LOAD-DISTRIBUTING PROPERTIES OF OPEN-GRID STEEL FLOORING

by

HAROLD KENNETH BONE

A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1952

APPROVED:

Associate Professor of Engineering Materials

In Charge of Major

Head of Department of Mechanical Engineering

Chairman of School Graduate Committee

Dean of Graduate School

Date thesis is presented August 17, 1951

Typed by Clara Homyer

ACKNOWLEDGMENTS

Acknowledgment is made to the Columbia Steel Company and Mr. J. R. Guptill, Technical Sales Representative, for sponsoring this project and furnishing specimens. Mr. Roy Edgerton of the Oregon State Highway Department, was very helpful with suggestions regarding tests and in obtaining test equipment.

Sincere appreciation is expressed to Professor C. O. Heath, who supervised the study and assisted in the evaluation of the data obtained, and to Professor S. H. Graf.

TABLE OF CONTENTS

LIST OF FIGURES

LOAD-DISTRIBUTING PROPERTIES OF OPEN-GRID STEEL FLOORING

INTRODUCTION

This is a study of the stress distributing properties of I-Beam-Lok bridge flooring manufactured by the United States Steel Corporation and distributed by the Columbia Steel Company on the West Coast.

For several years open-grid type steel decking has been used as a light weight flooring where a minimum of weight is essential. When used as bridge flooring the design has been based upon specifications for concrete floor slabs or empirical formulas, which may or may not be applicable to the various types of open-grid decking available.

A series of studies on three types of bridge decking was instigated by the Oregon State Highway Department and the American Association of State Highway Officials (AASHO). This thesis is concerned only with the I-Beam-Lok flooring.

Two types of I-Beam-Lok bridge flooring are manufactured. These are essentially the same, but differ depending upon the direction of traffic relative to the direction of the carrying 5-inch I-beams. The flooring used in this study was designed to be laid with the carrying 5-inch I-beams transverse to the direction of traffic.

inches by ¼ inches. These transverse crossbars are notched on the top edge to receive two supplementary 13/16 inch by ¼ inch bars equally spaced between and parallel to the 5-inch I-beams. The top edges of the main crossbars are dropped approximately 3/32 inch below the top of the 5-inch I-beams. The supplementary crossbars are flush with the 5-inch I-beams, and are rolled with depressions approximately 2 inches on centers. The flooring is fabricated by welding and weighs approximately 18.6 pounds per square foot.

TEST I

DETERMINATION OF MOMENT OF INERTIA AND SECTION MODULUS

This test was made by Mr. Richard H. Russell in the summer of 1950. The results are included in this thesis for a more complete study of the flooring.

Two general methods are used in the determination of Moment of Inertia and Section Modulus. One method requires the measurement of deflection and the other, stress in the outer fibers.

The stress method makes use of the simple flexure formula:

$$s = \frac{Mc}{I} = \frac{M}{Z}$$

The flexure formula primarily determines the

Section Modulus. Two values of the Section Modulus are obtained by using the measured tensile and compressive stresses in the outer fibers.

The location of the neutral axis can be determined from the tensile and compressive strain data. The Moment of Inertia can then be derived from the Section Modulus.

From the deflection measurements the Moment of Inertia can be determined directly by using the deflection formula for a simple beam with center loading:

$$y = \frac{PL^3}{48EI}$$

$$I = \frac{PL^3}{48Ey}$$

With the location of the neutral axis known, the Section Modulus can then be obtained. As the neutral axis is not in the center of the section, two values for the Section Modulus are found.

The 20-foot length of flooring was supported as a simple beam with a span of 15 feet. The supports at each end were 6-inch 12.5 pound I-beams placed on two 10-inch 25.4 pound supporting I-beams. These 10-inch I-beams rested on the base of the testing machine, and were spaced 20 inches center to center.

Type A-1, SR-4 electrical resistance strain gages were located on the top and bottom of each 5-inch I-beam under the applied load. The Baldwin-Southwark SR-4 Strain Indicator was used to measure strain. The use of this indicator is explained in the Appendix, p. 71.

Line loading to the flooring, at the center of the span, was through a 6-inch 12.5-pound I-beam. Between the flooring and the I-beam a notched 2-inch by 4-inch board was placed to protect the strain gages.

A reference bar for deflection measurements was placed across the 10-inch supporting I-beams in order to measure deflections at the center of the span. Drill point marks were made on each 5-inch I-beam of the flooring and the reference bar to provide accurate seating of the inside micrometer.

Loads were applied in increments of 1,000 pounds to 5,000 pounds where the maximum resulting stress in the 5-inch I-beams was 17,380 psi. Deflection and strain readings were made at each load. Two complete runs were made and the values averaged.

The results of this test are shown in Table I and graphically in Fig. 1, p. 8. This table also includes the results of similar tests made for the United States Steel Corporation and published in their booklet "Light Weight Steel Flooring".

Higher values for the Moment of Inertia and

TABLE I
Results of Test I
Moment of Inertia and Section Modulus

	Load, Pounds					U. S. STEEL DATA		
						Calculated Properties		
	1,000	2,000	3,000	4,000	5,000	5" I-Beam Only	5" I-Beam Plus Bars	Test Results
Tension psi	3,280	7,340	10,480	13,980	17,380			
Compression psi	3,740	7,030	10,230	13,580	16,620			
C, tension	2.53	2.55	2.53	2.54	2.56	2.12	2.70	2.53
C, compression	2.47	2.45	2.47	2.46	2.44	2.88	2.30	2.47
Deflection inches	0.141	0.269	0.393	0.517	0.625			
I inches^4 (Stress)								
Tension	4.42	4.64	4.84	4.86	4.91			
Compression	4.41	4.65	4.83	4.84	4.90			
I inches^4 (Deflection)	4.26	4.46	4.58	4.64	4.80	3.16	5.00	4.02
Z inches^3 (Stress)								
Tension	1.75	1.82	1.91	1.91	1.92			
Compression	1.78	1.90	1.95	1.97	2.00			
Z inches^3 (Deflection)								
Tension	1.68	1.75	1.81	1.83	1.87	1.50	1.85	1.59
Compression	1.72	1.82	1.85	1.88	1.97	1.10	2.17	1.63

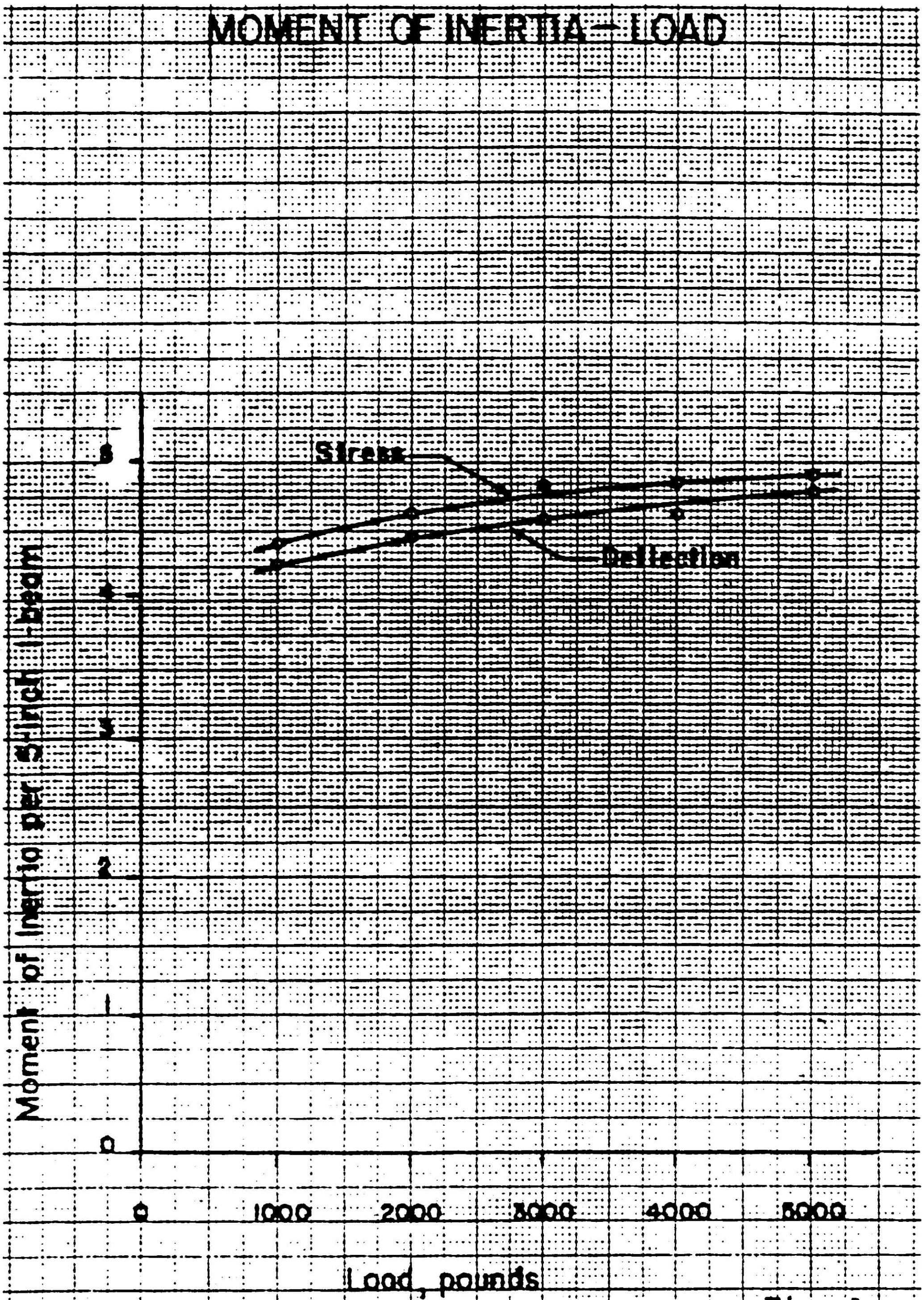

MOMENT OF INERTIA — LOAD
Moment of Inertia per 5-inch I-beam
5
4
3
2
1
0
0
1000
2000
3000
4000
5000
Load, pounds
Stress
Deflection

Fig. 1

Section Modulus were obtained with stress data than from deflection data. Both of these methods gave values somewhat smaller than the calculated Moment of Inertia of 5.00 but larger than the 4.02 given by the United States Steel Corporation tests. The results obtained from the United States Steel Corporation were made from deflection measurement only.

Referring again to Fig. 1, it is apparent that as the load increases there is a distinct increase in the Moment of Inertia. The value of the Moment of Inertia at the 5,000-pound load is 12½ percent greater than for the 1,000-pound load. It would seem that the supplementary bars are not entirely effective at the lower loads. Nevertheless these bars do increase the Moment of Inertia of the flooring by more than 50 percent over and above the calculated value of 3.16 for the 5-inch I-beam alone. This line of reasoning is further borne out by the Load-Deflection curve, Fig. 2. When the loads are increased the amount of deflection is not proportional to load. This would again indicate the Moment of Inertia is increasing with higher loads.

TEST II

STRESS DISTRIBUTION

It was the object of this test to determine the maximum allowable span using a H20 load (plus 30 percent for impact) and unit stress of 18,000 psi. In addition the distribution of the load by the 5-inch I-beams.

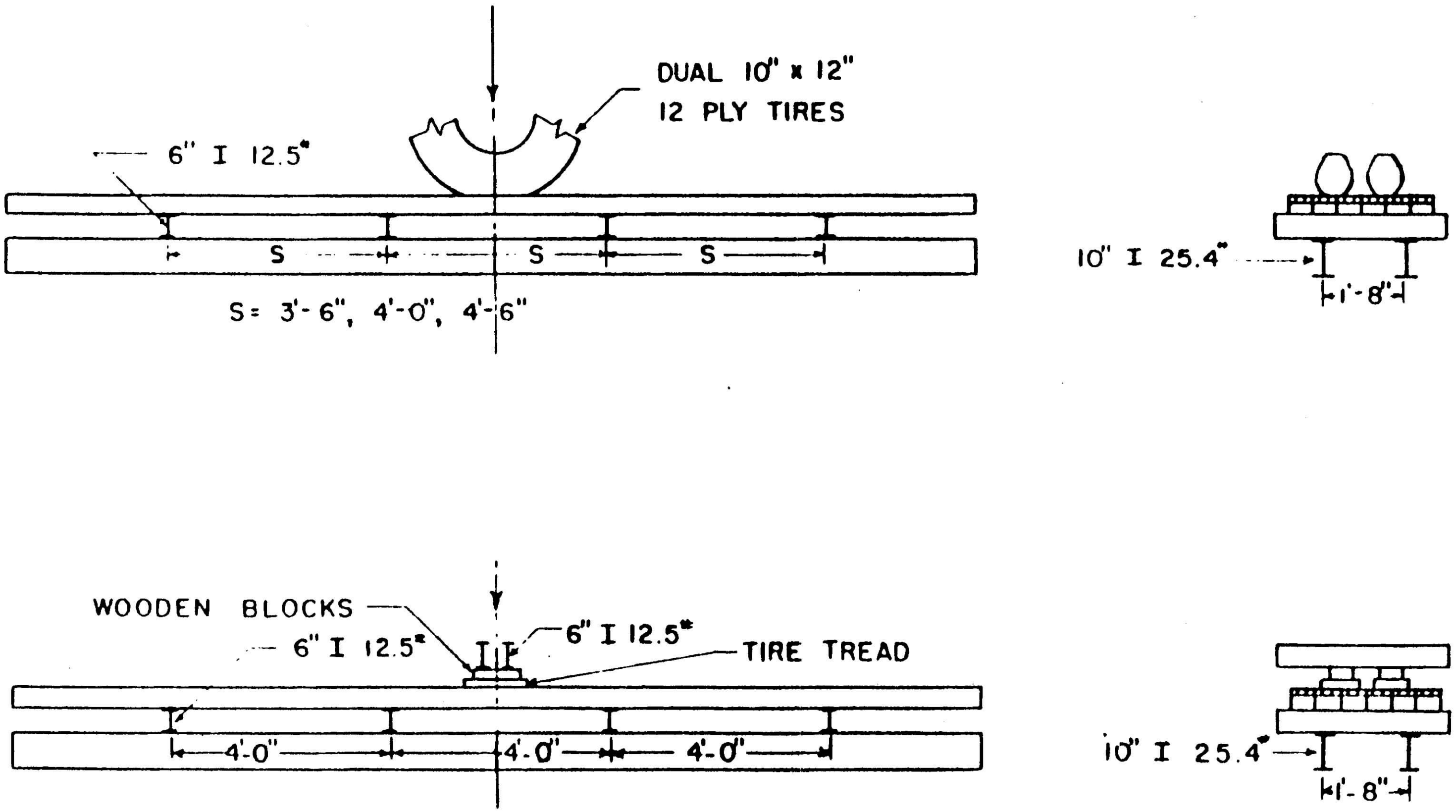
In this test the flooring was mounted as a continuous slab with three spans over four supports. Fig. 3, p. 12.

