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Prestressed concrete bridge members. Condensation of progress report no. 1 a comparison between ordinary reinforced and prestressed reinforced concrete beams.

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A COMPARISON BETWEEN ORDINARY REINFORCED AND PRESTRESSED REINFORCED CONCRETE BEAMS

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A COMPARISON BETWEEN ORDINARY REINFORCED AND PRESTRESSED REINFORCED CONCRETE BEAMS

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For three quarters of a century, researchers have investigated the field of reinforced concrete. Although there is still much to be learned, numerous tests and structures have proven it to be a sound construction material. A new type of concrete, namely; prestressed concrete, now appears in its infancy in the U.S. and much research will be necessary to solve all of its idiosyncrasies.

In preparation for repetitive load tests on full scale 38' pretensioned and posttensioned, prestressed concrete bridge members, a series of pilot tests were conducted during the past year at Lehigh University. The first pilot test involved the construction and testing of three beams whose elevation and cross-section appear on Fig. 1. A regularly reinforced, a posttensioned prestressed and a pretensioned prestressed concrete beam were tested for the primary purpose of comparing physical properties. All beams were 8"x12"x12'. They were poured according to essentially the same mix design and were tested by applying loads to the third points of an eleven foot test span.

The normally reinforced beam was a balanced design conforming to the straight line theory. The design of the posttensioned prestressed concrete beam appears on Fig. 2. The dead load and desired live load moments were 18,200 and 422,500 in. lb. respectively. End thrust and eccentricity were computed by solving two simultaneous equations involving the principles of zero stress in the top fiber with prestress plus dead load and zero stress in the bottom fiber with prestress plus dead load plus design live load. The solution of the two equations yielded a required eccentricity of 2.18" and a required end thrust of 105,600 pounds. Working design stresses for concrete and steel were 2200 and 105,000 psi respectively. Allowing 20% for creep and flow, initial stresses of 2640 and 125,000 psi respectively for concrete and steel were considered satisfactory. The beam was designed for a concrete working stress of $0.4f_c$ which required a mix design for 5500 pound concrete.

The design midspan stress patterns for final prestress appear at the bottom of Fig. 2. They are from left to right, prestress plus dead load, live load, and prestress plus dead plus live load stresses.

Next, Fig. 3 shows the posttensioned beam in testing position. Variables considered on all beams were deflections, ultimate strengths, casting difficulties, stress variations and accuracy of design procedures. When an end thrust of 84,000 lbs. had been applied to the beam SR-4 strain gages indicated a top fiber tension of 640 psi and because of danger of a premature tension failure jacking was discontinued. Thus the strands were stressed to only 84,000 psi.

Fig. 4 shows the pretensioned beam prior to pouring. So that an adequate comparison could be made between the posttensioned and pretensioned beams, the pretensioned beam's strands were jacked to the point where they also yielded an end thrust of approximately 84,000 lbs. instead of the design value of 105,000 lbs. Only 63% of the design steel area was used but it was stressed to about 135,000 psi.

Fig. 5 shows the pretensioned beam in the testing machine after failure. Primary cause of failure was diagonal tension. The beam contained no diagonal tension reinforcement.

Measured and computed stresses at the midspan cross-section for both the posttensioned and pretensioned and prestressed concrete beams appear in Fig. 6.

Two slight errors in the fabrication of the posttensioned beam could have caused the 105,600 lb. design end thrust to be limited to 84,000 lbs. First, because of its stiffness the strand tended to follow a parabolic path instead of the designed 3 straight line path. Thus the eccentricity could easily have been in error by 1/4 inch, resulting in an e = 2.43" instead of 2.18". Second, the catenary effect probably resulted in an uplift pattern more of the type shown in Fig. 6 instead of the 1/3 point concentrated load uplift used in the design.

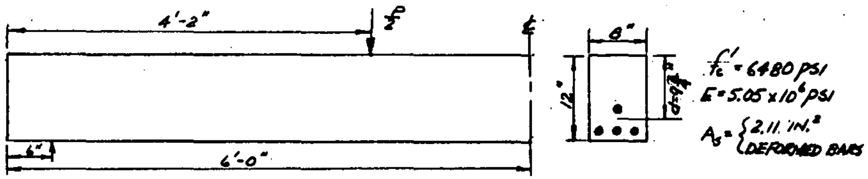
Assuming that the loading was as shown in the top left diagram, the computed midspan stresses would be as shown. The measured stresses for the live loads of zero; 10,000; 20,000; and 30,000 lbs. appear as the top group. The corresponding computed values appear as the lower group.

