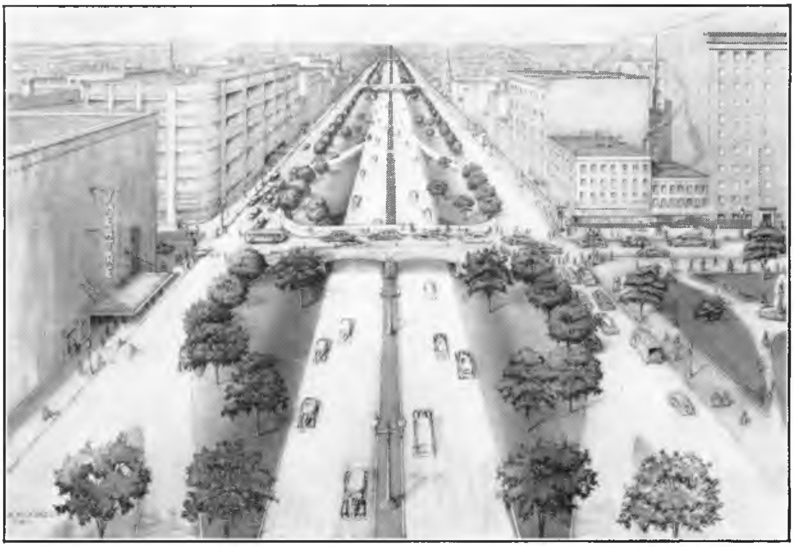

Fig. 11. There is great need for express highways cut directly into and through cities. This sketch shows how it may be done.

CONCLUSIONS

As a result of 25 years of research and experience, highway engineers have mastered the details of the structural design of pavements. They can point with pride to the endurance and smoothness of highways designed and built to their plans and specifications. Radical changes in structural design, therefore, are not to be expected. On the other hand, geometric design is quite another matter. A determined and united attack on that problem has been in progress for three years only. However, remarkable results have been attained, and special credit is due the state-wide highway planning surveys and the Special Committee on Design Policies of the American Association of State Highway Officials. Their findings, which have been used extensively in this paper, are likely to become the basis for the superior design standards needed to modernize old roads and insure maximum safety, utility, and comfort in the use of new ones.

PAVEMENT DESIGN

M. R. Keefe

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I wish to compliment Mr. Connor on his excellent paper on pavement design. He has given us a very comprehensive review of present-day pavement design as well as a digest of the studies on design now being conducted by the joint design committee of the Public Roads Administration and the state highway departments.

Most of the recommendations of this committee are being carried out by our design department so far as possible, taking into consideration local problems.

The matter of subgrade bearing power, touched on by Mr. Connor, is one of the most important features of present-day highway design. By improving our subgrades we can lengthen the life of our pavements. This has long been a neglected feature, and even now many of our highway departments are passing over this question all too lightly.

Another point touched on in this paper is the problem of design of flexible-type pavements, which is of exceptional interest to the highway department in Indiana.

Our law requires that all advertised lettings of contracts for paving shall state that bids will be received for two or more distinct types of highways, of which at least one shall be of the non-rigid type, and shall have equal load-carrying capacity with the rigid design.

The information presented by Mr. Connor is of such importance to the highway engineer that I hope all of you will read his paper when it is printed in the proceedings of this road school. You will be materially benefited if you will give it extensive study.

DESIGN DEVELOPMENTS IN INDIANA

I shall review briefly the developments of paving design in Indiana since the inception of the Highway Commission. This will give you some conception of the numerous changes in the past twenty years.

The first pavement designs for the State Highway System of Indiana were developed in 1919, and were used during the construction years of 1919, 1920, and 1921. Pavement width during this period was fixed at eighteen feet, and shoulder width was but five feet. During 1919 and 1920 the pavement design provided for 6-8-6-inch plain concrete using a 2-inch crown and a mix of 1:1½:3.

In 1920 the legislature passed an act requiring three competitive types on all paving contracts. Two more designs were immediately developed in addition to the concrete design outlined above. These two designs provided for a 1 1/2-inch bituminous-concrete surface course, and a 1-inch bituminous binder on a 5-inch concrete base course, making a total thickness of 7 1/2 inches. The second design provided a 3-inch brick surface course with 1-inch sand cushion on a 5-inch concrete base course, giving a total thickness of 9 inches. These three competitive rigid types were used in all lettings up to the year of 1934. Modifications were made in the concrete-pavement design through the years, and in 1931 there were added, to the three above-described competitive types, two flexible-pavement designs, making five types bid on in lettings of 1931 to 1934, inclusive.

