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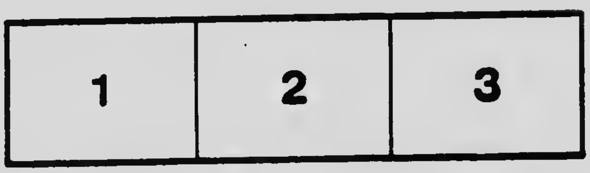

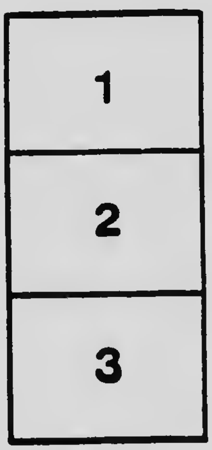

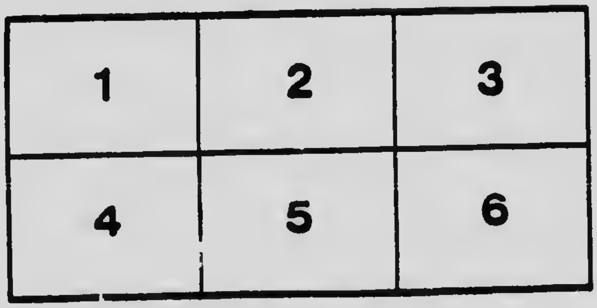

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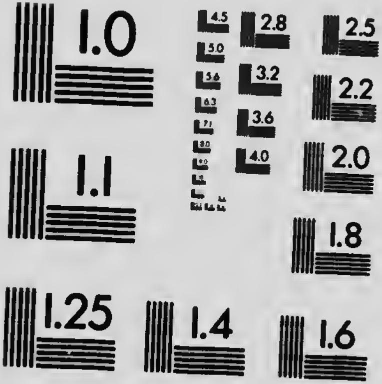

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PAVING ECONOMY

ROAD AND STREET

By

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Director of Paving Department, The Milton Hersey Company
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Montreal, New York, Winnipeg

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TABLE OF CONTENTS.

TABLES, LISTS, FORMS.

To the
Memory of My Father
Mr. ANDREW A. MULLEN
this work is dedicated

Born Jan. 6th, 1850, Baltimore, M-d.
Died May 3rd, 1916, New York, N.Y.

THE AUTHOR

PAVING ECONOMY

Road and Street

The Reason for This Writing.

In the summer of the year Nineteen-ten, the author of this treatise rather unexpectedly found himself thrust into control of and responsibility for the street paving policy and operations of the City of Milwaukee, having been called to that city by a newly elected administration bent upon the reform of a thoroughly unsatisfactory state of affairs in the municipality's street paving department, and being virtually forced to remain by the determined opposition of certain private interests opposed to these moves for the betterment of the city's paving situation which it was found necessary to recommend

While by no means unfamiliar with general street paving practice at the time, and reasonably well informed from the contractor's point of view it was a very short while before it became quite evident that there were many angles of the prob[illegible] it should be viewed by a city official to which [illegible]ntractor I had given but slight consideration [illegible] that these angles required more careful study before any decisive and comprehensive action could be intelligently determined upon.

It was after the realization of the above facts that the author really began the study of road [illegible] street paving economy, though it had previously received some casual thought on his part. This s... was extended through several years of very active municipal service, and still continued despite the fact that I was afterwards on the outside of the city treasury looking in instead of on the inside looking out.

It is not given to every city official concerned with street paving matters to enter the public service with the general knowledge of pavements and paving affairs and paving men that the author possessed; and many are therefor quite easily imposed upon by clever promoters and agents who work in all the devious ways known to modern industry. Because of the above, and the belief that his own present view of the problem after several years of its study may act as a valuable background of information from which others may start with at least a knowledge of the different points of value in street pavement surfaces the author is moved to this rather tedious writing.

To Whom it is Addressed.

The following paragraphs are directed particularly to newly elected or appointed mayors, city managers, city commissioners, directors of public works, superintendents of streets and roads, city aldermen, commissioners of highways, ministers of roads, secretaries of boards of trade, chambers of commerce, civic societies, and all others who suddenly find themselves in need of a working knowledge of road and street pavement values; and to those old in service who do not feel that they already have a sufficiently comprehensive grip upon this side of the subject.

No attempt is made in this article to inform the reader how to lay a given pavement properly. That job is left for the competent paving engineer and chemist who are employed for the particular work, and who should be consulted frequently when laying a pavement in order that the field men may not go wrong in matters of technical importance. Values only are discussed herein; values, from the public's point of view.

The reader is not asked to accept the author's opinions and conclusions. They are offered to him as a starting point only, from which he can do his own reasoning and draw his own conclusions. If the reader's conclusions agree with the author's, well and good; if they do not, the reader will at least have benefitted by having considered the several items of value that the author has listed for his convenience; and he will know why and at what points the disagreements occur, and their relative importance.

It is, of course, understood by the author that many who are well versed in the paving industry will disagree with him; some from honest and uninfluenced convictions, others because of the economic pressure of their positions in the industry operating upon their conscious or subconscious minds or both. The pages of the trade journals will be found open to these parties, and as far as it is in the author's power, he will reply to any criticism of a friendly nature.

Basis of Author's Knowledge.

The author believes that he is competent to say a few words on the subject of road and street paving economy, and for the following reasons:

As a youth, he grew up in a street paving environment, listening to much learned and practical discussion of the subject on the parts of his father, grandfather, other relatives, and their friends, nearly all of whom were more or less prominently engaged in the paving industry, covering all its varied branches.

As a young man, he passed through all the different stages of practical training from time-keeper to superintendent, had experience in every branch of the trade from promotion to management, and later laid about one hundred thousand square yards of pavement surface in and around New York City, at a profit, as an independent contractor.

From August Nineteen-ten to the end of Nineteen-eleven, he served as Superintendent of Street Construction and Repair of the City of Milwaukee.

during which period about one-half million square yards of pavements were contracted for and about one-half of that amount was completed, besides which about one hundred thousand square yards of repairs and resurfacings were done by direct employment and with city equipment.

During Nineteen-twelve and Nineteen-thirteen, the author served as Commissioner of Public Works of Schenectady, New York, where about one hundred and fifty thousand square yards of paving were contracted for in Nineteen-thirteen, and mostly completed; besides which a considerable amount of repairs and resurfacings were made by direct employment, including ten thousand square yards of modern improved granite block wearing surface four inches in thickness that was made by taking up five thousand square yards of large granite block surface, splitting, dressing and relaying the new blocks into a mortar bed upon a four inch wet concrete foundation, thereby forming a monolithic pavement consisting of concrete bottom and granite block top.

In the case of neither city was the appointment made for political reasons. Each city was facing a serious paving problem and needed a practical paving man for the job. In Schenectady, the author had, of course, much other public work to do besides, paving being but an important incident to the position.

Again back in the business as a paving contractor, the winter of Nineteen fifteen-sixteen found the author for the first time with the opportunity to begin writing the conclusions at which he has arrived as a result of this experience.

Since the first of July Nineteen-sixteen, the author has been a member of the staff of the Milton Hersey Company, a firm of engineers, industrial chemists and inspectors with laboratories and offices at Montreal, Winnipeg and New York, his principal work being the direction of their road and street paving department.

One of the most important works that the above firm has been required to perform in the paving field was when called upon last season by Mr. Paul E. Mercier, Chief Engineer, and the Board of Control of the City of Montreal, to investigate, direct, inspect, make tests for, and report upon the efficiency and practical economy of the large asphalt paving industry that the City owns, in particular, and upon the entire paving situation in the City, in general.

It is upon the foregoing work and experience, and the large amount of investigation growing out of it, that this treatise is principally based. It is offered to the reader for what he may find it worth; with the earnest wish that it may be of real assistance to him in connection with his public service.

The Breadth of the Subject.

It has wisely been said that the three greatest needs of an enlightened people are good laws, good schools and good roads.

The subject of this discourse falls under the general head of good roads.

The family of Roads is a very broad one. It includes all the various means of transit; the railroads, the steamboats, the street railways, the telephone and telegraph, the postal service, and the other systems that afford us our ways and means of intercommunication, just as much as it includes our city streets and county highways and byways. The news service organizations also properly belong to this great family, for these are but the channels through which we receive our knowledge of current events.

In considering our road and street paving question, we are but studying the local side of one branch of the great family of Roads; namely, the construction and maintenance of suitable and serviceable wearing surfaces upon our own city streets or rural highways. And insignificant though the paving question may seem when considered in its relation to the entire subject of roads, it is still a matter of very great importance to the comfort and welfare of each of us living in a well populated community.

The Line of Its Study.

There are two co-related viewpoints from which our road and street paving problem must be studied. First, we wish a serviceable and desirable pavement surface maintained for our use, not only upon a few of our roads and streets some of the time, but upon all of them all of the time. Second, we must secure the foregoing desired result at a cost that is well within our means of the present and our prospects of the immediate future.

The real paving question is how we can originally construct and permanently maintain upon all of our country roads and city streets at all times a serviceable and desirable pavement surface at a cost for original pavement construction and permanent pavement maintenance that will neither spell confiscation to the small abutting home-owner in his special assessment taxes nor bankruptcy to the general public fund in bond redemptions and interest and in current budget taxation.

In attempting to select the most satisfactory and economical pavement to lay, we, of course, must not start out with the idea of finding a perfect pavement; for pavements, like men, all have their faults. We should go about the purchase of our road and street pavements just as we go about any other good purchase; seeking the best value for the money, all things carefully considered

What Features are Desirable.

The special features in the wearing surface of a pavement that are most desirable from the physical point of view are that the surface presented for use be smooth, cleanly, sanitary, dustless, noiseless, non-slippery, easy of traction, easy to construct, easy to repair and renew, susceptible to repair and renewal, susceptible to constant use, and attractive to the eye.

The desirable features in a pavement from the point of view of economy are that it be originally constructed at a minimum cost, that its wearing surface be permanently maintained in a serviceable, sanitary and desirable condition at a minimum cost, and that it be trafficked at a minimum cost for motive power and vehicular upkeep.

Under the heading of economy must also be considered very carefully the important items of home industry and the possible extent of municipal control and ownership of the production of the pavement; two items that seem not to have received any consideration at all in most of our cities up to the present time, though they are of vital importance to those who must pay the pavement bills.

Wherein Pavements Differ.

It is in their wearing surfaces mostly that modern pavements differ, both as to their physical and their economic characteristics. Indeed, for purposes of comparison, we need hardly consider the foundations at all, for practically every new pavement of a substantial nature is being laid upon a standard six-inch thick and approximately one-three-six mixture Portland cement concrete foundation.

The only real difference in the concrete foundations for one pavement or the other is in the cost of excavating or filling a greater or a lesser depth to establish the proper subgrade, which fact usually militates against the block surface class of pavements with its greater thicknesses of wearing surfaces. This difference in the cost of regulating and grading will run from about one cent minimum to about four cents maximum per inch of thickness of the pavement, and it will probably average about two cents per inch.

Pavement Foundations.

The character of the foundation that is proper for modern pavements is a matter upon which there is but slight disagreement. While there may be and are many differences of opinion as to which is the most economical and desirable wearing surface for the pavement, there are hardly any who do not recognize the standard six-inch thick and approximately one-three-six mixture Portland cement concrete foundation as the most economical and suitable base for all pavement surfaces of both classes. In some special cases, thinner concrete foundations have been employed successfully, and in other cases hard old Telford macadam pavements have proved sufficient foundations for very good wearing surfaces.

A wearing surface laid upon a foundation that is not sufficient, of whatever character that foundation may be, can hardly be termed a pavement at all, and certainly it is a waste of money to lay a good wearing surface upon a defective base. It is also a waste of money to make the concrete foundation of a pavement any more costly than is really necessary, either by increasing its thickness or by unduly enriching the mixture. It is more economical to make a thorough examination of the foundation, and then to have a few sinkages in spots representing a very small percentage of the total area of the pavement surface, and repair them, than it is to increase the cost of each square yard of the entire surface area just to avoid possible failures in such spots as may escape even very careful inspection.

Two Classes of Surfaces.

Taking up the physical properties of pavement surfaces first, we find that they readily divide into two broad classes, into one or the other of which nearly every modern pavement surface will properly classify. These two main classes are the small unit block or brick surface class and the bituminous sheet layer surface class. The latter class is better known as that of the asphaltic surfaces, the bituminous binder used to hold their mineral particles together being in most cases a good asphaltic cemen[illegible]

The noteworthy exception to t[illegible] above classification is the hydraulic cement con[illegible]te pavement; and the asphalt block surfaces are very much inclined to merge into the sheet layer class under moderately heavy traffic in warm weather. It is often found more satisfactory to repair old asphalt block surfaces with sheet asphalt surface mixtures.

In the first class of surfaces fall the granite block, sandstone block, creosoted wood block, vitrified brick or block, asphalt block, and all other pavement surfaces that are made up of many small unit blocks to the square yard. In the bituminous sheet layer surface class are found sheet asphalt, stone-filled sheet asphalt, asphaltic concrete, asphaltic macadam, and all those proprietary forms of bituminous or asphaltic concrete and macadam that operate under letters patent, copyrighted trade names, and other forms of protection against competition.

Thickness of Wearing Surfaces.

It is of no value to have pavement surfaces, or their foundations either for that matter, any thicker than actually required to prevent traffic from crushing through; due attention being paid to weakening of foundations from badly filled trenches and the consequent necessity of some form of arch to carry the load above such soft spots. Of course some pavement surfaces, because of their nature, must be built thicker than others, but this additional thickness adds not at all to their comparative values.

Pavement surfaces do not in the majority of cases wear out because of the volume of traffic that passes over them; and even where the traffic is so heavy that a rapid wearing does occur, the unevenness that develops under such traffic always requires a resurfacing long before any additional thickness over those now in use would avail.

It is an interesting truism that the only part of the pavement that can actually be used is the top surface, and our entire interest is in the ways and means of maintaining that top surface area in the serviceable and desirable condition in which we wish to have and to use it.

The Physical Points.

The special features in the wearing surface of a pavement that are most desirable from the physical point of view, as stated before, are the following:

1. Smoothness, ... See Page 16
2. Cleanliness, ... 17
3. Sanitation, ... 18
4. Dustlessness, ... 18
5. Noiselessness, ... 19
6. Non-slipperiness, ... 20
7. Ease of traction, ... 23
8. Ease of construction, ... 25
9. Ease of repair and renewal. 26
10. Susceptibility to repair and renewal 27
11. Susceptibility to constant use. 28
12. Attractiveness of appearance. 29

The Points of Economy.

The main points that enter into the financial economy of a pavement surface, as broadly covered in a former paragraph, are the following:

1. Cost of construction. ..... See Page 36
2. Cost of repair, ... 40
3. Cost of renewal, ... 41
4. Cost of permanent maintenance, ... 51
5. Cost of cleaning, ... 44
6. Cost of motive power to traffic, ... 46
7. Cost of resulting vehicular upkeep, .. 47
8. Extent of home industry involved, .. 48
9. Possible control of production, ... 50
10. Durability, relatively considered. 42

Smoothness of Surfaces.

The bituminous sheet layer class of surfaces, laid in a continuous operation at a temperature far above that of the atmosphere and then rolled with heavy compressing and surfacing rollers until they have received their initial temperature set, and having no joints except those carefully welded ones that mark the progress of a 's work, are necessarily smoother than the small unit block class of surfaces that are laid by hand. of blocks that have slightly varying thicknesses and that pave many units to the square yard.

In passing quickly over even the smoothest block surfaces in an iron tired vehicle, a vibration or tremor is very distinctly noticeable that is not noticeable at all in passing over well laid bituminous sheet layer surfaces; and as the block surfaces become older, this tremor develops into more and ever more objectionable proportions, until in their last stages it is a positive discomfort to pass over such surfaces on rubber tires, and sometimes even on pneumatics.

Of course, bituminous sheet layer surfaces can be so neglected that they become worse than country roads, but there is no possible excuse for such neglect. Any old bituminous surface in reasonable repair is practically as smooth as when new, while with the block class of surfaces the roughness that develops with age is of a general nature not susceptible to any successful repair short of a complete and costly resurfacing with once turned or recut blocks or with new materials.

Cleanliness of Surfaces.

For the reason that they present smooth and jointless traffic areas composed of stone and sand particles cemented together with bituminous cement, the bituminous sheet layer surfaces are the most cleanly. They neither have nor develop a multiplicity of joints and crevic to collect and hold the street dirt; and being the asiest and cheapest surfaces to clean and keep clean. they are usually found in a more satisfactory condition of cleanliness than the others.

Were it not for the nuisance incident to the use of the horse as a motive power on the streets of our cities, and the fact that in most cities all our side streets are not paved and the mud from these dirt roadways is tracked upon the paved streets, it would be a comparatively easy matter to keep any type of our modern street pavement surfaces in a pleasingly clean condition at all times. Uncleanliness is not a difficulty experienced to any great extent on paved rural highways.

Sanitation of Surfaces.

The factors that make for the potential cleanliness of a road and street surface will also operate in its favor with the sanitarian. The same smoothness and freedom from joints that make the bituminous sheet layer surfaces the easiest to clean and keep clean also render them the most satisfactory of road and street surfaces from the sanitary viewpoint. Joints in a pavement surface are but harboring places for filth and germs, and the fewer of them to be found in a given type of surface, the more acceptable that type of surface must be considered, other factors being equal, when sanitation is being discussed.

There is but one type of pavement surface that is subject to possible criticism by the sanitarians because of the material that enters into its composition, and that type is the creosoted wood block surface. All others are composed of matter of a mineral nature and are not subject to a breaking down process that can make them undesirable from a health viewpoint; but the creosoted wood block surfaces, once the saving grace of the creosoting oils has been wholly or partly carried away by the elements operating upon the surface, can be expected to furnish some trouble on this score. We all know how objectionable the old dipped round cedar block pavement surfaces became in their old age; and they did not have to be very old either.

Dustlessness of Surfaces.

