

ENGINEERING RESEARCH INSTITUTE
THE UNIVERSITY OF MICHIGAN
ANN ARBOR

Technical Report

ELASTIZELL CONCRETE OVER MILCOR

CELLUFLOR PANEL TYPE BB 16-16

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Project 2326

ELASTIZELL CORPORATION OF AMERICA
ALPENA, MICHIGAN

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INTRODUCTION

The Milcor Celluflor Panel Type BB 16-16 is one of a series of corrugated structural steel sections produced by the Inland Steel Products Company. One of the design economies of these sections is that they decrease the dead load of the structures in which they are used. In the use of Milcor Celluflor Panels, concrete is normally placed over the panel to provide a plane floor surface, to distribute concentrated loads, to provide fire protection, to cover miscellaneous electrical, plumbing, and heating services, and to stiffen the floor section.

Elastizell concrete is a cellular concrete which can provide structural strengths at densities less than the density of ordinary concrete.

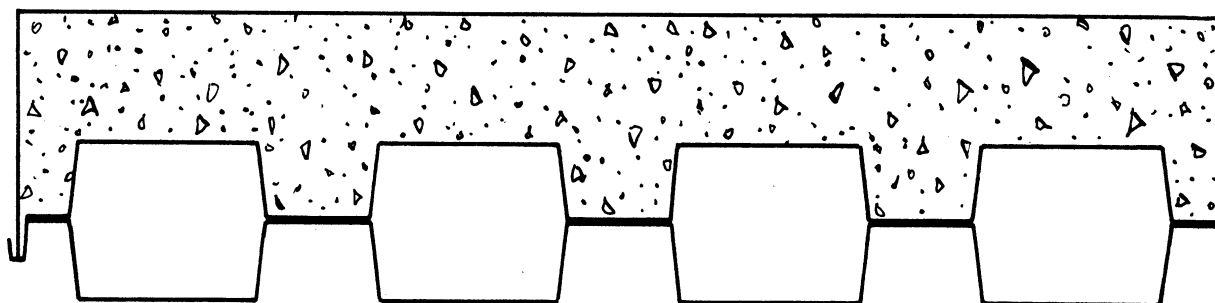
Since both Elastizell and Celluflor are designed for lightweight structural use, a successful combination of the two products should greatly increase the potential of both products. With this thought in mind, the Elastizell Corporation of America and the Inland Steel Products Company jointly sponsored the tests which are summarized in this report. The project was under the direction of Professor L. M. Legatski of The University of Michigan.

SUMMARY

The tests included four sections of Panel, Type BB 16-16, three of which were covered with Elastizell concrete and one with regular dense concrete. The results of these tests indicate that Elastizell concrete may be substituted for ordinary concrete over Milcor Celluflor corrugated panels in building construction with the advantage of carrying the same allowable live load as may be carried when ordinary concrete is used and simultaneously greatly decreasing the dead load.

TEST SPECIMENS

The four test sections were prepared March 10, 1956 at The University of Michigan, Willow Run Laboratories. Each specimen consisted of one type BB 16-16 panel covered with concrete to a depth of 2-1/2 inches over the corrugations.



The Elastizell concrete was mixed in a 17-cubic-foot Elasticrete Mixer yielding the following properties:

Section No.	Dry Density pcf	Material Parts by Weight of Cement				28-Day Compressive Strength (f'_c) psi	E_c psi
		Sand	Water	Elastizell	Elastimulse		
J-1-2	94	2.3	0.45	0.005	0.02	898	----
J-2-4	104	2.3	0.45	0.003	0.02	1912	1.57×10^6
K-1-2	95	2.55	0.45	0.005	0.02	1218	0.875×10^6

The regular concrete was standard ready-mix concrete proportioned to yield 3000 to 3500 psi at 28 days and was supplied by the Ann Arbor Construction Company. Its average 28-day compressive strength (f'_c) was 4576 psi and its modulus of elasticity (E_c) was 3.31×10^6 psi.

TEST PROCEDURES

After placing and finishing the concrete, the test sections were moist-cured for six days and air-dried for thirty-six days. Standard 6 by 12 in. cylinders were taken of the concretes and were moist-cured for twenty-four days and dried to constant weight. The cylinders were used to determine the modulus of elasticity and the 28-day compressive strength of each concrete.

The test sections were placed on simple supports at 9 ft—6 in. centers and were loaded by approximately equal concentrated linear loads at the $1/3$ points. The following measurements were made at each increment of load:

1. Deflection at the center line.
2. Strain in steel at center line.
3. Strain in concrete at center line.

4. Horizontal movement of the concrete relative to the steel at the end of the section.

The following photographs illustrate the method of loading and the location and types of gages.

