CITY PAVEMENT PROBLEMS

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The problem of the city paving engineer today, is the securing of adequately strong pavement foundations and satisfactorily smooth pavement surfaces. The problem of the maintenance engineer is the keeping of the foundations from becoming weakened and the surface from being displaced.

Stated thus simply, the matter of city pavements does not appear in a greatly different light from that presented in Tillson's text-book when I studied it twenty-five years ago, but when we come to consider the details of the problem, we find them changed from every angle. A satisfactorily strong foundation today is not the same foundation that would have then been so considered, and the pavement surface that was acceptable to the driver of a horse-drawn vehicle may be an abomination to the driver of a high-speed automobile.

And, if and when a really satisfactory modern pavement has been laid, the problem of keeping it satisfactory is involved in unending complications when it appears that all those agencies which are not actively engaged in chopping holes in the pavement are busily occupied in bouncing heavy trucks and buses over it at high speed.

Probably the most interesting difference grows out of the unwillingness of the public today to release any street from service for sufficient time to permit its repaving in a calm and orderly manner, and so we are beginning to introduce new methods, new materials, and queer subterfuges in order to be able to do our paving work without the general public or the abutting owner realizing that it is going on. Our repair problem is almost as difficult and while night organization for this purpose has not yet appreciably developed, its necessity can already be foreseen, and in our larger cities, at least, it may be expected to be effectively operating within the next few years.

Probably our changed paving situation can be best brought out by considering, in turn, each of the major features of the pavement. The lowest layer of our pavements, that is the subgrade, I will pass over for the present, not because of any lack of realization of its importance, but rather because our growing knowledge of soil mechanics is causing the development of a whole new art in the preparation of the pavement subgrades, and an attempt here even at a cursory review of our present knowledge would result in an elimination of any study of the remaining pavement factors.

Pavement Foundations

When we come to the consideration of pavement foundations, we of course recognize the value of old stone bases, existing in so many of our cities, as foundations for newer pavements, but too often the attempts to make use of these old foundations have resulted in false economies and the quick destruction of expensive surfaces laid over them. In my own practice, every attempt is made to avoid the disturbance of such foundations and I am inclined to consider them as highly consolidated and very satisfactory subgrades, but would desire to have a modern foundation of nearly full depth laid on top of the old stone or macadam. Experience would indicate that a six or seven inch telford stone base in fair condition, should be built up with at least five inches of good concrete in order to be a satisfactory foundation under heavy traffic. In some instances where the existence of street car rails made appreciable raising of grade impossible, we have secured additional strength by washing out all small stone from between the large rip rap, carrying out this operation with a high pressure fire hose and so opening up the top of the telford as to permit of a penetration of two or three inches by the new concrete. In this way a new concrete and the old stone base have been so tied together that a three inch layer over the top of the rip rap becomes the equivalent of possibly seven inches of solid masonry. Where elevations and grades are such that additional concrete base can not be added to the old stone, we agree at once that the old foundation is unsalvagable, tear out as much as is in the way and start anew.

Pavement foundations of bituminous concrete, the so-called "black base", are being used extensively in some localities. These foundations, even in the same thickness, apparently cost more than good cement concrete. Arguments advanced either in justification of a greater expense or of a thinner foundation with black base have not seemed to me to be convincing, and I doubt this type of foundation to be economically justified in many instances. I believe that cement concrete can still be considered the standard pavement base.

The cement concrete foundation itself has been of continually changing character. As I first knew of it, common practice was to construct in thickness of from four to five inches with proportions averaging about 1:4:7, with aggregates to which very little attention was given and not uncommonly with hydraulic cement. We are tearing up the old foundations of this kind at the rate of many miles per year. Now and then, we are surprised to find a section of very hard concrete but in general this base has disintegrated pretty well into the original particles and can be shoveled out like sand and stone. Fifteen years ago, the proportions had been increased in most instances to the 1:3:6 now most commonly

used. Better grading of aggregates was secured and thickness varied from five to six inches, but little attention was given to the quality of the mixing operation and it was common practice to drown the concrete completely in water. Even these improved foundations have in the main been pounded to pieces by the heavy traffic of the last ten years, and our testing gangs sampling these pavements in advance of estimates for reconstruction, occasionally report, "base concrete fair", but almost never, "foundation sound".

We continued to construct foundations of this type long after we should have known better. The profession seemed to shrink from the idea of introducing greater first cost or of attempting to educate contractors and workmen away from their old habits, and it would seem that only in the last five years have we acquired the necessary courage to frankly meet the situation and definitely revise our ideas. Today the paving policies of the larger cities are being radically revised and important projects in the smaller towns are evidencing increased thought along this line.