In order to use the same specimen with variable spans it was not possible to weld the flooring to the 6-inch I-beams, instead ½ inch hook-bolts were used to secure the flooring. Fig. 4, p. 13. The stringers in turn were fastened to the 10-inch supporting I-beams with C clamps.

A total of 58 SR-4 electrical resistance strain gages were located on the 5-inch I-beams and the supplementary bars. Figs. 5, 6, pp. 14 and 15. The Young Testing Machine Company Type A-Strain Indicator was used in this test giving readings directly in micro-inches per inch.

The flooring was loaded at the center of the middle span, through the 10 x 20, 12 ply heavy duty dual tires. Fig. 7, p. 16. The tires were inflated to

TEST SET UP



SCALE: 3/8" = 1'0"

Fig. 3

METHOD OF ATTACHING DECKING TO STRINGERS

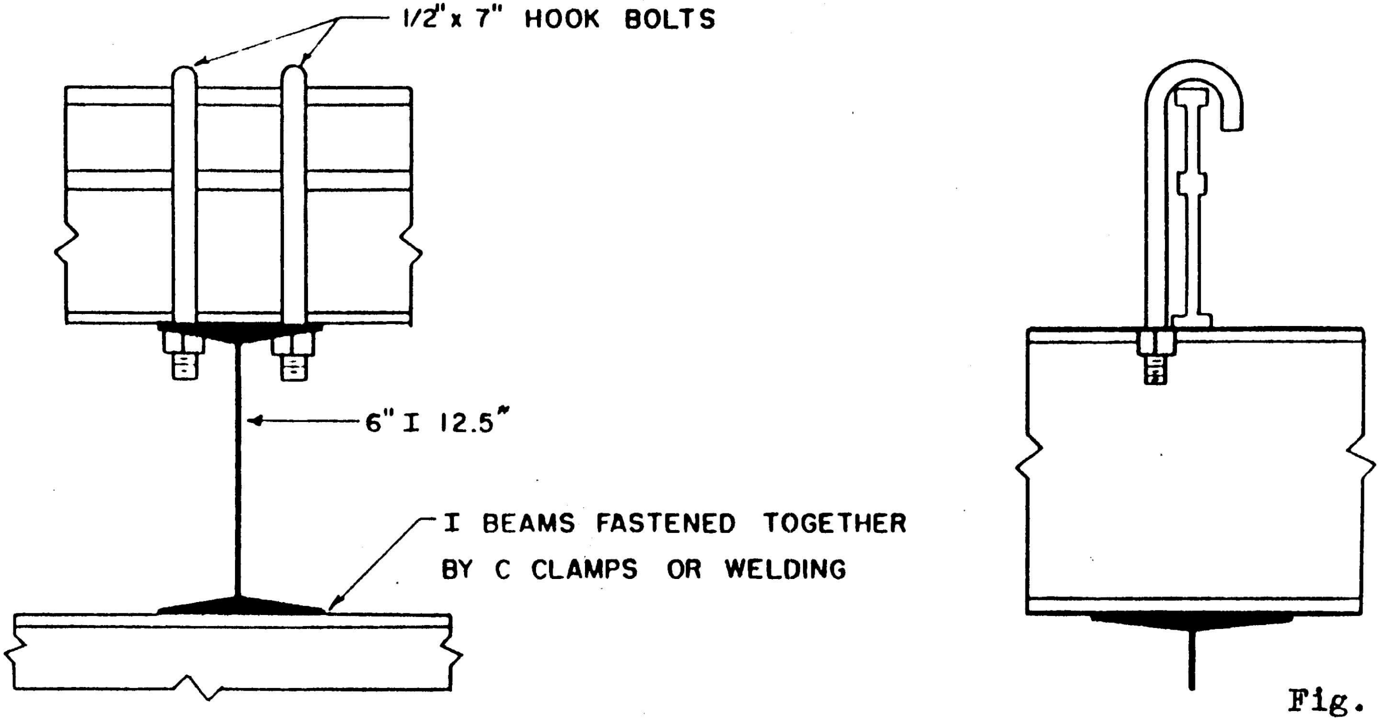
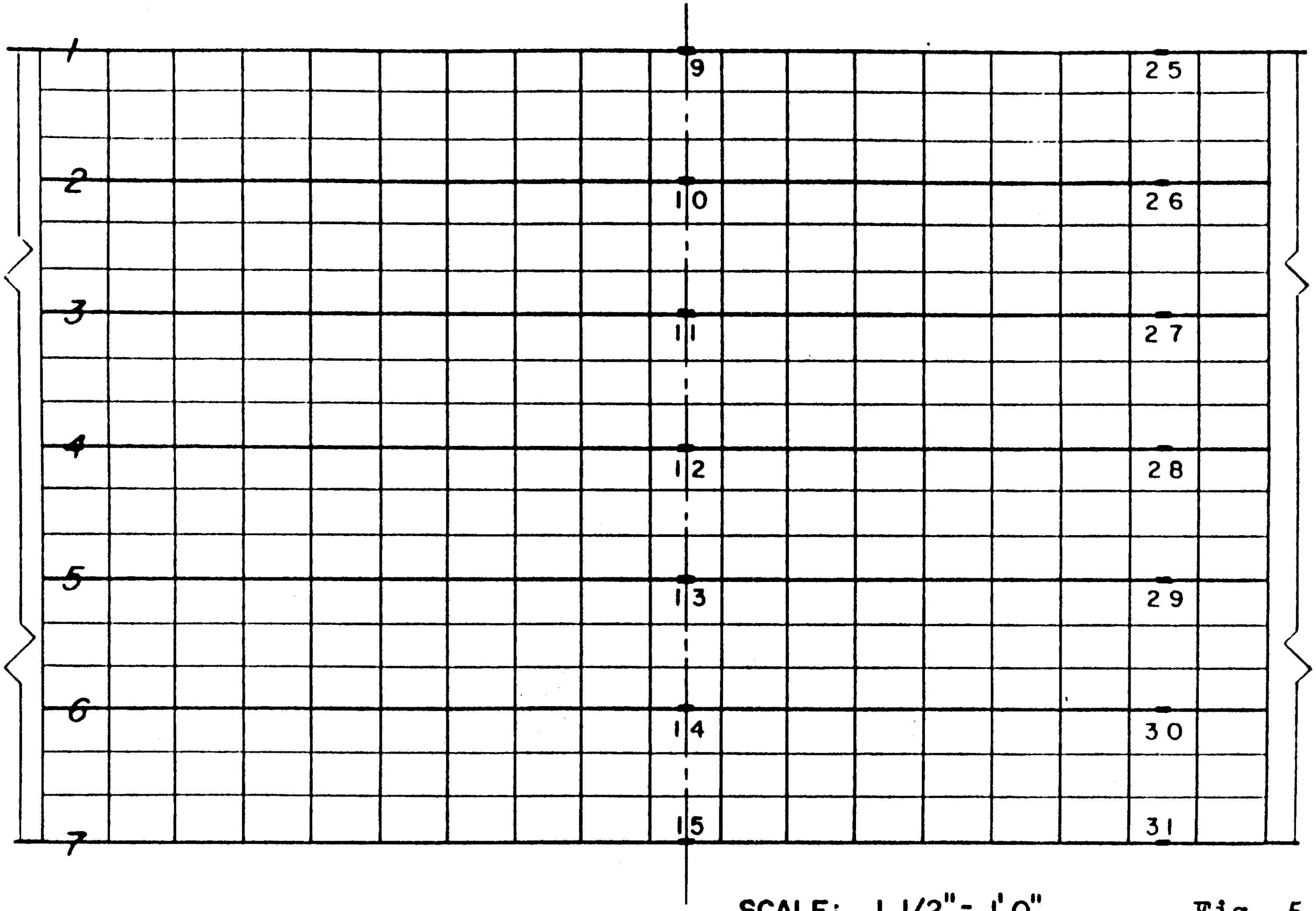


Fig. 4

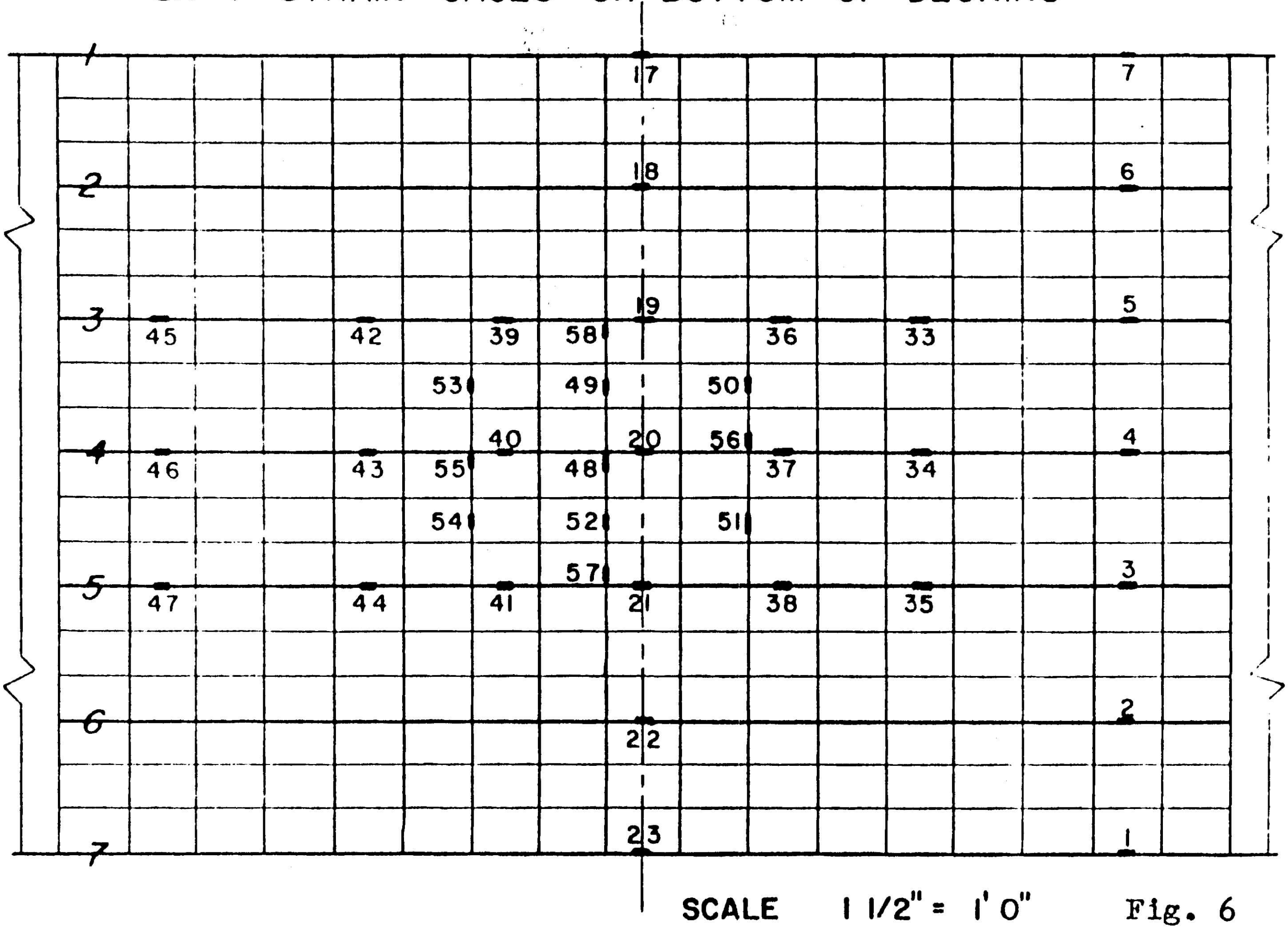
SR-4 STRAIN GAGES ON TOP OF DECKING



SCALE: 1 1/2" = 1'0"

Fig. 5

SR-4 STRAIN GAGES ON BOTTOM OF DECKING



SCALE 1 1/2" = 1' 0" Fig. 6

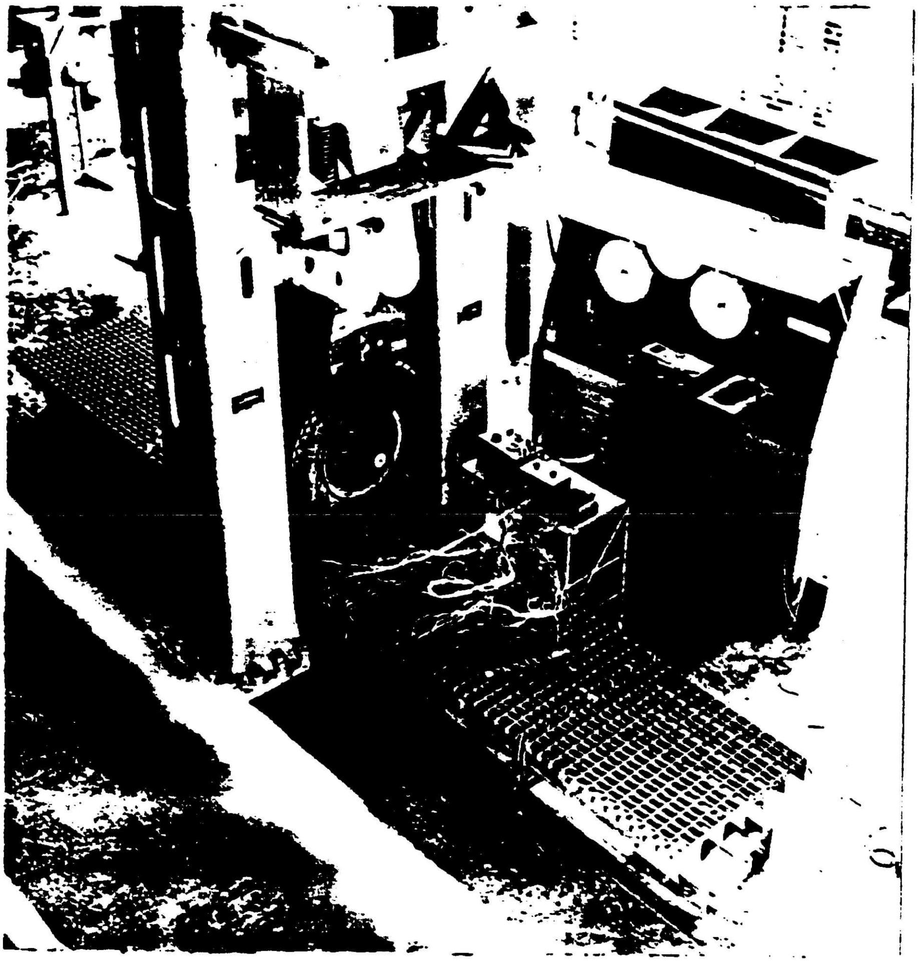


Fig. 7

General View of Test
With Dual Tires

90 psi and all runs made at this pressure. This is 20 psi above that recommended by the manufacturer but is common procedure in the trucking industry. Although the flooring was designed for loading transverse to the 5-inch I-beams, loadings were made parallel and transverse in each span length.

