Evaluation of Pulse Velocity Tests

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●THE CALIFORNIA Division of Highways acquired a soniscope of Canadian manufacture in 1952. It has been used intermittently since then in condition surveys of timber and concrete structures. A few examples of its use will be described.

The soniscope has been found to be useful in detecting hidden decay in wood bridge piles and timbers. Small volumes of decayed wood cause a substantial drop in pulse velocity. Since virtually the entire member can be scanned rapidly at close intervals, pulse velocity measurements permit a more thorough survey than is practical by conventional means of boring and sounding. The results, however, must be interpreted with caution. Sound Douglas fir or redwood when dry, has a pulse velocity of the order of 6,000 to 7,000 ft per second. When thoroughly saturated, the velocity may be as low as 5,500 ft per second. The velocity of decayed wood when dry, may be as low as 4,000 ft per second, but when saturated, may rise to 5,200 ft per second. Obviously, more significant results can be obtained during the dry season. Low velocities found in certain timber piles have been found to be due to hidden circumferential shakes. Small volumes of decayed wood that might be overlooked in a conventional survey by boring and sounding, can be detected by a systematic survey with the soniscope, but confirmation of the suspected condition should be made by boring.

The pulse velocity of concrete in sound condition may vary within the range of 12,000 to 15,000 ft per second. The interpretation of soniscope readings of old concrete is seriously handicapped unless a good value for the particular concrete in a sound condition can be established. One solution lies in assuming that the highest velocities found in protected portions of the structure represent sound concrete. In the absence of good information, velocities above 12,000 ft per second may or may not be indicative of deterioration.

If the velocity is lower than about 10,000 ft per second, it may be assumed that deterioration has occurred, but in such cases there is usually visible evidence of the condition. The value of the soniscope result, then, lies in the possibility of assigning a numerical rating to express the degree of deterioration. Unless the pulse velocity of the concrete when it was sound is known, the assumed rating may not be suitable for comparison with other concrete. Nevertheless, without knowledge of previous pulse velocity, information of value may be obtained if successive readings are taken over a period of years. Such data may indicate a trend in rate of deterioration from which estimates of useful life may be made.

Deterioration of concrete due to alkali-aggregate reaction has been studied with the soniscope on several bridges 25 to 30 yr old. The general experience has been that pulse velocities vary over considerable range within short distances, a result that undoubtedly is due to a random distribution of cracks of varying width and depth.

An example of pulse velocity measurements of a bridge affected by alkali-aggregate reaction is given in Table 1.

The velocities shown in Table 1 are averages of results across several paths with the transducers placed each time at marked points. Inability to secure consistent readings from year to year is believed to be due to variations in moisture conditions and consequent changes in the width of cracks or of exudations within the cracks.

TABLE 1

BRIDGE 44-06, CONSTRUCTED 1931
1000-ft Steel Spans and 654-ft Reinforced Concrete Approach Spans

Part of Structure	Average Pulse Velocities, (ft per second) Dec 1953	Nov 1954	Nov 1955	% Change, 1953 to 1955
Beams at E end				
Inner	13,700	14,600	14,100	+2.8
Outer	10,700	9,800	9,800	-8.4
Columns	9,600	8,600	8,100	-15.6
E. Pier for Steel Span				
Central Portion	8,800	7,800	8,400	-4.5
North End	6,300	6,000	6,600	+4.2

Figure 1. Crack in top face of bridge strut, December 1953.

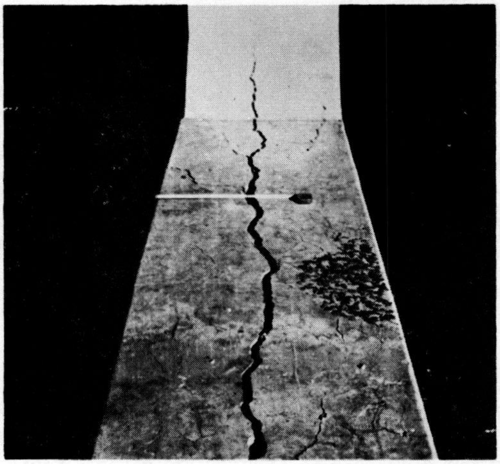

Figure 2. Same view as Figure 1, November 1955.