Stronger foundations than we have been building are now admittedly necessary. Few have had the courage to go beyond this point and attempt to state definitely what strength is needed or what physical form would supply it. Our colleagues in the rural highway field have reduced the concrete pavement to a formula but the assumptions on which this formula is based, are not adaptable to city pavements. We are not prepared to consider the slab unsupported and if we were, we would not be able to agree on the points or extent of the lack of support. Our slabs are broken at numerous points by manhole heads. We may attempt to lay out contraction joints, but we know full well that within a year or two new seams will be created where the repair over trenches will have met the original base. In consequence, we are still groping but we are agreed on one thing and that is that foundations must be stronger than they have been in the past.

Modifications of Early Practice

We are trying to secure this result through various modifications of our earlier practice. The first and most evident is an increase in thickness. Six-inch bases are now being considered light traffic foundations; seven are common; and eight and nine inch found occasionally. Even beyond that, it is with the greatest satisfaction that we occasionally find our construction projects permitting a whole new foundation on top of a foundation, with resulting bases of from twelve to twenty inches in thickness.

Our second effort is along the lines of better selected and prepared aggregates.

Our third, a tendency to use more cement, but in doing this

I feel that we are relying too much on the beam strength of the foundations and I should prefer to see the same expenditure go to increased mass. I feel this for two reasons: First, that the added strength of the pavement foundation secured through a richer concrete, will be mainly lost after a few ditches have been run down the street, and on the other hand I feel that our additional strength should in a large measure take the phase of resistance to vibration against which mass is our most satisfactory agent.

The fourth, the most interesting because of the possible economics involved and the most difficult because of the eternal clashing of human personalities which it brings about, is the securing of greater strength through more efficiently planned operations and more intelligent workmanship. This involves not only the determination of an economic minimum water cement ratio, but seeing that this ratio is lived up to batch after batch and day after day; and along with the proper amount of water is the proper time to secure a well mixed batch, involving in comparison with earlier practice, generally decreased production until our contractors have learned that larger mixers are the cheaper solution; and then the better concrete having been laid, better protection from damage by traffic and by weather is justified, and we are coming to a more scientifically thought-out and a more completely enforced system of curing.

The fifth possibility in the direction of stronger foundations involves steel reinforcement, but in our attempt intelligently to use steel, we are in the same difficulty as when we attempted to calculate a proper base thickness. We can not agree on our points of support for the application of our loads. As a result, we are generally in agreement that reinforcement can not be efficiently used in street pavement bases to secure strength, and it is now being used only in the integral concrete pavements which are in the main, adaptations from our rural highway practice.

As a corrollary to our efforts to secure stronger bases, we are definitely attempting to reduce pavement stresses through more detailed attention to our foundation subgrades and to the maintaining of smoother surfaces thereby avoiding, insofar as possible, impact shocks.

Pavement Surfaces

Our pavement surfaces fall into three general classes: The first of these, is the cement concrete, integral with the base, the pavement complete in itself. The second class includes block pavements from which wood block has now nearly vanished, and asphalt block is still limited, but including vitrified brick in several forms and granite. The third class is made up of sheet pavements, our old standbys of sheet asphalt and

asphaltic concrete laid hot being still the standard, but other types of bituminous concrete, both hot and cold, having extensive use and in some instances definite advantages.

The cement concrete pavement which is now the admitted standard for rural highway work, is still at a serious disadvantage as a city pavement. The more definite disadvantages are that it is not usually laid as a city pavement in sufficient quantity or continuity to permit of a type of high class organization which the rural pavement has brought forth, and as a result more than one-half of our concrete streets are being laid under untrained supervision and by unskilled workmen. If this handicap were not sufficient, it could be noted that the same general conditions have prevented the development of high class equipment for handling and finishing the concrete on city streets. Only where the smaller cities will here and there bring out large yardages of concrete, can the mechanical equipment be used to advantage. On the narrower streets, up to twenty-six foot roadway, finishing machines are not uncommon. On a few of the very wide roadways, concrete has been laid in alternate strips, approximately under State Highway practice. It is to be hoped that the rapidly increasing yardage of concrete streets which the Cement Association is reporting, will stimulate invention and production along the lines necessary to permit of the city concrete being the equal of its country cousin, but we must recognize that the existence of valve boxes and manhole heads in great numbers in all our streets will always prevent us from maintaining the smooth surface slab that we have on the road, and that we must develop a greater pride of workmanship on repairs before our cut and restored concrete pavement can remain a thing of beauty.

