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Effects of Added Reinforcement in Steel-deck Slabs

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EFFECTS OF ADDED REINFORCEMENT IN STEEL-DECK SLABS

by

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Introduction

The use of cold-formed steel-deck-reinforced floor slabs has increased significantly over the past 10 to 15 years due primarily to several economic advantages including:

- elimination of the need to install and remove formwork;
- ease in handling and placing the steel deck sheets;
- convenience of a working platform prior to casting;
- pre-engineered ducting for electrification, communication, and air distribution;
- a diminished likelihood of construction fires since most wooden formwork is absent;
- a reduction in time of construction since casting of additional floors may proceed without waiting for previously cast floors to gain strength;
- composite steel-deck positive reinforcement for the floor slab; and
- availability for composite action between slab and support beam.

Bottom reinforcement in a floor slab is achieved by a steel deck

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section through various shear connection devices such as rolled embossments, transverse wires, holes, or buttons to give a positive interaction between the steel and the concrete. A typical composite steel deck floor slab system is shown in Fig. 1.

In addition to the steel deck reinforcement, many such floor slabs contain supplementary steel to

- satisfy minimum shrinkage and temperature reinforcement requirements,
- provide transverse reinforcement for concentrated load distribution, or
- reduce crack widths and/or provide negative bending moment reinforcement over interior supports.

This paper will provide results found from tests of five full-scale two-way floor slabs and eight one-way slab elements reinforced with cold-formed steel decking and differing amounts of supplementary reinforcing. These tests were part of an extensive theoretical and experimental research program undertaken at Iowa State University in 1967 under the sponsorship of the American Iron and Steel Institute (AISI) to investigate behavioral characteristics, analysis, and design of steel-deck-reinforced floor slabs. To date, the entire research program has included total of 353 tested specimens as outlined in the table given in Ref. 1.

Description of Two-Way Slab Tests

All five of the full-scale two-way slab tests were supported and tested as shown in Fig. 2. The slabs were simply supported with roller and pin bearing supports on the south and north sides, respectively, and with ball-bearing-ball caster bearing supports on the west and east sides as shown. The first slab tested contained corner restraints that were instrumented to determine vertical uplift reactions of the corners. The remaining slabs did not contain corner restraints, and the corners were free to lift upward.

All slabs had nominal out-to-out plan dimensions of 16 ft by 12 ft (4.88 m by 3.66 m) with the steel deck corrugations paralleling the 12-ft (3.66 m) sides. The design thickness for the first four slabs was established at 4.5 in. (114 mm) and for the fifth slab was 5.5 in. (140 mm). However, the actual thicknesses of each slab deviated somewhat due to variations in deflection under the weight of the wet concrete. The actual thickness was measured at various points throughout each slab, and these values were utilized in the analysis.

Each of the slabs was cast directly on the supports shown in Figure 2. In addition, the slabs were supported by a single line of shoring located at mid-length to the span of the steel deck, i.e. located at approximately six feet (1.83 m) from the east edge.

The five test slabs were composed of steel deck sections obtained from three different manufacturers. The first three slabs had the same type of steel deck section consisting of a nominal 20-gage (0.9 mm) steel thickness. This deck was 1-1/2 in. (39.4 mm) in depth and achieved its composite slab action by means of rolled embossments. The fourth slab consisted of a 24-gage (0.6 mm) steel deck, which was nominally 1-5/16 in. (33.5 mm) in depth and provided composite slab action by means of transverse wires spot-welded to the top corrugations. The fifth slab consisted of a nominal 20-gage (0.9 mm), 3 in. (76.2 mm) deep deck section that achieved composite action by means of embossments.

Table 1 provides a data summary of significant material properties including supplementary reinforcing for each slab. Concrete and steel reinforcing strengths are provided in this table along with the average measured out-to-out slab thicknesses, steel deck depths and cross-sectional areas, and corner support conditions. The tabulated cross-sectional area and centroid of the steel deck are for a section perpendicular to the deck corrugations. The concrete compressive strength is the average strength obtained from 6 in. by 12 in. (152 mm by 305 mm) cylinder tests at the same age as the test slabs. Steel strengths were obtained from coupons cut from steel deck sheets contained in the same shipment as those used in the test slabs.

Three test slabs had supplementary reinforcement in the form of welded wire fabric (WWF). Slab 1 contained 6 x 6 -D6 x D6 WWF and Slab 2 contained 6 x 12 -D0 x D4 WWF each placed directly on top of the steel decking. Slab 5 contained 6 x 6 -D10 x D10 WWF located approximately 1 in. (25 mm) from the top of the slab. Slabs 3 and 4 contained no welded wire fabric, but Slab 4 contained supplementary reinforcing transverse to the deck corrugations in the form of deformed wire spaced 3 in. (76 mm) apart and spot-welded to the top corrugations.

Instrumentation for the slab tests consisted primarily of the following: 1) Electrical strain gage rosettes and single strain gages placed at an average of 17 locations on the top surface of the concrete and at corresponding locations on the steel decking; 2) Vertical load transducers (roller and ball-bearing-ball caster types - see Fig. 2) to determine the vertical reaction distributions; 3) Corner tie-down transducers on Slab 1 only to measure up-lift force at the corners; 4) Mechanical deflection gages for determining deflections at an average of 33 locations; 5) Pressure gages for reading calibrated hydraulic cylinder loads; and 6) Deflectometer indicators or mechanical deflection gages, or both, to measure end-slip at an average of ten locations along the east and west edges of each slab. Additional details of the instrumentation are given in Ref. 2.

Loading for Slab 1 was applied, in increments, from zero to ultimate. A time period of about 10 min to 15 min was required after application of each increment for instrumentation readings. The other four slabs were loaded incrementally from zero to a designated cycling load amounting to about 64% of ultimate load. At this stage, unloading and reloading to the cycling load occurred ten times. After cycling, a final loading was made from zero to ultimate failure of the slab. The increments generally consisted of 4 kips to 8 kips (17.8 KN to 35.6 KN) of total load applied over a time interval of approximately 2 min.

Description of One-Way Slab Elements

All eight of the one-way slab element tests were simply supported and tested as shown in Fig. 3. Six of the slab elements contained nominal 20-gage (0.9 mm) 1-1/2 in. (39.4 mm) deep steel deck reinforcement like that used in two-way Slab 1, 2, and 3 (see Table 1) and two contained nominal 20-gage (0.9 mm) 3 in. (76.2 mm) deep deck reinforcement like that used in two-way Slab 5. Two of the first six contained no welded wire fabric, two contained 6 x 6 -D6 x D6 fabric, and two contained 6 x 12 -D0 x D4 fabric. The welded wire fabric for the initial six specimens was placed directly on top of the decking and oriented to correspond to the full-size companion two-way slabs containing the same reinforcement. The overall nominal size of these six one-way slab elements was 6 ft in length by 2 ft in width by 4-1/2 in. in depth.

The final two slab elements were nominally 12 ft by 3 ft by 5-1/2 in. and contained 6 x 6 -D10 x D10 welded wire fabric placed approximately 1 in. (39.4 mm) from the top fiber of concrete. These two specimens were companion to two-way Slab 5. Table 2 gives a summary of the eight slab element tests.