Photo - 1

This photograph illustrates the use of hydraulic jacks at the $1/3$ points over a specimen in the loading frame. The gage at the extreme right is measuring the horizontal movement of the concrete relative to the steel. The loads were measured through the use of dynamometers.

Photo - 2

This photograph illustrates in greater detail the measurement of relative movement of the concrete with respect to the steel.

Photo - 3

This photograph shows the deflection gage at the center line of the span and also the SR-4 Strain Gage on the concrete at the center line. Another SR-4 Strain Gage is directly under the visible gage and was used to measure the strain in the steel.

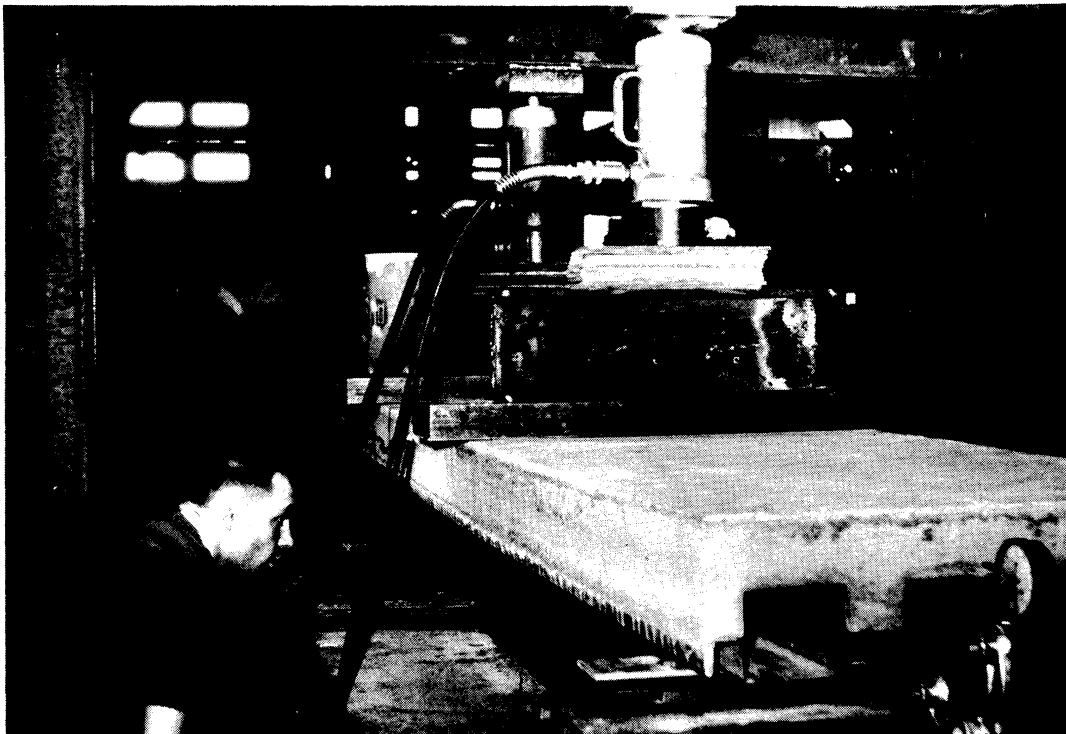


Photo - 1

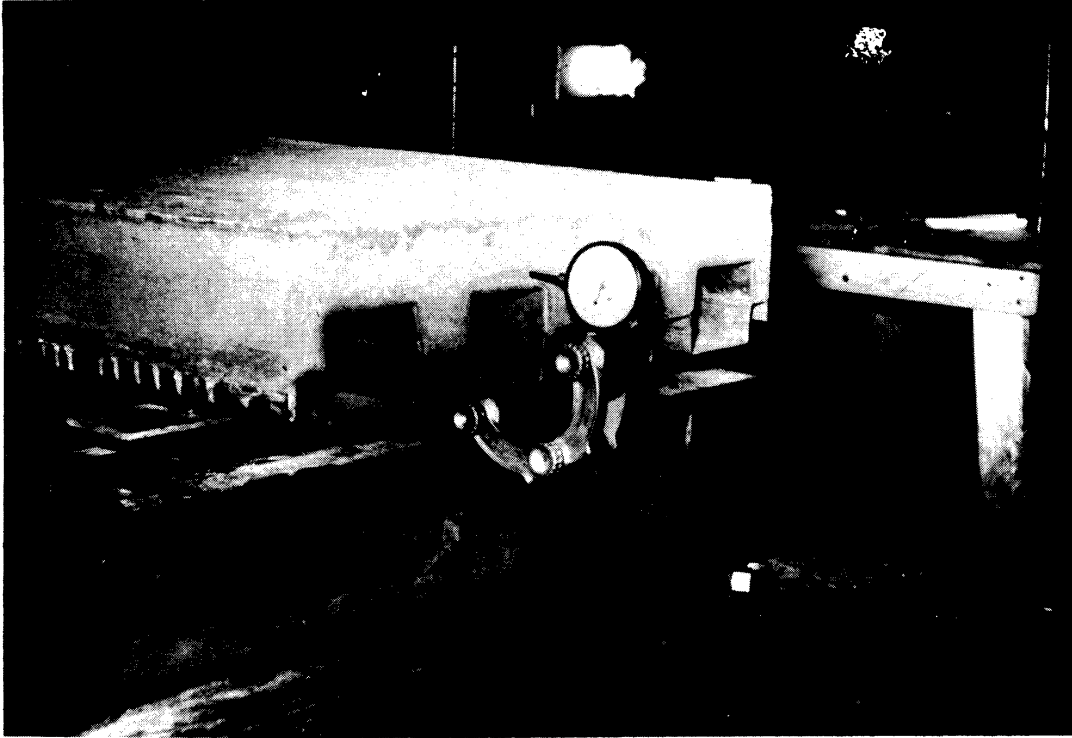


Photo - 2

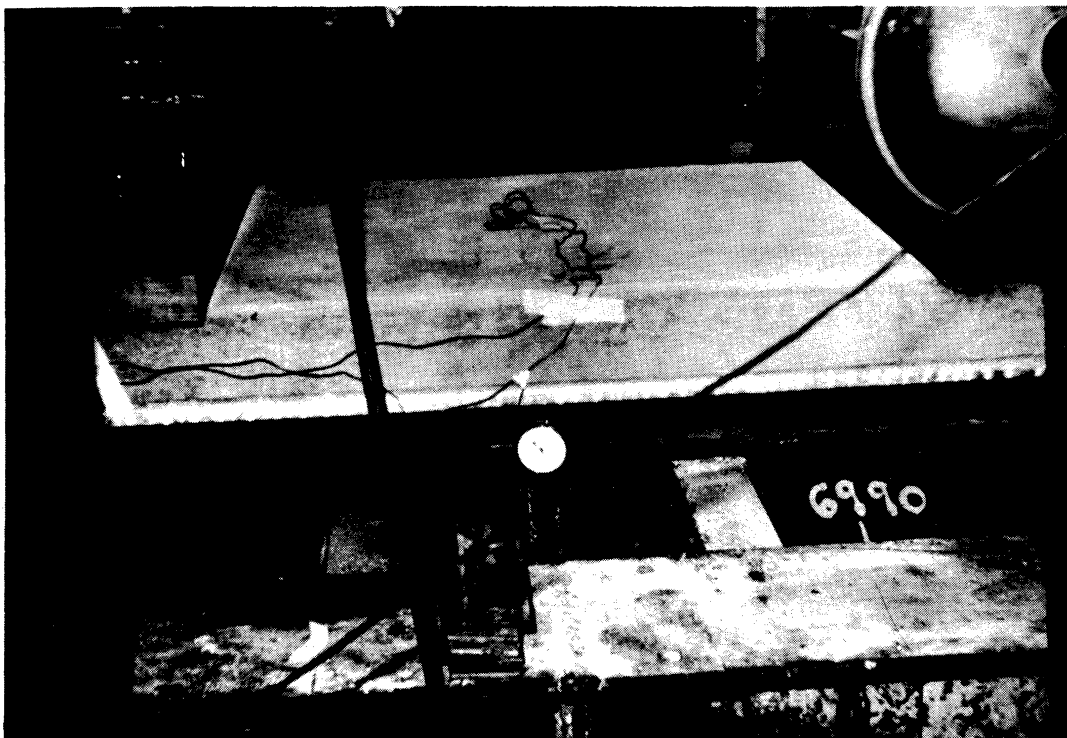


Photo - 3

TEST RESULTS

Each specimen was progressively loaded to failure with results as illustrated on Figs. 1 to 4 and in the Appendix.

SPECIMEN J-1-2

The first crack was a horizontal crack noticed just above the steel at the slab edge at a total load of approximately 3900 lb. These horizontal cracks were visible for approximately 6 in. from the ends of the specimen.

A complete bond failure occurred at a total load of approximately 7500 lb. Bond failure was visible from the supports to the load points. Diagonal cracks appeared outside the load points and tension cracks (vertical) appeared near the center of the span. The concrete did not crush until the load was at the maximum.

SPECIMEN K-1-2

The first horizontal crack occurred at the north end of the specimen when the total load was approximately 3800 lb and at the south end at a total load of approximately 4200 lb. Vertical cracks also appeared in the concrete at this loading at a distance of 15 in. from the north end and 10 in. from the south end.

Flexural cracks (vertical) appeared in the concrete at the center of the span under a total load of approximately 5300 lb.

