A Cooperative Bridge Deck Study

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•A NUMBER of papers and discussions dealing in some cases with a particular aspect of the bridge deck problem, and others with the general problem of performance have been presented at this Annual Meeting. There is general agreement that difficulties with respect to performance of concrete bridge decks exist; however, there is not general agreement as to the degree of nonperformance nor to the importance of the various physical signs of change. This probably stems from a lack of adequate quantitative information on performance and the manner in which performance is related to exposure, concrete properties, design, construction methods, and numerous other factors.

This cooperative bridge deck study was undertaken in an effort to remedy this lack of adequate information. The participants are the Bureau of Public Roads, a number of State highway departments, and the Portland Cement Association. The study has four major objectives:

1. To determine the extent of deck deterioration in selected areas.
2. To determine the causes of the various types of deterioration.
3. To develop reliable methods, where needed, for preventing deterioration on future construction.
4. To develop methods of retarding deterioration on existing bridges now showing deterioration.

The first objective is being accomplished by a random survey of structures in ten States. Nine of these random field surveys have been completed, one remains to be done this spring. These States, chosen to provide a wide range in traffic intensities, exposure, and bridge design characteristics, are New Jersey, Michigan, California, Texas, Maine, Vermont, Minnesota, Illinois, Ohio, and Virginia. The results of these random surveys also serve as a basis for selecting certain states in which a detailed study of structures will be made to achieve the second objective of this cooperative program.

Bridges to be studied are those built since 1940 on the Federal Aid Primary, Secondary, and Interstate Highway systems having decks of reinforced concrete, either covered with a wearing surface or uncovered. To achieve precise information on the extent of deck deterioration would necessitate a survey of each structure in this population in each of the ten states, a procedure that would require an excessive amount of time, money, and personnel. Accordingly, a random sampling procedure was established. The theory of this sampling procedure is based on sound statistical considerations. As a preliminary it was necessary to decide (a) the amount of acceptable error in the results and (b) a level of probability that this error will not be exceeded. These decisions directly influenced the size of the sample used; hence, precision had to be tampered with realization of available resources. Accordingly the limits of error were selected at ±8 percent and the probability of not exceeding these limits was selected as 2 standard deviations, or 95 percent of the results falling within the limits of error selected. For these conditions, the relation between the number of bridges in the population and the required size of the sample was calculated and is shown in Table 1. In each state, cards for each bridge meeting the age and location requirements were placed in a container, mixed, and the number of cards equal to the required sample size were drawn randomly. A guide for the conduct of the field inspections was furnished to personnel conducting the survey. This guide included a classification and definitions of the various types of

TABLE 1

No. of Bridges in Population	Required Sample Size
500	119
1,000	135
1,500	142
2,000	145
2,500	147

known defects and instructions for reporting. It also included a classification of bridges into various types, such as continuous span reinforced concrete, simple span prestressed concrete I-beam, or simple span composite steel I-beam. This guide was discussed thoroughly with the Association people making the surveys in each of the states. For each structure, an inspection sheet was filled out. Observations were recorded span by span for each structure.

The guide for the inspectors contained both a picture and a definition for each category of each type of defect. The defects were subdivided to provide for a clearer picture of severity and character. Scaling was broken down into light, medium, heavy, and severe. Cracking included transverse, longitudinal, diagonal, pattern, D, and random cracking. Each category of cracking was reported as light, medium, or heavy. Rusting of steel was also to be noted. Surface spalls were classified as small or large and the number of such spalls per span were reported. The total length of joint spalls per span, both at transverse or longitudinal metal expansion devices and along sealed joints, was reported. Popouts were reported as few or many per span. Photographs of typical defects were submitted by each inspector, including over-all views of the deck and the whole structure. The principle adhered to in preparing the guide was to sort these defects into reportable categories by physical description without attributing cause for the defect.

