rigidly mounted on an iron

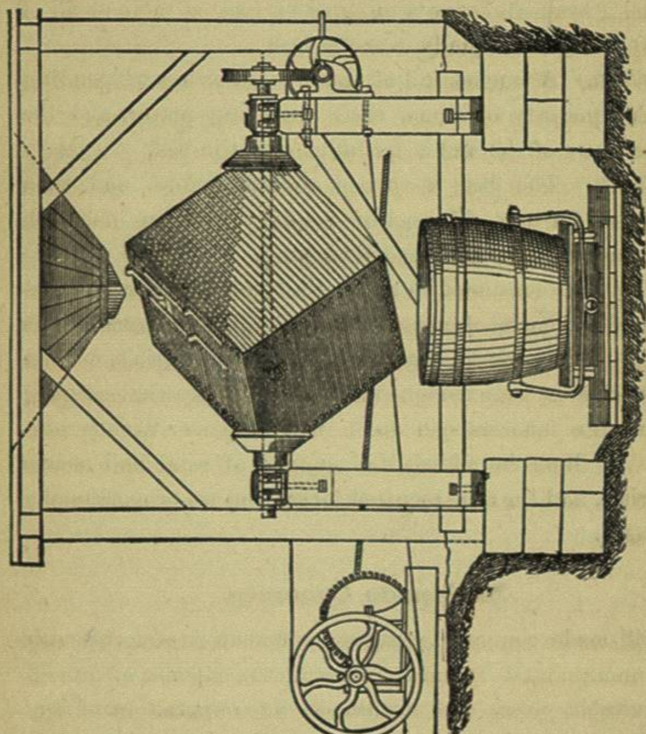

Fig. 64.

axle passing through opposite diagonal corners. It is provided with a trap door about two feet square, close to one of the six angles farthest from the axle, for charging and emptying the box. Eight to ten revolutions of the box,

made in less than one minute, are found to be quite sufficient to produce a thorough incorporation of the ingredients. A small steam hoisting engine, which may be used for other purposes at the same time, furnishes the best power for turning the mixer, and screw gearing is probably the best method of applying it.

The mixer is charged through a hopper, by means of a tub, swung from a common derrick crane, and holding just one batch of concrete, the volume of which should not exceed one-third to two-fifths the entire capacity of the box.

The crane should of course be worked by the same power that turns the box, and should have a sweep reaching from the platform where the materials are measured to the hopper.

The process should be conducted in the following order :

First and *Second*, spread the sand and the cementing material upon the platform, as in direction for hand-made concrete.

Third. The dry materials may be mixed together with shovels, as for hand-made concrete, or they may be only partially incorporated by long teethed rakes passed back and forth through them without disturbing the position of the bed.

Fourth. Empty the coarse materials upon the bed of sand and cement and spread them over the same, not necessarily with much care.

Fifth. Dash over the bed the requisite quantity of water, in such manner that it will be absorbed by the material, and not run off upon the platform.

Sixth. Shovel the materials into the tub, taking care that each shovel full shall contain a portion of each of the ingredients.

Seventh. Empty the tub into the box and set the latter in motion.

Eighth. After ten or twelve revolutions, occupying about one minute, stop the motion, open the trap-door and empty the mixed concrete into the tub, so that it can be deposited by the crane in some convenient spot within its sweep, and thus be out of the way of the succeeding batch.

It will generally be found convenient to convey the concrete to its allotted place in wheel-barrows. It should be compacted with rammers, in horizontal layers 5 to 6 inches in thickness, until all the coarse materials are driven below or flush with the general surface.

As a rule concrete should be compacted in place before the cement has had time to take its initial set. Where the cement contains quicklime, a delay of a few hours is sometimes necessary to allow the lime to become thoroughly slaked.

CHAPTER VII.

TRAMWAYS, AND STREET RAILWAYS.

A horse can draw, upon a good stone tramway, a load 11 times as great as he can move with the same effort and at the same speed upon an ordinary gravel road, the force of draught being only $\frac{1}{170}$ of the load in the first instance while in the second it is $\frac{1}{15}$. Even upon a very dry and smooth broken stone road—*i. e.* a macadamized road in its best condition—the tractive force is $3\frac{1}{2}$ to 4 times as great as upon a good stone tramway.

The marked advantages of a hard smooth surface for the wheels of heavy vehicles to move upon on the one hand, and the comparatively great expense of providing such surfaces on the other, has led to the practice in some localities of restricting the width of the wheel tracks to what will simply suffice for the convenient use of the several kinds of vehicles upon which the traffic is conducted, while the rest of the roadway is finished with a less costly covering.

A construction of this kind is called a tramway, which consists of two parallel tracks of suitably smooth and hard material to receive the wheels, while the spaces between them on which the animals travel, as well as the road surface on either side, is paved with a different material.

The wheel tracks are usually of stone; occasionally of wood or iron.

As tramways are intended for the equal and common