CHAPTER 3

MATERIALS SPECIMENS TEST PROCEDURE AND INSTRUMENTATION

Materials

a) Reinforcement

Two sizes of prestressing wires, conforming to Thai Industrial Standard (TIS) 95-2525, were used as longitudinal reinforcement. They were 7 mm. and 4 mm. diameters. The mechanical properties of 7 mm. steel wire as shown in Fig. 3.1; the yield strength at 0.2 percent offset was 165,000 ksc., the ultimate strength was 17,590 ksc., the modulus of elasticity was $2.0x10^6$ ksc. and the elongation was 5.9 %. That of 4 mm. steel wire was 165,000 ksc. in yield strength, 17,625 ksc. in ultimate strength, $2.0x10^6$ ksc. in modulus of elasticity and 5.3 % in elongation. The results shown in Fig. 3.1, tabulated in Table 3.1, are summarized from three average consecutive tests conforming to ASTM A-370. Stress-strain relationship of the wires are shown in Fig. 3.1. In elastic range the curves are relatively straight, but the yield strength can not be obviously shown as ordinary steel bars. The 0.2 percent offset of the strain are generally defined as the yield strength of such wires. For convenience it may be assumed as bi-linear stress-strain relationship.

b) Web Reinforcement

Mild steel bars 6 mm. diameter, conforming to TIS 20-2525, were used as shear reinforcements to prevent diagonal tension failure in

