Investigation of the Performance of Concrete in Service

E. O. AXON, Deceased, formerly Materials Research Director, Missouri State Highway Commission

•IN HIS remarks Dr. Mielenz has stated that in any investigation of the performance of concrete it is necessary to define the scope and objective of the investigation. I most certainly want to stress the importance of this requirement. If this procedure is not followed, the investigator will ultimately find that he has assembled a vast amount of nonpertinent records. This, of course, is most costly, but what is perhaps more serious is that unplanned action reduces the probability of attaining the desired results. Because the objectives of investigations of poor concrete performance can differ appreciably, identical records will not be assembled for each study. This makes it impossible for me to specifically list what records should or should not be assembled.

Now by mentioning investigation of poor performance of concrete, I do not want to imply that all investigations are or should be concerned with poor performance. But, I sincerely believe that the records will show that the vast majority of investigations are initiated because of poor concrete performance. This does not mean that good performance of concrete is not investigated, but rather that good performance is rarely the cause for initiation of an investigation. Actually, good performance of concrete is undoubtedly investigated as much as or more than poor performance, because it is investigated in conjunction with poor performance. In many instances the investigator is able to pinpoint the cause or the degree of poor performance by determining wherein the affected concrete differs from that exhibiting good performance.

I previously mentioned that the objectives of a study of poor performance of concrete could vary appreciably, and to illustrate this point I suggest that you consider the following two objectives:

First: To determine the cause for the poor performance of concrete, and
Second: To determine the location, amount, and degree of deteriorated concrete in a structure in which the concrete exhibits poor performance.

The type of records that would be assembled for these two studies would be radically different. For the second study, one would probably not be particularly concerned with records concerning materials, construction, or maintenance, but would be primarily concerned with surveys and tests on the concrete. Although this type of study can be a most complicated one, it usually is not the type that would require, and the needed answer would not permit, a study of long duration.

On the other hand, a study of the cause of poor concrete performance can be most lengthy. The cause of poor concrete performance is very likely to be a result of the following:

1. The standards established by the plans and specifications were not sufficiently high for the conditions of service.
2. A change in the conditions of service resulted in the established standards being inadequate.
3. The concrete did not meet the standards established by the plans and specifications.

This may appear to be a short and incomplete list. However, I believe that this list actually covers most causes of poor performance, and even if it does not, I am sure that it is sufficient for purposes of illustration.

The term "insufficient standards" covers a multitude of possible causes for poor performance, such as inadequate (a) design, (b) construction practices, (c) concrete

strength, (d) air requirements, (e) quality requirements for materials, and (f) protection and curing.

Then we have the possibility that the specified standards were adequate for the anticipated service conditions, but that unforeseen changes in service conditions caused them to be inadequate. Examples of such changes are unforeseen increases in traffic (particularly heavy traffic), and/or increased use of de-icers.

Finally, we have the possibility that the concrete did not meet the standards established by the plans and specifications. Here again the possibilities of nonconformance are great, as is also the degree of nonconformance.

From the preceding, it should be obvious that the amount of records that could be assembled is enormous, and many records may not be pertinent to a particular investigation. Consequently, prior to assembling records, the investigator must first determine whether an extensive investigation is warranted. Second, if it is warranted, he should then define the scope and objectives and prepare a detailed outline for future work. This outline should spell out in detail what records should be assembled, what information is needed from condition surveys and how they shall be obtained, and what samples are needed and how they shall be tested by either physical or analytical methods.

I feel sure that most organizations maintain a fairly complete file of the plans, specifications, construction and materials inspection reports and diaries, maintenance records, and traffic counts for most concrete in service. Also, official weather information is usually on hand or can be obtained. Finding records to assemble is, therefore, no serious problem. The problem is to know what records are needed and how to fill in the gaps where needed data are missing.

The initial approach to an investigation of poor performance of concrete is, therefore, to determine with what the poor performance is related or not related. This is usually accomplished by a reconnaissance survey and the assembling of the minimal amount of records. In Missouri the experienced researcher would initially do little more than check the information recorded on the proportioning plant inspector's daily reports. This would provide the researcher with such information as source of materials, concrete proportions, slump, air content, size of batch, air temperature at time of construction, whether the concrete was job- or truck-mixed, and the location of the proportioning plant. With this information and his knowledge of the materials, weather, traffic, construction and maintenance practices, and types of concrete deterioration found in Missouri, the researcher is fairly well equipped to analyze the type and scope of the problem, and to determine what additional information he needs to assemble from construction records, surveys, laboratory tests on concrete samples, or other sources.

If the survey indicates that the poor performance is related to batches or portions of batches, the researcher may well conclude that the problem is not worthy of extensive investigation. If the survey indicates a type of deterioration not associated with batches, the researcher looks for other associations. Do the manifestations of deterioration occur along joints and cracks? Is the deterioration primarily in cuts? Does it occur with a certain type of material? To get a good picture, the researcher may broaden the reconnaissance survey to include concretes in other projects and locations. This will continue until he has a rather clear picture of the type and scope of the problem.

At this point I would add a word of warning about reconnaissance surveys. Although these surveys are neither detailed nor exhaustive, they must be sufficiently thorough to determine whether the concrete deterioration under investigation does or does not occur in specific concretes. Consequently, these surveys must be made with care inasmuch as the data being obtained will be used in outlining the future course of the investigation. Hastily obtained and erroneous data at this stage of an investigation can have a rather disastrous effect on its probable success. For example, when we started our bridge deck investigation in 1959, we were rather suddenly confronted with a serious problem occurring as the development of a fracture plane in the upper part of bridge decks. This problem appeared to be so acute that it was deemed necessary to hurriedly obtain an estimate of the extent of the problem throughout the state. Consequently, engineers inexperienced in the problem were asked to investigate and report as to whether a fracture plane was developing in the bridge decks in their districts. One engineer reported that fracture plane was not a problem in their bridge decks. This report, which was

erroneous, started a chain reaction that almost caused us to ship coarse aggregate entirely across the state. The reason for this almost disastrous action was that the type of coarse aggregate used in the area where fracture plane was known to exist differed from the type of coarse aggregate used in the area where fracture plane was reported to be nonexistent or not significant. So the erroneous report resulted in the erroneous conclusion that the cause of the fracture plane was the use of a particular type of coarse aggregate.

