DEVELOPMENTS IN PAVEMENT CONSTUCTION *

By Thomas H. Sellew, *Assistant Director of Planning & Design Connecticut State Highway Department*

THE history of serious road building in America dates back to about 1785 with the advent of original turnpikes. At first the travel way was the then popular corduroy road. By 1790 loosely packed broken stone, having water as a binder, came into use. This, of course, was copied from none other than the famous John L. McAdam whose name is connected with many forms of pavement today. Another material appeared when a plank road was built in 1845-46 from Syracuse, N. Y. to Oneida Lake, a distance of about 14 miles.

Not long after, turnpikes fell into disuse for the railroad had arrived and proved the better means of travel over long distances. Canals, too, took passenger and freight business from the turnpikes. There followed a period known as "the Dark Ages of American Roads."

Then, about 1900 road improvements were again on the scene with cobblestones, brick and wood or granite block. It was near the end of the nineteenth century in fact that concrete pavement was first used in America, about 40 years after it had been introduced in Scotland. Asphalt was first used in the United States to pave Pennsylvania Avenue in Washington, D.C.

About the year 1920, the bicycle and automobile were responsible for greater attention being paid to roads of better all weather quality. Demands increased which led to the Good Roads Movement in the 1920's with the slogan, "Get the Farmers out of the Mud." The success of that movement is now apparent to all of us.

Engineers, road builders and suppliers of roadbuilding materials have made many advances in the fields related to road metal, mostly by trial and error. Only in relatively recent years have more scientific and possibly more sophisticated techniques been developed to guide the industry in materials to use and methods to apply to achieve quality pavements. This has caused those planning roads to be more alert, more receptive and certainly attentive to the fact that we must not gamble precedent against progress, development and consequential improvement. I am suspect that some engineers reflecting on this last statement this morning might say "there's a plug for the retirement system." Let me hasten to say that precedent does have value and new developments must be tested against known successes

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* Presented at the Town Affairs Meeting of Connecticut Society of Civil Engineers, Wethersfield, Conn., November 17, 1964.

and failures before expenditures are made in any direction. On the other hand, we do not mean that precedent should serve as inhibition.

As stated, we have more recently investigated, arrived upon, and provided for, different pavement elements than those used in the past. We have confidence in what we have adopted and are close to finding good tools for use in substantiating our determinations.

It is a fact that a great deal in today's pavement selection is the outgrowth of the well over $27 million test road undertaking by the American Association of State Highway Officials. This was financed, according to Report No. 73 of the Highway Research Board of the National Academy of Sciences as follows:

Joint State Fund	$11,820,000
Bureau of Public Roads	7,305,700
Illinois Federal Aid	4,042,000
Automobile Manufacturers' Association	1,300,000
Department of Defense	1,486,450
American Petroleum Industry	875,000
Other Agencies	260,070
American Institute of Steel Construction	25,000
Total	$27,114,220

As a point of interest, the Connecticut share in this was $115,832.

Now what was done at the test road? Actually, several pavement structures and bridge structures were put on the ground and then subjected to the abuse of accelerated traffic loadings. This was done by setting off the various types of construction in loops, then putting extreme and repeated axle loadings over them to determine those which withstood the loadings and the extent of loadings taken to cause pavement failure on the others. The measurement of failure was cessation of acceptable serviceability as determined by a group of experts in the highway field. Briefly, these specialists declared a pavement section "out of test" when it dropped below structural qualities capable of a predetermined level of service or performance. From their observations and instrumentation, the experts collectively arrived at values to assign to each layer of a flexible pavement structure. For example, the lowest layer, the subbase of good bank gravel, or an equivalent, was given a value of .11 per inch depth, and something in the area of .05 to .10 for sand foundations. Cement-treated bases ranged from .15 to .23 as related to 400 p.s.i. to 650 p.s.i. seven-day strength. Bituminous bases of better quality, say densities nearer 150 lbs. per cubic foot, were rated at a value of .34 per inch depth. High stability bituminous concrete was rated as high as .44. Interesting, by way of comparison, is that penetration as we know it has since been in the .24 or .25 area as arrived at coincidentally by Connecticut and Massachusetts. Waterbound macadam is rated .15 to .30 but this is considered unrealistically high in many places. The structural numbers are still under study and it is expected that they will be modified as time goes on. Some are even challenged at this time so the earlier comment that they be used with caution is most pertinent.

