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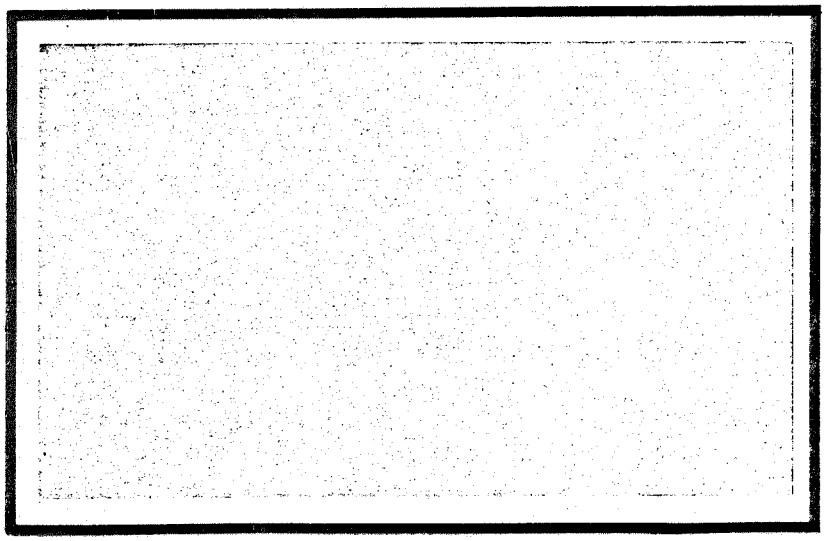

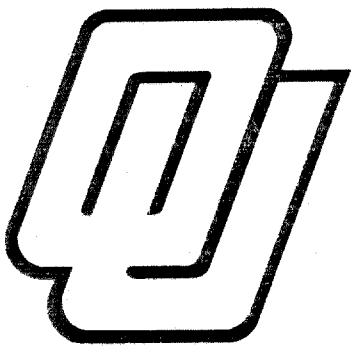

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VI . 2.1.8

Research Report
HILTI HVB 105 SHEAR CONNECTOR PUSH-OUT TESTS

by

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Sponsored by

HILTI, Incorporated
Tulsa, Oklahoma

Report No. FSEL/HILTI 86-01

March 1986

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CHAPTER I

INTRODUCTION

A limited research program to study the strength and ductility characteristics of the HILTI HVB 105 shear connector was conducted at the Fears Structural Engineering Laboratory, University of Oklahoma, under the sponsorship of HILTI Incorporated. The purpose of this research was to compare the connector strength and relative slip performance of push-out specimens using HILTI HVB 105 shear connectors and the more common welded stud shear connectors. In addition, the results of this testing program were compared to results from two European testing programs.

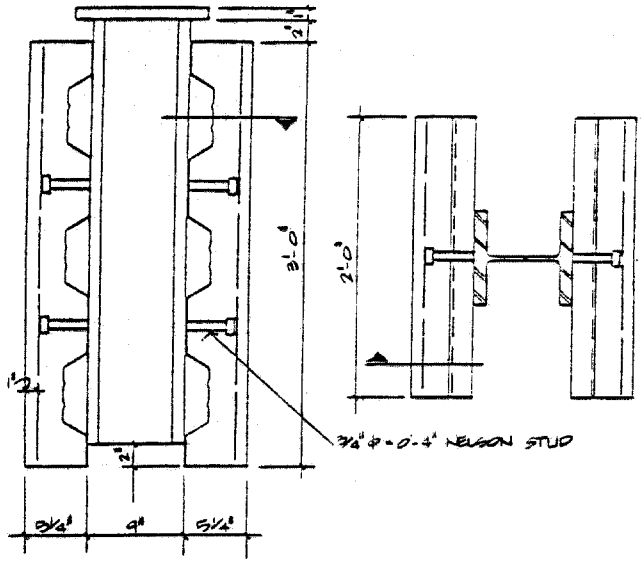
The tests were conducted in four series with the following parameters: (1) metal deck perpendicular to the beam flanges and stud shear connectors, (2) metal deck ribs perpendicular to the beam flanges and HVB 105 shear connectors, (3) metal deck ribs parallel to the beam flanges and stud shear connectors, and (4) metal deck ribs parallel to the beam flanges and HVB 105 shear connectors.
Each series consisted of three push-out specimens; a total of twelve tests. Two of the four series (series 1 and 3), were control specimens utilizing the welded stud shear connectors.

Test configurations are summarized in Table 1.1 and the push-out specimens are shown in Figures 1.1 and 1.2. Test details are found in Chapter II; results and comparisons are found in Chapters II and III.

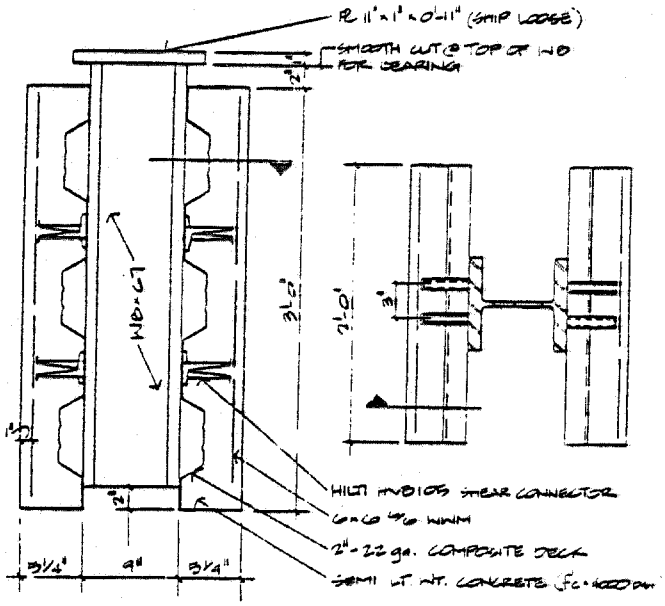
Table 1.1

Test Matrix

Series	Test No.	Test Designation	Shear Connector	Parameters
1	1 2 3	1-NS-3/4-PLR 2-NS-3/4-PLR 3-NS-3/4-PLR	3/4 inch diameter by 4 in. high Welded Stud	Metal Deck Ribs Perpendicular
2	4 5 6	1-HVB-105-PLR 2-HVB-105-PLR 3-HVB-105-PLR	HVB 105	Metal Deck Ribs Perpendicular
3	7 8 9	1-NS-3/4-PL 2-NS-3/4-PL 3-NS-3/4-PL	3/4 inch diameter by 4 in. high Welded Stud	Metal Deck Ribs Parallel
4	10 11 12	1-HVB-105-PL 2-HVB-105-PL 3-HVB-105-PL	HVB 105	Metal Deck Ribs Parallel

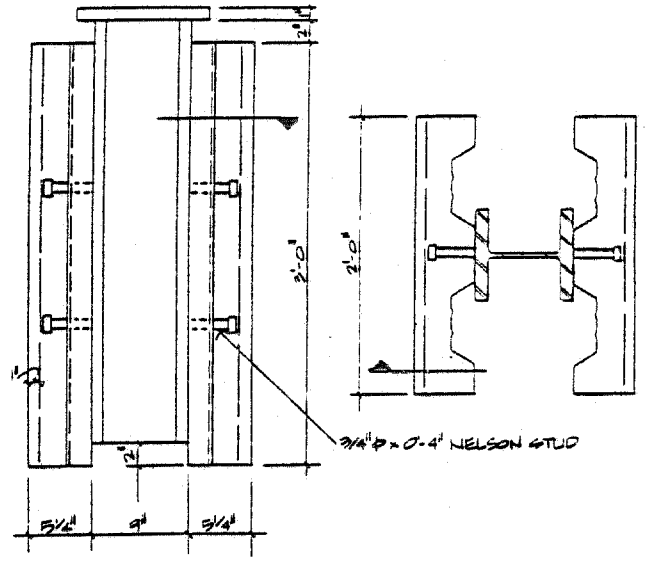


a) Welded Stud Push-out Specimen

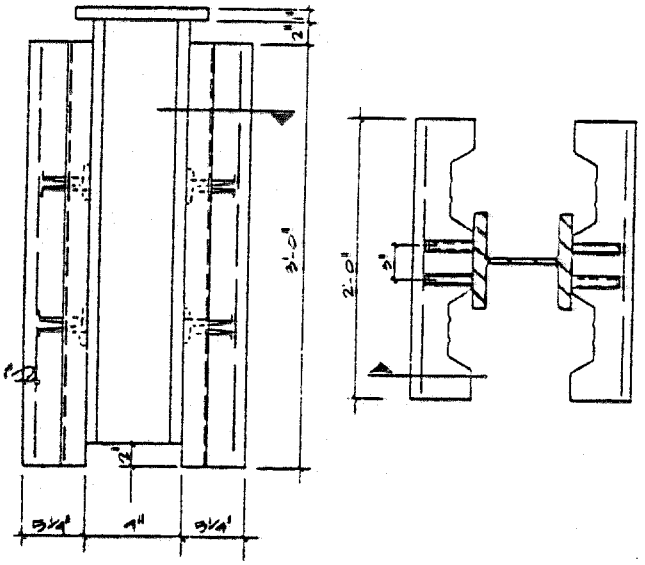


b) HILTI HVB 105 Connector Push-out Specimen

Figure 1.1 Typical Perpendicular Deck Ribs Push-out Specimens



a) Welded Stud Push-out Specimen



b) HILTI HVB 105 Connector Push-out Specimen

Figure 1.2 Typical Parallel Deck Ribs Push-out Specimens

CHAPTER II

TEST DETAILS

2.1 Push-Out Specimens

Each test specimen consisted of a 36 inch long, W8x67 A572 Gr 50 steel wide flange section with two 5 1/2 inch thick, welded wire mesh reinforced concrete slabs cast symmetrically on each flange of the steel section. Each slab was 24 inches wide, 36 inches long and was attached to the steel section by either the HILTI HVB 105 or welded stud shear connectors. The HILTI HVB 105 shear connectors were fastened to the steel section in two rows, (two connectors per row spaced 3 inches apart), at a distance of 12 inches apart with the profile sheet metal in place by HILTI personnel (according to the HILTI procedure) at the Fears Structural Engineering Laboratory. The welded stud shear connectors were 4 inches long and 3/4 inches in diameter. They were welded to the steel section with the profile sheet metal in place by an independent steel fabricator.

All lightweight concrete was obtained from a local ready-mix plant with a design strength of 4000 psi. The design slump was between 3 and 5 inches. The slabs of the twelve specimens were cast simultaneously, one side at a time, slabs on opposite sides of the beam were cast three days apart to allow time to strip the forms, turn the specimens over and set the forms for the next pour. During each concrete pour, a total of ten 6 inch diameter by 12

inch high control cylinders were also cast. Slump tests were performed before the cylinders were cast. The slump, and strengths of concrete are given in Table 2.1.

The W8 X 67 A572 Gr 50 wide flange sections were obtained from a local independent steel fabricator. Standard ASTM tension coupon tests were performed by the sponsor to determine the yield stress and ultimate strength of the steel. The reported yield stresses and ultimate strengths are given in Table 2.2.

2.2 Test Setup

Each of the test specimens was placed in a universal testing machine capable of applying a compressive load of 200.0 kips. The specimen was leveled and a 1 inch thick slab was poured under each of the concrete slabs to insure an equal distribution of load acted on each of the slabs. A load spreader consisting of a steel wide flange section with welded stiffeners, and a 1 inch thick, 11 inch square plate was placed atop the wide flange cross-section to insure that there was an even distribution of load over the wide flange cross-section. Figure 2.1 shows the test specimen in the universal testing machine.

