SPLICE REQUIREMENTS FOR ONE-WAY SLABS REINFORCED WITH SMOOTH WELDED WIRE FABRIC

by

John P. Lloyd

Private Communication
Not for Publication

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Prepared as a Part of an Investigation Conducted

by the

SCHOOL OF CIVIL ENGINEERING

OKLAHOMA STATE UNIVERSITY

in cooperation with

THE WIRE REINFORCEMENT INSTITUTE

Publication No. R(S) 4

Oklahoma State University

Stillwater, Oklahoma

June, 1971

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1. INTRODUCTION

1.1 General

Smooth or deformed welded wire fabric is commonly used to reinforce floor slabs. Lap splices of adjacent sheets of fabric are used to transfer stresses from one sheet to another.

The splice requirements for smooth and deformed welded wire fabrics have been the subject of several investigations (1, 2, 3),* and building codes have provisions regarding the splicing of these materials. The investigations which considered smooth wire fabric (1, 2), were restricted to styles and sizes of reinforcement most commonly utilized in building construction. At present, there is an interest in the application of heavy styles of smooth wire fabric as the principal reinforcement in slabs and other structures. These styles of fabric can contain four times as much steel per linear foot as fabrics studied in the previous smooth wire fabric investigations. The application of existing splice requirements to these heavy styles of fabric will not result in adequate strength (4).

1.2 Scope

The objective of this study is to evaluate the variables which influence the strength of lap splices of heavy smooth wire fabric in one-way slabs. Consideration is given to design recommendations for the design of lap splices.

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*Numbers in parentheses refer to entries in the list of references.

1.3 Notation

The symbols used in this report are:

A_s = area of tensile reinforcement, sq in.

A_w = area of longitudinal wire, sq in.

b = width of slab, in.

C_1 = constant relating $\sqrt{f'_c}$ to shear strength of concrete

D = diameter of reinforcement, in.

d = effective depth of reinforcement, in.

f = steel stress, psi.

f'_c = compressive strength of concrete, psi.

f_f = steel stress at failure, psi.

j = constant relating the internal moment arm to the effective depth.

L_o = total lengths of wire extending beyond outermost transverse wires, for each pair of spliced wires, in.

ℓ_s = distance between outermost transverse wires in lap, in.

M = moment, in-kips.

M_c = calculated strength of splice, in-kips.

M_t = ultimate moment applied to slab, in-kips.

M_u = yield moment, in-kips.

p = reinforcement ratio.

S_ℓ = distance between longitudinal wires, in.

u_u = ultimate bond stress, psi.

π = 3.14

1.4 Acknowledgments

This study was conducted in the School of Civil Engineering at Oklahoma State University under the sponsorship of the Wire Reinforcement Institute.

2. EXPERIMENTAL PROGRAM

2.1 Specimens

Thirty-six one-way flexural slabs reinforced with smooth welded wire fabric were tested; details of the specimens are given in Table 1. All slabs were 192 in. long and, with one exception, were 36 in. wide. One slab, No. 25, was 32 in. wide. The overall depth of the slabs was varied from 6 to 16 in. to permit the study of various parameters.

Specimens were cast in forms lined with a plastic film, and the splices were located at the center of the slab. Reinforcement was supported by standard beam bolsters. With the exception of the steel in the two specimens with nested splices, the fabric was positioned with the longitudinal wires on both sheets oriented nearer the tensile face of the slab. Except in nested splices, the longitudinal wires in the splice were oriented directly above one another and were separated by the transverse wires on the lower sheet of fabric. The strength of lap was measured between the outermost transverse wires in the lap.

2.2 Materials

2.2.1 Concrete

The concrete used in the study was obtained from a local ready-mix plant. Type 1 portland cement and aggregate, meeting relevant ASTM specifications, were used for all concrete. The ready-mix concrete contained sand from a local source and crushed limestone coarse aggregate. The mixed proportions by weight of cement, sand, and gravel were 1.00:3.63:4.57 and 1.00:2.32:3.36 for mixes developing compressive strength of 3000 and 5000 psi, respectively. The water-to-cement ratios were 0.76 and 0.55 for the 3000 and 5000 psi mixes, respectively.

2.2.2 Reinforcement

Previous investigation of the lap splices of smooth wire fabric reinforcement considered fabric which contained as much as 0.35 sq in. of steel per linear foot. The fabric styles chosen for this study contained 0.60, 0.90, and 1.20 sq in. of steel per foot. Longitudinal wires were spaced at either 4 in. or 8 in. and the transverse wires were spaced at either 6 in. or 12 in.

A summary of strength properties of the fabric is provided in Table 2, and average stress-strain curves are given in Fig 1. The fabric exceeded the requirements of the ASTM Standard Specifications for Welded Steel Wire Fabric for Concrete Reinforcement, A185-69, except that fabric style 4x6:W40xW20* did not meet the required 35,000 psi weld shear strength requirement. All fabric styles exhibited a strength of at least 73,000 psi at a strain of 0.0035.

2.3 Experimental Procedure

All slabs and control specimens were cast in accordance with pertinent ASTM specifications. Slabs and control cylinders were removed from forms 24 hours after casting and were cured under wet burlap for 6 days. Control cylinders, which received the same curing conditions as the the slabs, were tested at frequent intervals during the curing period. Based upon the strength gain curves developed from these cylinder tests, the slabs were scheduled for test at nominal compressive strengths of 3000 or 5000 psi.

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*Fabric style designated as 4x6:W40xW20 indicates that longitudinal and transverse wires are spaced on 4 in. and 6 in. centers, respectively, and that the cross-sectional areas of the longitudinal and transverse wires are 0.40 and 0.20 sq in., respectively. A common industrial method of designating this style is 4" x 6"--.714" x .504".

Slabs were inverted from the casting position and placed in the test set-up shown schematically in Fig 2. The load, which was applied through a hydraulic system, placed the slabs in a concave downward curvature. Loading was applied in increments equal to 2 per cent of the calculated yield moment. After each increment was applied, the load was held constant for approximately 2 minutes, while measurements of the load and deflection were made and recorded. Surface cracking was observed and marked on the surface of the specimen and recorded photographically at the completion of the test. Between 2 and 3 hours were required for the test of each slab. Control cylinders were tested at the time of the slab test to provide an accurate estimate of the compressive strength of the concrete.

3. EXPERIMENTAL RESULTS

3.1 General

All slabs failed in the splice except slab 8 which failed by crushing of the concrete at the compressive face of the member. Visual observation of cracks on the lateral faces of the slabs revealed the development of multiple horizontal and inclined cracks at the level of the splice shortly before the maximum load capacity was reached. At failure, these cracks were interconnected and formed a continuous failure surface between the outermost transverse wires in the splice. The longitudinal wires which extended beyond the outermost transverse wires exhibited a pull-out type of failure. The outward characteristics of the splice failures closely paralleled the types of failure which have been noted with splices of deformed wire fabric (3). No failures were a result of weld failure.

The results of the slab tests are presented in Table 3. From a design standpoint, it is convenient to express the data in terms of a nominal design strength. The frequently-used ultimate strength equation (16-1) of ACI 318-63(5) was chosen for this purpose.

$$M_u = \phi A_s f_y \left(d - \frac{A_s f_y}{1.7 f'_c b} \right) \times 10^{-3}$$

where:

M_u = yield moment, in-kips,

ϕ = 1.00,

A_s = area of tensile reinforcement, sq in.,

f_y = yield strength of reinforcement, psi,

d = effective depth of slab, in,

f'_c = compressive strength of concrete, psi, and

b = width of slab, in.

Because the designer seldom has a knowledge of the actual yield strength of the reinforcement, the minimum specified yield strength for smooth wire fabric, 65,000 psi, was used to calculate the yield moments given in Table 3. It should be emphasized that these yield moments are not intended to represent the actual maximum moments the slabs would have developed if the splices were completely effective. They are used to allow comparison of the actual splice strength with a standard strength which might be used in design. The influences of various test parameters on the strength of splices are considered below.