Results From Two-Way Slab Tests

Loads and Primary Variables. Table 3 contains the applied ultimate and cycling loads for each of the five two-way slabs. These loads are tabulated on the basis of amount of applied load at each of the four concentrated load points and include the weight of the loading apparatus, but do not include the slab dead weight. The equivalent uniform loads were obtained by simply dividing the total load placed at the four load points by the actual area included between the reactive supports.

The test results shown in Table 3 indicate the value of supplementary reinforcing. Note that Slabs 2 and 4, with the greater amount of additional supplementary reinforcing transverse to the corrugations, sustained the greater ultimate loads. This result is due to the supplementary reinforcing transverse to the corrugations located below the neutral axis, allowing a better distribution of the positive moments transverse to the deck corrugations in the central region of the slab. Thus, Slab 3, which had no supplementary reinforcing transverse to the corrugations, sustained the lowest ultimate load. A comparison of Slab 3 vs. Slab 2 indicates an increase in ultimate load of 78%.

The ultimate load of Slab 1 probably would have been lower if subjected to the same conditions as Slabs 2 and 3. That is, Slab 1 was not cycled ten times, thus allowing a somewhat higher ultimate load to be applied. In addition, Slab 1 had its corners restrained from uplift by corner tie-downs that were not present on the other slabs. The presence of the corner restraints provided an increased stiffness to Slab 1.

Mode of Failure. In conjunction with the ultimate loads shown in Table 3, it is important to note the type of failure that occurred. All five slabs failed ultimately by a shear-bond type of failure. This failure was characterized by a horizontal end slippage accompanied by the development of diagonal cracks over the central regions on the vertical faces at the east and west sides of the slabs. This end slippage was similar to that experienced in one-way slab element tests. No end slip was observed along the north and south edges.

Of particular interest is a comparison of end-slip behavior for the one-way slab elements to that for the two-way slabs having the same deck type and supplementary reinforcing. The first observable end slip for the one-way specimens occurred at the ultimate load, whereas initial slip was observed in the central regions of the east and west sides of all five two-way slabs. This behavioral difference can be attributed to the presence of the neighboring elements of the slabs in two-way action helping to restrain the slab from failure.

The approximate loads at which first observable slip occurred for two-way Slabs 1-5 are given in Table 3 along with a percent comparing the load at first end-slip to the ultimate load. This percent indicates that those slabs with higher amounts of supplementary reinforcing were able to sustain an ultimate load significantly higher than those slabs with a lower or no amount of added reinforcing. The supplementary reinforcing in Slab 5 was not on top of the deck and consequently did not contribute as much to the increased ultimate after first slip. Further details regarding end-slip behavior (e.g. displacement distribution along the sides) can be seen in Refs. 2 and 3.

Effective Width Behavior. The cracking of the slabs on the top surface, given in Fig. 4, was commensurate with the type of loading applied. That is, the areas included by the four concentrated loads displaced downward and eventually broke away from the outer regions of the longer 'irection of the slabs, leaving a central region of each slab as the effective load-carrying element. This effective load-carrying width, based on an average distance between major crack lines near ultimate load, is shown by the L" distance in Fig. 4. The crack numbers in the figure indicate the order of occurrence.

A comparison of the L" distance found from top surface cracking and the amount of supplementary reinforcing indicated that the supplementary steel aided in increasing the effective load-carrying width (L"). This behavior resulted directly from the added transverse flexural capacity provided by the supplementary reinforcing in a direction transverse to the steel deck corrugations. Table 4 provides a summary of the computed transverse flexural capacity (as well as the longitudinal flexural capacity in the direction of the deck corrugations), the measured L" distance, and the computed L" distance based upon the mechanism theory provided by a yield-line theoretical analysis. Details of the method of computation of the quantities in Table 4 are given in Ref. 2. The data given in Table 4 indicates that the increase in transverse moment capacity was compatible with a resulting increase in the effective load-carrying width (L") for those slabs having larger amounts of supplementary steel transverse to the steel deck corrugations. Crack patterns obtained on the bottom surface of the concrete after removal of the steel deck indicated the same correlation and are given in Refs. 2 and 3.

Deflection Behavior. General behavior of the two-way slabs during loading can be ascertained from the load vs. deflection diagrams shown in Fig. 5. The deflection relationships pertain to the centerpoint during the final cycle of loading. The deflections measured during the repeated loading of Slabs 2, 3, 4, and 5 are not shown in order to obtain clarity.

Included in Fig. 5 for a reference guide is the deflection associated with 1/180 times the span length (L) in which L is in the direction parallel to the corrugations. As can be seen, all slabs except 3 and 5 exhibited fairly linear load-deflection relationships below the level defined by a deflection of L/180. Slabs 3 and 5, without effective supplementary reinforcing, did show some nonlinear behavior at the L/180 level and did not undergo as much ultimate deflection as did the other slabs.

As can be seen in Fig. 5, Slab 2 with highest amount of WWF reinforcing was capable of sustaining the largest displacement at ultimate load. On the other hand, Slab 3 without any additional steel, indicated the lowest ultimate strength as well as the least ultimate deflection.

Horizontal arrows, associated with each slab, indicate the load at which the first observed crack occurred. As can be seen, the slabs exhibited a stable behavior well beyond the first observable crack. Also, those slabs containing the higher amounts of supplementary reinforcing (Slabs 1, 2, and 4) were able to develop much larger deflections after initial cracking prior to reaching ultimate. Additional behavioral results for the slab tests are given in Refs. 2 and 3.

The effects of the cycling may be seen in Fig. 6 which shows the load-deflection behavior for Slabs 2, 3, and 4 during the initial cycling phases only. As can be seen, Slabs 2 and 4 with the larger amounts of supplementary steel were cycled at a much higher load and sustained a much greater deflection under the repeated loading. The behavior of Slab 5 was similar to that of Slab 3, but was omitted from Fig. 6 for clarity.

The cycling loads were quite high and terms of percentage of ultimate load, they were 60.6, 72.7, 65.3, and 57.4 for Slabs 2-5, respectively. Each test was intended to be cycled at 60% of ultimate, but the cycling load was estimated from behavioral characteristics during loading which explains some of the variances in percentage of cycling load. Slab 3 tended to develop cracks more rapidly during cycling, and was most affected by the repeated loading. This result can probably be attributed to the lack of supplementary steel reinforcement to help keep the slab intact and to aid in the distribution of forces throughout the slab.

Results From One-Way Slab Element Tests

Loads and Failure Mode. The ultimate loads for the eight slab element tests are summarized in Table 5 along with some of the key parameters. All eight specimens failed, via the shear-bond mode. This failure was characterized by a sudden end-slip at the ultimate load, as opposed to the two-way slabs which experienced some slip prior to ultimate. The shear-bond failure mode for one-way elements typically occurs by the formation of a crack at or near one of the load points accompanied by horizontal slip of the concrete over the distance from the crack to the end of the specimen resulting in significant observed end-slip at one end of the specimen. Characteristics surrounding a shear-bond failure and the analysis for one-way slab elements may be found in Refs. 2 and 4-8. The shear-bond failure and end slippage occurred suddenly and simultaneously at the time of reaching the ultimate load with no evidence of slippage prior to ultimate for all eight of the one-way slab elements.