Cleanliness and dustlessness are partners. A clean street is also a dustless street; and therefor there is no excuse for excessive dustiness in our modern cities or on our modern paved highway. Of course, as long as we maintain dirt roadways and unoiled waterbound macadam surfaces on the side streets in our cities, we will have dust in unbearable abundance; and there is room for much more care in the regulation of vehicles that to-day seem not at all concerned if they spill a part of their loads along the thoroughfares. But the modern pavement surfaces, unless it be those of concrete pavements without bituminous top dressing, will not create any appreciable dust of themselves; and all are susceptible to economical and thorough cleaning by the power flushing process.

The only reason that the bituminous sheet layer surfaces may claim an advantage on the point of dustlessness is that they are easier and cheaper to clean and keep clean than any other modern road or street pavement surface; for when clean, all the modern pavements are practically dustless.

Noiselessness of Surfaces.

The entire class of bituminous sheet layer surfaces and the creosoted wood block surface lay claim to being noiseless. This factor was one of the best talking points when asphalt surfaces were originally introduced at the high prices that then prevailed. The other block surfaces are all open to very serious objection on this score, especially after a few years wear.

Creosoted wood block surfaces are possibly a little less noisy when they are new and smooth than the bituminous sheet layer surfaces, though the difference is of slight degree. The plea for the use of creosoted wood block surfaces upon our city streets because of their noiselessness would be a strong one were it not for the fact that sheet asphalt and stone-filled sheet asphalt surfaces are so nearly as noiseless that the difference could not be worth more than a few cents per square yard, while the latter surfaces have, as elsewhere noted herein, a tremendous preponderance of other factors in their favor.

Bituminous sheet layer surfaces are more noisy in winter, when windows are down, than they are in summer, when windows are up and the noise would be more objectionable. This is, of course, due to the temperature set of bituminous surfaces, for which reason a drop in the thermometer is accompanied by a hardening of the surface that makes the click of a horse's shoe very sharp in winter, while a warmer temperature deadens it.

When the creosoted wood block surfaces swell, there is apt to be a rumble as loads pass over them that is not altogether pleasing, especially as this occurs at the time windows are opened because of warm weather. The swelling of the wood causes a slight raisi of the wood block surface from its bed, making a sort of drum head of it.

None of the bituminous sheet layer surfaces nor the creosoted wood block surfaces can be said to give forth seriously annoying sounds from the impact of the wheel or from the jouncing of the load, but these are the principle causes of the very objectionable racket created by a heavy load on iron tires passing over any of the other surfaces in the block class. Even a load on rubber tires will create quite a noise from jouncing in passing over the other block surfaces.

Non-slipperiness of Surfaces.

The same pavement surfaces that justly lay claim to being the smoothest, cleanest, most sanitary, dustless and noiseless, may be just as surely credited with being the most slippery; and for the same reason of smoothness of surface that gives to them most of the above enumerated virtues. Of course, in fair weather, when all pavement surfaces are dry, none of them are slippery; though the glaze on certain types of brick surfaces when they are new and on certain types of granite block surfaces when they are old and the blocks rounded and polished from traffic are sometimes distinctly annoying.

When brick surfaces are in good condition and the joints not chipped off in the least, they are about as slippery in wet or frosty weather as are the bituminous sheet layer surfaces; but as comparatively few of the brick surfaces that are subjected to any considerable traffic remain for very long in that condition, most of them give a fairly good foothold or tirehold because of the crevices formed by the joints between the small unit blocks.

We may therefor safely say that in moist or frosty weather, the bituminous sheet layer surfaces, because of a superior smoothness that is in all other respects a virtue, are more slippery than any of the block surfaces except the creosoted wood block, which, rivaling the bituminous sheet layer surfaces to some extent in the matter of smoothness, and therefor in all the points of virtue growing therefrom, are still, because of their fibrous nature in conjunction with their smoothness, by all odds the most slippery street pavement surfaces known to modern times

It would seem that this one feature of excessive slipperiness in creosoted wood block surfaces would fully balance the feature of superior noiselessness as compared to the bituminous surfaces.

It may be said that most of the slipperiness of pavements is due to moisture making a scum of the fine particles of dust and trash that accumulate on road and street pavement surfaces; this, of course, being patently more dangerous on the smooth surfaces than on the rougher ones. and on a fibrous surface as compared to a granular one. Most of this difficulty will disappear with the passing of our old friend Dobbin from the principal city streets and paved highways.

The Passing of the Horse.

In planning for the future pavement surfaces it does not seem necessary to give very weighty consideration to the needs of the horse. He is a fast disappearing factor from our city life, and the cheap farm tractor has given notice that his days are numbered even in the country. It is safe to estimate that in ten years one will seldom see a horse on the public highways. and in twenty years many of us may be taking our grandchildren to the menageries to see our once beloved friend and daily companion.

The next step will be for some enterprising young city father to rise in the city council chamber to offer a resolution reading to the effect that, for reasons of public health and sanitation, on and after a certain date all horses shall be debarred from the city streets; and it will be so ordained, and enforced.

If this seems an extreme view, one has only to look back the period of ten years, when the automobile was not a very great factor on our roads and streets, next consider that more than fifty percent of the traffic on our streets to-day is automobiles, and then contemplate the tremendous momentum the industry of automobile manufacture has now developed, and that it is still gathering speed.

It would be no argument if there were more horses on our roads and streets to-day than there were ten years ago; though such is not the case. The percentage the horse bears in the total traffic figures is what counts. He is gradually being competed out of existance by the mechanical wagon, and the name of his worst enemy is Henry Ford.

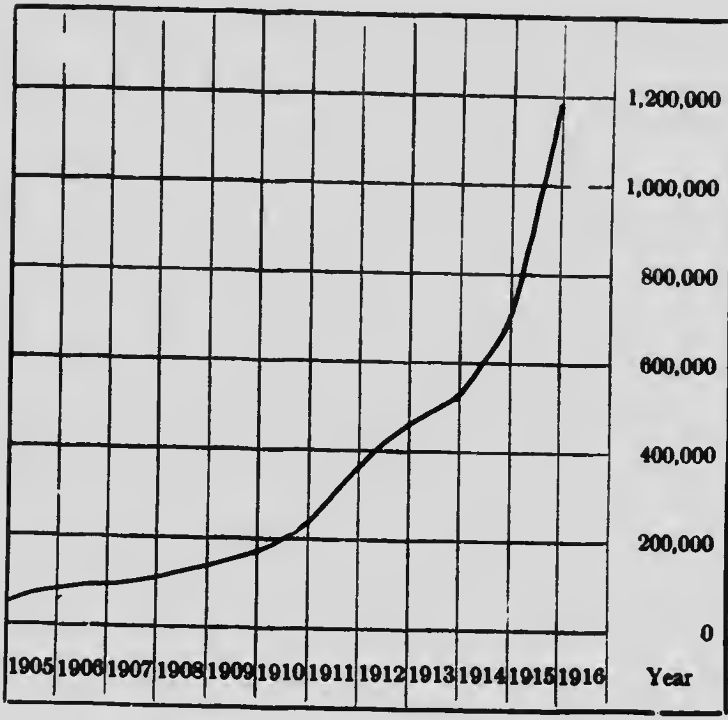
Nor is it an argument to point to the fact that some large concerns, after disposing of their horses and installing automobiles for their heavy hauling, have now disposed of the automobiles and are going back to horses. That fact merely proves that at the time automobiles were too expensive to maintain and not sufficiently reliable; but invention and manufacturing efficiency will soon overcome those objections, and these same firms will again find it good policy to scrap their horses and buy more modern and more economical automobiles.

The passing of the horse is of no little consequence in the selecting of the type of pavement surface to lay. His going will give us less noisy, cleaner, more sanitary, less dusty and less slippery streets. Moreover, it will be tirehold and not foothold that will concern us; and the scum making trash being absent, armed with the knowledge that clean surfaces are not slippery even in wet weather, we will be inclined to select the smoother pavement surfaces for our roads and streets.

In case any one still has doubts as to what is going to happen to the horse as a factor in traffic, the following automobile production curve is given to relieve his mind on that score and to set him straight.

Automobile Production.

Number of cars manufactured per annum.



After examining the above chart, one innocently wonders how long it will be before the curve will merge into a straight line pointing upwards.

Ease of Traction.

The matter of smoothness largely governs the ease with which a load may be drawn over a pavement surface. The bituminous sheet layer class of surfaces would therefor seem to afford the easiest traction; and except in warm weather, there is no question but that they do. However, we must take into consideration the difficulty that is experienced in drawing a heavy load over a standard sand mixture sheet asphalt surface in very warm summer weather because of the sinking of the wheels into the softened wearing surface mixture. This difficulty has no practical existance with the other forms of bituminous sheet layer surfaces, except slightly in the most intensely hot weather; for the stones in the bituminous concretes and macadams give them much greater hardness.

But since these bituminous concrete and bituminous macadam mixtures made with large size stones do not withstand heavy city traffic as well as standard sand mixture, many cities have removed this difficulty of the sinking of the wheels into the surface on warm days by the incorporation of from twenty-five to thirty per cent of quarter inch hard limestone, trap rock or other suitable stone chips into the standard sheet asphalt paving mixture, thereby making what is known as a stone-filled sheet asphalt wearing surface mixture. These stone chips range from one-half inch in their greatest dimension down, and act as a substantial reinforcement to the pavement surface.

The stone chip reinforcement described above makes the sheet asphalt surface slightly more gritty and very much harder than the standard mixture that was used almost exclusively for so many years, and this is accomplished without hardening the asphaltic cement used therein, or increasing the dust content.

The author has never heard of any difficulty being experienced in drawing heavy loads over stone-filled sheet asphalt wearing surfaces in summer, and believes there can be none when the mixture is properly and scientifically proportioned and made; though an unwise cheapening of the mixture would make it soft. ; the hardening effect of a full amount of filler is vitally necessary even if expensive.

The smooth block surfaces are, of course, quite easy of traction, becoming less so as they become rougher. A block pavement that is old is apt to be sufficiently rough to present a considerable amount of obstruction to the hauling of a load over its surface.

Ease of Construction.

There is no type of pavement surface that an experienced contractor would rather lay than the bituminous sheet layer surfaces. Of course, if a man does not know this branch of the pavement industry thoroughly, he can not successfully construct such a surface; but to the well informed workman it is a very satisfactory process to both manufacture his own wearing surface mixture and lay it in place on the same day, opening it to traffic at once.

With the block class of surfaces, the contractor must purchase the small unit blocks and pay therefor most of the money that he gets for his pavement surface, he must then unload and haul these small unit blocks to the street and there re-unload them and pile them on the sidewalks, after which he must make the bed and lay the blocks in it, roll or ram them, and finally fill the multitudinous joints with either a bituminous or a hydraulic cement filler. If it is the latter, he must apply the filling and then blockade the roadway for several days while the Portland cement has time to acquire a firm set.

The difficulty about laying bituminous sheet layer pavement surfaces in very small cities is the expense of moving a mixing plant to the locality of the work; but this can be largely overcome in nearly all cases by an intelligent handling of the matter, arranging to do the largest possible yardage at one time and letting the work in one award to one contractor, so that the cost of moving the mixing plant can be spread over as many square yards of pavement surface as possible and the unit cost be kept at the lowest possible figure consistent with good workmanship.

If the award of all the pavement surface work at one time and to one contractor can not otherwise be accomplished according to law, it can always be practically effected by making it a condition of the advertising of the work and the receipt of proposals therefor that unless one contractor shall be the successful bidder on at least a fixed minimum square yardage that will make the work worth any bidder's while, the said successful bidder shall have the option of withdrawing his proposals.

Ease of Repair and Renewal.

When one stops to consider that an asphalt repair gang can travel along a road or street, cut out the defective places and fill them with new material, roll them and open them to traffic in the space of an hour, in the case of the bituminous sheet layer surfaces, while block surface patches must be slowly and painstakingly fitted in with either new or old blocks, and if cement grout is used for the joint filler must then be blockaded for several days while the Portland cement sets, there does not seem much room for argument on this point.

While the bituminous sheet layer surfaces are decidedly the easiest to repair, they are also much easier to renew than any of the block surfaces. A section of this type of surface can be torn up from street intersection to street intersection and either relaid with the remelted and remixed old materials or renewed with entirely new materials and thrown open for traffic again in the course of a day. The author does not know of any other pavement surface with which this can be conveniently accomplished.

In this case again, the difficulty of securing an asphalt mixing plant for small cities enters into the question, though the problem would seem largely to be settled by the recent manufacture of so many very efficient small capacity asphalt mixing equipments, some of which will either make new mixture or remelt and remix old wearing surface.

In the case of cuts made through the pavements by plumbers, public service corporations and city departments to get at the subsurface structures of a street, the bituminous sheet layer wearing surface can be neatly removed in sections of about one-half or one-quarter square yard area and piled carefully at the side of the road or street, and when the work that made the removal of the pavement necessary has been completed, the concrete foundation can be restored, and these sections fitted back into place upon the wet concrete, the joints plastered up with the surplus mortar from the concrete, and the patch opened to traffic as soon as the concrete foundation thereunder and the mortar joints have had time to set sufficiently, which is but a few days.

The author has seen repairs of this type made and has known them to last for years on streets of moderate traffic, until in fact they were finally taken up and repaired in the usual way to remove the unsightliness of the cement joints that offended the sensitive natures of some abutting property owners.

Susceptibility to Repair.

It has often been said that a brick pavement is new until its surface has once been patched, then it is old. This is equally true of creosoted wood block surfaces. Satisfactory repairs can not be made to either of these block surfaces unless the work is done as an exceptional case and at great expense. In practice, the author has never been able to secure a satisfactory job at patching brick or wood block surfaces, even when employing the best grade of workmen at five dollars per day of eight hours, and it is most probable that the experience of others has been about the same. Satisfactory repairs can be made on granite block and sandstone block surfaces if reasonable care is taken in fitting back the blocks and filling the joints with Portland or bituminous cement.

As any reasonably efficient asphalt patching gang can repair a bituminous layer surface, on a street where there is sufficient traffic to weld the joints, in such a way that it is quite impossible to find the patch several days later, it is obvious that this class of surfaces, especially the sheet asphalt, is the most susceptible to repair because of the quickness with which the operation can be accomplished, and the sameness in appearance between the renewed surface and the old surface where they join at any point.

Susceptibility to Use.

This depends upon the time required to lay, repair and resurface a pavement, and the necessary frequency of the repairs and renewals. As shown in discussing the ease with which repairs and renewals can be made to the different surfaces, a bituminous sheet layer surface can be either patched or renewed in less time and with less interference with traffic than any other surface. It takes considerably longer to make the block surface repairs and renewals even where sand or tar and gravel joints are used, and if the cement grout joints are employed, the patch or resurfacing must then be blockaded for several days.

In the matter of the frequency with which repairs and renewals will be required in comparable cases, it is difficult to point to any definite difference between the creosoted wood block, the vitrified brick or block and the bituminous sheet layer surfaces. It is the author's opinion that creosoted wood block and sheet asphalt surfaces will about balance honors in this respect, and leave brick in second running. Granite block undoubtedly leads by a safe margin, with sandstone block a tardy second.

Granite block surfaces with tar and gravel joints and bituminous sheet layer surfaces of the sheet asphalt variety will probably divide honors evenly in the matter of their susceptibility to constant use, the granite block surfaces requiring less frequent repairs and renewals and the sheet asphalt surfaces requiring considerably less time for the actual making of the repairs and renewals.

In this connection, it is fair to mention that as the granite block surfaces and the vitrified brick surfaces become aged, usually for quite a period precedin their removal and renewal, they can hardly be said to be susceptible to very considerable use, for traffic will go out of its way to avoid th ecause of their roughness. This is not true of the bituminous sheet layer surfaces, which even in their old age can easily be kept in a condition of smoothness that will be satisfactory to all kinds of traffic.

Lightness of Weight.

The matter of lightness of weight is not included in the list of the physical features that are desirable in the wearing surface of a pavement that is given in a former paragraph, for the reason that it is only in the selection of a roadway surface for some few bridges and viaducts of very light floor construction that this feature can properly become the determining factor. It is the important factor only when the structure that is to carry the roadway is of so light a nature that wood instead of concrete is to be used for the underflooring, when it would seem that creosoted wood in either block or strip form is about the only logical pavement surfacing material to employ.

In cases where a substantial steel and concrete floor construction is to be had, there does not seem to be a sufficient percentage of difference in the total floor weight of the bridge or viaduct, whether creosoted wood block, vitrified brick, stone-filled or standard sheet asphalt is used as the pavement surfacing, to justify the selection of a given type of surface especially because of its lightness in weight. Even a shallow granite block surface, laid upon a very thin bedding or upon the concrete foundation or flooring when it is just placed, would not seem to present unsurmountable difficulties because of its weight. The vibrations caused by the impact of the wheels on the slightly uneven surfaces of the blocks would be a far better argument against the use of granite.

Attractiveness of Appearance.

Some block surfaces look very well when new, and have even been referred to at such times as artistically resembling mosaics. New block surfaces are not unpleasing to the eye, but as the newness wears off the attractiveness ceases to be. As soon as the joints between the blocks begin to open up a little or repairs have to be made, the block pavement surfaces are no longer in any sense attractive. This is particularly true of creosoted wood block and vitrified brick surfaces, and somewhat less true of granite block and sandstone block surfaces.

To the author's eye, which he believes is an average organ of sight sensation, the bituminous sheet layer surfaces are far more pleasing than the block surfaces. To make a fair comparison of pavement surfaces from this point of view, one must visit the City of Washington or some other city that is paved almost exclusively with sheet asphalt wearing surfaces, then visit some city where block wearing surfaces prevail, and feel rather than otherwise sense the difference between the two classes.

But of far greater importance than just their original attractiveness is the fact that the bituminous sheet layer surfaces, if kept in reasonable repair and reasonably clean, do not lose any of their attractiveness with age, as do the block class of pavement surfaces in spite of good care.

The Author's Conclusions.

It would seem to the author from the foregoing statement of the facts in relation to the physical properties of the several pavement surfaces in general use on city streets and rural highways, that any one of the bituminous sheet layer surfaces surpasses each of the block surfaces in the desirable physical properties when all the physical points of advantage are considered collectively.

The bituminous sheet layer surfaces surpass all the block surfaces in smoothness, cleanliness, sanitation, ease of construction, ease of repair and renewal, susceptibility to repair and renewal, and attractiveness of appearance. They surpass all except the creosoted wood block surfaces in noiselessness, and are a very close second to even this type of surface in that matter. They are in turn surpassed by the creosoted wood block surfaces in the feature of slipperiness in wet or frosty weather, which is a point that at least counterbalances the wood block surface's advantage in being slightly less noisy. All the other block surfaces surpass the creosoted wood block and the bituminous sheet layer surfaces in that they give better foothold and tirehold in unfavorable weather.

