ACCELERATED SPLITTING-TENSION TEST FOR DETERMINING POTENTIAL 28-DAY SPLITTING-TENSILE STRENGTH AND MODULUS OF RUPTURE OF CONCRETE

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Recently, accelerated strength tests have been proposed for estimating the potential 28-day compressive strength of concrete. Attempts are also under way to find a means of replacing the 28-day compression test by one of the accelerated strength tests. This paper reports results of studies performed to determine if an accelerated test can be used to predict the potential 28-day modulus of rupture of concrete. In the modified boiling method adopted for this purpose, test cylinders are moist-cured for 18½ hours, boiled for 3½ hours, and tested in splitting tension 2 hours later. The companion 6 by 12-in. (15.2 by 30.5-cm) cylinders and 6 by 6 by 20-in. (15.2 by 15.2 by 50.8-cm) prisms are tested for splitting-tensile strength and modulus of rupture at 28 days. Correlation coefficients have been obtained for the results of accelerated splitting-tension and 28-day splitting-tension and modulus-of-rupture tests performed in both the laboratory and the field. From the limited test data available to date, it is concluded that the accelerated splitting-tension test can predict with sufficient accuracy the potential 28-day splitting-tensile strength and modulus of rupture of concrete.

•RECENTLY, accelerated strength tests have been used more frequently to determine potential 28-day compressive strengths. This was possible because of the pioneering researches of Akroyd (1), Malhotra (2, 3), and others (4). Accelerated strength tests are now being seriouly considered by the Canadian Standard Association to replace the 28-day standard acceptance test. However, little or no work has been reported to determine the feasibility of using a similar accelerated strength test to predict the potential 28-day modulus of rupture of concrete.

The present investigations were therefore undertaken to establish relationships between the accelerated splitting-tension tests and the 28-day splitting-tension modulus-of-rupture tests using standard test specimens and procedures. Preliminary experimental work was performed in a laboratory, and then the investigations were done in the field during the construction of street pavements in Monterrey City, Mexico.

LABORATORY INVESTIGATIONS

Materials Used

Normal portland cement (ASTM type 1) was used in the investigations. The physical properties of the cement are given in Table 1. The coarse aggregate was dolomitic limestone and had a maximum size of 1½ in. (3.8 cm). The fine aggregate was a natural sand. The bulk specific gravity and absorption of coarse and fine aggregate were 2.77 and 0.7 percent and 2.70 and 1.4 percent respectively.

Concrete Mixes

Six batches, covering wide water-cement ratios, were made in a 3-ft^3 (0.085-m^3) laboratory mixer. The mixes were designed to have a slump of 2 ± ½ in. (5.1 ± 1.3 cm). Nine test specimens consisting of six 6 by 12-in. (15.2 by 30.5-cm) cylinders and three 6 by 6 by 20-in. (15.2 by 15.2 by 50.8-cm) prisms were cast by hand-rodding from each batch by using standard ASTM procedures.

The standard 6 by 12-in. (15.2 by 30.5-cm) cylinders for the accelerated splitting-tension test were covered with tight-fitting steel plates; the cylinders and beams for 28-day tests were covered with a layer of impervious plastic.

After they were cast, all test molds were left in the laboratory at 73 F (23 C) and at a relative humidity of 65 percent for 18½ hours after which the cylinders and beams for 28-day testing were removed from the molds and transferred to a moist curing room.

The test cylinders for accelerated splitting-tension test were treated as follows. Three 6 by 12-in. (15.2 by 30.5-cm) cylinders while still in their molds were placed in a water tank maintained at 196 F ± 2 F (91 C ± 1 C). This temperature was selected to avoid excessive evaporation at boiling. After 3½ hours of curing at this temperature the cylinders were removed from the tank, demolded, and allowed to cool at room temperature for 1½ hours. The cylinders were then prepared for splitting-tensile strength and tested 30 min later. The total curing cycle was 24 hours.

The cylinders and beams for 28-day splitting-tension and modulus-of-rupture tests were tested in accordance with ASTM C 496-71 and C 78-72.