Two or more runs were made for each span and the values averaged. By the use of this strain data the variation of strain in both directions from the tires could be determined.

The H20 load (plus 30 percent for impact), as specified by the AASHO Standard Specifications for Highway Bridges, fifth edition, 1949, sections 3.2.5 (b) and 3.2.12 (c), was used as the design load. This amounts to a total of 15,600 pounds.

The maximum unit stress in the steel is given by sections 3.4.2 in the above specifications as 18,000 psi.

For a given maximum allowable stress and design load the maximum allowable span length may be determined.

Maximum Allowable Span

For any given span a load-stress curve will indicate that load causing a stress of 18,000 psi in the most severely stressed member of the specimen. Figs. 8, 9, 10, pp. 18, 19, and 20. Stress values indicated by

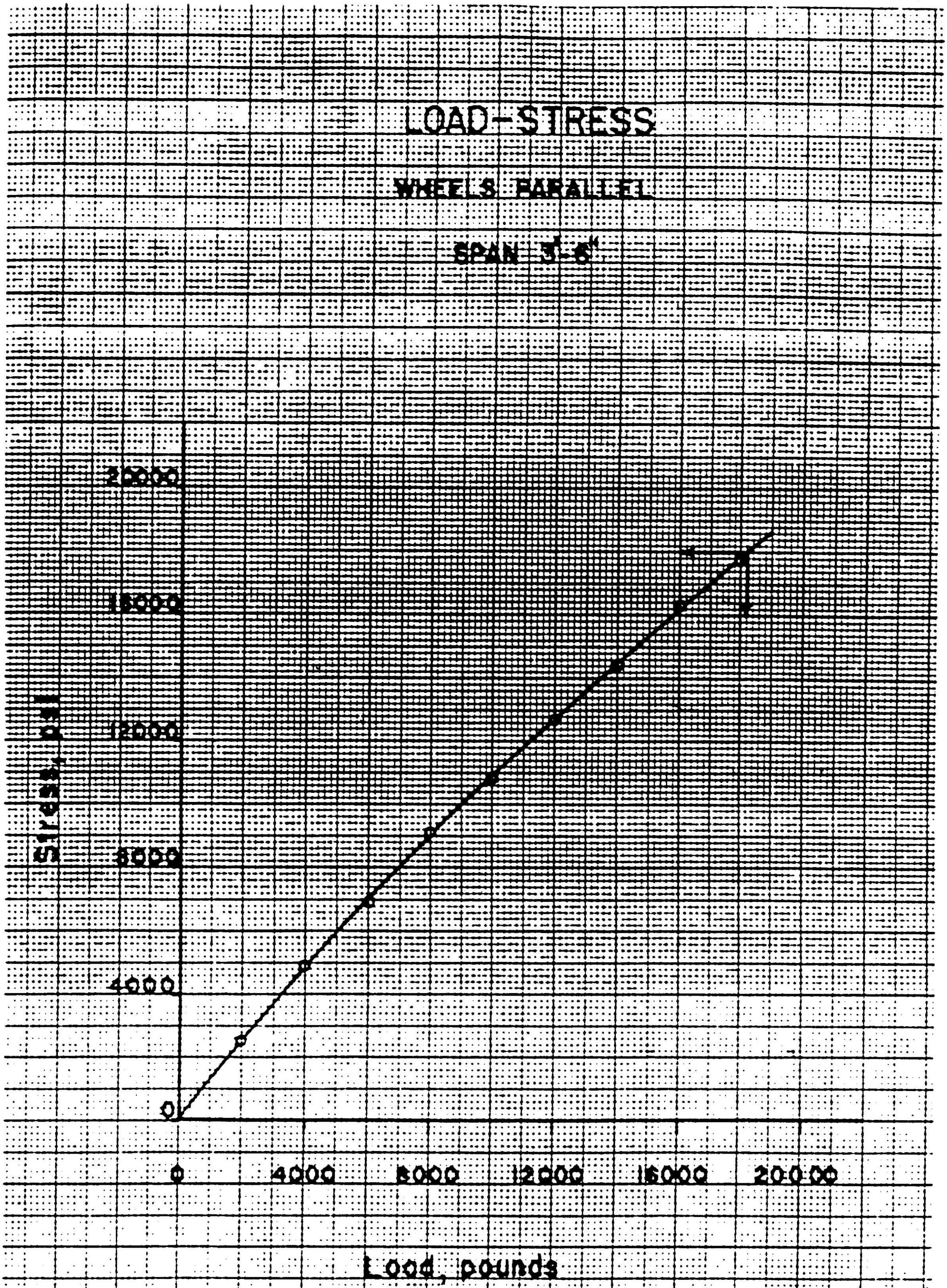

LOAD-STRESS
WHEELS PARALLEL
SPAN 3'-6"
Stress, psi
20000
16000
12000
8000
4000
0
0
4000
8000
12000
16000
20000
Load, pounds

Fig. 8

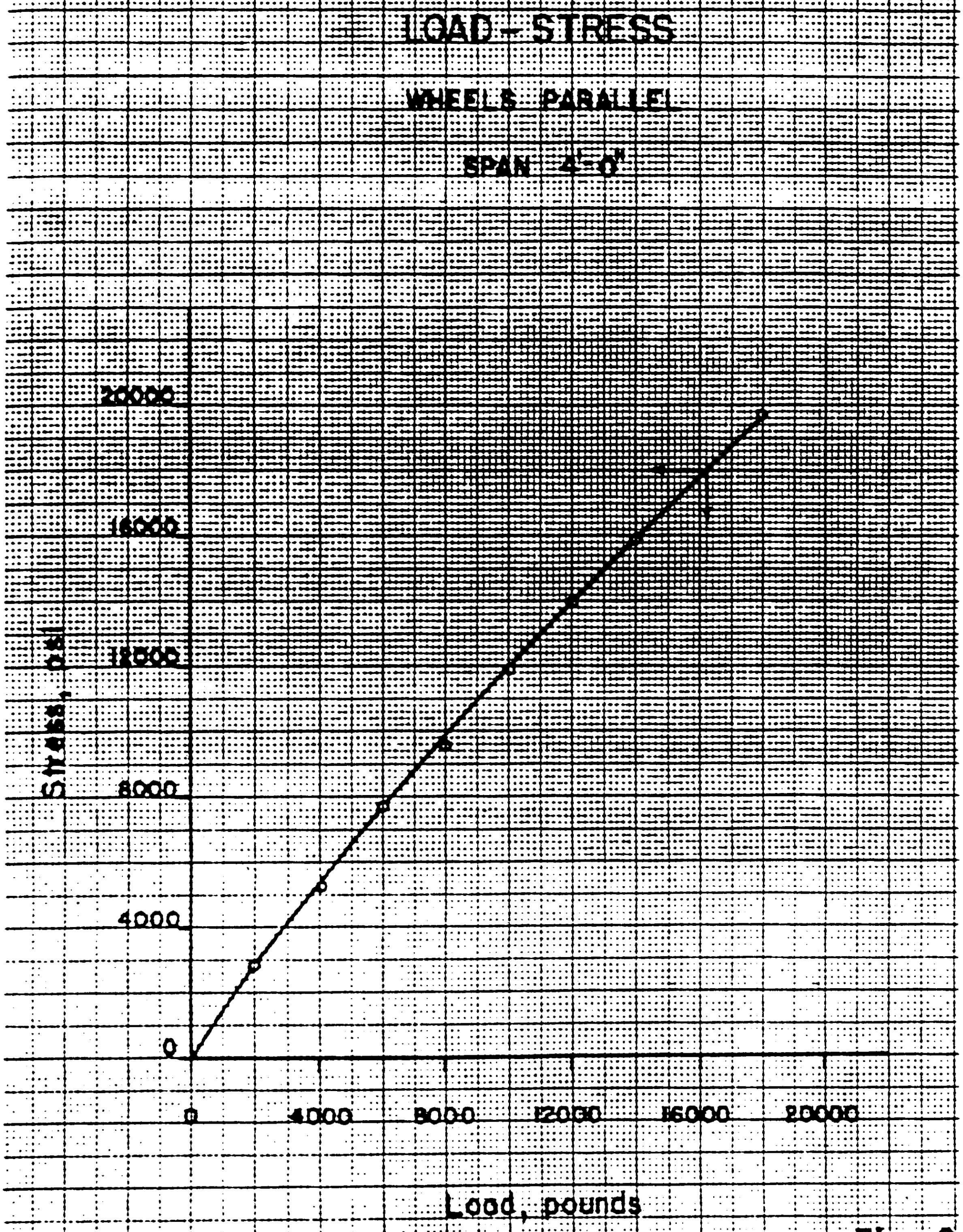

LOAD - STRESS
WHEELS PARALLEL
SPAN 4'-0"
20000
16000
12000
8000
4000
0
Stress, psi
0
4000
8000
12000
16000
20000
Load, pounds

Fig. 9

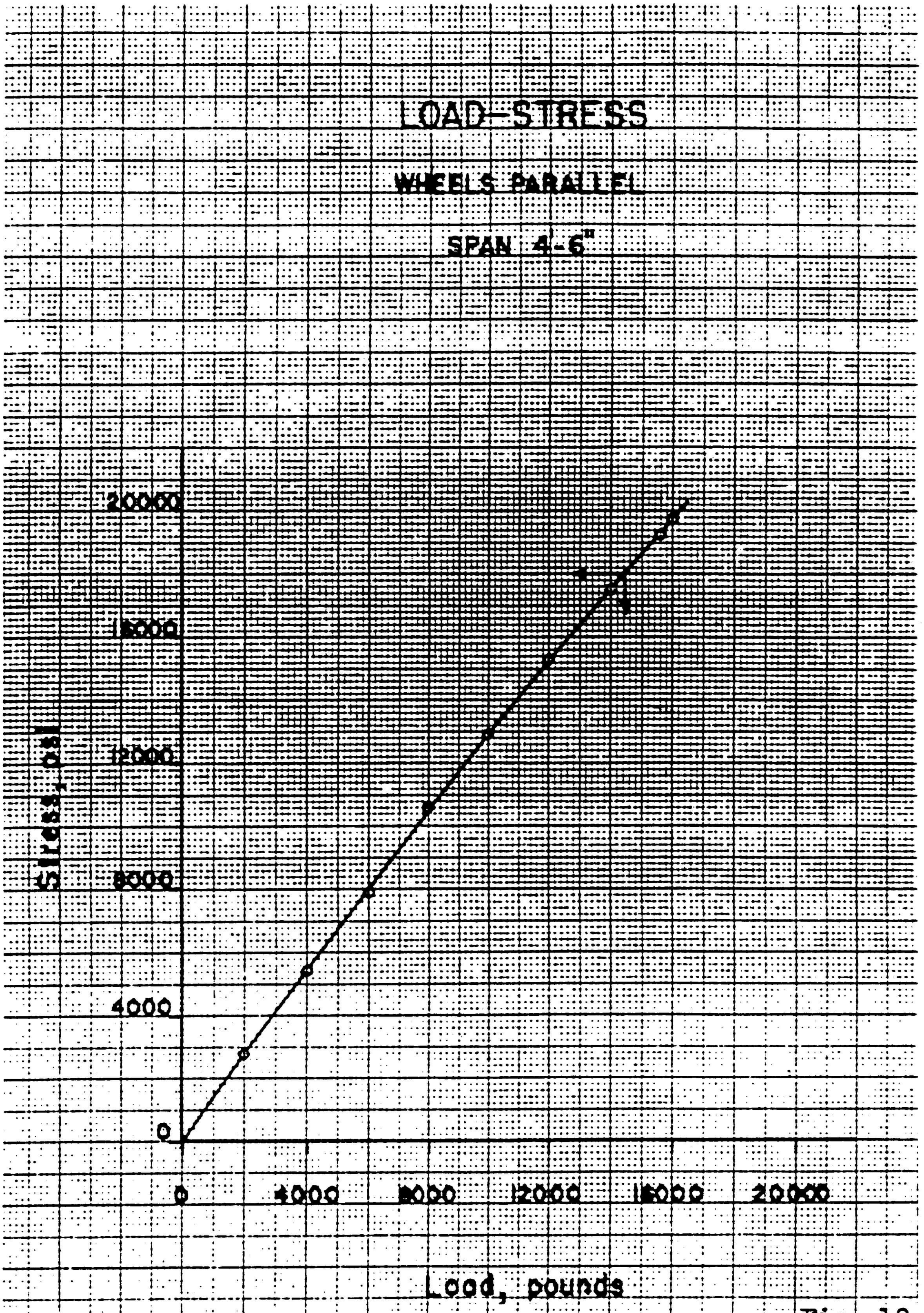

LOAD-STRESS
WHEELS PARALLEL
SPAN 4-6"
Stress, psi
20000
16000
12000
8000
4000
0
0
4000
8000
12000
16000
20000
Load, pounds

Fig. 10

gage 21 located on I-beam 5 directly under one of the tires were used to plot these curves. As the span length is increased this stress will result from lower applied loads.