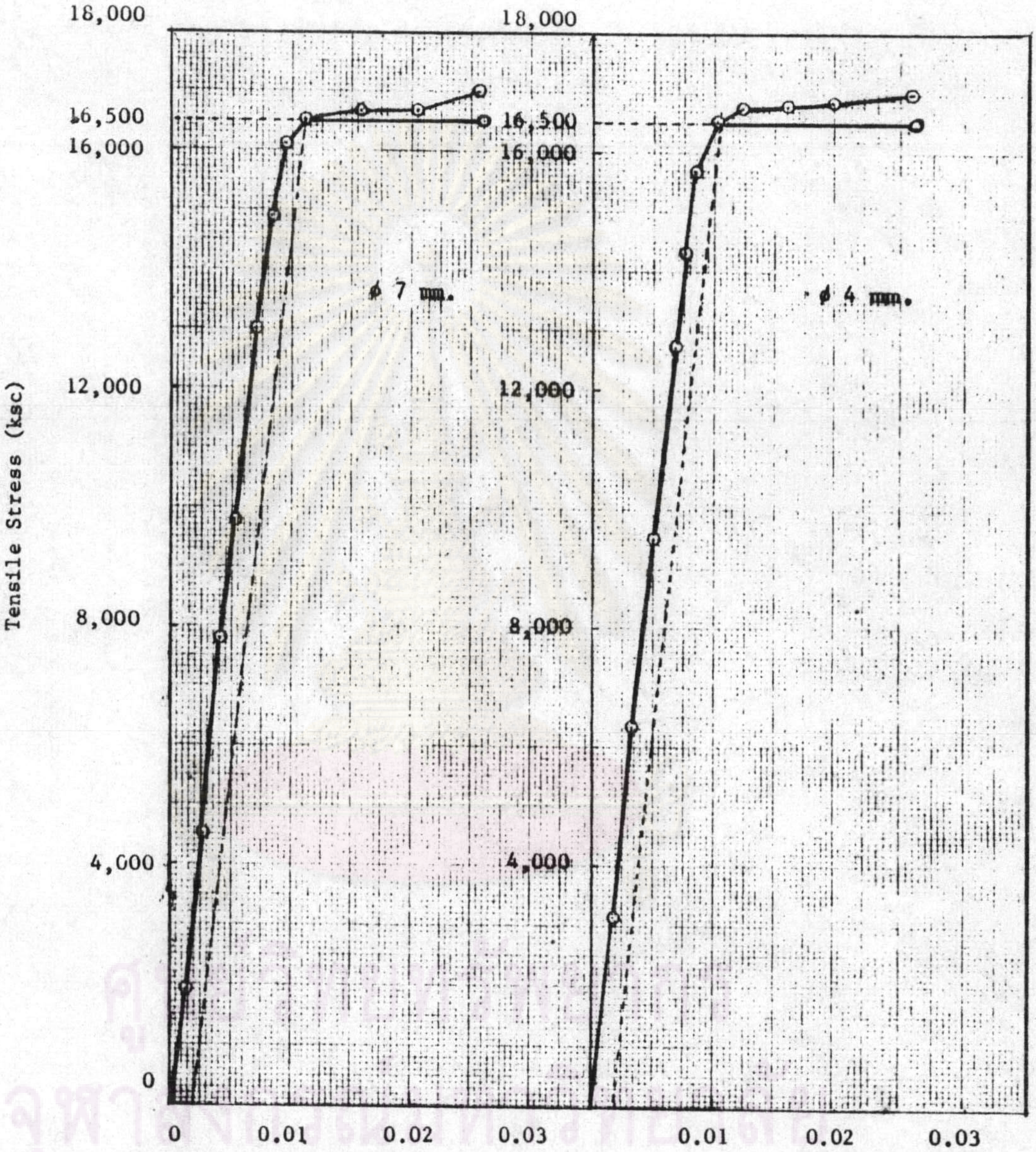

Fig. 3.1 Stress-Strain curve of Longitudinal Reinforcement

Table 3.1 Properties of Prestressing Wires

Size of bar (mm.)	Area As (cm^2)	Yield Strength at 0.2 % offset f_y (ksc)	Modulus of Elasticity 10^6, E_s (ksc)	Elongation %
7	0.38	16,500	2.000	5.9
4	0.12			5.3

Table 3.2 Concrete Mix Data

Cement : Sand : coarse aggregate (by weight)	1.000 : 1.333 : 2.150
Maximum size of coarse aggregate	½"
Water-cement ratio	0.24
Finess modulus of sand	2.95
Specific gravity of sand	2.73
Specific gravity of coarse aggregate	2.76
Admixture* per cement content (by weight)	2.4 %

* Admixture used in this study was naphthaline acid

shear span of each test beam and the spacing used were sufficint to assure the flexural behavior.

c) Very-High Strength Concrete

Concrete mix proportion used in this study were resulted from several trials and the final proportion was shown in Table 3.2. It supposed to be very high strength concrete proportions, where the water-cement ratios were kept at around 0.30 and the super-plasticizer was used to improve the workability. High early strength cements or Type III conforming to TIS 15 or ASTM C-150 were used in the concrete mix in order to obtain high strength at the early ages.

It was stated by Freedman[8] that coarse aggregage gradation was of minor importance in mixes with high cement contents and the grading of coarse aggregate of a given maximum size may be varied over a relatively wide range within the ASTM C-33 limits without appreciably affecting the strength if the proportion of fine aggregate produces concrete of good workability, and ½" maximum size appears to give optimum strength. In this study, the maximum size of aggregate is ½", with the specific gravity of 2.76 and the gradation is shown in Fig. 3.2.

Fine aggregate as typical specification ASTM C-33 limits is not highly critical[7], however, slightly coarse sand would probably be beneficial and the finess modulus should be around 2.7 to 3.20. Finess modulus of fine aggregate used in this study was 2.95 with a specific gravity of 2.73 and the sieve analysis is shown in Fig. 3.2.