In line with the value assigned to the different type courses within a pavement structure, one report points out the following:

1″ bituminous surface = 3″ stone base, approximately
1″ bituminous surface = 4″ subbase, approximately
3″ stone base = 4″ subbase, approximately
and it may be assumed
1″ bituminous surface = 1″ bituminous base (This is questioned.)
1″ bituminous base = 4″ subbase
and from another observation
1″ bituminous base = 1.3″ cement-treated base
1″ bituminous surface = 1.3″ cement-treated base

A typical analysis would be a pavement structure such as that used on the eastern section of the Connecticut Turnpike

3½″ Bituminous Concrete × .44 = 1.54
3 ″ Bituminous Macadam Base × .25 = .75
4 ″ Broken Stone (Waterbound) Base × .15 = .60
11 ″ Gravel Subbase (Minimum) × .11 = 1.21

21½″ Total Depth of Pavement Structure
Total Structural Value 4.10

We should be mindful though, that even if we regard the Connecticut Turnpike as a relatively recent project, it predated the type of analysis now being made. Still prior to the findings of the mentioned test road, was the adoption of another flexible pavement structure for Connecticut expressways. This provided:

4″ Bituminous Concrete × .44 = 1.76
3″ Bituminous Macadam Base × .25 = .75
6″ Broken Stone Base × .15 = .90
10″ Subbase (Minimum) × .11 = 1.10

23″ Total Depth
Total Structural Value = 4.51

On later projects this was modified to eliminate the bitnuminous macadam, or penetration base and use plant-mixed, dense-graded bituminous base. This change raised the SN from 4.51 to 4.78, but this is not the full extent of developments. We have more recently found that there is something left to be desired in the conventional sand-filled, broken stone base or so-called waterbound macadam base. After cooperative development on the part of industry, it became apparent that a dense mix, chemically stabilized, could be used in place of broken stone or waterbound macadam base to considerable advantage and within economically justifiable limits. In consequence we have adopted as a regular item calcium chloride, dense-graded, stabilized base. In short, premixed bituminous base prepared in a plant is replacing penetration base and chemically stabilized dense-graded base, also plant-mixed, is replacing waterbound macadam base. To compare this with the two pavement structures discussed earlier, there are the two following analyses:

4″ Bituminous Concrete × .44 = 1.76
6″ Premixed Bituminous Base × .34 = 2.04
4″ Calcium Chloride Stabilized Base × .25 = 1.00
10″ Subbase (Minimum) × .11 = 1.10

24″ Total Depth
Total Structural Value = 5.90

and another structure which should certainly be considered for pavements with a moderate percentage of truck traffic could well be:

3½″ Bituminous Concrete × .44 = 1.54
4 ″ Premixed Bituminous Base × .34 = 1.36
4 ″ Calcium Chloride Stabilized Base × .25 = 1.00
10 ″ Subbase × .11″ = 1.10

21½″ Total Depth
Total Structural Value = 5.00

More recent indications are that the total structure value, or SN should be in the area of 5.00 for pavements carrying substantial traffic volumes without heavy trucking and somewhere around 5.50 or greater for large traffic volume including a high percentage of trucks.

You perhaps have noticed that the four pavement sections shown vary in total thickness from the surface to the bottom of subbase from 21½ inches to 24 inches. Although that represented by the subbase thicknesses are increased more than the 10 or 11 inches illustrated, I doubt that anything deeper than 24 inches should be regarded as part of the pavement structure or could be computed into the SN. This is mentioned because deeper subbase is generally for drainage in Connecticut. Maine and New Hampshire place three feet or more of granular material under flexible pavement because of the frost depths they have to contend with. There, too, I feel the pavement structure as such is in the top 24 inches. The New Jersey Turnpike is another illustration of considerable subbase depth, but here because of the characteristics of the supporting soil and the same assumptions could be made. In any case, it is reasoned that the total flexible pavement structure for heavily traveled Connecticut systems should be close to 24 inches.

Pavement design involves many considerations other than simple arithmetical studies such as we have covered. There are numerous fundamentally practical matters of import and substance that must be given conscientious attention. In recognition of this, those associated with the test road sought a means of incorporating factors in a formula which was later reduced to a nomograph. This starts with soil support values, equivalent daily 18 kip single axle load applications and a regional factor and ends up with a structural number. Unfortunately, further investigation is necessary in order to perfect this to the point of reliability, particularly with respect to the regional factor which ranges from 0.2 to 1.0 where roadbeds become frozen to shallow depths and then on up to 4.0 to 5.0 where roadbeds become saturated — due to spring thawing. The regional factor, therefore, has severe effect on the outcome when this system is used. Further, as of this date, there is no known empirical means of establishing guides for determining the regional factor. The mentioned nomograph, therefore, is only a suggestion as to needs. You might note also that the nomograph could be worked in reverse to determine needed soil support.

Other engineering considerations in pavement work are (1) available materials, (2) costs, (3) materials qualities, (4) future maintenance, (5) life expectancy, (6) ability to withstand conditions of weather and traffic, (7) adaptability to stage construction, (8) riding qualities, (9) safety,

(10) night visibility, (11) available equipment, (12) matching adjacent pavements, (13) season of construction, (14) pavement contrast.

Another important aspect of pavement selection is planning. If we look ahead for expected use, development, increased traffic loads and traffic interference for maintenance, appropriate provisions may be made. We do know that there is constant pressure to increase legal load limits and this may be a consideration. In other words, it is not prudent to build a short lived road for long periods of service, nor is it wise to do the opposite.