All except the standard sand mixture sheet asphalt surfaces surpass every form of block surface in the ease with which a load may be transported over them, and the standard sheet asphalt surface surpasses except in very warm weather; the other bituminous sheet layer surfaces have a constant advantage on this point. New vitrified brick surfaces and creosoted wood block surfaces are close seconds.

The bituminous sheet layer surfaces surpass in their susceptibility to constant use all except the granite block surfaces having either sand or tar and gravel joints. They also surpass or equal all the block surfaces, except the granite block, in the relatively important item of durability; and are excelled only by creosoted wood block surfaces in lightness of weight.

But while the bituminous sheet layer surfaces have a decided lead in a consideration of the physical properties most desirable in a pavement surface, it is when we have completed our investigation into the relative financial economy of the different surfaces that we are forced to the conclusion that beyond a doubt, excepting some well known special instances of course, there is but one type of pavement surface that most cities can afford to adopt as their general street surfacing material.

One might easily narrow this conclusion still further, and state that the one street surfacing which should be generally employed is stone-filled sheet asphalt; but more evidence to that effect later. It is the conclusion at which the author has arrived, and in the following pages he will try to state the reasons for the forming of this opinion.

The Measure of Economy.

It seems to the author that the nearest we can get in a practical way to the true measure of paving economy is by carefully estimating the cost of original construction of the several kinds of pavement surfaces that are available or can be made available at a given locality, plus a sum of money that when wisely invested will provide an interest fund sufficient to maintain that type of pavement surface by repair and renewal so that it may be looked upon as a permanent pavement surface, which matter of financial paving economy must then be considered in conjunction with the general suitability and desirability of the pavement surface for the purpose.

There is one factor that is not included in the above equation, but is scarcely a determining factor in many cases. That is the matter of the destruction of value incident to the removal of the pavement surface or a part thereof for the purpose of getting at the subsurface structures of a street, for street alterations and abandonments, or for any other purpose other than ordinary wear.

In all considerations of paving economy, the factor of the interest on the money invested is a very important one not often given the serious consideration that its gravity demands.

The Municipal Dollar.

In this treatise, there is no occasion to enter into the matter of the why or wherefor of the interest value of a dollar. Suffice to say that the municipal dollar is worth to its possessor about four cents or four per cent per annum; for that is about the rate of interest that municipal bonds of cities in good credit usually carry in normal times.

Money can ordinarily be had by a municipality through the sale of its long term bonds at a four per cent rate; and conversely, one who has money to invest can nearly always secure the same rate, and incidentally enjoy a high grade of security for his principal, through the purchase of some good city bonds. It can safely be stated then that the municipal dollar is worth about four cents or four per cent per annum, whether it is coming or going.

It does not matter whether it is a dollar spent or a dollar saved, if it is a municipal dollar it is worth or it costs four cents a year; and it is often worth much more than that to the man who has it to pay or not to pay into the city treasury as the result of extravagance or economy in the carrying out of road and street paving improvements.

In probably the most of cases, a city will sell an issue of bonds running a given number of years and all payable at the same time in the future. In such cases it is customary to prepare for such final payment by putting a certain amount each year into a sinking fund that will pay off the bonds at their maturity. In some instances, however, an issue of bonds is so arranged that a certain number of them become due at stated periods; but in any event the result should be much the same to the taxpayer.

Sad to relate, some cities have been known to issue bonds at one rate of interest, and then create sinking funds to repay them at maturity and deposit such funds at a lower rate of interest; but this is not the rule in well managed cities, the sinking funds being largely invested in the city's own later issues of bonds, or in those of some neighbor.

Interest at Four Per Cent.

The tables that follow are compiled from those found in "Accountancy of Investment," by Charles E. Sprague, published by the author in 1910, and "Interest and Bond Values," by M. A. Mackenzie, the University Press, Toronto, 1912. Only those columns are shown that figure interest at the rate of four per cent per annum compounded or discounted annually, as these tables seemed sufficient for the author's purpose of illustration.

FOUR PER CENT INTEREST AND DISCOUNT TABLES.

Yrs.	Table 1.	Table 2.	Table 3.	Table 4.	Table 5.	Table 6	Yrs.
1	1.04000	.961538	1.0000	.9615	1.040000	1.000000	1
2	1.08160	.924556	2.0400	1.8861	.530196	.490196	2
3	1.12486	.889996	3.1216	2.7751	.360349	.320349	3
4	1.16986	.854804	4.2465	3.6299	.275490	.235490	4
5	**1.21665**	**.821927**	**5.4163**	**4.4518**	**.224627**	**.184627**	**5**
6	1.26532	.790315	6.6330	5.2421	.190762	.150762	6
7	1.31593	.759918	7.8983	6.0021	.166610	.126610	7
8	1.36857	.730690	9.2142	6.7327	.148528	.108528	8
9	1.42331	.702587	10.5828	7.4353	.134493	.094493	9
10	**1.48024**	**.675564**	**12.0061**	**8.1109**	**.123291**	**.083291**	**10**
11	1.53945	.649581	13.4864	8.7605	.114149	.074149	11
12	1.60103	.624597	15.0258	9.3851	.106552	.066552	12
13	1.66507	.600574	16.6268	9.9856	.100144	.060144	13
14	1.73168	.577475	18.2919	10.5631	.094669	.054669	14
15	**1.80094**	**.555264**	**20.0236**	**11.1184**	**.089941**	**.049941**	**15**
16	1.87298	.533908	21.8245	11.6523	.085820	.045820	16
17	1.94790	.513373	23.6978	12.1657	.082199	.042199	17
18	2.02582	.493628	25.6454	12.6593	.078993	.038993	18
19	2.10685	.474642	27.6712	13.1339	.076139	.036139	19
20	**2.19112**	**.456387**	**29.7781**	**13.5903**	**.073582**	**.033582**	**20**
21	2.27877	.438834	31.9692	14.0292	.071280	.031280	21
22	2.36992	.421956	34.2480	14.4511	.069199	.029199	22
23	2.46472	.405726	36.6179	14.8568	.067309	.027309	23
24	2.56330	.390121	39.0826	15.2470	.065587	.025587	24
25	**2.66584**	**.375117**	**41.6459**	**15.6221**	**.064012**	**.024012**	**25**
26	2.77247	.360689	44.3117	15.9828	.062567	.022567	26
27	2.88337	.346817	47.0842	16.3296	.061239	.021239	27
28	2.99870	.333477	49.9676	16.6631	.060013	.020013	28
29	3.11865	.320651	52.9663	16.9837	.058880	.018880	29
30	**3.24340**	**.308319**	**58.0849**	**17.2920**	**.057830**	**.017830**	**30**

Table Number one is a principal and interest table showing the future value of a present dollar at the end of any given number of years from one to fifty.

To separate the accumulated interest from the principal, deduct one dollar from any item.

Table Number two is an interest discount table showing the present value of a future dollar at the end of any given number of years from one to fifty.

Table Number three is an annuity accumulation table showing the future value, at the end of the period, of a series of one dollars, to be deposited at the end of each year, for any given number of years from one to fifty.

FOUR PER CENT INTEREST AND DISCOUNT TABLES.

Yrs.	Table 1.	Table 2.	Table 3.	Table 4.	Table 5.	Table 6	Yrs.
31	3.37313	.296460	59.3283	17.5885	.056855	.016855	31
32	3.50806	.285058	62.7015	17.8736	.055949	.015949	32
33	3.64838	.274094	66.2095	18.1476	.055104	.015104	33
34	3.79432	.263552	69.8579	18.4112	.054315	.014315	34
35	**3.94609**	**.253415**	**73.6522**	**18.6646**	**.053577**	**.013577**	**35**
36	4.10393	.243669	77.5983	18.9083	.052887	.012887	36
37	4.26809	.234297	81.7022	19.1426	.052240	.012240	37
38	4.43881	.225285	85.9703	19.3679	.051632	.011632	38
39	4.61637	.216621	90.4091	19.5845	.051061	.011061	39
40	**4.80102**	**.208289**	**95.0255**	**19.7928**	**.050523**	**.010523**	**40**
41	4.99306	.200278	99.8265	19.9931	.050017	.010017	41
42	5.19278	.192575	104.8196	20.1856	.049540	.009540	42
43	5.40050	.185168	110.0124	20.3708	.049090	.009090	43
44	5.61652	.178046	115.4129	20.5488	.048665	.008665	44
45	**5.84118**	**.171198**	**121.0294**	**20.7200**	**.048262**	**.008262**	**45**
46	6.07482	.164614	126.8706	20.8847	.047882	.007882	46
47	6.31782	.158283	132.9454	21.0429	.047522	.007522	47
48	6.57053	.152195	139.2632	21.1951	.047181	.007181	48
49	6.83335	.146341	145.8337	21.3415	.046857	.006857	49
50	**7.10668**	**.140713**	**152.6671**	**21.4822**	**.046550**	**.006550**	**50**
55	8.64637	.115656	191.1592	22.1086	.045231	.005231	55
60	10.51963	.095060	237.9907	22.6235	.044202	.004202	60
65	12.79874	.078132	294.9684	23.0467	.043390	.003390	65
70	15.57162	.064219	364.2905	23.3945	.042745	.002745	70
75	**18.94525**	**.052784**	**448.6314**	**23.6804**	**.042229**	**.002229**	**75**
80	23.04980	.043384	551.2450	23.9154	.041814	.001314	80
85	28.04360	.035659	676.0901	24.1085	.041479	.001479	85
90	34.11933	.029309	827.9833	24.2673	.041208	.001208	90
95	41.51139	.024090	1012.7846	24.3978	.040987	.000987	95
100	**50.50495**	**.019800**	**1237.6237**	**24.5050**	**.040808**	**.000808**	**100**

Table Number four is an annuity purchase table showing the present value, at the beginning of the period, of a series of one dollars, to be deposited at the end of each year, for any given numberof years from one to fifty.

Table Number five is an amortization table showing the equal amount that may be secured at the end of each year, for any given number of years from one to fifty, by the investment of a present dollar at the beginning of the period.

Table Number six is a sinking fund table showing the equal amount which if invested at the end of each year, for any given number of years from one to fifty, will produce a future dollar at the end of the period.

Note: Each table is extended to give values at five year periods from fifty to one hundred years.

Mr. Sprague's book is the more valuable for its tables, as it carries all of them to the eighth decimal and has the supplement running from fifty to one hundred years. Table five is found only in Mr. Mackenzie's book, and table six only in Mr. Sprague's book, number six being Mr. Sprague's number five table. It will be noted, however, that by adding or subtracting four cents in each item, table five will be converted into table six, or table six into table five.

As none of the elements of cost, labor, material or rate of interest, is the same for any two cities in all cases, and as some cities pay interest annually, some semi-annually and some quarterly, to get accurate results for comparisons, one must apply the examples, in each case using accurate local financial data.

The Cost of Construction.

In a consideration of the cost of the original road or street surface constructions, the bituminous sheet layer surfaces have a very great advantage over the block surfaces; that is, unless one is unwise or otherwise enough to lay some one of the proprietary bituminous sheet layer surfaces at an unwarranted price per square yard. But before we can get very far into this subject, it will be necessary for us to make some tentative estimates for the purpose of comparisons, and the author suggests the following:

Stone-filled sheet asphalt surface.........	$ .75
Standard sheet asphalt and binder surface	1.00
Vitrified paving brick or block surface	1.50
Creosoted wood paving block surface......	2.25
Improved granite paving block surface ...	2.50

In each of the above cases, the estimated price includes the laying in place of the entire wearing surface upon the concrete foundation, and the number of inches of grading made necessary by the particular displacement of the surface estimated, but the cost of such grading is but a very small item in any case unless there is rock excavation.

Each type of pavement surface considered and estimated has in many instances been laid for less and in many other cases for more than the figure stated, but the author thinks that the percentage of more or less will be constant when the honest constructions of each type are compared. For instance, in Greater New York City, stone-filled sheet asphalt wearing surfaces two inches thick have been laid for about sixty cents per square yard, and standard sheet asphalt and binder wearing surfaces three inches thick have been laid for about seventy-five cents per square yard, but these prices do not represent good contract paving practice in that city.

It might be well to state at this point that in most places a six-inch one-three-six mixture Portland cement concrete foundation can be laid for about seventy-five cents per square yard, including the six inches of average grading that its displacement makes necessary, so by adding this amount to the prices above given for the different surfaces we have the total estimated contract price for the original construction of the completed pavements considered suitable for modern city streets; but as noted in the former paragraph stating wherein pavements differ, the concrete foundations do not need to enter into our comparisons at all, they being almost always the same in all cases.

The thicknesses of the several wearing surfaces considered above are two inches for stone-filled sheet asphalt, three inches for standard sheet asphalt and binder, four inches for vitrified paving brick or block, three and one-half inches for the creosoted wood block, and five inches for the improved granite block surface.

While the author fully recognizes that the foregoing prices do not hold good at the present time as fully representative, owing to the extraordinary conditions of labor growing out of the war, it is believed that they suffice for the comparative purposes for which they are desired in this writing. Work is still being done in some places at these figures or less, and the present day figures would be very misleading, if an average were taken. It is therefore thought best to use prices prevailing a short time ago and that may be expected to prevail again as soon as conditions for labor and material are normal.

Totals to Illuminate.

When figures are made on the square yard unit basis, and the differences appear in cents, or at the most a dollar and some cents per square yard, all of us do not appreciate the gravity of these small differences. For that reason, it will help to a better understanding of the subject if we work these unit figures into some interesting totals.

As an instance, take a municipality of but fifty thousand inhabitants, which will probably have about fifty miles of streets averaging twenty thousand square yards of roadway surface per mile, or a total of about one million square yards of street roadway that is or ought to be paved.

The table that follows will show the total cost of either originally surfacing or later resurfacing this entire area with a modern pavement surface of each of the several types under consideration as suitable:

Stone-filled sheet asphalt surface	$ 750,000
Standard sheet asphalt and binder surface	1,000,000
Vitrified paving brick or block surface	1,500,000
Creosoted wood paving block surface	2,250,000
Improved granite paving block surface	2,500,000

It is at once seen that two square yards of stone-filled sheet asphalt wearing surface can be laid at the same cost as one square yard of vitrified paving brick or block surface, three square yards at the cost of one square yard of creosoted wood paving block surface, and three and one-third square yards at the cost of one square yard of improved granite block surface.

After a consideration of the above, it would seem to the author that there would need to be some very strong preponderance of physical and financial reasons to justify the laying of any other street pavement surface than stone-filled sheet asphalt; too steep a grade being the most common and important justification.

The Improvement Charge.

The fixed annual interest charge per square yard on the original investment of our municipal dollars in the construction of pavement wearing surfaces is a matter of considerable importance, so let us see what it amounts to in the case of each type of pavement surface when calculated at the rate of four per cent:

Stone-filled sheet asphalt surface	$ .03
Standard sheet asphalt and binder surface .	.04
Vitrified paving brick or block surface	.06
Creosoted wood paving block surface	.09
Improved granite paving block surface	.10

To appreciate the gravity of these figures, one has but to multiply the given number of cents per square yard per annum of the interest charge on the cost of the original construction of each type of pavement surface by the one million square yards of street roadway area to be found in a city of but fifty thousand inhabitants, with this result:

Stone-filled sheet asphalt surface	$ 30,000
Standard sheet asphalt and binder surface	40,000
Vitrified paving brick or block surface . .	60,000
Creosoted wood paving block surface	90,000
Improved granite paving block surface . .	100,000

The above statements mean, for instance, that a city must be able to maintain permanently by repair and renewal a square yard of improved granite paving block surface for at least seven cents per square yard less per annum than it can permanently maintain a stone-filled sheet asphalt surface before the two wearing surfaces will be equally economical; and in most cases, as will be seen later, this is impossible.

In other words, the improved granite paving block surface is laboring under a handicap of seven cents per square yard per annum from the day of its laying because of its greater cost of original construction. It is only when we look into the full permanency cost, however, that the real gravity of the situation created by the interest charge becomes fully apparent.

The Cost of Repairs.

The material costs for making repairs due to wear will be about the same as in the case of the original construction of the several types of pavement surfaces. The labor costs will necessarily increase, because of the small quantities in which repair work must be done, but this increase will not be in any great disproportion for the several surfaces.

When repairs are made because of wear, there is not much salvage to be had from the old surface materials, especially old blocks that lose their value with their shapes. What is left of the bituminous sheet layer surfaces is always perfectly good for reuse. What is left of old vitrified bricks and granite blocks is fit only for crushing into concrete material, unless the granite blocks are recut; and old creosoted wood blocks make a wonderful bonfire.

When repairs are due to openings in the street surface, a large number of the old blocks are available for reuse. The exception is when cement joints have been used and the blocks are broken in the removal of the surface. The entire removed section of a bituminous sheet layer wearing surface is, of course, susceptible to reuse by the remelting, remixing, rejuvenating and relaying process, and the results are somewhat more satisfactory than in the case of blocks, which at the best can seldom be reused more than once.

Repairs to bituminous sheet layer surfaces can be made, using all new materials, for about $1.25 per square yard, by contract. Municipal asphalt repair plants do the work for under $1.00 per square yard. The above prices will about purchase the number of vitrified paving bricks, but will not begin to pay for the number of creosoted wood or granite paving blocks required to lay one square yard of wearing surface.

Asphalt repairs can be made by a municipal asphalt repair plant, using the old materials, for about sixty cents per square yard. It is not possible to make repairs to a block surface, even if all the old blocks are available, for anything like this cost.

Where new materials must be used in making repairs and renewals the bituminous sheet layer surfaces have the same advantage they have in the matter of the original construction. Where the old materials are available, they have a still greater advantage, both in the matter of cost and the relative value of the repair accomplished.

The Cost of Renewals.

There is a time in the life of every pavement surface when it is more economical and desirable to take it up and completely resurface the foundation with a new wearing surface of the same or a different character; and though much that is said about the cost of repairs applies in proportion to the cost of renewals, there are still some points of difference worth noting.