Complete bond failure occurred after about one minute under a total load of 9633 lb. Vertical cracks appeared about 8 in. outside the bearings, but no flexural cracks were visible in the center third of the specimen. The compression flange of the steel was buckling in the center third.

SPECIMEN J-2-4

The first horizontal crack occurred in bond for about 12 in. at the north end under a total load of approximately 6100 lb. A flexural crack (vertical) also appeared at the center line.

The specimen failed in bond with no evidence of failure in the steel at a total of 11,733 lb.

REGULAR CONCRETE

This specimen also failed in bond at a total load of 18,153 lb. Cracking, although not visible, could be heard at a total load of approximately 6000 lb.

DISCUSSION OF TEST RESULTS

The results of these tests indicate that Elastizell concrete may be substituted for regular concrete over Milcor Celluflor corrugated panels with the advantage of carrying the same or greater live load and simultaneously reducing the dead load.

The factor of safety for each specimen is as shown below and is defined as the ratio of the ultimate load to the design load.

Specimen	Design Load*	Ultimate Load**	Safety Factor
J-1-2	1752	7505	4.29
J-2-4	1752	11733	6.70
K-1-2	1752	9633	5.50
regular concrete	1752	18153	10.37

*Design load is the sum of two equal concentrated loads at the 1/3 points of the span which would cause a deflection of 1/360 of the span.

**Ultimate load is the sum of two equal concentrated loads at the 1/3 points of the span which caused failure of the test specimen.

In the above table the design loads are the same for all specimens because the deflection limitation controls the design. The design of Celluflor slabs is based on the assumption that the steel alone is the resisting section. See pages 7, 8, and 9 for design computations.

DESIGN LOADINGS

CONDITIONS

Simple Span 9 ft—6 in. c. to c. of supports.
 Panel Type BB 16-16:

$$W_{\text{steel}} = 7.5 \text{ lb/sq ft}$$

$$I = 2.42 \text{ in.}^4/\text{ft width}$$

$$S = 1.45 \text{ in.}^3/\text{ft width}$$

ALLOWABLE MOMENTS

Uniformly distributed load:

(a) For maximum allowable fiber stress, $f_s = 18000$ psi

$$M_t = f_s S = 18000 \times 1.45 = 26,100 \text{ in.-lb or } 2,175 \text{ ft.-lb}$$

(b) For maximum deflection at $\zeta = \text{span} \times 1/360$

$$d_{\zeta} = \frac{L}{360} = \frac{9.5 \times 12}{360} = .317 \text{ in.}$$

$$M_{\mu} = \frac{48EI d}{5L^2} = \frac{48 \times 29.5 \times 10^6 \times 2.42 \times .317}{5 \times 114 \times 114}$$

$$M_{\mu} = 16,667 \text{ in.-lb or } 1391 \text{ ft.-lb}$$

Equate Allowable Moments

For uniformly distributed load to allowable moments for equal concentrated loads at $1/3$ points:

Call P total live load in tests of 2 ft wide sections.

I is for 1 ft width.

Then $P/4 =$ concentrated load for 1 ft width.

$$M_t = \frac{PL}{12} = \frac{W_{11}L^2}{8}$$

Where W_{11} is equivalent uniform live load.

$$P = 1.5 W_{11} L \text{ or}$$

$$W_{11} = 2P/3L$$

CONCRETE VOLUME

(See Cross-Section Dimensions in Inland Steel Products Company Catalog No. 270.)

Concrete cross-sectional area

$$24 \times 2.5 = 60.0$$

$$+ \frac{(2.125 + 2.375)}{2} (1.5)(4) = \underline{13.5}$$

Area = 73.5 sq in.

Volume = 73.5 x 9.5 x 1/144 = 4.85 ft³

Volume per sq ft = $\frac{4.85}{9.5 \times 2} = .255 \text{ ft}^3/\text{ft}^2$

DEAD LOAD MOMENTS

$$M_{d1} = M_{\text{steel}} + M_{\text{concrete}}$$

$$M_{\text{steel}} = \frac{W_s L^2}{8} = 84.6 \text{ ft-lb}$$

$$M_{\text{concrete}} = \frac{W_c L^2}{8}$$

Section	W_c lb/ft ²	M_c ft-lb	M_s ft-lb	M_{d1} ft-lb
J-1-2	24	271	84.6	355.6
J-2-4	26.5	299	84.6	383.6
K-1-2	24.2	273	84.6	357.6
regular concrete	36.7	414	84.6	498.6

ALLOWABLE TOTAL LIVE LOADS

$$M_{11} = M_t - M_{d1}$$

$$W_{11} = \frac{8 M_{11}}{L^2}$$

$$P = 1.5 W_{11} L \text{ See page 7}$$

(a) For $f_s = 18000$ psi:

Section	M_t ft-lb	M_{d1} ft-lb	M_{11} ft-lb	W_{11} lb/ft ²	P lb
J-1-2	2175	355.6	1819.4	161.3	2300
J-2-4	2175	383.6	1791.4	159	2265
K-1-2	2175	357.6	1817.4	161	2295
regular concrete	2175	498.6	1676.4	148.7	2120

(b) $d_{\underline{L}} = \text{span} \times 1/360$

Section	M_{11} ft-lb	W_{11} lb/ft ²	P lb
J-1-2	1391	123.0	1752
J-2-4	1391	123.0	1752
K-1-2	1391	123.0	1752
regular concrete	1391	123.0	1752

ALLOWABLE STRAIN CONDITIONS

Steel: $f_s = 18,000$ psi

$E_s = 29.5 \times 10^6$ psi

$$e = \frac{f_s}{E_s} = \frac{18 \times 10^3}{29.5 \times 10^6} = .00061 \text{ in./in.}$$

Concrete:

Specimen	f'_c lb-sq in.	$f_c = 0.45 f'_c$ lb-sq in.	E_c lb-sq in.	$e = f_c/E_c$ in./in.
J-1-2	898	404	---	
J-2-4	1912	860	1.57×10^6	.000548
K-1-2	1218	547	0.875×10^6	.000625
regular concrete	4576	2060	3.31×10^6	.000623

APPENDIX

The design loads shown on Figs. 1, 2, and 3 are (1) P_{360} = the sum of two equal $1/3$ point loads which would cause a calculated deflection of $L/360$, assuming the concrete to provide no rigidity and (2) P_S = the sum of two equal $1/3$ point loads which would cause a stress in the steel of 18000 psi, assuming the concrete to provide no rigidity.

Figure 1: Total load versus mid-span deflection.

This figure shows the relationship of total load to deflection at the center of the span.

The equation $D = L/360$ is shown on each curve to indicate the actual loading at which the center line deflection was equal to $1/360$ of the span. As may be seen for all specimens, the actual loading causing such deflection is greater than the design loading.

The deflections of specimen J-2-4 plot as a straight line above a load of about 2000 lb. The curved portion near the origin is probably due to uneven bearing on the supports. The dashed line drawn parallel to the straight part of the curve through the origin should be used in predicting the deflection of this specimen.

Figure 2: Total load versus strain in steel at center line.

This figure shows the relationship of total load to the strain in the steel section at the center of the span.

The symbol F_S is shown on each curve to indicate the actual loading at which the maximum stress in the steel was equal to 18000 psi. As may be seen for all specimens, the actual loading causing such a stress is greater than the design loading.

Figure 3: Total load versus strain in concrete at center line.

This figure shows the relationship of total load to the strain in the concrete at the center of the span.

The symbol F_C is shown on each curve to indicate the actual loading at which the maximum stress in the concrete was

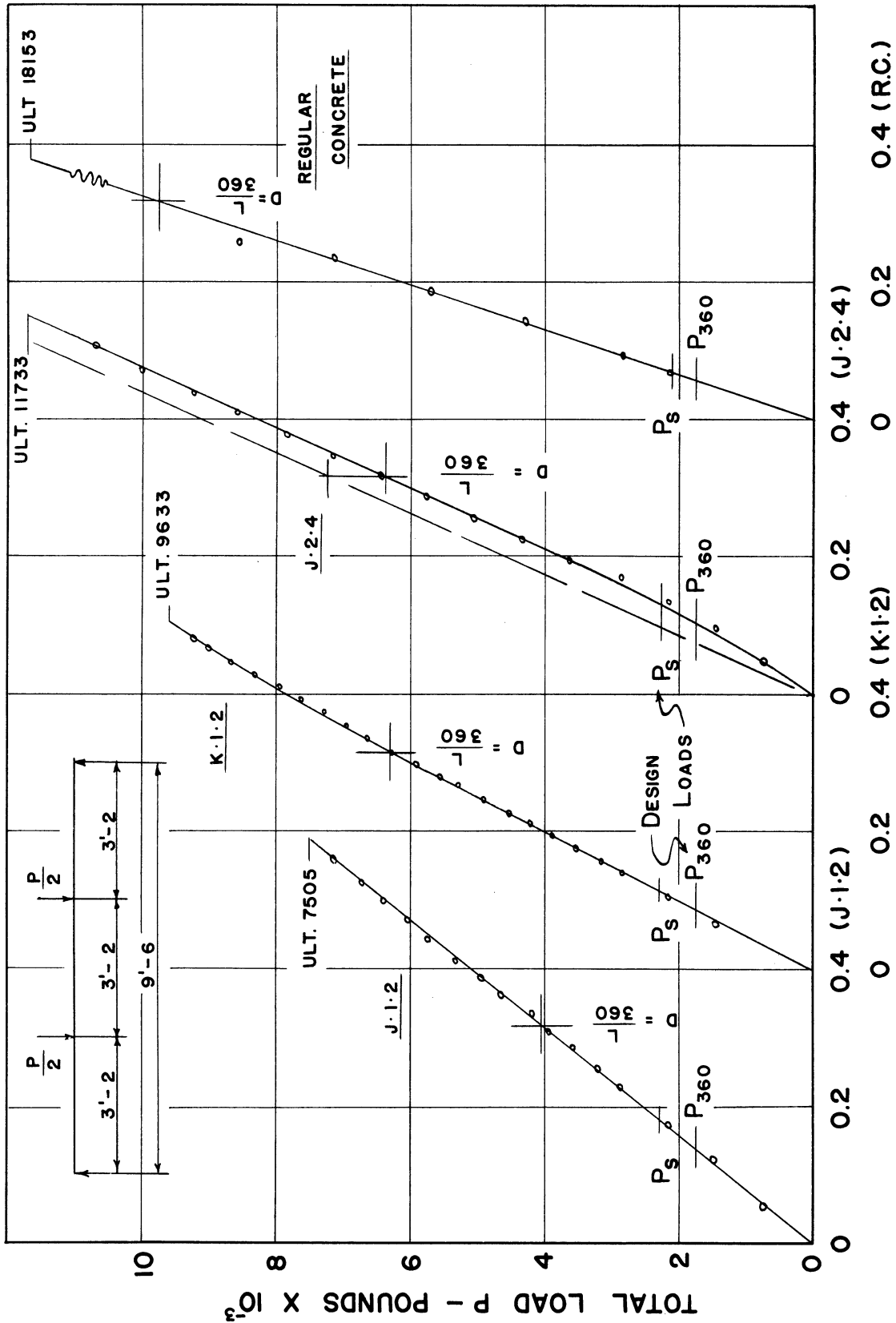
equal to 0.45 of the 28 day compressive strength. Such data are not available for specimen J-1-2.