From these results a composite curve, Fig. 11, p. 22, can be constructed showing the load required at any given span to cause a maximum stress of 18,000 psi in the members. From this curve the span length corresponding to a 15,600-pound load can be obtained. It is apparent that a span of 4 feet 2 inches is permissible.

Figures 12, 13, 14, pp. 23, 24, and 25, show a similar set of curves for the conditions when the tires are transverse to the 5-inch I-beams. With this type of loading a 5-inch I-beam is not the most severely stressed member. Gage 50 located as close as possible to the center of a crossbar directly under one of the tires indicates stress considerably in excess of that existing in the I-beams indicated by gage 20. Figure 15, p. 26, indicates that a span of 4 feet 0.2 inch will stress the I-beam to 18,000 psi but a much shorter span would be required for the crossbar. Unfortunately there are insufficient data to determine the allowable span if the stress in the crossbar is not to exceed 18,000 psi.

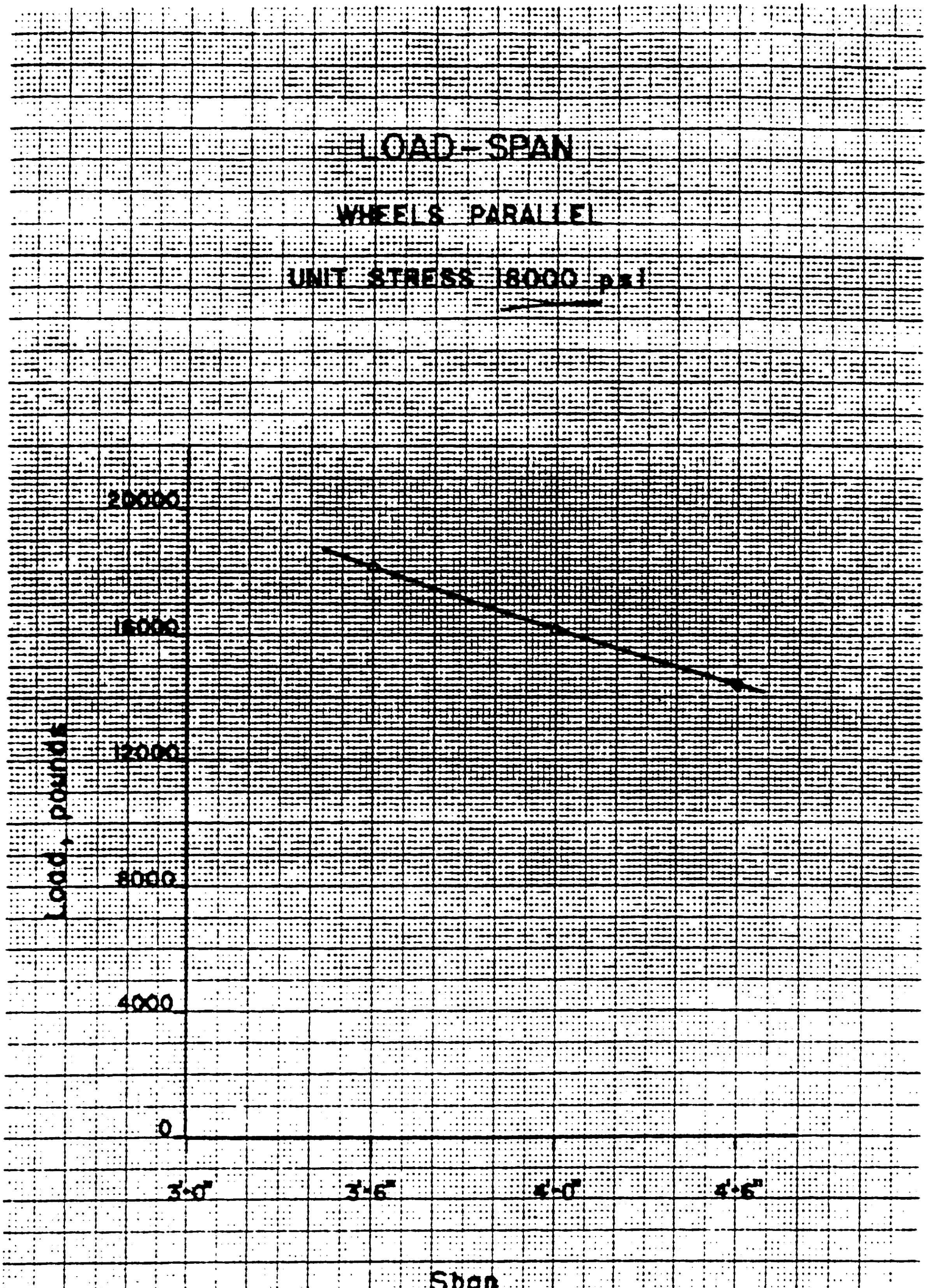

LOAD-SPAN
WHEELS PARALLEL
UNIT STRESS 18000 psi
Load, pounds
20000
16000
12000
8000
4000
0
3'-0"
3'-6"
4'-0"
4'-6"
Span

Fig. 11

LOAD-STRESS

WHEELS TRANSVERSE

SPAN 3'-6"

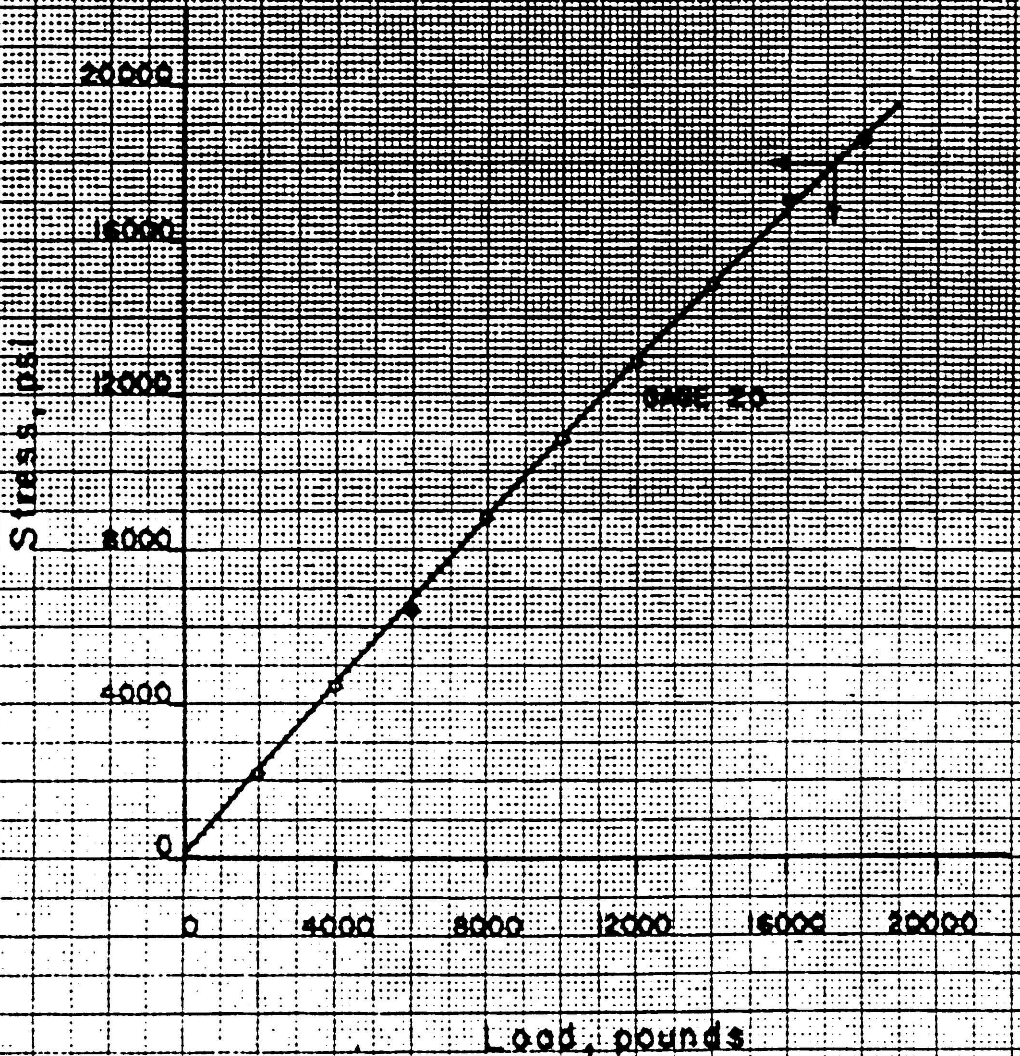


Fig.12

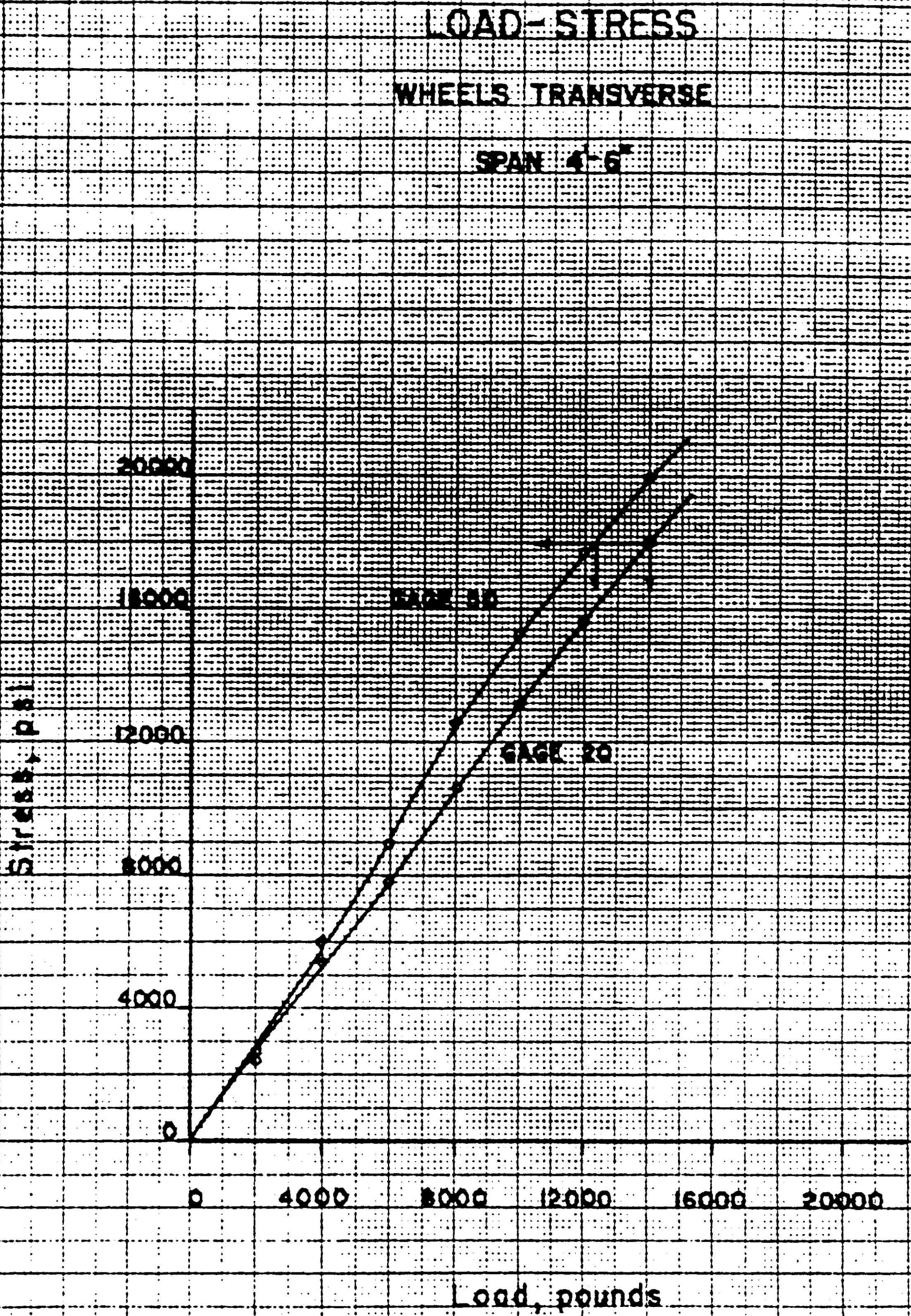

LOAD-STRESS
WHEELS TRANSVERSE
SPAN 4'-6"
GAGE 50
GAGE 20
Stress, psi
20000
16000
12000
8000
4000
0
0
4000
8000
12000
16000
20000
Load, pounds