The cost of the new surface when the original surface has worn out is practically the same as the cost of the original surface construction. The only material difference is that between the cost of the original grading for the displacement of the original surface, and the cost of removing the old surface. The difference is not of sufficient moment to demand very much consideration.

There is almost no salvage when a worn out old block wearing surface is torn up. With the exception of a small percentage of blocks that have been out of the line of traffic, the paving blocks are all so misshapen that they usually go to the crusher. The few good blocks can best be employed in repairing other streets of the same surface material, thus saving the purchase of new blocks. It is the author's belief that sheet asphalt pavements can be resurfaced for about twenty-five cents per square yard by putting the old surface through a plant operating on the street.

Re-using Old Asphalt Surface.

All the bituminous sheet layer surface material that remains on a street when it is found advisable to resurface it is salvage. The stone chips, sand and stone dust are no different than they were when originally laid, and the asphalt cement is the same except for the loss of some of the lighter oils that have been drawn out by the action of the sun and can readily be replaced by the addition of suitable flux.

When it is considered that except in the case of heavy traffic streets probably at least eighty per cent of the original materials are left, the resurfacing being made necessary more because of the hardening and cracking of the wearing surface than because of wear, and that the lighter oils of the asphalt cement that have departed and must be replaced constitute only about ten per cent of the asphalt cement or about one per cent of the total aggregate, the value of the salvage is at once apparent.

The crux of the matter is that the shape of an old bituminous sheet layer surface has nothing whatever to do with its value as salvage, while this is the all important item in the case of old paving blocks. Old granite paving blocks may be turned once, and so may old vitrified paving brick, but in each case the new face is the one that was rejected in the original laying. Where strong cement grout joint filler has been used, there can be no turning of the blocks, and this is the most approved filler of the present day. The item of cleaning a bituminous filler from the sides of the blocks is also a matter of considerable cost; and sand joints are a thing of the past.

Any way one looks at it, the economy of renewals lies with the bituminous sheet layer class of surfaces.

Durability of Surfaces.

This item of value in a comparison of road and street pavement surfaces might also have been listed as a physical point of consideration, but inasmuch as all types under discussion are of sufficient durability not to be seriously objected to because of the frequency with which repairs and renewals must be made, it is only necessary at this time to consider the durability of the several types of pavement surfaces as it relates to the financial economy of permanent pavement surface maintenance.

It is the author's opinion that vitrified paving brick or block surfaces are considerably less durable under heavy traffic and somewhat less durable under light traffic than stone-filled sheet asphalt, standard sheet asphalt and binder, or creosoted wood paving block surfaces; that the three last mentioned are about equal in durability, and that the improved granite paving block surfaces are more durable than any other pavement surface now in general use.

If required to estimate the relative and probable life of each type of surface under given heavy traffic conditions, the author would first locate the nearest bomb proof cellar, and then venture to state his opinion about as follows:

Stone-filled sheet asphalt surface	10 years
Standard sheet asphalt and binder surface .	10 years
Vitrified paving brick or block surface ..	5 years
Creosoted wood paving block surface	10 years
Improved granite paving block surface ...	25 years

For light traffic residential streets, the author would make the following estimate of durabilities:

Stone-filled sheet asphalt surface	25 years
Standard sheet asphalt and binder surface	25 years
Vitrified paving brick or block surface ..	20 years
Creosoted wood paving block surface	25 years
Improved granite paving block surface	50 years

Directly after issuing such a statement as the foregoing estimate of durability, it would seem but the part of worldly wisdom in the author to seek his prelocated nearest safe shelter until the storm had blown over, for it is a moral certainty that whatever reasonable estimates of relative durability one may make, they will be viciously challenged by each of the financial interests concerned in the promotion of a special type of surface construction.

It is also quite certain that the interested advocates of each type of construction can point to almost innumerable instances where their type of surface has lasted longer under heavy traffic conditions and where the other fellow's has gone to pieces under light traffic conditions, all of which will succeed in proving absolutely nothing, as good construction and poor construction have been practised quite impartially with each type of pavement surface.

One must virtually have lived pavements for many years to have secured any worth while direct idea of the relative durability of the different surfaces, for there is no valuable collection of data on the subject; and even then, different "lifers" will have formed different opinions based each on his own experience.

It must not be thought that the small repairs made to a wearing surface for several years prior to its final removal have been lost sight of in the foregoing estimates of durability. What is meant is the average life of the original surface.

Some of an original wearing surface may remain on a heavy traffic street for eighteen years; yet the average or mean life or durability of that original surface may only have been fifteen years; and in estimates of durability it should be so considered. Unfortunately, there are no valuable data on the cost of repairs for the different surfaces, such information as may be had being of no comparable worth.

The Cost of Cleaning.

It stands to reason that the smooth, hard and jointless bituminous sheet layer surfaces are the easiest and the least expensive to clean and keep clean. There should not be much difference between the cost of cleaning bituminous sheet layer surfaces and new paving block surfaces of the several types, but the difference grows as the surfaces age. There is practically no increase in the cost of cleaning the bituminous sheet layer surfaces, as these remain smooth even in old age, but there is a very great difference with the block surfaces that roughen with age and acquire deep joints in which dirt will lodge and not readily leave.

The Engineering Record of February 22nd, 1908, carried the summary of a report to the mayor of the City of New York that discussed the methods of street cleaning best adapted to the several boroughs of that city. This report was made by Messrs. H. deB. Parsons, Rudolph Hering and Samuel Whinery, and in conducting their investigations it was, of course, necessary for them to look into the question of the ease and relative economy with which the different forms of pavement surfaces could be kept clean. This investigation brought out many points which were very much in favor of the use of bituminous sheet layer or asphalt wearing surfaces. The Record of March 7th carried some comments on this report, and both the report and the comments are worth reading.

After stating in detail the results of many tests, the commissioners point out that it is an obvious fact that smooth, continuous, hard surfaces can be kept clean with less labor and at a smaller cost than surfaces of a more or less rough and uneven nature, with joint spaces that catch and retain dirt.

Later on, after giving some very interesting tables, these engineers remark that if their figures are even approximately correct, they show that the kind of pavement surface in use in a city affects very materially the cost of keeping the streets clean; and they suggest that relative cost of cleaning is an element of no little importance in selecting the kind of pavement that a city should lay. It should also be considered that streets which can be cleaned cheaply are much more apt to be maintained in a sanitary condition.

The well known authors of this report estimate the relative cost of cleaning the different surfaces we have under consideration as follows:

Sheet asphalt wearing surfaces	....	100
Vitrified paving brick surfaces	....	120
New wood paving block surfaces	....	105
Old wood paving block surfaces	....	125
Granite paving block surfaces	....	140

The difference between cleaning a sheet asphalt wearing surface and a granite block wearing surface, from other tables in the report, seems to be slightly over one cent per square yard per annum; not by any means an inconsiderable amount when multiplied by the one million square yards in our small city of fifty thousand inhabitants, to say nothing of the larger municipalities that house millions.

The Cost to Traffic.

The ease of traction upon a given pavement surface with a given grade governs the cost of drawing or propelling a given load thereover at a given rate of speed. There are many minor factors entering into the equation, such as the use of too smooth a pavement on a very steep grade, and the slipperiness of certain surfaces under certain unfavorable weather conditions, but these minor factors are of special rather than general consideration.

The two chief factors are, of course, smoothness and hardness in the pavement surface, both of which qualities are possessed in a marked degree by all pavement surfaces now approved for use on modern city streets and heavily trafficked rural highways.

The bituminous sheet layer surfaces, because they are by a little the smoothest when new, and very much the smoothest as the different surfaces suffer from age and wear, are considerably less expensive to traffic upon all grades reasonable for their use than are any of the block class of pavement surfaces. The difference in cost increases as the roughness of the block surfaces becomes greater with age and wear, while the bituminous sheet layer surfaces, when kept in reasonable repair, remain smooth and becomes harder with age.

With the exception of the standard sheet asphalt mixture, all the bituminous sheet layer surfaces are sufficiently hard at all times, and in this special case the softness is only in evidence on very warm summer days. As an objection, this feature does not figure very heavily when averaged up for the year, and would not be a sufficient handicap to make this type of bituminous sheet layer surface second to any of the block class of surfaces in the cost to traffic when considered for the life of the various surfaces.

Several years ago, quite a number of standard sheet asphalt surfaces were laid very soft, and many will remember the difficulty with these particular surfaces; but as the practice of laying them so soft has been abandoned, it is not worth while to consider at this time the excessive warm weather tractive resistance of these unsuccessful experimen˙ ,.

While there are no data of especial value to be had on this subject, such items as have been collected seem to uphold the conclusions one would reach from a common sense consideration of the factors involved. In one case, Belgian block surfaces required twice as much tractive power as asphalt, and asphalt was only slightly excelled by planed granite and iron trams. These tests are too old and not sufficiently definite to be of value to-day, except as they seem to corroborate or upset our conclusions.

The Upkeep of Vehicles.

There is not, as far as the author knows, a particle of available data upon the cost of vehicular upkeep in its relation to pavement values, but an application of ordinary good judgment tells us that the smoother a pavement surface the less wear there will be to vehicles passing over it, and that the rougher the surface the greater will be the wear. The expense of maintaining vehicles in which to travel and transport freight in such cities as the Baltimore and the Brooklyn of a few generations ago must have been no inconsiderable item in the cost of living.

While the cost of vehicular upkeep in a given community is not an item that appears in the municipal budget, it should nevertheless receive the consideration that it deserves. The public pays, no matter whether it hands its money to the blacksmith, the wagonmaker or the garage proprietor, or whether it pays along with the taxes handed to the city treasurer. A very poor public official indeed is the city manager or county commissioner who can not see any further than the budget and the tax rate.

The matter of vehicular upkeep, though not reducible to figures by any convenient method of which the author has knowledge, should still be carefully weighed before selecting a rougher pavement surface in preference to a smoother surface.

Home Industry Involved.

It is not the author's intention to approach this subject in a narrow sense, but the basic principle of trade and commerce is or should be founded on the idea that a community will secure from a distance those things that it has not or can not produce as well locally, exchanging therefor the things that it has and can produce locally to advantage and beyond its own reasonable needs.

Therefor, if a city within its corporate limits or in the surrounding neighborhood a majority of the materials from which a certain type of economical and desirable pavement wearing surface may be constructed, with a minimum cost for the importation of other necessary ingredients, there is no logical reason why that city should freight in from a distance the expensive materials from which another type of pavement surface must be constructed, unless it can be clearly shown that by so doing it will secure such great advantages of economy and desirability as to justify this extraordinary procedure.

Sand and crushed stone are nearly always local products, while asphalt cement and sometimes pulverized stonedust or Portland cement filler must be imported for the bituminous sheet layer surfaces, and bituminous cement and Portland cement joint fillers, vitrified paving bricks and blocks, creosoted wood paving blocks, and improved granite paving blocks must be imported for the block surfaces.

The following table will show at once about how much of a city's money goes out of the community with the laying of a square yard of each type of pavement wearing surface:

Stone-filled sheet asphalt surface	$ .25
Standard sheet asphalt and binder surface ...	.40
Vitrified paving brick or block surface	1.25
Creosoted wood paving block surface	2.00
Improved granite paving block surface	2.25

All of the above figures are high for many places, but they are in proportion. A substitution of the actual costs for a certain city will not alter the result except in a very few cases. For instance, vitrified paving brick is considerably cheaper in Ohio than on the coasts, and asphalt cement is much cheaper near the coasts. In some places, the out of town material cost for stone-filled sheet asphalt surfaces is not over fifteen cents " asphalt cement, and vitrified brick surface materials would amount to slightly less than one dollar in other places. Freight is usually the governing factor, especially with blocks.

It must be remembered that these figures hold good every time the pavement surface is repaired or renewed with new materials. The destination of money is a matter of legitimate inquiry when a community is spending it in large amounts, though by no means a governing factor. If one does not think so, he had best consult the president of his local bank on the subject and be properly informed.

Since the bituminous sheet layer surfaces are susceptible to indefinite resurfacings, using the old materials with the addition of a little new material, not over five cents per square yard needs to be spent out of town each time the pavement is resurfaced.

Control of Production.

Largely because of the greater amount of home industry involved in their manufacture, the possible outside control of the production of the bituminous sheet layer surfaces is less than in the case of any of the paving block surfaces.

A municipality can not manufacture its own paving blocks at a great saving, for the reason that no one city can advantageously take the entire output of one block manufacturing plant of sufficient size for economical production. These plants are seldom in the city for which blocks are furnished, and shipments of blocks are frequently made from great distances by rail or water, and sometimes by both.

Most cities or progressive counties can use the entire output of one asphalt mixing plant that will produce any of the bituminous sheet layer surface mixtures, and some of the very large cities have several such plants operating to advantage within their corporate limits. A great many small places have such plants to take care of their repairs and renewals alone, and wherever they have been installed they have operated to advantage and at a reasonable cost.

If there should be a control of the asphaltic cement necessary for the manufacture of bituminous sheet layer wearing surfaces and the price were advanced thereby one-hundred per cent, the tax per square yard would still be less than might be effected by an advance of but a few per cent per square yard in the cost of the paving blocks for any one of the block class of surfaces.

At present there is an association of vitrified paving brick and block manufacturers, an association of creosoted wood paving block manufacturers, and an association of granite paving block manufacturers, each association spending vast sums of money for the publicity necessary to promote the use of their materials. About the only producers of an important element in pavement construction of a special type that have no association are the manufacturers of asphaltic cement. For this reason, this type of surface, by far the most desirable and economical of them all, has not had its merits presented to the public in such a way as to insure its proper use.

One is not coaxed to lay high grade bituminous sheet layer wearing surfaces on one's roads and streets at moderate prices, but many city authorities have already perceived the great advantages of this form of surface construction, and are laying these pavements in ever increasing quantities without coaxing from any source.

It is a fact to-day that the most expensive, least economical and desirable pavement wearing surfaces are the most widely advertised and strenuously promoted. While it does not pay the municipality or county to lay these surfaces, it does tremendously pay the promoters and producers.

The Permanency Cost.

In order to find the present comparative cost of originally constructing and permanently maintaining a given type of pavement wearing surface upon a given road or street, it is necessary to add to the cost of the original construction that sum of money that, properly invested, will produce in interest accumulations a fund from which may be taken such amounts as will be needed from time to time for repairing and renewing the pavement wearing surface under discussion indefinitely.

The author's comparative estimates of the cost of originally constructing each of the pavement surfaces under consideration are available in a foregoing paragraph on page thirty-six, and the cost of renewing the surfaces will be substantially the same.

By consulting the compound interest tables that have been given, we will find in table number one the amount of compound interest that one dollar will produce in any given number of years that we may take as the mean life of a type of pavement surface upon a certain street. As this table gives the sum of principal and interest, the one dollar principal must be deducted to ascertain the amount of accumulated interest separate from the principal.

By dividing the cost per square yard of renewing the pavement surface under consideration by the amount of compound interest that one dollar will produce during that pavement's estimated life we will get the amount of money that must be properly invested to provide for the permanent maintenance of that particular pavement surface, which when added to the original cost of construction will give us the comparative present cost of a permanent pavement surface of the type considered.

For instance, we have estimated that a stone-filled sheet asphalt wearing surface will cost $ .75 per square yard to originally construct or to renew when it is worn out. If its mean life on a given street is ten years, $ .75 per square yard must be spent for its renewal at the end of each ten year period to permanently maintain it on that street.

To find out what amount of capital will produce $ .75 in compound interest at four per cent per annum every ten years, we must divide $ .75 by the amount of compound interest that $ 1.00 will accumulate in ten years, which we find to be $ .48 by referring to interest table number one.

The cost of the pavement surface in question, $ .75 per square yard, divided by $ .48 gives us $ 1.56 as the amount of capital that must be invested per square yard to take care of the permanent maintenance of that surface, which when added to the cost of original construction, $ .75 per square yard, gives us $ 2.31 per square yard as the present cost of originally constructing and permanently maintaining a stone-filled sheet asphalt wearing surface upon the particular street under consideration.

The same wearing surface on a street where its life will be but one year would show a cost for permanency of $ 19.50 per square yard, while on a street where its life would be twenty-five years the cost for permanency would be but $ 1.20 per square yard. An interesting set of graphs would result from that kind of a study of permanency costs.

Calculations to Illustrate.

By using the foregoing rule for determining the present value of the original construction and permanent maintenance of each type of pavement wearing surface, under given conditions, we get the interesting results shown on the next page.

The first table shows the several permanency values, using the comparative durabilities estimated by the author for heavy traffic conditions; and the second table shows the values, using the durabilities estimated for residential light traffic conditions.

As it is quite certain that many will disagree with these estimates of durability, the third and fourth tables are compiled to show the number of years each type of pavement surface must endure to be even as economical as a stone-filled sheet asphalt wearing surface that endures five and ten years respectively.

To get the results shown in tables three and four, deduct the original cost of each pavement surface from the permanency cost of stone-filled sheet asphalt shown as having a life of five years in table three and ten years in table four respectively, and thereby get the amount of capital available as an investment fund for the creation of an interest fund to permanently maintain each of the other pavement surfaces. Then divide the original cost of each surface by the investment fund available for the creation of an interest fund to permanently maintain such surface, and get the amount of compound interest that each dollar of the investment fund must produce to pay for the renewal of the surface in question.

By referring to the foregoing interest table number one, we then find the nearest number of years it will take a dollar to produce the required amount of interest, when invested at four per cent per annum.

Tables 1 and 2 of the Permanency Cost.

Character of Pavement Surface	Life Years	Original Cost	Invested Fund	Permanency Cost
Stone-filled Sheet Asphalt......	**10**	$ .75	$ 1.56	**$ 2.31**
Sheet Asphalt and Binder.........	**10**	1.00	2.08	**3.08**
Vitrified Paving Bricks or Blocks....	**5**	1.50	6.92	**8.42**
Creosoted Wood Paving Blocks......	**10**	2.25	4.69	**6.94**
Improved Granite Paving Blocks......	**25**	2.50	1.50	**4.00**
Stone-filled Sheet Asphalt.....	**25**	$ .75	$ .45	**$ 1.20**
Sheet Asphalt and Binder........	**25**	1.00	.60	**1.60**
Vitrified Paving Bricks or Blocks....	**20**	1.50	1.26	**2.76**
Creosoted Wood Paving Blocks......	**25**	2.25	1.35	**3.60**
Improved Granite Paving Blocks......	**50**	2.50	.41	**2.91**

Tables 3 and 4 of the Permanency Cost.

