Condition Surveys of Concrete in Service

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•THE PRIMARY EMPHASIS in this paper is on condition surveys of concrete in service. It is sometimes difficult, and at times undesirable, to concentrate on concrete as a material to the exclusion of the structure or pavement built with the concrete, but quite often investigations deal with the material only and not with the structure. Usually, individuals or groups work in cooperation with others in making a condition survey, some being responsible for studying the concrete and others, such as structural engineers, being responsible for the survey of the structure. The two fields, though interdependent, require different skills and different investigational equipment. However, in order to study the performance of concrete in service effectively, it is almost essential that the investigation be made on the concrete as it is used. This paper deals with the procedures and techniques that are employed in the field studies.

Briefly, the steps involved in a condition survey of concrete in service may be listed as follows:

1. Define the problem.
2. Ascertain who is involved.
3. Determine the scope and participants.
4. Establish a procedure.
5. Plan the investigation.
6. Conduct the investigation.
7. Analyze and report the findings.

The application of these steps, through use of a few examples of field surveys, will be the objective of this paper.

In a way, a field research engineer is a diagnostician, a "doctor of concrete". A condition survey may be made on concrete in any condition, from new and unused to severely deteriorated concrete that is no longer useful structurally. Every investigation requires its own detailed procedure, and each investigator will approach the problem in his own way. Condition surveys may be of any extent, ranging from an investigation of a single small element to a nationwide study, such as the bridge deck survey that was undertaken by the Portland Cement Association (PCA) in cooperation with the Bureau of Public Roads and a number of state highway departments (1).

The procedures followed in conducting a bridge deck survey have been presented a number of times, but a brief review will illustrate how such an investigation is made. The major objectives of this survey were (a) to determine the types and extent of deck deterioration in selected areas, (b) to determine the causes of the various types of deterioration, (c) to develop methods for preventing deterioration of future construction, and (d) to develop methods for retarding deterioration of existing bridges now showing deterioration.

It is essential that the reasons for a condition survey be clearly understood and stated. In order to answer the first of the objectives as just stated, it was necessary to examine bridge decks to find out what was wrong with them; in other words, to define the problem.

Condition surveys were made in two ways: (a) random surveys on approximately 100 bridges in each of 12 states by local representatives of the Portland Cement Association, the Bureau of Public Roads, and the particular state highway departments, who were provided with a carefully prepared set of instructions, including definitions and appropriate photographs of each type of deck deterioration, and a form to fill in for each bridge; and (b) detailed surveys of approximately 12 bridges in each of five states that were included in the random surveys. The detailed surveys were made by a team of observers from the PCA Structural Bureau and the Research and Development Laboratories accompanied by representatives of the Bureau of Public Roads and the selected state highway departments. For this inspection, sketches were made of each span showing location and description of every defect on the deck. Cores were taken from each deck in carefully designated locations.

The data from both the detailed and random surveys were carefully analyzed and reported. One report provides an analysis of the observations of all the bridges visited, and should answer the first objective—types and extent of deck deterioration. In spite of very careful planning in preparation of the instructions, individual interpretations were made by the different inspection teams, and it has been difficult to analyze the random data. For uniformity in reporting the random survey data, a representative of the PCA Structural Bureau or of the laboratory probably should have accompanied each of the local survey teams.

Details of the bridge deck investigation have been purposely omitted, but it clearly qualifies as an unusually comprehensive condition survey of concrete in service. It was carefully planned and conducted and the information, when available, will be authentic and valuable.

For the bridge deck survey, the answers to the seven previously listed steps would be as follows:

1. The problem: An investigation of types and causes of concrete bridge deck deterioration.
2. Who is involved: PCA, the Bureau of Public Roads, and the selected state highway departments.
3. The scope and participants: Twelve states, the Bureau of Public Roads, and PCA.
4. The procedure: Agree on the need for the investigation and secure the cooperation of the several organizations.
5. The plan: Review the literature on other studies of a similar nature, and prepare a brochure on details to be investigated.
6. The investigation: Send brochures and forms to all states included in the random survey; select personnel from PCA and the cooperating organizations for making random and detailed surveys, and carry out the surveys.
7. The analysis and report: Make petrographic studies, assemble all available data, analyze, prepare a draft report, review with the cooperating organizations, and publish.

Another example of a survey, conducted on a less comprehensive scale, resulted from the occurrence of extensive pattern-cracking observed in two southeastern states (Georgia and Alabama) about 20 years ago. The first evidence of this cracking was reported by a regional bridge engineer of the Bureau of Public Roads who was making routine inspections of bridges in his area. The pattern-cracking was then observed in numerous other bridges in this state and a preliminary analysis by the particular state highway department pointed to an incompatability between certain aggregates and cements. A meeting of engineers from the state highway department, Bureau of Public Roads, and PCA was arranged, with a field inspection of about 20 selected bridges and a discussion of what to do about the problem. Samples of concrete from one of the affected bridge elements were found to contain copious deposits identified as alkali-silica gel, the by-product of alkali-silica reaction. A full-scale investigation of bridges in two states was suggested, the author being assigned the task of making the surveys.

In order to be completely impartial and fair in making the survey, it was decided that a relatively complete coverage of the two states would be required, with an examination of every bridge encountered. For rating purposes, four classifications of condition were established: Classes I and II were considered as being without the typical pattern-cracking, and therefore unaffected; and Classes III and IV demonstrated pattern-cracking, light and heavy respectively, and were considered as being affected. In the early stages of the survey, the author was accompanied by a representative of the particular highway department, and bridge classifications were a mutually agreeable value.

