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LOAD CONCENTRATIONS ON STEEL FLOOR JOISTS OF WOOD FLOOR HIGHWAY BRIDGES

By
T. R. AGG
C. S. NICHOLS

BULLETIN 53
GOOD ROADS SECTION
ENGINEERING EXPERIMENT STATION

Ames, Iowa

Published weekly by Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa. Entered as second-class matter, and accepted for mailing at special rate of postage provided for in section 1103—Act of Oct. 3, 1917. Authorized Sept. 23, 1918.

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For the industries related to agriculture in the solution of their engineering problems;

For all people of the State in the solution of the engineering problems of urban and rural life.

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ACKNOWLEDGMENTS

During the progress of this investigation, valuable assistance was given by Messrs. E. F. Kelley and E. W. Blumenschein, engineers in the Bridge Department of the Iowa Highway Commission. A considerable part of the experimental data were taken by Messrs. B. S. Myers and C. A. Baughman, at that time members of the instructional staff of the civil engineering department, Iowa State College.

LOAD CONCENTRATIONS ON STEEL FLOOR-JOISTS OF WOOD FLOOR HIGHWAY BRIDGES

PURPOSE

The investigation was undertaken to determine the manner in which heavy wheel loads, such as those of traction engines, are distributed to the various I-beams and channels in a highway bridge floor system consisting of I-beam and channel joists and wood planking.

While this is a type of bridge floor that is no longer employed for main highways if its use can be avoided, it is still employed to some extent on secondary roads. A large number of such bridges now in service are of such design that the trusses will not carry the additional dead load resulting from the addition of a concrete floor, and the wood floor must be maintained or the bridge replaced. It is economical to keep such structures in service so long as the trusses remain in good condition and it is possible to maintain the floors under tractor and motor truck traffic.

In many of these structures, light I-beam joists were used originally and in strengthening the floors it is difficult to replace the old I-beam joists with new ones of greater depth without altering many other details of the floor system; it was this situation which prompted the investigation of the distribution of loads on floor systems designed with lighter I-beam joists than is good practice for new construction.

SCOPE OF INVESTIGATION

The investigation was confined to the following:

1. The determination of the percentage of a wheel load carried by each I-beam and channel joist of a highway bridge carrying a wood floor, for various positions of a certain pair of tractor wheels.

2. The determination of the effect of using two layers of floor planks, the upper one being laid (a) lengthwise of the floor, (b) on a diagonal.

3. The determination of the effect upon distribution of load of loosening the planks from the nailing pieces.

4. The determination of the effect of the wheel lugs upon the distribution of the load.

METHOD OF CONDUCTING THE INVESTIGATION

The Floor System: Two low concrete abutments were built of such dimensions that they would accomodate a floor system identical with that employed by the Iowa Highway Commission for an 18 ft. span with 16 ft. roadway. Metal bearing plates were used on the abutments so as to give a clearly defined span length of I-beam. Modifications of the standard design were also employed to secure data relative to load distributions on light I-beams. Figure 1 shows the various types of floor systems studied.

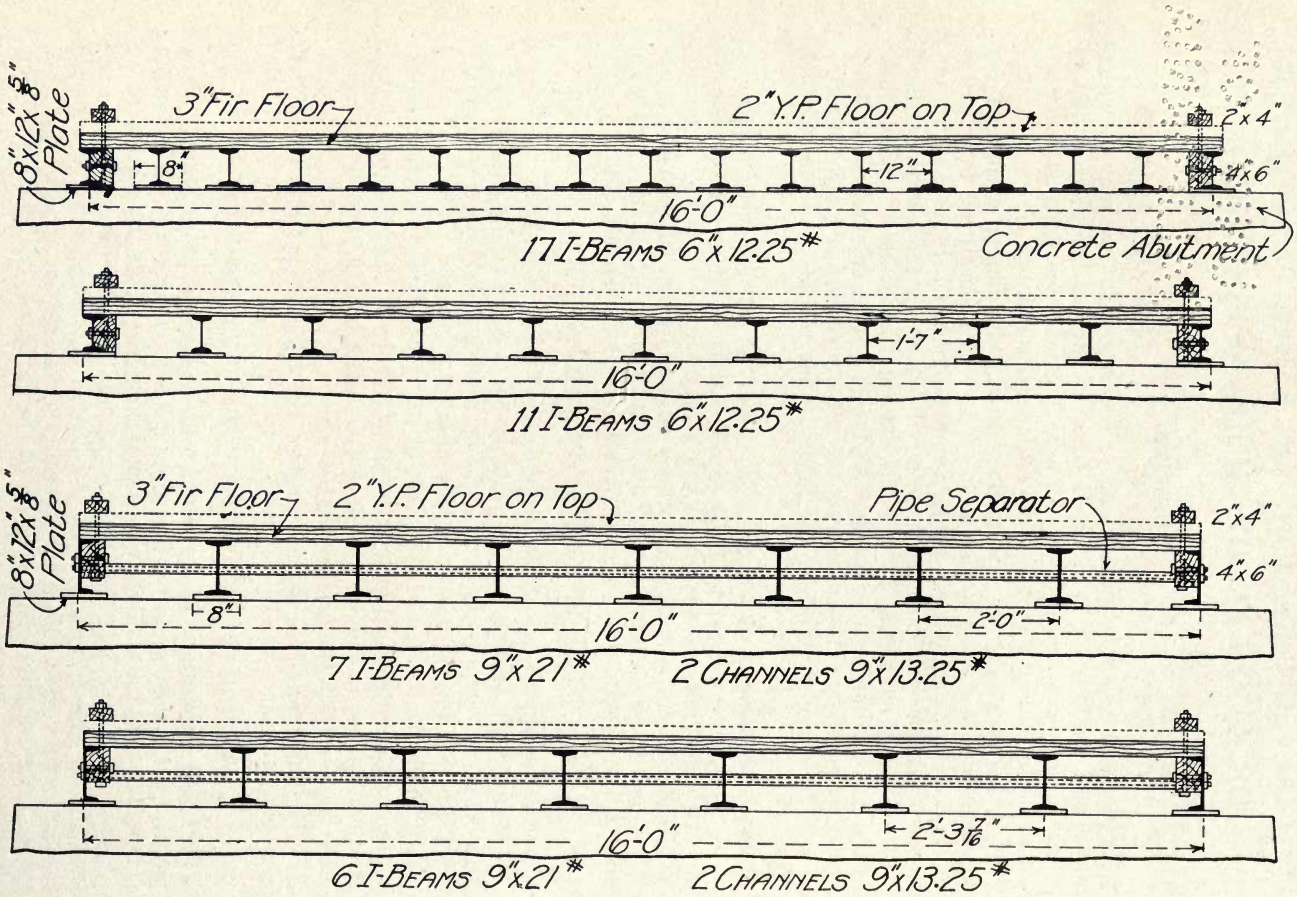


Fig. 1. Types of Floor Systems Studied.