The two flexible-type pavements, first designed in 1931, consisted of two waterbound courses, a penetration course, and alternate wearing courses of bituminous-concrete and rock asphalt, all with a total depth of 13 1/2 inches.

In 1922 the concrete-pavement design was modified to a 7-8-7 inch section using a 2-inch crown and a concrete mix of 1:2:3.

In 1923 the concrete-pavement design was again changed, this time going to an 8-inch uniform thickness, still retaining the same 2-inch crown. At this time the shoulders were changed from 5-foot width to 6-foot width. Right-of-way widths up to 1926 were fifty feet for all types of roads in the state system.

In the year 1922 the first flexible-design pavement was put under contract. This was on State Road 62, Boonville to Pigeon Creek, and consisted of two 4-inch waterbound macadam courses and a 2 1/2-inch penetration course, making a total thickness of 10 1/2 inches. This road has been surface treated a number of times until it must have attained a thickness of at least 13 or 14 inches. It was surfaced with rock asphalt in 1937 and is now carrying 1500 vehicles per day with low maintenance costs.

In November, 1923, a new design for concrete pavements was adopted that involved more radical changes than had been made in any of the numerous sections used up to that time. This design provided for a uniform thickness of seven inches with 3/4-inch reinforcing bars on 17-foot centers, that is, one bar along each edge of the pavement 6 inches in from the edge. One-half inch transverse bars were spaced four feet center to center. The pavement width still remained 18 feet and the crown 2 inches. Up to this time none of the several designs provided for any type of joint, and the pavement thickness had either been uniform or thickened at the center.

During the year of 1924 seven projects were built in which the pavement width was reduced to 16 feet, with reinforcement and pavement thickness as stated above. These projects were built in the south part of the state and are still in good condition as to cracking and deterioration.

After two years' use of the reinforced section just described, the sixth change of concrete-pavement design in as many years was effected. This design used a 9-7-9-inch cross-section, with a 3/4-inch marginal bar along each edge. For the first time a longitudinal joint was required and the pavement crown was reduced from two inches to 1 1/4-inch. The narrow, six-foot shoulders were still in use; but during this year, right-of-way widths were increased from 50 feet to 60 feet.

BUREAU OF PUBLIC ROADS REQUIREMENTS

This design remained in use from 1926 until 1934, at which time the Bureau of Public Roads issued a regulation requiring the use of expansion joints in concrete pavements on Federal Aid Projects. A maximum spacing of joints was fixed by this regulation.

In compliance with this request, our designs were revised so that transverse joints were spaced 105 feet apart, with two intermediate contraction or weakened plane joints 35 feet apart. Load transfer was provided for at all expansion joints, but none at the contraction joints. The expansion joints used were of the air-cushion type and three different joints were approved. Load transfer was effected by use of 3/4-inch round bars or by a "translode" base device.

Although not required by the Bureau's regulation, our revised design provided mesh reinforcement for crack control. The pavement thickness was changed at this time to 9-6-9-inch on medium-traffic roads, but we still used 9-7-9-inch on heavy-traffic roads. The concrete mix was also changed so that the cement content was lowered from 1.72 to 1.5 barrels per cubic yard.

A lighter pavement design was also developed at this time. This design provided expansion and contraction joints as in the heavier design, but pavement thickness was reduced to 8-5-8-inch. Several projects have been built under this design on roads carrying light truck traffic and, although the oldest is but five years old, they are proving entirely satisfactory.

Since 1934 the design of rigid pavements has undergone several changes. Expansion-joint spacing has changed to 80 feet, with one contraction joint at 40 feet, and again to 100-foot spacing with two contraction joints at 33 1/3 feet; and at present we are using 120-foot spacing of expansion joints with 40-foot spacing of contraction joints. Load transfer is now provided for both expansion and contraction joints. Mesh reinforcement is still being used for crack control.

Pavement width on two-lane roads has increased from 18 feet to 20 feet, and on high-traffic roads with heavy truck traffic we are now constructing 22-foot pavement.