This example not only points up the necessity of making accurate reconnaissance surveys, but it is related to another problem concerning assembly of records. Construction records are often not sufficiently detailed to provide the desired information. In such instances the researcher can frequently find inspectors and workmen who observed the placement of the concrete. Talks with these individuals can be helpful, but at times the most helpful answer that can be obtained is "I don't know". In my opinion, the possibility of obtaining desirable information from such interviews is more dependent on the interviewer than on the person being interviewed. The interviewer is after facts, not conversation. The interviewer should know what information he desires; he should be so familiar with construction practices that he can fairly well visualize what may have happened; and, above all, he should be sure that the one being interviewed is kept at ease.

Actually, in such interviews the researcher is often seeking verification of facts that can be obtained by more costly means. The person being interviewed should be made aware of this possibility, as it may help to remove any reluctance he may have about freely discussing control problems that were encountered during the job but were not recorded in detail.

Having determined the type and scope of the problem and having sufficient knowledge to describe the type or types of deterioration, the researcher is ready to decide whether further investigation is or is not warranted. If additional investigation is warranted, the investigator proceeds to prepare an outline for future work. He specifically states the objectives of future studies and the procedures for attaining these objectives. In doing this, he should refer to the literature pertinent to the problem under study.

The outline could necessitate determining the population of available concretes containing the variables under investigation. Before doing this, however, much time may be saved if consideration is given to limiting the investigation to concretes having approximately the same age, environment, traffic, design, materials, proportions, air content, and de-icing controls. Many agencies have an immense amount of concrete in service, but often the amount available for a statistically sound investigation of concretes placed under normal procedures is extremely small. This is due to the fact that changes in more than one variable are often made simultaneously.

The point is, however, that adequate preplanning can save an enormous amount of time in assembling records. Inadequate planning necessitates the assembling of an overabundance of records or the making of numerous trips to the files for additional data. Good planning permits an orderly assembly of records in the minimum of time, because the outline spells out the rules for selecting the concretes to be investigated and the pertinent records needed. The outline also spells out what laboratory tests are needed, how samples of concrete are to be obtained or made, and how these samples are to be tested.

To select the concretes meeting the specified requirements and to assemble the pertinent information concerning each, it may be necessary to refer to the plans, specifications, construction records, maintenance records, and weather records. The difficulty encountered in this task will undoubtedly depend on the type of records kept and the filing system used by the organization. If we are looking for concrete pavements constructed during a specific period, located in specific areas, and containing one or more variables, we can often obtain the desired list by making several sortings of computer cards. Most of the pertinent information concerning design and construction data, for our concrete pavements built prior to 1952, have been coded and punched on these cards. This procedure greatly facilitates the assembling of records, but it entails a considerable amount of work in keeping the records up to date. We are behind in this work primarily because we have reached a point where considerable time must

be spent in revising the coding system to permit inclusion of new variables. Because there is some question regarding the economic justification for this work, it has not been continued. The disadvantage of the system is that much unneeded data are coded, whereas the advantage is that considerable time is saved in assembling needed data for particular studies.

We do, however, have summary data sheets for all concrete paving projects on file in our research section. These sheets, containing most of the information placed on the computer cards, are filed by year of construction. Because these sheets can be sorted rather rapidly, a list of concrete pavements containing specific variables can be obtained in a short time.

I might mention one more thing about records. It is very unusual for a researcher to need construction records during the first or second year following construction. Surely we would hope that most concretes would last longer than that. However, administrators are faced with an ever-increasing volume of records that they desire to dispose of as soon as practicable. Many records may be disposed of in 5 years, but in investigating concrete the need for assembling records may not occur until 10, 15, or more years after construction. At these ages one may find that a large portion of the records have been destroyed. This is where we find our summary sheets most useful. We wish now that we had summary sheets for the concretes in our bridge decks. These summary sheets have been most valuable to us in making pavement surveys because we try to record on one sheet all the pertinent information concerning the concrete, pavement design, joints, reinforcement, base, and subgrade. We have or should have a summary sheet for each concrete pavement project, and all are filed in one map cabinet. If we had to obtain these data from our files and microfilms, we would have a tremendous task and would very possibly find much data destroyed.

This system (or systems) of preassembling records points up the fact that the assembling of detailed records starts during the construction of a concrete pavement or structure. Once a job has been completed and accepted, it is most difficult to add to the recorded information in inspection reports and in diaries. Being a researcher, I would urge all construction personnel to keep the best possible records.

As has been previously suggested, information assembled from plans, specifications, construction reports and diaries, maintenance records, and other sources may be inadequate to determine the specific cause of inadequate concrete performance. In such instances, the researcher must assemble the necessary records by conducting planned studies. Methods and procedures available to the researcher for assembling the necessary records will be presented in subsequent papers.

In closing I would again stress that assembly of records for investigation of concrete performance should be an orderly process. First, the type and scope of the problem should be determined. Then, if additional investigation appears warranted, a detailed outline of the investigation should be prepared, and the records pertinent to the study assembled. Insofar as possible, the pertinence of records should be determined prior to and not after assembly.