Abridgment

Nondestructive Testing of Concrete Block Foundations for Telecommunication Towers

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The long-term performance of concrete blocks more than 25-years-old that anchored the guy wires bracing telecommunication towers was evaluated. Tasks included on-site visual inspection and nondestructive field and laboratory tests. Laboratory tests on drilled cores permitted correlation of nondestructive tests to the concrete compressive strength. Test results were analyzed, and recommendations were made to provide guidelines for evaluating the performance of similar concrete structures.

Although the deterioration of concrete is a common problem, severe service conditions, such as exposure to sulfates, deicing salts, and freezing and thawing, can be accommodated with proper design. Because many concrete structures are approaching their serviceability limit because of neglect or improper design, appropriate nondestructive testing procedures to evaluate their structural integrity are continuing at the University of Saskatchewan. The most common nondestructive testers available on the market are the rebound hammer, and the ultrasonic pulse velocity and pin penetration testers. Nondestructive field tests were compared with laboratory tests made on core samples obtained from the same structure, and guidelines for evaluating in situ strength of similar concrete structures are presented here.

INVESTIGATION

Saskatchewan Telecommunications, because of concerns about the integrity of concrete blocks used to anchor transmission towers, commissioned the investigation of three sites located near three communities in the Province of Saskatchewan, Canada. The below-ground anchor blocks, with dimensions of 60 × 36 × 72 in. in the community of Swift Current, 30-in. diameter × 70-in. depth in Rosetown, and 72-in. diameter × 50-in. depth in Oxbow, were made of concrete produced on site and are more than 25 years old. Another anchor block near the Oxbow site, which was only 5 years old, was also included in the study in order to increase the data base. The blocks were excavated to permit visual inspection and in-place testing.

Visual inspection of the anchor blocks revealed some spotty minor deterioration on the top surface of the concrete. The overall quality and condition of the blocks appeared to be satisfactory. No evidence of reinforcing steel corrosion was observed on the surface of the blocks.

The rebound hammer (ASTM C805) and the ultrasonic pulse velocity (ASTM C597) tests were chosen to investigate the condition of the concrete blocks. Results obtained from in situ nondestructive tests were compared with data from cores that were tested in the laboratory using the same nondestructive tests. The cores were then failed by either compression (ASTM C39) or splitting tension (ASTM C496). The air void systems of the hardened concrete were determined by the linear traverse modified point-count method (ASTM C457).

Because soils in most areas of Saskatchewan are known to contain sulfates that may affect the long-term durability of concrete, samples taken from each location were tested to determine sulfate content.

NONDESTRUCTIVE TEST DETAILS

Rebound Hammer

After the exposed surfaces were cleaned, ground relatively smooth, and marked with a grid pattern, surface hardness of the in-place concrete was determined by a rebound hammer to provide a relative measure of the quality of the surface concrete. Eight readings in the vicinity of a grid point were averaged to give one rebound number. In laboratory testing, the cores were lightly loaded in a compression testing machine, and the rebound hammer tests were performed on the circumferential surface.

Ultrasonic Pulse Velocity

Pulse velocity measurements were taken using a "V" meter. Depending on the arrangement of the transducers on the concrete surfaces, the transmission may be direct, indirect, or semidirect. In the direct transmission method, the transmitter and receiver are positioned on two opposite parallel faces; longitudinal pulses leaving the transmitter are propagated in the concrete in a direction normal to the transducer faces to provide maximum sensitivity along a well-defined path length. The indirect transmission method, in which both transducers are placed on the same concrete face, is the least satisfactory because, apart from its relative insensitivity and less well-defined path length, it gives pulse velocity measurements that are influenced by the concrete layer near the surface, and this layer may not be representative of the concrete

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in deeper layers. Intermediate accuracy is obtained by using semidirect transmission by placing the transmitting transducer on a face perpendicular to the receiving transducer.

Direct transmission longitudinally through the cores was used in the laboratory tests, whereas in the field all three measurements were used. Grease was used as a coupling medium between transducers and concrete. Because the amount of reinforcing steel in the blocks was minimal, no attempt was made to locate it.

ANALYSIS OF TEST DATA

Laboratory Calibration Tests

Part of the evaluation program was based on testing 4- × 8-in. cores that were drilled from the concrete block foundations. For each core, measurements were made to determine density, water absorption, pulse velocity, rebound number, and pin penetration. Most cores were then failed in compression; the remaining cores were failed in splitting tension. Average results for each site are presented in Table 1, and individual core compressive strengths are shown in Figure 1.