2.3 Instrumentation

The relative slip between the concrete slabs and steel wide flange section were measured by four 3/4 inch stroke linear displacement transducers. Figure 2.2 shows the placement and numbering of the transducers. The transducers were attached to the flanges of the wide flange section and the tips of the transducers touched steel plates which were anchored to the concrete by 1/4" expansion bolts placed in the concrete. All transducers were calibrated prior to the

Table 2.1

Concrete Properties--Shear Connector Tests

Properties	Age (days)	First Pour 1-30-86	Second Pour 2-3-86
Slump (in.)	--	2"	4.5"
Compressive Strength (psi)	4	4046	--
	8	4396	--
	22	4478	--
	30	4768	--
	68	--	5112

Table 2.2

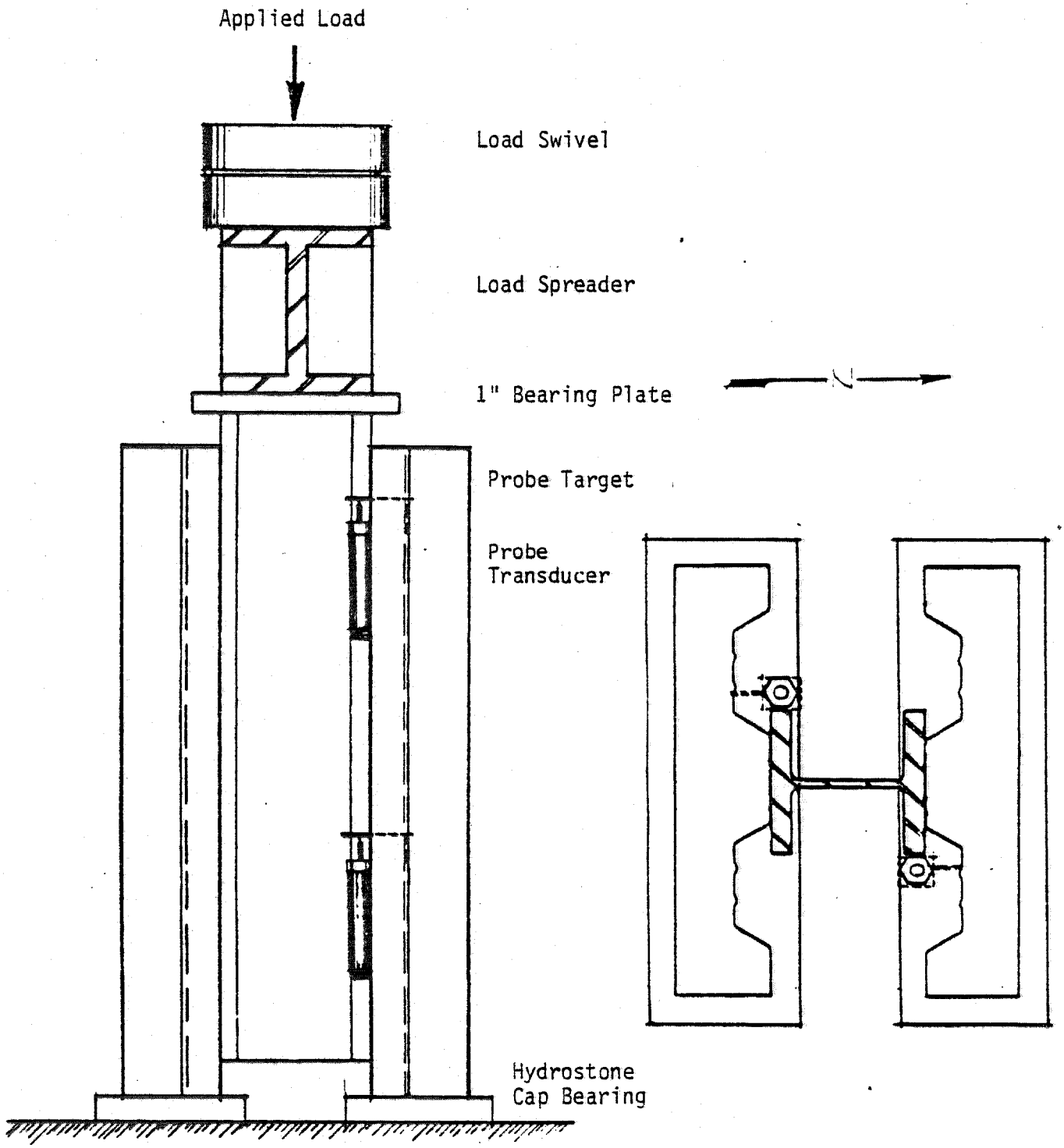
Steel Properties--Shear Connector Tests

Yield Stress (ksi)	Ultimate Strength (ksi)
50.8	75.7
51.9	75.8

testing. Data was recorded using a micro-computer based data acquisition system. Load versus (displacement) slip curves were plotted, by the data acquisition system as the testing progressed.

2.4 Testing Procedures

After the hydrostone had been allowed to set for 12 hours, the formwork was removed and instrumentation was installed. Load was applied at a slow and constant rate in 10.0 kip increments. After each increment, readings of all linear displacement transducers were recorded, and the data points plotted on the load versus (displacement) slip curve. When the specimen was near failure as determined from the plotted load versus (displacement) slip curve, the loading rate was decreased to 1.0 kip increments. Notes were taken concerning concrete cracking, deck separation, and the failure mode. A photographic record of each test was also made.



a) Elevation of Test Setup

b) Section

Figure 2.1 Push-out Specimen Test Setup

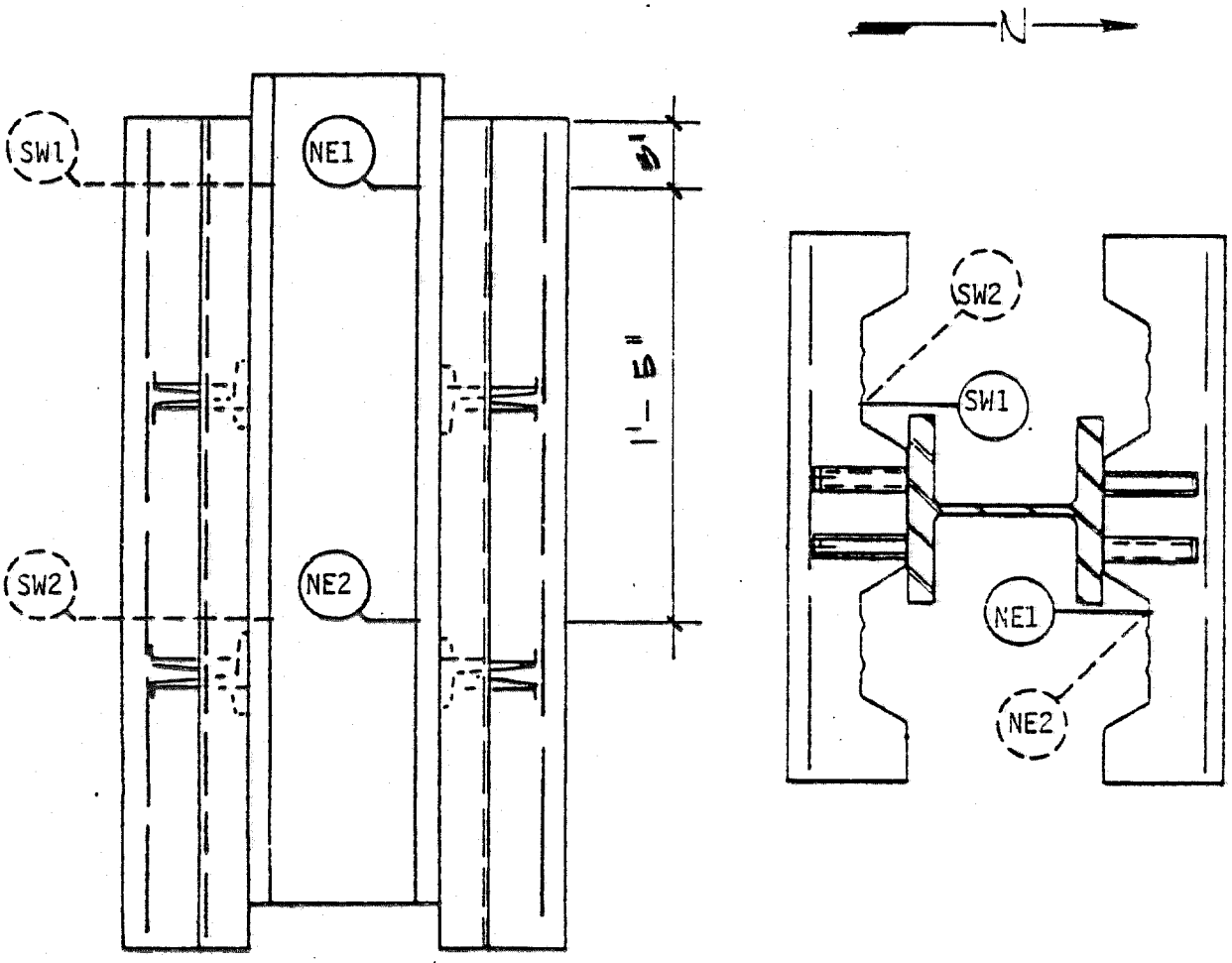


Figure 2.2 Location of Probe Transducers

CHAPTER III

TEST RESULTS

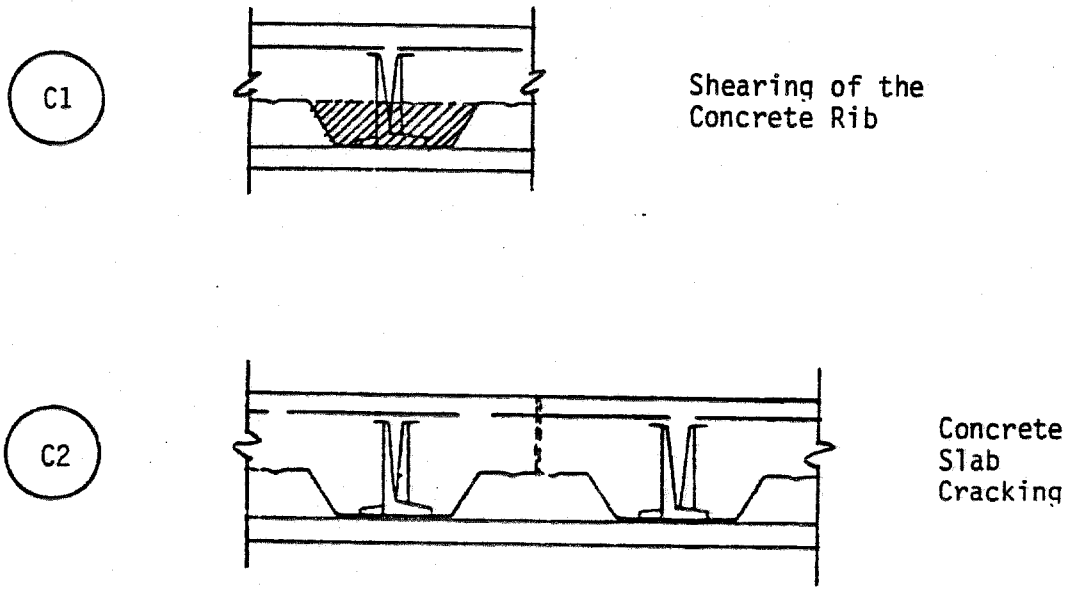
3.1 General

Test results consist of load versus displacement data, and description of the failure mode. Load versus displacement data includes plots of applied load versus relative slip. The failure modes are categorized by concrete failure and/or connector failure as given in Figure 3.1.

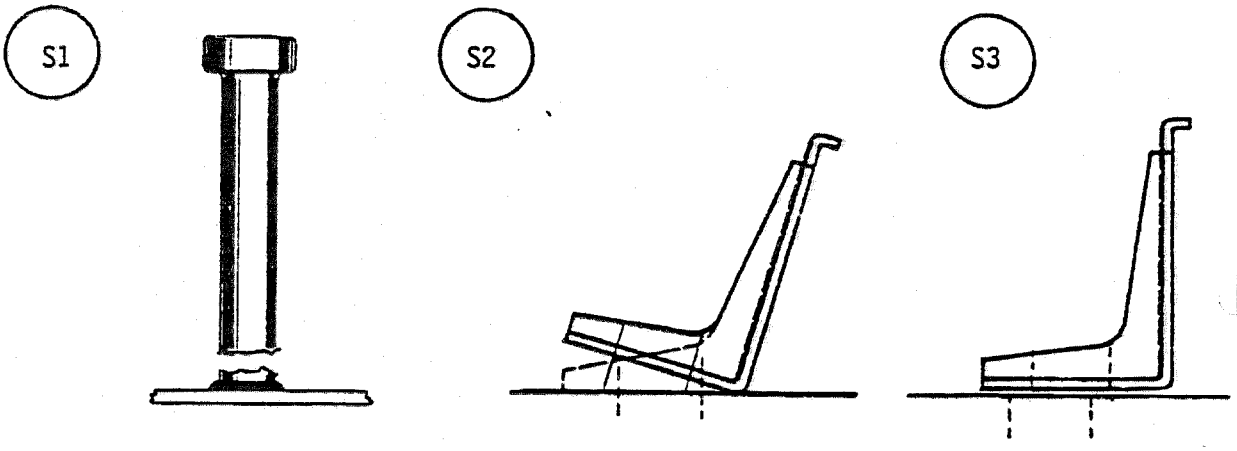
Table 3.1 is a summary of the test results. Detailed descriptions and data for each test are found in the appendices. Welded studs with perpendicular rib orientation test results (Tests 1 through 3) are found in Appendix A. HILTI HVB 105 connectors with perpendicular ribs test results (Tests 4 through 6) are found in Appendix B. Welded studs with parallel ribs test results (Tests 7 through 9) are found in Appendix C. HILTI HVB 105 connectors with parallel ribs test results (Tests 10 through 12) are found in Appendix D. Figures 3.2 through 3.4 are photographs of typical failure modes for each series of tests.