The figure at the top right shows the forces on the pretensioned beam. The initial end thrust was about 85,500 lbs. It was assumed shrinkage, creep and plastic flow reduced this to 78,000 lbs. at the end of 14 days. The midspan computed and measured values of stress for the same live loads appear below this diagram.

The first figure tabulates the results of the tests. In order of normal, posttensioned and pretensioned beams the results are (1) first visible crack--4000; 25,000; and 1900 lbs.; (2) maximum deflection 0.85; 0.95 and 1.75 inches (3) failure load--36,750; 39,300; and 41,000 lbs.; (4) primary failure--steel, concrete and diagonal tension.

Last July a no eccentricity, pretensioned beam was tested and in December a final pilot test was made on another 8"x12"x12' pretensioned beam containing approximately 90 SR-4 strain gages. A view of this beam under test appears in Fig. 7. A view of the beam after failure appears in Fig. 8. Bond Tests are being conducted in conjunction with the beam tests. We hope that with good fortune we will have our 38 ft. beams under repetitive tests within the next three months.

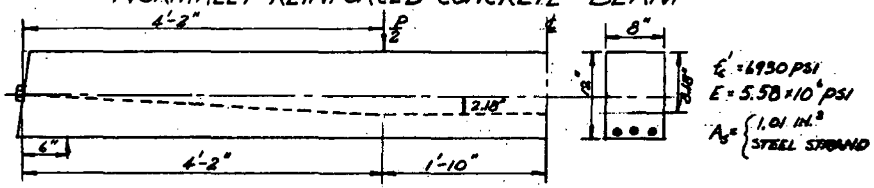
FIG 1.- COMPARISON OF THE THREE BEAMS



TEST RESULTS

"P" AT FIRST VISIBLE CRACK = 4000 LBS.
MAXIMUM DEFLECTION = 0.85 INCHES
"P" AT FAILURE = 36,750 LBS.
TYPE OF FAILURE = PRIMARILY STEEL FAILURE

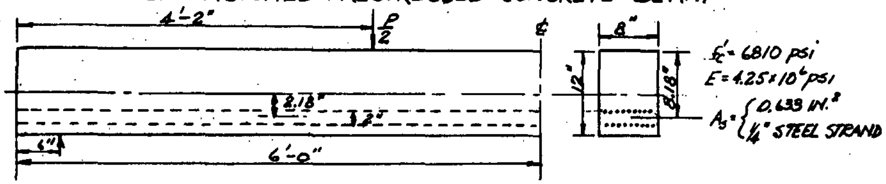
NORMALLY REINFORCED CONCRETE BEAM



TEST RESULTS

"P" AT FIRST VISIBLE CRACK = 25,000 LBS.
MAXIMUM DEFLECTION = 0.95 INCHES
"P" AT FAILURE = 39,300 LBS.
TYPE OF FAILURE = COMPRESSION FAILURE

POSTTENSIONED PRESTRESSED CONCRETE BEAM

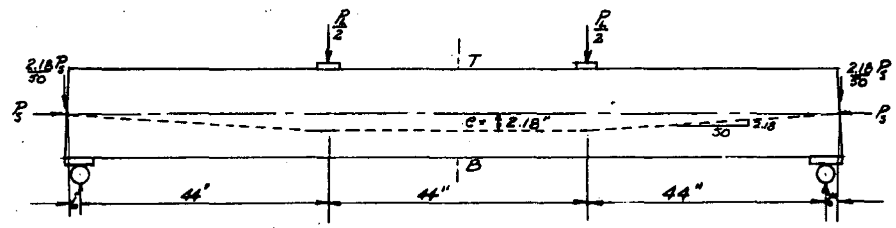


TEST RESULTS

"P" AT FIRST VISIBLE CRACK = 19,000 LBS.
MAXIMUM DEFLECTION = 1.75 INCHES
"P" AT FAILURE = 41,000 LBS.
TYPE OF FAILURE = PRIMARILY DIAGONAL TENSION