Regression analyses were performed on the data obtained from the core tests to correlate compressive strength with measured pulse velocity (Figure 1). A correlation curve from a previous study (*1*) is also shown.

Analysis of the rebound hammer data from the cores showed unsatisfactory correlation of strength with the rebound hammer number. It is possible that cored surfaces do not provide reliable readings.

Field Tests

Field pulse velocity test data were converted to concrete compressive strength data using the correlation curves obtained from the core tests. Rebound hammer field data were converted to concrete strength using the calibrations provided with the hammer, because rebound hammer tests on the cores did not provide a reasonable correlation curve. A statistical summary of the estimated strength data is provided in Table 1.

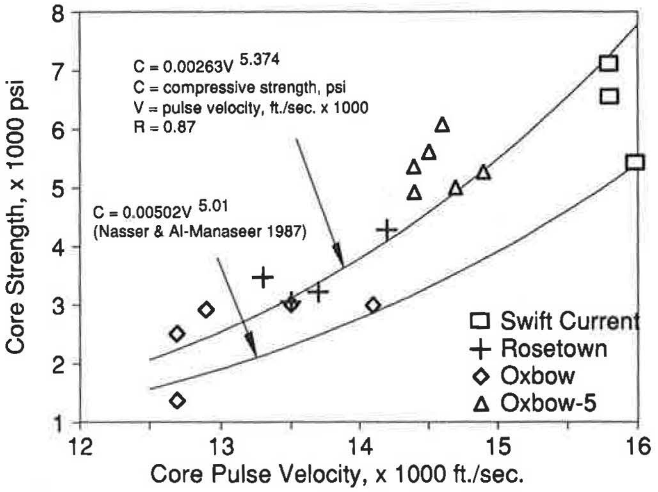

FIGURE 1 Relationship between core pulse velocity and core strength of concrete.

Pulse Velocity Tests and Data

The high ranges and coefficients of variation common in much of the strength data predicted from pulse velocities in Table 1 do not necessarily reflect the variation of the concrete strength through the various anchor blocks. Much of the pulse velocity data recorded is unreliable, because readings were attempted under conditions beyond the capabilities of the equipment.

TABLE 1 SUMMARY OF TEST DATA

	Core Tests				Field (In-situ) Tests								
Site	SC*	R	O	O-5	SC			R			O		
Pulse Velocity	D**	D	D	D	D**	S	I	D	S	I	D	S	I
No. of tests	4	5	7	8	3	21	12	6	14	15	3	17	16
Comp. Strength													
Mean, psi	7110	3530	2640	4700	3110	4080	2070	3500	2760	1360	2790	700	100
Maximum, psi	7780	4100	3120	5300	4760	6560	3380	4420	5500	4930	4250	1450	494
Minimum, psi	6120	2880	2250	4420	770	21	770	1660	810	390	1320	44	2
Coef. of Var. %	9.9	13.1	17.1	6.6	67	43	35	28	52	84	74	66	148
Rebound													
No. of tests	4	5	7	8		32			22			21	
Comp. Strength													
Mean, psi	1700	2800	1700	3500		4750			2070			1570	
Maximum, psi	1800	3000	1800	4200		6690			3700			2200	
Minimum, psi	1500	2800	1000	2800		2570			1100			1100	
Coef. of Var. %	9.2	3.2	17.5	14.2		4.6			8.1			5.5	
Core Comp.													
No. of tests	3	4	6	6									
Comp. Strength													
Mean, psi	6830	3510	2590	5390									
Maximum, psi	7130	4290	3010	6100									
Minimum, psi	5440	3060	1370	4920									
Coef. of Var. %	13.5	15.6	24.0	8.1									

Other Core Tests	SC	R	O
WaterAbsorption %	1.2	3.7	3.5
Density, lb./cu.ft.	147.3	142.8	141.7
Rebound Number	24	30	24
Splitting Tension, psi	564	421	353
Modulus of Elasticity, x 10^6 psi	2.70	1.35	1.17
Air Content %	5.5	5.2	4.9
Air-void Spacing Factor, in.	0.015	0.015	0.037