3.2 Effect of Length of Lap

The following parameters and results of the study of splice length are given below:

Slab	Reinforcement Style	Splice Length, in.	M_t, in.-kips	M_t/M_u
1	4x12:W40xW20	14	1206	0.70
2	4x12:W40xW20	26	1574	0.91
3	4x12:W40xW20	32	2000	1.14
4	4x12:W40xW20	38	1936	1.11
5	4x12:W30xW20	8	638	0.63
6	4x12:W30xW20	14	754	0.75
7	4x12:W30xW20	26	1081	1.07
8	4x12:W30xW20	32	1146	1.16
9	4x12:W20xW12	2	247	0.51
10	4x12:W20xW12	8	393	0.81
11	4x12:W20xW12	14	467	0.95
12	4x12:W20xW12	26	624	1.29

where M_t is the maximum test moment obtained with the slabs and M_t/M_u is the ratio of test moment to the calculated yield moment.

All specimens had a nominal strength of 3000 psi, a cover of 1 in., and a reinforcement ratio of 0.0011. The results are plotted in Fig. 3, where it can be seen that the strength increases with an increase in splice length.

Specimens 1 through 12 had overhangs equal to one-half of the transversal wire spacing, or 6 in. beyond the outermost transverse wire. Results from specimens in which all variables except overhang were held constant are given below. It can be seen that bond along the overhangs provides significant stress transfer.

Slab	Reinforcement Style	Splice Length, in.	Overhang, in.	M_t, in.-kips	M_t/M_u
28	4x12:W40xW20	26	0	1217	0.70
2	4x12:W40xW20	26	6	1574	0.91
29	4x12:W40xW20	26	12	1893	1.08
30	4x12:W20xW12	14	0	323	0.65
11	4x12:W20xW12	14	6	467	0.95
31	4x12:W20xW12	14	12	500	1.01

3.3 Effect of Cover

Details of six slabs used to study the effect of cover are given below:

Slab	Reinforcement Style	Cover, in.	M_t, in.-kips	M_t/M_u
2	4x12:W40xW20	1	1574	0.91
13	4x12:W40xW20	2	1726	0.97
14	4x12:W40xW20	3	1850	1.08
11	4x12:W20xW12	1	467	0.95
15	4x12:W20xW12	2	457	0.95
16	4x12:W20xW12	3	432	0.90

The slabs had a reinforcement ratio of 0.0011 and were tested at compressive strengths of about 3000 psi. Splice lengths of 26 in. and 14 in. were used with slabs 2, 13, and 14, and with slabs 11, 15, and

16, respectively. These results, which are plotted in Fig. 4, indicate that the amount of cover did not produce a large effect on splice strength.

3.4 Effect of Concrete Strength

The details of 6 slabs used to investigate the influence of concrete strength are given below:

Slab	Reinforcement Style	Splice Length, in.	Cover, in.	f'_c, psi	M_t, in.-kips
2	4x12:W40xW20	26	1	3000	1574
17	4x12:W40xW20	26	1	5000	1843
14	4x12:W40xW20	26	3	3000	1850
13	4x12:W40xW20	26	3	5000	2179
16	4x12:W20xW12	14	3	3000	432
20	4x12:W20xW12	14	3	5000	593

The results for this study are plotted in Fig. 5. It is seen that increasing the strength of the concrete produces a slight increase in splice strength and that the strength of the concrete appears to have an equal influence on the strengths of slabs with a cover of either 1 in. or 3 in.

3.5 Effect of Reinforcement Ratio

Nine slabs were cast and tested to study the influence of the reinforcement ratio on the strength of splices. Data regarding these specimens are given below.

All slabs were cast with 1 in. of clear cover and were tested at a nominal strength of 3000 psi. Specimens 24, 34, and 35 had a lap length of 14 in; the other six slabs had a lap length of 26 in.

Slab	Reinforcement Style	p	M_t, in.-kips	M_t/M_u
2	4x12:W40xW20	0.0116	1574	0.91
21	4x12:W40xW20	0.0086	2116	0.87
22	4x12:W40xW20	0.0068	2612	0.83
7	4x12:W30xW20	0.0112	1081	1.07
32	4x12:W30xW20	0.0086	1444	1.06
33	4x12:W30xW20	0.0070	1835	1.05
24	4x6:W20xW12	0.0105	527	1.10
34	4x6:W20xW12	0.0074	748	1.05
35	4x6:W20xW12	0.0057	925	0.96

As shown in Fig. 6, there is a small increase in values of M_t/M_u with an increase in the reinforcement ratio. These data suggest that deeper members which have smaller curvatures and strain gradients at ultimate may be slightly weaker; one might anticipate that this effect would be most pronounced in the case of splices in structures such as water tanks where a minimum of flexural action occurs.

3.6 Effect of Reinforcement Style

The table below indicates the variables considered in this phase of the investigation.

Slab	Reinforcement Style	Splice Length, in.	p	M_t, in.-kips	M_t/M_u
2	4x12:W40xW20	26	0.0116	1574	0.91
23	4x6:W40xW20	26	0.0116	2612	0.76
11	4x12:W20xW12	14	0.0111	477	0.95
24	4x6:W20xW12	14	0.0105	527	1.10
25	8x12:W40xW20	14	0.0108	341	0.82

Slabs 2 and 23 and slabs 11 and 24 were used to investigate the influence of spacing of transverse wires. In the case of slabs 2 and 23, reducing the spacing of the transverse wires from 12 in. to 6 in. did not improve the strength, while the results from slabs 11 and 24 indicate that reducing the spacing of transverse wires is beneficial. Slabs 11 and 25, which contain the same amount of steel per linear foot, provide data on the influence of the longitudinal wire spacing. Results indicate an increased strength results from smaller wires more closely spaced.

3.7 Effect of Nesting

Slab data pertaining to nested splices is given below.

Slab	Reinforcement Style	Remark	M_t, in.-kips	M_t/Mu
2	4x12:W40xW20	not nested	1574	0.91
26	4x12:W40xW20	nested	1330	0.77
11	4x12:W20xW12	not nested	467	0.95
27	4x12:W20xW12	nested	360	0.75

Although slabs 2 and 26 and slabs 11 and 27 contained similar cover, concrete strength and overlap, a significant reduction in strength occurred with slabs 26 and 27 which contained nested splices. A possible explanation for this reduction in strength is that the close proximity of adjacent longitudinal wires hinders the placement and consolidation of concrete around the steel.

3.8 Effect of Spiral Reinforcement in Lap

Splitting failures in lapped splices or in anchorages are a result of the relative weakness of concrete in diagonal tension. In beams stirrups are sometimes used to minimize splitting failures; however, in slabs reinforced with fabric, stirrups are unsuitable because of the difficulties encountered in placing them. To investigate an alternative to stirrups, slab 36 was cast with a length of 7 in. diameter spiral reinforcement laid in the splice region. The spiral was fabricated from No. 2 smooth bar with a pitch of 4 in.

As indicated in Table 3, slab 36 was not stronger than Slab No. 1 which was geometrically similar but did not contain spiral reinforcement. This indicates that the case of spiral reinforcement to prevent splitting failures is not satisfactory.

4. ANALYSIS OF DATA

4.1 General

The moment which is applied to any section of a reinforced concrete beam is resisted by an internal moment. This internal moment is composed of equal and opposite forces in the steel and the concrete acting at a distance jd apart.

The internal lever arm, jd, remains fairly constant after flexural cracks have developed. For this reason, the steel stress, f, at any load level, M, can be estimated as $(M/M_u)f_y$, where M_u is the calculated yield moment based on the specified yield strength f_y.