The Load. The load was applied to the axle of a pair of tractor wheels by means of hydraulic jacks and the loads given in the various diagrams include the weight of wheel and half the weight of the axle. The general arrangement of the load apparatus is shown in Figs. 2 & 3. Repeated trials with this apparatus showed that loads could be repeated with exactness, but it is possible for the loads given in the diagrams to be in error by 5.0 percent and the percentages of concentrations may be in error by 5.0 percent, although the average error is probably less than 2.0 percent. The wheels were placed in a symmetrical position on the floor at the mid-span, and one, two and three feet off the center line of the bridge at mid-span, a total of four positions for each floor system studied. These various positions are indicated by the letters A, B, C, and D in the diagrams of Figs. 5 to 23.

Experimental Data. The lower flanges of the I-beams and channels were drilled for a 15 in. Berry strain gauge, the gauge lengths being symmetrically laid off from the middle of the span and being continuous, as shown in Fig. 4. Before the I-beams were placed in the bridge, they were loaded by means of a standard beam testing machine and the strain corresponding to various concentrated loads measured with the strain.

In the floor tests the wheels were raised from the floor and zero readings were taken on all of the gauge lengths on the I-beams and channels. The wheels were then placed in the desired position and the pressure applied by means of the jacks. This load was maintained while the strain was read on all gauge lengths. A second load considerably heavier than would ordinarily result from any vehicle now using highway bridges was then applied and the gauge readings again recorded. Each final value of strain for a given load is an average of at least three separate determinations in which the individual determinations checked within .0002 inch.

Calculations. It was expected to plat the moment diagram for each I-beam and for each load, calculated from the elongation of outer fiber which had been measured by the strain gauge, and from these diagrams compute the load. Upon platting the moment diagrams, it was found that the load acted very nearly as a concentrated load at the middle of the I-beam, and that to so consider it gave results sufficiently near correct for the purpose of the investigation. Fig. 4 shows a set of moment diagrams for one loading and these are typical of all of those obtained. Table No. 1 shows the calculation of concentration of load on each I-beam, and it will be noted that the sum of the calculated loads on all of the floor joists is 29,400 pounds, while the actual load is 29,800 pounds, the error being 1.4 percent. As a rule the error was slightly greater than this, although in no case was it gre ater than 5.0 per cent.

RESULTS OF OBSERVATIONS

The diagrams in Figs, 5 to 24 are drawn to show the concentration of load on each joist in the floor system in percentage of one wheel load. They illustrate the variation in concentration for the several positions

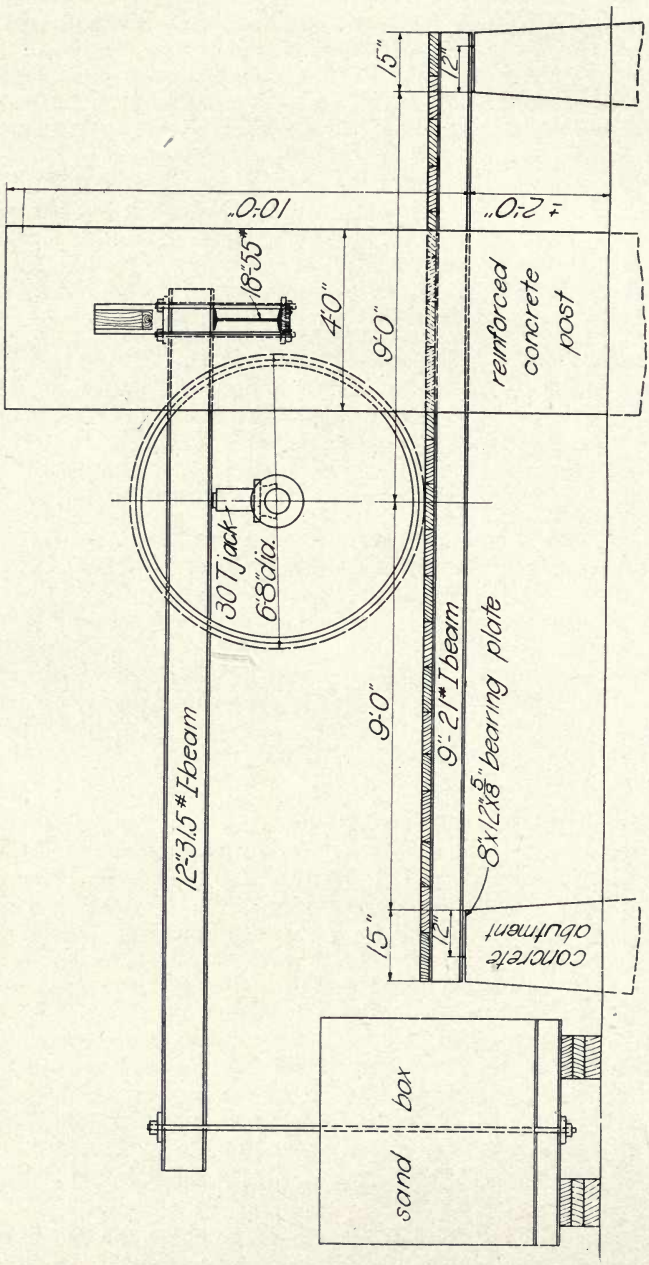


Fig. 2. Side View of Loading Apparatus in Place.