Analysis of Test Results

Plots of the results of the accelerated splitting-tension tests versus those of the 28-day splitting-tension and modulus-of-rupture tests are shown in Figures 1 and 2. Correlation coefficients and regression equations are also shown on these figures. Correlation coefficients for accelerated splitting-tensile strength and 28-day splitting-tensile and modulus-of-rupture values are greater than 0.98. This indicates highly significant correlations. This is even more remarkable, considering that water-cement ratios covering a wide strength range were used.

FIELD INVESTIGATIONS

After promising test results in the laboratory had been obtained, investigations were carried out to evaluate the reliability with which accelerated splitting-tensile tests could be used in the field to predict the later age splitting-tensile strengths and modulus-of-rupture values.

Table 1. Physical properties of type 1 portland cement used in laboratory investigations.

Physical Properties	Measurement
Fineness[a]	
Air permeability, cm^2/g	3300
Percent passing No. 325 mesh	92
Time of setting, hours and minutes	
Initial	2, 25
Final	3, 10
Soundness, percent	
Autoclave, expansion	0.14
Compressive strength of 2-in. cubes, psi	
3-day	2,560
7-day	3,510
28-day	4,960

Note: 1 in. = 2.5 cm. 1 psi = 6.9 kPa.

[a]Property supplied by the cement manufacturer.

Figure 1. Accelerated-cured splitting-tensile strength versus 28-day standard-cured splitting-tensile strength for laboratory tests.

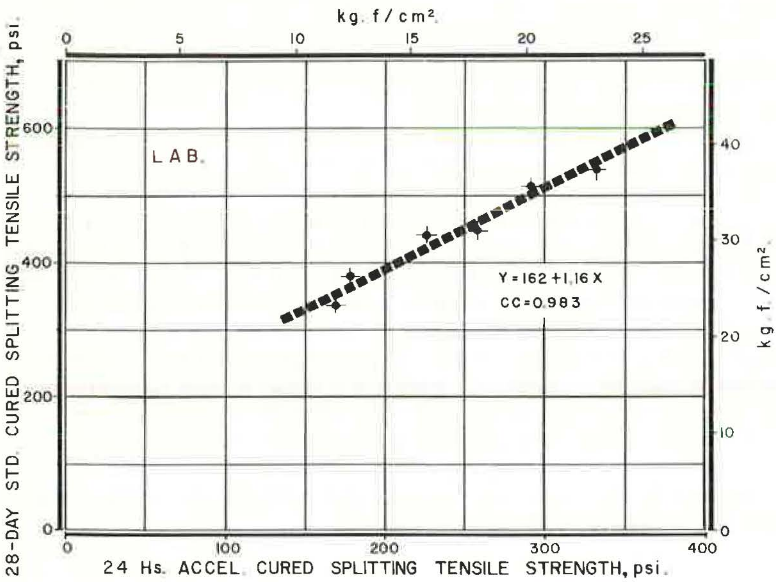
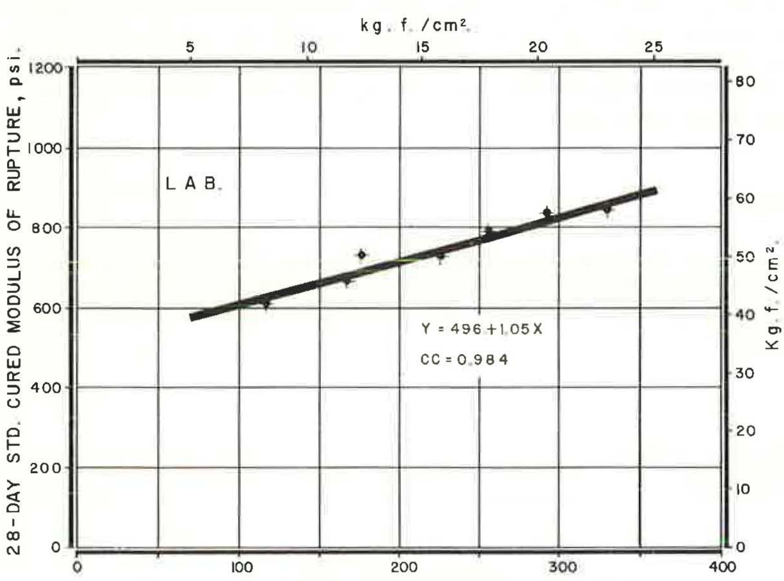


Figure 2. Accelerated-cured splitting-tensile strength versus 28-day standard-cured modulus of rupture for laboratory tests.