4.2 Data Analysis

The test results indicate that although the strength is strongly related to the length of lap measured between the outermost transverse wires in the splice, the influence of bond stress acting along overhanging longitudinal wires contributes significantly to the strength of the splice. This type of behavior was noted in an earlier study of the behavior of deformed wire fabric (3). It was found in that study that the test moment can be related to bond acting along the overhanging longitudinal wires, to the distance between the outermost transverse wires, and to the strength of the concrete. Noting that the slabs failed when, as a result of the high shear stress in the concrete between the sheets of fabric, a horizontal crack developed between the outermost transverse wires in the lap, the steel stress at failure can be expressed as

$$f_f = \frac{u_u \pi D L_o + C_1 \sqrt{f'_c}\, S_\ell \ell_s}{A_w},$$

where f_f = estimated steel stress at failure, psi,

u_u = ultimate bond stress, psi,

L_o = total lengths of wire extending beyond outermost cross wires, for each pair of spliced wires, in.,

D = diameter of the longitudinal wires, in.,

C_1 = constant to relate f'_c to shear strength of concrete,

f'_c = compressive strength of concrete, psi,

S_ℓ = spacing of longitudinal wires,

ℓ_s = distance between outermost transverse wires in the lap, in., and

A_w = cross-sectional area of a longitudinal wire, sq in.,

and if $f = (M/M_u)f_y$, the ratio of maximum test moment to calculated yield moment based on f_y = 65,000 psi can be expressed as

$$\frac{M_t}{M_u} = \frac{f_f}{f_y} = \frac{u_u \pi D L_o + C_1\sqrt{f'_c}\, S_\ell \ell_s}{A_w \times 65,000} .$$

Assuming that the bond stress u_u is approximately constant for the sizes of wire encountered in this study, the above equation was used to analyze the results obtained from tests of slabs 1 through 12. The constants u_u and C_1 were evaluated by the method of least squares and found to be 340 psi and 2.17, respectively. Using these values, calculated strengths for slabs 1 through 12 were obtained with the use of the following equation:

$$\frac{M_c}{M_u} = \frac{340 \pi D L_o + 2.17\sqrt{f'_c}\, S_\ell \ell_s}{A_w \times 65,000} .$$

A comparison of calculated to actual strength is shown in Fig 7.

Noting that the method predicted splice strength reasonably well, the same approach was applied to the data obtained from 30 slabs. Slabs 26 and 27 with nested splices and slab 8 which failed by crushing of the concrete rather than a failure of the splice were not considered. In addition, a preliminary analysis of data indicated that the computed strength of slabs 12 and 31 would be at least 30 per cent greater than their yield strengths; because such strengths were not physically possible, these slabs were not considered in the analysis. Slab 19 was eliminated because of errors in measurement of the failure load.

Attempts to ignore the effect of bond stress and relate the strength of slabs to the distance between the outermost wires in the lap, or to the total lap length, or to the number of transverse wires in the lap, were found to be less accurate than the above approach.

5. DESIGN CONSIDERATIONS

5.1 General

As presently stated (5) the splice requirements for smooth wire fabric are:

> "1. Lapped splices of wires in regions of maximum stress (where they are carrying more than one-half of the permissible stress) shall be avoided wherever possible, such splices where used shall be so made that the overlap measured between outermost cross wires of each fabric sheet is not less than the spacing of the cross wires plus 2 in.
>
> 2. Splices of wires stressed at not more than one-half the permissible stress shall be so made that the overlap measured between outermost cross wires is less than 2 in."

The intent of these provisions is to insure that there is sufficient weld strength in the overlap. It is emphasized that although the deep, heavily reinforced slabs in this study did not fail as a result of weld shear, the above recommendations should remain as minimum length requirements.

5.2 Design Considerations

To account for the types of splice failure encountered in this investigation, two design approaches can be taken which are based on

$$\frac{M_c}{M_u} = \frac{u_u \pi D L_o + C_1 \sqrt{f'_c}\, S_\ell \ell_s}{A_w \times 65,000} .$$

The value of u_u can be taken as 250 psi which is in close agreement with test results and conforms to the bond strengths permitted for smooth wire by the ACI Building Code (5). The value of C_1 obtained for all data was 2.72. Recognizing the fact that this constant is expressing the magnitude of diagonal tension which can be developed in a splice, it is recommended that it be taken equal to a slightly lower value of 2.50.

For the designer who either has no knowledge of the length of over-hangs which will exist in the splice or who wishes to neglect bond stress for the sake of simplicity or greater conservatude, the strength expression reduces to

$$\frac{M_c}{M_u} = \frac{2.50\sqrt{f'_c}\, S_\ell\, \ell_s}{A_w \times 65,000}.$$

Based on a concrete strength of 3000 psi which is typical for floor slabs,

$$\frac{M_t}{M_u} = \frac{2.50\sqrt{3000}\;\; S_\ell\, \ell_s}{A_w \times 65,000} = \frac{0.00211\, S_\ell\, \ell_s}{A_w}.$$

Since the area of steel per linear foot can be expressed as

$$(A_s/\text{foot}) = \frac{A_w 12}{S_\ell},$$

substituting into the above equation,

$$\frac{M_c}{M_u} = \frac{0.025\,\ell_s}{(A_s/\text{foot})}.$$

If a designer wishes to obtain a splice capable of transferring the full strength of the beam, $M_c/M_u = 1.00$, then $\ell_s \geq 40(A_s/\text{foot})$. For a splice to transfer at less than one-half of the permissible moment, $\ell_s \geq 20(A_s/\text{foot})$.

If a designer wishes to obtain a minimum length of splice, he will now need to consider the contribution from bond acting along the over-hanging longitudinal wires.

$$\frac{M_c}{M_u} = \frac{250\pi DL_o}{A_w \times 65,000} + \frac{0.025\,\ell_s}{(A_s/\text{foot})}.$$

Since $A_w = \pi D^2/4$, this can be rewritten as

$$\frac{M_c}{M_u} = \frac{L_o}{65D} + \frac{0.025\,\ell_s}{(A_s/\text{foot})}.$$

Since from a design standpoint the ratio M_c/M_u is equivalent to the ratio (A_s required/foot)/(A_s provided/foot), the distance between outermost cross wires in the splice should be at least

$$40(A_s \text{ provided/foot})\left[(A_s \text{ required/foot})/(A_s \text{ provided/foot}) - 0.02\,L_o)\right],$$

or

$$40(A_s \text{ required/foot}) - 0.80\,L_o\,(A_s \text{ provided/foot}).$$

5.3 Examples of Design Procedure

5.3.1 Design a splice to transfer the full permissible stress in a 4x12:W40xW20 fabric which has longitudinal wires (W40) with 6 in. overhangs.

$$(A_s \text{ provided/foot}) = 12 \times 0.4/4 = 1.2 \text{ sq in./ft}$$

and

$$\ell_s = 40\,(A_s \text{ required/foot}) - 0.80L_o \times (A_s \text{ provided/foot})$$

or

$$\ell_s = 40 \times 1.2 - 0.80 \times (6 + 6) \times (1.2) = 36.5 \text{ in.}$$

The existing ACI Building Code provisions which require a minimum distance of 14 in. between outermost cross wires for this fabric style are satisfied and the required distance between the cross wires is at least 36.5 in.

5.3.2 Design a splice to transfer the full strength of 4x16:W20xW12 fabric which has longitudinal wires (W20) with 8 in. overhangs.

$$(A_s \text{ provided/foot}) = 12 \times 0.2/4 = 0.6 \text{ sq in./ft},$$

and

$$\ell_s = 40(A_s \text{ required/foot}) - 0.8L_o\,(A_s \text{ provided/foot})$$

$$= 40 \times 0.6 - 0.8 \times (8 + 8) \times (0.6)$$

$$= 16.3 \text{ in.}$$

But since the existing Building Code requires a distance between outermost cross wires of at least 18 in. for this fabric style, the minimum distance is 18 in.

6. CONCLUSIONS

6.1 General

Based on the results of 36 slabs which contained various reinforcement styles, lap lengths, cover, concrete strength steel percentages, and lap configurations, it is concluded that existing Building Code splice requirements which require one or two cross wires in the splice length to transfer less than 50 or more than 50 percent of the permissible stress in the fabric are not conservative in all cases. It is further concluded that for slabs which contain high to moderate amounts of steel per foot, the strength of splice is controlled by the amount of stress which can be carried by bond along the overhanging longitudinal wires and by shearing stress in the concrete between the overlapped sheets of reinforcement.

6.2 Recommendations for Design

It is recommended that the existing splice requirements for smooth wire fabric be revised to reflect the findings of this study as stated below.

6.2.1

Lapped splices of wires carrying more than one-half of the permissible stress shall preferably be avoided. Where such splices must carry more than one-half of the permissible stress, they shall be so made that the overlap measured between the outermost cross wires is in no case less than the spacing of cross wires plus 2 in; and, to prevent a splitting failure, the overlap distance shall not be less than 40 times the area of steel required per linear foot unless the checks of 6.2.3 are made.

. . 6.2.2

Splices of wires stressed at not more than one-half the permissible stress shall be so made that the overlap measured between outermost cross wires is in no case less than 2 in.; and to prevent a splitting failure, the overlap distance shall not be less than 20 times the area of steel required per linear foot unless the checks of 6.2.3 are made

6.2.3

To prevent a splitting failure between the sheets of reinforcement, the amount of overlap measured between the outermost cross wires shall not be less than (40(A_s required/foot) - 0.80 L_o($A_s$provided/foot)) where L_o is the total lengths of wire extending beyond cross wires, for each pair of spliced wires.