The data obtained from these random field surveys is at present being transferred to punch cards for machine processing and evaluation. It is anticipated that this analysis will provide information on the extent of deterioration of concrete decks built since 1940 on the Federal Aid Primary, Secondary, and Interstate systems in these states. In addition, information will be obtained on the relationship between the various types of defects and such factors as bridge type, traffic, climate, and age.

The second objective of the program is being achieved through the detailed study of selected structures in certain of the ten states. In each of the states selected for this detailed investigation, approximately 15 structures are being studied. The field inspections are being conducted by a party consisting of representatives of each of the three participants: BPR, the State highway department concerned, and PCA. The bridges are thoroughly inspected and a plan sketch for each span is made showing the location of defects and other features, photographs are made of these, and locations marked on the deck for subsequent coring for samples. In general, cores are being taken for each type of defect noted in the deck (for example, over a transverse crack or from a scaled area) and from good areas immediately adjacent. Cores are obtained as soon as possible after completing the inspection. Measurements of the amount of concrete over the top steel in the deck and the diameter of the bar are also included. Electronic equipment for this purpose is now available. Those cores taken directly over steel will provide a check on these nondestructive measurements.

It is anticipated that a study of the cores will provide clues to the reasons for, or the causes of, the occurrence of the type of defect. Uniformity, top to bottom is being checked by measurements of pulse velocity. Air void characteristics are being determined by the linear traverse technique, including the total number of voids per unit volume. This is being done not only on the core as a whole but also as a function of the distance from the top of the core to the bottom. This information will be of value in interpreting performance relative to scaling and possibly certain other defects. A microscopic study of cracking found in the cores is being made by experienced petrographers, providing information on the time at which the cracks were formed (i. e., before hardening or after hardening) or whether chemical reactivity may have been involved in the cracking noted. A complete petrographic study is being made of each core to determine paste quality and the suitability of the aggregates. In many cases, the concentration of de-icer as a function of depth is being determined. These examinations require painstaking and time-consuming effort on the part of trained petrographers, but the results are generally rewarding.

The detailed plans and construction records for each structure in the detailed surveys are being studied. The influence of primary and secondary stresses on the presence of cracking will be evaluated. Construction records may provide information on concrete temperature, weather conditions, interruptions, etc., which may have been of importance with regard to subsequent performance.

Although not included in the random survey, the states of Kansas and Missouri had completed or were well along in a survey of their bridge decks. With this background data available, detailed investigations as just described were made in these two states during late summer of 1961. It will be of interest to see whether the results of these limited detailed investigations will be in agreement with those derived from the more extensive studies, at least in number, now in progress by these two highway departments. In addition, the field phase of a detailed investigation has been completed in Michigan. Cores and construction records for these three states are currently under study. The next detailed investigation will be in California. It is likely that a least one more state, probably New Jersey, will be included in the detailed studies. Detailed investigations will then have been conducted in five states.

It is anticipated that the results of the detailed investigations, supplemented by the random field survey data, will provide knowledge of the cause or causes for the various types of defects noted. In many of these cases, the solution is now probably available. For example, increased resistance to freezing and thawing and the use of chemical deicers can be obtained with adequately cured, air-entrained concretes having low water-cement ratios. Some defects might be remedied by indicated changes in design features. Yet others may necessitate more detailed study of means for avoiding their occurrence.

With respect to retarding existing deterioration, a study of the adequacy of current methods is under way as a part of the general PCA research program. Similar work by other investigators is in progress. Some of it was described in previous sessions at this meeting. All of this will serve as a basis for recommendations for retarding further deterioration.

As a supplement to the cooperative bridge deck study, the PCA laboratory has plans for laboratory and outdoor exposure tests of simulated bridge deck sections fabricated to include the various types of defects, both individually and in combination, that will evaluate their influence on performance, evaluate methods of voiding their occurrence, and evaluate recommended means for retarding deterioration.

The results of this cooperative bridge deck study will be reported at future meetings and in the technical literature after full review and concurrence by all of the participants in the program.