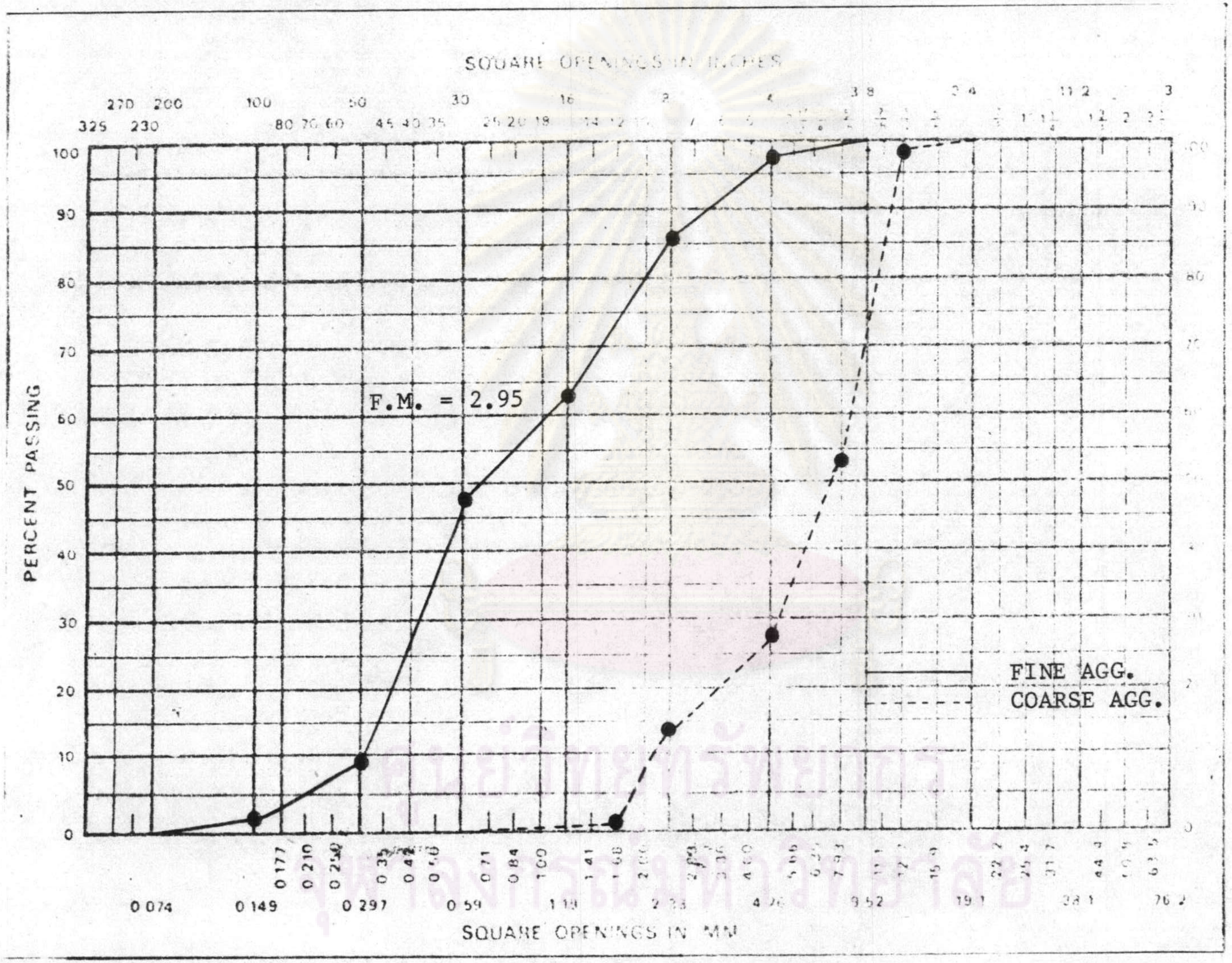

Fig. 3.2 Sieve Analysis of Fine and Coarse Aggregate

The super-plasticizer for large amount water-reduction in concrete mix can be one of these three groups; salts of sulfornated lignin, salts of hydroxy acids and hydroxylated polymers. The admixture used in this study was a salt of sulfornated lignin. It was used as water reducing agent to obtain the required strength at the proportion of 2.4 % by weight of cement content.

The compressive strengths of very-high strength concrete at 70 days were tested conforming to ASTM C39-80 to be 646 ksc. by average. Three average stress-strain curves are shown in Fig. 3.3. The spliting tensile strength, conforming to ASTM C496-80 was found to be 46 ksc. by average and plotted between corresponding compressive strength shown in Fig. 3.5.

Test Specimens

The specimens were very-high strength concrete beams reinforced with prestressing wires having a rectangular cross section of 10x18 cm. The beams were 240 cm. long but were tested at 210 cm. span length. The details of the specimens are illustrated in Table 3.3.

Stirrups were made of 6 mm. diameter mild steel bars, placed along the shear span of the beam and tied to the longitudinal reinforcement. The amounts of web reinforcements were sufficiently provided to prevent any shear failure.