No theoretical loading has been computed to cause $F_c = 0.45 f'_c$ since it is assumed in this type of construction that the concrete is not a part of the structural system.

Figure 4: Total load versus concrete movement relative to steel.

This figure shows the relationship of total load to the horizontal movement of the concrete relative to the steel at the end of the specimen.

Only the curve for J-2-4 follows the expected pattern. The instrumentation may have been responsible for these erratic curves.



CENTER LINE DEFLECTION - INCHES

Fig. 1. Total load versus mid-span deflection.

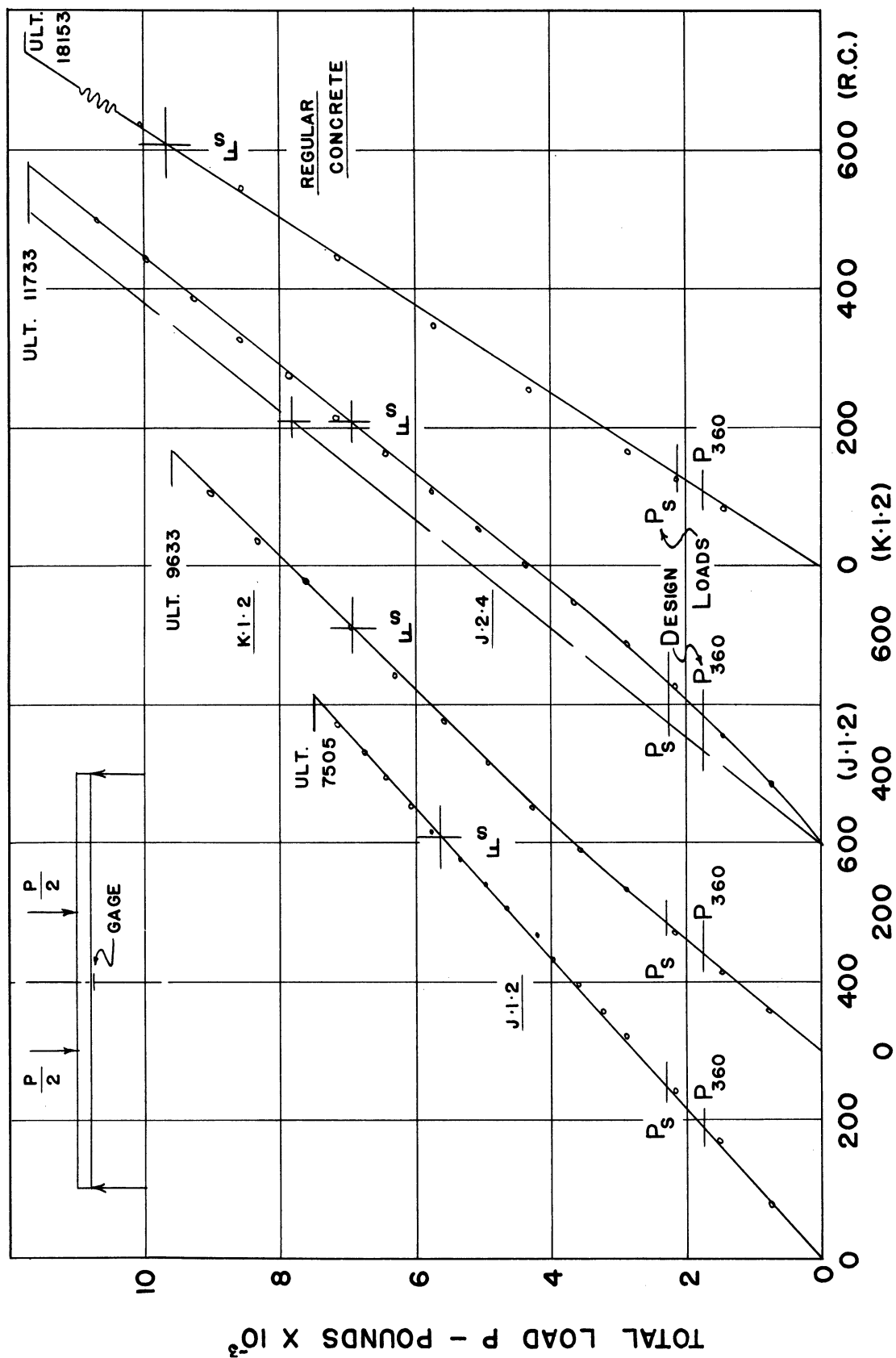


Fig. 2. Total load versus strain in steel at center line.

