Estimating Pervious PCC Pavement Design Inputs with Compressive Strength and Effective Void Content

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Abstract

This Tennessee Concrete Association sponsored study used a two-fold approach to obtain information on pervious PCC static modulus of elasticity (ASTM C 469), split tensile strength (ASTM C 496), and flexural strength (ASTM C 78). In the first approach existing correlations for normal PCC were applied to pervious PCC field and laboratory data. Secondly, the impact of effective void content on the previously mentioned properties was determined.

Thirty-three pairs of field cores and cylinders from various locations in Tennessee were used to evaluate the Ahmad and Shah correlation between compressive and split tensile strength. Predicted and measured values differed by twenty percent or less in 91.9 percent of the cases.

The average compressive strength and unit weight of twenty-three sets of laboratory cast cylinders were used to predict static modulus of elasticity using the ACI 318 equation. Predicted and measured values differed by twenty percent or less in 87 percent of the cases. Further, the relationship was found to be conservative (measured greater than predicted) in 82.6 percent of the cases.

Twelve pairs of field sawed beams and cores as well as six sets of laboratory cast cylinders and beams were used to evaluate the Ahmad and Shah and ACI 318 correlations between flexural and compressive strength. For the Ahmad and Shah relationship, predicted and measured values differed by twenty percent or less in 88.8 percent of the cases. For the ACI 318 relationship, predicted and measured values differed by twenty percent or less in 61.2 percent of the cases. The relationship was conservative in 66.7 percent of the cases.

All parameters declined with increasing effective void content; correlation coefficients ranged from 0.3827 to 0.7805.

Introduction

Pervious concrete is a mixture of coarse aggregate, water, Portland cement, and possibly admixtures. Unlike traditional Portland cement concrete (PCC), pervious concrete contains little or no fine aggregate, and has been called "no-fines" concrete for many years. This lack of fine aggregate gives the pavement its open void structure and produces a permeable concrete. Again unlike traditional PCC, a typical mix design for a pervious concrete will yield a wide range of engineering properties, depending on the degree of compaction. Design professionals such as architects, engineers, and municipal officials might be more comfortable designing and specifying pervious PCC if they had more information on pervious PCC design inputs for the pavement design programs they commonly use. Therefore, relationships between compressive, splitting tensile, and flexural strengths, as well as voids and unit weight should be determined with pre-construction testing for use as pavement design inputs *(Tennis et al. 2004*). Modulus of elasticity is also an important property used for the design of pervious PCC pavements (*Pasko, 1998*). ACI 330R-01, PCA, and AASHTO all use modulus of rupture as a design input to determine the pavement thickness (*ACI 330R-01, 2001; PCA, 1984; AASHTO, 1993*). AASHTO also uses the modulus of elasticity in design and mentions split tensile strength as a factor (*AASHTO, 1993*).

Research Objective

This Tennessee Concrete Association (TCA) sponsored study used a two-fold approach to obtain information on pervious PCC split tensile strength (ASTM C 496), flexural strength (ASTM C 78), and static modulus of elasticity (ASTM C 469). In the first approach, existing correlations for traditional PCC were applied to pervious PCC field and laboratory data. Secondly, the impact of effective void content on the previously mentioned properties was determined.

Literature Review

Split Tensile Strength. No standard tests have been adopted by ASTM to provide a direct measurement of the tensile strength of concrete. ASTM C 496 (*ASTM, 2004*) is used to determine the splitting tensile strength, which is an estimate of the tensile strength through an indirect tension test *(Mindess et al. 2003*). The splitting tension test is the easiest tensile test to accomplish and also gives the most reliable results (*Raphael, 1984*).

Research has shown that the proportionality of splitting tensile to the square root of compressive strength is not the most precise relationship *(Carino & Lew, 1982*). Many researchers have determined better relationships for wider ranges of compressive strengths. S.H. Ahmad and S.P. Shah provide the following relationship between splitting tensile and compressive strengths: $f_{ct} = 4.34\, f'_c{}^{0.55}$ (psi) *(Ahmad & Shah, 1985*).

In general, as age and strength increase, the ratio of split tensile to compressive strength decreases *(Ahmad & Shah, 1985*). Also, since crushed coarse aggregate seems to improve tensile strength more than it does compressive strength, the ratio of split tensile to compressive strength (f_{ct}/f'_c) also depends on the type of aggregate. In general, this ratio ranges from 0.08 to 0.14. The actual relationships between tensile and compressive strengths vary widely and exhibit significant scatter *(Mindess et al. 2003*). The differences in aggregate surface texture influence the paste-aggregate bond strength, which seems to control the overall tensile strength *(Cetin & Carrasquillo, 1998*). Also, the overall splitting tensile strength of concrete tends to increase as the splitting tensile strengths of the aggregates increase *(Wu et al. 2001*).

Ghafoori and Dutta reported the following equation for pervious PCC: $f_{ct}=c*f'_c{}^{0.5}$ (psi), where c is 5.67, 5.90, and 6.15 at ages of 28, 60, and 90 days respectively. Ratios of splitting tensile strength to compressive strength ranged from 0.1 to 0.142 for pervious PCC *(Ghafoori & Dutta, 1995*).