Preliminary Pavements

Many of the objections to the integral concrete pavement just described, will not apply forcefully to the concrete pavement which is constructed as a preliminary pavement only. Many cities are now adopting this practice and are laying in their rapidly growing and not too prosperous districts, a concrete pavement deliberately made somewhat better than the foundation and somewhat cheaper than a first-class integral pavement, with the idea that its low first cost will lighten the tax burden on property in the early stage of development, that it can endure all the cutting and trenching by utilities and plumbers incident to a growing suburb and finally when the building is about complete and the damage is all done, may be repaired at a small cost into a satisfactory foundation and the scars covered with some type of separate surfacing. Such a plan is economically sound and seems to meet with the approval of real estate promoters, of home builders and of mu-

nicipal maintenance departments. A variant of this preliminary pavement which is being used quite extensively in St. Louis, consists of constructing a twenty-foot central strip of concrete sometimes uniformly eight inches thick with mesh reinforcement, and in other cases practically a standard State Highway specification. The advantage of this pavement is that it gives access during building operations and will serve fairly well while homes are being paid for. It permits the laying of gas and water pipe out from under the pavement and all connections can be made without any cutting whatever. Whenever the property is ready, generally within five years of the first construction, the paving is supplemented by the setting of curb and the construction of concrete gutter strips three to eight feet in width. The original twenty feet may be left as part of the new pavement surface if still satisfactory or the new gutters may be raised two or three inches and the old center covered with bituminous concrete. This strip plan has some advantages over the first, but is not quite so favorably considered by real estate salesmen.

Neither plan seems to have taken hold to any great extent in our smaller cities. Possibly the city engineer or officials feel that they would be out of office before the second stage of the pavement could be carried through, leaving to some unfriendly or politically minded opponent the opportunity to point out the work as horrible evidence against the earlier administration.

Block Pavements

It is interesting to note the stages through which vitrified brick has gone since the war. Up to 1914, four inch cement grouted brick was the standard of this type of construction. During the war, the price of brick increased at a far greater rate than other paving material and since 1918, the four inch brick pavement has averaged nearly $1.50 per square yard higher than the three inch asphalt which had long been considered a direct alternate in cost. Brick manufacturers and associations attempted to meet this situation by promoting thinner brick pavements and finally standardized on the present three inch vertical fibre brick with bituminous filler. In our larger cities, the cost even of this pavement has been considerably in excess of standard sheet asphalt, and this factor in combination with the persuasion of our modern automobile drivers for extreme smoothness, has resulted in reducing the brick paving of the larger cities almost to a vanishing point. This situation is exemplified in my own city where a one and one-half million yard program for next year will contain only about ten thousand yards of vitrified brick.

I understand that in the smaller cities where the hot mix pavements are likely to be somewhat more expensive, three

inch brick is occasionally the prevailing type, a choice which would probably be well justified when the ease of repair in the absence of a municipal asphalt plant is taken into account. My personal experience would not lead me to give any preference to three inch brick as against sheet asphalt. I feel that the present brick pavement is at some disadvantage from a construction viewpoint on account of the absence of any form of lug, to give a separation which will permit the easy application of bituminous filler. I believe the placing of bituminous filler on the vertical fibre brick can only be done properly by the hands of skilled workmen and in our hottest weather, and that brick pavements laid and filled during wet periods or in the chill of the spring and fall will never be entirely satisfactory. It would seem important to so arrange paving schedules that surfacing could be carried to completion in midsummer.

With the advent of the "modern specification" close dressed granite block, our most durable pavement, has been made a satisfactory one to the most particular users of the streets. The granite block pavement has always been our most expensive type. The requirement for close dressing and for carefully placed bituminous filler, has added to the cost, the present price probably averaging $5.00 per square yard exclusive of the concrete foundation. In my opinion where property values are such as to permit of so high a charge for the initial pavement cost, granite block will not only give general satisfaction but will in the end fully justify the expense.

Bituminous Types

Today, the program of all of our larger cities shows hot mixed sheet pavements as its biggest item. Of the various types, sheet asphalt pavement consisting of one and one-half inch binder and one and one-half inch of fine top mix is still the standard for use under heavy traffic.

The impetus given to the study of asphalt mixtures has spread until today under the auspices of such organizations as the American Society for Municipal Improvements and the Association of Asphalt Paving Technologists, a wide program of research is being carried out in the laboratories of our cities and colleges of an extent and intensity approaching the work in concrete mixtures in which we are all taking a great interest.