Up to this point, the newer pavement designs have been discussed from the general standpoint of quality and more or less as to strength. There are other advantages as well, starting with the plant-mixed bituminous base.

1. This material may be placed during a longer construction season, as it is not as vulnerable to lower temperatures as penetration macadam.
2. It is blended under plant controls and, therefore, uniform.
3. Machine-spreading assures good uniformity in depth; also, the advantage of placing a layer in a single operation.
4. Traffic may ride over the surface for a considerable period before the placement of subsequent overlaying material.
5. The densities achieved with this material not only constitute a good support but allow for better compaction of overlying material.
6. The cost is in line with the end product.
7. There is no need for special equipment to produce, transport, place or compact the material as conventional bituminous concrete plants and equipment are used.
8. This work eliminates the need for stockpiling and rehandling of aggregates.
9. The use of this material reduces the amount of hand-labor.
10. Time element is particularly favorable.

Calcium Chloride Stabilized Base has about the same advantages and both can be credited with good strength per inch depth. This feature permits thinner courses or less tonnage so that the square yard cost of the finished pavement is not materially increased; and, in fact, sometimes reduced. Cost in each case is dependent on location and haul, quantity, season, accessibility and traffic conditions.

I have not discussed the calcium chloride base material in particular detail because another speaker, who has intimate knowledge of the subject, and who I know to be very capable, will cover the uses of calcium chloride more comprehensively. I hesitate to get too deeply into the subject of Portland Cement Concrete Pavement for the identical reason. There are a few points, however, that might be brought out under this discussion.

There have been some impressive advances in the mixing, transporting, placing, finishing and curing of rigid pavements in this area in the last several months. Probably the foremost is the increasing use of central plant mixed concrete, which is hauled in special truck bodies or truck mixers to the working site. Such concrete is batched and mixed under superior controls, this leading to greater uniformity, more assurance of compliance with specifications and, consequently, better pavement. The automation introduced into more modern plants contributes efficiency and accuracy to the work as well.

Paving 24-foot widths or two contiguous 12-foot lanes simultaneously is becoming more popular where space limitations do not demand the placement of one lane at a time.

Newer innovations for the forming of transverse joints by mechanical means has been helpful.

Curing with membrane compound has, for the most part, supplanted the use of wet mats, paper and polyethylene sheets.

These few items have been mentioned as they have contributed either improvements or economies, or both, in rigid pavement construction.

As for the performance of Portland cement concrete at the mentioned test road, the analyses was based on a measurement of performance or serviceability similar to that applied to flexible pavements. There does not appear to be any counterpart in rigid pavements for the structural numbers in flexible pavement. The design of rigid pavement is from an entirely different approach and therefore cannot be considered in the same light. Briefly, it was observed that even relatively thin slabs performed well at the test road, reinforcement was not as highly important as believed in the past and subbase did not contribute as greatly to the performance as had been anticipated. I would prefer, however, to defer to another speaker on the subject of Portland cement concrete pavement and cement treated bases.

The foregoing has covered some of the more progressive and possibly pleasing phases of the work. There is one area where we in Connecticut are in some trouble and that is with our supply of pit gravel. In some areas this material is depleted, in others that available is not of satisfactory quality. In still other locations, zoning regulations or other ordinances have rendered gravel excavation exceedingly costly or virtually impossible.

We recently conducted a survey to determine the severity of the situation along the following lines:

Letters of inquiry concerning the availability of gravel throughout the State were sent to the four State District Offices of the State Highway Department. The results show that of the 169 towns in the State, 43 have plenty of sand and gravel deposits, 101 have some deposits, and 25 have none at all.

Similar inquiries were also sent to all 169 towns asking about excavation regulations of these materials. The results were as follows: Of the 98 towns that regulate excavation, 82 require both a permit and bond by the excavator, 14 require a permit only, and 2 require a permit, bond and plan of the site. There are 56 towns that have no excavation regulations and 15 towns from which we have no reply.

Our survey also shows that there is some gravel in most areas of the State with the exception of the large cities and several towns in lower Fairfield County.

May I submit that this poses a problem for a contractor bidding on construction work not knowing the stipulations that may be imposed if he is the successful bidder. This can lead to contingency provisions in the bid and ultimate cost to taxpayers in general.

In recognition of these conditions, there is a trend to modify specifications to provide for the use of amended pit run natural materials, processed aggregates or other combinations of natural and processed aggregates to get the equivalent of bank gravel that stands up to test. These materials are coming into greater use as time goes on. Another thing too, engineers are learning more and more to design around the problem rather than play ostrich with the problem.

I believe I have taken enough time from my side; perhaps some of you would care to comment from the floor. May I suggest remarks from those in public works of the different cities relative to problems, typical pavement standards and like subjects. I belieive we have time, and open discussion is always beneficial to this type of meeting.