The addition of the supplementary reinforcing did not alter the mode of failure for the one-way tests. That is, the addition of WWF was not sufficient to prevent the horizontal slippage between the concrete and steel interface. However, a comparison of shear loads in Table 5 for the first six specimens indicates an apparently slightly higher ultimate shear for those specimens containing supplementary reinforcing as opposed to those without. The comparison is summarized in Table 6 showing the average increase for the like specimens. As can be seen the addition of WWF placed directly on the deck apparently increases the shear-bond capacity by about 10 or 11%. However, this conclusion requires a look at the shear-bond regression analysis to properly account for the pertinent parameters affecting the strength of such specimens.

Utilizing the shear-bond regression equation and procedures given in Refs. 4, 5, 7, and 8, the following equation was used to determine the computed shear strength, neglecting the addition of the WWF steel.

$$V_u = \frac{bd}{s}\left(\frac{m\rho d}{L'} + k\sqrt{f'_c}\right) \qquad (1)$$

The above equation is simply a formulation of the straight line of the plot of the parameters $\dfrac{V_{ue}s}{bd\sqrt{f'_c}}$ as ordinates versus $\rho d/L'\sqrt{f'_c}$ as abscissas where

V_u = the calculated ultimate shear, lb/ft of width

V_{ue} = the experimental ultimate shear, lb/ft of width

ρ = steel reinforcement ratio, $\rho = A_s/bd$

A_s = cross-sectional area of steel deck, in.^{2}/ft

d = effective depth of slab element measured from top fiber to c.g.s. of deck, inches

b = width of specimen, normally taken as 12 in.

L' = shear span, inches

s = spacing of shear transfer devices, if variable from deck section to section, otherwise $s = 1$, inches

f'_c = compressive strength of concrete

m = slope of straight-line regression

k = intercept of straight-line regression

In order to determine the effects of supplementary reinforcement on the one-way shear-bond strength, a regression analysis was performed on previously tested specimens (Refs. 6, 7, and 9) reinforced with the same deck type having a wider range of parameters. A plot of this regression is shown in Fig. 7. Superimposed on this plot are the points associated with one-way Specimens 1, 3, 5, and 6 which contained WWF. These points fall reasonably close to the regression of those specimens not having supplementary reinforcing, but reflect about the same general increase as shown in Table 6. Thus, the addition of the supplementary reinforcing did not appreciably affect the shear-bond strength by more than about 11% (taken from Table 6).

A look at the effects of the WWF placed in Slabs 7 and 8 can be seen in Fig. 8. The supplementary reinforcing in these two specimens was placed approximately 1 in. from top surface as opposed to Specimens 1, 3, 5, and 6 which had WWF placed directly on the deck. As can be seen in the plot, these two tests compare very closely to the regression line of those specimens not containing WWF. This result is due probably to the location of the supplementary steel, i.e., not at the interface surface where shear-bond slippage occurs. Thus, it appears based on these two tests that there is not any appreciable increase in strength when supplementary reinforcing is placed in the top portion of the specimen.

These conclusions regarding the effects of WWF on the shear-bond strength seem reasonable; however, they are based on a limited number of preliminary tests. Perhaps more tests would verify these results over a wider range of parameters. For simplicity, many steel-deck-reinforced slab designs are based upon one-way action where only uniform loads are involved. Thus, the 10 to 11% of added shear-bond strength in one-way slabs is generally not enough to consider, particularly if the WWF is not placed directly on the steel deck. However, for slabs where concentrated loads are involved, the distribution of forces transverse to the corrugations is very important and the benefits of supplementary reinforcing should be considered.

Conclusions

The test results for five two-way slabs and eight one-way slab element specimens provided the following conclusions regarding the effects of supplementary reinforcing steel in steel-deck-reinforced slabs.

1. Two-way slabs containing supplementary reinforcing placed directly on top of the steel deck were found to sustain

significantly greater ultimate loads (e.g., 78%).

2. Supplementary reinforcing was found to be beneficial in aiding in distributing forces in a direction transverse to the steel deck corrugations for two-way slabs subjected to concentrated loads, i.e. the supplementary steel provided for a wider effective load-carrying width.
3. End-slip for the two-way slabs occurred prior to ultimate, whereas first observable slip for the one-way slab elements occurred simultaneously upon reaching the ultimate load.
4. The mode of failure was unaltered by the addition of supplementary reinforcing steel for both the two-way and one-way specimens tested.
5. Two-way slabs containing higher amounts of supplementary reinforcing were capable of developing larger displacements at ultimate load and larger deflections after initial cracking prior to reaching ultimate.
6. The addition of supplementary reinforcing in the form of WWF placed directly on the steel deck did not appreciably affect the one-way shear-bond strength by more than 11%.
7. The addition of supplementary reinforcing placed in the top portion of a slab element did not show any appreciable effect on the one-way shear-bond strength.

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Appendix II - Notations

A_s = cross-sectional area of steel deck, in.^{2}/ft

b = width of specimen, normally taken as 12 in.

d = effective depth of slab element measured from top fiber

f'_c = compressive strength of concrete

k = intercept of straight-line regression

L = span length, in the direction parallel to the corrugations

L' = shear span, inches

L'' = effective load-carrying width

m = slope of straight-line regression

s = spacing of shear transfer devices, if variable from deck section to section, otherwise s = 1, inches

V_u = the calculated ultimate shear, lb/ft of width

V_{ue} = the experimental ultimate shear, lb/ft of width

ρ = steel reinforcement ratio, $\rho = A_s/bd$

Table 1. Summary of Significant Material Properties for Two-Way Slab Specimens

Item (1)	Slab 1 (2)	Slab 2 (3)	Slab 3 (4)	Slab 4 (5)	Slab 5 (6)
(a) Concrete					
Concrete compressive strength, f'_c, in pounds per square inch	4,160	3,538	3,951	3,835	4,300
(b) Slab Thickness and Corner Support					
Average out-to-out thickness, in inches	4.83	4.62	4.63	4.68	5.44
Corner support condition	Restrained	Free	Free	Free	Free
(c) Steel Deck Properties					
Cross-sectional area, in square inches per foot	0.625	0.625	0.625	0.376	0.575
Deck depth, in inches	1.55	1.55	1.55	1.32	3.00
Steel thickness, in inches	0.0369	0.0369	0.0369	0.0252	0.0347
Centroid (from bottom) of steel cross section, in inches	0.63	0.63	0.63	0.665	1.504
Yield point or strength (at 0.5%), in kips per square inch	42.2	42.2	42.2	101.6	49.4
(d) Supplementary Reinforcing (WWF or Transverse Wires)					
Type	6 x 6-D6 x D6	6 x 12-D0 x D4	None	T-wires	6 x 6-D10 x D10
Position	on deck	on deck	--	attached to deck	one inch from top of slab
Area parallel to deck corrugations, in square inches per foot	0.057	0.034	None	None	0.0282
Area transverse to deck corrugations, in square inches per foot	0.057	0.144	None	0.150	0.0282
Yield strength (at 0.5%), in kips per square inch	79.0	82.6(No.0 gage) 84.6(No.4 gage)	None	92.1	119.4

Note: 1 psi = 6.9KN/m^2; 1 in. = 25.4 mm; 1 sq in./ft = 21.15 cm^2/m; 1 ksi = 6.9MN/m^2.