Right-of-way widths have increased from the 50-foot width in the early twenties to 60 feet in the late twenties, 70 feet in 1930, and now to 80 feet on two-lane secondary roads, 100 feet on two-lane first class roads, and up to 200 feet on divided four-lane roads.

Shoulder widths, which were five feet in 1922, six feet in 1923, and eight feet in 1928, are now eleven feet wide on all classes of roads. On more than a thousand miles of our older roads shoulder widening projects have been carried out making shoulders eleven feet wide, contributing much to cutting down our accidents.

MULTIPLE LANES

The first four-lane road was built in Indiana in 1922 on U. S. 30, the Lincoln Highway, just east of Dyer. This 1.36 miles of four-lane, forty-foot highway was financed mainly by contributions of the National Lincoln Highway Association. It was designated to be the ultimate development of highways and was publicized all over the country as the ideal section for highway construction.

The pavement had a uniform thickness of 10 inches, was reinforced with 1/2-inch square bars spaced 1 foot 9 1/2 inches center to center longitudinally and three feet center to center transversely. The specified mix was 1:2:3 and expansion joints were provided. A lighting system was installed, which I understand was rarely if ever used. The twenty-foot steel poles with the remains of the lights still exist. The section was also landscaped and a gravel walk for pedestrians provided along one side, which was never used and is not visible today.

No three-lane pavements have been built in Indiana since 1938. All the three-lane pavement projects have unlimited sight distance and show a high accident rate, and consequently are very unpopular with the traveling public.

Our first four-lane divided pavement provides for two 20-foot lanes divided by a 20-foot median strip, crowned so that all drainage from the center is carried over the pavement. In towns, the dividing strip was narrowed to four feet and raised 5 inches above the pavement surface.

The four-lane divided design now provides for a dividing strip with a minimum width of thirty feet, except in suburban areas where we have built some with a four-foot divider. This design, using a four-foot dividing strip, has only been used where right-of-way and property damage would be prohibitive if a wider dividing strip were used.

We now have under construction a four-lane divided project that utilizes the existing 18-foot concrete pavement. This design provides four eleven-foot lanes and a four-foot dividing strip. The existing 18-foot pavement is widened to 26-feet with concrete base. Two new 11-foot concrete lanes are built on the outside of the widened section. The two inside lanes will be surfaced with a bituminous binder course and rock-asphalt wearing surface, all divided by a 4-foot raised dividing strip built of white concrete.

Just a word on sight distances used on design of pavements by our engineers. On first-class, two-lane roads we design for a 900-foot sight distance, on lesser important roads

700-foot sight distance, and on low-traffic, third-class roads, 600-foot sight distance. If any more three-lane roads are designed, a 1500-foot sight distance will be specified. On four-lane divided roads we are specifying a 700-foot sight distance.

SOME SPECULATIONS REGARDING THE FUTURE OF UNEMPLOYMENT RELIEF THROUGH HIGHWAY CONSTRUCTION

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The creation of the Federal Works Agency for coordination of administrations directing various forms of public works, presupposes the continuation, in some form, of the services with which the various agencies have in the past been charged.

Likewise it is conceded that, these services being necessary and desirable for national welfare, the operation of the various agencies will be realigned to contribute most economically and efficiently under the new estate considered necessary, and as recognized through their inclusion in the jurisdiction of the Federal Works Agency.

It is quite permissible, therefore, to assume the continuation of the services of the Work Projects Administration and the Public Works Administration, to provide for measures to alleviate the stress of unemployment and to seek the prevention of economic distress by the stabilization of industry and the provision of public works programs as needed to equalize employment.

Because of its demonstrated ability to absorb a large volume of labor unassimilable by modern industry, and of the distribution of its services and needs to the remotest regions of the nation, the national highway program offers unusual advantages as a public works facility. It is, therefore, assumed that the highway program will be included in plans for national stabilization, and that the Public Roads Administration, the Public Works Administration, and the Work Projects Administration will be coordinated to contribute their established facilities to that end.

Pursuing the assumption further, and realizing that the highway program will be prosecuted along efficiently planned policies, designed to provide relief to present unemployment and to minimize future unemployment but, at the same time, to extend highway improvement to every county in the United States, it is evident that unemployment needs cannot be allowed to set artificial political boundaries to the objectives of the combined effort.