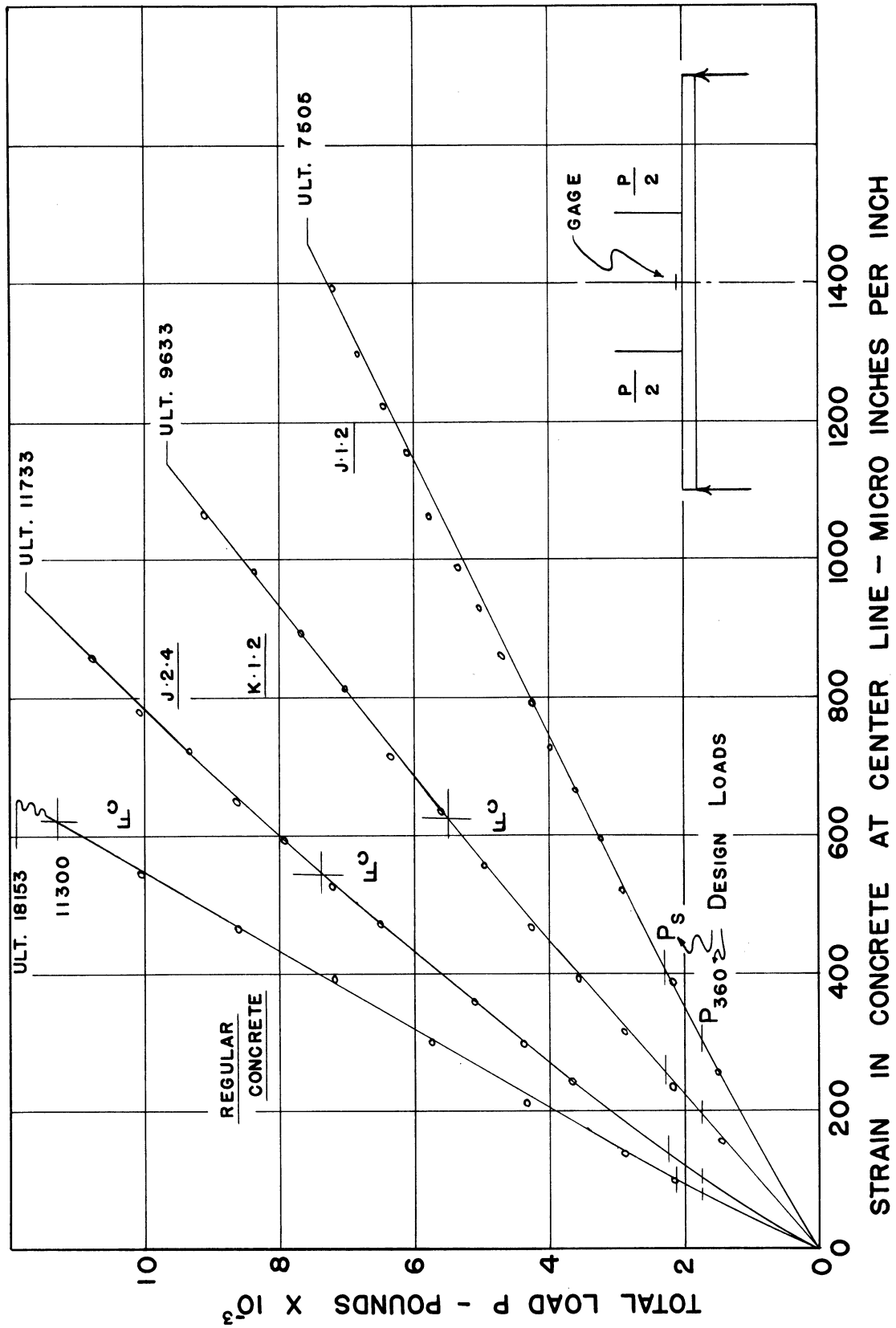


Fig. 3. Total load versus strain in concrete at center line.