Manufacture of Test Specimens

a) Preparation of Steel Reinforcement

First the longitudinal wires were cut in pieces to accommodate

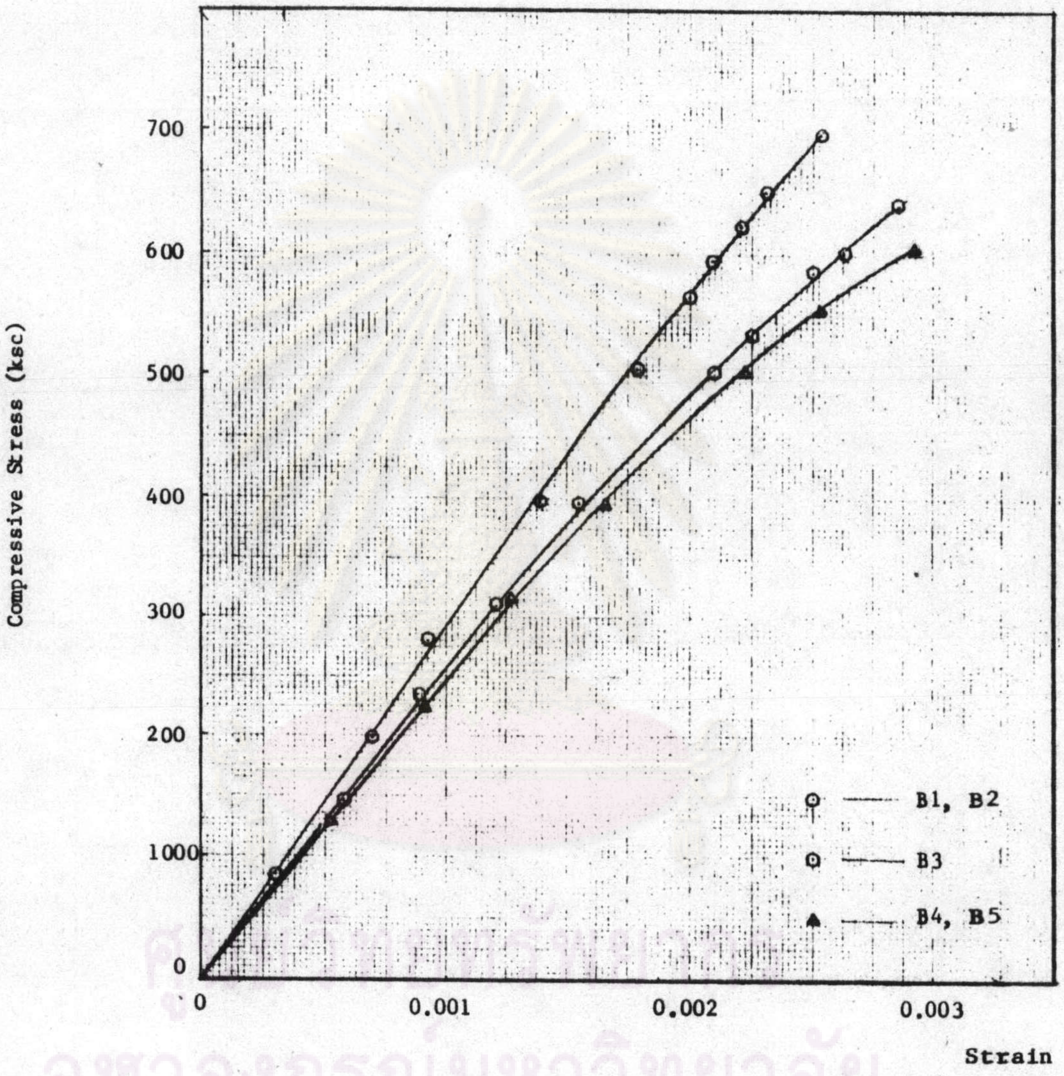

Fig. 3.3 Stress-Strain Curve of Very-High Strength Concrete

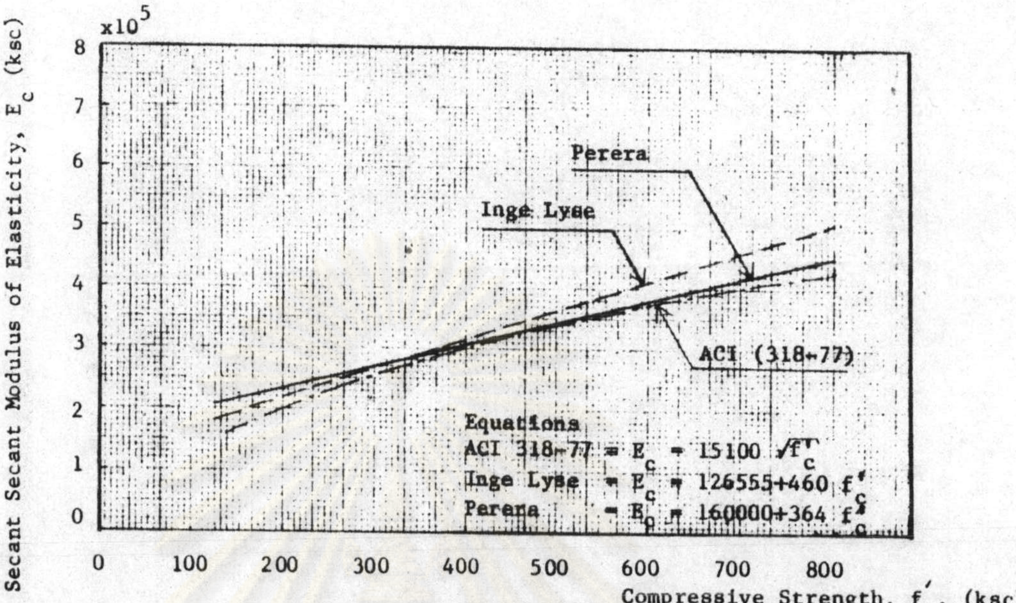

