MODULUS OF ELASTICITY

ASTM C 469, the "Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression," describes modulus of elasticity as a stress to strain ratio value for hardened concrete at whatever age and curing condition that may be designated. This Standard also states that the modulus of elasticity is applicable with the customary working stress range of 0 to 40% of the ultimate concrete strength. The modulus of elasticity is often used in sizing reinforced and non-reinforced structural members, establishing the quantity of reinforcement, computing stress for observed strain, and is especially important in the design of pre-stressed concrete members (8). Due to the fact that very little published information was available on actual values of modulus of elasticity for lightweight concrete with compressive strengths more than 8,000 psi (55 MPa), the following research project was conducted (9).

Nine concrete mixtures were batched at Carolina Stalite Company's laboratory in the summer of 2001. The mixtures consisted of several sizes of lightweight coarse aggregate (3/4", 1/2", and 3/8"), concrete sand from Lilesville, North Carolina, Type 1 Cement, regular and high range water reducers, and local water. Three mixtures with each size lightweight aggregate were batched in the testing at water/cement ratios of 0.25, 0.35, and 0.45. The amount of coarse lightweight aggregate was held constant in all of the mixtures. The mixture proportions are listed in Table 9. Fifteen 4"x8" cylinders were cast from each of the nine mixtures. The cylinders were made in accordance with ASTM standards and wet cured until the time of testing. Two cylinders from each mixture were tested for compressive strength at 7, 28, and 90 days in accordance with ASTM C 31. The average compressive strengths for these cylinders are listed in Table 10.

Three samples were tested for modulus of elasticity from each bath at 7, 28, and 90 days in accordance with ASTM C 469. The samples were tested using a Humboldt compressometer and a Forney calibrated load frame. The samples were tested to 40% of the ultimate concrete strength listed in Table 10 and the modulus was calculated from the following equation:

$$E=(S_2-S_1)/(\varepsilon_2-0.000050)$$

Where :
E=chord modulus of elasticity (in psi)
S_2=stress corresponding to 40% of the ultimate load of the concrete (in psi)
S_1=stress corresponding to a longitudinal strain of $\varepsilon_1$at 50 millionths (in psi)
ε_2=longitudinal strain produced by S_2

The results of the testing listed in Table 10 show modulus of elasticity values ranging from 3.40×10^6 psi to 4.72×10^6 psi. The variances in the results are due to the different compressive strengths yielded by the mixtures, the different size coarse aggregates, the varying mortar contents and the age at testing. The results indicate that the highest modulus values were obtained from the mixtures made using the ¾" (top size)

lightweight aggregate. The ultimate compressive strength of these mixtures was less than 1/2" and 3/8" mixes, but the modulus of elasticity was higher. The modulus also varied with age; it typically increased with age for all the mixtures. The increase from 7 days to 28 days in most cases was much higher than the increase from 28 days to 90 days.

TABLE 9 Modulus of Elasticity Research Project
Mixture Proportions (10)

	Lightweight Aggregate Size								
	3/4" (19 mm)			1/2" (12.5 mm)			3/8" (9.5 mm)		
Mix Number	1	2	3	4	5	6	7	8	9
Cement (lb)	1100	786	611	1160	829	644	1240	886	689
Sand (lb)	1034	1363	1509	1042	1318	1473	990	1286	1450
LWA (lb)	900	900	900	900	900	900	900	900	900
Water (lb)	275	275	275	290	290	290	310	310	310
Advaflow (oz)	9.5	5.3	3.1	9.6	5.5	3.2	10.2	7.3	5.7
WRDA 35 (oz)	3.1	2.1	1.75	3.2	2.3	1.8	3.4	2.4	1.9
W/C ratio	0.25	0.35	0.45	0.25	0.35	0.45	0.25	0.35	0.45

TABLE 10 Modulus of Elasticity Research Project
Average Compressive Strength and Modulus of Elasticity Test Results (10)

	7 Days		28 Days		90 Days	
Mix Number	Comp Strength (psi)	Ę (psi x 10^6)	Comp Strength (psi)	Ę (psi x 10^6)	Comp Strength (psi)	Ę (psi x 10^6)
1	9,634	3.99	10,991	4.63	10,704	4.72
2	9,413	3.88	9,672	4.16	10,512	4.37
3	8,416	3.70	8,739	3.75	9,303	4.30
4	10,730	4.00	11,622	3.99	12,352	4.55
5	8,776	3.64	9,759	3.80	10,524	4.18
6	6,892	3.41	7,491	3.43	8,205	3.79
7	12,546	4.15	14,469	4.40	16,200	4.55
8	11,227	3.90	12,976	4.36	13,570	4.45
9	7,408	3.40	9,050	3.62	10,950	3.71

Comp Strength = Average Compressive Strength
Ę = Modulus of Elasticity