When it is true, that experience is still the biggest unit in the stock in trade of the asphalt specialists, nevertheless we are each year introducing into our practice, new scientific knowledge and as a result improved technique. Most of our efforts have been concentrated on securing an asphalt top mixture which will not readily displace or wave, and while well organized and widespread research is slowly bringing about a development of the ideal mix, we have in the meantime at-

tempted to meet the situation by laying drier pavements, that is using less bitumen and by applying harder asphalts. This trend is undoubtedly in the right direction, but extreme caution is necessary to avoid overstepping satisfactory limits which might result in asphalt pavements so loosely bound as to wear away and ravel quickly under traffic.

One result of the laying of harder asphalt pavements and of their being laid on good concrete foundations, has been the common appearance in the last few years of contraction cracks in sheet asphalt. The general public having been used to the old style plastic asphalts which would stretch indefinitely and never crack, has occasionally become excited over this new so-called "defect". Personally I do not so interpret the appearance of cracks, but feel to the contrary that they are a definite assurance that the mix is of a character which will not be displaced or waved under traffic. Such contraction cracks can be readily repaired by the same methods that are used in treating the cracks in cement concrete pavements, and when so repaired constitute no serious disadvantage.

Asphaltic concretes of several styles are in general use and have been found entirely satisfactory for lighter traveled streets. Two well known proprietary types, Warrenite Bitulithic, a coarse graded mixture laid hot but so covered with the fine graded "seal coat" as to have the appearance and much of the quality of sheet asphalt, and the Amiesite pavement generally laid cold or only slightly warm and depending on the use of some solvent as kerosene to secure the plasticity necessary for laying, are both giving good service under medium and occasionally under heavy traffic, and are of distinct advantage for use in the smaller communities because of the supervision and testing service rendered by experts attached to the companies. Because of this service and the proprietary character of the pavements, they are usually somewhat higher in cost than a well designed open specification of asphaltic concrete and occasionally cost more than sheet asphalt.

Of the unpatented asphalt concretes, the so-called Topeka specification, and the even finer graded stone filled sheet pavements, are the most popular. In St. Louis, we are using an asphaltic concrete two inches in thickness which consists essentially of a standard sheet asphalt mixture to which has been added about thirty per cent of stone between the ten mesh and one-half inch sizes. This pavement laid on a six-inch cement concrete foundation is costing about $2.85 per square yard or very nearly the same as our eight inch reinforced concrete street. Its use over a period of ten years has been satisfactory in every respect and it seems to be the favorite of the general public for paving residence sections.

It is a well known fact that all types of bituminous pavements require a reasonable amount of traffic to keep them in

good order, or as it is generally expressed, "ironed out". We find that such pavements not used appreciably, will dry up and crack, and on the other hand when used for intensive parking will absorb large quantities of motor oil drippings and become soft and mucky. To meet this situation, we are now generally laying a combination pavement in which the central strip consists of some form of bituminous sheet on a cement concrete foundation, and the side strips on which parking occurs, consist of solid concrete slabs from six inches to eight inches in thickness. On our narrower roadways of twenty-six feet, the concrete gutters are four feet in width; on thirty-six foot streets, they may be five feet; and on streets of fifty feet or more, eight feet in width. As an indication of how this works out, a program of 800,000 yards of so-called sheet paving, will consist of 670,000 yards of bituminous center, and 130,000 yards of concrete sides. The concrete gutter, yard for yard, is cheaper than the bituminous pavement, so that the gross cost of the improvement is lowered somewhat by the adoption of the combined scheme.

Playing Fair With the City Taxpayer

City paving departments still fail to measure up to the full expectation of the citizenship in two respects. The first of these is in the matter of surface smoothness and ease of riding on our newer streets. Most of us feel that we are doing a pretty fair job in this respect, but again our country cousins with all the advantages of highly organized mechanical equipment are doing better, so that our city automobile owners returning from a pleasure drive outside, are filled with a mild discontent at the small jigging their wheels receive over some apparently smooth asphalt. However little criticism may be justified, the demand for further smoothness is here, and it will be up to us to set aside our self-satisfaction with our present work and find means of further improvement. I have already mentioned the disadvantage at which we are working on account of the absence of high grade mechanical equipment for the finishing of any of the types now in use on city streets. I think such equipment will be developed and that we can hasten this development if we continue to tighten up on our specifications for true pavement surface and on our efforts to see that specifications are carried out. The general adaptations of finishing machines to concrete streets does not seem to involve serious difficulties provided we once get over being satisfied with the inequalities of hand work and seriously demand something better.