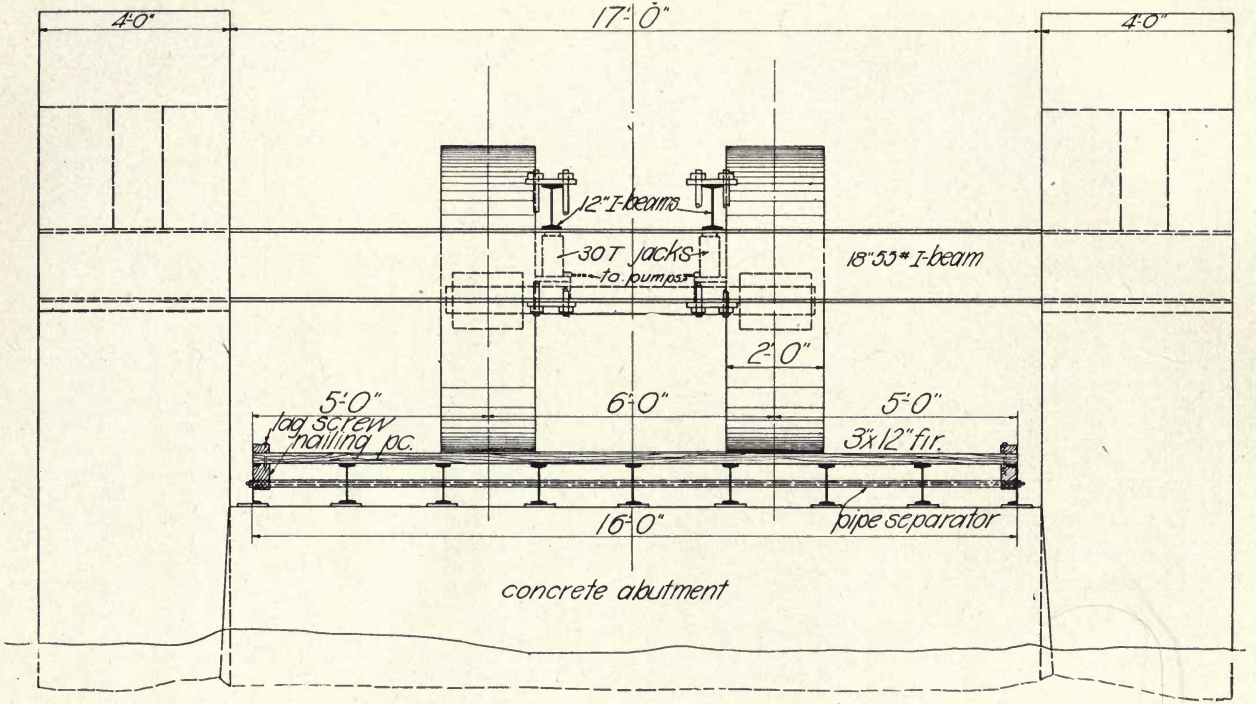


Fig. 3. End View of Loading Apparatus in Place.

CALCULATED CONCENTRATION OF LOADS ON FLOOR JOISTS

Joist	Average Reading of Strain Gauge		Difference	Calculated Load on Joist lbs.	Percentage of One Wheel load
	No. load	Load 29400			
Channel A	—26	—25	1	75	.50
I-Beam B	10	30	20	2850	19.40
I-Beam C	—36	14	50	7400	50.34
I-Beam D	—25	4	29	4000	27.20
I-Beam E	—12	22	34	4600	31.30
I-Beam F	—79	—29	50	6975	47.44
I-Beam G	—11	10	21	3100	21.10
Channel H	—24	19	5	400	2.72
Total Calculated Load				29400	200.00

Actual load 29,800 lbs.
Ratio Calculated load to actual load 0.986.

of the wheels. The lines are drawn to connect points of calculated concentration and do not indicate the rate of change between points.

Fig. 24 shows the effect of the various positions of the lugs on the concentration, which is of value for comparison only when the diagonal lugs, such as were on the tractor wheels used in the test, are employed.

It is not shown by the experimental data what effect diameter and width of wheel will have on the concentration, but it seems probable from a study of the diagrams of concentration and from the observations of the progress of the experimental work that the results given herein will closely approximate those with any other diameter and width of wheel likely to be employed for motor trucks or traction engines weighing in excess of four tons.

CONCLUSIONS

A concentration on a single floor joist, equal to 55.0 per cent of one wheel load is possible where a single thickness of wood floor is laid on the steel floor joists.

The concentration on the joists immediately under the wheels is generally increased slightly if the ends of the plank are loosened, but the additional concentration is small.

The concentration on the joists immediately under the wheels is slightly reduced by a second layer of floor planks laid lengthwise of the bridge floor.

The concentration on the outer I-beam or channel increases rapidly as the load approaches the side of the bridge. The outer joist should have a section modulus as great as that of any other joist in the floor system.

The concentration on light I-beams used for joists and placed at the intervals as shown in Fig. 1 is much less than on the heavier I-beam joists with wider spacing, so they may be safely employed if enough are used to insure wheel bearing on two joists.