Materials Used

Portland blast furnace slag cement (ASTM C 595-73) was used for investigations in the field. The chemical analysis and physical properties of the cement are given in Table 2. The coarse aggregate was crushed blast furnace slag and had a maximum size of $1\frac{1}{2}$ in. (3.8 cm). Its chemical analysis is also given in Table 2. The fine aggregate was crushed limestone sand. The bulk specific gravity and absorption of coarse and fine aggregates were 2.40 and 4.5 percent and 2.63 and 1.5 percent respectively. A water-reducing admixture was also incorporated in the mixes.

Mixing, Sampling, and Curing Test Specimens

The concrete was batched in a dry mix plant and transit mixed in 6-yd^3 (4.6-m^3) mixers. The slump and air content of the mix were maintained at $2 \pm \frac{1}{2}$ in. (5.0 ± 1.3 cm) and 4 ± 1 percent respectively. All sampling was carried out in accordance with ASTM C 172-71.

Six specimens were cast from each batch sampled. They consisted of four 6 by 12-in. (15.2 by 30.5-cm) cylinders for the splitting-tension test and two 6 by 6 by 20-in. (15.2 by 15.2 by 50.8-cm) prisms for modulus-of-rupture test. A total of 30 batch samples were obtained.

The cylinder and beam specimens were cast in steel molds in accordance with ASTM C 31-69, and compaction was achieved by hand-rodding. The cylinder molds for accelerated curing were covered with tight-fitting steel plates, and the remaining molds were covered with wet burlap.

After they were cast, all molded specimens were left at the site for 16 hours and then were transported to the university laboratory. The molded specimens for accelerated splitting-tensile strengths had at least $18\frac{1}{2}$ hours of curing before they were placed in the hot-water tank. The procedures for the modified curing cycle used for accelerated strength tests and the 28-day tests were the same as those described for laboratory investigations.

Analysis of Test Results

Plots of results of accelerated splitting-tension test versus those of 28-day splitting-tension and modulus-of-rupture tests and correlation coefficients and regression equations are shown in Figures 3 and 4. The correlations are generally less than 0.75. These correlation coefficients are not so high as those obtained in the laboratory; this is to be expected. Nevertheless, with more stringent control of the concrete mix proportions at the ready-mix concrete plants, the degree of correlations should improve.

Within-Batch and Between-Batch Variations

The within-batch and between-batch variations for the test results are given in Table 3. These values seem to be reasonably satisfactory for specimens cast in the field.

CONCLUDING REMARKS

From the limited investigations discussed it can be concluded that the accelerated splitting-tension test offers possibilities of predicting 28-day splitting-tensile strengths and modulus-of-rupture values. The predicted values fall within ±15 percent limits.

In the investigations reported, only the 24-hour cycle has been tested for accelerated curing. Further research is needed to optimize the curing cycle so that the accuracy with which later age strengths can be predicted can be improved.

Table 2. Physical properties and chemical analysis of portland blast furnace slag cement and chemical analysis of blast furnace slag aggregate used in field investigations.

Item	Measurement
Physical properties of cement	
Fineness[a]	
Air permeability, cm^2/g	4200
Percent passing No. 325 mesh	97
Time of setting, hours and minutes	
Initial	2, 45
Final	3, 00
Soundness, percent	
Autoclave, expansion	0.02
Compressive strength of 2-in. cubes, psi	
3-day	2,770
7-day	3,840
28-day	6,120
Chemical analysis of cement, percent	
CaO (total)	55.50
SiO_2	25.50
Al_2O_3	7.70
Fe_2O_3	2.50
SO_3	1.83
Lost by ignition	1.20
Alkali (total)	0.44
No soluble remnant	0.20
Chemical analysis of aggregate, percent	
CaO	42.00
SiO	33.92
Al_2O_3	13.24
MgO	9.52
S	2.12
TiO_2	0.84
Fe_2O_3	0.72
P and Mn	0.14

Note: 1 in. = 2.5 cm. 1 psi = 6.9 kPa.