3.2 Welded Studs with Perpendicular Ribs Test Results

Test 1. The load versus deformation curves (Figure A.1) indicate an elastic relationship between the applied



a) Concrete Failure Modes



b) Connector Failure Modes

Figure 3.1 Typical Failure Modes

Table 3.1

Summary of Test Results

Test No.	Test Designation	Shear Connector	Parameters	Maximum Applied Load (kips)	Maximum Shear per connnector (kips)	Failure Modes
1	1-NS-3/4-PLR	3/4 inch diameter by 4 in. high Welded Stud	Metal Deck Ribs	75.6	18.90	C1,C2
2	2-NS-3/4-PLR			86.4	21.60	C1,C2,S1
3	3-NS-3/4-PLR			72.6	18.15	C1,C2,S1
4	1-HVB-105-PLR	HVB 105	Metal Deck Ribs	64.0	8.00	C2,S2
5	2-HVB-105-PLR			65.0	8.13	C2,S2
6	3-HVB-105-PLR			67.8	8.48	C2,S2
7	1-NS-3/4-PL	3/4 inch diameter by 4 in. high Welded Stud	Metal Deck Ribs	79.8	19.95	S1
8	2-NS-3/4-PL			85.0	21.25	S1
9	3-NS-3/4-PL			92.3	23.08	S1
10	1-HVB-105-PL	HVB 105	Metal Deck Ribs	70.0	8.75	S2
11	2-HVB-105-PL			71.0	8.88	S2,S3
12	3-HVB-105-PL			69.0	8.63	S2

Concrete Failure

C1 - Shearing of the concrete rib

C2 - Concrete slab cracking

Connection Failure

S1 - Shearing of headed stud

S2 - Nail pullout

S3 - Shearing of nail

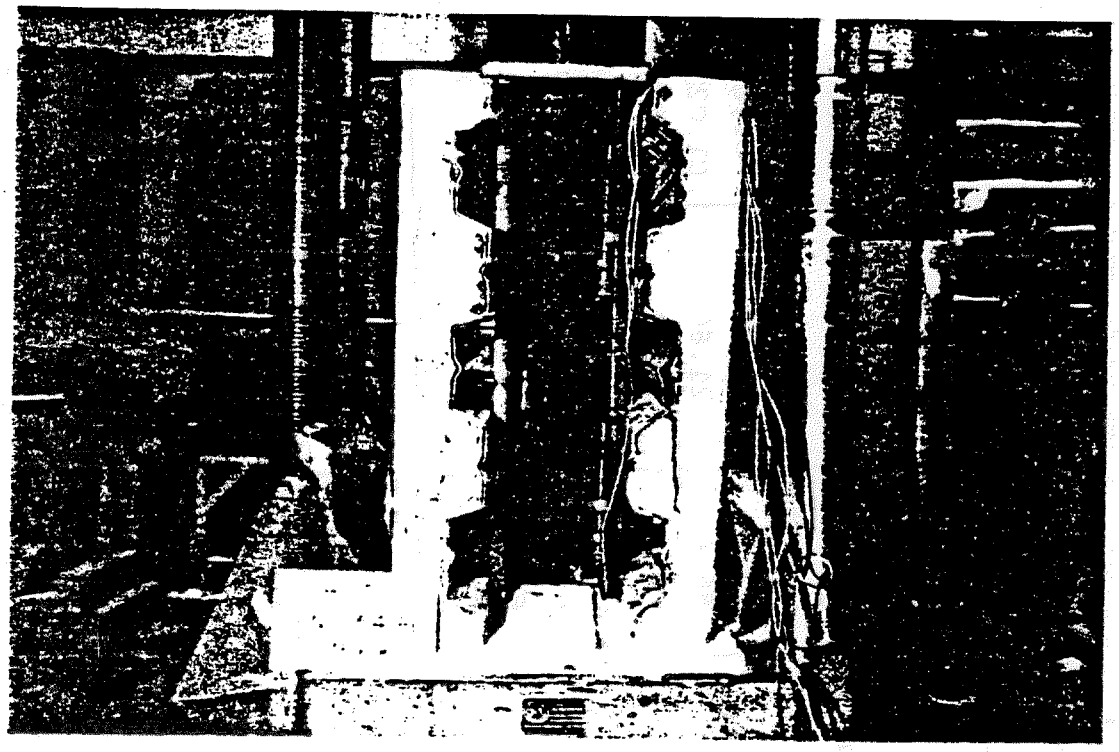


Figure 3.2 Photograph Showing Shearing of Concrete Rib, Failure Mode C1

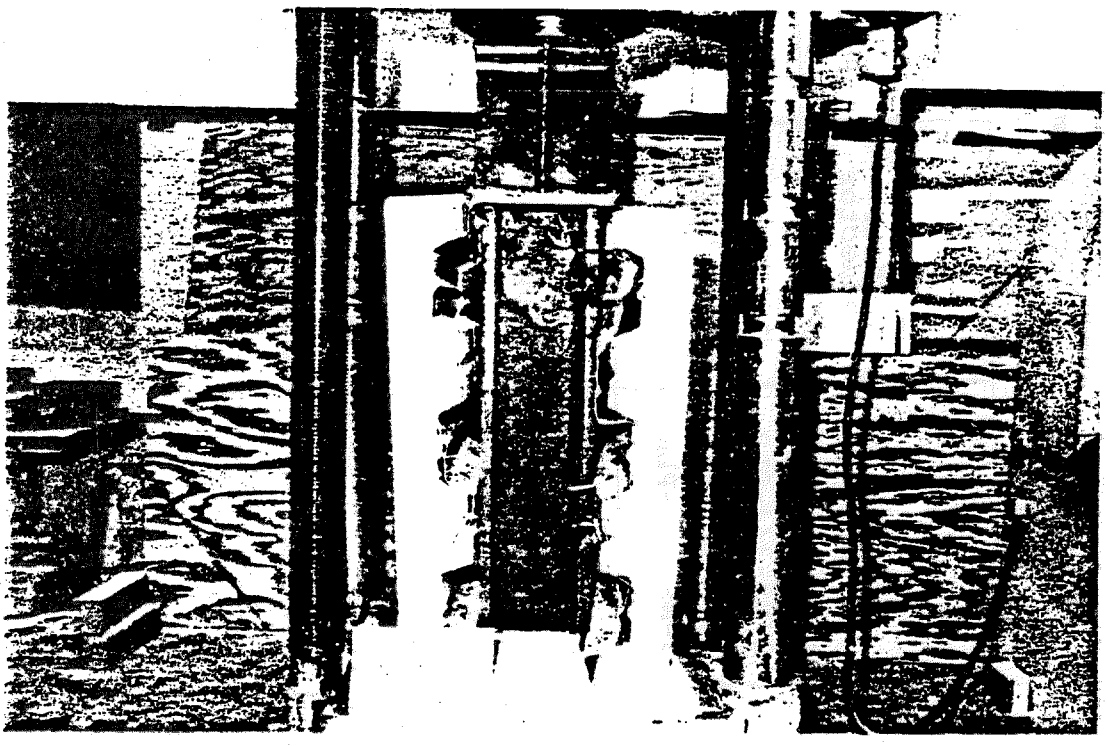


Figure 3.3 Photograph Showing Combined Concrete Slab and Welded Stud Failures, Failure Modes C1, C2, S1

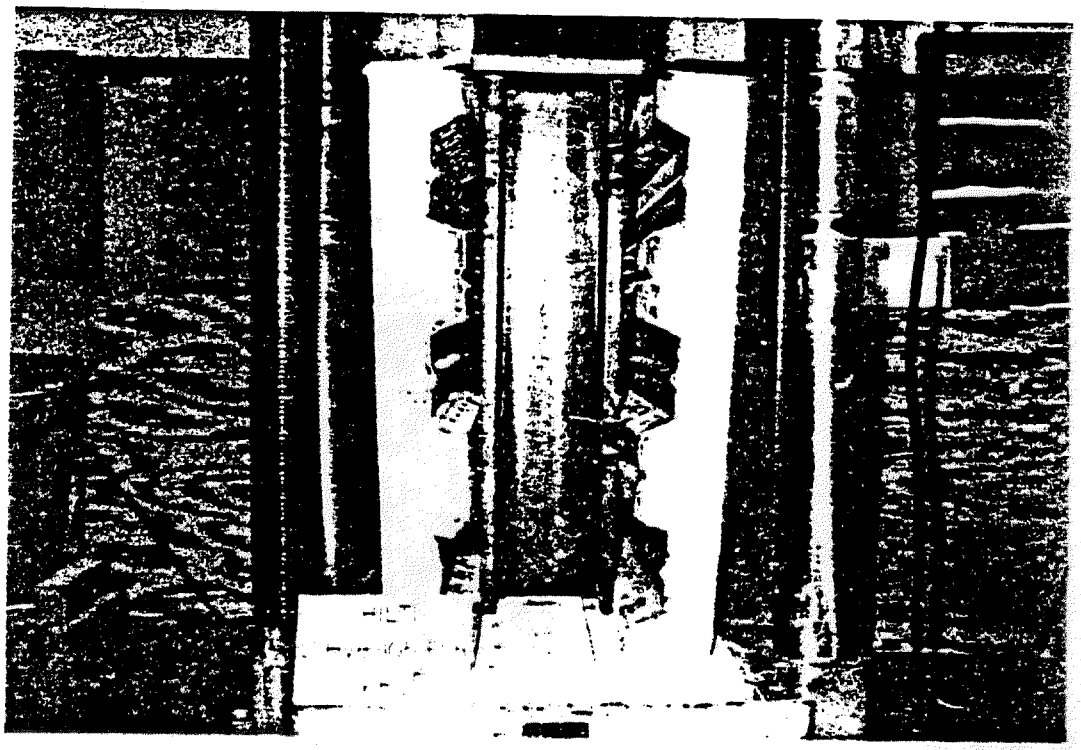


Figure 3.4 Photograph Showing Combined Concrete and Nail Pullout Failure Modes C2, S2