Table 2. Summary of Properties of Slab Element Specimens

Slab Element No. (1)	Concrete Compressive Strength, f'_c, in pounds per square inch (2)	Supplementary Reinforcing (3)	Steel Deck and WWF Reinforcing Properties Same as Slab No. (See Table 1)[b] (4)	Position of WWF (5)
1	4036	6 x 12 - D0 x D4 WWF[a]	2	on deck
2	4036	None	1, 2, & 3	--
3	4036	6 x 6 - D6 x D6 WWF	1	on deck
4	4036	None	1, 2, & 3	--
5	4036	6 x 12 - D0 x D4 WWF[a]	2	on deck
6	4036	6 x 6 - D6 x D6 WWF	1	on deck
7	4419	6 x 6 - D10 x D10 WWF	5	1 in. from top of concrete
8	4419	6 x 6 - D10 x D10 WWF	5	1 in. from top of concrete

[a]The number 4 gage wire was placed parallel to the corrugation.

[b]No slab elements were companion to Slab 4 since there was no supplementary reinforcing parallel to the deck corrugations in the two-way slab.

Table 3. Load Results for Five Full-Scale Slab Tests

Parameter (1)	Slab 1 (2)	Slab 2 (3)	Slab 3 (4)	Slab 4 (5)	Slab 5 (6)
Cycling Load, in kips per load point	None	9.4	6.4	9.4	5.4
Ultimate Load, P_u, in kips per load point	13.7	15.7	8.8	14.4	9.4
Equivalent ultimate uniform load, in pounds per square foot	305	345	196	321	209
Load at first observable end-slip, kips per load point	11.4	9.4	7.9	7.4	8.8
Percent of P_u for first end-slip	83	61	90	51	94

Note: 1 kip = 4.45 KN; 1 psf = 47.9 N/m^2.

Table 4. Flexural Capacities and Effective Widths of Two-Way Slabs

Slab No. (1)	Longitudinal moment (ft.-kip/ft.) (2)	Transverse moment (ft.-kip/ft.) (3)	Computed Effective width (L") ft. (4)	Measured Effective width (L") from Fig. 4, ft. (5)
1	9.55	1.16	8.4	8.1
2	8.62	2.73	10.1	9.8
3	8.18	0.80	8.3	8.2
4	10.68	2.40	9.4	9.0
5	8.69	0.55	7.4	7.7

Note: 1 ft.kip/ft. = 4.45 m-KN/m; 1 ft. = 0.305 m.

Table 5. Results of One-Way Slab Element Tests

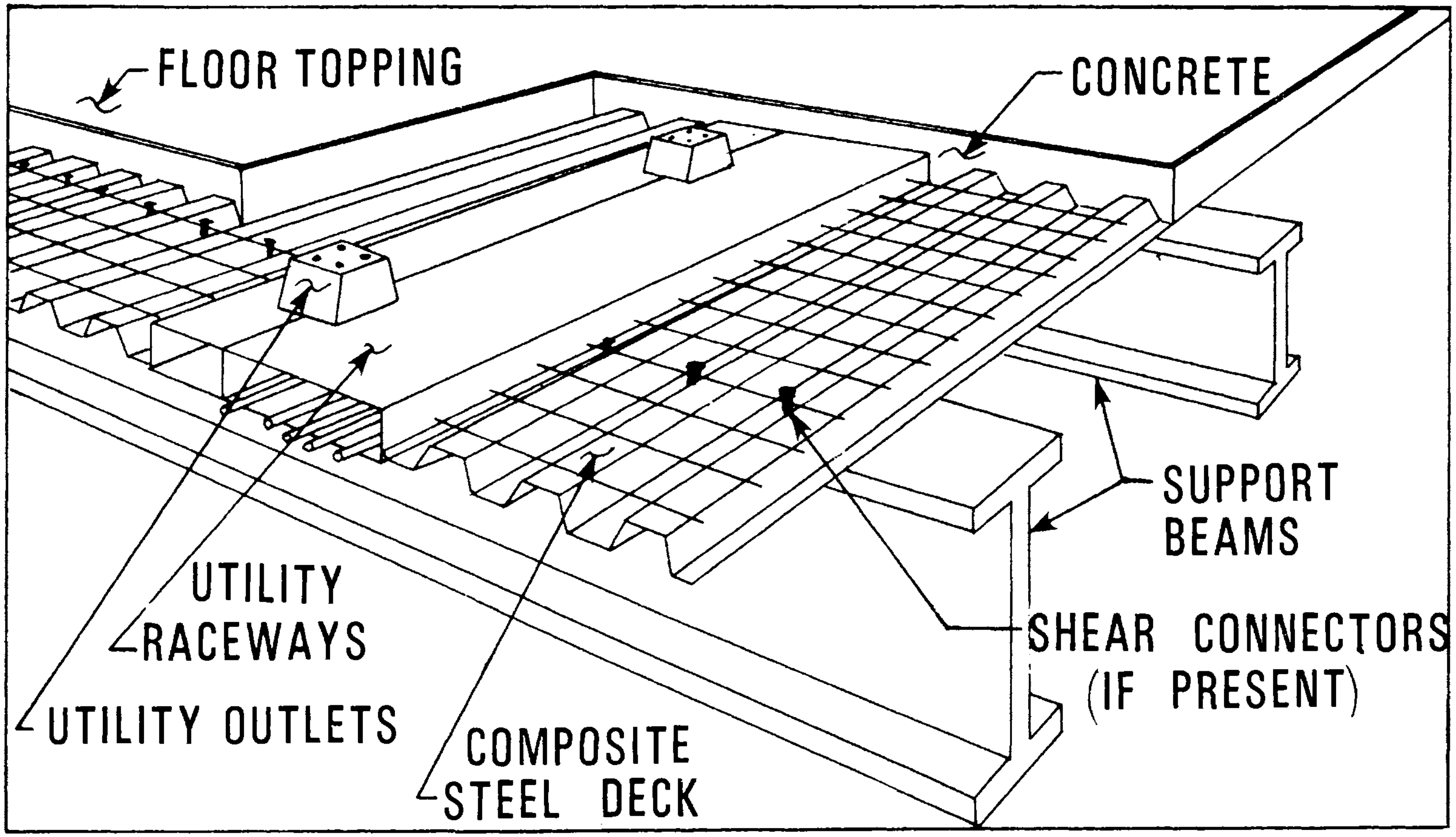
Slab element No. (1)	Span length, L in. (2)	Shear span, L', in. (3)	Total applied shear, V_{ue} (kips/ft.) (4)	Area of steel decking, A_s (in.^{2}/ft.) (5)	Area of supplementary steel parallel to length, A_s, (in.^{2}/ft.) (6)	Depth to c.g.s. of deck (in.) (7)	Depth to supplementary steel parallel to length (in.) (8)
1	68	24	2.73	0.625	0.039	4.07	3.66
2	68	24	2.58	0.625	0	4.15	--
3	68	24	3.03	0.625	0.057	4.07	3.78
4	68	24	2.58	0.625	0	4.27	--
5	68	24	2.95	0.625	0.039	4.17	3.76
6	68	24	2.70	0.625	0.057	4.14	3.85
7	140	45.5	1.57	0.575	0.0282	4.36	1.0
8	140	45.5	1.54	0.575	0.0282	4.12	1.0

Note: 1 in.^{2}/ft. = 21.15 cm^2/m; 1 kip/ft. = 0.407 N/m; 1 in. = 2.54 cm.