Flexural Strength. Flexural strength is determined in accordance with ASTM C 78-02 *(ASTM, 2004)*, which uses a 6 by 6 by 20 inch (152.4 by 152.4 by 508-mm) beam with a third point loading. The flexural strength is also referred to as the modulus of rupture, or the theoretical maximum tensile strength *(Mindess et al. 2003).* One concern with determining the modulus of rupture is that the equation used is derived from elastic theory, which assumes elastic behavior of concrete to the point of failure. However, this is not the case and can result in variations between the measured and predicted values *(Raphael, 1984).*

Pervious Concrete Pavements reports that the flexural strength of pervious concrete in a rigid pavement is very important to its design. However, testing to determine the flexural strength of pervious concrete may be subject to high variability. Therefore, it is common to measure compressive strengths and use an empirical relationship to estimate flexural strengths for use in design *(Tennis et al. 2004).*

Two of these relationships for normal PCC are given by ACI 318 and Ahmad & Shah, respectively: $f_r=7.5f'_c{}^{0.5}$ (psi) and $f_r=2.30\ f'_c{}^{2/3}$ (psi). The ratio of flexural to compressive strength (f_r/f'_c) ranges from about 0.11 to 0.23 *(Mindess et al. 2003).* It has been reported that the current ACI code expression for modulus of rupture overestimates the actual value for very early-age concretes and underestimates the modulus of rupture for concretes above 2175 psi (15 MPa) *(Khan et al. 1996).* Analysis of a wide range of data indicates that the best-fit for flexural strength depends on a power greater than the square root, as shown in the Ahmad & Shah relationship.

Pervious Concrete Pavements reports that flexural strengths in pervious concretes generally range between about 150 psi (1 MPa) and 550 psi (3.8 MPa). Many factors have shown to influence the flexural strength, particularly degree of compaction, porosity, and the aggregate to cement ratio *(Tennis et al. 2004*). An increase in aggregate size results in a reduction in the flexural and compressive strengths of pervious PCC, due to the increased total porosity and pore size *(Marolf et al. 2004*).

Modulus of Elasticity. The term modulus of elasticity does not represent a single value because concrete is not a linear elastic material. ASTM C 469 *(ASTM, 2004)* is used to determine an estimate of the modulus of elasticity by estimating the chord modulus. This value is more easily determined experimentally and is a more conservative measure than the initial tangent modulus, which is the closest approximation to a modulus of elasticity derived from a truly elastic response *(Mindess et al. 2003*).

ACI 318 predicts the modulus of elasticity based on the compressive strength and the unit weight: E_c (in psi) = (Unit weight in pcf)$^{1.5}$*33*(Comp. Strength in psi)$^{0.5}$ *(ACI,* *2002)*. Researchers have shown this value to be conservative and that actual elastic moduli values are up to 55% higher *(Klink, 1986*). The relationship between the modulus of elasticity and compressive strength of pervious PCC was found to be very similar to that of normal PCC *(Ghafoori & Dutta, 1995)*. Research has shown that the aggregate properties have a large effect on the static modulus of elasticity of normal concrete. Due to the inherent stiffness and large volume fraction it occupies, the aggregate exerts the major influence on the elastic modulus. Both the aggregate stiffness and aggregate type affect the elastic modulus *(Wu et al. 2001*). Crushed aggregates provide a superior bond when compared to gravel, thus resulting in better strength properties *(Cetin & Carrasquillo, 1998)*.

Laboratory Materials

Limestone and creek gravel coarse aggregates were obtained locally. The limestone aggregate had a gradation slightly more uniform than AASHTO No. 89 *(AASHTO M43-88, 2004)*. The creek gravel was sieved and recombined to produce a similar gradation. In order to reduce the amount of sieving required, a local river sand was obtained, sieved, and used to provide the finer portions, passing No. 4 sieve and retained on the No. 50 sieve, of the creek gravel coarse aggregate gradations. Type 1 Portland cement from bulk storage was obtained from a local PCC producer. Local tap water was used for all laboratory mixtures.

Laboratory Sample Preparation Procedure

The mixture proportions used for all laboratory mixtures are similar to those shown in the NRMCA paper "Determining Pervious PCC Permeability with a Simple Triaxial Flexible-Wall Constant Head Permeameter" (*Crouch et al. 2006*), which will also be presented at the symposium. All test batches were mixed in a 6 cubic foot (0.17 m^3) nominal capacity laboratory electric mixer. 3.25 to 3.75 cubic foot (0.091 to 0.105 m^3) batches were used. In each case, seven 6 by 12 inch (152.4 by 304.8-mm) cylinders, seven 4 by 8 inch (102 by 203-mm) cylinders, and three 6 by 6 by 21 inch (152.4 by 152.4 by 533.4-mm) beams were cast from each batch. Compactive effort was achieved using a 10-lb (44.5 N) Marshall Hammer (*AASHTO T245-97, 1998*) with an 18 inch (457-mm) drop and a 3.875 inch (98.4-mm) diameter base plate for the 4 inch (102-mm) diameter specimens or a 22.5-lb (100 N) Marshall Hammer *(ASTM D 5581-96, 2005)* with an 18 inch (457-mm) drop and a 5.88 inch (149.4-mm) diameter base plate for the 6 inch (152.4-mm) diameter cylinders. The larger hammer with a 5.88 inch (149.4-mm) square base plate was used for the beam specimens. The research team attempted to apply equal compactive effort to specimens of different sizes using the equivalences in ASTM D 5581-96 *(2005*). Seven different levels of compactive effort (hammer blows and rodding) were chosen to attempt to encompass the entire range of field compactive efforts.