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4. J. P. Lloyd. "Strength of Lapped Splices of Welded Wire Fabric in One-Way Slabs," Unpublished report of exploratory study sponsored by Engineering Research, Oklahoma State University, 1970.

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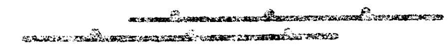
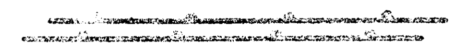
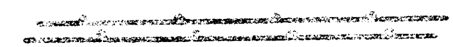
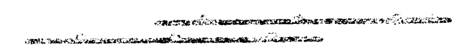
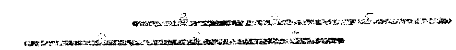
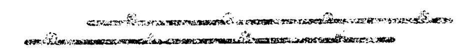
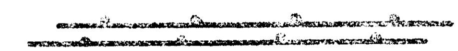
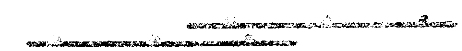
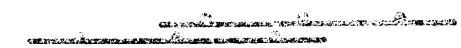
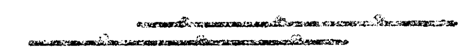
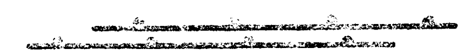
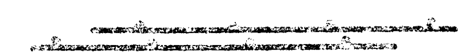
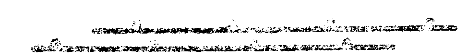
TABLE 1--DETAILS OF SPECIMENS

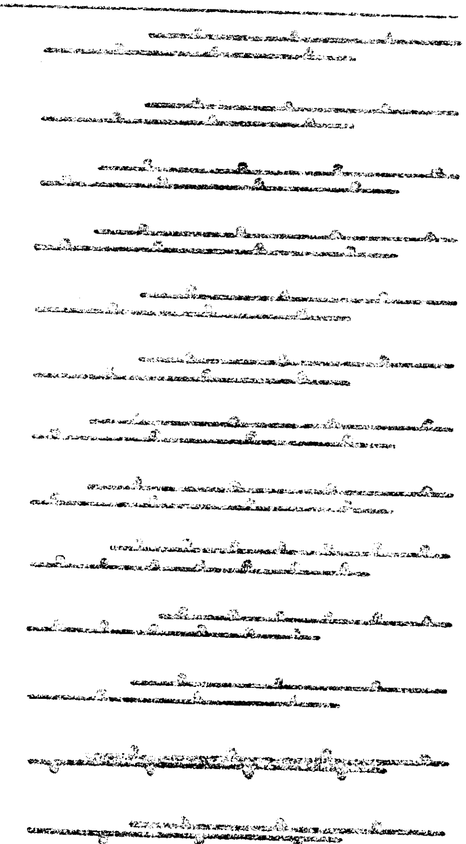
Slab No.	Reinforcement Style	Splice[a] Length, in.	f'_c, psi	Cover, in.	Total Depth, in.	p^b	Detail of Splice
1	4x12:W40xW20	14	3000	1	10	0.0116	
2	4x12:W40xW20	26	3000	1	10	0.0116	
3	4x12:W40xW20	32	3000	1	10	0.0116	
4	4x12:W40xW20	38	3000	1	10	0.0116	
5	4x12:W30xW20	8	3000	1	8	0.0112	
6	4x12:W30xW20	14	3000	1	8	0.0112	
7	4x12:W30xW20	26	3000	1	8	0.0112	
8	4x12:W30xW20	32	3000	1	8	0.0112	
9	4x12:W20xW12	2	3000	1	6	0.0111	
10	4x12:W20xW12	8	3000	1	6	0.0111	
11	4x12:W20xW12	14	3000	1	6	0.0111	
12	4x12:W20xW12	26	3000	1	6	0.0111	
13	4x12:W40xW20	26	3000	2	11	0.0116	
14	4x12:W40xW20	26	3000	3	12	0.0116	

[a]Measured between the outermost transverse wires in the lap.

[b]Reinforcement ratio.

TABLE 1--DETAILS OF SPECIMENS (CONTINUED)

Slab No.	Reinforcement Style	Splice[a] Length, in.	f'_c, psi	Cover, in.	Total Depth, in.	p^b	Detail of Splice
15	4x12:W20xW12	14	3000	2	7	0.0105	
16	4x12:W20xW12	14	3000	3	8	0.0105	
17	4x12:W40xW20	26	5000	1	10	0.0116	
18	4x12:W40xW20	26	5000	3	12	0.0116	
19	4x12:W20xW12	14	5000	1	6	0.0105	
20	4x12:W20xW12	14	5000	3	8	0.0105	
21	4x12:W40xW20	26	3000	1	13	0.0086	
22	4x12:W40xW20	26	3000	1	16	0.0068	
23	4x6:W40xW20	26	3000	1	10	0.0116	
24	4x6:W20xW12	14	3000	1	6	0.0105	
25	3x12:W40xW20	14	3000	1	6	0.0108	
26	4x12:W40xW20	26	3000	1	10	0.0116	
27	4x12:W20xW12	14	3000	1	6	0.0105	



[a]Measured between the outermost transverse wires in the lap.

[b]Reinforcement ratio.

TABLE 1--DETAILS OF SPECIMENS (CONCLUDED)

Slab No.	Reinforcement Style	Splice[a] Length, in.	f'_c, psi	Cover, in.	Total Depth, in.	p^b	Detail of Splice
28	4x12:W40xW20	26	3000	1	10	0.0116	
29	4x12:W40xW20	26	3000	1	10	0.0116	
30	4x12:W20xW12	14	3000	1	8	0.0111	
31	4x12:W20xW12	14	3000	1	8	0.0111	
32	4x12:W30xW20	26	3000	1	10	0.0086	
33	4x12:W30xW20	26	3000	1	12	0.0070	
34	4x6:W20xW12	14	3000	1	8	0.0074	
35	4x6:W20xW12	14	3000	1	10	0.0057	
36	4x12:W40xW20	14[c]	3000	1	10	0.0116	

[a] Measure between the outermost transverse wires in the lap.

[b] Reinforcement ratio.

[c] Spiral reinforcement with a diameter of 0.25 in. was placed in splice.

TABLE 2 - STRENGTH PROPERTIES OF FABRIC

Fabric Style	Yield Strength, psi		Ultimate Strength, psi	Measured Weld Shear Strength,[b] psi	Average[c] Weld Embedment, in.
	0.0035[a]	0.005[a]			
4x12:W20xW12	74,000	77,000	90,000	54,850	0.101
4x6:W20xW12	76,000	79,000	90,000	47,900	0.090
4x12:W30xW20	73,000	78,000	86,000	45,670	0.123
4x12:W40xW20	77,000	82,000	90,000	38,850	0.152
4x6:W40xW20	75,000	80,000	90,000	31,300	0.093
8x12:W40xW20	78,000	82,000	87,000	44,380	0.145

[a] Strains.

[b] ASTM A185 requires a weld strength of 35,000 psi for smooth wire fabric.

[c] Sum of nominal diameters of the longitudinal and transverse wires minus the thickness of the fabric at the weld intersections.

TABLE 3--TEST RESULTS

Slab No.	Reinforcement Style	Effective Depth, in.	Splice[a] Length, in.	f'_c, psi	M_u,[b] in.-kips	M_t,[c] in.-kips	M_t/M_u
1	4x12:W40xW20	8.64	14	3000	1724	1208	0.70
2	4x12:W40xW20	8.64	26	3000	1724	1574	0.91
3	4x12:W40xW20	8.64	32	3400	1752	2000	1.14
4	4x12:W40xW20	8.64	38	3150	1738	1938	1.11
5	4x12:W30xW20	6.69	8	3300	1017	638	0.63
6	4x12:W30xW20	6.69	14	3000	1006	754	0.75
7	4x12:W30xW20	6.69	26	3100	1012	1081	1.07
8	4x12:W30xW20	6.69	32	2950	989	1146[d]	1.16
9	4x12:W20xW12	4.50	2	3000	481	247	0.51
10	4x12:W20xW12	4.50	8	3100	483	393	0.81
11	4x12:W20xW12	4.50	14	3400	490	467	0.95
12	4x12:W20xW12	4.50	26	3150	484	624	1.29
13	4x12:W40xW20	8.64	26	3300	1751	1726	0.99
14	4x12:W40xW20	8.64	26	2950	1721	1850	1.08
15	4x12:W20xW12	4.75	14	3000	481	457	0.95
16	4x12:W20xW12	4.75	14	3000	481	432	0.90
17	4x12:W40xW20	8.64	26	5100	1842	1843	1.00
18	4x12:W40xW20	8.64	26	5100	2315	2179	0.94
19	4x12:W20xW12	4.75	14	5050	*		
20	4x12:W20xW12	4.75	14	5050	505	593	1.17

*Load measurement equipment gave inaccurate readings and the strength of slab 19 is not considered in the analysis.