Table 6. Experimental Effects of Slab Elements Containing WWF

Average of specimen No. (1)	Area of WWF parallel to length, A_s (in^2/ft.) (2)	Average total applied shear load, kips/ft.	% increase of specimens with WWF over those without
2 and 4	0	2.58	
1 and 5	0.039	2.84	10.08
3 and 6	0.057	2.87	11.05
		Average % Increase	10.57

Note: 1 in.^{2}/ft. = 21.15 cm^2/m; 1 kip/ft. = 0.407 N/m.



TYPICAL STEEL-DECK FLOOR CONSTRUCTION

Figure 1. Typical composite floor construction utilizing cold-formed steel decking.

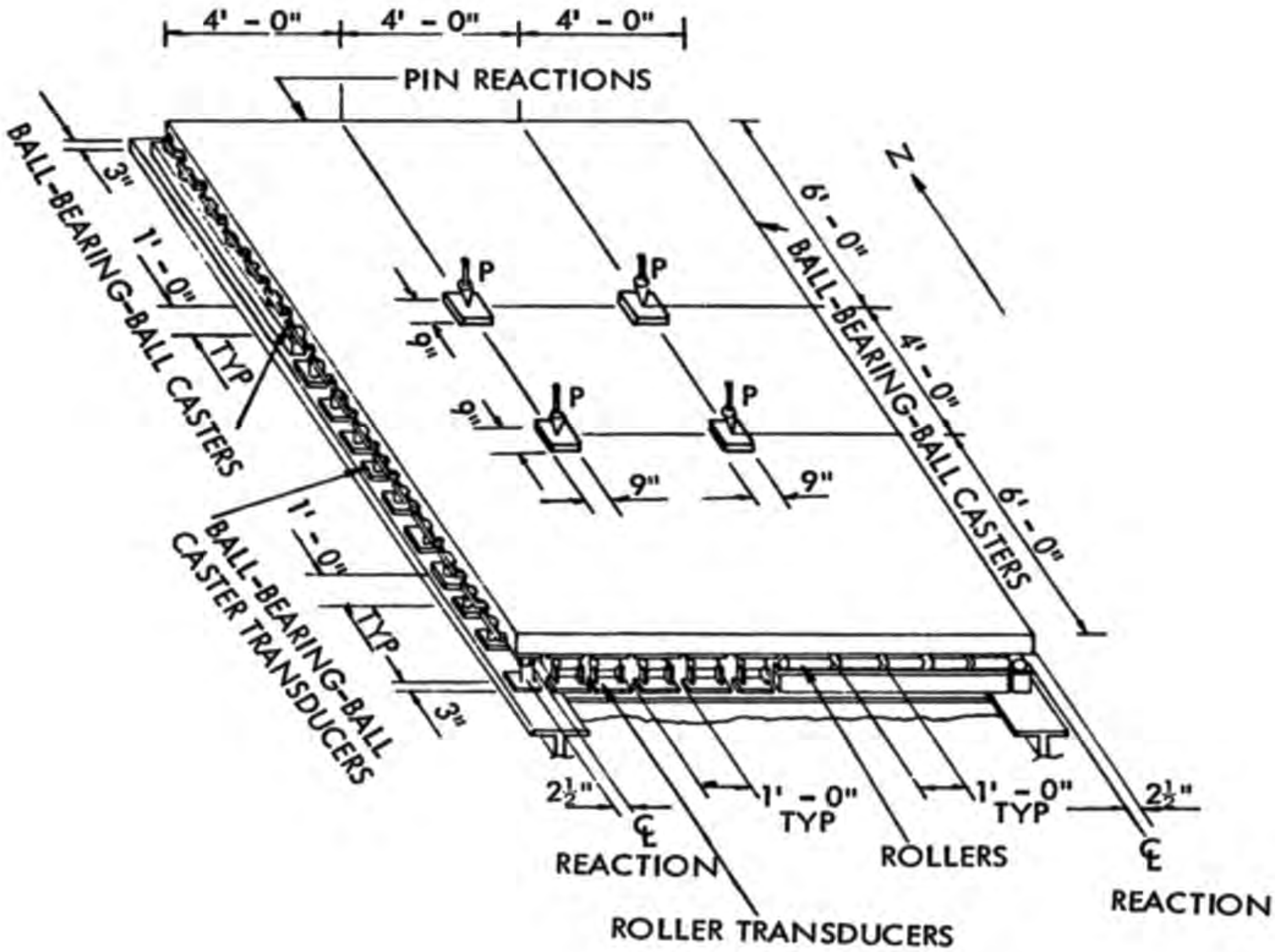


Figure 2. General test configuration for two-way full-scale slabs.

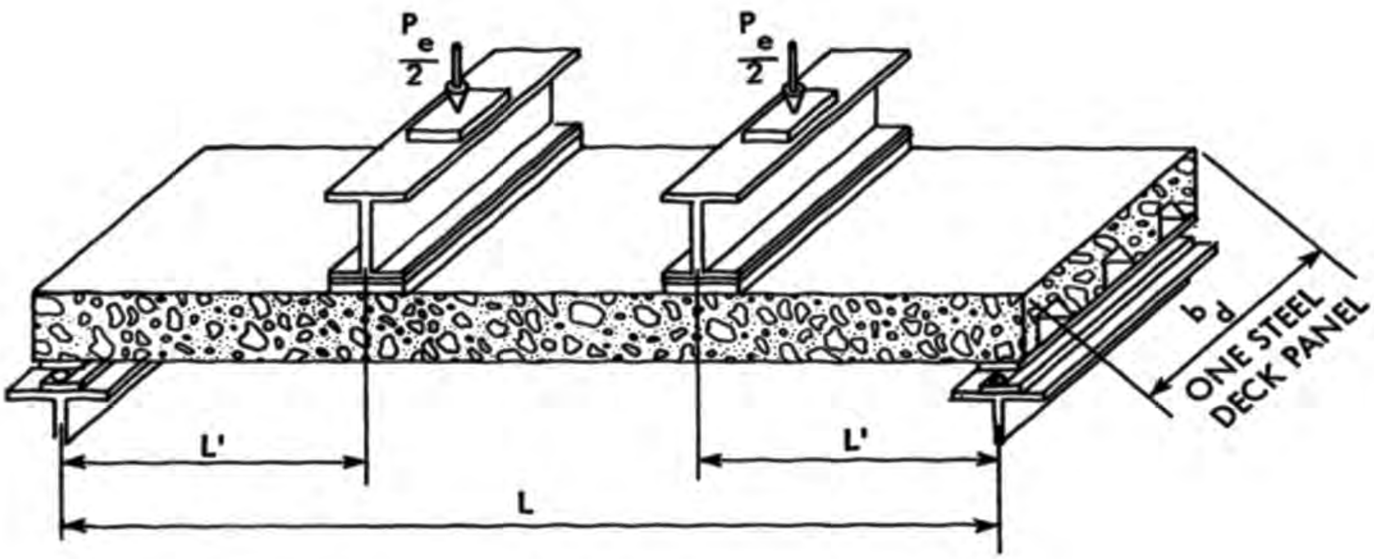


Figure 3. Typical arrangement for testing one-way slab elements.