On the day after casting, all cylinders were de-molded, labeled, and placed in a lime-water immersion at 73±3°F (22.9 ± 1.7°C). Two of each size cylinder and one beam cast for each mixture at each compactive effort level were used to determine the effective air void content. Effective air void (voids which can be penetrated by water from the surface) determination was performed as per Crouch et al *(2003)* with the exception that the cylinders remained in the water bath 24 hours prior to determination of submerged weights. Since effective air void determination required oven drying at 212°F (100°C), the cylinders used for this procedure were not used for any other testing. Concrete block testing *(ASTM C 140-99b, 2001)* uses a similar procedure to determine volumetric properties on some units and assume they are representative of other units in the lot.

Field Samples

Field samples were obtained by coring or sawing as per ASTM C 42 (*ASTM, 2004*) from the locations of TCA pervious concrete placements in Tennessee. Unlike laboratory samples, field samples were oven-dried at 125°F (51.7°C) to essentially constant mass for effective void content determination (*Crouch et al. 2003*). Drying the samples at a lower temperature allowed them to be used for subsequent testing without alteration of the sample properties. Available information on field mixture proportions is shown in another NRMCA paper which will be presented at the symposium, "Determining Pervious PCC Permeability with a Simple Triaxial Flexible-Wall Constant Head Permeameter" (*Crouch et al. 2006*).

Strength and Modulus Determination Procedures

Compressive strength, splitting tensile strength, flexural strength and static modulus of elasticity were determined in accordance with ASTM Test Methods C 39, C 496, C 78, and C 469 *(ASTM, 2004)*, respectively. Testing of all laboratory fabricated and field cast cylinder specimens was at 28 days. All laboratory fabricated test specimens were cured by lime-water immersion from the time of demolding until the time of capping or testing. Field cast and cut specimens were cured by lime-water immersion from demolding till void determination at low temperature. Following void determination, field specimens were returned to lime-water immersion until the time of permeability testing (cylindrical specimens only). After permeability testing, the specimens were returned to the lime-water curing tank until the time for capping or testing. Timing of the testing of field specimens varied and was based on availability.

Results

Field results used to evaluate the compressive strength–split tensile strength relationship are shown in Table 1. Laboratory results used to evaluate the compressive strength–static modulus of elasticity relationship are shown in Table 2. Field and laboratory results used to evaluate the compressive strength–flexural strength relationship are shown in Table 3. Field data was always preferred and when available in sufficient quantity, such as for the compressive strength-split tensile strength relationship, evaluation was used exclusively. However, no core obtained to date and few field cast cylinders had sufficient length for determining the static modulus of elasticity, therefore laboratory fabricated specimens were used for evaluating the compressive strength–static modulus of elasticity relationship. In the case of the compressive strength–flexural strength relationship, an inadequate amount of field data was available and data obtained from laboratory fabricated specimens was used to augment the evaluation.

Specimen pairs for evaluation of the compressive strength-split tensile strength and compressive strength-flexural strength relationships were selected based on similar effective void contents. Effective void content differences are also shown in Tables 1 and 3. Specimen pairing was not required for evaluation of the compressive strength-static modulus of elasticity relationship. Except for the companion cylinder required by ASTM C 469 *(ASTM, 2004*) to determine forty percent of the ultimate load, static modulus of elasticity and compressive strength were performed on the same specimens. Effective void contents are shown in Table 2.

Table 1. Field Data Used for Evaluating the Relationship between Compressive Strength and Split Tensile Strength