Character of Pavement Surface	Permanency Cost	Original Cost	Invested Fund	Life Years
Stone-filled Sheet Asphalt......	**$ 4.21**	$ .75	$ 3.46	**5**
Sheet Asphalt and Binder.........	**4.21**	1.00	3.21	**7**
Vitrified Paving Bricks or Blocks....	**4.21**	1.50	2.71	**11¼**
Creosoted Wood Paving Blocks......	**4.21**	2.25	1.96	**19½**
Improved Granite Paving Blocks......	**4.21**	2.50	1.71	**23**
Stone-filled Sheet Asphalt......	**$ 2.31**	$ .75	$ 1.56	**10**
Sheet Asphalt and Binder.........	**2.31**	1.00	1.31	**14½**
Vitrified Paving Bricks or Blocks...	**2.31**	1.50	.81	**26¾**
Creosoted Wood Paving Blocks......	**2.31**	2.25	.06	**92¼**
Improved Granite Paving Blocks......	**2.31**	2.50	**— .19**	**x**

What These Figures Show.

Probably the most striking point in the foregoing tables of permanency values is found in the last section, table four, where it appears that on a given street, **if a stone-filled sheet asphalt wearing surface will last ten years, an improved granite paving block wearing surface would be just nineteen cents per square yard dearer even if it lasted forever without repairs or renewals.** The stone-filled sheet asphalt wearing surface can be originally constructed and permanently maintained for that much per square yard of present value less than will be the actual cost of originally constructing the improved granite block surface.

On the same street, a creosoted wood block wearing surface must last ninety-two and one-quarter and a vitrified paving brick surface must last twenty-six and three-quarter years to be as economical as the stone-filled sheet asphalt wearing surface lasting ten years; and on a street where the latter surface will last but five years, the creosoted wood block surface must last nineteen and one-half, the vitrified paving brick surface must last eleven and one-quarter, and the improved granite paving block surface twenty-three years to be as economical. The block surfaces have no such comparative durabilities; not even the improved granite paving block surface.

It should be borne in mind, while making these comparisons, that except for some special cases, the sheet asphalt surfaces are far more desirable physically than the block class of surfaces; and that they have other points of financial advantage, such as the lesser cost of cleaning, of motive power to traffic, of resulting vehicular upkeep, and the greater extent of home industry involved. Also, one should not overlook the lesser possibility of outside control when cities lay the bituminous sheet layer class of surfaces.

Another item that we have not considered above is the re-use of old wearing surface materails, and here we have already noted a very great advantage in favor of the sheet asphalt wearing surfaces.

In considering permanency costs, it should be borne in mind that the fund invested to take care of the permanent maintenance is never spent, but always remains to be recovered for other purposes if for any reason the roadway pavement should be abandoned. This is a matter of considerable importance, in connection with which one should not lose sight of the possible very rapid development of the flying machine both for commercial purposes and for pleasure.

The Average Annual Cost.

The yearly interest on the permanency cost, determined by the rule that has been stated, is the average annual cost of the pavement wearing surface. However, as many will prefer to get at the average annual cost directly, tables showing the same comparisons as those given to show the permanency costs have been prepared to set forth comparative average annual costs. The comparative results are the same.

The first and second tables show the average annual costs based on the author's estimates of durability for each type of pavement surface under given heavy and light traffic conditions. The average annual cost is arrived at in these tables by adding to the yearly interest on the original cost of construction that sum of money which must annually be set aside in a sinking fund to repay that original cost at the end of the estimated average life.

The third and fourth tables show the average length of life that each type of surface must necessarily attain in order to have as low an annual cost as a stone-filled sheet asphalt wearing surface that will last five years and ten years respectively under given traffic conditions.

It will be noted that in these tables the average annual cost of a stone-filled sheet asphalt wearing surface lasting a certain number of years, five years for table three and ten years for table four, is taken as the starting point; and that the annual interest on the original cost of each type of surface is then deducted to get the annual amount available for sinking fund purposes in each case. This amount annually available divided by the original cost of the surface, shows how much of this amount is available as an annual sinking fund for each dollar of the original cost.

A reference to table six of interest values at four per cent will then tell how many years it will require for this amount per dollar of original cost to be put into the sinking fund to accumulate one dollar of the original cost, which number of years will be the necessary life of the surface in question if its average annual cost is to be as low as that of stone-filled sheet asphalt.

Tables five and six are given to show what lives are required of the other types of surface where stone-filled sheet asphalt will last but one or two years. The author knows of but few instances where this type of surface construction, when properly laid, would have so short a life, but the calculations are interesting.

Tables 1 and 2 of Average Annual Cost.

Character of Pavement Surface	Life Years	Original Cost	Interest on O.C.	Sinking Fund	Annual Cost
Stone-filled Sheet Asphalt . . .	**10**	$ .75	$ .03	$.0625	**$.0925**
Sheet Asphalt and Binder	**10**	1.00	.04	.0833	**.1233**
Vitrified Paving Bricks or Blocks.	**5**	1.50	.06	.2769	**.3369**
Creosoted Wood Paving Blocks. .	**10**	2.25	.09	.1874	**.2774**
Improved Granite Paving Blocks. .	**25**	2.50	.10	.0600	**.1600**
Stone-filled Sheet Asphalt . . .	**25**	$ .75	$ .03	$.0180	**$.0480**
Sheet Asphalt and Binder	**25**	1.00	.04	.0240	**.0640**
Vitrified Paving Bricks or Blocks. .	**20**	1.50	.06	.0504	**.1104**
Creosoted Wood Paving Blocks. . .	**25**	2.25	.09	.0540	**.1440**
Improved Granite Paving Blocks. . .	**50**	2.50	.10	.0164	**.1164**

Tables 3 and 4 of Average Annual Cost.

Character of Pavement Surface	Original Cost	Annual Cost	Interest on O.C.	Sinking Fund	Life Years
Stone-filled Sheet Asphalt...	$ .75	**$.1685**	$ .03	$.1385	**5**
Sheet Asphalt and Binder....	1.00	**.1685**	.04	.1285	**7**
Vitrified Paving Bricks or Blocks.	1.50	**.1685**	.06	.1085	**11¼**
Creosoted Wood Paving Blocks.	2.25	**.1685**	.09	.0785	**19½**
Improved Granite Paving Blocks...	2.50	**.1685**	.10	.0685	**23**
Stone-filled Sheet Asphalt...	$ .75	**$.0925**	$ .03	$.0625	**10**
Sheet Asphalt and Binder.....	1.00	**.0925**	.04	.0525	**14½**
Vitrified Paving Bricks or Blocks.	1.50	**.0925**	.06	.0325	**26¾**
Creosoted Wood Paving Blocks...	2.25	**.0925**	.09	.0025	**92¼**
Improved Granite Paving Blocks...	2.50	**.0925**	.10	**—.0075**	**x**

Tables 5 and 6 of Average Annual Cost.

Character of Pavement Surface	Original Cost	Annual Cost	Interest on O.C.	Sinking Fund	Life Years
Stone-filled Sheet Asphalt...	$ .75	**$.7800**	$ .03	$.7500	**1**
Sheet Asphalt and Binder.....	1.00	**.7800**	.04	.7400	**1½**
Vitrified Paving Bricks or Blocks.	1.50	**.7800**	.06	.7200	**2**
Creosoted Wood Paving Blocks...	2.25	**.7800**	.09	.6900	**3**
Improved Granite Paving Blocks...	2.50	**.7800**	.10	.6800	**3½**
Stone-filled Sheet Asphalt...	$ .75	**$.3976**	$ .03	$.3676	**2**
Sheet Asphalt and Binder.....	1.00	**.3976**	.04	.3576	**2¾**
Vitrified Paving Bricks or Blocks.	1.50	**.3976**	.06	.3376	**4¼**
Creosoted Wood Paving Blocks...	2.25	**.3976**	.09	.3076	**6½**
Improved Granite Paving Blocks	2.50	**.3976**	.10	.2976	**7½**

Cost by Amortization.

Where the rate of interest carried by the municipal bonds and the rate of interest realized on the sinking fund account are substantially the same, which they should be, there is a much easier way of arriving at the average annual cost of a given type of pavement wearing surface on a particular street, once we have correctly estimated the original cost and the period of durability of that surface.

The four per cent interest table numbered five in a previous paragraph shows the annual payment that will amortize one dollar in any given number of years from one to fifty, with supplement from fifty to one hundred years. By taking the figure given for the number of years corresponding with the estimated life of a particular type of pavement surface on a certain street, and multiplying it by the estimated original cost of that surface, we have its average annual cost on the street under consideration.

The following tables of annual costs per square yard for each type of pavement wearing surface have been figured by the above rule and are based on interest at the rate of four per cent per annum. They should show some very enlightening comparative results to the careful reader who is sufficiently interested to ponder them. It will be noted that the items in these tables check with the results in the former tables of permanency costs and average annual costs; but give a much more ready means of comparing the values of the several types of pavement surfaces.

The blackface figures with the letters A, B, C, D, E, F, G, and H placed opposite are to indicate approximately the same average annual cost for each of the pavement surfaces, showing up readily the number of years of average life each surface must have in order to be as economical as the others. A separate statement of the items selected out of the amortization table by these letters follows said table, and shows up some very startling contrasts.

Table of Cost by Amortization.

Life in Years	Stone-filled Sheet Asphalt $ .75	Sheet Asphalt and Binder $1.00	Vitrified Paving Bricks or Blocks $1.50	Creosoted Wood Paving Blocks $2.25	Improved Granite Paving Blocks $2.50	Life in Years
1	$ .7800	$1.0400	$1.5600	$2.3400	$2.6000	1
2	.3976	.5302	.7953	1.1929	1.3254	2
3	.2703	.3603	.5405	.8108	.9009	3
4	.2066	.2755	.4132	.6199	.6887	4
5	A **.1685**	.2246	.3369	.5054	.5616	5
6	.1431	.1908	.2861	.4292	.4769	6
7	.1250	A **.1666**	.2499	.3749	.4165	7
8	.1114	.1485	.2228	.3342	.3713	8
9	x .1009	.1345	.2017	.3026	.3362	9
10	B **.0925**	.1233	.1849	.2774	.3082	10
11	.0856	.1141	A **.1712**	.2568	.2856	11
12	.0799	.1066	.1598	.2397	.2664	12
13	.0751	.1001	.1502	.2253	.2504	13
14	.0710	B **.0947**	.1420	.2130	.2367	14
15	C **.0675**	.0899	.1349	.2024	.2249	15
16	.0644	.0858	.1287	.1931	.2146	16
17	.0616	.0822	.1233	.1849	.2055	**17**
18	.0592	.0790	.1185	.1777	.1975	18
19	.0571	.0761	.1142	.1713	.1903	19
20	D **.0552**	.0736	.1104	A **.1656**	.1840	20
21	.0535	.0713	.1069	.1604	.1782	21
22	.0519	.0692	.1038	.1557	.1930	22
23	.0505	C **.0673**	.1010	.1514	A **.1683**	23
24	.0492	.0656	.0984	.1476	.1640	24
25	E **.0480**	.0640	.0960	.1440	.1600	25
26	.0469	.0626	.0939	.1408	.1564	26
27	.0459	.0612	B **.0919**	.1378	.1531	27
28	.0450	.0600	.0900	.1350	.1500	28
29	.0442	.0589	.0883	.1325	.1472	29
30	F **.0434**	.0578	.0867	.1301	.1446	30
31	.0426	.0569	.0853	.1279	.1421	31
32	.0420	.0559	.0839	.1259	.1399	32
33	.0413	D **.0551**	.0827	.1240	.1378	33
34	.0407	.0543	.0815	.1222	.1358	34
35	G **.0402**	.0536	.0804	.1205	.1339	35
36	.0397	.0529	.0793	.1190	.1322	36
37	.0392	.0522	.0784	.1175	.1306	37
38	.0387	.0516	.0774	.1162	.1291	38
39	.0383	.0511	.0766	.1149	.1277	39
40	H **.0379**	.0505	.0758	.1137	.1263	40
41	.0375	.0500	.0750	.1125	.1250	41
42	.0372	.0495	.0743	.1115	.1238	42
43	.0368	.0491	.0736	.1105	.1227	43
44	.0365	.0487	.0730	.1095	.1217	44
45	**.0362**	.0483	.0724	.1086	.1207	45
46	.0359	E **.0479**	.0718	.1077	.1197	46
47	.0356	.0475	.0713	.1069	.1188	47
48	.0354	.0472	.0708	.1062	.1180	48
49	.0351	.0469	.0703	.1054	.1171	49
50	**.0349**	.0466	.0698	.1047	.1164	50
55	.0339	.0452	C .0678	.1018	.1131	55
60	.0332	.0442	.0663	.0995	.1105	60
65	.0325	F **.0434**	.0651	.0976	.1085	65
70	.0321	.0427	.0641	.0962	.1069	70
75	**.0317**	.0422	.0633	.0950	.1056	75
80	.0314	.0418	.0627	.0941	.10[illegible]5	80
85	.0311	.0415	.0622	.0933	.1037	85
90	.0309	.0412	.0618	B **.0927**	.1030	90
95	.0307	.0410	.0615	.0922	.1025	95
100	**.0306**	G **.0408**	.0612	.0918	x **.1020**	**100**

It is seen from the above tables that if an improved granite paving block wearing surface will last one hundred years on a given street without repair or renewal, it is still slightly more expensive than a stone-filled sheet asphalt wearing surface that will last but nine years on the same street; in fact, when other elements besides the original, repair and renewal costs are considered, the cost of cleaning for instance, it will be considerably more expensive.

TABLE SHOWING ELIMINATIONS.

References:	A	B	C	D	E	F	G	H	
The Average Annual Cost	.1685	.0925	.0675	.0552	.0480	.0434	.0402	.0379	
Stone-filled Sheet Asphalt . .	5	10	15	20	25	30	35	40	years
Sheet Asphalt and Binder	7	14	23	33	46	65	100	*	years
Vitrified Paving Bricks or Blocks	11	27	55	*	*	*	*	*	years
Creosoted Wood Paving Blocks	20	90	*	*	*	*	*	*	years
Improved Granite Paving Blocks	23	*	*	*	*	*	*	*	years

In the table sho ing eliminations, which is compiled from the table of cost by amortization, the stars indicate that the pavement surfaces they are opposite could not have as low an average annual cost per square yard as a stone-filled sheet asphalt wearing surface that will last the number of years stated opposite the latter surface at the head of the column even if such other surfaces would last forever without repair or renewal.

It will be noted that if the stone-filled sheet asphalt will last ten years, granite block is completely eliminated, and wood block must last ninety years; if it will last fifteen years, both granite and wood block are eliminated, and brick must last fifty-five years; if it will last twenty years, granite, wood and brick are eliminated, and sheet asphalt and binder must last thirty-three years; if it will last twenty-five years, sheet asphalt and binder must last forty-six years; if it will last thirty years, sheet asphalt and binder must last sixty-five years; if it will last thirty-five years, sheet asphalt and binder must last one hundred years; and if it will last forty years, sheet asphalt and binder would have a higher average annual cost even if that surface lasted forever without repair or renewal. **At the age of forty, a stone-filled sheet asphalt surface has eliminated all the other surfaces.**

When we consider that the De Sales Street surface in Washington, D. C., which is a mixture very similar to the stone-filled sheet asphalt, has already lasted forty-one years, it does seem that the argument of what type of surface to use on most residential streets should be about closed.

Pavement Cost Data.

There are very few pavement cost data of any real value in existance to-day. In most cases, no attempt whatever has been made to keep them, and in those cases where a sincere effort in this direction has been made, the results are vitiated by one or more causes over which the official keeping the records has in most cases had little or no control.

All records of past performances must be read in the light of present knowledge of altered conditions in the performers, and with a recognition of the merits of the new competitors in the field. All things change. At least some slight improvement in pavement construction is made each year; and traffic conditions are constantly becoming more severe. Even the caliber of city officials and public contractors is improving with the spirit of the times.

The most corrupting influence upon the gathering of past pavement data has been the political situation, for where the city engineer depends upon a politician for his tenure of office, and the politician either is the contractor or is dependent upon the contractor for his campaign funds, the vicious circle is complete and the engineer is in bondage. Add to this the political inspector and the corrupting force of the present competitive system, and the picture is complete. It should not surprise one that many of our pavements are poor.

The future promises better pavement cost data. To-day, for the first time, really good pavements are being laid as a rule and not as the exception in many of our cities, and the habit is spreading.

The knowledge that the original construction was properly conducted is the matter of first importance if our cost data are to be of any value. Then we must know the cost of the wearing surface separate from the cost of the concrete foundation, and must be able to deduct the cost of other items that do not enter into the matter of surface economy.

A card index system is probably the best method of keeping pavement cost data. A separate card should be entered for each block of pavement, and a separate card for each intersection. The number of square yards of surface laid and the cost per square yard, with dates and other data, should be entered on these cards, and as repairs are made, the date, yardage and cost of these should be entered also, either on the same card, or on a separate card to be filed with it, preferably locating the repairs with a diagram on such separate cards.

When it becomes necessary or desirable to renew the pavement wearing surface, its actual annual average cost should be figured in the manner illustrated in the following paragraphs.

Calculating the Annual Cost.

It must be clear to everyone who gives the matter a moment's thought that no true basis for determining the actual average annual cost of a pavement wearing surface can be reached until all the debits and credits have been reduced to a common factor of time, for it is evident that it costs more to spend a dollar to-day and pay four per cent interest on it for the next ten years than to spend that dollar at the end of the ten year period, since in the latter case we have saved the interest value for that length of time.

There are two equally good ways of arriving at the actual average annual cost of a street pavement wearing surface that has become a matter of history. We can either discount all the later expenditures and receipts on its account to the time of its laying, and work on that figure as a basis; or we may compound interest upon all the debits and credits to the time of its removal, and by using the proper method, secure exactly the same accurate result.