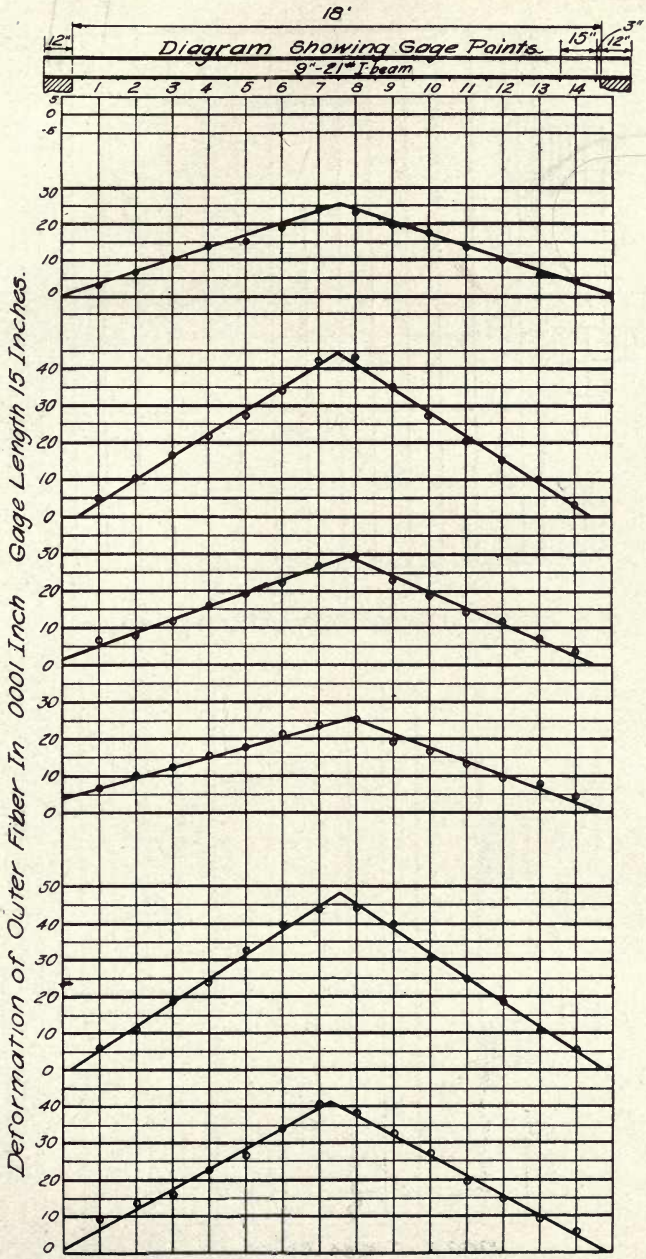


Fig. 4. Typical Moment Diagram.

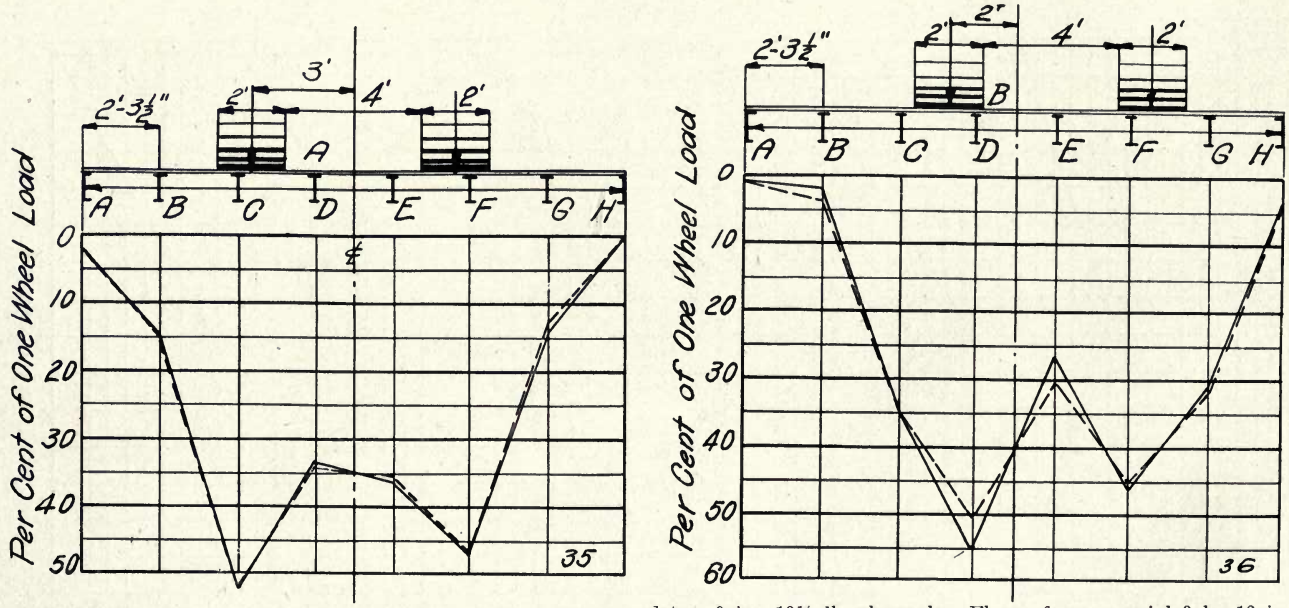
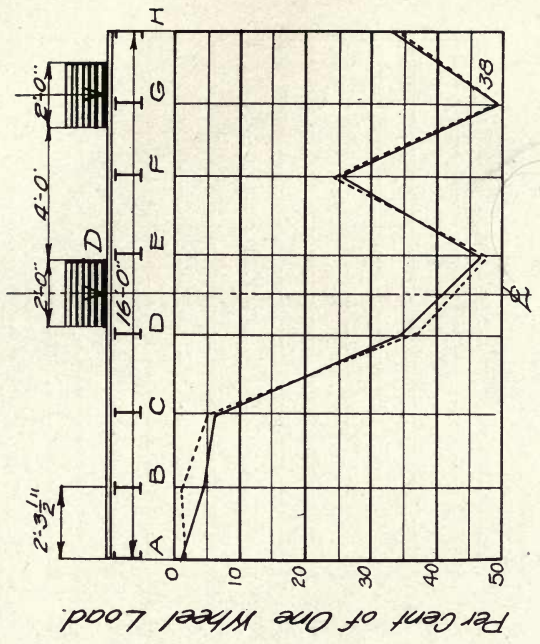


Fig. 5. Floor system consisting of six 9 in., 21 lb. I beams and two 9 in., 13¼ lb. channels. Floor of commercial 3 by 12 in. fir laid transversely with ends fastened to nailing pieces on the channels. Solid line connects points showing concentration for load of 14,900 lb. at each wheel and dotted line connects points showing concentration for load of 18,900 lb. at each wheel. Positions A and B in this figure.



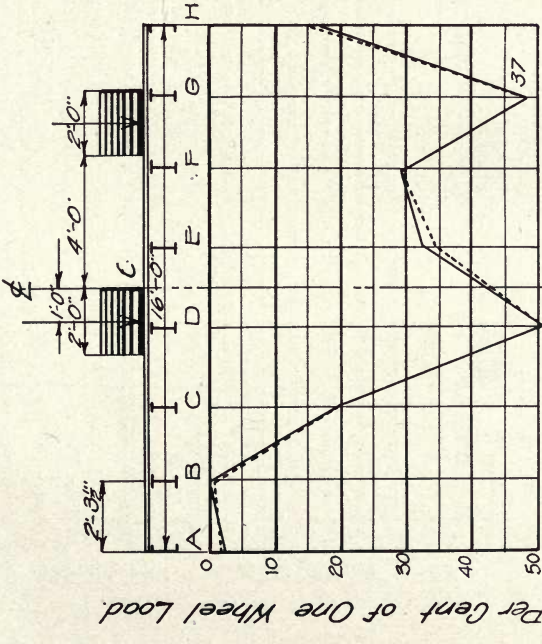


Fig. 6. See note for fig. 5, positions C and D in this figure.