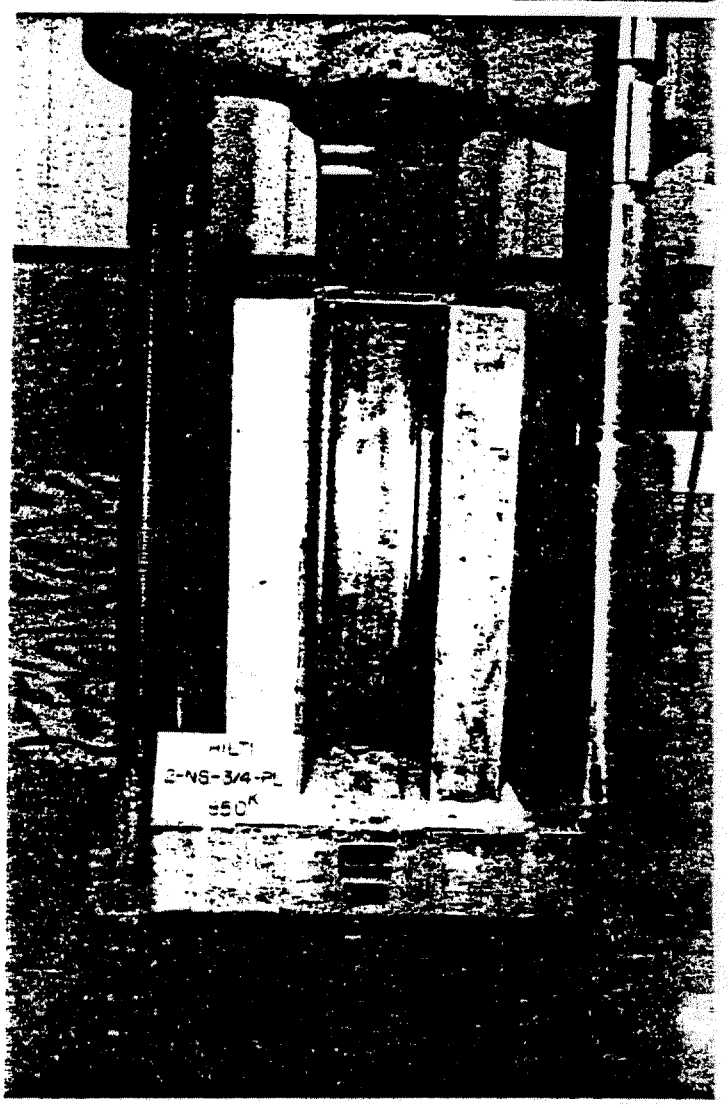


Figure 3.5 Photograph Showing Shearing of Welded Stud, Failure Mode S1

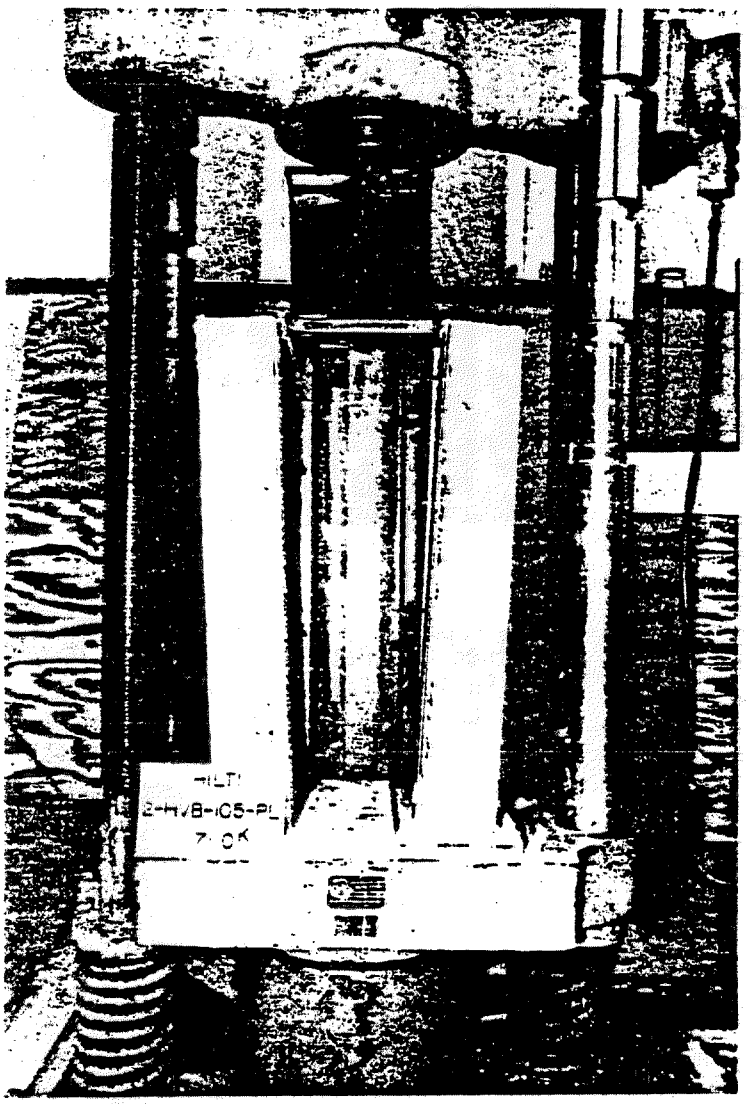


Figure 3.6 Photograph Showing Failure of Nail Connection, Failure Modes S2, S3

load and relative slip to an applied load of 30 kips. From an applied load of 30 to 50 kips, slip increases slightly with increase in applied load. At 50 kips, audible cracking sounds due to separation between the concrete slabs and profile sheet metal occurred. From an applied load of 50 to 70 kips, slip increases at an increasing rate. At a load of 60 kips, visible profile sheet metal separation from the concrete slabs occurred along the second and third full ribs up from the bottom of both north and south slabs. At a load of 70 kips, slip increases at an increasing rate until the maximum applied load of 75.6 kips was reached. At 73.2 kips, a crack running the full 2 ft. width of the north slab, the third full concrete rib up from the bottom was observed. At the maximum load of 75.6 kips, resistance to the applied load decreased rapidly. The second full rib up on the north slab shears at the 2 inch height of the profile metal deck. No shear stud failure occurred. The failure modes were characterized as C1 and C2.

Test 2. The load versus deformation curves (Figure A.2) indicate an elastic relationship between the applied load and relative slip to an applied load of 22 kips. From an applied load of 22 to 69 kips, the slip increases at an increasing rate. Separation between both slabs and profile sheet metal occurred along with slab cracking running the full 2 ft. width of the north slab, the third full rib up. At an applied load of 70 kips, the load versus deformation curves are asymptotic indicating very large increases in slip with incremental increases in applied load. At a load of 75 kips, the load versus slip curve indicates resistance increased, and that the rate at which slip occurred with respect to load was applied had decreased. This behavior continued until a maximum load of 86.4 kips was reached. At this load, definite deck separation between the profile sheet metal and north slab along the fourth full rib up

existed. The second rib of the south slab was cracked. The top welded stud of the south slab was sheared off at the wide flange section. The failure modes are characterized by C1, C2, and S1.

Test 3. The load versus deformation curves (Figure A.3) indicates an elastic relationship between the applied load and relative slip to an applied load of 30 kips. From an applied load of 30 to 50 kips, the slip increases linearly at a slightly increasing rate. From an applied load of 50 to 70 kips, slip increases at an increasing rate. At 50 kips, audible cracking due to separation between the profile sheet metal and concrete slabs occurred. At a load of 70 kips, the load versus deformation curves are virtually asymptotic, horizontal. At an applied load of 72 kips, cracks running the full 2 ft. width of both north and south slabs, the third full rib up was observed. At a maximum applied load of 72.6 kips, resistance to the applied load decreased, and the top and bottom shear studs of the south slab sheared off at the wide flange section. Rib cracking along the second and fourth full ribs of the north slabs was observed. The failure modes were characterized as C1, C2, and S1.

3.3 HILTI HVB 105 Connectors with Perpendicular Ribs Test Results

Test 4. The load versus deformation curves (Figure B.1) indicate an elastic relationship between the applied load and the relative slip to an applied load of 30 kips. From an applied load of 30 kips to the maximum applied load of 64 kips was reached, slip increases at an increasing rate. At an applied load of 56 kips, cracking was observed at the third full rib up of the north slab, extending the full 2 ft. width of the slab. At an applied load of 62

kips, cracking was observed at the third full rib up of the south slab, extending the full 2 ft. width of the slab. At the maximum load of 64 kips, resistance to the applied load decreased while slip continues increasing, and nail pullout causing complete separation of the north and south slabs from the wide flange section was observed. The failure modes are characterized by C2 and S2.

Test 5. The load versus deformation curves (Figure B.2) indicate an elastic relationship between the applied load and the relative slip to an applied load of 26 kips. From an applied load of 26 kips to the maximum applied load of 65 kips, slip increases at an increasing rate. Erratic readings from probe SW2 were due to the probe plunger being stuck. At a load of 54 kips, profile sheet metal separation is visible at the fourth full rib up of both north and south slabs. At a load of 56 kips, cracking was observed at the third full rib up of both north and south slabs, extending the full 2 ft. width. At a load of 60 kips, deck separation was easily visible and occurring along the second and fourth full ribs up of both north and south slabs. At the maximum load of 65 kips, resistance to the applied load decreased while slip continues increasing until failure as a results of nail pull out causing complete separation of the slabs from the wide flange section occurred. The failure modes are characterized by C2 and S2.

Test 6. The load versus deformation curves (Figure B.3) indicate an elastic relationship between the applied load and the relative slip to an applied load of 31 kips. From an applied load of 31 kips to the maximum applied load of 67.8 kips, slip increases at an increasing rate. At an applied load of 52 kips, deck both north and south slabs. From applied loads of 52 to 56 kips, cracking of both north and south slabs extending the full 2 ft. width. At the

maximum load of 67.8 kips, resistance to the applied load decreased while slip continues increasing until complete separation of both slabs from the side flange section by nail pullout occurred. The failure modes are characterized by C2 and S2.

3.4 Welded Studs with Parallel Ribs Test Results

Test 7. The load versus deformation curves (Figure C.1) indicate an elastic relationship between the applied load and the relative slip to an applied load of 30 kips. From an applied load of 30 kips to the maximum applied load of 79.8 kips was reached, slip increases at an increasing rate. At the maximum applied load of 79.8 kips, resistance to the applied load decreased while slip continues increasing until complete separation of both slabs from the wide flange section by shearing of the welded studs at the flange occurred. The failure mode is characterized by S1.

Test 8. The load versus deformation curves (Figure C.2) indicate an elastic relationship between the applied load and relative slip to an applied load of 32 kips. From an applied load of 32 to 75 kips, slip increases at an increasing rate. From an applied load of 75 kips to the maximum applied load of 85 kips, slip increases at a still increasing rate. At the maximum applied load of 85 kips, resistance to the applied load decreased while slip continues increasing until complete separation of both slabs from the wide flange section by shearing of the welded studs at the flange occurred. The failure mode is characterized by S1.

Test 9. The load versus deformation curves indicate an elastic relationship between the applied load and the relative slip to an applied load of 40 kips. From an

applied load of 40 to 70 kips, slip increases at an increasing rate. From an applied load of 70 kips to the maximum applied load of 92.8 kips, slip increases at an ever increasing rate. At the maximum applied load of 92.8 kips, resistance to the applied load is reduced and slip continues until complete separation of both slabs from the wide flange section by shearing of the welded studs at the flange occurred. The failure mode is characterized by S1.

3.5 HILTI HVB 105 Connectors with Parallel Ribs Test Results

Test 10. The load versus deformation curves (Figure D.1) indicate an elastic relationship between the applied load and the relative slip to an applied load and the relative slip to an applied load of 31 kips. From an applied load of 31 kips to the maximum applied load of 70 kips, slip increases at an increasing rate. At the maximum applied load of 70 kips, resistance to the applied load decreased while slip continued increasing until complete separation of both slabs from the wide flange section by nail pullout occurred. The failure mode is characterized by S2.

Test 11. The load versus deformation curves (Figure D.2) indicate an elastic relationship between the applied load and the relative slip to an applied load of 30 kips. From an applied load of 30 kips to the maximum applied load of 71 kips, slip increases at an increasing rate. At the maximum applied load of 71 kips, resistance to the applied load decreased while slip continued increasing until complete separation of both slabs from the wide flange section by nail pullout and nail shearing occurred. The failure modes are characterized by S2 and S3.

Test 12. The load versus deformation curves (Figure D.3) indicate an elastic relationship between the applied load and relative slip to an applied load of 30 kips. From an applied load of 30 kips to the maximum applied load of 69 kips, slip increases at an increasing rate. At the maximum applied load of 69 kips, resistance to the applied load decreases while slip continues increasing until complete separation of both slabs from the wide flange section as a result of nail pullout occurred. The failure mode is characterized by S2.

CHAPTER IV

COMPARISONS AND CONCLUSIONS

4.1. Comparison of HVB 105 and Welded Stud Results

4.1.1 Perpendicular Rib Tests. The following observations are made from the results of the perpendicular rib tests:

1. The HVB 105 push-out specimens underwent greater slip than the welded studs before reaching the maximum applied load.
2. The HVB 105 specimens attained a maximum applied load 20% lower than that for the similar welded stud specimens.
3. The average maximum force resisted by each 3/4 inch diameter welded stud connector was 19.55 kips. The average maximum force resisted by each HVB 105 connector was 8.20 kips, thus 2.38 HVB 105 connectors are required to replace one 3/4 inch diameter welded stud connector.

4.1.2 Parallel Rib Tests. The following observations are made as a result of the parallel rib tests:

1. More slip was observed for the HVB 105 specimens than for the welded stud specimens.
2. The HVB 105 connector push-out specimens attained a maximum applied load 17% less than that attained by the similar welded stud push-out specimens.

3. The average maximum force resisted by each 3/4 inch diameter welded stud connector was 21.43 kips. The average maximum force resisted by each HVB 105 connector was 8.75 kips, thus 2.45 HVB 105 connectors are required to replace one 3/4 inch diameter welded stud connector.

4.2 Effect of Rib Orientation on HVB 105 Behavior

Comparison of the load versus slip plots for Tests 4-6 (ribs perpendicular) with Tests 10-12 (ribs parallel) shows insignificant differences in behavior. The average failure load per connector for the ribs parallel orientation is approximately 7% greater than that of the ribs perpendicular orientation.

4.3 Conclusions

From the results of this limited testing program, it is apparent that the load/slip characteristics of push-out specimens constructed using HILTI HVB 105 connectors have as much ductility as specimens constructed using 3/4 inch diameter welded stud connectors. Further, is was found that for the metal deck and concrete used in the testing program, approximately five HILTI HVB 105 connectors are required to provide the same strength as two 3/4 inch diameter standard welded studs.

APPENDIX A

WELDED STUD/PERPENDICULAR RIB

TEST RESULTS

TEST SUMMARY

Project: HILTI

Test No.: 1-NS-3/4-PLR

Test Date: 2-17-86

Parameters: 2-3/4 in. diameter welded studs per flange
Perpendicular deck ribs

Failure Load: 75.6 kips

Failure Mode: Shearing of the concrete rib
Concrete Slab Cracking

Discussion:

- 50^{k}: Audible cracking observed
- 60^{k}-70^{k}: Visible profile metal deck separation from north and south slabs, the second full rib up.
- 73.2^{k}: Hairline crack develops along full 2 ft. width of north slab, the third full rib up.
- 75.6^{k}: Resistance to the applied load reduces rapidly. The north slab cracks along the shear plane of the second full rib up. Failure due to shearing of concrete rib. No welded stud failure.