Fig. 3.4 The Relationship between Secant Modulus of Elasticity and Compressive Strength of Concrete

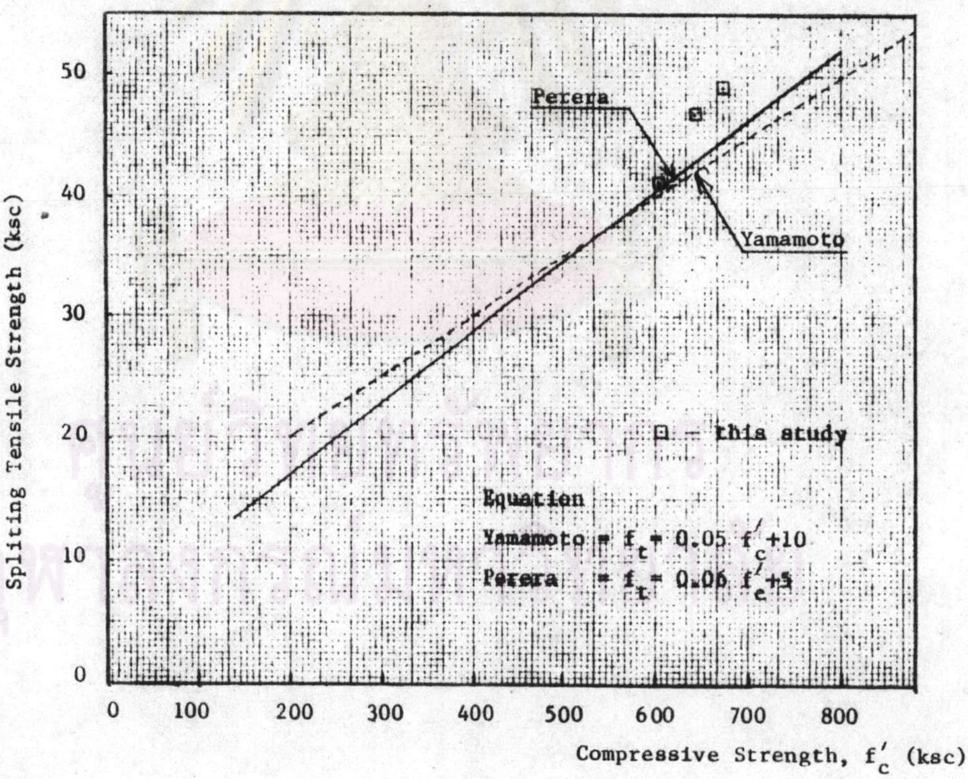

Fig. 3.5 The Relationship between Spliting Tensile Strength and Compressive Strength of Concrete.