TABLE 3--TEST RESULTS (CONCLUDED)

Slab No.	Reinforcement Style	Effective Depth, in.	Splice[a] Length, in.	f'_c, psi	M_u,[b] in.-kips	M_t,[c] in.-kips	M_t/M_u
21	4x12:W40xW20	11.64	26	3150	2440	2116	0.87
22	4x12:W40xW20	14.64	26	3100	3138	2612	0.83
23	4x6:W40xW20	8.64	26	3000	1724	1305	0.76
24	4x6:W20xW12	4.75	14	3000	481	527	1.10
25	8x12:W40xW20	4.64	14	3000	416	341	0.82
26	4x12:W40xW20	8.64	26	3000	1724	1330	0.77
27	4x12:W20xW12	4.75	14	3000	481	360	0.75
28	4x12:W40xW20	8.64	26	5140	1733	1217	0.70
29	4x12:W40xW20	8.64	26	3340	1755	1893	1.08
30	4x12:W20xW12	4.75	14	3650	494	323	0.65
31	4x12:W20xW12	4.75	14	3820	497	500	1.01
32	4x12:W30xW20	8.69	26	3040	1330	1444	1.08
33	4x12:W30xW20	10.69	26	3800	1744	1855	1.06
34	4x6:W20xW12	6.75	14	2900	712	748	1.05
35	4x6:W20xW12	6.75	14	3300	333	325	0.98
36	4x12:W40xW20	8.64	14	4250	1311	1201	0.86

[a]Measured between outermost transverse wires in the lap.

[b]Based on Eq 16-1, ACI 318-63 with f_y = 65,000 psi and ϕ = 1.00.

[c]Maximum test moment.

[d]Exhibited crushing of concrete at compressive face at ultimate.

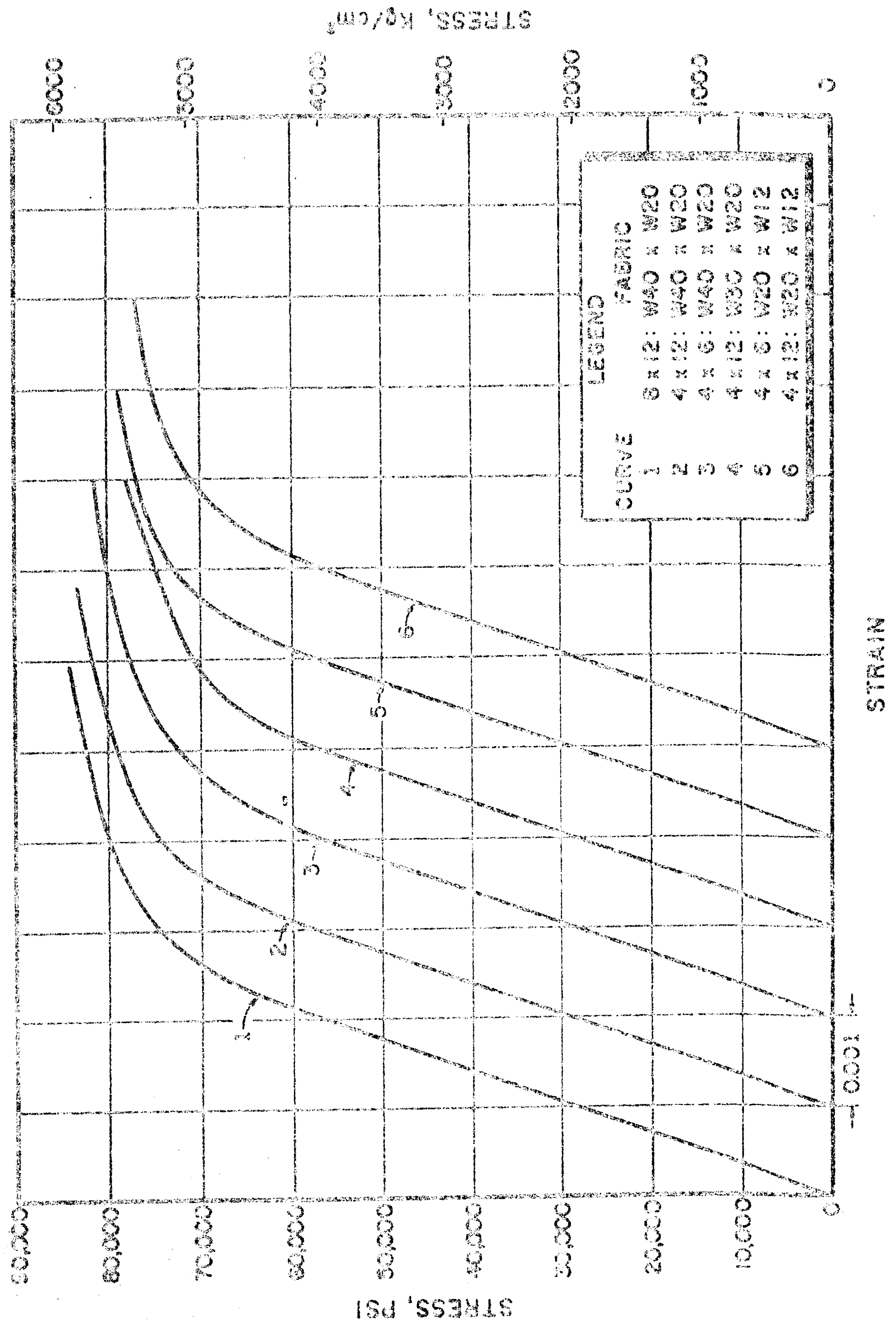


Fig. 1 - AVERAGE STRESS-STRAIN CURVES FOR LONGITUDINAL WIRES FROM FABRIC.