In the laying of our block pavements, the use of running templates is already common, but in the case of asphaltic mixtures, we are still entirely dependent on the eye of the raker and the diligence of the roller man. I feel sure mechani-

cal equipment for raking and levelling will be developed. I know that several agencies are studying the possibilities at this time. Only recently we have heard of a road contractor laying asphaltic concrete under a standard concrete finishing machine. The perfection of equipment for mechanical raking and rolling will require much time and experiment, and more immediate improvement must be secured by forcing more intelligent workmanship through the pressure of more intensive and careful inspection and checking. It has been hard to persuade either foreman or workman that a concrete foundation to be covered by an asphaltic mixture, has any need to be practically true in contour. If there is a defect, why not let the asphalt gang take care of it, and a lot of that has been done with the result that our asphaltic layers will often vary seventy per cent in thickness, and that rollers working on ununiform thickness must necessarily leave great variations in density as well as unfortunate waves in the surface.

We are going to specify that our foundation concretes be finished to the quarter-inch limit heretofore given to surfaces, and if necessary to secure this we are going to check our concrete bases with string lines on five foot intervals before the concrete has set. This is going to be hard work for the inspectors and harder work for the engineers to keep the inspectors doing it, but it is a task that paving engineers must undertake and carry through if they expect their work to meet with the full measure of public approval.

Speeding Up Repair and New Paving Work

The other thing that makes a citizen dislike us, is our propensity to tearing up the street in front of his store or home and keeping it torn up for two or three months in order to lay a new pavement. I feel that we have been too prone to stand on our rights of taking streets out of service in order to carry out such public work. We have been too inclined to do this work in the way it has always been done and to carry out our paving program in the way best suited to the type of organization that our contractors have customarily placed on the work. We have not understood completely what serious economic losses our street closing signs and barricades involve. Where we have a residence street under construction, the loss is perfectly definite and the annoyance is quite obvious, but when commercial and industrial thoroughfares are taken out of service the excess costs imposed upon the abutters and through them on the whole community, are very serious.

In the larger cities, the realization of this situation has been growing for some years, and in the year past definite efforts have been made to introduce improved methods. As an example of this definite planning, there was carried out during the past summer in St. Louis, the repaving of Washington Avenue, a major thoroughfare running through the retail

and jobbing districts, in which the work was all done in accordance with the schedule set out in the contract and specifications. This contract provided for the removal of an old wood block wearing surface, the greater part of an old concrete foundation, the laying of a new concrete foundation, and a granite block surface with asphalt mastic filler. The contract laid down an ideal schedule which involved an elapsed time of four days from the disturbance of the old pavement to the laying of the new. On account of weather conditions and some slight labor trouble, this schedule was not lived up to in every detail but it was very nearly met. In the main, the high speed was accomplished by the introduction of night work, the requirement that concrete be mixed in a central plant and hauled into the work as fast as needed, specifications for a quick hardening cement, and finally a requirement for refinement of organization and supervision in every possible detail.

All of these innovations cost money, some of them not so much as might be expected, but in every single instance when the expected accomplishment was explained to the tax payer and the expected increased cost figured up, the plan met with approval.

In this particular project, the biggest item of time saving came from the use of the early strength cement. This cement, one of several of this type now on the market, gave strengths in two days equal to twenty-eight day Portland cement concrete. It costs less than $4.00 per barrel as compared with $2.00 for standard Portland cement. With increased production of cement of this type, there is every reason to expect further reduction in price, but even at present prices the increased cost per barrel will not exceed $1.75, and the cost per square yard for six-inch foundation will not increase more than thirty cents. This will amount to an average increased assessment of seventy-five cents per front foot or $30.00 for the forty-foot store building. For this increased cost, the saving of ten days in the time of curing concrete, is secured. There would be few merchants who would not tell you that their loss on account of street closure would not be in excess of $3.00 per day, and that they would gladly pay two or three times that amount to speed up a paving program.

With the full appreciation of what we are doing in the way of improved engineering and contracting to secure stronger pavements, pavements better adapted to modern traffic, and with every consideration of the necessity for economies in cost wherever possible, I feel that the biggest tasks before the city paving engineers today, are to secure pavements of more perfect riding quality, and to carry out our paving construction with the least possible disturbance to living conditions or to commercial activity. Our success in these two respects, is of the greatest possible importance in holding the continued support of the public to sound paving programs.