Location	Sample Type	Compressive Strength, psi (MPa)	Split Tensile Strength, psi (MPa)	Effective Voids Difference in Specimens (%)
Greenville, TN 2005	Cylinder	1650 (11.4)	280 (1.9)	≤ 0.5
		1930 (13.3)	320 (2.2)	0.5– 1.0
		3490 (24.1)	380 (2.6)	0.5 – 1.0
		2945 (17.2)	345 (2.4)	≤ 0.5
	Core	2230 (15.4)	305 (2.1)	0.5 – 1.0
		2010 (13.9)	290 (2.0)	≤ 0.5
		1520 (10.5)	165 (1.1)	≤ 0.5
Burgess Falls, TN 2005	Cylinder	3320 (22.9)	325 (2.2)	≤ 0.5
		3995 (27.6)	440 (3.0)	≤ 0.5
		4710 (32.5)	500 (3.5)	≤ 0.5
		4840 (33.4)	565 (3.9)	0.5 – 1.0
	Core	3500 (24.1)	355 (2.5)	0.5 – 1.0
		2910 (20.1)	370 (2.6)	0.5 – 1.0
		2560 (17.7)	295 (2.0)	≤ 0.5
		2260 (15.6)	285 (2.0)	≤ 0.5
		2720 (18.8)	320 (2.2)	≤ 0.5
Williamson Co. TN, 2005 Agricultural Expo Center Class F Fly Ash	Cylinder	2070 (14.3)	305 (2.1)	≤ 0.5
		2580 (17.8)	355 (2.5)	1.5 - 2
		4390 (30.3)	530 (3.7)	1 – 1.5
		2495 (17.2)	365 (2.5)	0.5 – 1.0
	Cores	1230 (8.5)	190 (1.3)	≤ 0.5
		1440 (9.9)	220 (1.5)	≤ 0.5
		1160 (8.0)	195 (1.3)	0.5 – 1.0
		1450 (10.0)	195 (1.3)	≤ 0.5
Williamson Co. TN, 2005 Agricultural Expo Center Class C Fly Ash	Cylinders	2160 (14.9)	280 (1.9)	≤ 0.5
		2660 (18.3)	360 (2.5)	≤ 0.5
		4810 (33.2)	450 (3.1)	0.5 – 1.0
		2925 (20.2)	350 (2.4)	1 – 1.5
	Cores	2140 (14.8)	270 (1.9)	≤ 0.5
		1870 (12.9)	270 (1.9)	≤ 0.5
		2370 (16.3)	325 (2.2)	≤ 0.5
		2600 (17.9)	280 (1.9)	≤ 0.5
Norris Dam TN, 2004	Cores	1270 (8.8)	180 (1.2)	0.5 – 1.0

Table 2. Laboratory Data Used for Evaluating the Relationship between Compressive Strength and Static Modulus of Elasticity

Sample / Diameter	Average Effective Voids (%)	Average Compressive Strength, psi (MPa)	Average Modulus of Elasticity, ksi (GPa)
Limestone 4-inch	35.5	1750 (12.1)	2100 (14.5)
	31.5	2330 (16.1)	1500 (10.3)
	29.0	2430 (16.8)	2500 (17.2)
	27.0	3090 (21.3)	2700 (18.6)
	23.0	4190 (28.9)	3800 (26.2)
	29.5	2790 (19.2)	2500 (17.2)
	27.0	3090 (21.3)	2300 (15.9)
Limestone 6-inch	35.0	1790 (12.3)	2000 (13.8)
	32.0	2140 (14.8)	1900 (13.1)
	28.5	2550 (17.6)	2600 (17.9)
	26.0	3800 (26.2)	2950 (20.3)
	25.5	4150 (28.6)	3050 (21.0)
	29.0	2720 (18.8)	2750 (19.0)
	27.0	2720 (18.8)	2650 (18.3)
	25.5	2930 (20.2)	2750 (19.0)
Gravel 4-inch	32.0	2470 (17.0)	2550 (17.6)
	31.0	2890 (19.9)	2450 (16.9)
	17.0	6320 (43.6)	3950 (27.2)
	23.0	4280 (29.5)	2950 (20.3)
Gravel 6-inch	30.5	2880 (19.9)	2400 (16.5)
	32.5	2240 (15.4)	1950 (13.4)
	19.0	5100 (35.2)	3450 (23.8)
	19.5	5070 (35.0)	3450 (23.8)

Analysis of Results

A plot of measured values of split tensile strength and compressive strengths compared to values predicted by the Ahmad and Shah Relationship for normal PCC is shown in Figure 1. A plot of measured values of static modulus of elasticity and compressive strength compared to values predicted by the ACI 318 Relationship for normal PCC is shown in Figure 2. Similarly, a plot of measured values of flexural strength and compressive strengths compared to values predicted by the Ahmad and Shah relationship and the ACI 318 relationship for normal PCC is shown in Figure 3. Figures 4 through 6 show comparisons of split tensile strength, static modulus of elasticity, and flexural strength with effective void contents, respectively. Table 4 shows statistical analysis of applying normal PCC correlations to pervious PCC data.

Split Tensile Strength. There is no statistically significant difference in measured split tensile strengths and Ahmad and Shah predictions of split tensile strengths at the 95 percent confidence interval in a two-tailed paired t-test. The Pearson Correlation coefficient was 0.9376 indicating a very strong relationship. In 91.9 percent of cases, the prediction differed from the measured value by less than 20 percent. Based on these facts, the Ahmad and Shah Equation appears to be a promising method of estimating split tensile strength of pervious PCC from pervious PCC compressive strength. The

Table 3. Field and Laboratory Data Used for Evaluating the Relationship between Compressive Strength and Flexural Strength