Table 3.3 Detail of Test Beams

Beam	Pieces & Bar Type	Cross Section cm^2	Effective Depth d, cm.	Area of Reinforcement A_s, cm^2	Percentage of steel 10^{-1}, ρ	Reinforcement Index ω	Concrete Cylinder Strength f'_c, ksc	Concrete Tensile Strength f_r, ksc	I_{un} * cm^4	I_{cr} ! cm^4	E_c + 10^5, ksc
B1	2ϕ7+1ϕ4	10.2x18.6	17.1	0.89	5.103	0.121	694	49.08	5682	969	3.978
B2	2ϕ7	10.3x18.5	17.0	0.77	4.397	0.104	694	49.08	5617	846	3.978
B3	1ϕ7+2ϕ4	10.3x18.5	17.0	0.63	3.598	0.092	644	46.75	5584	710	3.832
B4	1ϕ7	10.0x18.5	17.0	0.38	2.235	0.061	601	41.50	5367	451	3.702
B5	2ϕ4	10.0x18.2	16.7	0.25	1.497	0.041	601	41.50	5081	297	3.702

* I_{un} computed from equation (2.2)

! I_{cr} computed from equation (2.6)

\+ E_c computed from equation (2.15)

$\rho = \frac{A_s}{bd} \cdot 100$

$\omega = \rho \frac{f_y}{f'_c} \cdot \frac{1}{100}$

the formwork of 240 cm. in length. Two 6 mm. diameter mild steel bars were used as top reinforcement to hold stirrups in place where the wires were hold at bottom. The longitudinal and web reinforcement were prefabricated before placing into the wooden forms. An electrical strain gage of 8 mm. gage length, 120 ohm resistance and 2.01 gage factor was mounted to each steel wire. Waterproofed adhesive coating was provided to prevent damages due to moisutre during concrete pouring. Lead wires were also well protected from moisture.

b) Casting of Concrete

Concrete was mixed in a $\frac{1}{6}$ m^3. mixer. Special care were taken during placing concrete into the wooden forms to avoid damage to the electrical strain gages. Twelve cylinders were cast along with each two test specimens for strength evaluation. The side forms were removed after overnight air cured and then the beams were cured in the fog room for approximately two months. After that they were air cured until they were tested.

The cylinders were cast and cured in the same manner as the test beams. The mechanical properties would be evaluated in the same day as the beams were tested.

Only one electrical strain gage was attached to concrete surface at the mid span top fiber on each beam. This gage was used to monitor the maximum compressive strain. Other than that mechanical strain gages were used to measure strains throughout entire depth of the beam at both sides. Strain at each level were average from four measurements and the strain distribution could be obtained.

Test Setup

The specimens were tested as simply supported beams with a span length of 210 cm. and a shear span of 70 cm. The beams were loaded by means of a universal testing machine, Amsler 500 tons, whose the working range was set at 50 tons. However, the test loads were also monitored by a load cell with maximum capacity of 20 tons and the accuracy of 0.05 % of full capacity. The calibration of this load cell is shown in Fig. 3.6. The beams were set on the test bed with adjustable span length attached to the ram of the testing machine. The loads were applied onto I-beam with sufficient stiffness to transfer load into two point loads as shown in Fig. 3.7.

Instrumentation

A mechanical strain gage of 20 cm. gage length was used to measure strains in concrete for both compressive and tensile stresses. The locations of gage points are shown in Fig. 3.7. Electrical strain gages were used to measure strains in steel wires and monitor maximum compressive strains at mid span top fiber of the beams as shown in Fig. 3.8. Deflections of test beams were measured by three dial gages with 0.005 cm. accuracy shown in Fig. 3.7.