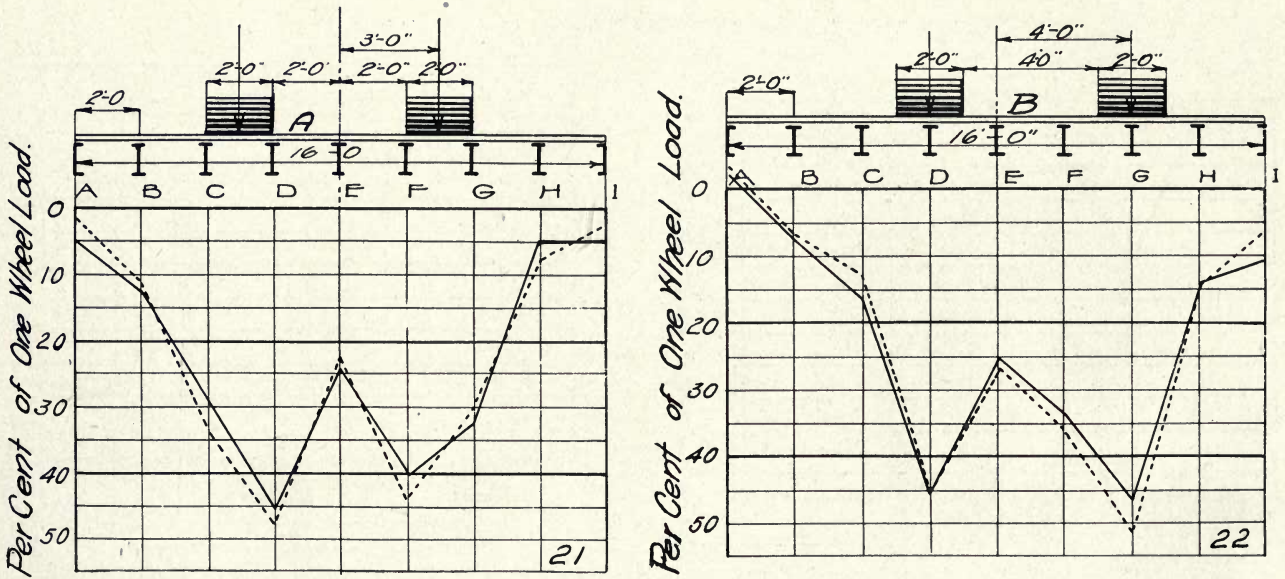


Fig. 7. Floor consisting of seven 9 in., 21 lb. I-beams and two 9 in., 13¼ lb. channels, with floor of commercial 3 by 12 in fir laid transversely with ends fastened to nailing pieces on the channels. Solid line connects points showing concentration for load of 14,900 lb. at each wheel, dotted line connects points showing concentration for load of 18,900 lb. at each wheel. Positions A and B in this figure.

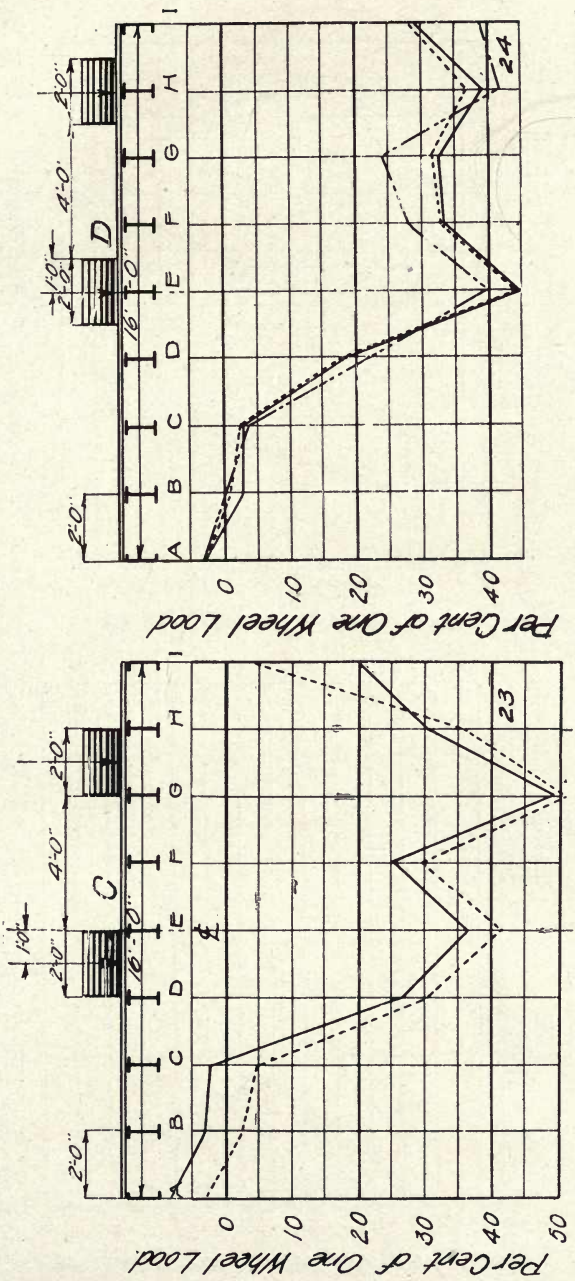


Fig. 8. See Fig. 7 for note. Dash and dot line connects points showing concentration when lugs were removed from wheel. Positions C and D in this figure.