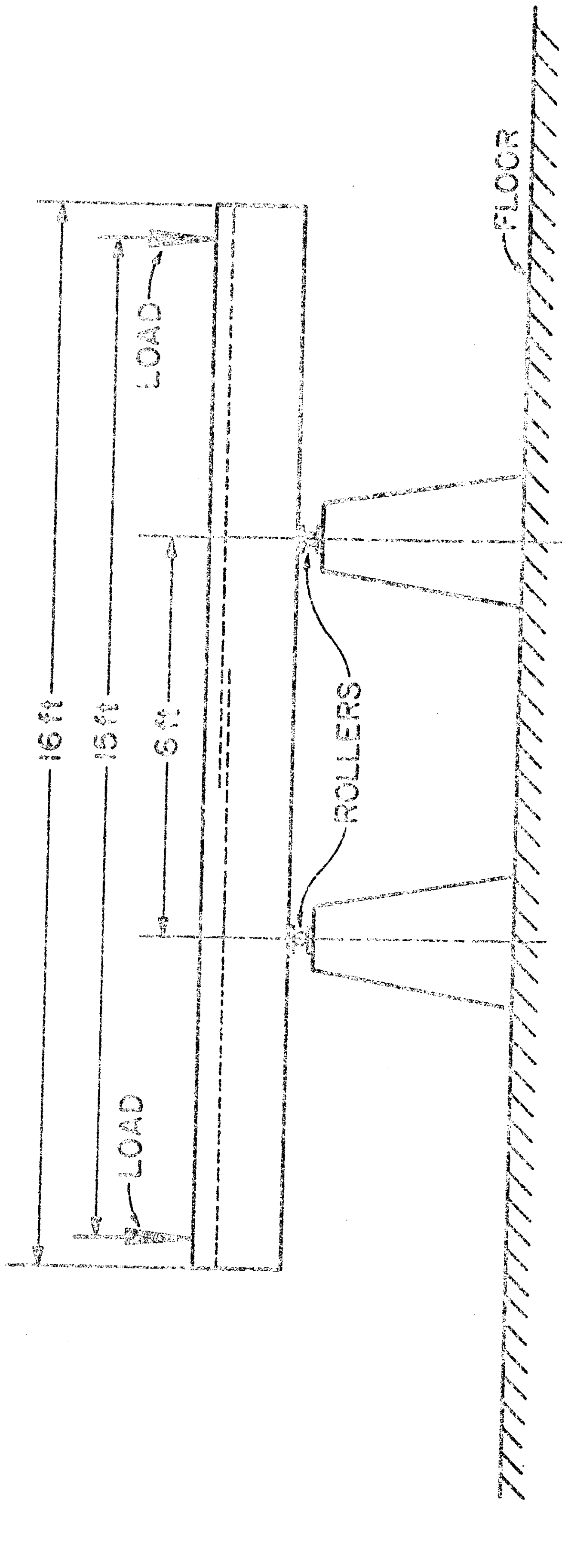


Fig. 2 - TEST SETUP

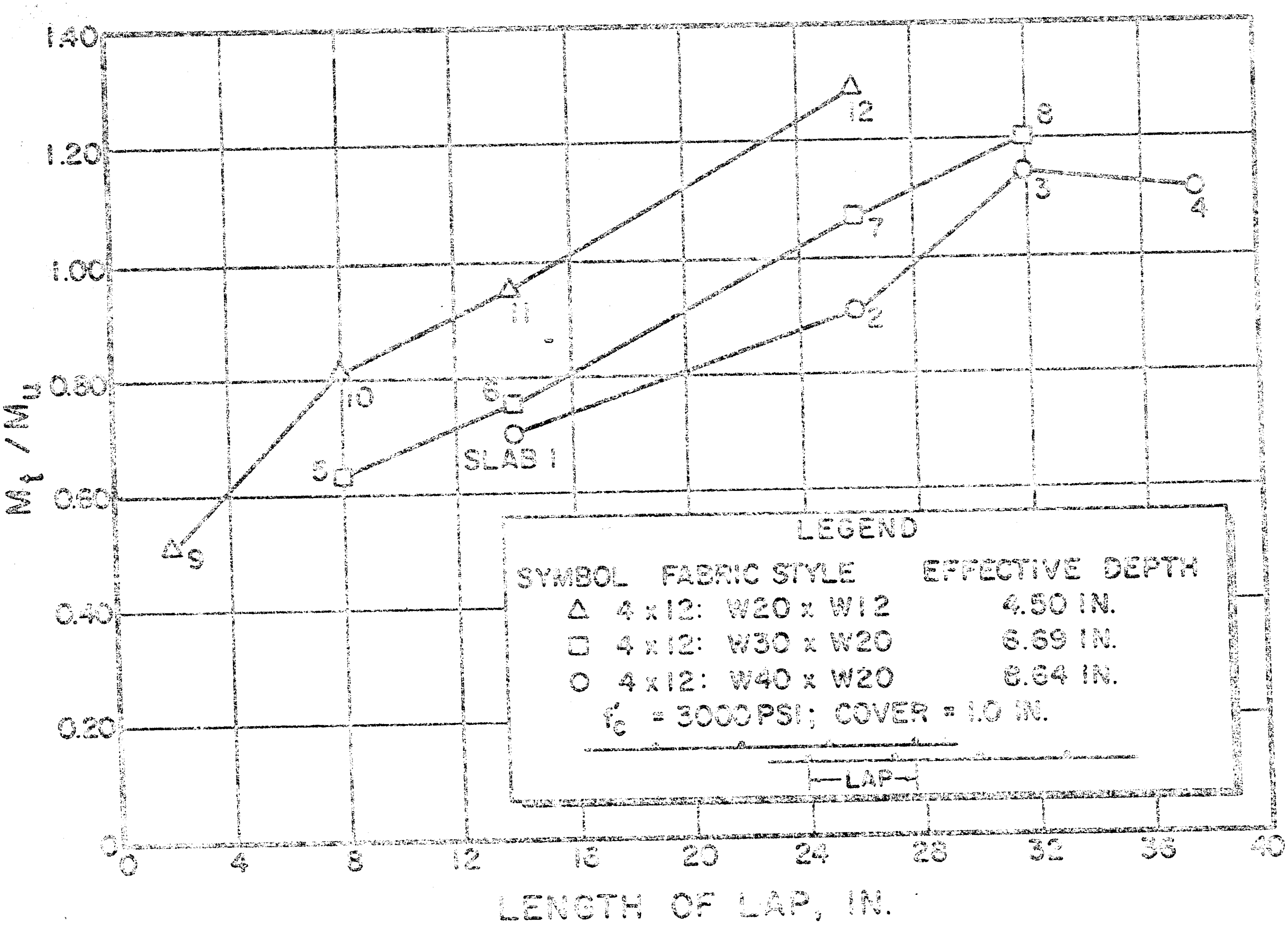


Fig. 3 EFFECT OF LAP LENGTH ON SPLICE STRENGTH.

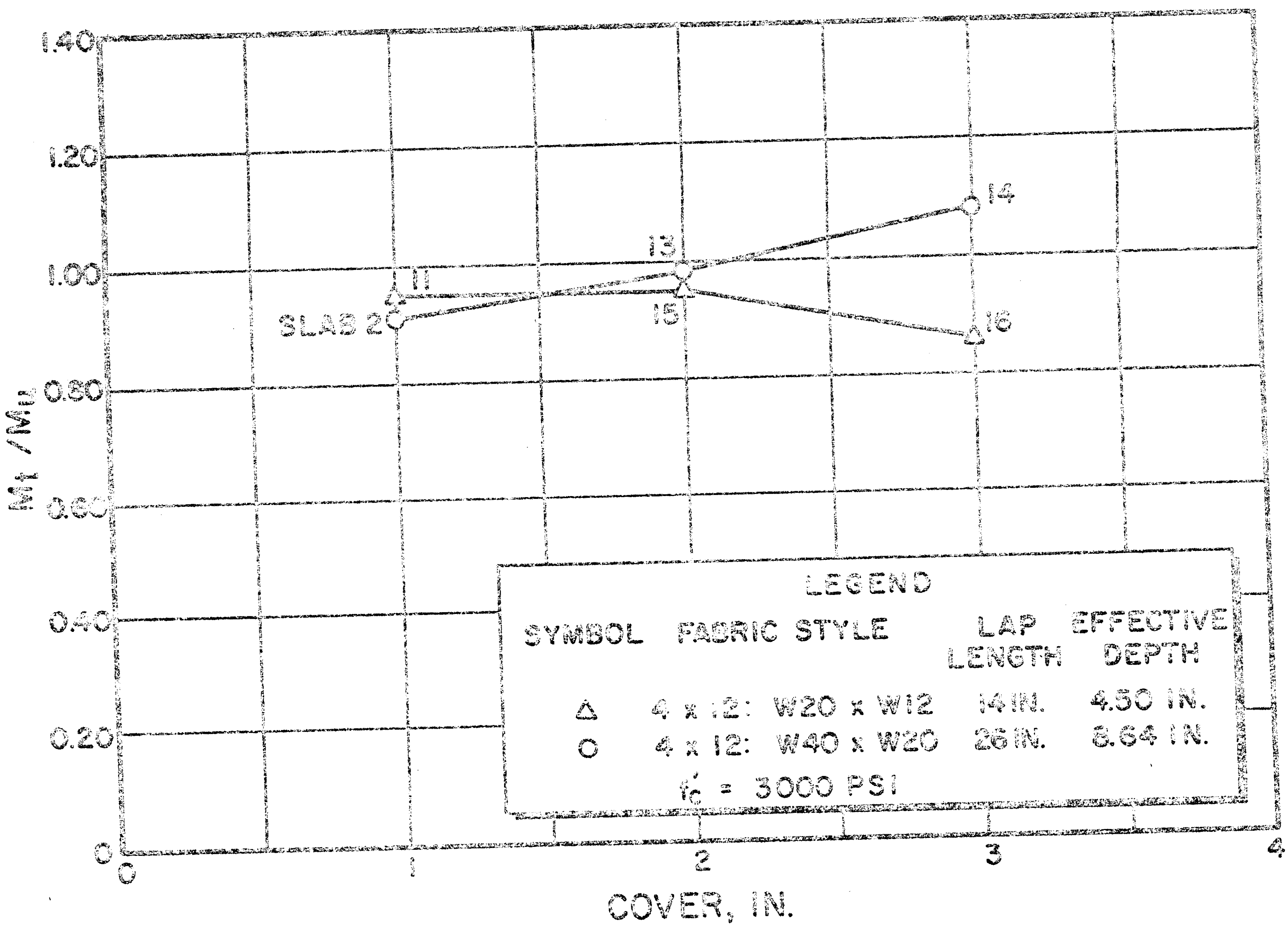


Fig. 4 EFFECT OF COVER ON SPLICE STRENGTH.