PRETENSIONED PRESTRESSED CONCRETE BEAM

FIG. 2 DESIGN OF PRESTRESSED CONCRETE BEAM



SIMPLIFIED DESIGN - STRESSES @ ℄ SPAN

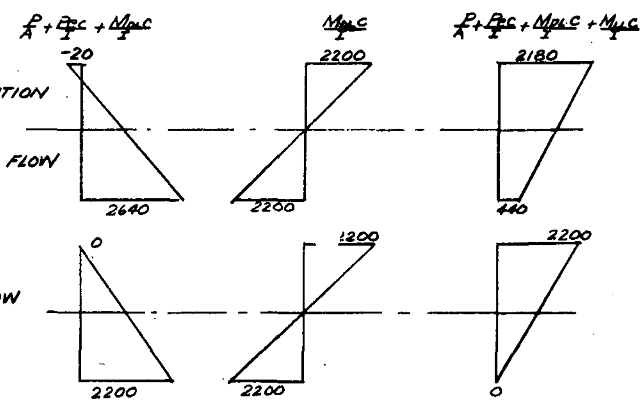
(1) $f_{TOP} = \frac{P_s}{A} - \frac{P_s e}{S_t} + \frac{M_{DL}}{S_t} = 0$

(2) $f_{BOT} = \frac{P_s}{A} + \frac{P_s e}{S_b} - \frac{M_{DL}}{S_b} - \frac{M_{LL}}{S_b} = 0$

P_s = PRESTRESS FORCE AFTER CREEP AND FLOW
e = ECCENTRICITY
M_{DL} = DEAD LOAD MOM. @ ℄
M_{LL} = LIVE LOAD MOM. @ ℄
$S_b = S_t$ = SECTION MODULUS OF UNCRACKED SECTION

WORKING CONCRETE COMP. STRESS = 0.4 x 5500 = 2200
INITIAL " " " = 120% x 2200 = 2640
INITIAL STEEL STRESS = 125,000 PSI
WORKING " " = 105,000 PSI
FOR 8X12 SECTION $S_b = S_t$ = 192 IN.³
M_{DL} = 18,200 IN. lb.
M_{LL} = 422,500 IN. lb.
P_s = 105,625#
$P'_s = \frac{125,000}{105,000} \times 105,625$ = 125,800#

e = 2.18"
A_s = 1.005" = 1-1"ϕ STRAND
= 2-0.600"ϕ "