Location	Compressive Strength, psi (MPa)	Flexural Strength, psi (MPa)	Effective Voids Difference in the specimens
Burgess Falls,TN 2005	3500 (24.1)	490 (3.4)	≤ 0.5
	2910 (20.1)	455 (3.1)	0.5 – 1.0
	2560 (17.7)	500 (3.5)	≤ 0.5
	2260 (15.6)	465 (3.2)	≤ 0.5
	2720 (18.8)	455 (3.1)	≤ 0.5
Williamson Co. Class C Fly Ash	2140 (14.8)	305 (2.1)	≤ 0.5
	2010 (13.9)	335 (2.3)	≤ 0.5
Williamson Co. Class F Fly Ash	1230 (8.5)	390 (2.7)	≤ 0.5
	1440 (9.9)	255 (1.8)	≤ 0.5
	1160 (8.0)	210 (1.5)	≤ 0.5
	1450 (10.0)	330 (2.3)	0.5 – 1.0
	970 (6.7)	215 (1.5)	1 – 1.5
Lab 6-inch Samples with Limestone Aggregate (average of 2 specimens)	2550 (17.6)	365 (2.5)	2 – 2.5
	3800 (26.2)	490 (3.4)	2 – 2.5
	2720 (18.8)	410 (2.8)	2 – 2.5
	2720 (18.8)	510 (3.5)	≤ 0.5
	2930 (20.2)	570 (3.9)	1.5 - 2
	4150 (28.6)	635 (4.4)	3 – 3.5

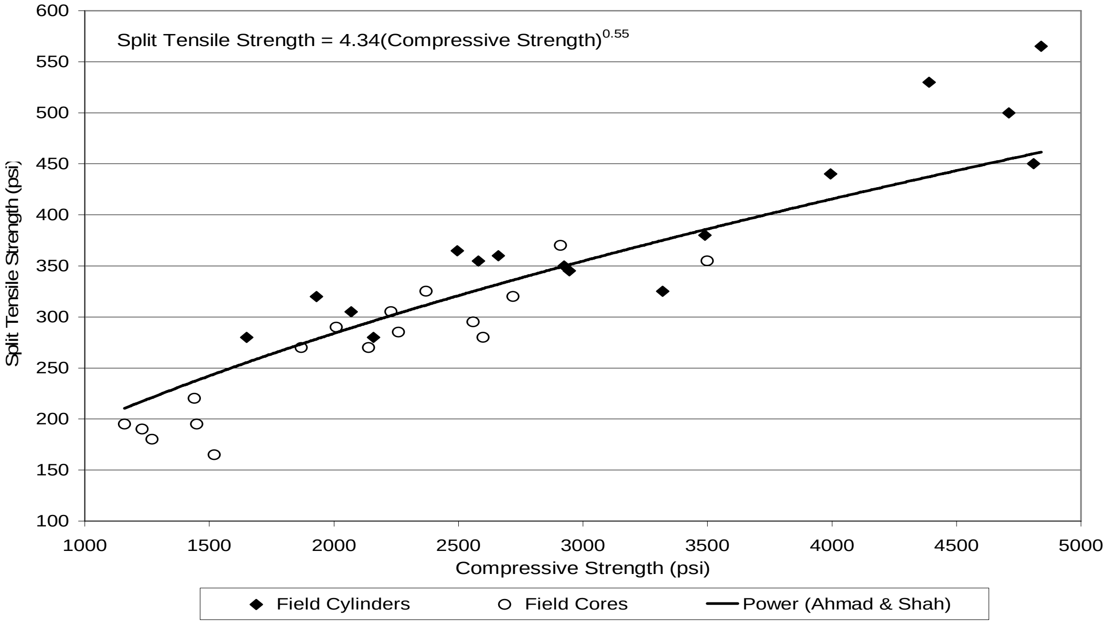

Figure 1. Split Tensile Strength vs. Compressive Strength for Field Samples

correlation coefficient between split tensile strength and effective void content was 0.7805 indicating a fair relationship. The correlation equation for split tensile strength based on voids will most likely provide an estimate of split tensile strength inferior to the estimate based on compressive strength.