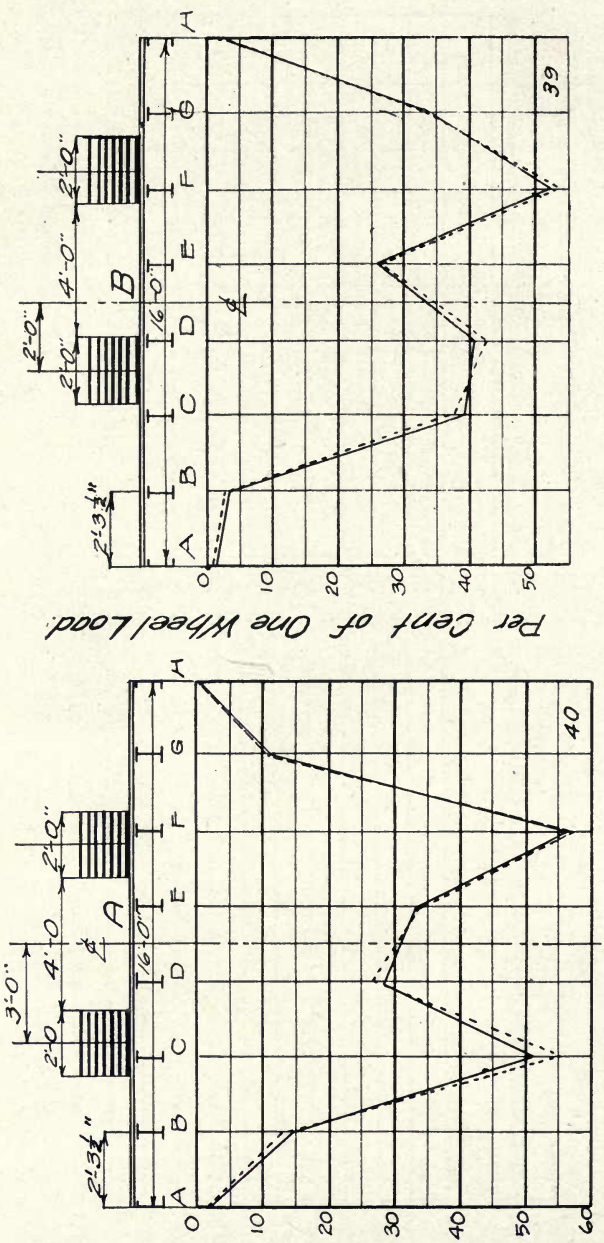
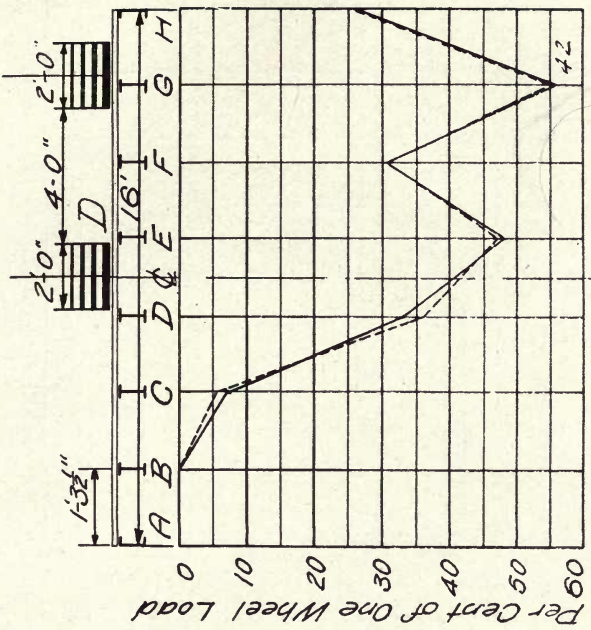


Fig. 9. Floor system consisting of six 9 in., 21 lb. I-beams and two 9 in., 13¼ lb. channels. Floor of commercial 3 by 12 in. fir laid transversely with ends **loose**. Solid lines connect points showing concentration for load of 14,900 lb. at each wheel and dotted lines connect points showing concentration for load of 18,900 lb. at each wheel. Positions A and B in this figure.



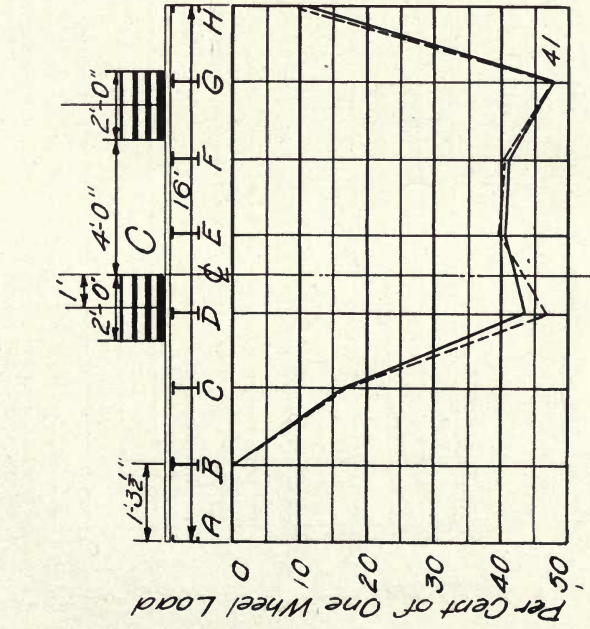


Fig. 10. See note for Fig. 9. Positions C and D in this figure.