The inner beams are free from visible cracks and appear to represent concrete that has not been weakened by alkali-aggregate reaction because of protection from rainfall. They thus form a basis for estimating the percentage drop in pulse velocity of affected parts. Using the results obtained in 1955 (age 24 yr), reductions in pulse velocity are as follows:

Outside Beams	30 percent
Columns	43 percent
Pier, Central Portion	40 percent
Pier, End	53 percent

This bridge is still carrying main line traffic, and except for the deck, has not been repaired.

An illustration of periodic variations in pulse velocity due to alkali-aggregate reaction is afforded by tests of several large fragments from a bridge at Pismo Beach that was constructed in 1925 and was wrecked in 1955 to make room for freeway construction. The fragments in question were secured at locations where protection from rainfall was afforded by the deck. They were brought to the laboratory and after sawing the ends to produce plane faces for application of the soniscope transducers, were immersed in water for 10 days and subsequently have been stored in the fog room. A record of pulse velocity of one of the fragments which in general typifies the behavior of all, starting at the end of the 10-day soaking period, is as follows:

Months in Fog Room	Pulse Velocity (ft per second)	Months in Fog Room	Pulse Velocity (ft per second)
0	12,600	8	9,500
1	13,000	9	12,800
2	13,500	10	13,600
3	13,800	13	13,600
4	13,200	16	12,900
5	13,000	20	14,400
7	9,500	22	13,000

The results indicating alternate periods of weakening and recovery, are typical of five other specimens but maximum and minimum velocities are not found at the same ages. The results, therefore, indicate that the observed variations are not due to errors in

Figure 3. Side of strut shown in Figures 1 and 2.

soniscope measurements. Continuous exposure to saturated air has produced a gelatinous film on the surfaces and a number of pop-outs have developed.

The results illustrate the difficulty of forecasting the future course of deterioration of concrete in structures affected by alkali-aggregate reaction unless it can be done after many years of measurements.

A horizontal strut between columns of the Pismo Beach structure was observed to have a longitudinal crack which in 1953 had a surface width of $^3/_4$ in. The depth of the crack estimated from pulse velocity measurements at various distances was 6 in. In 1955, the surface width of the crack had increased to $1^1/_2$ in. and its depth was estimated to be 28 in. Top and side view of this strut are shown in Figures 1, 2, and 3.

The extreme width of cracks in this structure raised the question of the condition of the reinforcing steel, particularly since it is located about one-half mile from the ocean. Due to a misunderstanding with the contractor, an opportunity was not afforded to examine the reinforcement at critical locations as the structure was being wrecked.

The soniscope has been used in surveying the condition of the San Mateo-Hayward Bridge[1], a low level structure 7 mi long spanning the southern arm of San Francisco Bay. Chemical and physical tests of cores indicate that at the age of 25 years, the concrete has undergone a moderate amount of sulfate attack. The general average of pulse velocity in this concrete is about 13,000 ft per second. In a few locations, in uncracked concrete, pulse velocities lower than 11,000 ft per second have been measured. Only one series of pulse velocity measurements has been made to date, but it seems probable that future surveys will make it possible to follow the progress of sulfate attack and furnish a warning if a serious condition should develop.

A reinforced concrete bridge deck with frequent cracking visible on the surface was surveyed with the soniscope primarily because the lower side of the deck is difficult of access for visual inspection. Some difficulty was experienced in interpreting pulse velocities because of the presence of closely spaced reinforcing steel. However, when diagonal paths were selected, low pulse velocities were believed to be reliable indications that many of the cracks visible on the surface did in fact extend the full depth of the slab.

In cooperation with Southern California Edison Company and the Portland Cement Association, comparative tests for pulse velocity have been made with three soniscopes each operated by separate crews. Excellent agreement from a practical standpoint was found.

There is a need for a reliable calibration bar. It would serve a useful purpose in training soniscope operators. It would improve the accuracy of readings taken over short paths. It would provide a base for adjusting velocity measurements made several years apart, possibly with different instruments.

Periodic adjustments or the replacement of parts of the soniscope may be required. For this reason it is desirable that the operator be well trained in electronics of that he have ready access to the services of a competent technician.

[1] Tremper, Bailey, Beaton, John L., and Stratfull, R. F., "Corrosion of Reinforcing Steel and Repair of Concrete in a Marine Environment, Part II." HRB Bulletin 182.