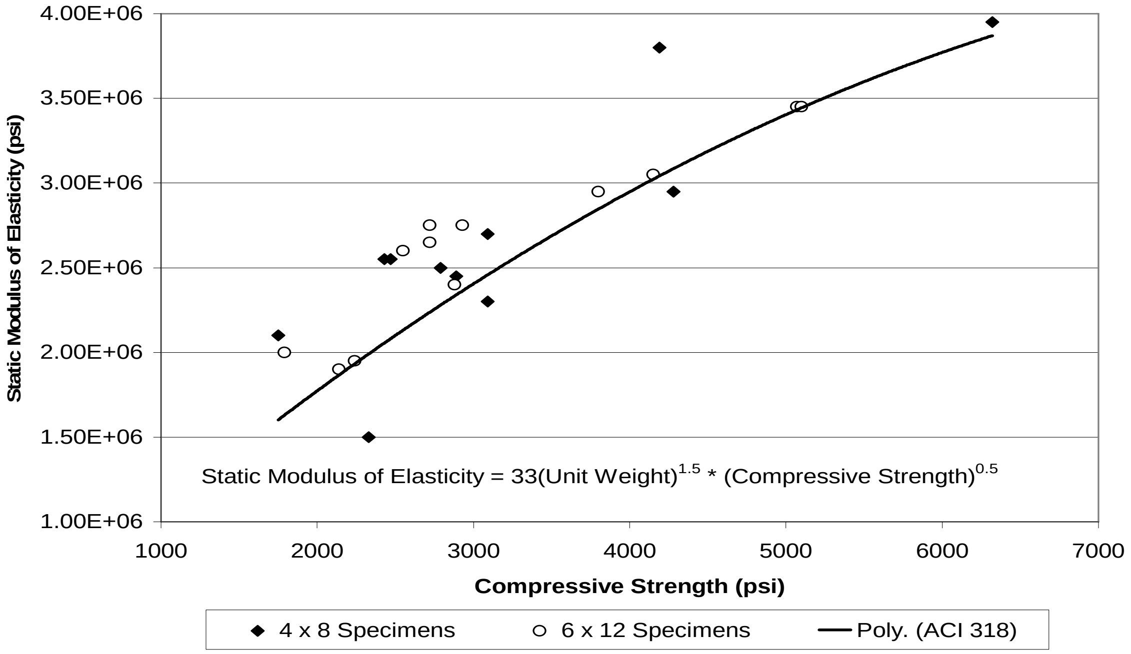

Figure 2. Static Modulus of Elasticity vs. Compressive Strength for Lab Samples

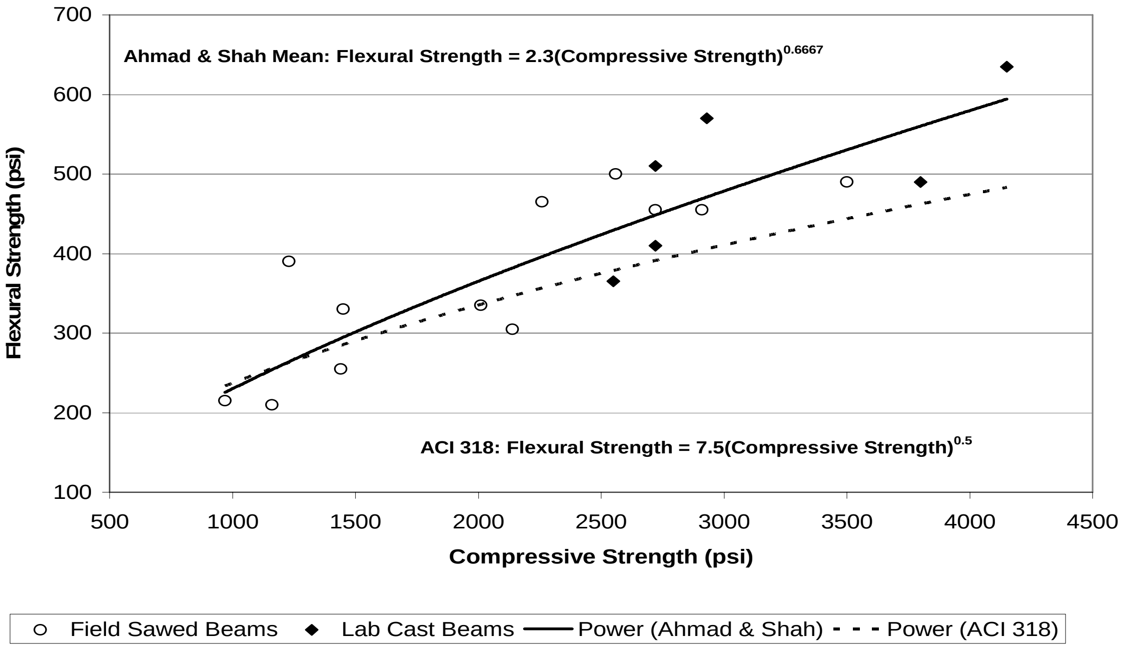

Figure 3. Flexural Strength vs. Compressive Strength for Field and Lab Samples

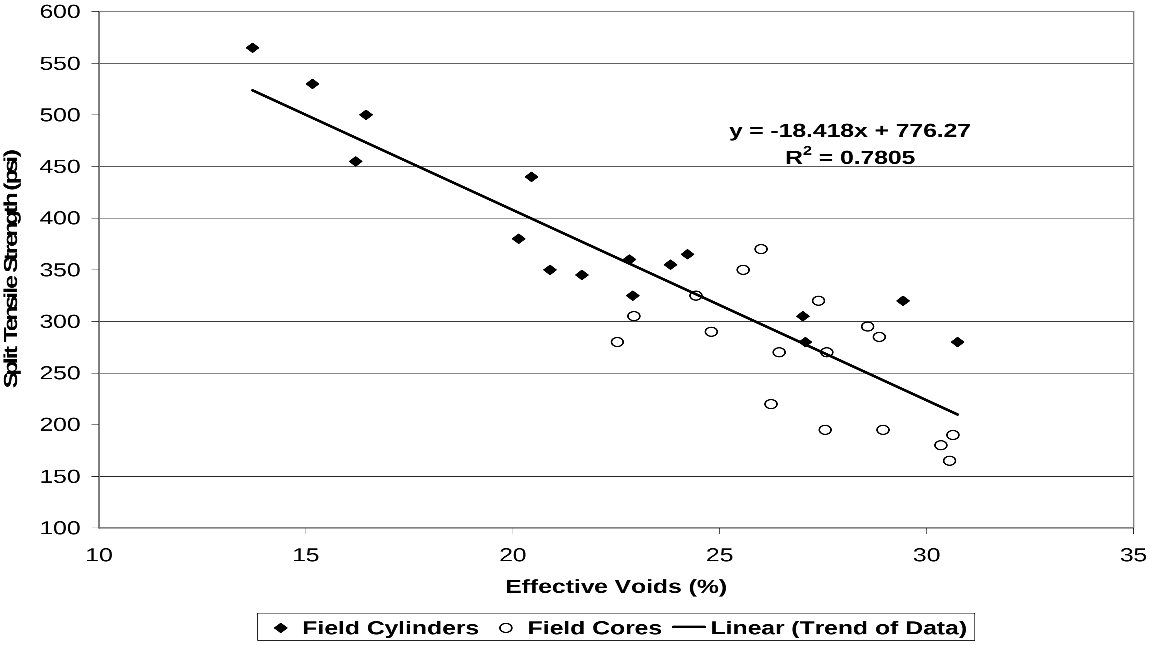

Figure 4. Split Tensile Strength vs. Effective Void Content for Field Samples

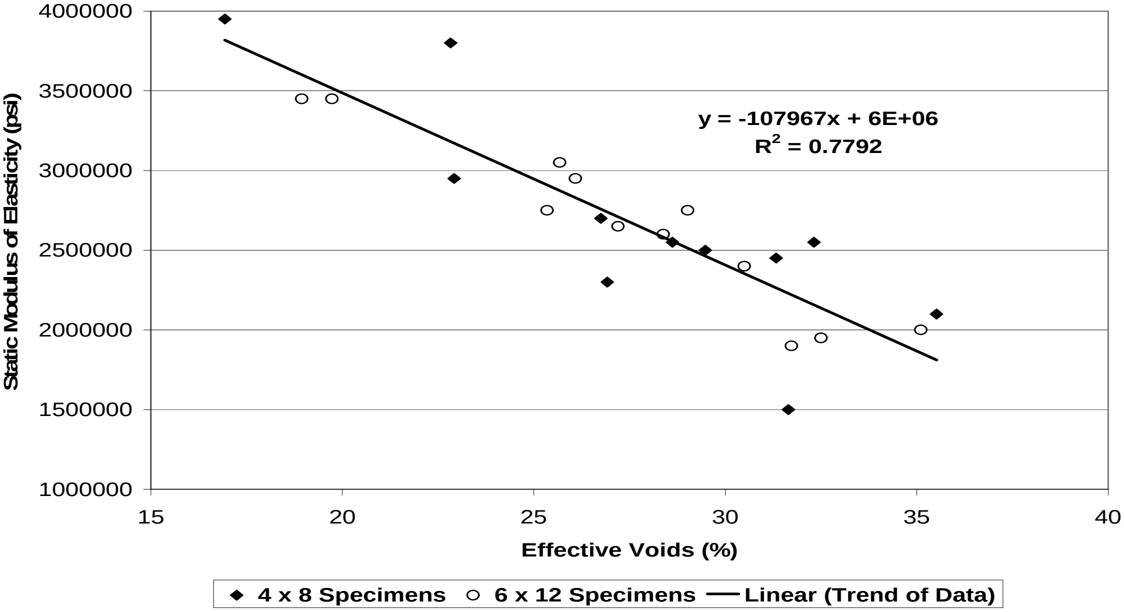

Figure 5. Static Modulus of Elasticity vs. Effective Void Content for Lab Samples

Static Modulus of Elasticity. There is a statistically significant difference in measured static modulus of elasticity and ACI 318 predictions of static modulus of elasticity at the 95 percent confidence interval in a two-tailed paired t-test. The Pearson Correlation coefficient was 0.9008 indicating a very strong relationship. In 87 percent of cases, the prediction differed from the measured value by less than 20 percent. However, in 82.6 percent of the cases, the prediction yielded a conservative estimate. Based on these facts,