℄ STRESS DISTRUBUTION
P_s = 125,800
NO CREEP AND NO FLOW
- INITIAL -

℄ STRESS DISTRIBUTION ASSUMING CREEP AND FLOW REDUCE
P'_s = 105,625#
- FINAL -

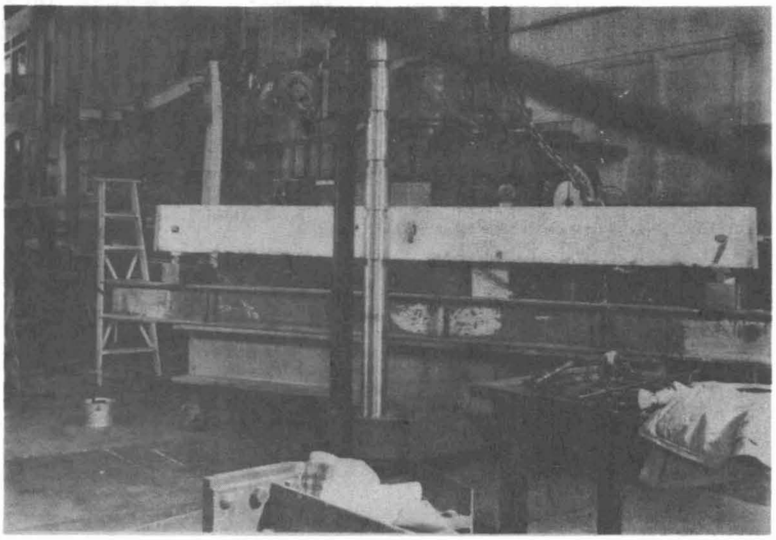


FIG. 3. POSTTENSIONED BEAM IN TESTING POSITION

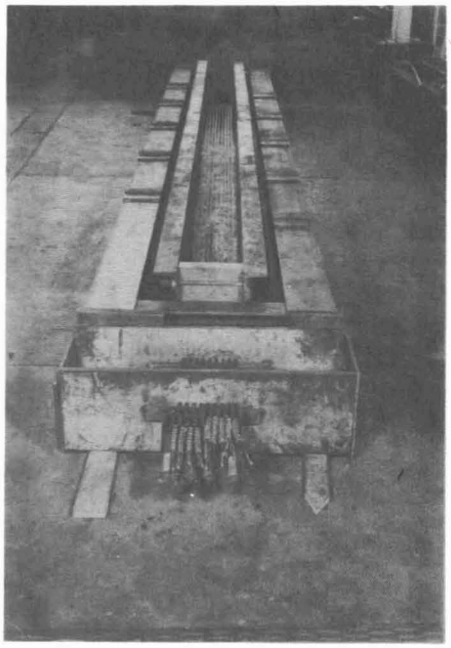


FIG. 4. PRETENSIONED, BEAM PRIOR TO POURING