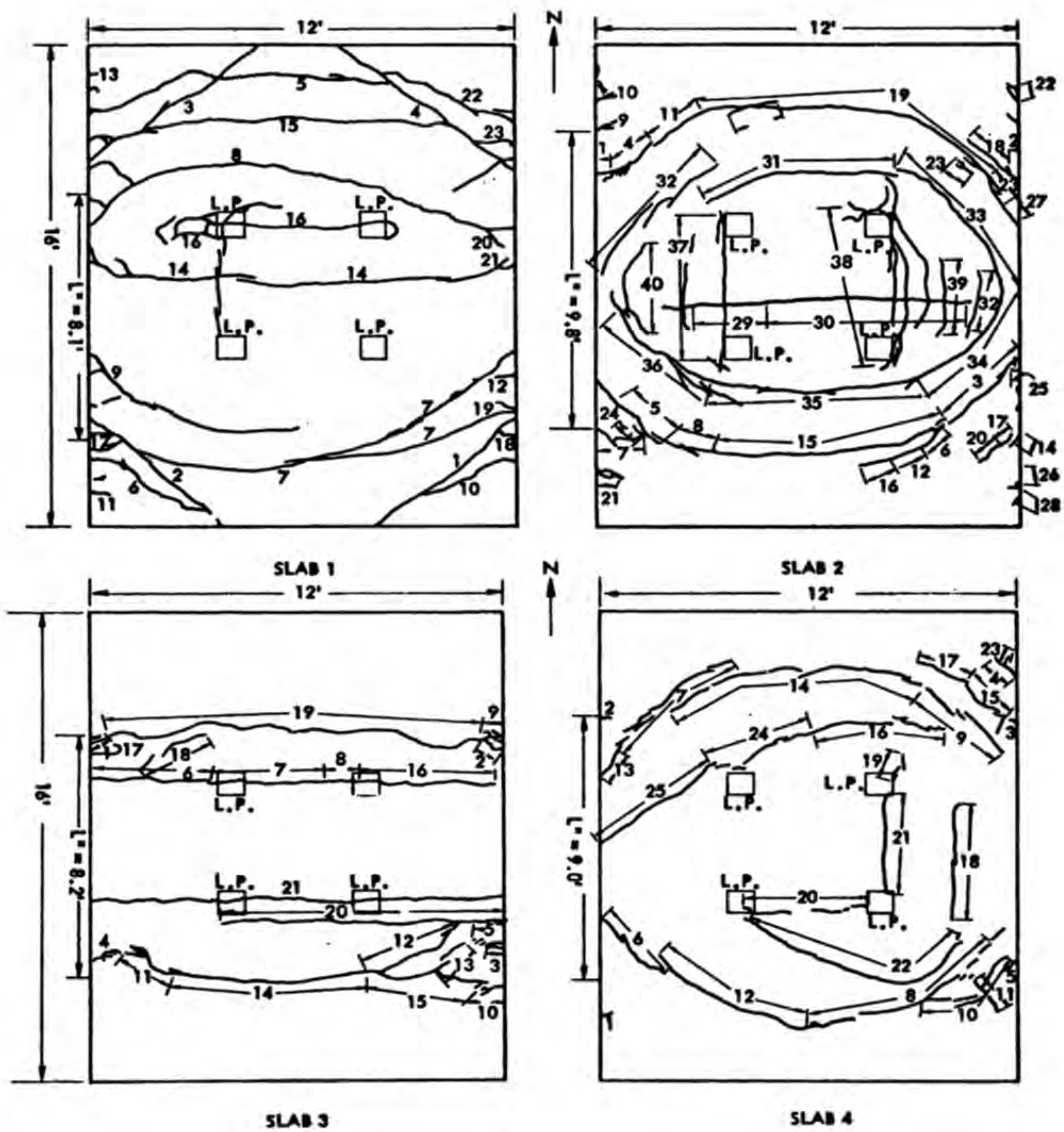
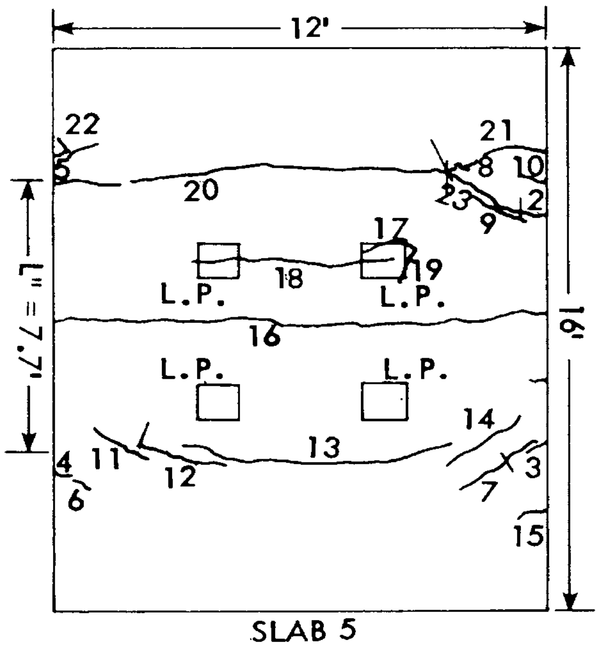


Figure 4. Crack patterns on top surface of each slab test.



NOTES:

1. NUMBERS INDICATE APPROXIMATE ORDER OF CRACK OCCURRENCE.

2. DIAGONAL CORNER CRACKS EXIST ONLY FOR SLAB 1 DUE TO PRESENCE OF CORNER TIE DOWNS.

3. THE L" LENGTHS SHOWN ARE AVERAGE MEASURED VALUES FOR THE CRACK MECHANISM OF EACH SLAB.

Figure 4. (continued)