In the first case, to the original cost of the pavement wearing surface must be added the cost of each year's repair bill discounted to the time of the laying of the pavement surface, from which amount must be subtracted the salvage value of the old materials at the time the surface is removed, also discounted to the time of the laying of the surface, which gives us the original cost value. Interest table number two shows the discounts of one dollar, and by using this table, the figures are easily made.

When the original cost value has been determined, it should be reduced to a unit basis by dividing the total by the number of square yards of surface under consideration. Interest table number five will give us the annual cost of amortizing one dollar in the number of years that the surface has remained on the street, so by multiplying this figure by the original cost value per square yard, we arrive at the real average annual cost per square yard.

The other way of arriving at the same result is by compounding interest on the original cost of the pavement surface, and on each year's repair bill, from he time of the expenditure until the time of the removal of the surface, and deducting from this amount of principal and interest the salvage value of the removed wearing surface. Interest table number one shows the compounded value of one dollar and interest for the number of years desired.

When the final cost value has been determined by this method, it should also be reduced to a unit basis by dividing the total by the number of square yards of surface under consideration. Interest table number six will then give us the annual cost of a sinking fund that will create a dollar in the number of years that the surface has remained on the street, and by multiplying this figure by the final cost value per square yard, one arrives at the same real average annual cost per square yard determined by the first method.

The Dual Cost Systems.

For example, we will take the stone-filled sheet asphalt type of pavement wearing surface, and assume the following as the fictitious history of the case.

One thousand square yards of surface were laid on a given street in the year nineteen hundred at a cost of seventy-five cents per square yard.

In the laying, two burnt batches were used, and it was necessary to make ten square yards of repairs at one location in the year nineteen-one.

Wear holes began to appear after the tenth year, and in the year nineteen-eleven it was necessary to repair fifty square yards of surface.

In nineteen-thirteen, one hundred and fifty square yards had to be relaid for the same reason, and in the year nineteen-fifteen it was thought advisable to take up the entire one thousand square yards and relay it.

The small repairs all cost at the rate of one dollar per square yard; and when the old surface was removed from the street and hauled to the plant, the materials thereof were estimated to have a salvage value of twenty-five cents per square yard, which was credited to the street and debited to the special account kept of work performed with old materials.

In making the allowance for the old wearing surface materials, it was taken into consideration that to otherwise dispose of them would have required a longer haul and the payment of a dump charge at the destination.

CALCULATIONS FOR AVERAGE ANNUAL COST.

Dual Cost Systems:	Original Cost Value	Final Cost Value
Cost of originally constructing 1,000 square yards of stone-filled sheet asphalt wearing surface in the year 1900 at $ .75 per square yard—		
With no interest discount	$ 750.00	
With compound interest to 1915		$1,350.70
Cost of repairing 10 square yards in the year 1901 at $ 1.00 per square yard—		
With interest discount to 1900.	9.62	
With compound interest to 1915		17.32
Cost of repairing 50 square yards in the year 1911 at $ 1.00 per square yard—		
With interest discount to 1900.	32.48	
With compound interest to 1915		58.49
Cost of repairing 150 square yards in the year 1913 at $ 1.00 per square yard—		
With interest discount to 1900.	90.09	
With compound interest to 1915		162.24
Total debits	$ 882.19	1,588.75
Credit for 1,000 square yards of old wearing surface materials hauled to the paving plant in 1915, for re-use, at $ .25 per square yard—		
With interest discount to 1900.	132.82	
With no compound interest, 1915		250.00
1900—Total original cost value	$ 743.37	
1915—Total final cost value ...		$1,338.75
Total square yards 1,000	$ 743.37	$1,338.75
1900—Cost per square yard ..	$ .7434	
1915—Cost per square yard ..		$ 1.3387
Multiplied by annual cost of amortizing $ 1.00 in fifteen years, taken from amortization table number five on page thirty-four	.0899	
Multiplied by annual sinking fund payment required to produce $ 1.00 in fifteen years, taken from sinking fund table number six on page thirty-four		.0499
Average annual cost ...	**$ .0668**	**$ .0668**

It will be noted that either system of figuring brings the same result, and that the late lamented stone-filled sheet asphalt wearing surface on the street in question has cost on the average $ .0668 per square yard per annum for the fifteen years that it remained with us.

If such information were available, we might add to this the annual cost of cleaning per square yard, which would be lower for a sheet asphalt wearing surface than for any other; but reliable figures on this point are very difficult to secure at the present time, and evidently would not change our conclusions.

The other factors of real cost would not add a very imposing figure to that already at hand, and are not even as available as the figures extant on the costs of celaning. The advantages of one surface over another in the cost of power to traffic, cost of resulting vehicular upkeep, extent of home industry and possible outside control of production should not be lost sight of, however, even if they add but slightly to the annual cost of street transportation viewed in the broader sense.

There are, of course, many other angles to this problem. Was the surface removed at the most economical time? for instance. Would the average annual cost be reduced by removing it a few years later? or sooner? Also, still greater accuracy can be had by figuring each expenditure to the day instead of to the year; but the author does not think the additional work warranted.

Good Asphalt Pavement.

The essentials of a good asphalt pavement are:

1. A solid, well drained sub-base.

2. A standard Portland cement concrete foundation.

3. No intermediate binder course or paint coat.

4. A high grade asphalt cement, from any source.

5. A standard or stone-filled sheet asphalt wearing surface, scientifically graded and proportioned and properly mixed and laid, one and one-half, two, or two and one-half inches in thickness, but uniformly of the thickness chosen, placed directly upon the concrete foundation and shoveled into position and thoroughly raked out before being rolled to a true surface.

Four inches of concrete will sometime be sufficient upon residential or light traffic roads and streets that have a good sub-base, or even an average three inches as a concrete capping will sometimes serve heavy traffic when the sub-base is a good old Telford macadam roadway. The standard is six inches, and it is possibly best to adhere to this thickness unless there seems special reason for doing otherwise.

The surface of the concrete foundation should be true to line and grade with not more than one-half inch variation allowed; but the surface should be carefully roughened in a uniform manner so as to give the asphalt wearing surface the best possible latteral support. Variations greater than one-half inch are undesirable in the thickness of the asphalt wearing surface; though this of course does not include the occasionally greater projections and depressions due to the careful roughening of the surface of the Portland cement concrete foundation.

While two inches is the standard thickness for a stone-filled sheet asphalt wearing surface, one and one-half inches have been used to advantage on residential light traffic roads and streets, and two and one-half inches are probably advisable on some heavy traffic streets. It should be borne in mind, however, that an asphalt wearing surface is but the carpet; the concrete foundation is the pavement proper that is protected and made suitable for traffic by such carpet.

A too great thickness of asphalt wearing surface is of no advantage, as it only tends to develop unevennesses more rapidly, and is more difficult and more expensive to repair. The difference in original cost between a thicker and a thinner surface, and the compound interest thereon, can always be used to advantage later, even if it is in making earlier repairs to the thinner surface than a thicker might require.

When a good asphalt pavement is laid, a guarantee or maintenance bond is not needed. In these days of independent and competent chemical engineers and paving specialists, it is within the power of every city to know whether the pavement it is buying is what it should be. The cost of a bond is really the price of incompetence or indolence on the part of the official in charge. At its best, it is but a poor substitute for honest inspection.

The So-Called Binder Course.

The author has never been able to locate or acquire a legitimate reason for the laying of the so-called binder course between a concrete foundation and a sheet asphalt wearing surface. The name is certainly a misnomer for the one inch thickness of crushed stone coated with asphalt cement, since this material does not and can not bind anything.

When the so-called binder course is laid upon the concrete foundation, it does not adhere to it any more than does a sheet asphalt wearing surface laid thereon direct; which is not at all. In fact, if it did actually bind anything, that alone would be a sufficient reason for not laying it; as such a binding would be very undesirable from the maintenance point of view, and entirely unnecessary for any other reason that has yet been advanced.

The sheet asphalt wearing surface at once binds or adheres, by heat fusion, to the so-called binder course as soon as it is laid thereupon; and then the binder course becomes a permanent part of the sheet asphalt surface, and a very undesirable part.

The open binder course formerly used was found to be an actual source of weakness, so in recent years it has been strengthened by a filling of sand that makes it really an asphaltic concrete intermediate course that would act as a wearing surface by itself: though it would not be a very good one. At its best, it is a Bitulithic surface covered over with sheet asphalt mixture to keep it from wearing out.

As this book goes to press, it is interesting to note that the Borough of Manhattan, New York City, after making some investigations, has determined to lay several miles of sheet asphalt pavement during the present season without the so-called binder course between the concrete foundation and asphalt surface. Mr. E. W. Stern, Chief Engineer in charge of Highways, has recently advised the author to that effect.

The Naptha Paint Coat.

Neither is the paint coat that is sometimes used on the concrete foundation before the sheet asphalt wearing surface is laid a desirable thing, though this usually appeals to the layman paver. While it actually accomplishes a binding that the so-called binder course does not, as before stated, such a binding of the wearing surface to the foundation is unnecessary and actually undesirable in the case of a good sheet asphalt pavement.

There is no force that tends to pull a sheet asphalt wearing surface from its foundation until the pick in the hands of a repair man is applied; and then, the easier it comes up the less expensive is the operation. Neither a binder course so-called, nor a paint coat, ever prevented an asphalt wearing surface from shoving. They are both more likely to help the shoving along. It has been said the first acts as roller bearings; the second as a lubricant.

It is necessary to look to other sources to find the real causes of shoving or creeping in a sheet asphalt wearing surface mixture. Poor sand grading and an insufficiency of filler are not the least of such causes. The uniform roughening of the surface of the concrete foundation will do much to prevent even a poorly constructed sheet asphalt wearing surface from shoving, and is also a distinct advantage in the case of the best type of surface.

A naphtha paint coat to hold a thin bituminous top dressing upon a cement concrete road may function; for this dressing is an uncertain quantity at its best.

The Fine Stone Filling.

A standard sheet asphalt wearing surface mixture is composed of about seventy-three per cent graded sand, fifteen per cent stone-dust or other filler therefor, and twelve per cent bitumen content of asphalt cement. If one adds to this mixture enough clean quarter-inch stone chips, in sizes ranging from one-half inch in the greatest dimension down to one-tenth inch, until the stone chips form about thirty per cent of the total mixture, it is the author's opinion that the resulting pavement surface will be improved.

The stone chips in the mixture, to an extent not exceeding thirty per cent that will be held on a ten mesh sieve, and in size not greater than one-half inch, will act as a reinforcement to the mixture; hardening the pavement surface so that traffic will not be impeded by sinking slightly into it even in very warm weather, and hindering the mixture from shoving or creeping if there is a tendency that way. The stone chips also make the surface presented for traffic more gritty, and therefor less slippery in wet weather.

A rough statement of the ingredients of the types of sheet asphalt wearing surface is about as follows:

Sheet Asphalt Wearing Surface:	Standard	Stone-filled
Asphalt Cement, Bitumen content	12%	10%
Stone-dust Filler	15%	10%
Graded Sand	73%	50%
Stone Chips, ½-inch down	00%	30%
Total Paving Mixture	100%	100%

It is only a co-incidence, but a very interesting one, that when a standard sheet asphalt wearing surface, with the so-called binder course attached, is taken up, remelted and remixed, the result is a reasonably good stone-filled sheet asphalt mixture. The binder stone is usually three-quarter instead of one-half inch in its largest dimension; and if the standard surface was very old, the asphalt cement will be somewhat too hard and in need of a fluxing agent. In some cases, no additions whatever are required.

If instead of crushing the old standard wearing surface into small lumps by hand prior to remelting it, a suitable disintegrator is used, the binder stone will be broken to a more satisfactory size in the operation. It makes very good mixture by the hand breaking process, however, and the author's first experience with stone-filled sheet asphalt wearing surface was gained through producing mixtures for winter repairs in this manner. In one case, the old surface was taken from the trench opening over which the new stone-filled surface, made from the old, was laid; and the two mixtures remained side by side under constant observation for several years.

Fortunately, the so-called binder course has never been used to any extent under stone-filled sheet asphalt wearing surfaces; for instead of improving them in the remaking, the surplus of stone would ruin them, making something like a bituminous macadam surface. The separation of the binder course from the wearing surface is a practical impossibility, and no one would attempt it with the paving equipment now known.

Asphalt at the Car Rail.

Some think that a sheet asphalt wearing surface can not be successfully laid abutting a street car rail. If the rail construction is light and the work of laying poorly done, this is quite true. It is also true in the case of every other kind of pavement surface.

When heavy rail construction is used, and the ties well bedded in concrete or broken stone, sheet asphalt can be laid abutting the rail and maintained there on most streets at a lower average annual cost per square yard than any other type of pavement surface. The work must be done properly, however, and in accordance with well known principles.

The correct form of construction abutting a car rail is to first parget the side of the rail with cement mortar or other suitable filling material so that it will have a perpendicular side from the edge of its head or lip to the base of the rail. The concrete foundation should be laid abutting this perpendicular side without any attempt to form a bond, and should be slightly depressed at the rail to allow a slightly greater thickness of wearing surface at this point. The sheet asphalt wearing surface should then be laid as nearly as possible flush with the top of the rail, a cushion of the mixture being first tamped in place. The last two items are of considerable importance.

It would be an improvement to paint the pargeted side of the rail with asphalt cement before placing either the concrete foundation or asphalt wearing surface against it. As in laying a sheet asphalt wearing surface, however, it is the custom to paint all abutting surfaces with asphalt cement just before placing the wearing surface mixture against them; it is only necessary to see that this regulation painting is done particularly well at the car rails.

As soon as the cars pass over a section of track against which a sheet asphalt wearing surface has been laid, a separation appears along the side of the rail. This reaches a certain unobjectionable stage and then usually does not increase further. The main idea of having the side of the rail pargeted to a perpendicular line is so that as the rail depresses under the weight of the passing car, though the action be ever so slight, it will take down with it neither the pavement surface nor the pavement foundation.

When the construction work is carefully done, no appreciable amount of moisture will penetrate far into this perpendicular joint along the side of the rail. The asphalt cement paint will add to the waterproofing of this joint, however, and make certain that there will be no bond between the pargeting and the pavement foundation. Even if the rail should sink an inch or so, if the work is done as described there is no reason why the pavement should not remain in place and unshattered by the sinking of the rail.

Asphalt at the Curb Line.

In some cities, it is the custom to lay brick gutters on streets that are to be paved with sheet asphalt: and occasionally cement gutters have been used. This is done on the theory that brick and cement do not decompose from the moisture that is likely to collect and remain in a defective or uncared for gutter.

Where streets are not properly cleaned, so that a considerable amount of leaves and other litter is allowed to collect and remain in the gutters, this may seem a wise precaution. Trouble has also arisen because the flatness of some asphalt gutters has caused them to hold shallow pools of water extending two or three feet from the curb lines.

It is undesirable, however, to have two different types of pavement wearing surface on a street between curbs. It is even undesirable to have them anywhere on the same street; though in some cases, because of steep grades, intensive traffic points, special track work, and for other reasons, this is quite unavoidable.

There is no reason why litter of any sort should be allowed to accumulate and remain in the gutters of any modern city's streets, and in self respecting municipalities such a condition of affairs will not be tolerated. Therefor, this reason for brick or cement gutters, where it exists, should be removed and not catered to by the authorities: and flat spots in gutters will not occur where reasonable attention is given to the grades and cross-sections of a street at the time of paving.

Every possible endeavor should be made to lay a sheet asphalt wearing surface from curb to curb, whether there are car tracks in the roadway or not. If it is desired to lay another type of surface within the tracks, by no means should this other type of pavement be allowed outside the outer rails.

A ribbon of foreign pavement surface either along the curb line or along the rail only adds another joint in the pavement; one that must be maintained by the city, and that is apt to be at a point where it will be directly in the line of traffic and subject to uneven wear at an exceptionally weak spot.

Not only are all the other types of pavement surface more expensive to repair than sheet asphalt, but it is a positive inconvenience bordering on inefficiency to be compelled to send two different repair gangs over one street to take care of the necessary maintenance work and restoration of openings.

Grades and Crowns.

The author has long held the view that the cross-section of a street pavement surface taken from curb to curb should consist of straight and not curved lines. The grade that will shed water towards the curb at a point a few feet from the centre of the roadway will likewise shed water at a point within a few feet of the gutter and at all points between.

An abrupt drop should be arranged in the last three feet near the curbs so as to confine the running water in a narrow stream; but beyond that point, the less the rise to the shoulder of the roadway the better it is bound to be for traffic.

It should not be lost sight of that street pavement surfaces are built primarily to be traveled, and only secondarily to shed water; though some have an idea that it is the other way about, and build accordingly.

The principles for laying out grades are well enough established; at least, the author has no quarrel with them. The saying that a road is no more passable than its steepest hill strikes not so much terror into our souls in these days of automobiles, however, for one now carries his hitch team along with him in his lower gears. The more important question to-day is on how steep a grade may we lay a certain type of pavement surface under given conditions.

For heavy traffic, the stone-filled sheet asphalt wearing surface should not be laid on a grade exceeding five per cent; on light traffic residential streets carrying no necessary through traffic, the limit can with reasonable safety be raised to ten per cent, and some have carried it even higher. There is a wide field for the application of good judgment in the determination of this important point.

To provide in a specification for the crown of a road or street, it may be stated that, unless otherwise expressly ordered by the city, the crown of the finished pavement surface should have a uniform rise of approximately one inch in each foot for the first three feet from the gutter line, and a uniform rise of approximately one-quarter of an inch in each foot from this point to the centre of the roadway, or until the line meets the corresponding line coming from the opposite gutter. Of course, special conditions call for and should receive special treatment.

On such a street, each side of the centre of the roadway, except for three feet from the curbs, is in a plane; and from this plane the gutter dips abruptly to form a decided and narrow channel for the water.

The above statements do not mean that there are sharp angles at the points three feet from the curbs and in the centre of the roadway. In actual practice, these points will be rounded off for about one foot on either side. The crown may be flattened somewhat on very steep grades, and slightly increased on flat sections of street roadway. One not accustomed to examining crowns will hardly notice the difference between the straight line crown and a curved line crown.

Straight lines in the crown make it possible to get a smoother surface, and smoothness of wearing surface is very important. Not only is it a pleasure to ride rapidly in an automobile over a pavement surface that reasonably approximates a true plane, but it is beyond question that such a surface drains better and wears much longer than an uneven one.