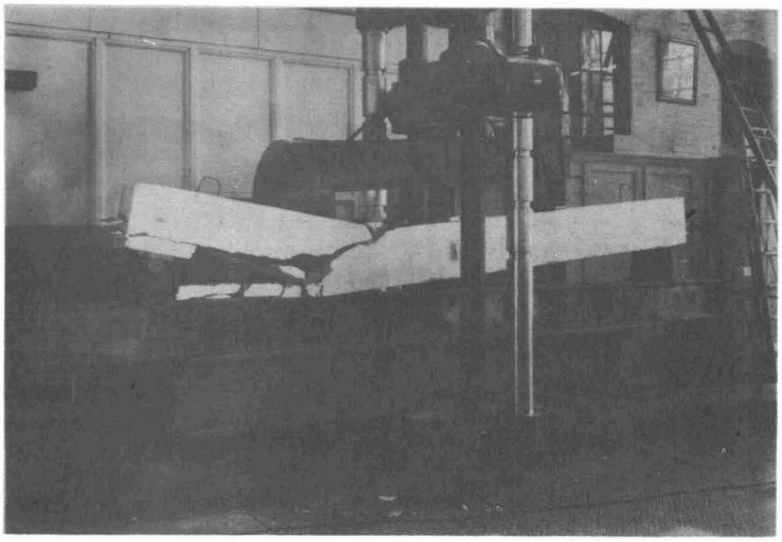


FIG. 5. PRETENSIONED BEAM AFTER FAILURE

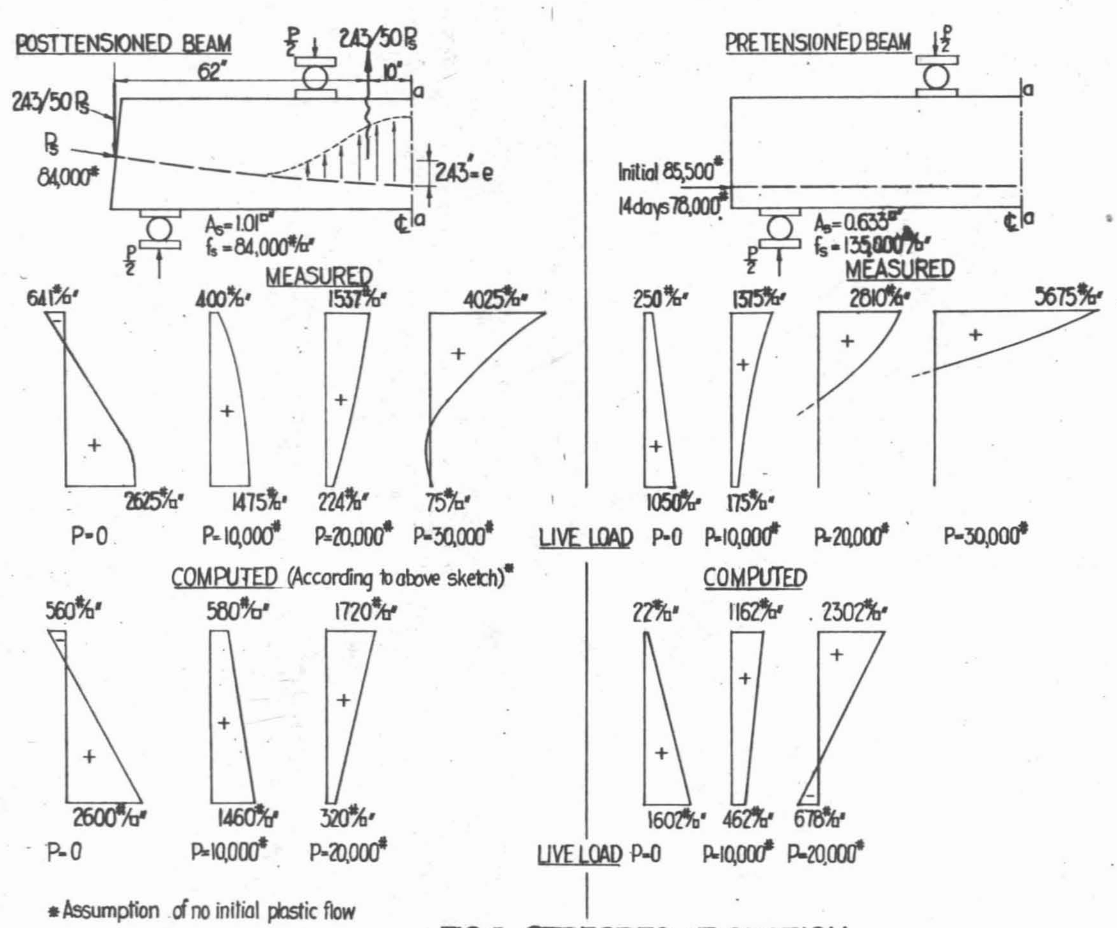


FIG 6.- STRESSES AT SECTION a-a

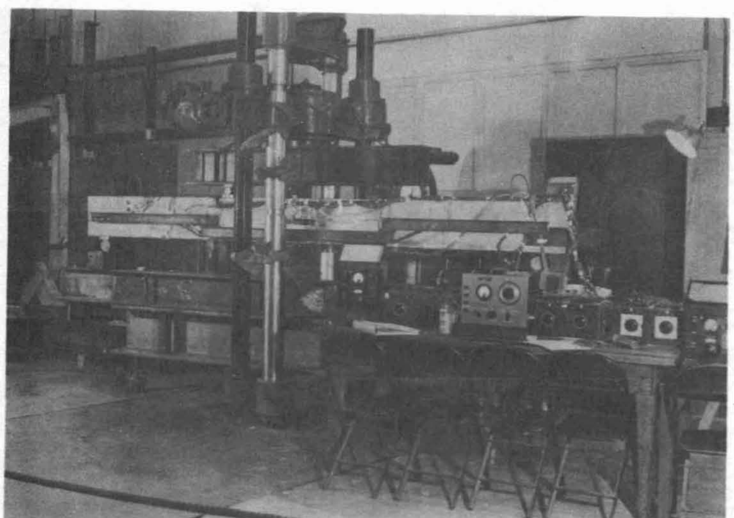


FIG. 7. PRETENSIONED BEAM UNDER TEST

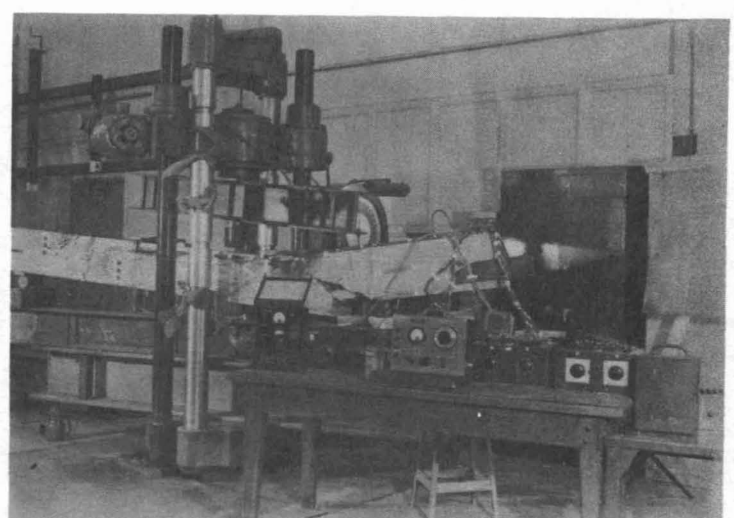


FIG. 8. BEAM OF FIG. 7 AFTER FAILURE