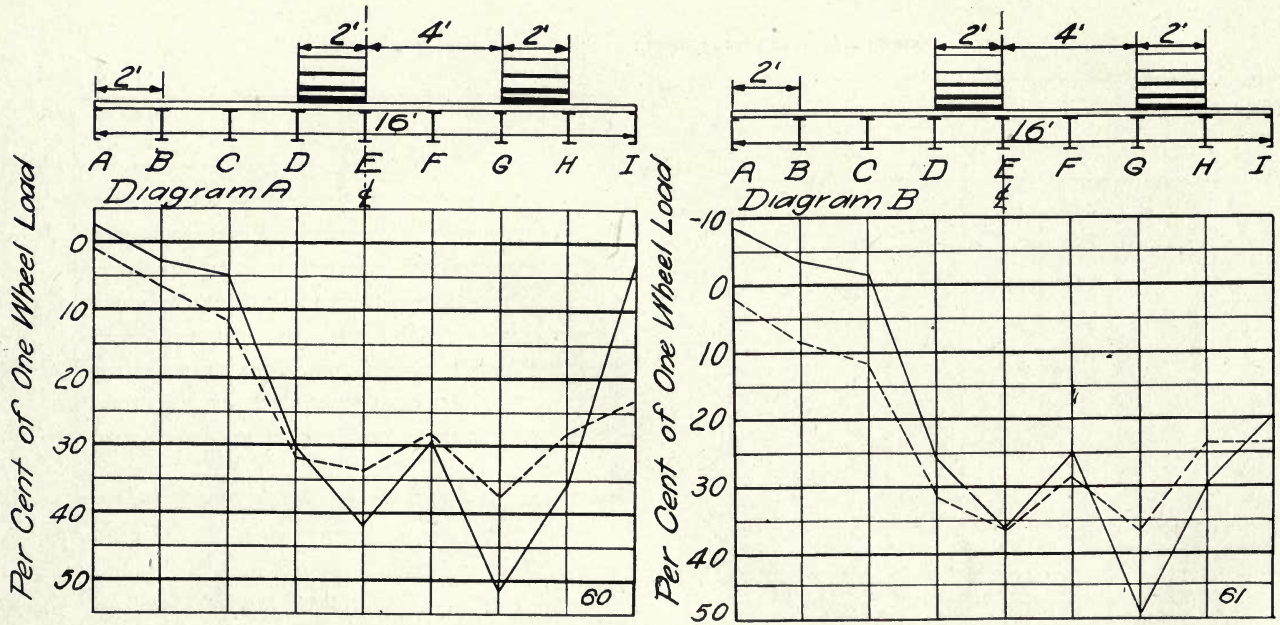


Fig. 11. Showing relative concentrations on single and double floors. The dotted line connects points showing concentrations for a floor consisting of commercial 3 by 12 in. fir laid square a cross, ends fastened to nailing pieces on the channels. The solid line connects points showing concentrations on a double fl oor consisting of commercial 3 by 12 in. fir laid square across over which 2 by 12 in. was laid diagonally. Planks fastened to nailing pieces on the channels. Load of 14,900 lb. at each wheel in Diagram A and load of 18,900 lb. in Diagram B.

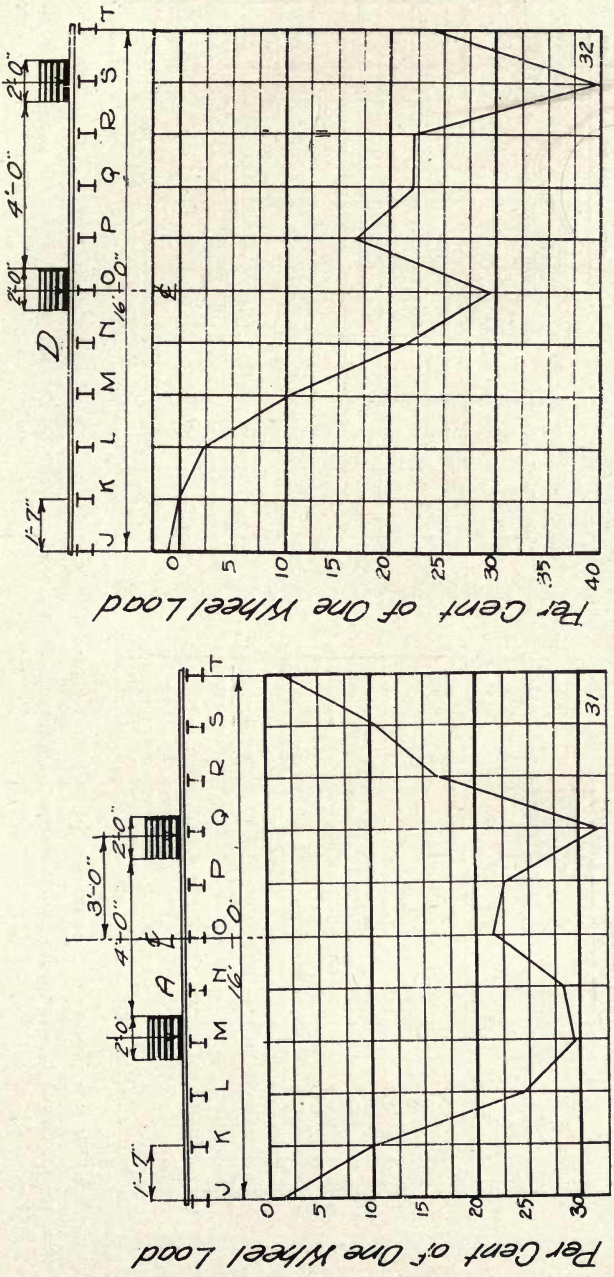


Fig. 12. Floor system consisting of eleven 6 in., 25¼ lb. I-beams with a floor of commercial 3 by 12 in fir laid transversly with ends fastened to nailing pieces on outer I beams. Load of 8,900 lb. at each wheel. Positions A and D in the figure.