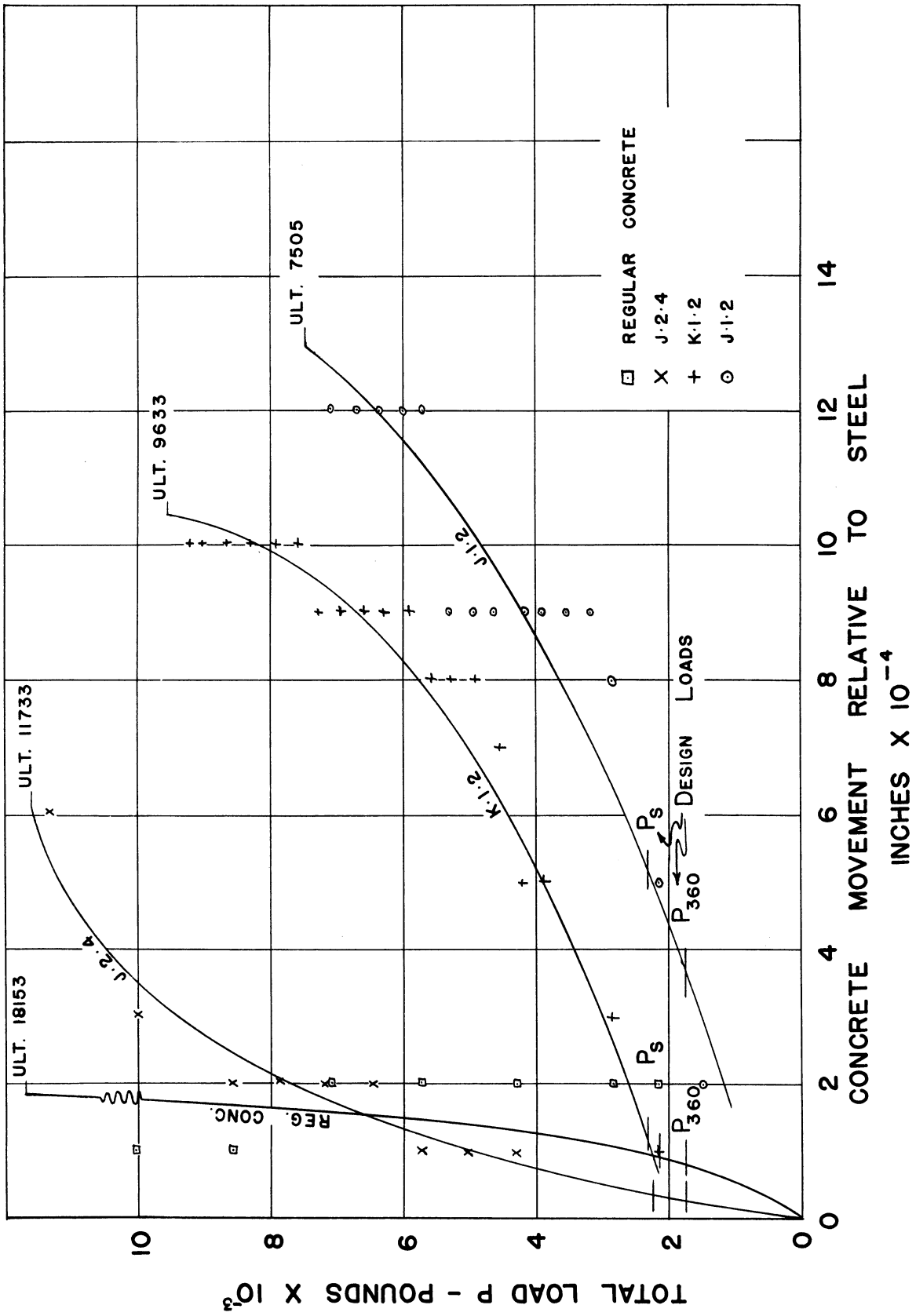


Fig. 4. Total load versus concrete movement relative to steel.