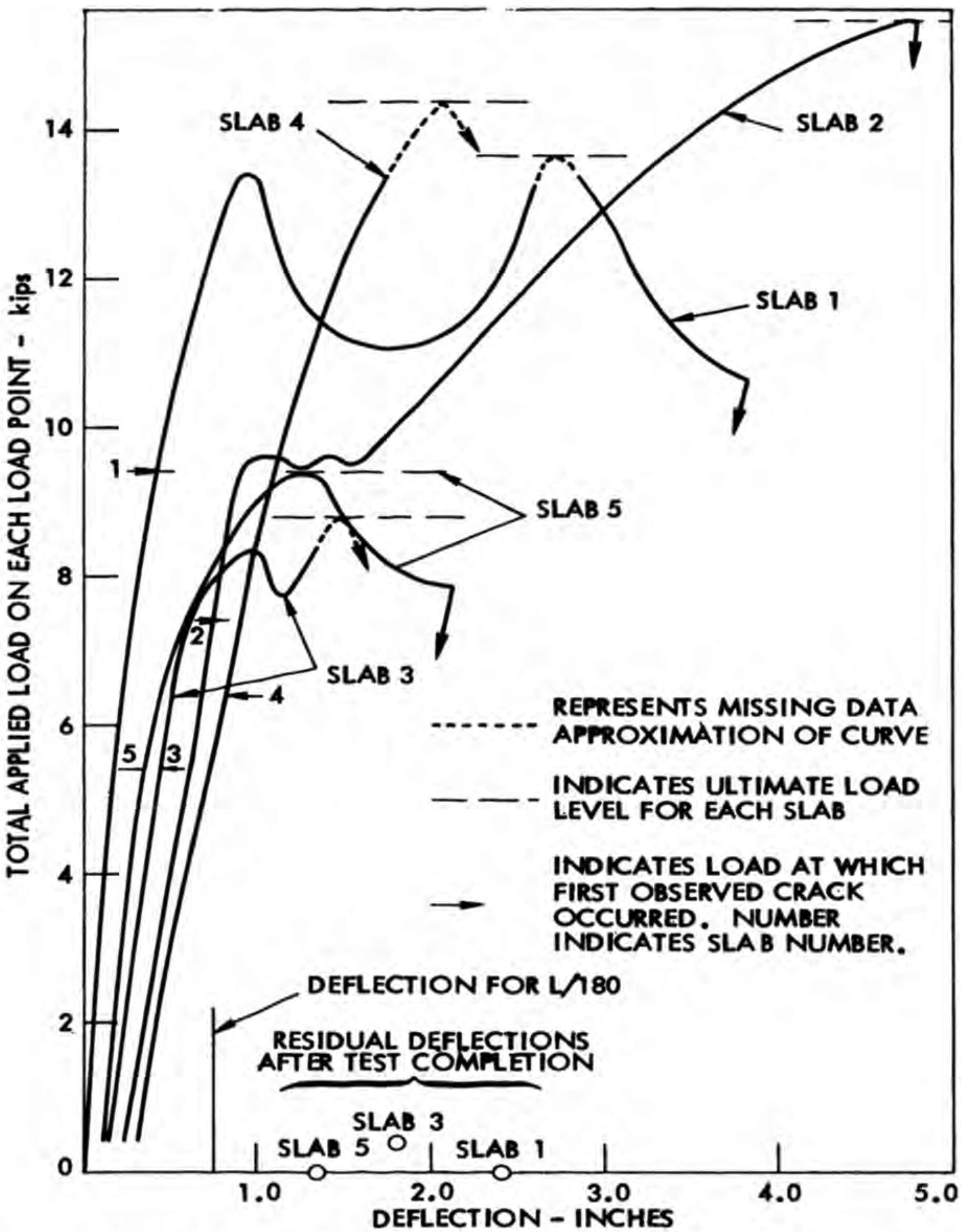


Figure 5. Load versus centerpoint deflection for entire final load cycle. (1 in. = 25.4 mm; 1 kip = 4.45 KN)

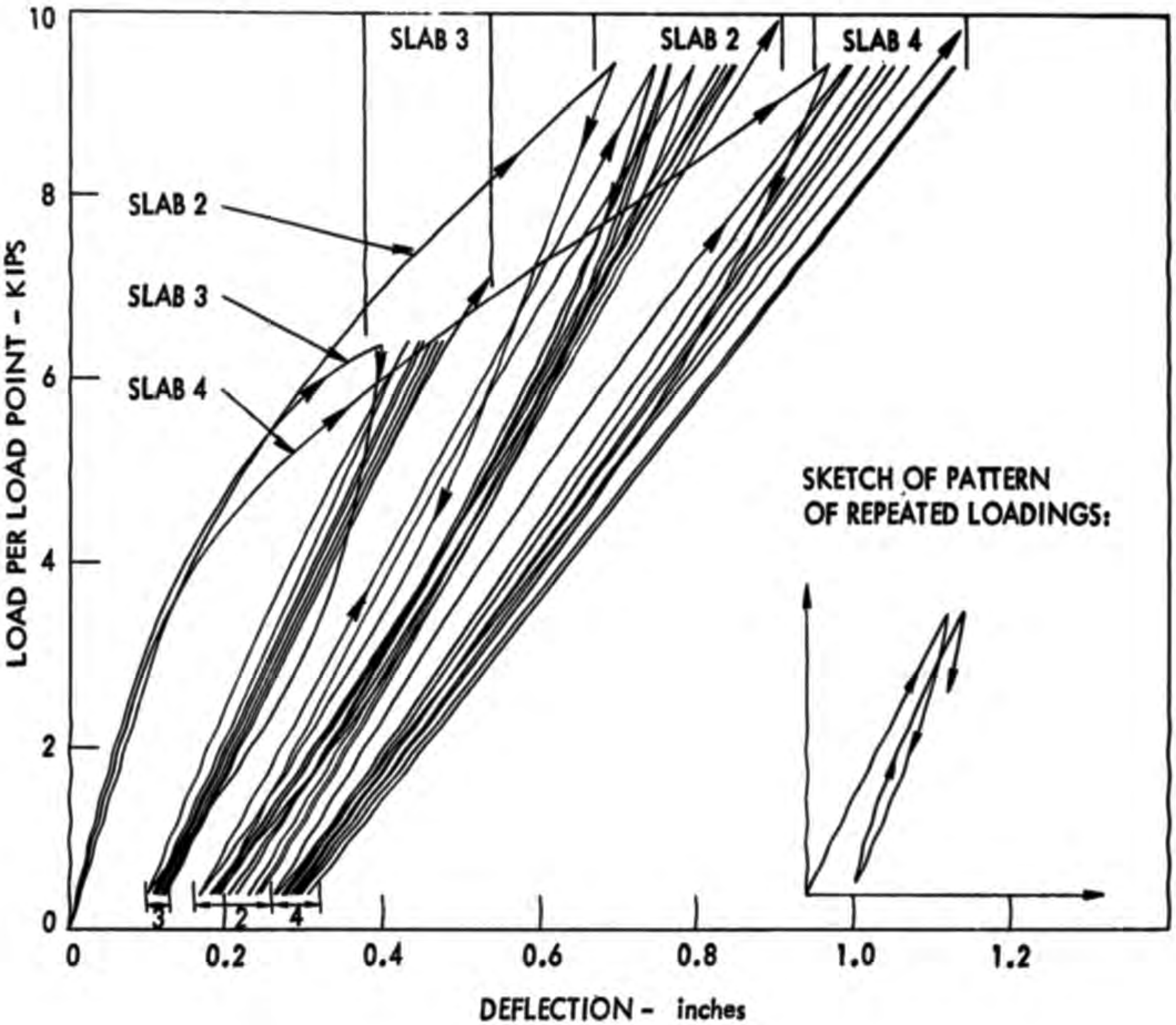


Figure 6. Effect of load cycling on load-deflection behavior for Slabs 2, 3, and 4.