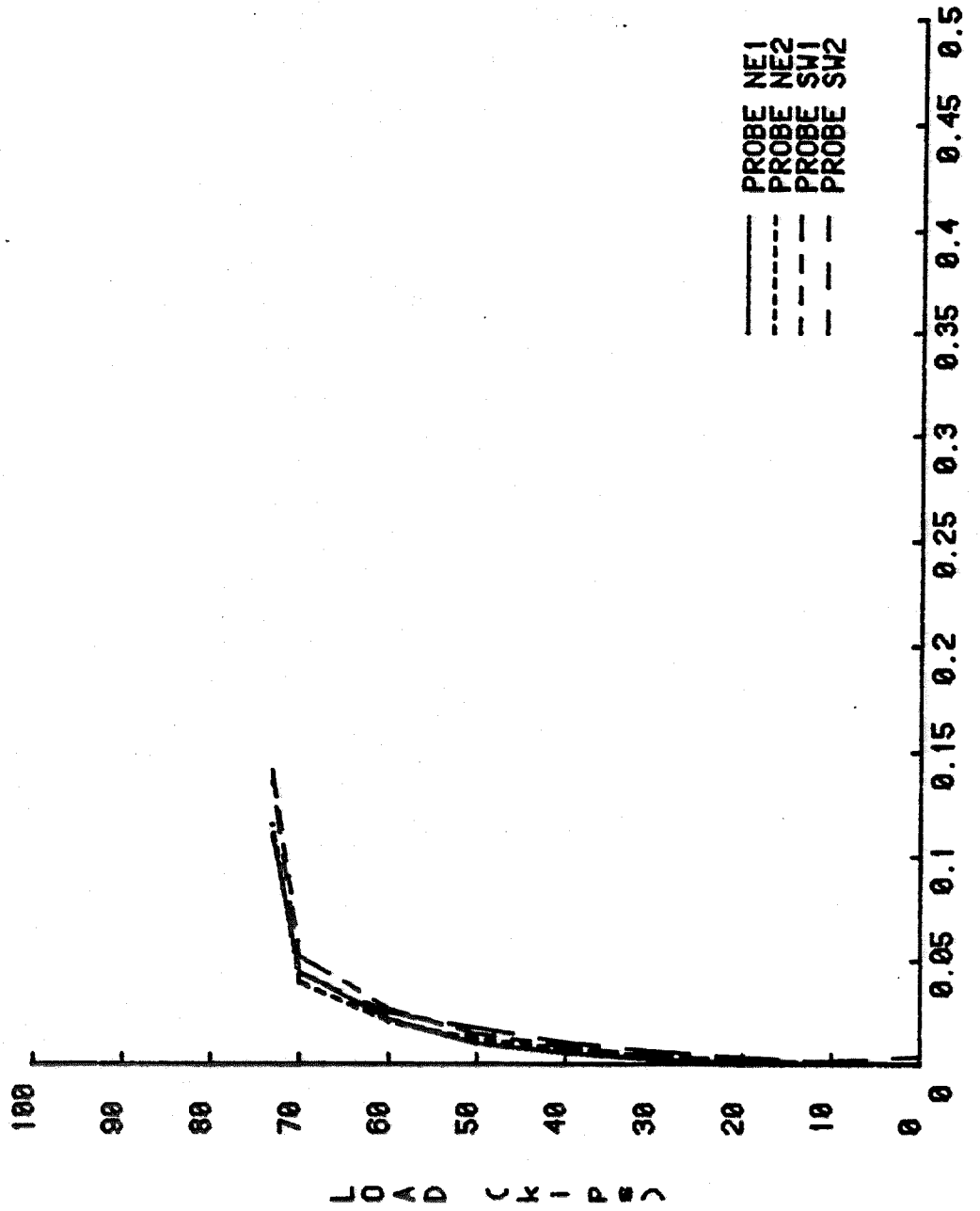


Figure A.1 Load Versus Slip, Test 1
Welded Stud/Perpendicular Rib

TEST SUMMARY

Project: HILTI

Test No.: 2-NS-3/4-PLR

Test Date: 2-24-86

Parameters: 2-3/4 in. diameter welded studs per flange
Perpendicular deck ribs

Failure Load: 86.4 kips

Failure Mode: Shearing of the concrete rib
Concrete slab cracking
Shearing of headed stud

Discussion:

- 60^{k}: Hairline crack develops along full 2 ft. width of north slab, the third full rib up.

- 67^{k}: Separation of profile metal deck from north and south slabs, the fourth full rib up.

- 86.4^{k}: Resistance to applied load reduced. The south slab cracks along the shear plane of the second full rib up. Failure due to shearing of concrete rib and top welded stud of south slab.

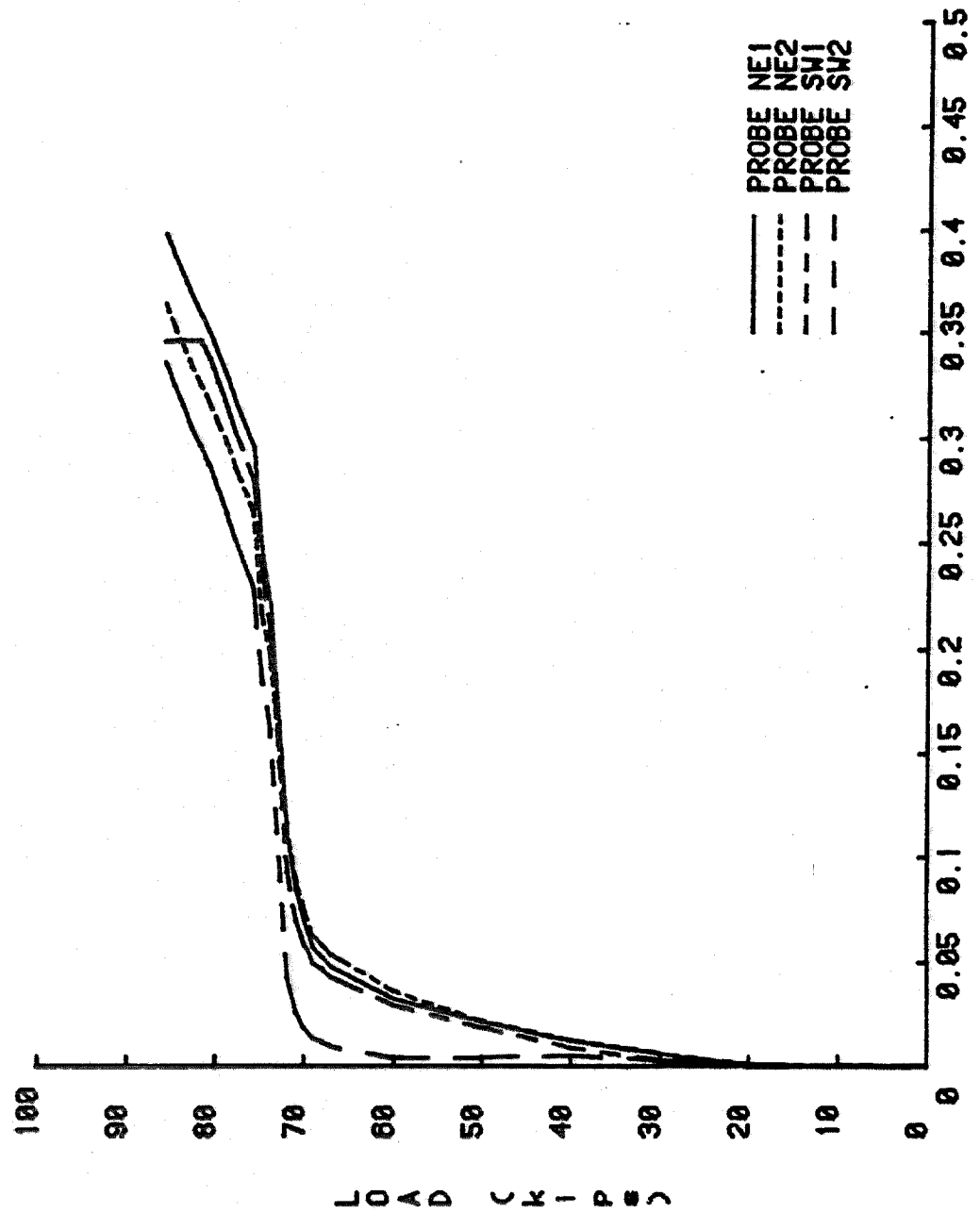


Figure A.2 Load Versus Slip, Test 2
Welded Stud/Perpendicular Rib

TEST SUMMARY

Project: HILTI

Test No.: 3-NS-3/4-PLR

Test Date: -3-86

Parameters: 2-3/4 in. diameter welded studs per flange
Perpendicular deck ribs

Failure Load: 72.6 kips

Failure Mode: Shearing of the concrete rib
Concrete slab cracking
Shearing of headed stud

Discussion:

- 50^{k}: Audible cracking observed

- 72^{k}: Hairline crack develops along full 2 ft. width of north and south slabs, the third full rib up.

- 72.6^{k}: Resistance to the applied load reduces rapidly. The north slab cracks along the shear plane of the second and fourth full ribs up. Failure due to shearing of concrete ribs (north slab) and shearing of welded studs of south slab.

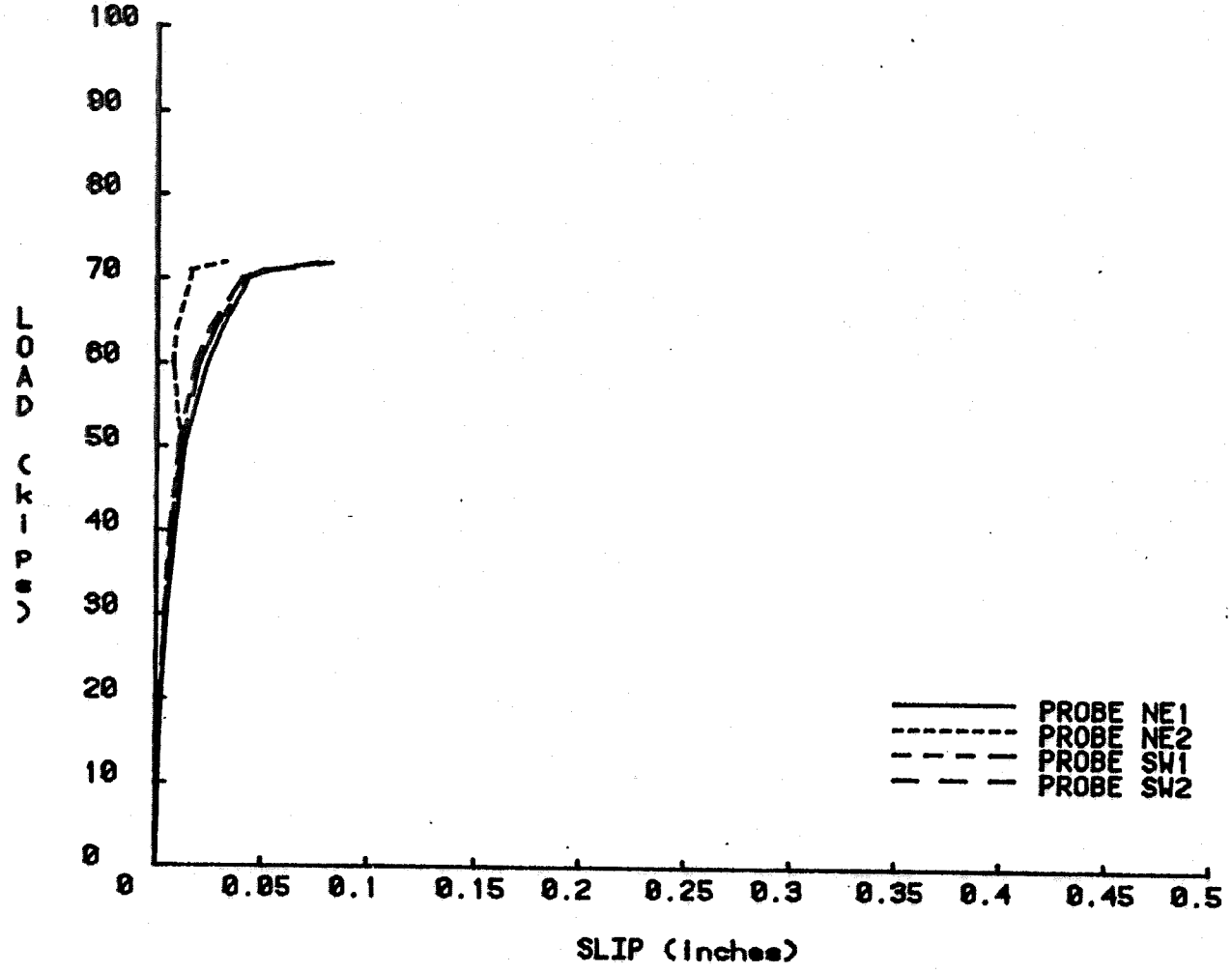


Figure A.3 Load Versus Slip, Test 3
Welded Stud/Perpendicular Rib

APPENDIX B

HILTI HVB 105/ PERPENDICULAR RIB

TEST RESULTS

TEST SUMMARY

Project: HILTI

Test No.: 1-HVB-105-PLR

Test Date: 2-21-86

Parameters: 2-HILTI HVB 1-5 connectors
per profile metal deck rib
(4 per flange)
Perpendicular deck ribs

Failure Load: 64 kips

Failure Mode: Concrete slab cracking
Nail pullout

Discussion:

- 30^{k}: Audible cracking observed
- 56^{k}: Hairline crack develops along full 2 ft. width of north slab, the third full rib up.
- 62^{k}: Hairline crack develops along full 2 ft. width of south slab, the third full rib up.
- 64^{k}: Resistance to the applied load reduces. Complete separation of north and south slabs from wide flange section occurs. Failure due to slab separation from wide flange section due to nail pullout and concrete slab cracking.