It was found that if a structure was affected with the pattern-cracking, the cracking could almost invariably be observed in the concrete end posts of the handrails. Each bridge in each state was given a sequential number and was identified in any other way that would make fruitful a search for highway department records relative to that bridge. Sampling of the cracked concrete was part of the program, and it was reasoned that, because the end posts were rather hopelessly damaged anyway, it would not hurt to remove any amount of concrete necessary to find evidence of the reaction. A letter from the chief engineer of the highway department was provided, authorizing removal of such samples at the author's own discretion, in case there should be any question about someone from out of state breaking up bridges.

Some of the bridges involved were almost a mile in length and ranged in height above the ground or stream from 20 to over 70 ft. Inspection of the substructure was difficult from the top of the bridge, but this problem was solved by use of a swinging basket that was suspended from a truck with a power-operated boom. The truck moved along the bridge roadway and the basket was raised or lowered as necessary to permit the inspection. For some of these basket inspections, a portable recorder proved to be very helpful in making a running record of what was observed. The record was transcribed as time permitted.

Bridges in these two states were among the first field structures to be included in the Portland Cement Association's soniscope test program. Trucks, scaffolds, ladders, and manpower were provided to assist in the work whenever necessary.

After the field work was completed and structures had been rated, a search for construction records was made and the materials used in the concrete were determined. For the ratings, only the most severe condition found in a given structure was used, even though such a condition may have been limited in extent. For example, several of the end posts may have been severely cracked, with a rating of Class IV, while the balance of the concrete would be no worse than Class III, or even Class II, but the structure would be rated as Class IV.

Where the records showed that two cements had been used without a specific record of where each had been used, the bridge was not accepted for analytical purposes. However, where two different aggregates were shown, such as a gravel and a granite, the elements in which each had been used were easy to separate by the field inspection. The results of this work have been reported elsewhere (2).

PCA has cooperated in making comprehensive condition surveys of concrete dams in the United States. F. R. McMillan participated in an initial survey more than 30 years ago, and helped to make repeated observations of the same dams in 1957. The record for each dam included a visual description of conditions found by the observers supplemented by photographs. These observations have been included in a series of reports that are available for future reference as needed (3).

The usual procedure followed in making these surveys was for an inspection party, including McMillan and several companions, to visit the dam and make detailed visual observations. Other tests were generally not made during these inspections, but any applicable construction data, where available, were recorded. These condition surveys provide a permanent source of reference material for use at any later date.

A final example illustrates a condition survey made on a single structure. Early in 1965 an investigation of dams in the Los Angeles area by a team of consulting engineers disclosed that a relatively small concrete arch dam (165 ft high by 620 ft long) in Ventura County had developed signs of pattern-cracking near the top, and there was some evidence that one of the abutments might be shifting. Further studies by a consulting engineering firm resulted in three alternatives with respect to the dam:

1. Remove defective concrete in the dam and replace with better concrete;
2. Remove most of the top 20 ft and permanently lower the spillway crest; or
3. Remove the dam completely.

This much of the study was reported in the April 22, 1965, issue of Engineering News-Record.

Articles in the Los Angeles papers and one technical journal then reported that the Ventura County Board of Supervisors had ordered that the dam be demolished. PCA was requested to make additional tests of the concrete using its soniscope. Arrangements for the tests, including the furnishing of equipment for going down both faces of the dam, were made by the Los Angeles office of the Portland Cement Association in cooperation with the Ventura County engineers in charge of the dam. Two engineers from the PCA Field Research Section visited the dam, which had been dewatered pending a decision as to its future.

A visual inspection showed that several of the upper lifts of concrete, under the spillway crest, were definitely, although not severely, pattern-cracked. For the evaluative tests, locations were selected at each end of the dam where there was no evidence of cracking, and at other intermediate locations that included pattern-cracked sections. The soniscope tests were made from upstream to downstream faces, radially through the arch concrete. Pulse velocity through undamaged concrete was established at about 13,500 fps plus or minus a few hundred feet per second. The tests also showed that pulse velocities dropped to as low as 9,300 fps in the cracked sections. The soniscope tests clearly showed that the concrete, except for the cracked sections, was in excellent condition and that there should be no fear concerning the safety of the structure so far as the undamaged concrete was concerned.

The Ventura Star Free Press carried an account of our tests and a statement that the dam would be saved but that two notches 30 ft deep and 140 ft long would be cut from the top of the arch, thus lowering the spillway crest and the pressure against the dam. This treatment was later reported (6).

In this case, the condition survey was limited to measuring the quality of the concrete in the dam and had nothing to do with other factors such as foundation stability. However, the tests provided assurance about the concrete that would have been very difficult if not impossible to learn in any other way.

SUMMARY

1. A survey may be made on concrete in any condition, from new and undamaged to completely deteriorated.
2. The objectives of the survey should be clearly defined.
3. Preliminary plans for the survey should be thoroughly laid out.
4. The field work will almost invariably be cooperative in nature, with the owner providing necessary clearances and authorization for making the investigation.
5. Whenever possible, and to such an extent as they are available, records of construction, including any data on materials, should be consulted and studied.
6. Sampling is generally necessary in order to provide information on any abnormalities of the concrete. An on-the-site investigation will sometimes reveal the presence of deteriorating influences, but usually a more thorough laboratory study is required.
7. Soniscope tests have been very useful in making nondestructive field examinations of concrete.
8. Complete impartiality and objectivity is of utmost importance in making a condition survey.
9. The records obtained in any survey must be kept in an orderly manner and in such a way that they may be filed for future use. A bound field book is excellent for permanent filing, but loose leaves are sometimes more suitable, depending on the circumstances.

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