* SC = Swift Current, R = Rosetown, O = Oxbow, O-5 = Oxbow-5 year old concrete block
** D = direct transmission, S = semi-direct transmission, I = indirect transmission

Detailed examination of the concrete strengths estimated from the pulse velocities revealed that unrealistically low strengths usually resulted from semidirect transmission if one or both of the concrete surfaces on which the sending and receiving transmitters were placed were not formed but the concrete was simply cast against a plastic sheet separating the concrete block from the clay excavation. Although the unformed surfaces were ground to remove some roughness, apparently the coupling of the transducer with the concrete was not adequate for semidirect transmission. Only with direct transmission could reasonable results be obtained with an unformed surface. If both faces were formed or troweled, semidirect transmission usually gave a reasonable strength prediction.

With indirect transmission, unrealistic results were often obtained even if both faces were formed, and even if the distances between the transmitters were short. Because strength (f'_c) is a function of pulse velocity (V) raised to a high power ($f'_c = aV^b$, with b ranging from 5 to 6, where a and b are calibration constants), extreme caution is needed in evaluating the statistics. Even a small error in pulse velocity will indicate a large error in predicted strength. Although other factors, such as voids in the concrete along the transmission path, or the presence of reinforcing steel, can invalidate pulse velocity data, in the current study it appears that rough concrete surfaces or long transmission paths make much of the semidirect and indirect pulse velocity data suspect.

In two of the three sites investigated (Rosetown and Oxbow), the mean concrete strength predicted from direct transmission pulse velocity measurements lay within the range of strengths measured from compression tests on the cores and were relatively close to the mean strengths of all cores from the site considered (Table 1). At the Rosetown site, a large amount of the semidirect pulse velocity data was obtained between two smooth faces over relatively short distances. One was a formed vertical face, whereas the second face was the troweled top face of the block. These data yielded better correlation with the core strengths than the limited data that were recorded from direct transmission pulse velocities. The low value of 770 psi obtained from one of the three pulse velocities recorded by direct transmission was between two rough unformed surfaces separated by a relatively long (5 ft) transmission path.

Rebound Hammer Tests and Data

Compressive strengths obtained from rebound hammer numbers are summarized in Table 1. The calibration data obtained from the Schmidt hammer were applied directly, because the calibration using the data obtained from the 4- × 8-in. cores was unsuccessful. The mean strength predicted at each site from the rebound hammer data was only on the order of 60 to 75 percent of the measured average compressive strengths obtained in cores from the corresponding sites.

Accurate correlation was not expected because the rebound hammer approach is known not to provide accurate assessment of strength in old, hardened concrete. However, that the rebound numbers provided some correlation with concrete strength, in samples that were different in design, materials used, service location, and strength, shows potential for field evaluation of old concretes.

Other Tests and Measurements

The sulphate contents (percent by weight of dry soil as SO_4) were negligible at the Swift Current site, 0.31 percent at Rosetown, and 0.016 percent at Oxbow. Design records showed that the concrete blocks were made with ASTM Type V sulphate resisting cement, thus the high sulphate content in the Rosetown area did not cause significant deterioration of the concrete block as witnessed during the visual inspection.

The water absorption, density, modulus of elasticity, and splitting tensile strength presented in Table 1 for the various cores indicated that the core strength increased with concrete density and decreased with the degree of water absorption. Modulus of elasticity and splitting tensile strength were related to the compressive strength of the cores.

The air contents determined from cores (Table 1) show approximately 5 percent air, although it is believed that air-entraining agents were not used in the mix designs. The relatively high air-void spacing factors, exceeding the 0.1-in. value recommended as a maximum by Powers (*2*) for ensuring frost resistance under severe exposure, suggests that the air content is entrapped air only.

RECOMMENDATIONS

Recommendations for investigating the integrity and condition of buried concrete structures are as follows:

1. A visual inspection is needed for preliminary information on the surface condition and defines the field testing required.
2. The limitations of the nondestructive tests that will be used in the investigation must be known in advance. A minimum of two nondestructive tests are recommended for estimating in situ strength. Testing of representative cores is essential to ensure that reasonable calibration curves are used for evaluating field data.
3. For rough concrete surfaces (e.g., concrete cast against an excavated clay wall), direct transmission with the pulse velocity test yields representative results. Semidirect transmission may be unreliable with rough surfaces. Indirect transmission may be unreliable with all surfaces.

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