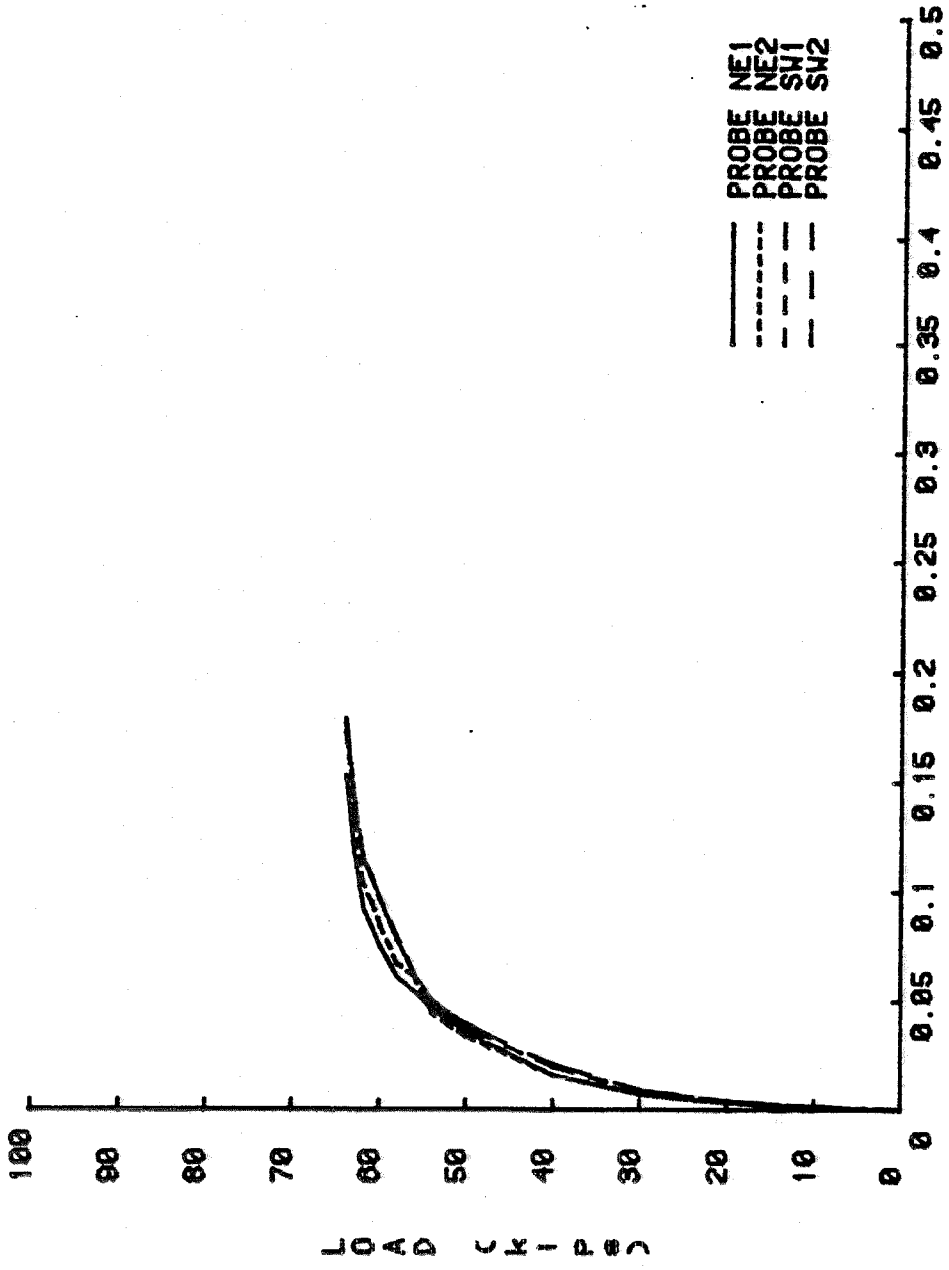


Figure B.1 Load Versus Slip, Test 4
HVB 105/Perpendicular Rib

TEST SUMMARY

Project: HILTI

Test No.: 3-NS-3/4-PL

Test Date: 3-26-86

Parameters: 2-3/4 in. diameter welded studs per flange
Parallel deck ribs

Failure Load: 92.8 kips

Failure Mode: Shearing of headed stud

Discussion:

- 60^{k}: Audible cracking observed

- 92.8^{k}: Resistance to applied load reduced. Shearing of all four welded studs occurs. Failure due to shearing of all four welded studs.

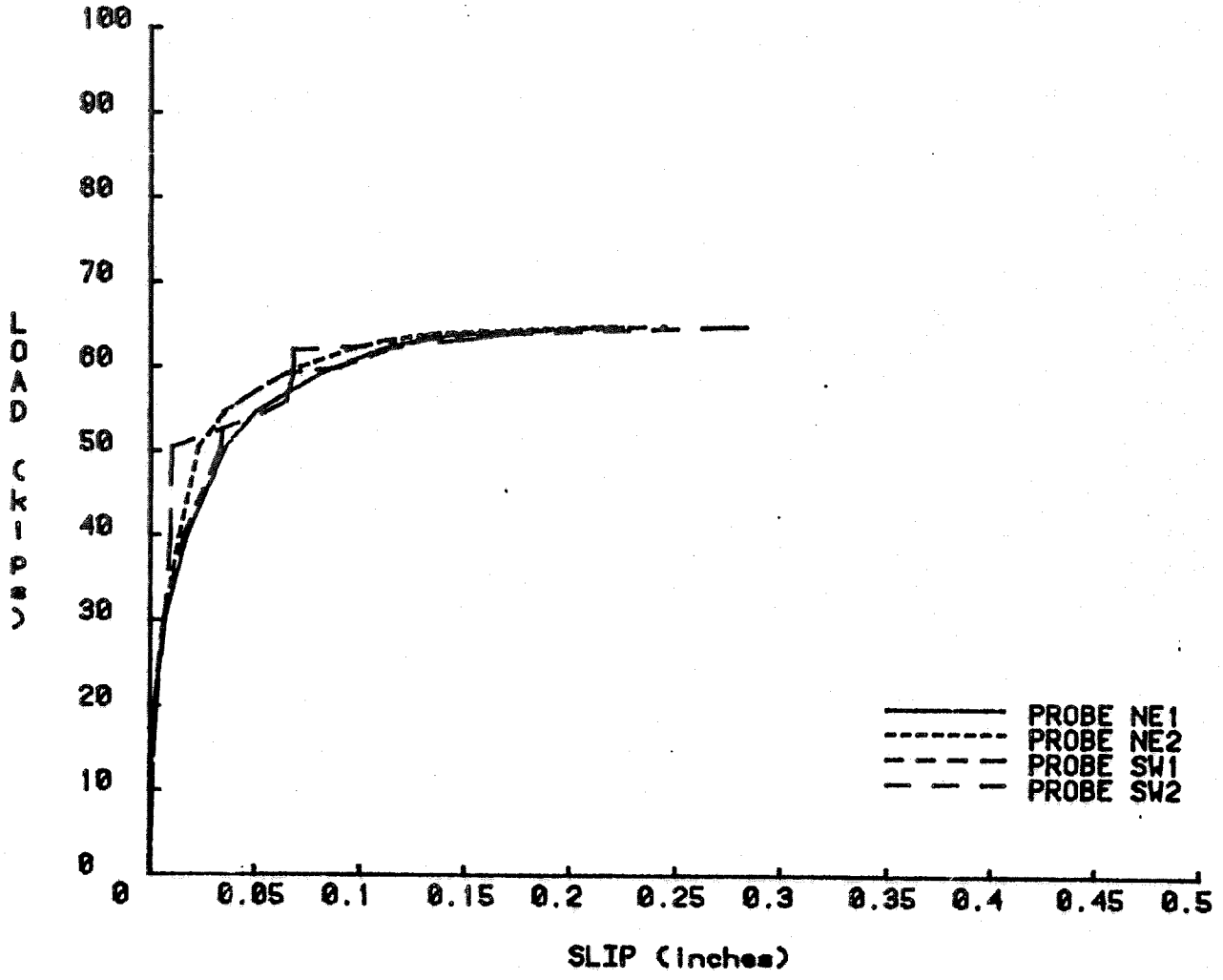


Figure B.2 Load Versus Slip, Test 5
HVB 105/Perpendicular Rib

TEST SUMMARY

Project: HILTI

Test No.: 3-HVB-105-PLR

Test Date: 3-4-86

Parameters: 2-HILTI HVB 105 connectors per profile metal deck rib (4 per flange)

Failure Load: 63 kips

Failure Mode: Concrete slab cracking
Nail pullout

Discussion:

- 30^{k}: Audible cracking observed
- 45^{k}: Separation of profile sheet metal deck from north concrete slab, second and fourth full ribs up.
- 53^{k}: Hairline crack develops along full 2 ft. width of north slab, the third full rib up.
- 56^{k}: Hairline crack develops along full 2 ft. width of south slab, the third full rib up.
- 67.8^{k}: Resistance to the applied load reduces. Complete separation of north and south slabs from wide flange section occurs. Failure due to slab separation from wide flange section due to nail pullout and concrete slab cracking.

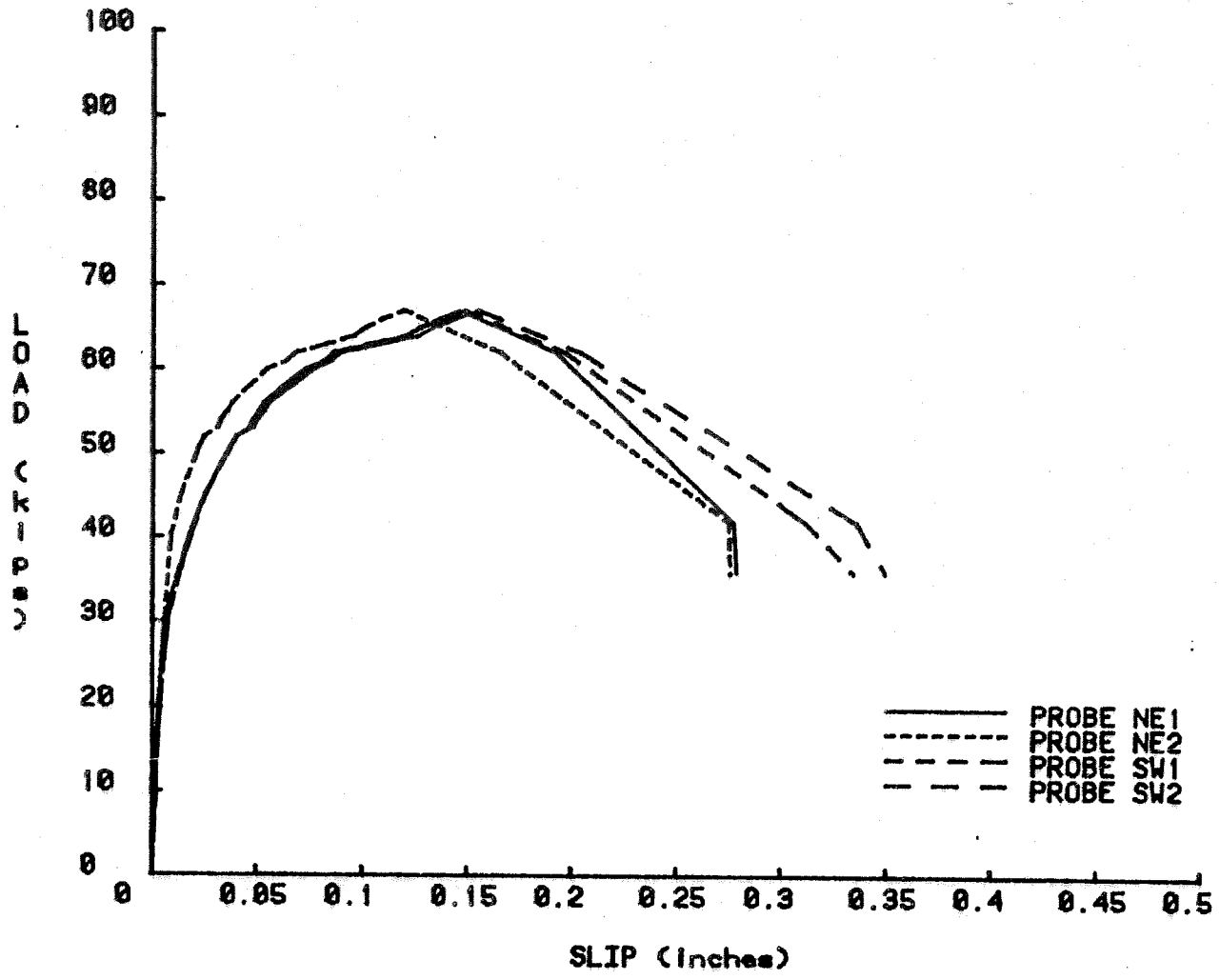


Figure B.3 Load Versus Slip, Test 6
HVB 105/Perpendicular Rib

APPENDIX C

WELDED STUD/PARALLEL RIB

TEST RESULTS

TEST SUMMARY

Project: HILTI

Test No.: 1-NS-3/4-PL

Test Date: 2-20-86

Parameters: 2-3/4 in. diameter welded studs per flange
Parallel deck ribs

Failure Load: 79.8 kips

Failure Mode: Shearing of headed stud

Discussion:

- 50^{k}: Audible cracking observed

- 79.8^{k}: Resistance to applied load reduces. North and south slabs completely separate from wide flange section as a result of shearing of headed studs.