In sheet asphalt surfaces, there is less likelihood of the mixture shoving or creeping if it has been laid very evenly; and there is less possibility of it forming depressions that will hold water. A fourteen foot light weight straightedge is a handy thing to have around when any pavement surface is being laid, and when a straight line crown is used, the straightedge can be completely turned around on both sides of the roadway with either very gratifying results or with very unsatisfactory results that should be at once remedied while the surface is still hot.

It pays to have a pavement wearing surface laid correctly; and carelessness, not expense, is usually the main reason for it not being done properly.

Rural highways are best built with a crown of two straight lines, without either gutter or drop at the edge other than a slight rounding off in some cases. The growing practice of having a cross-section of just one straight line at the curves, so tilted as to bank them, seems a matter of common sense.

Guarantees and Bonds.

It does not seem that at this late stage of the game it should be necessary for a city to exact a guarantee on any well known type of pavement surface. City authorities have in their hands the drawing of the specifications for and the full inspection of all paving work; and to ask a guarantee, especially on a standard or well known construction, would seem an admission of incompetence.

At their best, maintenance bonds are very unsatisfactory. The greatest value seems to be in that they satisfy the general demand for something guaranteed; but the public is made to pay far too dearly for this more or less worthless privilege through additional cost added by both the contractor and the bonding company that is his surety.

While it is the author's opinion that the best practice does not require a maintenance guarantee bond, he does think that every city contract should contain what is known as the no-estoppel clause. This clause holds the contractor to a strict accounting if at any future time it is found that he has practised fraud upon the city in the prosecution of his work, or if it is shown that the work was not performed up to the reasonable requirements of the contract.

Such a clause should specify that no acceptance or other action on the part of any city official will debar the city from recovering, at any future time, if the city can show where it has received substantially less in quantity or quality of workmanship or material than that for which it paid.

In one instance of which the author has personal knowledge, the contract called for concrete under the curb, and provided for a five year guarantee on the entire work. The contractor forgot all about the concrete, and set the curb in the natural soil. The people kicked; but the administration, owned by the contractor, accepted and paid for the work in spite of their protests and the known facts.

There was no such clause as that described in the foregoing paragraphs in this contract, and when a new city administration was elected, largely as the result of this and other open frauds practised upon the city, it found that the acceptance of the work by the former administration acted to estop the city from a recovery. The people had a five year guarantee bond, but there was no concrete under the curbs. The city had paid something for nothing.

Inspection and Tests.

If the specifications for street paving are very carefully drawn, and the actual work supervised by competent engineers, with inspectors both at the manufacturing plants and on the road, the city is quite certain to get a good pavement; one that will last twenty-five years on most roadways.

If in place of carefully drawn specifications and competent inspection, the usual five year guarantee is substituted, the city may get a good pavement; again, it may not. The odds are heavy that it will not. What it is most likely to get, when it relies upon the five year guarantee, is a pavement that will last five years and a day.

In case the contractor makes a slight error in his calculations, and the pavement fails before the five years for which it is guaranteed are up, the matter of securing indemnity from the contractor or bonding company is a very painful one fraught with many technicalities and other difficulties.

The above is not written to reflect upon average contractors. The author has spent much of his life as just an average contractor. It may as well be understood, however, that when paving work is done under the competitive contract system the least a city will accept is the most a contractor can afford to give. Otherwise, the contractor will soon face bankruptcy.

The city authorities set the standard for the work to be done under their supervision, either by their care or their carelessness, and economic necessity compels the contractor to bid to that standard rather than to the wording of the specifications. The contractor may prefer to build good roads; but if good roads are not the standard, he must either build lean roads, or some one else will. Whether the contractor is a good or bad man has not much to do with it; in either case he must make a living in Rome, and he must make it as the Romans do.

When a contractor the author always preferred to do good work. It is a pleasure to build a good road, and, when some friend remarks its excellence, to be able to say, Yes, I built it. But city officials must understand that builders of good roads can not compete with the builders of poor roads, and accordingly, must set high, but thoroughly practical standards to which all builders of roads under their jurisdiction must work. Such city officials will be surprised to find to what an extent they will receive real co-operation from the average contractor; but they had best beware of the contractor who starts in to grow a pair of wings; for wings aren't natural to contractors.

No city should attempt to do paving work of any kind without either its own testing laboratory and good consulting engineering connection, or an arrangement with some responsible firm of independent testing and inspecting engineers and chemists who maintain a well equipped laboratory and are specialists at the particular work.

Vitrified Brick Surfaces.

Recently, an important improvement has been made in the construction of pavements with vitrified paving brick or block wearing surfaces. This improvement consists in the laying of the brick directly upon the new concrete foundation before it has had time to set; or upon a thin layer of dry mortar spread on the wet concrete for the bedding of the blocks, this dry mortar bed being wet through the joints of the blocks as soon as they have been placed, and just before the joints are filled with cement mortar. In either case, the result is about the same; a monolith consisting of concrete foundation and brick surface.

The author laid an improved type of recut granite paving block surface upon a concrete foundation in this manner several years ago, and thinks the method a decided advance in the art of constructing the block type of surfaces, whether granite or brick blocks are being used. It should be borne in mind that this method of laying, while probably adding to the original life of the pavement surface, will also increase the difficulty and cost of making repairs and renewals.

It might also be urged in favor of the laying of vitrified brick or block wearing surfaces that when they wear out they can be covered with sheet asphalt wearing surfaces; for in fact, this has often been done. Such an argument, while thoroughly unsound even when advanced in advocacy of cement concrete pavements, has nothing whatever to recommend it when advanced for the laying of a vitrified paving brick wearing surface upon a concrete foundation; for this type of surface costs, not less, but about twice as much as a stone-filled sheet asphalt wearing surface, and will not usually last as long.

In greater New York City, the Borough of Manhattan has not a single vitrified brick pavement wearing surface, the Borough of the Bronx removed and replaced its last surface of this type with sheet asphalt several years ago, and the other boroughs are gradually abandoning this form of pavement.

There may be and probably are some circumstances that would warrant laying and maintaining a vitrified paving brick wearing surface, but the author has not happened to meet such an instance. In several cases, however, he has been forced to lay such surfaces, also creosoted wood paving block surfaces, under protest and against his best judgment, through petitions signed by duped property holders who had allowed themselves to become the pray of clever pavement promoters.

Creosoted Wood Surfaces.

If it can be shown that creosoted wood paving block surfaces can be originally laid and permanently maintained by repair and renewal on certain very heavily trafficked streets at a lower annual cost per square yard than stone-filled or standard sheet asphalt wearing surfaces, then if the economy is sufficient to overcome the points of undesirability in this type of surface, there may be some real reason for laying it.

There can be no legitimate reason for laying it on medium or light traffic streets, unless one thinks that the single advantage of being possibly less noisy than even sheet asphalt is sufficient to warrant its use around hospitals and schools. The author believes the advantage over sheet asphalt that creosoted wood has on this score of noiselessness is of but very slight degree, and by no means sufficient to overbalance the advantage of the sheet asphalt surfaces on every other point of economy and desirability by which pavement surface values must be measured.

The author's opinion of a creosoted wood paving block wearing surface is that, all things considered, it is the poorest investment of municipal dollars in pavement values that is being made to-day. Many will not agree with this, but it is the author's belief that the experience of the next ten years will prove his point of view absolutely correct; and that the creosoted wood paving block craze has nearly passed.

With no other type of wearing surfaces are the results of careful attention to good workmanship and materials so uncertain as with creosoted wood block. Even where the strictest inspection and supervision have prevailed, the surface is apt to start almost at once to perform strange and unaccounted for tricks.

Noteworthy instances of the unreliability of these surfaces that have come to the author's attention are the wood block surfaces on heavily trafficked Battery Place, in the Borough of Manhattan, and lightly trafficked Southern Boulevard, in the Borough of the Bronx, New York City. There is no reason to go into the history of these two surfaces, but the least that can be said of them is that they have acted with marked eccentricity and have proven very extravagant invesments in spite of having been laid under conditions that should have produced the best of the type.

Granite Block Surfaces.

Unlike the creosoted wood paving blocks, improved granite paving blocks meet a real need as a paving material. On heavy traffic steep grades, sheet asphalt can not be used because of its smoothness and its consequent slipperiness in wet and frosty weather. The granite and sandstone paving block surfaces are the only ones that can be used to meet this condition with any real and permanent success.

There are a few other places where an investment in improved granite paving block surfaces is justified in spite of the high cost of original construction. Under certain very intensive heavy traffic conditions the expenditure may even be warranted where the grades are not steep, though there are very few such places even in the larger cities. In street railway special work, around watering troughs, in narrow driveways subjected to much heavy trucking and under other special conditions granite will in the end often prove the more economical material.

But while the author recognizes the real value of improved granite block surfaces for certain conditions of traffic and environment, it is his conviction that such surfaces are being laid to-day in many places where the very high original investment is not warranted. It should be borne in mind that stone-filled sheet asphalt can be had for about one-third as much, and that this type of wearing surface is actually more desirable, where there is no special reason for its not being used, than is the high priced improved granite paving block wearing surface.

Wherever a city has already invested heavily in the old type of large granite block surfaces, as these surfaces need renewing they should be made into improved granite block surfaces by quartering and highly dressing the old blocks and laying the resulting small new blocks in a wet concrete foundation. A description of some work of this nature performed under the author's direction will be found in the May, 1914, copy of Municipal Engineering Magazine. This article gives the process in much detail, and states the actual cost of the work separated into the natural sub-divisions according to operations.

The author wishes to state it as his opinion that no granite block should be over four inches in depth, and that the blocks should be laid on morter beds and not on sand beds. This has been his practice since 1910, and he is glad to see others, including New York City, adopting the same system.

The Durax granite cube pavement now being put on the market in this country, at a somewhat lower price than other granite block pavement surfaces, has a slightly better standing in the matter of economy than the higher priced granite surfaces, of course, and there seems no reason why this pavement should not wear quite as well. There are reasons that make one think it may wear better. The small cubes are laid with closer joints; and when the fan shaped method of paving is employed, it throws nearly all the joints out of line with the direction of traffic.

Other Pavement Surfaces.

The principal types of road and street pavement surfaces only have been considered in the foregoing pages; the standard and stone-filled sheet asphalt, the vitrified paving brick or block, the creosoted wood and improved granite paving block surfaces.

Secondary forms of paving surfaces are asphalt paving blocks, the many proprietary or patented types of bituminous macadam or concrete surfaces, the penetration method bituminous macadam surfaces in which asphaltic or tar road binders are used, the surfaces treated with road oils of asphaltic or tar origin, and the cement concrete surface. While the author does not look upon any of the above as ranking with pavements of the first class, it may be well to say a word concerning them in passing.

Dirt roads and gravel surfaced roads cover a large road mileage that is but little travelled; and are a study in themselves, made necessary by the fact that some communities can afford nothing else. In far too many places, however, these unsatisfactory road surfaces are tolerated long after the economic advantage of the rural section in which they are doing service has demanded a hard surfaced pavement; and many such rural sections are backward in their development more from this one reason than for any other.

Many public officials have lent their ears to pavement promoters for so long that they may look upon some of the pavements classed as secondary as being in the first class. However, a few consultations with some one who understands pavements and is under no obligation to sell a particular type might open their eyes in more than one sense.

Asphalt Block Surfaces.

Where very small areas are to be paved and there is not sufficient work in view to justify the importation of an asphalt mixing plant, a reason exists for laying an asphalt block surface. These pavements are smooth, pleasing to the eye, and afford about the same foothold and tirehold as do stone-filled sheet asphalt and fine asphaltic concrete surfaces, which are slightly better than that afforded by standard sheet asphalt.

There is no great difference between the mixture used in the manufacture of asphalt paving blocks and the mixtures laid as stone-filled sheet asphalt and fine asphaltic concrete surfaces. The great advantage of the latter types is that where there is a mixing plant available it is more economical to lay the mixtures directly upon the road or street than it is to manufacture them into blocks at a much more expensive plant and then lay the blocks upon the roadway.

For small cities or villages that desire to improve their best residential streets, public squares and driveways, an asphalt block surface is certainly more to be desired than a vitrified paving brick surface; for the latter is very noisy and becomes more so with age, while the former is almost noiseless and remains that way as long as it is kept in reasonable repair.

Many of the disadvantages of the block class of surfaces also apply to the asphalt block surfaces; though the latter differ very widely in that they are plastic at high temperature while all the other block surfaces are brittle under all weather conditions. For this reason, the joints do not become more open with age, but the asphalt blocks weld together until the surface frequently resembles in appearance one of stone-filled sheet asphalt.

The expensiveness of an asphalt block manufacturing plant and the necessity for having it centrally located to serve a wide geographical area, thus requiring that the blocks must be freighted to their destination in most cases, coupled with the fact that over ninety per cent of stone and sand as contained in the manufactured blocks is often shipped from great distances directly past local supplies of these materials, makes a very heavy handicap for the asphalt block form of bituminous pavement construction as compared with the sheet layer forms.

The labor cost of laying asphalt blocks upon the street is between two and three times that of laying the hot mixtures of the stone-filled sheet asphalt and other sheet layer surfaces; besides which it must be remembered that the objectionable block joints are present even though in a mitigated form, and both the cost and the difficulty of making repairs are much higher for the block surface.

Wherever arrangements can possibly be made to secure an asphalt mixing plant, there is no good reason for laying as asphalt paving block surface at from fifty cents to one dollar per square yard more than a stone-filled sheet asphalt wearing surface would cost; for the latter, besides representing a lower capital expenditure, is in many other ways both more desirable and more economical.

Patented Roadway Surfaces.

For a patent to entitle the inventor or exploiter to a return, it must either accomplish something that has not been accomplished before, or perform something that has been done before in a way that is such an improvement over the methods previously in use as to justify by the results any additional cost that is asked for the patented article or process.

Patented pavements may in some cases be worth what their inventors and exploiters ask for them; but as a matter of fact most of the well known proprietary pavements of to-day are neither an improvement over nor as good as the standard unpatented pavements that have been laid for years and that can be manufactured by any one possessed of the necessary information and plant equipment.

A number of these patented pavements have been on the market for years; some of which are quite good, and others very poor. Circumstances may arise under which it would be advisable to select one of the better class of these proprietary pavements, but it depends entirely upon local conditions. The author does not believe that the adoption by a community of a pavement under the control of patents is warranted unless all the surrounding facts have been carefully weighed and it has been definitely determined that the preponderance of the evidence, as diligently sought out, is very greatly in favor of the patented surface.

Many millions of square yards of certain copyrighted and otherwise controlled pavements have been laid in the United States and Canada for the selection of which the author believes there was no good and legitimate reason. These patented pavements are more expensive and less desirable and durable than unpatented forms of pavement surfaces that were equally available, and their selection therefore obviously required careful data to support the additional expense.

This much may be said about the patented and proprietary pavements; the owners of the monopolies, as a rule, desire to do reasonably good work in order to make a reputation for their advertised products. Unless a community is doing its work under careful engineering and chemical control, as all communities should, then it is more apt to get poor work from a contractor who has no property right in the particular type of surface he is laying and who will not suffer financially by its failure provided such failure occurs after the expiration of his guarantee.

One should demand a carefully supported and convincing statement over the signature of some well known and responsible paving engineer before investing money in forms of pavement surfaces that are subject to monopoly control: and such statement should set forth definitely that the patented pavement at the price asked may be expected to be more economical in the long run than all other types available, and it should give the explicit reasons that lead the engineer to form his opinion.

Penetration Macadam Roads.

The only sound reason for laying a penetration method bituminous macadam road, using either asphalt or tar binding cement, is the same reason that will in some cases justify the construction of asphalt block surfaces; namely, where the amount of work is small, no asphalt mixing plant is available, and there is not sufficient work in sight to warrant the importation of such a plant.

The small saving in the cost of originally constructing a penetration method bituminous macadam road surface upon either a broken stone, old macadam or concrete foundation, over what it would cost to lay a stone-filled sheet asphalt or other mixed method bituminous wearing surface upon a like foundation, is not sufficient to justify the former much inferior type of construction. This is particularly true when the future maintenance of the road is considered; for after a few years the penetration method road is sure to require a great deal of attention that will run into heavy annual repair bills.

It is unfortunate that so many of our road authorities fail to see further ahead than their terms of office, or until after the next election; and look upon their road work as a political rather than an engineering science. The results of this attitude on the parts of many public officials may be seen on every side.

The author prefers the asphaltic road binders to the tar binders, as he considers them both more satisfactory and enduring. The tar binders are far more susceptible to the changes in temperature, being very hard and brittle in winter and very soft and sticky and inclined to bleed excessively in Summer. This will be readily appreciated if one has had the opportunity to daily observe a point where a section of road built with asphaltic binder meets a section constructed with tar binder. He will have noticed that in cold weather the deadened hoof-beat on the asphaltic section changes to a sharp, metallic sound as soon as the horse passes over the line and upon the section in which a tar product has been used as the road binding cement. In Summer the conditions are reversed, and the tar section is much softer than the asphalt section, in many cases being much too soft.

Road Oils as Preservatives.

As a means of preserving a road from rapid destruction by traffic and to allay the dust nuisance, road oils have been a blessing; though in some instances they are an expensive blessing. Too frequently it is attempted to maintain road surfaces by the oiling method when a study of economy would indicate paving; which might not only represent a lower average annual cost, but would do away with the annual or semi-annual nuisance of oiling the roads and then blocking them off until the oil has set, and would give a road surface in every way superior.

In oiling, one of the most important items is the removal of the dust from the road surface before the oil is applied. It is almost a waste of the entire cost of the oiling to apply it to the surface of a dusty road. After the oil has been spread, clean torpedo gravel or fine stone chips should be scattered. Three-quarter inch clean crushed stone has been used to decided advantage in some cases; but most any likely material will serve fairly well, except fine sand.

Tar road oils being very much a by product, though that in itself does not necessarily depreciate their value, should be subjected to even more frequent and careful analyses than may be necessary in the case of some of the asphaltic road oils known to be manufactured from the heavier crudes, which are likely to be more uniform.

The large amount of free carbon present in many of the road oils and binders manufactured from tars is deserving of careful attention. When removed by the usual testing methods, this free carbon looks exactly like and virtually is nothing more nor less than common lamp black. It cannot possibly function as a binding material on the road, and is waste matter or probably worse that has been purchased, transported and applied where it has no value.