Fig. 14

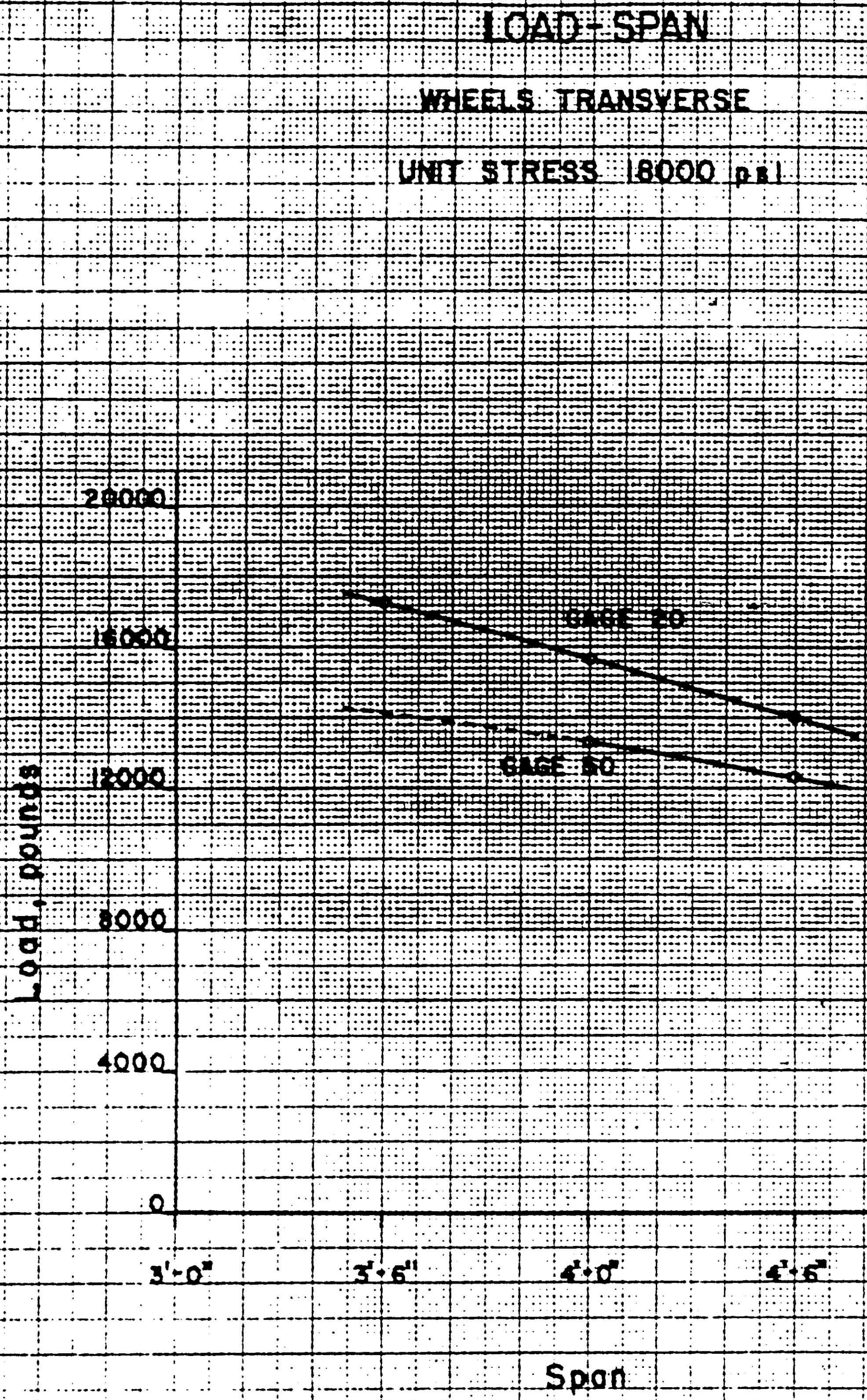

LOAD-SPAN
WHEELS TRANSVERSE
UNIT STRESS 18000 psi
20000
16000
12000
8000
4000
0
Load, pounds
GAGE 20
GAGE 30
3'-0"
3'-6"
4'-0"
4'-6"
Span

Fig. 15

Effective Distribution

The stress cross section curves, Figs. 16, 17, 18, pp. 28, 29, and 30, show the stress in each I-beam for any given load. Since stress is proportional to load, these curves indicate the manner in which the applied loads are shared among the I-beams.

For design purposes it is convenient to refer to an effective load distribution. The effective load distribution was determined at design load by dividing the sum of the stresses by the average of the two maximum stresses. By averaging the two maximum stresses any asymmetry due to eccentric loading would be eliminated.

The values of effective load distribution at design load for the three different spans are shown below:

TABLE II

Span	Effective Distribution (5-inch I-beams plus two parallel bars)
3' 6"	3.95
4' 0"	4.15
4' 6"	4.21

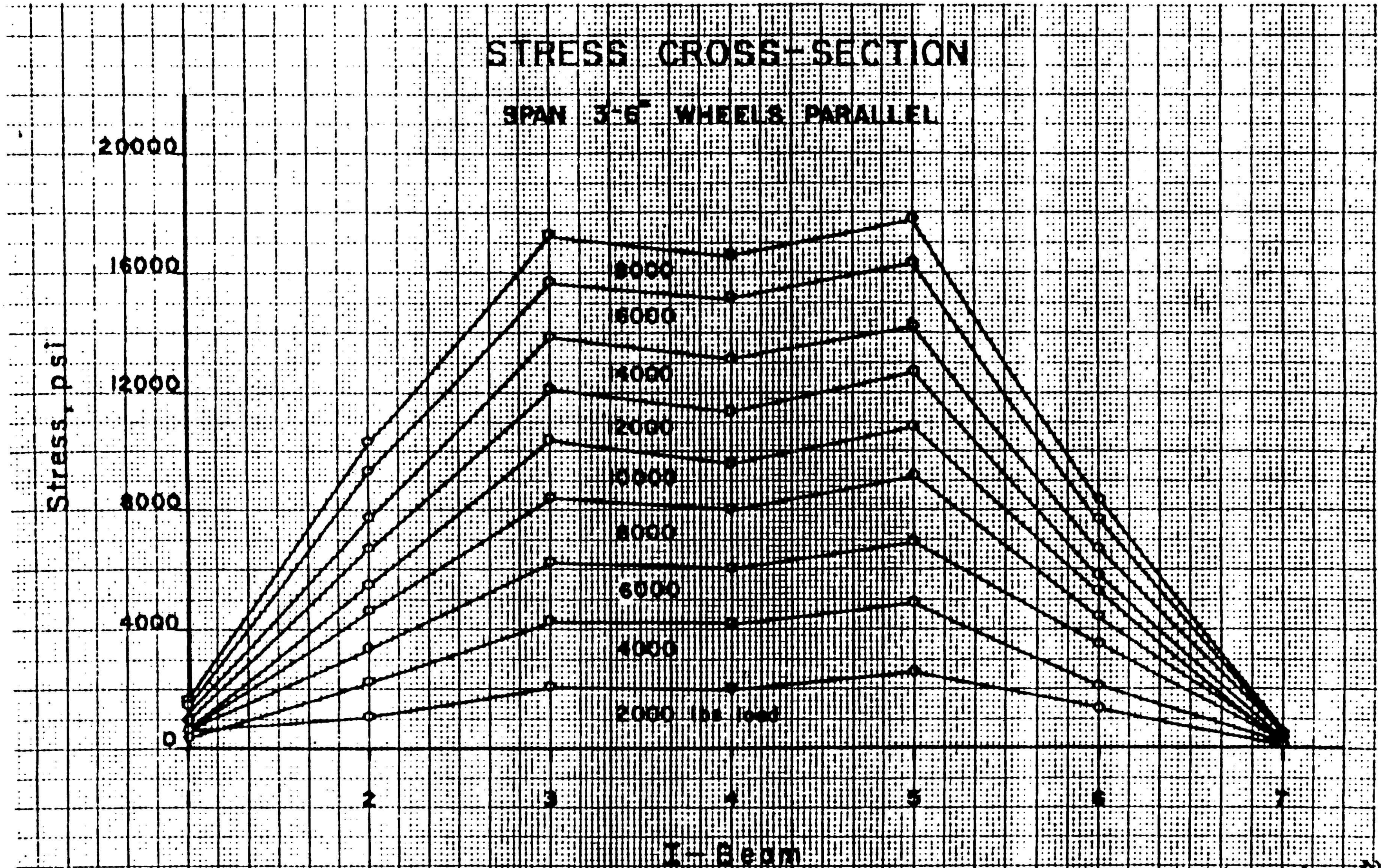

STRESS CROSS-SECTION
SPAN 3'-6" WHEELS PARALLEL
Stress, psi
20000
16000
12000
8000
4000
0
2
3
4
5
6
7
I-Beam
18000
16000
14000
12000
10000
8000
6000
4000
2000 lbs load

Fig. 16

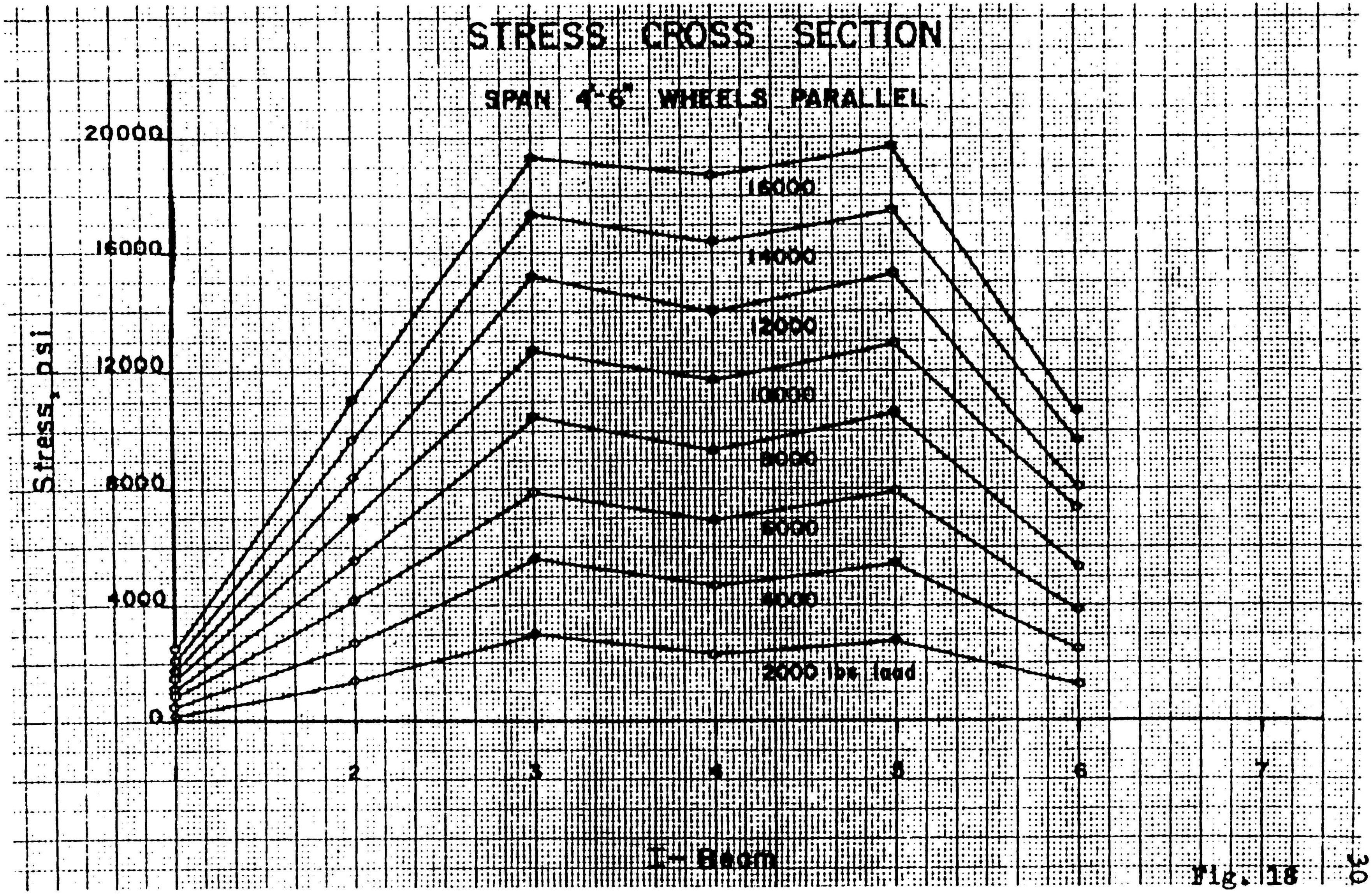

STRESS CROSS SECTION
SPAN 4'-6" WHEELS PARALLEL
Stress, psi
20000
16000
12000
8000
4000
0
2
3
4
5
6
7
16000
14000
12000
10000
8000
6000
4000
2000 lbs load
I-Beam

Fig. 18

It will also be noted that the effective load distribution increases with the span length.

The AASHO Standard Specifications for Highway Bridges, fifth edition, 1949, sec. 3.35 (c), states:

> "A wheel load shall be distributed normal to the main bars, over a width of W plus twice the distance center to center of the main bars, where W equals 1 inch per ton of weight of loaded truck."

I-Beam-Lok Flooring by these specifications should exhaust the H20 load (plus 30 percent for impact) in 44 inches.