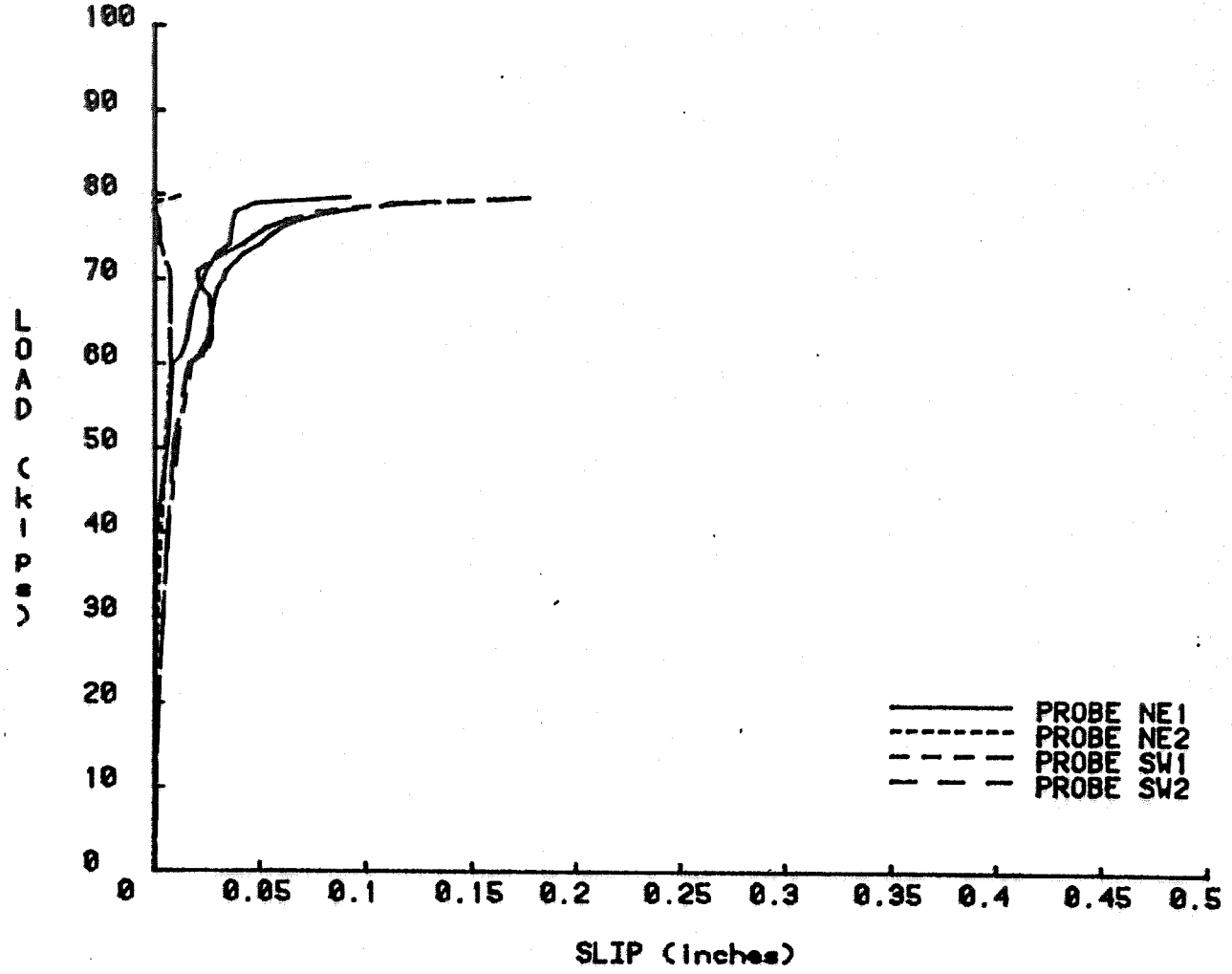


Figure C.1 Load Versus Slip, Test 7
Welded Stud/Parallel Rib

TEST SUMMARY

Project: HILTI

Test No.: 2-NS-3/4-PL

Test Date: 2-27-86

Parameters: 2-3/4 in. diameter welded studs per flange
Parallel deck ribs

Failure Load: 85^{k}

Failure Mode: Shearing of headed stud

Discussion:

- 50^{k}: Audible cracking observed

- 85^{k}: Resistance to applied load reduces. Shearing of welded studs occurs simultaneously. Slabs separate due to shearing of all four welded studs.

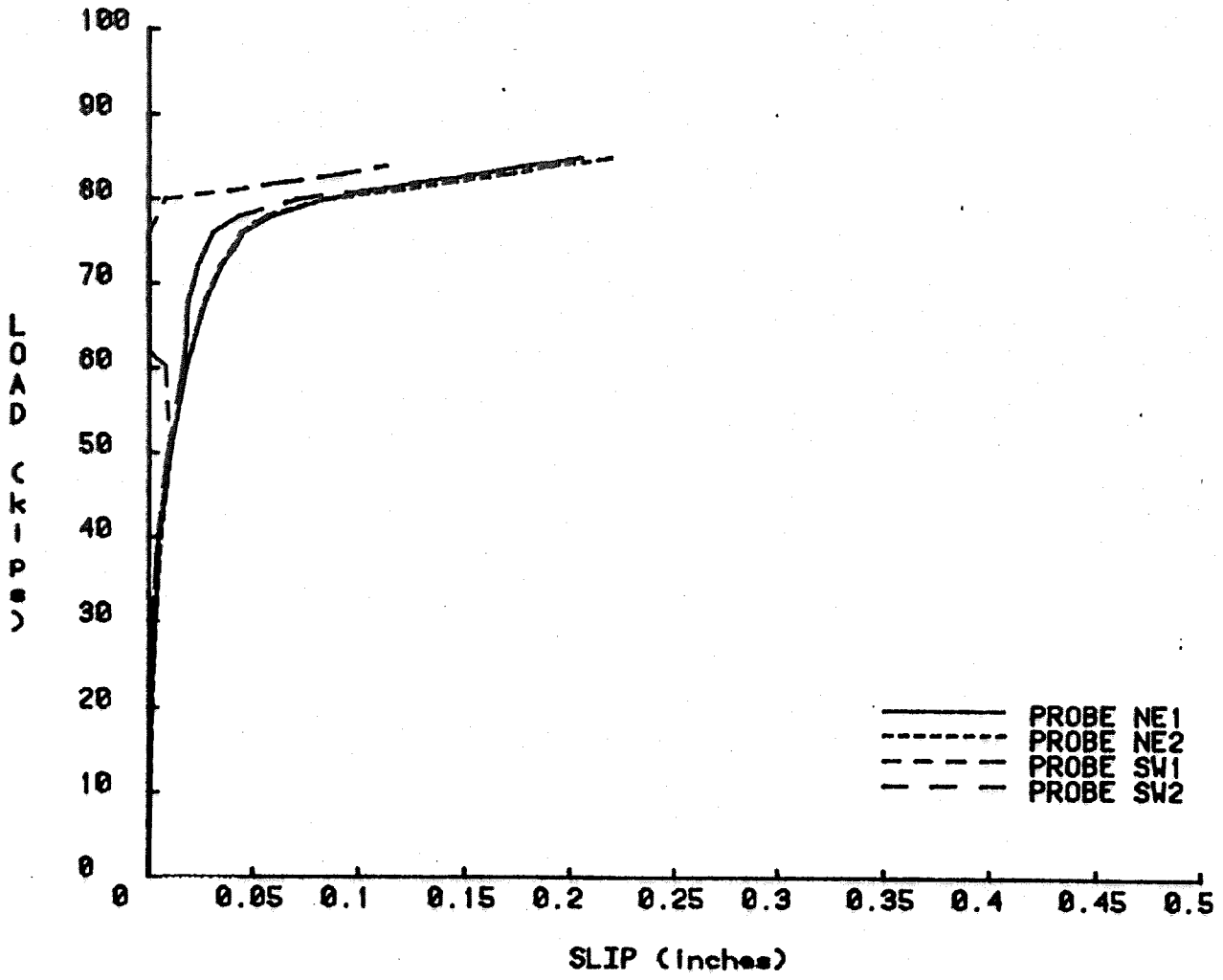


Figure C.2 Load Versus Slip, Test 8
Welded Stud/Parallel Rib

TEST SUMMARY

Project: HILTI

Test No.: 2-HVB-105-PLR

Test Date: 2-26-86

Parameters: 2-HILTI HVB 105 connectors
per profile metal deck rib
(4 per flange)
Perpendicular deck ribs

Failure Load: 65 kips

Failure Mode: Concrete slab cracking
Nail pullout

Discussion:

-30^{k}: Audible cracking observed

-54^{k}: Separation of profile sheet metal deck from south concrete slab occurs, the fourth full rib up.

-56^{k}: Hairline crack develops along full 2 ft. of north and south slabs, the third full rib up.

-60^{k}: Separation of profile sheet metal deck from north and south concrete slabs, the second and fourth full ribs up.

- 65^{k}: Resistance to the applied load reduces. Complete separation of north and south slabs from wide flange section occurs. Failure due to slab separation due to nail pullout and concrete slab cracking.

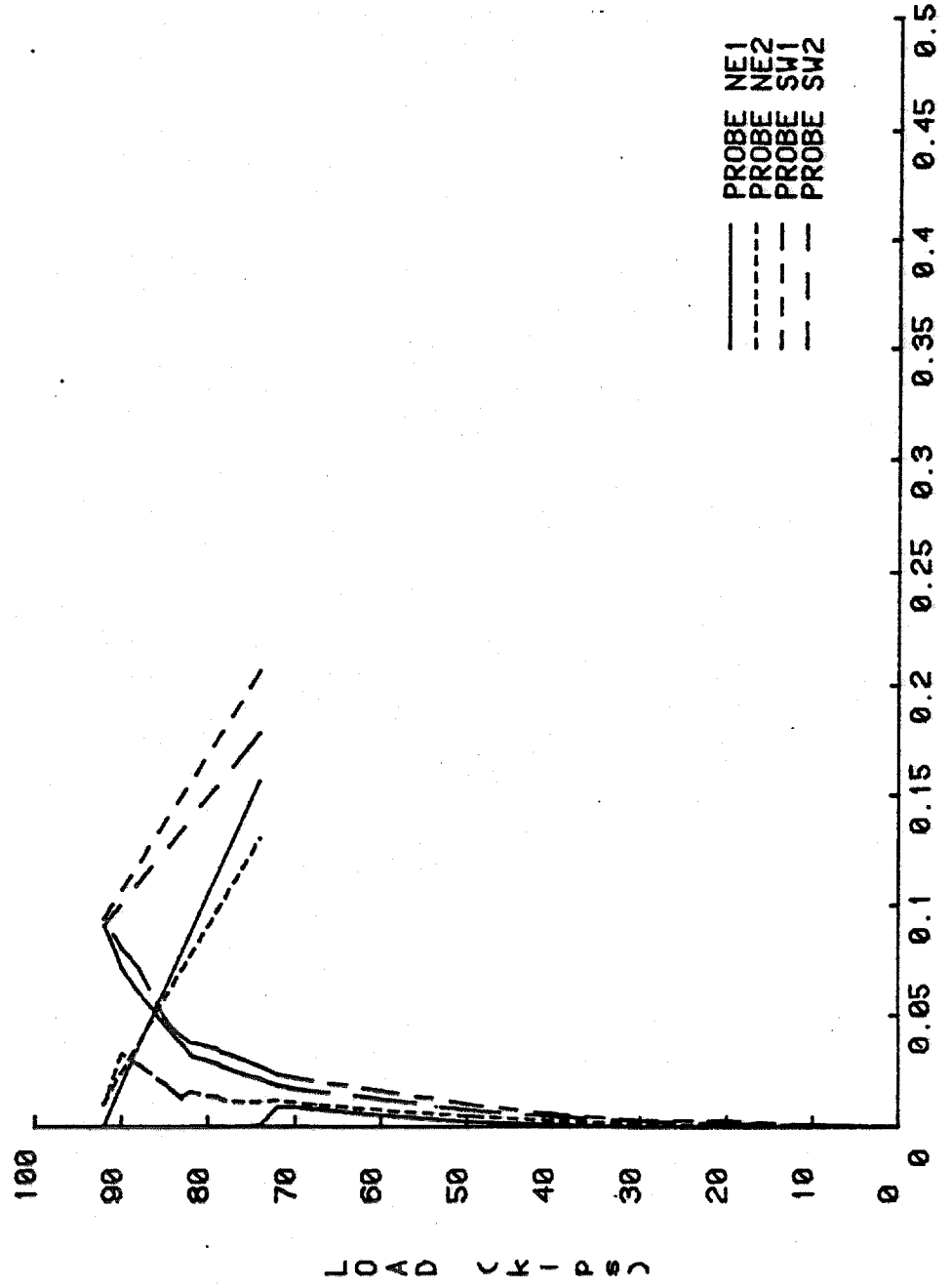


Figure C.3 Load Versus Slip, Test 9
Welded Stud/Parallel Rib

APPENDIX D

HILTI HVB 105/PARALLEL RIB

TEST RESULTS

TEST SUMMARY

Project: HILTI

Test No.: 1-HVB-105-PL

Test Date: 2-18-86

Parameters: 2-HILTI HVB 105 connectors per profile metal deck rib (4 per flange) Parallel deck ribs

Failure Load: 70 kips

Failure Mode: Nail pullout

Discussion:

- 50^{k}: Audible cracking observed

- 70^{k}: Resistance to applied load reduces. North and south slabs separate from wide flange section due to nail pullout. Failure due to nail pullout.