Tar road oils and binders should only be compared in price with those of asphaltic origin after an allowance has been made for the free carbon present. The author would only use the tar products for road oiling if the cost were much less than for an asphaltic oil, but would much prefer not to use tar road binders at all where the high grade asphaltic products could be had at a reasonable cost. In bituminous macadam work, the collateral expenditures are too great to risk by using a doubtful ingredient, and experience with tars has in many cases been rather sad.

It is a significant fact that none of the tar cements produced to-day are ever used in a sheet asphalt pavement or even recommended therefor; and the claim that the free carbon in a road oil is analogous to the filler material in a sheet asphalt surface is ingenious, but has no application in road oils and binders.

Cement Concrete Pavements.

The modern cement concrete pavement seems to many to be an important innovation; and it is an important one—to avoid. It may be that the only way some officials will learn their real value, or lack of it, is by experience. They are likely to get this experience within the next five years, but in the meantime, as in other well known cases, much public money will have been unnecessarily spent.

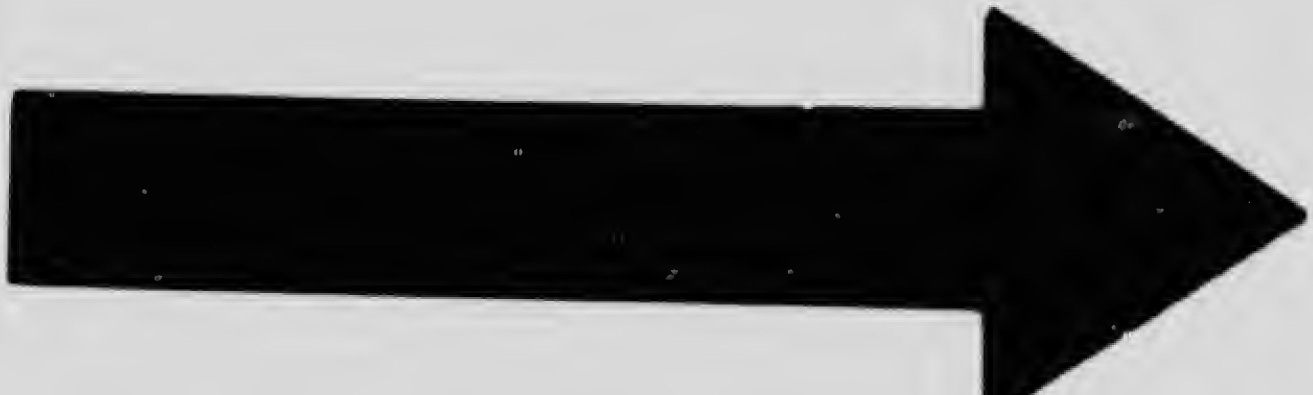
Cement concrete pavements have no suitable wearing surface. They are really extravagantly built pavement foundations exposed directly to traffic so that all possible damage can be done to them in the shortest possible space of time. In a few years, and in some cases a very few, they develop, almost without exception, widered expansion joints and cracks, especially longitudinal. The chipping off of the edges of construction, which usually are spaced about twenty-five feet apart, is unavoidable if the traffic is at all heavy, and the other cracks grow wider and wider until they are finally repaired in an unsightly manner with a bituminous cement and sand. In the last stages of desperation, some places lay real pavement surfaces over these much abused concrete foundations.

It will hardly be maintained that the surface of a cement concrete pavement is a desirable one. It is hard upon the horses, and glaring to the eye; and the unsightliness of the cracks and joints, increasing with age, is such that it requires magnificent selling ability on the part of highly specialized promoters in the employ, directly or indirectly, of the cement manufacturers' associations, to cause one to overlook these facts. Why lay a good floor in one's house and not put a pleasing and protecting rug or carpet upon it? Why lay a concrete road foundation and not put a pleasing, protecting and economical surface upon it?

The answer is that the cement manufacturers do not want one to, and therefore promotion funds of large proportions have been created and cement concrete roads have been boomed as no other road has ever been boomed before; with the inevitable result. The real reason most concrete roads are laid is not that anyone who is a road specialist of long experience believes they should be laid in preference to other roads, but for the reason that the cement companies sell just twice as much cement per mile for a concrete road as they would for a concrete foundation of the same width and thickness. Their bill for cement is so high that out of it they can well afford to take a goodly sum for further promotion work; and this they do, thereby making the public the victim of its own generosity. Cement concrete roads blow dust into people's eyes in more ways than one.

If the cement concrete road were a very cheap construction, more reason for laying it might be found; but, comparatively speaking, it is not cheap. In fact, a concrete foundation and a stone-filled sheet asphalt wearing surface can frequently be laid for about the same money, and in no case where there is a large amount of work to be done will the cost of the high grade asphalt pavement be much more.

The asphalt surface may be expected to go many years practically without repairs, and can finally be re-surfaced at a very low cost, re-using the old mate-



MICROCOPY RESOLUTION TEST CHART

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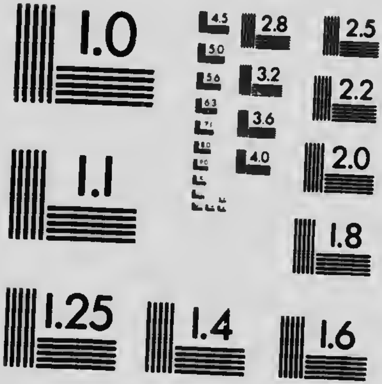

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rial. The concrete surface will not only need extensive repairs sooner, but the re-surfacing, when that becomes necessary, will be practically a rebuilding. In the intervening space of time, an unsightly road surface will have taken the place of a well known type of construction, more pleasing in appearance, and representing a considerably lower average annual cost than the cement concrete exposed surface.

It may just as well also be considered that when repairs need to be made to a cement concrete road, it requires the same withdrawal of the road from use while the cement sets up that proved such a nuisance at the time of the original construction. This is a matter of very serious inconvenience. The asphalt surface can be repaired and the repaired section thrown open to traffic almost at once.

Beware of the cement concrete road!

An Interesting Summary.

The following table setting forth opposite each point of desirability and economy the relative positions of each of the high grade pavement surfaces in relation thereto is quite interesting. While no doubt many readers will differ in the rating of the several surfaces on some points, the preponderance in favor of the sheet asphalt surfaces is so great that it will take a great amount of shifting of the first merit marks to alter even a little the conclusions drawn by the author.

The figure one indicates first merit, and the different grades of demerit are indicated by the higher figures up to figure five.

The Author's Opinion.

Possibly, after writing at such length upon the subject of street paving economy, the author will be pardoned if he states the general paving policy that he thinks at least ninety per cent of our cities could adopt to their lasting advantage, as follows:

All street roadways to have a pavement which shall consist primarily of a standard Portland cement

SUMMARY TABLE.

Character of Pavement Surface:	Sheet Asphalt.	Vitrified Brick	Creosoted Wood	Improved Granite.
Smoothness	*1	3	2	3
Clealiness	*1	2	2	2
Sanitation	*1	2	3	2
Dustlessness	*1	2	2	2
Noiselessness	2	5	*1	5
Non-slipperiness	3	2	5	*1
Ease of Traction	*1	3	2	3
Ease of Construction	*1	2	2	2
Ease of Repair	*1	2	3	2
Ease of Renewal	*1	2	2	2
Susceptibility to Repair	*1	3	3	2
Susceptibility to Renewal	*1	2	2	2
Susceptibility to Constant Use	*1	2	2	*1
Attractiveness to the Eye	*1	3	2	2
Cost of Construction	*1	2	3	4
Cost of Repair	*1	3	4	5
Cost of Renewal	*1	3	4	5
Average Annual Cost	*1	5	4	3
Cost of Cleaning	*1	3	2	3
Cost of Motive Power to Traffic	*1	2	2	2
Cost of Resulting Vehicular Upkeep	*1	3	2	3
Extent of Home Industry	*1	3	4	5
Extent of Possible Home Control	*1	3	1	5
Durability	3	4	3	*1

concrete foundation six inches thick and of one-three-six mixture, all foundations to be covered with a suitable and economical pavement wearing surface.

Stone-filled sheet asphalt pavement wearing surface from one and one-half to two and one-half inches in thickness, according to traffic, should be adopted as the standard pavement wearing surface, and used wherever there is no good and sufficient reason for employing another material.

Improved granite paving block wearing surfaces three to four inches in thickness to be laid on all roadways carrying heavy traffic where the grade is too steep to permit the use of stone-filled sheet asphalt, in street railway special work, around watering troughs, and in other places where stone-filled sheet asphalt will not stay in place; and on those blocks and points of intensely heavy traffic where experience proves that granite paving blocks are sufficiently lower in average annual cost, or otherwise sufficiently desirable to justify their use at the particular location despite their high original cost.

On light traffic residential streets where the grade is too steep for stone-filled sheet asphalt and the situation will not justify the expense of an improved granite block wearing surface, the ordinary concrete foundation or a little better to be laid with well roughened upper surface and left uncovered. This will crack and wear, but what of it? The average annual cost will be low compared to granite, it will be sanitary and clean, and it can later either be surfaced with improved granite blocks or crushed and used as aggregate for a new foundation for them.

Other pavement wearing surfaces should not be laid at all unless there are good and sufficient reasons therefor that overcome the facts presented herein; which reasons will, of course, prevail in some cases covering but a small percentage of the total pavable area of our city streets.

While this book has been written with city and interurban roadways principally in mind, the same facts and conclusions will apply to country and village highways where there is sufficient traffic to justify the laying of a pavement surface instead of putting up with a gravel or earth road covering.

CHARLES A. MULLEN

84 Saint Antoine Street, Montreal.
198 Broadway, New York.

March 30th, 1917.

Standard Sheet Asphalt Surface Mixture.

The accompanying photograph is a facsimile of the routine report on a standard sheet asphalt wearing surface as laid by the City of Montreal under the advice and direction of the author, acting for the Milton

FORM 1 PP 7-16

M EAST 1916 9-12

REPORT AND ANALYSES ON ASPHALT PAVING MATERIALS

Milton Hersey Company, Ltd.

INSPECTORS, ENGINEERS, and INDUSTRIAL CHEMISTS.

Directors of Industrial Operations

Dr MILTON L. HERSEY, President. Consulting Chemist to Quebec Government. City Analyst for Montreal.

ROBERT JOB, A.B., Vice-President. Director of Laboratories.

C. R. HAZEN, M Sc., Vice-President.

J. B. SAXE, Sec'y and Treas.

CAPT. JAS. G. ROSS, Consulting Mining Engineer.

CHARLES A. MULLEN, Director of Paving Department.

Main Office and Laboratories: 84 ST. ANTOINE STREET MONTREAL

Western Office and Laboratories: 287 PORTAGE AVENUE WINNIPEG

Formula of Manufacture	Pounds	Per Cent
Asphalt Cement	120	
Filler—Stone Dust	150	
Filler—Portland C'm't		
Sand from Collector	20	
Sand from Heating Drum	710	
Total Batch of Mixture	1000	

SAMPLE OF ASPHALT MIXTURE

Taken at Mixer of
EAST DIVISION ASPHALT PLANT
by Walter C. Adams.
8 A. M., SEPTEMBER 12th, 1916.
Mixture going to
LEPAILLEUR; N.Dame & Lafontaine.

Test No. M-743		Results of Tests of Sample Submitted				Model Mixture		Variations	Specifications		
									[illegible]	[illegible]	[illegible]
Bitumen		12	4	12	4	12	12		10	14	
Passing	Held on	Note.—Figures show percentages by weight.									
200	Mesh	12	8	12	8	13	13		10	20	
100	200	18	0			13					Not Less Than
80	100	10	0	28	0	13	26		10	35	25
50	80	20	4			23			4	35	15
40	50	12	4	32	8	10	33		4	25	to 50
30	40	6	4			8			4	20	10
20	30	6	0			5			4	12	to
10	20	1	6	14	0	3	16		2	8	35
Mesh	10								Penetration of Asphalt Cement		60
Totals		100	0	100	0	100	100	Test run by	W. M.		

REMARKS: This is an excellent paving mixture.

MILTON HERSEY COMPANY, LTD.

C. A. Mullen

DATE 9-12-16. DIRECTOR OF PAVING DEPARTMENT

Hersey Company. In some cases it was necessary to lay the so-called binder course because the concrete had already been prepared for a three-inch thickness of surface; in others, where it was possible, the so-called binder was eliminated at the author's suggestion.

Stone-Filled Sheet Asphalt Surface Mixture.

The accompanying photograph is a facsimile of the routine report on the stone-filled sheet asphalt wearing surface that appears on the page opposite. That part of the aggregate which will pass a ten mesh sieve has

FORM 1. P.P. 7-16

STONE-FILLED **M** WEST 10-25 1916.

REPORT AND ANALYSES ON ASPHALT PAVING MATERIALS

Milton Hersey Company, Ltd.

INSPECTORS, ENGINEERS, and INDUSTRIAL CHEMISTS.

Directors of Industrial Operations

Dr MILTON L HERSEY
President,
Consulting Chemist to Quebec Government.
City Analyst for Montreal.

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CHARLES A. MULLEN
Director of Paving Department.

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FORMULA OF MANUFACTURE	POUNDS	PER CENT
ASPHALT CEMENT	90	
FILLER - STONE DUST	100	
FILLER - PORTLAND C M T		
SAND FROM COLLECTOR		
SAND FROM HEATING DRUM	510	
4 MESH STONE HEATING DRUM / 2 MESH STONE HEATING DRUM	300	
TOTAL BATCH OF MIXTURE	1000	

SAMPLE OF ASPHALT MIXTURE

Taken at Mixer of
WEST DIVISION ASPHALT PLANT,
by Charles A. Mullen
9:30 A. M., OCTOBER 25th, 1916.
Mixture going to
SMITH; McCord and Murray.

REMARKS: This is a good mixture.

TEST NO M-?042	RESULTS OF TESTS OF SAMPLE SUBMITTED		MODEL MIXTURE		VARIATIONS	SPECIFICATIONS		
						Minimum	Maximum	Totals
BITUMEN	9 6	9 6	10	10		8	12	
PASSING / HELD ON	Note.—Figures show percentages by weight.							
200 / MESH	12 4	12 4	10	10		7	14	Not Less Than 18
100 / 200	14 2	18 8	9	18		7	25	
80 / 100	4 6		9					
50 / 80	12 4	19 2	16	23		3	25	11 to 36
40 / 50	6 8		7			3	18	
30 / 40	4 6	14 2	6	12		3	14	7 to 25
20 / 30	5 4		4			3	9	
10 / 20	4 2		2			2	6	
4 / 10	16 8	25 8	18	27		11	25	20 to 35
2 / 4	9 0		9			4	10	
/ 2						PENETRATION OF ASPHALT CEMENT	52	
TOTALS	100 0	100 0	100	100	TEST RUN BY	J. H. C.		

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C. A. Mullen
DATE 10-27-16 DIRECTOR OF PAVING DEPARTMENT

substantially the same grading as the standard sheet asphalt wearing surface shown in the facsimile report on the foregoing page, to which standard mixture stone-chips have been added to approximate between twenty-five and thirty per cent of the total.

Stone-Filled Sheet Asphalt Wearing Surface.

The accompanying photograph is an actual size reproduction of the wearing surface of a stone-filled sheet asphalt pavement laid by the City of Montreal under the advice and direction of the author, acting

for the Milton Hersey Company. The surface shown is of a section cut from the pavement and rubbed down on a marble bed to bring out the texture of the paving mixture as it will develop under traffic. This type of surface is usually laid without the so-called binder.

Grading of Sand Aggregate for Sheet Asphalt.

The accompanying photograph is a facsimile of a routine report on sand for asphalt paving purposes taken after it had passed through the drying and heating drum. It indicates some of the many difficulties

FORM E PP 7-16

S NORTH 11-23 1916.

REPORT AND ANALYSES ON ASPHALT PAVING MATERIALS

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Directors of Industrial Operations

DR MILTON L. HERSEY, President. Consulting Chemist to Quebec Government. City Analyst for Montreal.

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CHARLES A. MULLEN, Director of Paving Department.

Main Office and Laboratories: 94 ST. ANTOINE STREET MONTREAL

Western Office and Laboratories: 237 PORTAGE AVENUE WINNIPEG

IF SAND IS A MIXTURE OF TWO OR MORE SANDS, THE ORIGIN AND PROPORTION OF EACH MUST BE STATED BELOW	SAMPLE OF DRUM SAND	
		Taken at Mixer of
Saint Emelie Junot.	NORTH	DIVISION ASPHALT PLANT
Mixture of		by Joseph Labelle.
6 parts fine sand	7:30 A. M., NOVEMBER 23rd, 1916.	
3 parts medium		Furnished by
1 part coarse	J. AYBRAM, Joliette, Quebec.	

TEST NO. M-1265.		RESULTS OF TESTS OF SAMPLE SUBMITTED				MODEL GRADING		VARIATIONS	SPECIFICATIONS [illegible]	SPECIFICATIONS [illegible]	SPECIFICATIONS [illegible]
FOREIGN MATTER											
PASSING	HELD ON	Note.—Figures show percentages by weight.									
200	MESH	2	8	2	8					5	
100	200	13	6	-		17			10	25	20
80	100	11	2	24	8	17	34		6	20	to 40
50	80	38	4			30			5	40	20
40	50	20	8	59	2	13	43		5	30	to 60
30	40	7	6			10			5	25	12
20	30	3	2			8			5	15	to
10	20	2	4	13	2	5	23		2	10	45
MESH	10								0	5	
TOTALS		100	0	100	0	100	100	TEST RUN BY	I. B.		

REMARKS: This sand is deficient in 80 and 100 and in 10, 20 and 30 and is correspondingly overloaded with 40 and 50 mesh grains. It requires the admixture of larger proportions of the fine and the coarse sands, sufficient to remedy the defects noted.

MILTON HERSEY COMPANY, LTD.

C. A. Mullen

DATE 11-24-16. DIRECTOR OF PAVING DEPARTMENT

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of securing a suitable and uniform sand aggregate for sheet asphalt and stone-filled sheet asphalt wearing surface mixtures. The trouble in this case, though principally with ununiform shipments from the source of supply, was partly due to the plant arrangements.