Test Procedure

The beam was loaded incrementally at around 5 percent of the predicted ultimate load. At each load level the load was maintained constant for few minutes for measurements and recording deflections, strains and crack patterns. When the loads were up to around 75 percent of predicted ultimate load or when the load deflection response

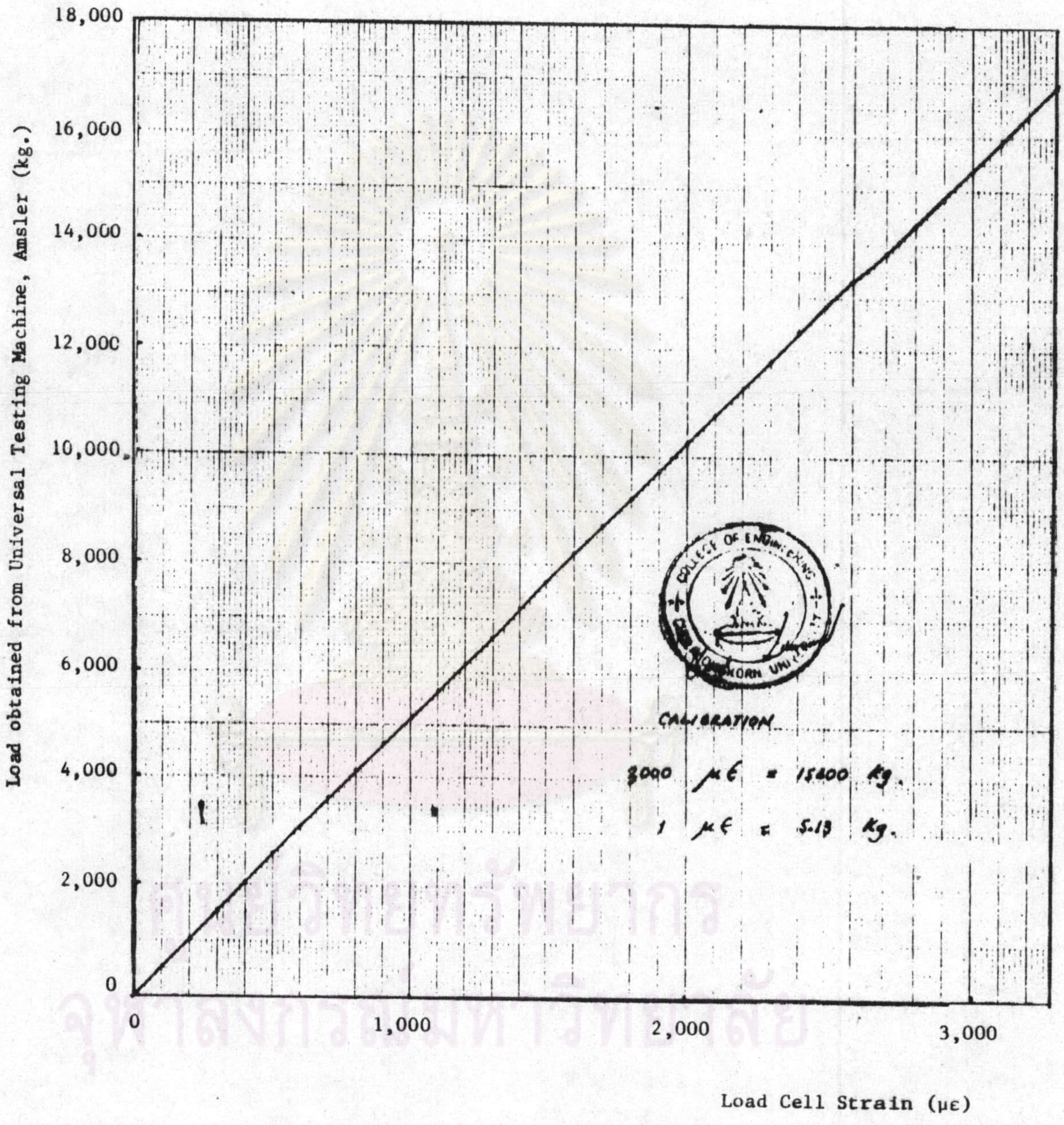

Fig. 3.6 Calibration Curve of Load Cell

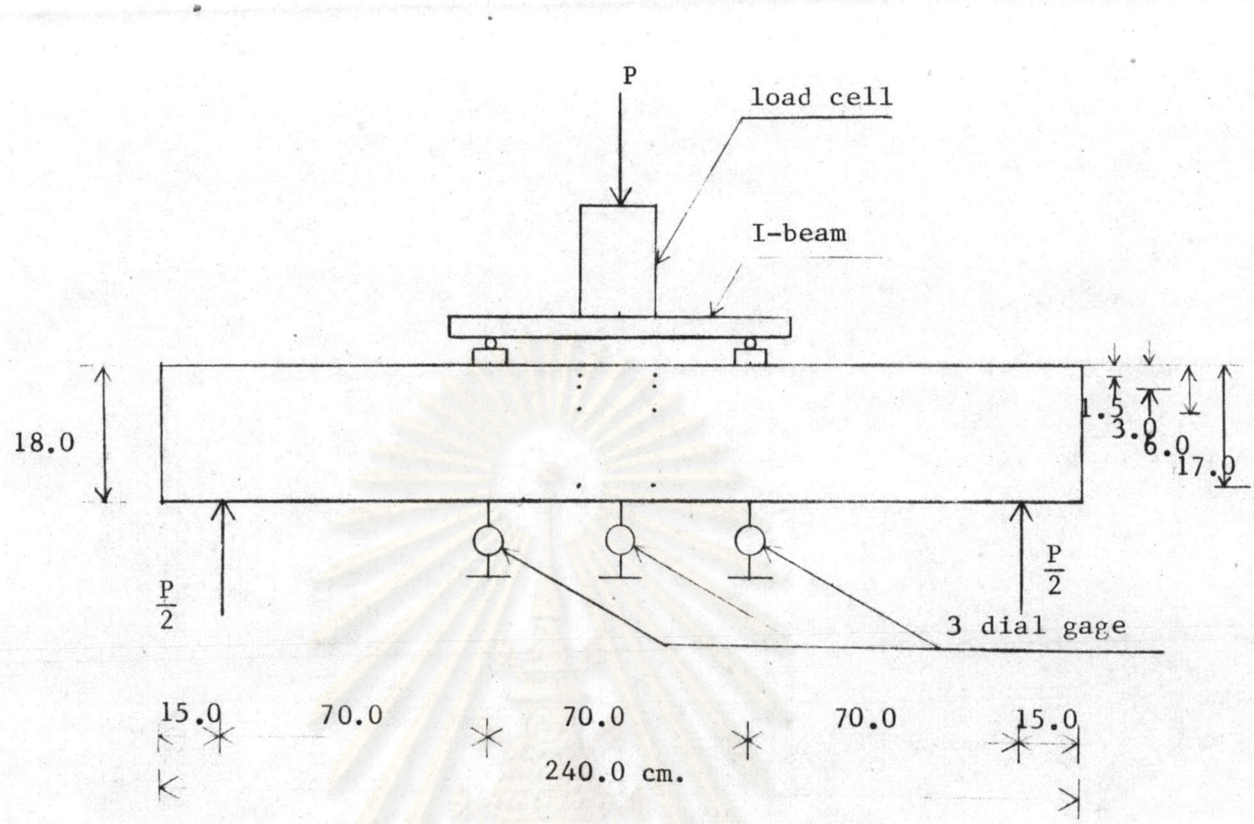

Fig. 3.7 Test Set up (side view)

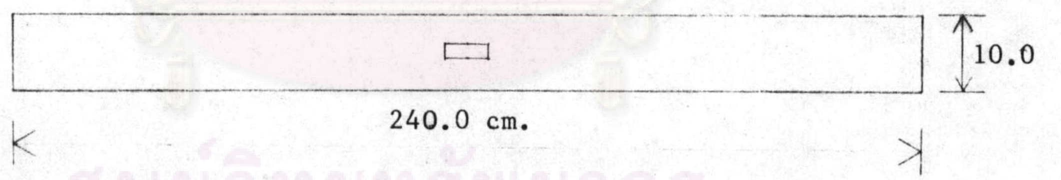

Fig. 3.8 Compression Face of a Test Beam with an Electrical Strain Gage (top view)

became non-linear then the measurements were taken at each 2 mm. deflection. For safety reson and to avoid any damage from crushing, some measurements were stopped when the applied load was reaching the predicted ultimate capacity. However, some other measurements such as load and electrical strain monitoring still keep on to the failure of the beam. Mode of failure and crack pattern at collapse were also sketched and photograph taken as shown in Fig. 4.22 to 4.24.