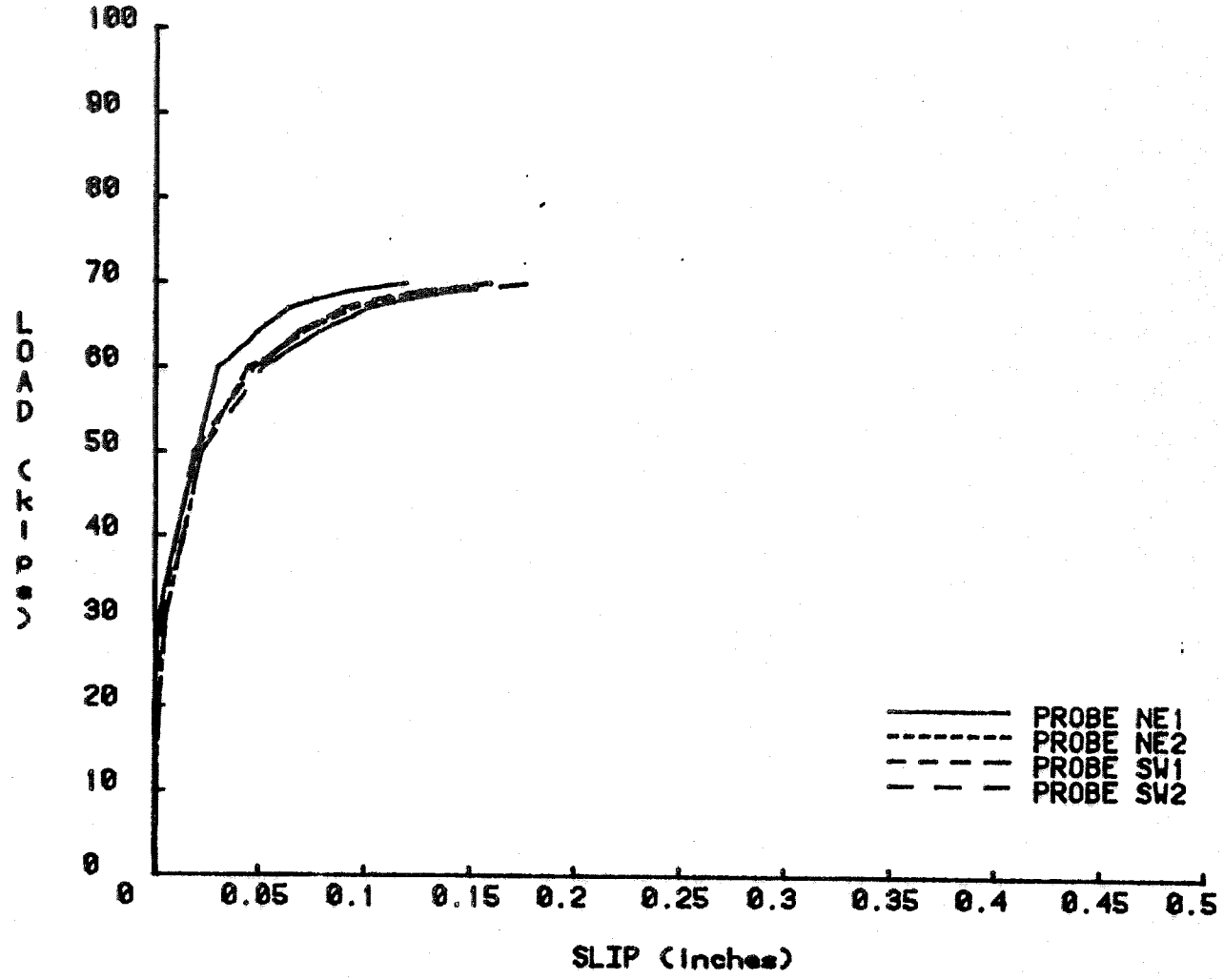


Figure D.1 Load Versus Slip, Test 10
HVB 105/Parallel Rib

TEST SUMMARY

Project: HILTI

Test No.: 2-HVB-105-PL

Test Date: 2-28-86

Parameters: 2-HILTI HVB 105 connectors
per profile metal deck rib
(4 per flange)
Parallel deck ribs

Failure Load: 71 kips

Failure Mode: Nail pullout
Shearing of nail

Discussion:

- 48^{k}: Audible cracking observed

- 71^{k}: Resistance to applied load reduces. North and south slabs separate from wide flange section as a result of nail pullout. Failure due to nail pullout (both slabs) and shearing of one nail (north slab).

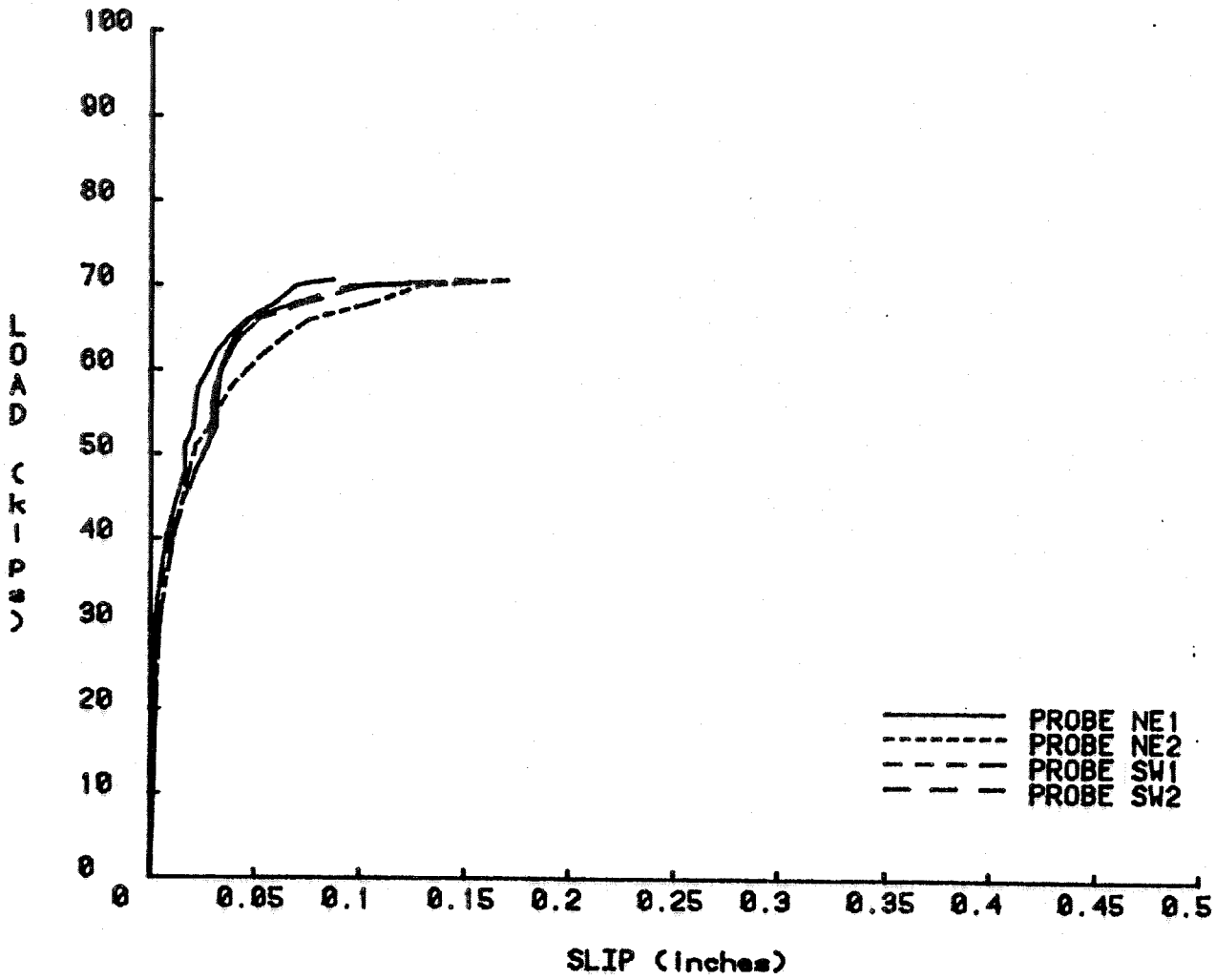


Figure D.2 Load Versus Slip, Test 11
HVB 105/Parallel Rib

TEST SUMMARY

Project: HILTI

Test No.: 3-HVB-105-PL

Test Date: 3-27-86

Parameters: 2-HILTI HVB 105 connectors
per profile metal deck rib
(4 per flange)
Parallel deck ribs

Failure Load: 69 kips

Failure Mode: Nail pullout

Discussion:

- 41^{k}: Audible cracking observed

- 69^{k}: Resistance to applied load reduces. Complete separation of north and south slabs from wide flange section occurs due to nail pullout. Failure due to nail pullout.

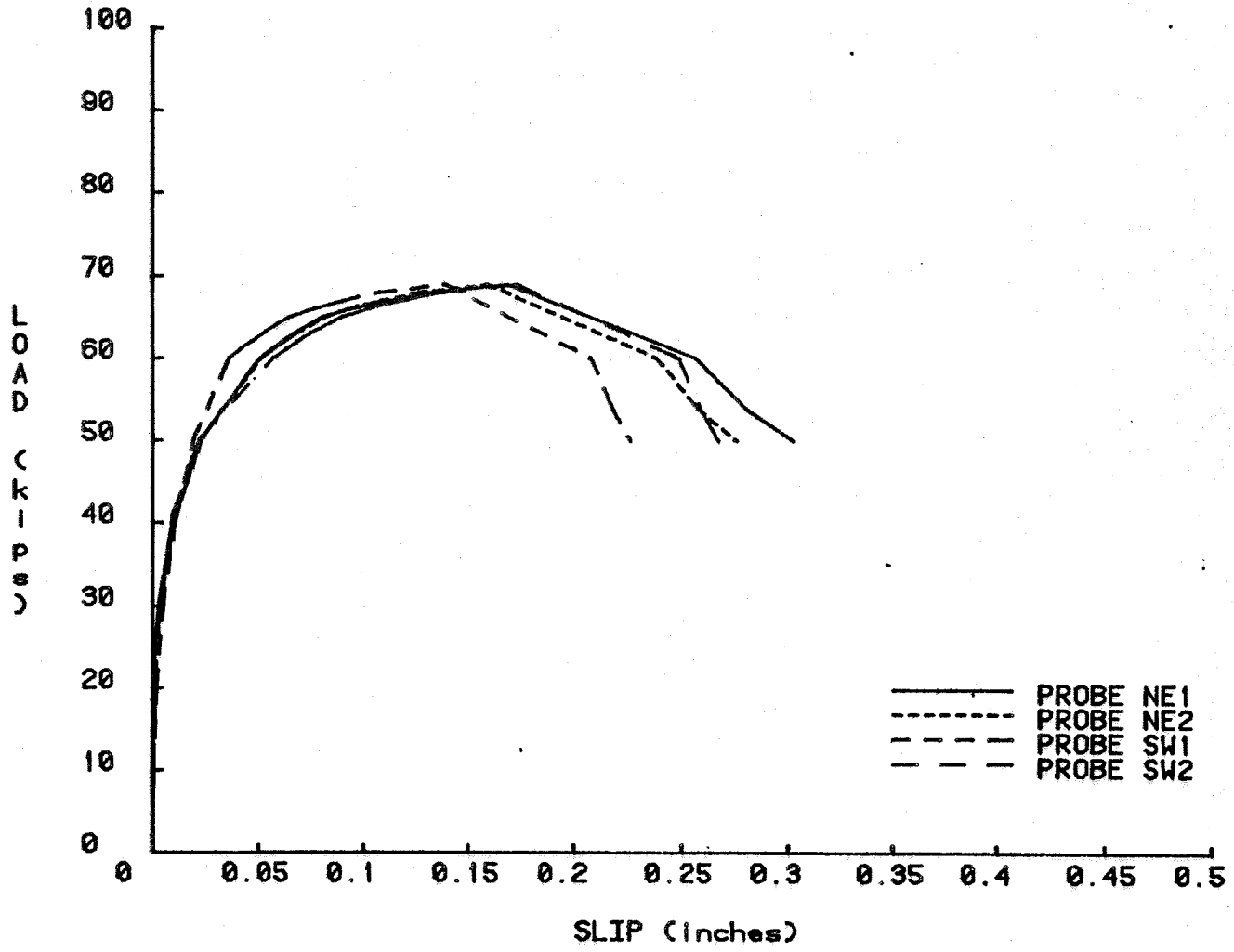


Figure D.3 Load Versus Slip, Test 12
HVB 105/Parallel Rib