[a]Property supplied by cement manufacturers.

Figure 3. Accelerated-cured splitting-tensile strength versus 28-day standard-cured splitting-tensile strength for field tests.

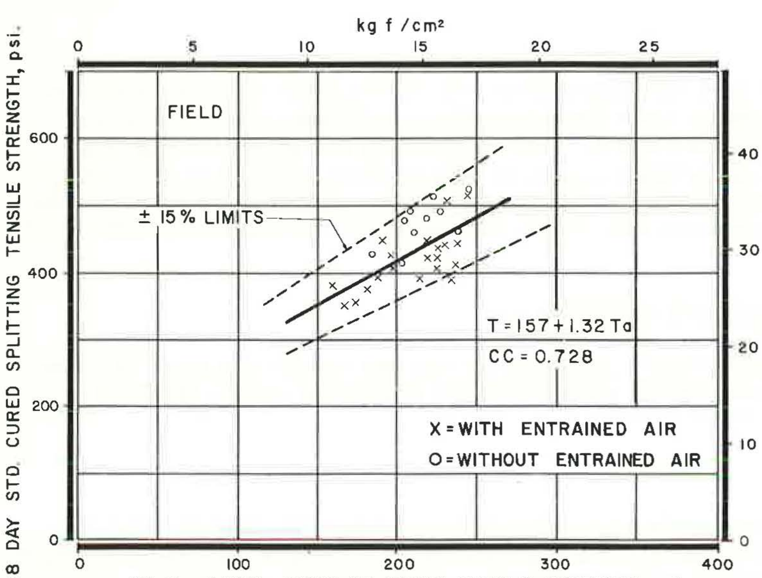


Figure 4. Accelerated-cured splitting-tensile strength versus 28-day standard-cured modulus of rupture for field tests.

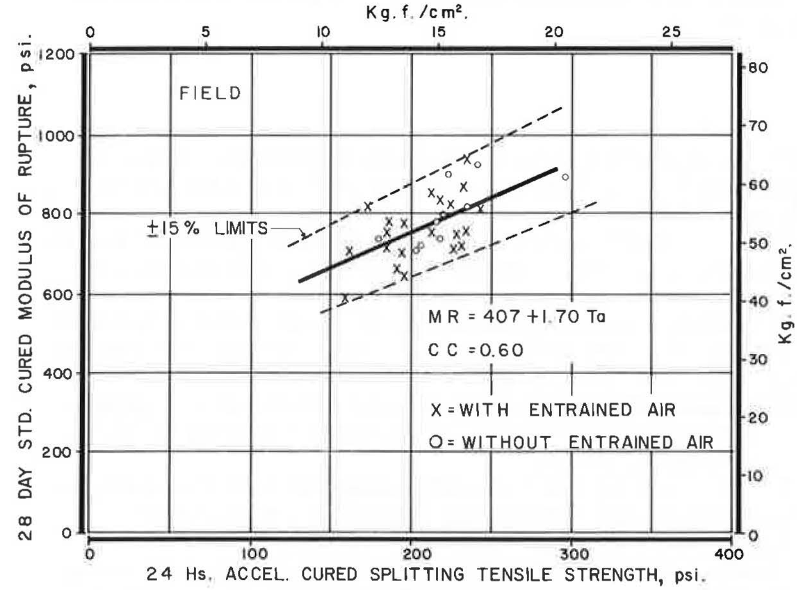


Table 3. Evaluation of within-batch and between-batch variations for field investigations.

			Avg Within-Batch Variation		Avg Between-Batch Variation	
Test	No. of Tests	Mean (psi)	Range (psi)	V_1 (percent)	Standard Deviation (psi)	Coefficient of Variation (percent)
28-day						
Modulus of rupture	52	768	54.0	6.16	23.3	16.06
Splitting tension	52	492	33.8	6.01	55.9	11.84
Accelerated						
Splitting tension	30	207	10.9	4.69	30.0	14.43

Note: 1 psi = 6.9 kPa.

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