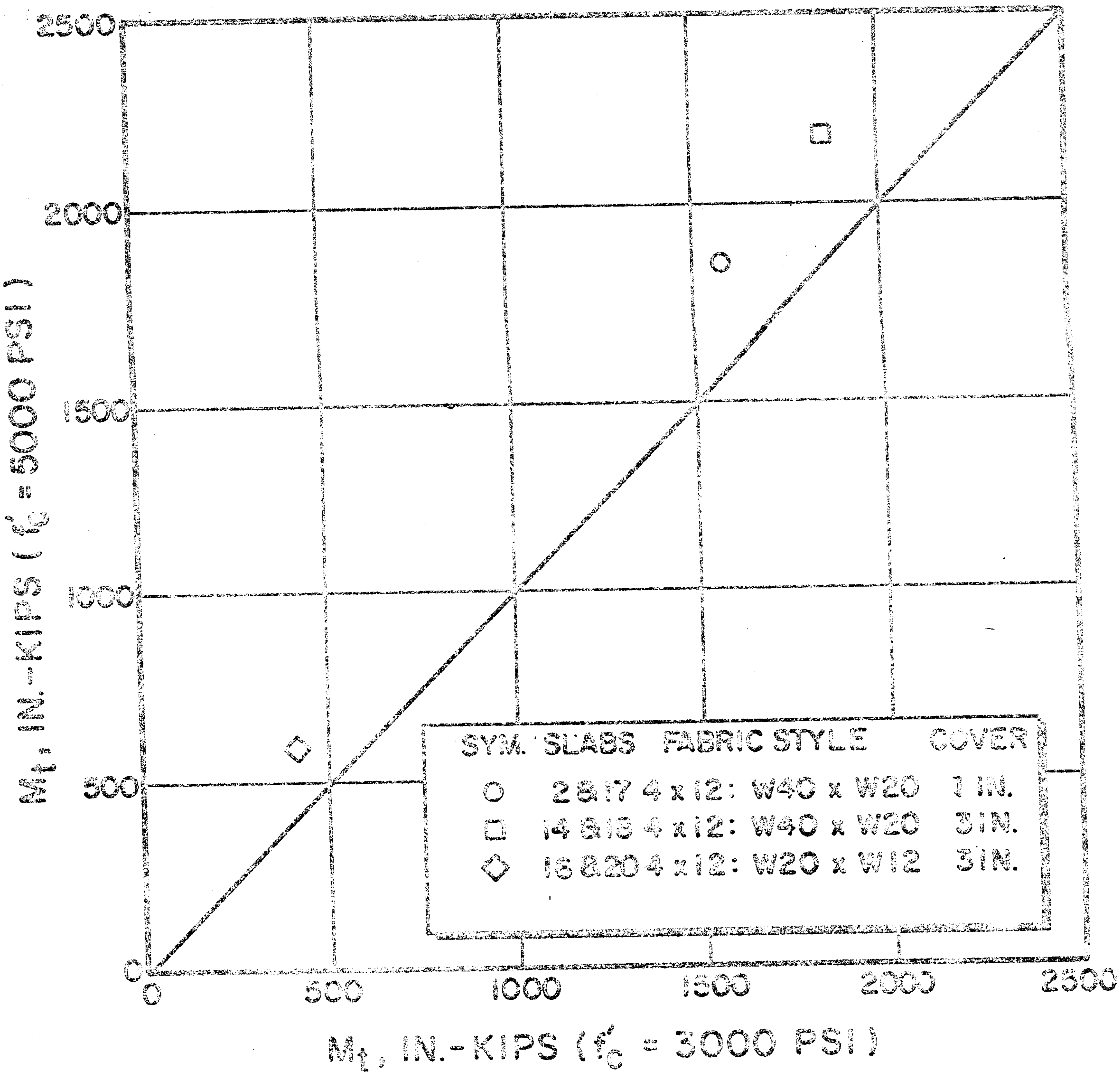


Fig. 5 EFFECT OF CONCRETE STRENGTH ON SPLICE STRENGTH

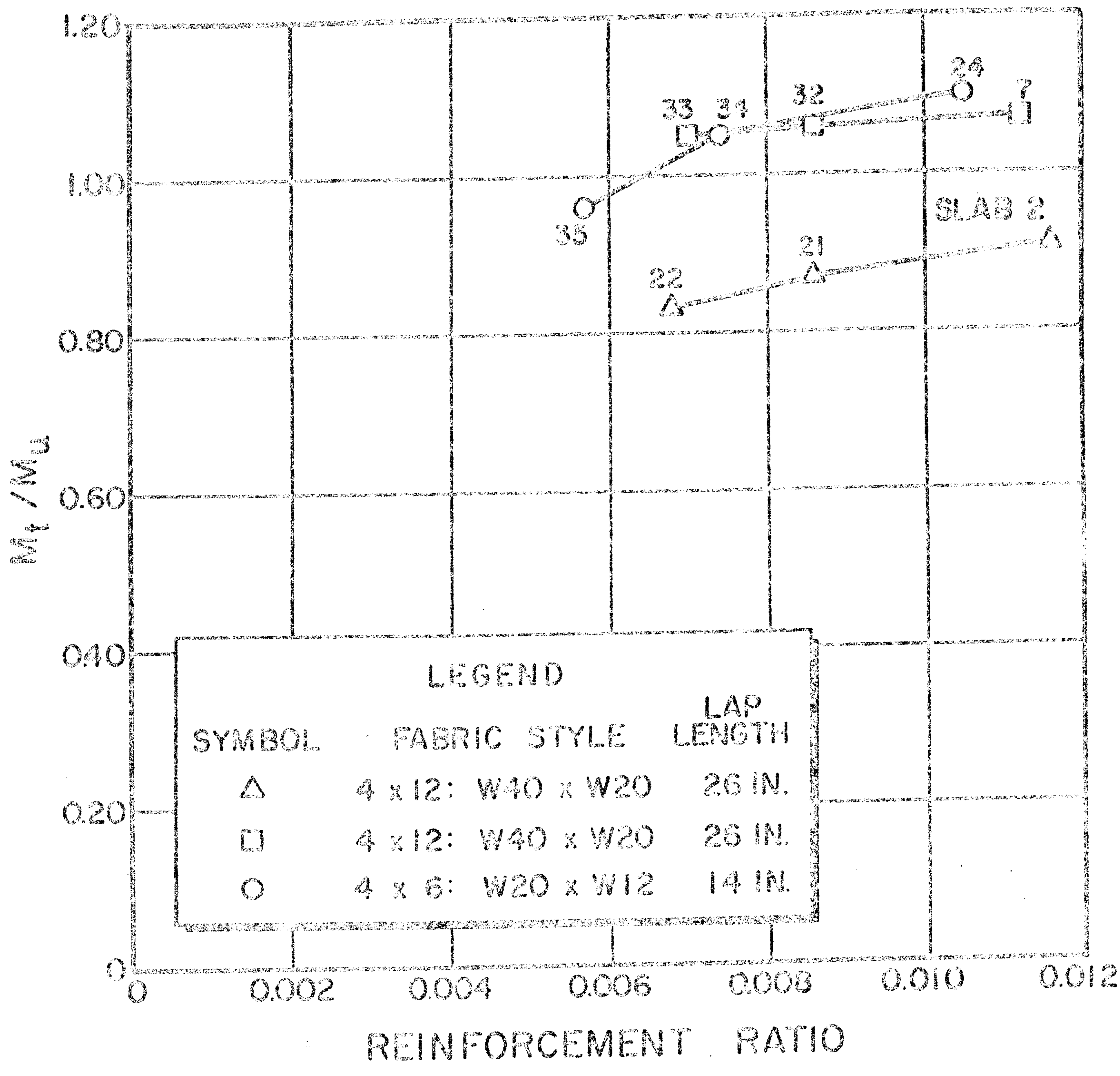


Fig. 6 EFFECT OF REINFORCEMENT RATIO ON SPLICE STRENGTH.