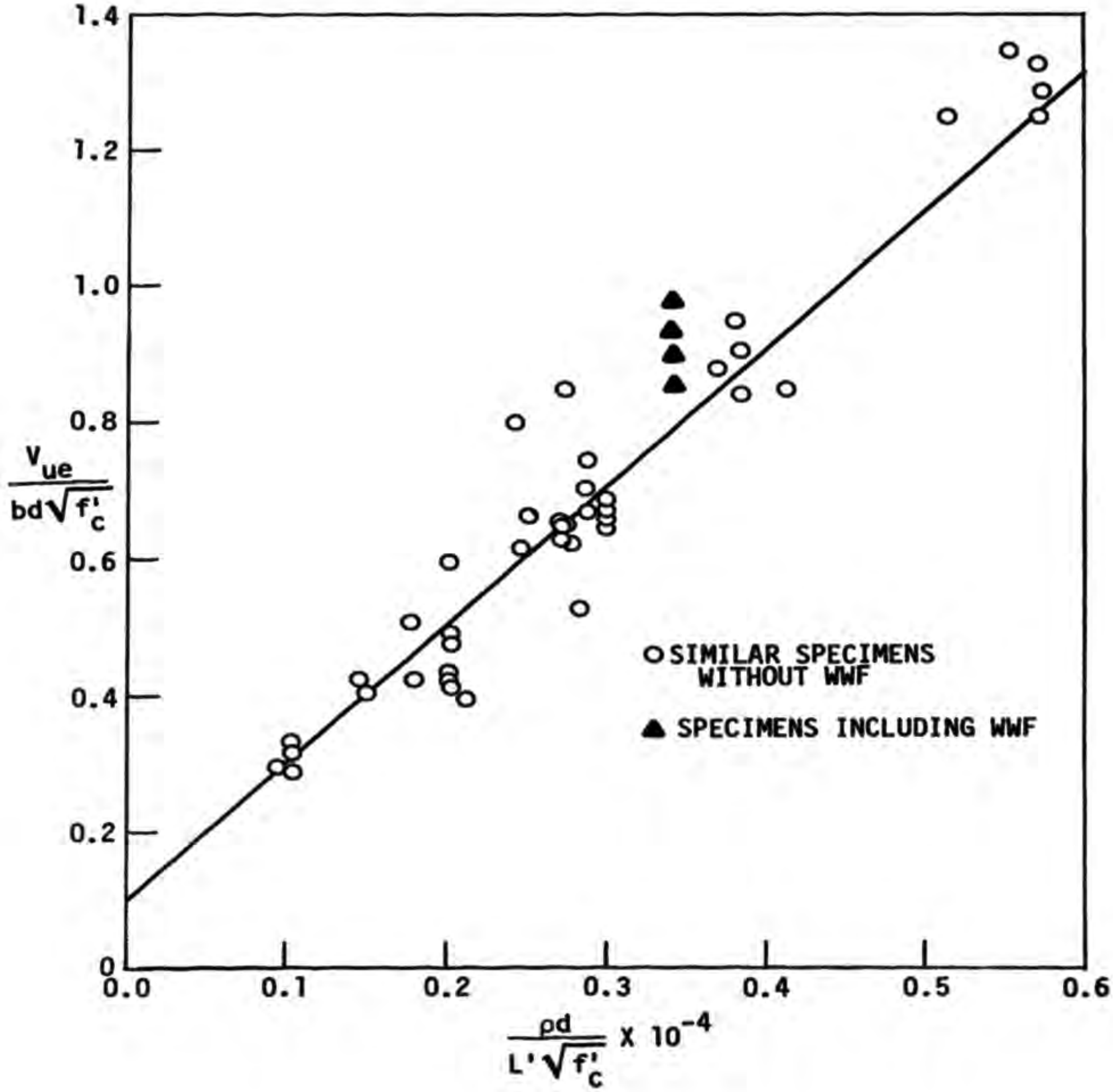


Figure 7. Plot of shear-bond strength of Slab Elements 1, 3, 5, and 6 containing WWF compared to those without WWF.

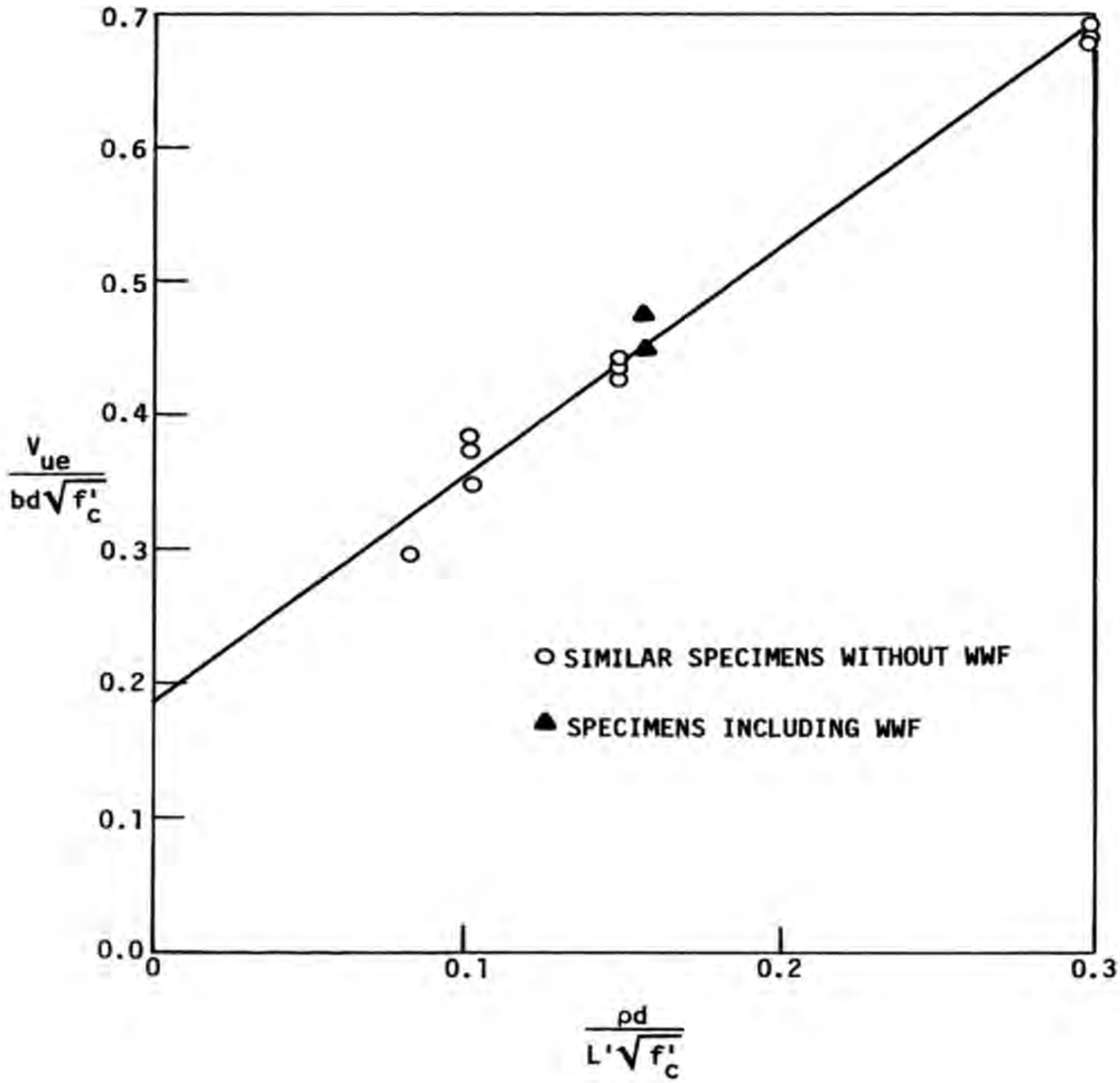


Figure 8. Plot of Slab Elements 7 and 8 containing WWF compared to those without WWF.