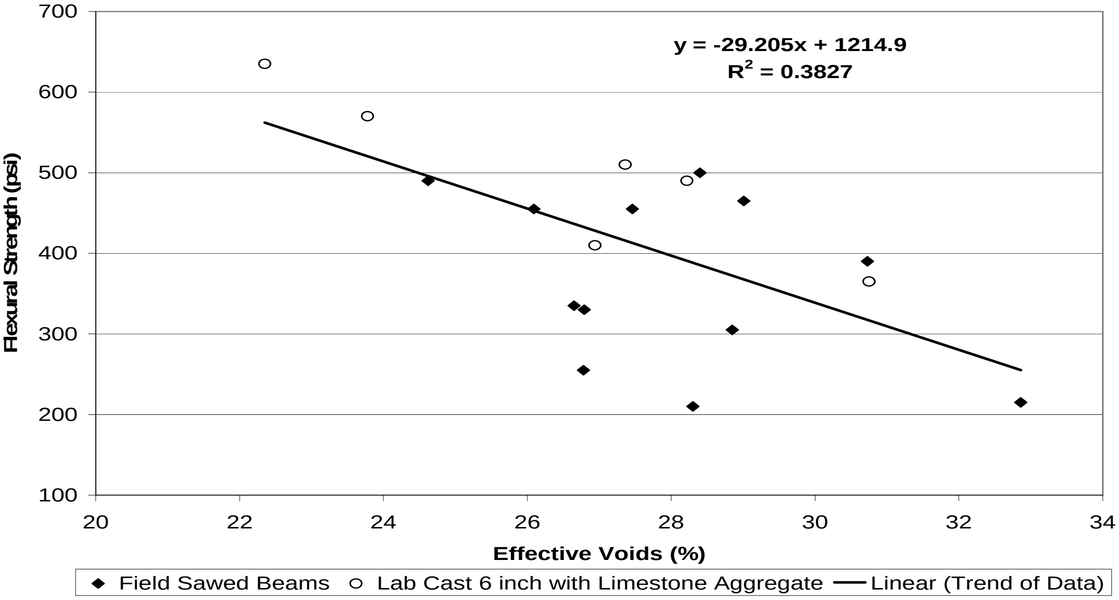

Figure 6. Flexural Strength vs. Effective Void Content for Field and Lab Samples

the ACI 318 Equation appears to be a promising but conservative method of estimating static modulus of pervious PCC from pervious PCC compressive strength and unit weight. The correlation coefficient between static modulus of elasticity and effective void content was 0.7792 indicating a fair relationship. Figure 5 indicates that if effective void content is less than 30 percent, the static modulus of elasticity is greater than 2,000,000-psi. Similarly, Figure 5 also indicates that if effective void content is less than 22 percent, the static modulus of elasticity is greater than 3,000,000-psi.

Table 4. Stat. Analysis of Applying Normal PCC Correlations to Pervious PCC Data

Relationship	# of Points	Significant difference @ 95% confidence in two-tailed paired t-test	Pearson Correlation Coefficient	% of predicted within ± 10% of measured	% of predicted within ± 20% of measured	Percent of predicted less than measured values (conservative)
Ahmad & Shah Split Tensile-Comp.	33	No	0.9376	66.6	91.9	45.4
ACI 318 Modulus of Elasticity	23	Yes	0.9008	56.5	87.0	82.6
Ahmad & Shah Flex. – Comp.	18	No	0.8584	38.9	88.8	39.0
ACI 318 Flex. – Comp.	18	Yes	0.8584	33.4	61.1	66.7

Flexural Strength. There is no statistically significant difference in measured flexural strengths and Ahmad and Shah predictions of flexural strengths at the 95 percent confidence interval in a two-tailed paired t-test. The Pearson Correlation coefficient was 0.8584 indicating a strong relationship. In 88.8 percent of cases, the prediction differed from the measured value by less than 20 percent. Based on these facts, the Ahmad and Shah equation appears to be a promising method of estimating flexural strength of pervious PCC from pervious PCC compressive strength.

There is a statistically significant difference in measured flexural strengths and ACI 318 predictions of flexural strengths at the 95 percent confidence interval in a two-tailed paired t-test. The Pearson Correlation coefficient was 0.8584 indicating a strong relationship. However in only 61.1 percent of cases, the prediction differed from the measured value by less than 20 percent. Further, in 66.7 percent of the cases, the prediction yielded a conservative estimate. Based on these facts, the ACI 318 equation appears to be a conservative less promising method of estimating flexural strength of pervious PCC from pervious PCC compressive strength than the Ahmad and Shah equation.

The correlation coefficient between flexural strength and effective void content was 0.3827 indicating a non-existent relationship. Flexural test data from this study supports the assertion of Tennis, Leming, and Akers *(Tennis et al. 2004*) that flexural testing exhibits high variability. It is very difficult to obtain a good flexural strength specimen.

Conclusions

Based on the limited data available, the following preliminary conclusions can be drawn:

1. The Ahmad and Shah equation appears to be a promising method of estimating split tensile strength of pervious PCC from pervious PCC compressive strength. The correlation shows no statistically significant difference at the 95 percent confidence interval in a two-tailed paired t-test, has a Pearson Correlation coefficient of 0.9376, and in 91.9 percent of cases, the prediction differed from the measured value by less than 20 percent.

2. The ACI 318 equation appears to be a promising but conservative method of estimating static modulus of pervious PCC from pervious PCC compressive strength and unit weight. The correlation shows a statistically significant difference at the 95 percent confidence interval in a two-tailed paired t-test, has a Pearson Correlation coefficient of 0.9008 and in 87 percent of cases, the prediction differed from the measured value by less than 20 percent. However, in 82.6 percent of the cases, the prediction yielded a conservative estimate.

3. The Ahmad and Shah equation appears to be a promising method of estimating flexural strength of pervious PCC from pervious PCC compressive strength. The correlation shows no statistically significant difference at the 95 percent confidence interval in a two-tailed paired t-test, has a Pearson Correlation

coefficient of 0.8584, and in 88.8 percent of cases, the prediction differed from the measured value by less than 20 percent.

4. The ACI 318 equation appears to be a conservative less promising method of estimating flexural strength of pervious PCC from pervious PCC compressive strength than the Ahmad and Shah equation. The correlation shows a statistically significant difference at the 95 percent confidence interval in a two-tailed paired t-test, has a Pearson Correlation coefficient of 0.8584 but the predicted differed from the measured value by less than 20 percent in only 61.1 percent of cases and in 66.7 percent of the cases, the prediction yielded a conservative estimate.

5. The split tensile strength, flexural strength, and modulus of elasticity of pervious PCC all decrease with an increasing effective void content.

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