The stress cross section curves indicate that the width of the specimen used in this test did not exhaust the distribution of the design load. Too narrow **The addition of one more section would possibly have exhausted this load.**

To compare the stress across the flooring for the two methods of loading, stress cross section curves have been drawn for each span at the design load. Figs. 19, 20, 21, pp. 32, 33, and 34. It should be pointed out that these curves may be compared on a stress basis. They are not comparable on a load basis. When the wheels are transverse the dual tires will give the effect of two point loading and therefore lower stress than would exist had the same load been applied centrally. The sum of the stresses across the flooring with the wheels transverse are therefore lower than those for

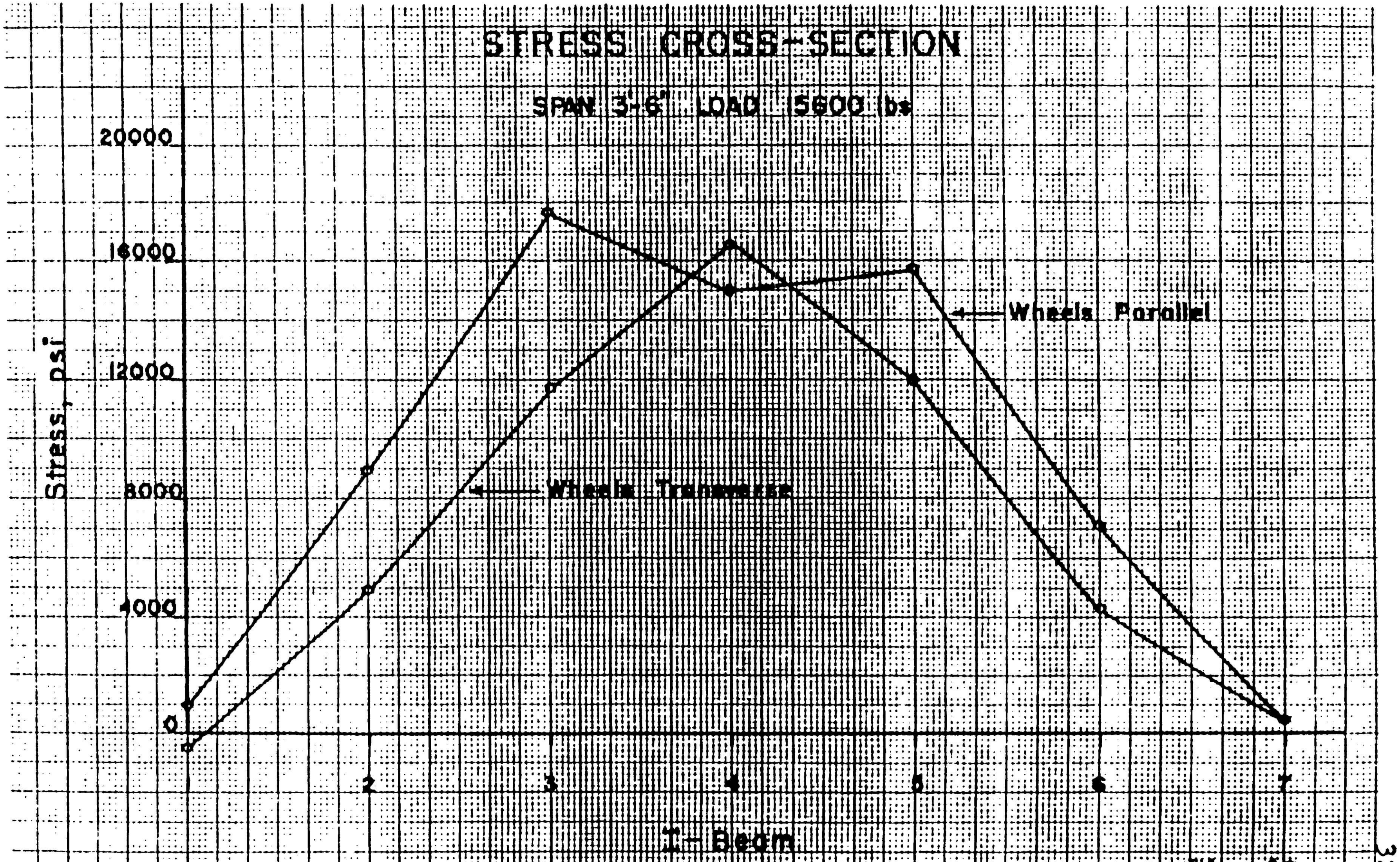

STRESS CROSS-SECTION
SPAN 3'-6" LOAD 15600 lbs
Stress, psi
20000
16000
12000
8000
4000
0
2
3
4
5
6
7
I- Beam
Wheels Parallel
Wheels Transverse

Fig. 19

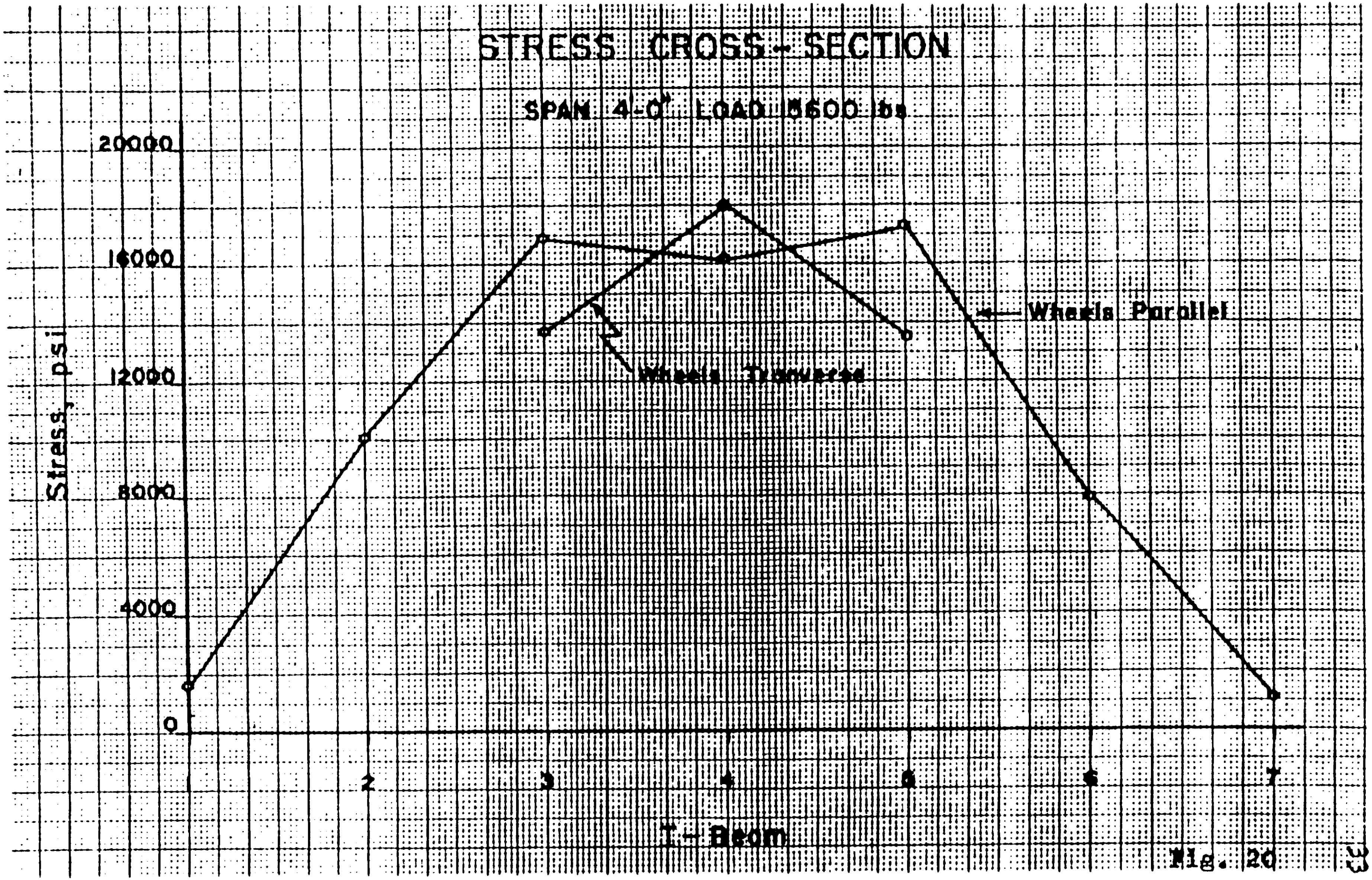

STRESS CROSS-SECTION
SPAN 4-0" LOAD 5600 lbs
Stress, psi
20000
16000
12000
8000
4000
0
2
3
4
5
6
7
I-Beam
Wheels Parallel
Wheels Traverse

Fig. 20

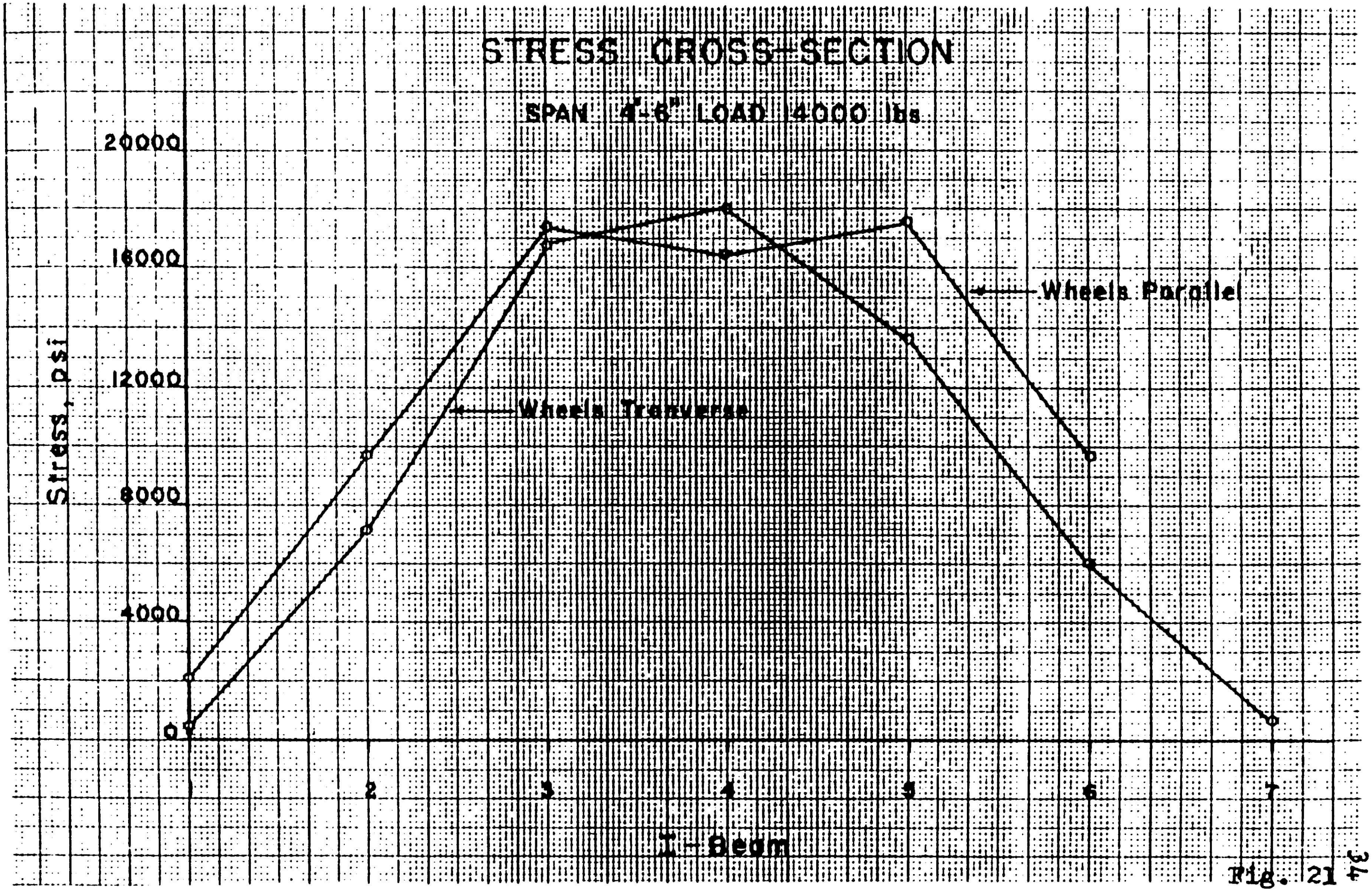

STRESS CROSS-SECTION
SPAN 4'-6" LOAD 4000 lbs
Stress, psi
20000
16000
12000
8000
4000
0
1
2
3
4
5
6
7
I-Beam
Wheels Parallel
Wheels Transverse

Fig. 21

the wheels placed parallel, although the total load is the same in both cases.

The maximum allowable span for I-Beam-Lok flooring, with the H20 load (plus 30 percent for impact) and unit stress of 18,000 psi, is 4 feet 2 inches when the 5-inch I-beams are parallel to the direction of traffic. When the 5-inch I-beams are transverse to the direction of traffic, the maximum allowable span length is 4 feet 0.02 inch, however, the crossbars should be strengthened.

TEST III

TEST TO DESTRUCTION

The factor of safety is usually based upon the allowable unit stress and the minimum yield point of the material. With a unit stress of 18,000 psi and a minimum yield point of 33,000 psi, for the ASTM Type A-7 steel used in the construction of I-Beam-Lok flooring, a factor of safety of 1.83 is indicated.

The actual factor of safety should be based on the actual load to cause failure and the design load.

To determine this factor of safety, using a specific span length, was the object of this test.

The flooring was set up as a continuous beam with three spans over four supports. Fig. 3, p. 12.

A span length of 4 feet was chosen instead of the maximum allowable span of 4 feet 2 inches determined in Test II. This was also the span recommended by the manufacturer.

The flooring was welded to the 6-inch 12.5 pound I-beam stringers according to the manufacturer's specifications. The stringers were in turn welded to the 10-inch 25.4-pound supporting I-beams which were spaced 20 inches center to center.

It was necessary in this test to replace the dual tires with some other means of loading which would duplicate the stress distribution of the dual tires.

To obtain the size and shape of the blocks, impressions were made of the dual tires at design load. Fig. 22, p. 37. These impressions were elliptical in shape, with a major axis of 13.75 inches and minor axis of 7.75 inches. Two wooden blocks, 2 inches thick, were substituted for the dual tires. To compensate for the extra width of the tire casing placed between the blocks and the flooring a strip ¼ inch wide was trimmed from around the edges.