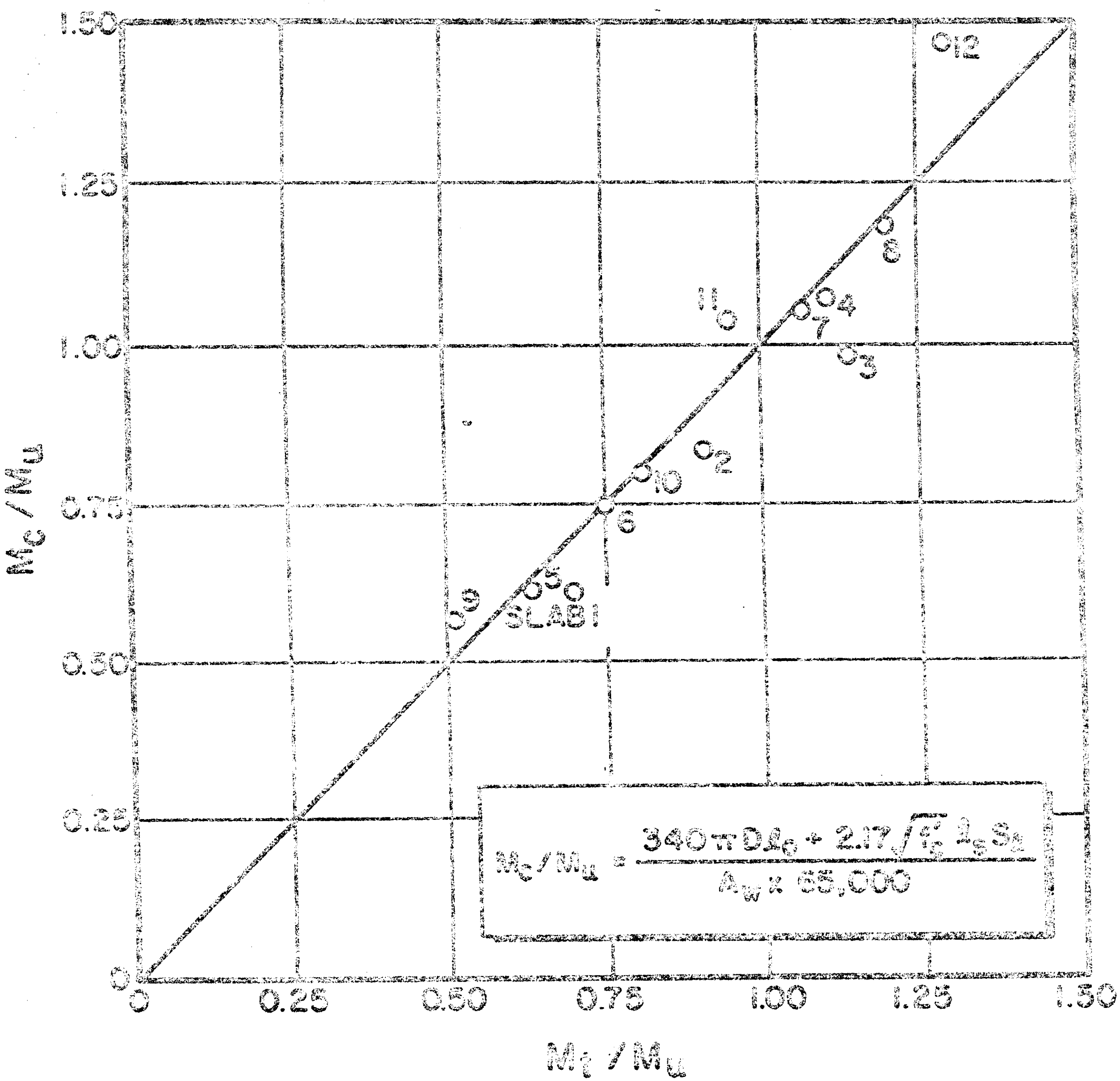


Fig. 7 COMPARISON OF CALCULATED AND MEASURED STRENGTHS.

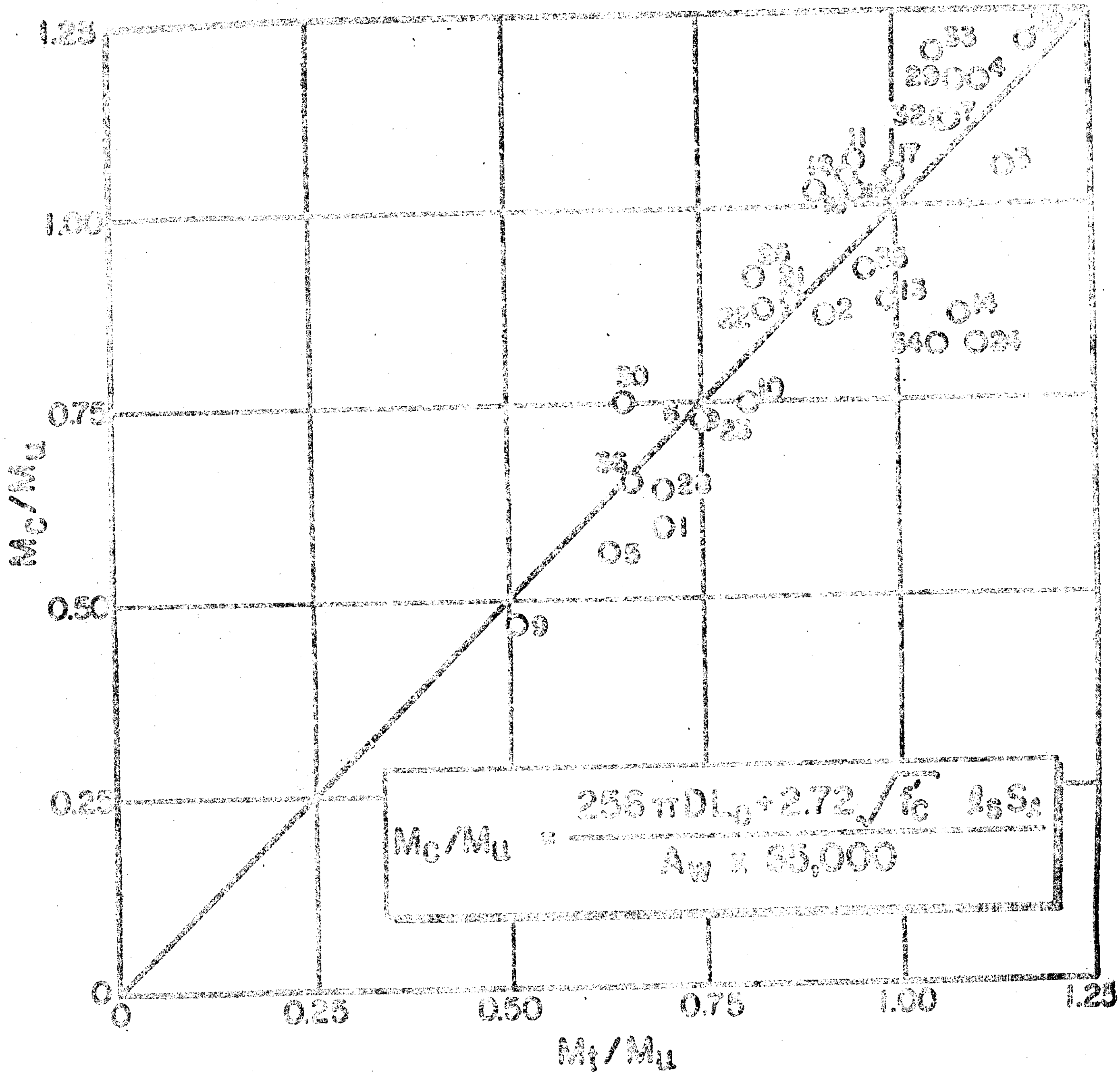


Fig. 8 COMPARISON OF CALCULATED AND MEASURED STRENGTHS.