To further simulate the uniform pressure of the pneumatic tires, a piece of tire casing was placed, tread down, beneath the blocks. Tests were made to verify that the load distribution of the blocks was the same as the dual tires. Fig. 23, p. 38. In this test

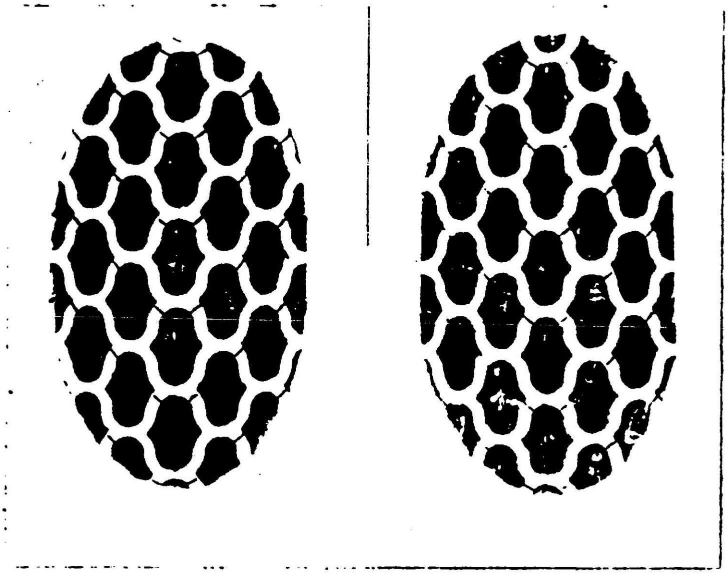


Fig. 22

Dual Tire Impressions

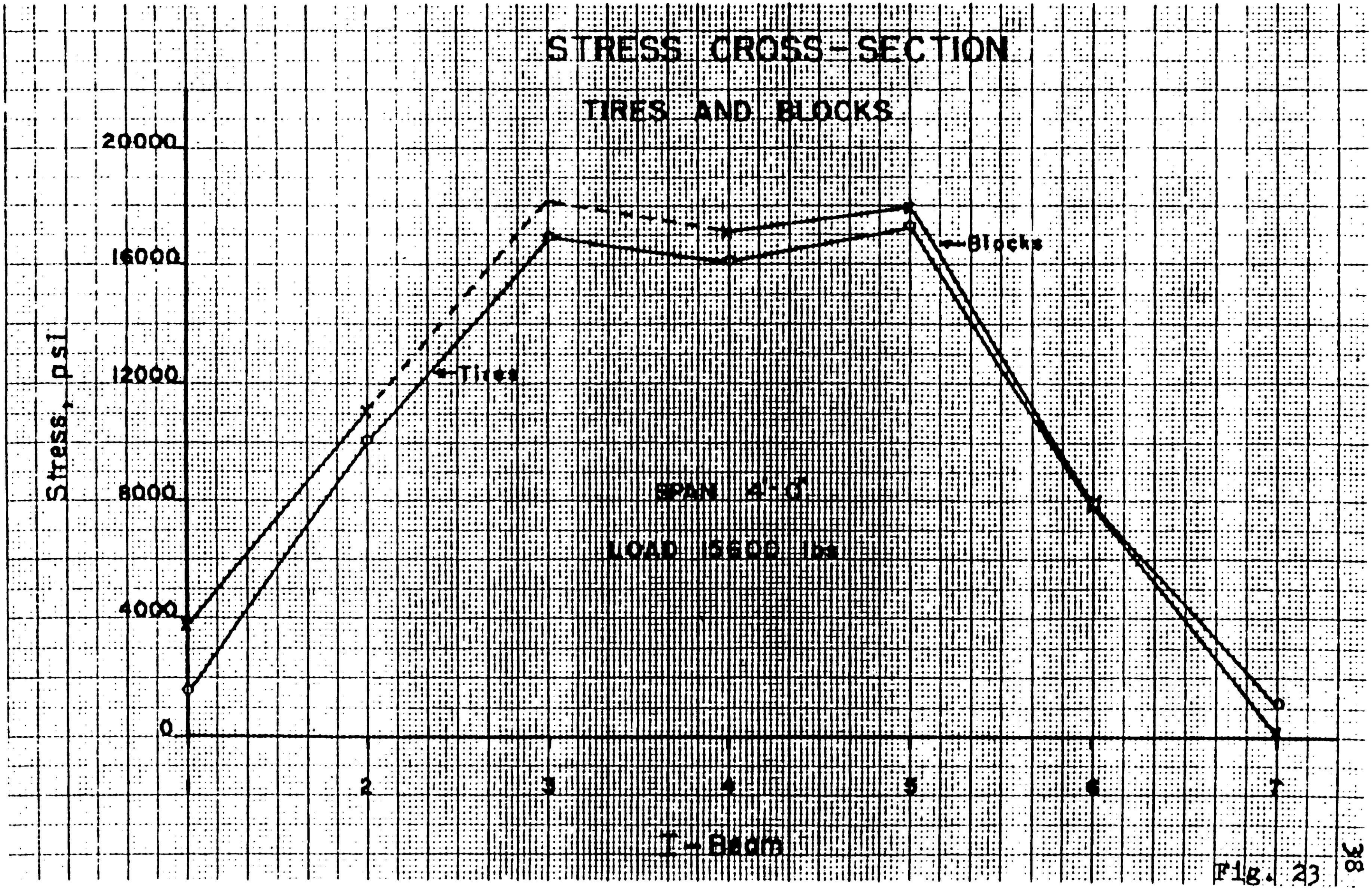

STRESS CROSS-SECTION
TIRES AND BLOCKS
SPAN 4'-0"
LOAD 15600 lbs
Stress, psi
20000
16000
12000
8000
4000
0
2
3
4
5
6
7
I-Beam
Tires
Blocks

Fig. 23

gage 19 was assumed to be defective since the zero reading was greater than usual and a very high stress was indicated. The symmetry of the remaining gages justified this assumption.

The loading set-up consisted of a 10 x 12 inch timber 2 feet long between the head of the testing machine, the wooden blocks and tire casings. Figs. 24, 25, pp. 40 and 41.

Deflection readings were not made in this test because of the lack of rigity in the supports.

Strain readings were taken with gage 21, located on I-beam 5 and under one of the blocks.

The load was applied to the decking in increments of 2,000 pounds until a load of 50,000 pounds was reached where gage 21 failed. Loading continued to 110,500 pounds and the 10 x 12 inch timber replaced with four 4-inch 7.7-pound I-beams. Fig. 26, p. 42. The load was increased to 136,500 pounds. At this point the deformation of the flooring allowed the 4-inch I-beams of the loading device to bear on the specimen.

The flooring was examined for ruptures and none were found. All welds were intact.

The deflection of the center 5-inch I-beams relative to the outside 5-inch I-beams was measured. The values are given in Table III:

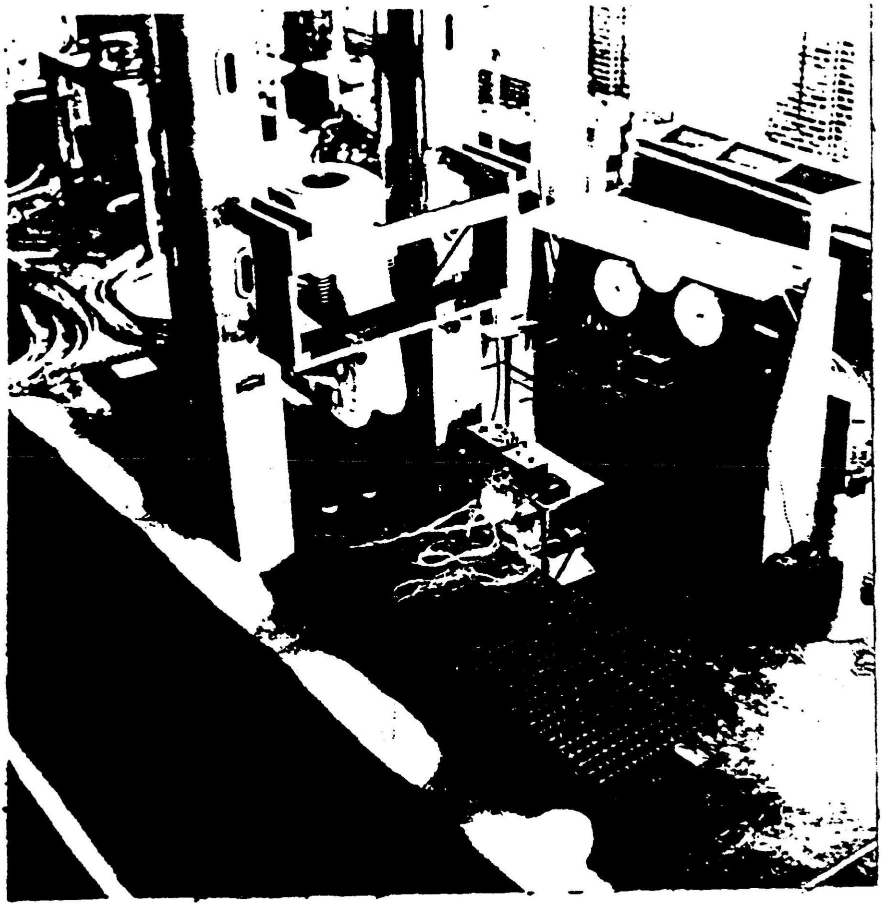


Fig. 24

General View of the
Test to Destruction

Fig. 25
Loading Device, with Timber,
For Test to Destruction

TABLE III

5-inch I-beam	Deflection Inches
2	1.28
3	2.58
4	2.66
5	2.56
6	1.20

The load strain curve plotted for this test indicates the elastic limit of the decking was reached at a load of 34,000 pounds. Fig. 27, p. 44.

The factor of safety based on a design load of 15,600 pounds is therefore 2.18.

CONCLUSIONS

From the results of the tests the following conclusions have been drawn:

(1) The Moment of Inertia for I-Beam-Lok Flooring was 4.91 inches^4.

(2) The supplementary bars increase the Moment of Inertia of the flooring 35 to 50 percent over and above what it would be for the 5-inch I-beams alone, this increase being greater the higher the load.

(3) The maximum allowable span with the H20 load (plus 30 percent for impact) was found to be 4 feet 2 inches when the tires are parallel to the 5-inch I-beams. With the tires in a transverse direction a span of 4 feet 0.20 inches would not overstress the 5-inch I-beams but the transverse bars would be stressed to approximately 21,600 psi. The transverse bars should be strengthened when the flooring is to be used transverse to the direction of traffic.

(4) For the recommended span of 4 feet the effective load distribution was found to be 4.15 repeating sections (one 5-inch I-beam plus two parallel bars). This is lower than the 4.75 value which would be obtained using the AASHO specifications. The value is somewhat lower because of the small width of the

specimen tested.

(5) The effective load distribution is dependent upon span length, increasing with longer spans.

(6) The factor of safety shown in the test, using a continuous span with three 4-foot spans, and the load applied parallel to the 5-inch I-beams, was 2.18 based on the apparent yielding of the specimen. A further increase of 8.75 times the design load caused no weld failures and only severe deformation in the flooring.

BIBLIOGRAPHY

American association of state highway officials. Standard specifications for highway bridges. Fifth edition. Washington, D.C., the society, 1949. 284p.

United States steel corporation, "Light Weight Steel Flooring", 1941. 107p. (issued by the company).

APPENDIX

TEST I

Run 1

	Deflection		Strain	
Load, Pounds	**Gage No.**	**Deflection**	**Δ S**	**Average Strain**
1,000	9	-	200	
	10	-	141	
	11	-	124	
	12	-	121	
	13	-	140	
	14	-	169	
	15	-	219	
			Av = 159	0.0001297
	17	0.159	186	
	18	0.153	162	
	19	0.143	137	
	20	0.149	131	
	21	0.144	141	
	22	0.141	162	
	23	0.145	197	
	Av =	0.147	Av = 159	0.0001297
2,000	9	-	348	
	10	-	260	
	11	-	239	
	12	-	242	
	13	-	263	
	14	-	331	
	15	-	373	
			Av = 294	0.0002398
	17	0.285	324	
	18	0.271	294	
	19	0.261	263	
	20	0.255	263	
	21	0.263	283	
	22	0.266	311	
	23	0.274	352	
	Av =	0.268	Av = 299	0.0002440

TEST I

Run 1

	Deflection		Strain	
Load, Pounds	Gage No.	Deflection	△ S	Average Strain
3,000	9	-	494	
	10	-	381	
	11	-	351	
	12	-	360	
	13	-	381	
	14	-	445	
	15	-	526	
			Av = 420	0.000342
	17	0.410	453	
	18	0.398	423	
	19	0.386	355	
	20	0.385	385	
	21	0.382	408	
	22	0.391	447	
	23	0.394	482	
	Av =	0.392	Av = 422	0.000344
4,000	9	-	642	
	10	-	502	
	11	-	468	
	12	-	483	
	13	-	510	
	14	-	601	
	15	-	697	
			Av = 558	0.000455
	17	0.532	590	
	18	0.514	568	
	19	0.499	487	
	20	0.507	520	
	21	0.517	553	
	22	0.507	595	
	23	0.517	648	
	Av =	0.513	Av = 566	0.000461

TEST I

Run 1

	Deflection		Strain	
Load, Pounds	Gage No.	Deflection	ΔS	Average Strain
5,000	9	-	775	
	10	-	623	
	11	-	573	
	12	-	612	
	13	-	631	
	14	-	720	
	15	-	829	
			Av = 680	0.000554
	17	0.633	717	
	18	0.590	733	
	19	0.629	648	
	20	0.619	667	
	21	0.623	709	
	22	0.629	754	
	23	0.641	783	
	Av =	0.623	Av = 716	0.000584

TEST I

Run 2

	Deflection		Strain	
Load, Pounds	Gage No.	Deflection	Δ S	Average Strain
1,000	9	-	186	
	10	-	127	
	11	-	113	
	12	-	122	
	13	-	120	
	14	-	157	
	15	-	205	
			Av = 147	0.0001198
	17	0.143	177	
	18	0.143	149	
	19	0.131	133	
	20	0.125	128	
	21	0.134	136	
	22	0.125	159	
	23	0.138	191	
	Av =	0.134	Av = 153	0.0001248
2,000	9	-	346	
	10	-	256	
	11	-	232	
	12	-	235	
	13	-	251	
	14	-	269	
	15	-	380	
			Av = 281	0.0002290
	17	0.283	324	
	18	0.270	294	
	19	0.262	264	
	20	0.254	260	
	21	0.269	282	
	22	0.275	322	
	23	0.274	363	
	Av =	0.270	Av = 301	0.0002454

TEST I

Run 2

	Deflection		Strain	
Load, Pounds	Gage No.	Deflection	△ S	Average Strain
3,000	9	-	487	
	10	-	376	
	11	-	346	
	12	-	362	
	13	-	378	
	14	-	445	
	15	-	523	
			Av = 417	0.000340
	17	0.413	459	
	18	0.398	440	
	19	0.388	386	
	20	0.387	395	
	21	0.403	421	
	22	0.399	458	
	23	0.395	492	
	Av =	0.398	Av = 436	0.000355
4,000	9	-	626	
	10	-	501	
	11	-	461	
	12	-	493	
	13	-	507	
	14	-	596	
	15	-	676	
			Av = 551	0.000450
	17	0.535	592	
	18	0.526	579	
	19	0.510	519	
	20	0.505	535	
	21	0.524	568	
	22	0.517	608	
	23	0.526	639	
	Av =	0.520	Av = 577	0.000471

TEST II

Span 3' - 6" Wheels Parallel

Stress psi Average of Runs 1, 2, 3

Gage	Load, Pounds 2,000	4,000	6,000	8,000	10,000	12,000	14,000	16,000	18,000
1	-75	150	150	450	450	675	750	900	1,050
2	-549	-699	-1,149	-1,350	-1,848	-2,475	-2,199	-2,400	-2,625
3	-699	-1,050	-1,449	-1,848	-2,100	-2,700	-2,925	-3,150	-3,525
4	-648	-1,050	-1,500	-2,100	-2,850	-3,360	-3,699	-3,825	-4,800
5	-549	-1,050	-1,449	-1,800	-2,649	-3,198	-3,600	-4,050	-4,500
6	-150	-450	-525	-750	-975	-1,275	-1,350	-1,575	-1,875
7	99	198	375	399	450	375	525	675	750
9	-150	-150	-375	-450	-675	-900	-900	-1,200	-1,425
10	-900	-1,800	-2,850	-3,900	-4,800	-6,000	-6,900	-7,800	-8,850
11	-1,800	-3,600	-5,400	-7,350	-9,000	-11,400	-13,050	-14,700	-16,200
12	-1,850	-3,360	-4,050	-5,700	-7,560	-9,210	-10,560	-11,640	-12,960
13	-2,100	-3,900	-6,000	-8,100	-11,550	-12,000	-13,500	-15,600	-17,100
14	-900	-1,698	-2,550	-3,498	-4,398	-5,298	-6,099	-6,750	-7,650
15	49.8	0	0	-48	-249	-249	-249	-48	-99
17	649	399	648	750	699	999	1,200	1,500	1,650
18	1,050	2,250	3,399	4,599	5,499	6,699	7,800	9,375	10,350
19	2,100	4,275	6,225	8,400	10,350	12,150	13,800	15,675	17,250
20	1,950	4,149	6,000	7,998	9,498	11,400	13,149	15,150	16,575
21	2,550	4,899	6,900	9,099	10,800	12,639	14,250	16,275	17,775
22	1,299	2,148	3,450	4,398	5,148	5,750	6,648	7,650	8,325
23	99	249	399	399	249	399	498	498	549
27	699	1,398	2,400	3,189	3,900	4,698	5,550	6,450	7,125
28	648	1,350	2,100	3,048	3,498	4,548	5,400	6,375	7,800
29	1,098	1,899	2,649	3,549	4,149	4,899	5,598	6,300	7,050

TEST II

Span 3' - 6" Wheels Parallel

Load 15,600 lbs. Average of Runs 4, 5, 6

Stress psi

Gage No.	Stress	Gage No.	Stress
1	750	29	6,099
2	-2,448	30	1,749
3	-3,300	33	2,499
4	-4,200	34	3,750
5	-4,050	35	2,700
6	-1,698	36	10,749
7	600	37	10,950
10	-7,698	38	11,448
12	-13,950	39	10,698
14	-6,900	40	10,950
17	999	41	11,100
18	8,898	42	3,750
19	17,649	43	4,899
20	15,000	44	3,348
21	15,750	45	-3,798
22	7,149	46	-3,600
23	498	47	-5,049
27	6,000	48	-99
28	5,799	49	6,450

TEST II

Span 3' - 6" Wheels Transverse

Stress psi Average of Runs 7, 8, 9

	Load, Pounds								
Gage	2,000	4,000	6,000	8,000	10,000	12,000	14,000	16,000	18,000
36	1,398	2,700	3,948	5,448	6,750	8,148	9,549	10,749	11,748
37	2,250	4,449	6,450	8,649	10,248	11,799	13,449	15,048	16,350
38	1,449	2,850	4,149	5,649	6,948	8,250	9,798	11,199	12,450
39	1,350	2,850	4,248	5,649	7,200	8,499	9,900	11,298	12,558
40	2,250	4,500	6,648	8,748	10,758	12,558	14,250	16,050	17,450
41	1,350	2,850	4,350	5,898	7,350	8,898	10,350	11,850	12,050
19	1,500	3,048	4,449	6,150	7,599	9,048	10,599	12,150	13,500
20	2,199	4,398	6,498	8,850	10,800	12,849	14,850	16,998	18,600
21	1,548	3,099	4,548	6,300	7,749	9,498	10,848	12,549	13,899
48	3,198	6,000	8,250	10,950	12,750	14,598	16,098	17,499	18,549
49	1,800	3,549	5,148	6,948	5,700	10,350	11,949	13,299	15,000

TEST II

Span 3' - 6" Wheels Transverse

Load 15,600 lbs. Average of Runs 10, 11, 12

Stress psi

Gage No.	Stress	Gage No.	Stress
1	1,089	34	4,200
2	-1,200	35	3,798
3	-3,000	36	10,350
4	-6,150	37	14,498
5	-3,450	38	10,599
6	-600	39	10,950
7	-1,200	40	15,498
17	-450	41	11,199
18	4,950	42	5,799
19	11,748	43	7,350
20	16,500	44	5,400
21	12,000	45	-3,600
22	4,299	46	-5,748
23	549	47	-5,049
33	3,498	48	17,049
		49	13,449

TEST II

Span 4' - 0" Wheels Parallel

Stress psi Average of Runs 1, 2

	Load, Pounds								
Gage	2,000	4,000	6,000	8,000	10,000	12,000	14,000	16,000	18,000
1									450
2									-1,800
3									-5,700
4									-5,400
5									-4,800
6									-1,800
7									-2,100
17									1,350
18									10,050
19	2,175	4,500	6,600	8,400	10,500	13,200	15,000	16,950	18,750
20	1,800	3,975	6,075	8,100	9,600	12,225	14,175	16,275	18,225
21	2,850	5,250	7,650	9,825	11,850	13,950	15,900		19,725
22									10,650
23									1,800
27									4,050
28									3,600
29									5,100
30									150
33									4,950
34									6,600
35									5,400
36									13,650
37									14,250
38									15,000
39									13,800

TEST II

Span 4' - 0" Wheels Parallel

Load 15,600 lbs. Average of Runs 3, 4, 5

Stress psi

Gage No.	Stress	Gage No.	Stress
1	648	36	12,399
2	-1,200	37	12,549
3	-4,698	38	12,699
4	-4,200	39	11,898
5	-4,299	40	12,399
6	-2,100	41	12,099
7	900	42	5,100
17	1,599	43	6,249
18	10,050	44	4,950
19	16,950	45	-3,600
20	16,149	46	-3,075
21	17,298	47	-4,650
22	7,950	48	1,248
23	1,149	49	10,248
30	-300	50	7,098
33	4,548	51	10,350
34	5,949	52	13,200
35	4,500	53	5,448
		54	9,849

TEST II

Span 4' - 0" Wheels Transverse

Stress psi Average of Runs 6, 7

				Load, Pounds					
Gage	2,000	4,000	6,000	8,000	10,000	12,000	14,000	15,600	16,000
19	1,725	3,450	5,100	6,975	8,625	10,350	12,075	13,650	13,950
20	2,250	4,650	6,900	9,375	11,610	13,875	16,050	18,000	18,450
21	1,800	3,600	5,400	7,200	8,850	10,650	12,450	13,500	14,250
48	3,450	6,450	9,150	11,625	13,650	15,375	17,250	17,850	18,675
49	2,025	4,125	6,075	8,100	9,960	11,760	14,100	15,600	15,600
50	2,925	6,150	9,150	12,600	15,000	16,800	18,600	19,650	20,310
51	2,850	5,700	8,625	11,325	13,500	15,600	17,610	18,450	18,900
52	2,025	3,900	5,700	7,575	9,300	11,100	13,200	14,550	14,700
53	2,700	5,400	8,175	11,025	13,125	14,775	16,800	18,300	18,060
54	2,550	5,550	8,100	10,710	12,810	14,910	16,875	18,300	18,525
55	2,700	3,200	6,600	8,100	9,600	10,500	12,600	12,900	13,500
57	600	1,350	2,400	3,300	4,200	4,950	6,600	7,500	7,950
58	750	1,800	2,700	4,200	5,400	6,300	7,500	8,400	8,700

TEST II

Span 4' - 6" Wheels Parallel

Stress psi Average of Runs 1, 2, 3

Gage	Load, Pounds								
	2,000	4,000	6,000	8,000	10,000	12,000	14,000	15,600	16,000
2								-1,650	
3								-3,348	
4								-2,949	
5								-2,649	
6								-360	
7								1,449	
17	198	549	900	1,200	1,500	1,800	2,100	2,349	2,550
18	1,398	2,748	4,200	5,550	7,050	8,400	9,750	10,800	11,100
19	2,949	5,598	7,875	10,500	12,675	15,180	17,325	18,948	19,350
20	2,298	4,596	6,900	9,300	11,775	13,998	16,425	18,249	18,750
21	2,799	5,499	7,875	10,599	12,975	15,300	17,550	19,248	19,725
22	1,248	2,499	3,825	5,298	7,350	7,998	9,675	10,398	10,650
23								2,550	
28								648	
33								6,099	
34								7,800	
35								6,399	
36								14,550	
37								15,150	
38								14,598	
39								13,698	
40								14,298	
41								13,698	

TEST II

Gage	2,000	4,000	6,000	8,000	10,000	12,000	14,000	15,600	16,000
	Load, Pounds								
42								6,750	
43								8,400	
44								7,200	
45								-1,698	
46								-600	
47								-948	
48	-300	-498	-750	-900	-600	-450	-75	360	600
49	1,149	2,448	3,750	5,199	6,750	8,250	9,525	10,698	10,950
50	999	1,998	3,300	4,650	6,150	7,599	8,850	10,149	10,275
51	849	1,698	2,775	3,750	5,775	9,198	7,650	8,700	9,150
52	1,350	2,850	4,275	5,850	7,500	8,850	10,275	11,448	11,700
53	750	1,500	2,325	3,348	4,350	5,349	6,525	7,449	7,725
54	849	1,698	2,625	3,498	4,650	5,700	6,900	5,148	8,400
57	2,100	3,699	5,250	6,450	7,625	8,649	9,375	10,050	10,125
58	2,400	3,840	5,160	6,540	7,950	8,460	9,360	9,960	10,110

TEST II

Span 4' - 6" Wheels Transverse

Stress psi

	Load, Pounds						
Gage	2,000	4,000	6,000	8,000	10,000	12,000	14,000
2							-750
3							-2,700
4							-4,500
5							-1,950
6							600
7							1,500
17	0	0	0	0	0	300	450
18	900	2,100	2,700	3,900	4,800	6,000	7,200
19	1,800	3,900	5,700	7,950	9,600	15,000	16,800
20	2,700	5,400	7,800	10,650	13,200	15,600	18,000
21	1,950	3,900	5,550	7,950	9,750	11,550	13,650
22	750	1,500	2,400	3,300	4,200	5,100	6,000
23							750
28							1,800
33							7,200
34							8,100
35							7,200
36							12,900
37							18,000
38							12,000
39							13,050
40							17,400
41							12,600

TEST II

	Load, Pounds						
Gage	2,000	4,000	6,000	8,000	10,000	12,000	14,000
42							7,950
43							9,300
44							8,400
45							-900
46							-1,800
47							300
48	3,600	6,900	9,600	12,600	14,700	16,800	18,750
49	2,100	4,200	6,300	8,700	10,800	12,900	1,500
50	2,400	6,000	9,000	12,600	15,300	17,700	19,950
51	2,550	5,400	8,250	11,100	13,500	15,750	17,700
52	1,950	4,050	5,850	8,250	10,050	11,850	13,950
53	2,700	6,000	9,000	12,300	14,550	16,500	18,600
54	2,400	5,550	8,250	11,100	13,500	15,600	17,700
55	3,000	5,550	7,500	9,300	10,800	12,000	13,650
57	600	1,500	2,400	3,600	4,800	6,000	7,200
58	450	2,100	3,000	4,200	6,000	7,200	8,400

TEST II

Load Applied Through Wooden Blocks

Span 4' – 0" Stress psi

Gage	Load, Pounds							
	2,000	4,000	6,000	8,000	10,000	12,000	14,000	15,600
2								-4,200
3								-6,000
4								-3,750
5								-4,200
6								-1,200
7								3,000
17								3,750
18								11,100
19	3,000	5,400	8,100	10,800	13,500	19,200	22,050	23,700
20	2,100	4,500	6,900	9,000	11,100	13,050	15,450	17,100
21	2,100	4,800	6,600	9,000	11,100	13,200	15,600	18,000
22								7,950
23								150
33								4,500
34								5,550
35								3,300
36								12,600
37								13,200
38								11,400
39								14,250
40								13,800
41								12,600

TEST II

				Load, Pounds				
Gage	2,000	4,000	6,000	8,000	10,000	12,000	14,000	15,600
42								6,150
43								7,500
44								5,400
45								-1,500
46								-3,000
47								-3,300
48								3,600
49								10,200
50								8,400
51								6,150
52								10,800
53								7,350
54								6,000
55								-1,200
56								0
57								9,000
58								9,300

TEST III

Test to Destruction

Span 4' - 0" Strain Microinches Per Inch

Gage 21

Load, Pounds	Strain
12,000	465
14,000	540
16,000	620
18,000	695
20,000	770
22,000	850
24,000	930
26,000	1,000
28,000	1,080
30,000	1,150
32,000	1,220
34,000	1,310
36,000	1,400
38,000	1,520
40,000	1,670
42,000	1,840
44,000	2,150
46,000	2,650
48,000	3,220
50,000	3,900

Gage 49

Load, Pounds	Strain
50,000	1,210
52,000	1,250
54,000	1,310
56,000	1,410
58,000	1,500
60,000	1,630
64,000	1,820
70,000	2,090
85,000	2,130
90,000	2,400
95,000	2,810
99,000	3,450
99,500	3,560

The following formula was used with the Baldwin-Southwark SR-4 Strain Indicator in Test I to convert the micrometer readings of the indicator to strain:

$$\text{Strain} = (\Delta S)(K)$$

ΔS = change in micrometer readings

$$K = \frac{\text{Bridge Sensitivity Factor}}{\text{Gage Factor}} = \frac{1.688 \times 10^{-4}}{2.07}$$