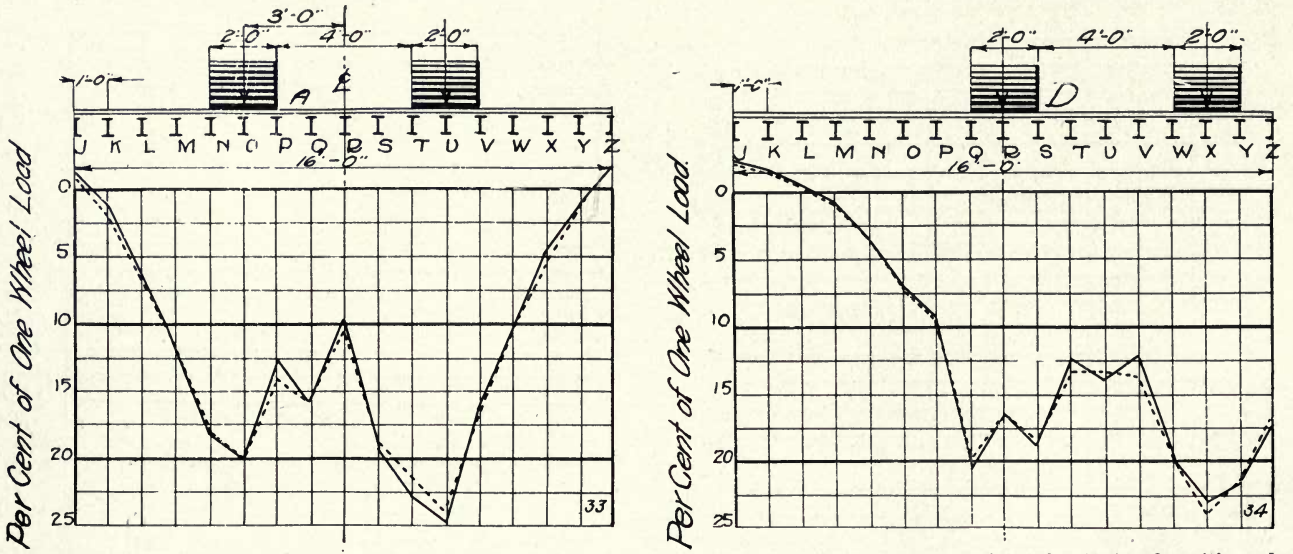


Fig. 13. Floor consisting of seventeen 6 in., 12¼ lb. I-beams with transverse floor of commercial 3 by 12 in. fir with ends fastened to nailing pieces on the outer I-beams. Solid line connects points showing concentration for loads of 8,900 lb. at each wheel, dotted line connects points showing concentrations for load of 12,900 lb. at each wheel. Positions A and D in this figure.

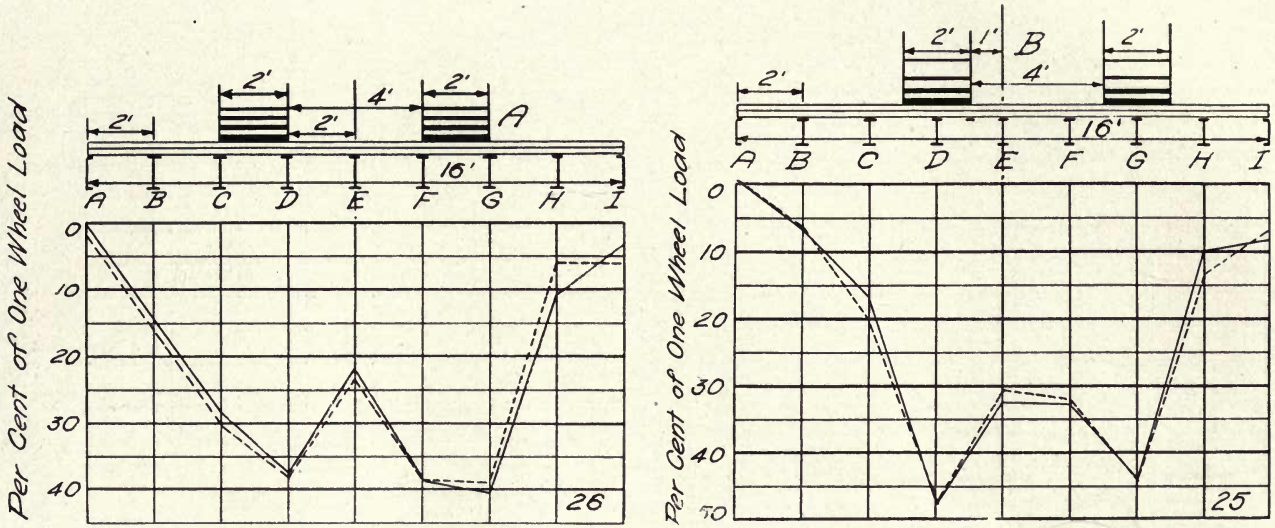


Fig. 14. Floor system consists of seven 9 in., 21 lb. I-beams and two 9 in., 13¼ lb. channels. Floor of 3 by 12 in. fir laid transversely and fastened to nailing pieces on the channels, over which commercial 2 by 12 in. y.p. was laid at 60° to center line of the bridge and ends fastened to nailing pieces on the channels. Solid lines connect points showing concentrations for load of 14,900 lb. at each wheel and dotted lines connect points showing concentrations for loads of 18,900 lb. at each wheel. Load in positions A and B in this figure.

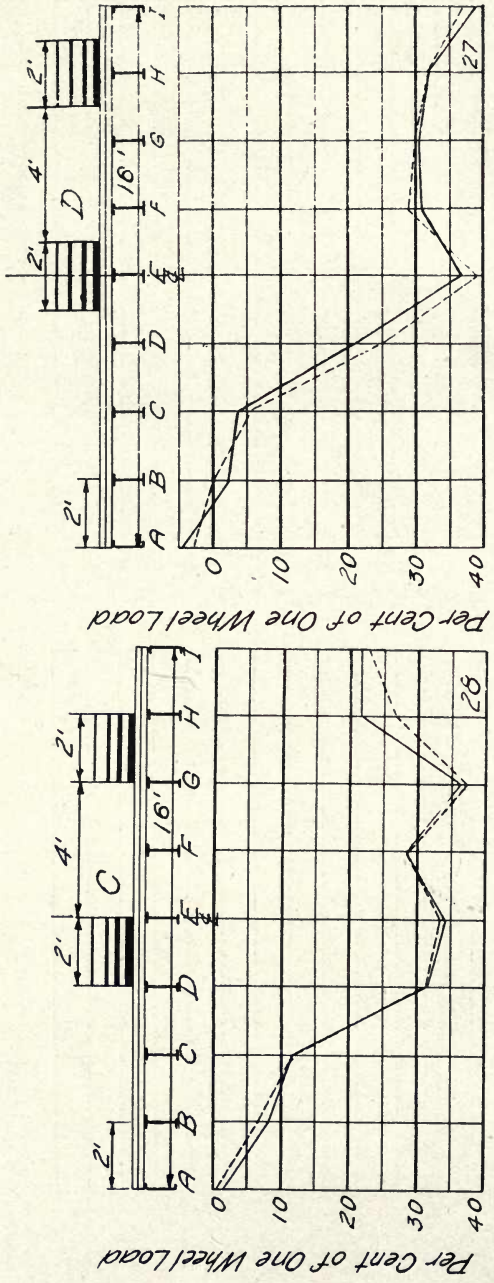


Fig. 15. Same conditions as for Fig. 14 but showing load in positions C and D.

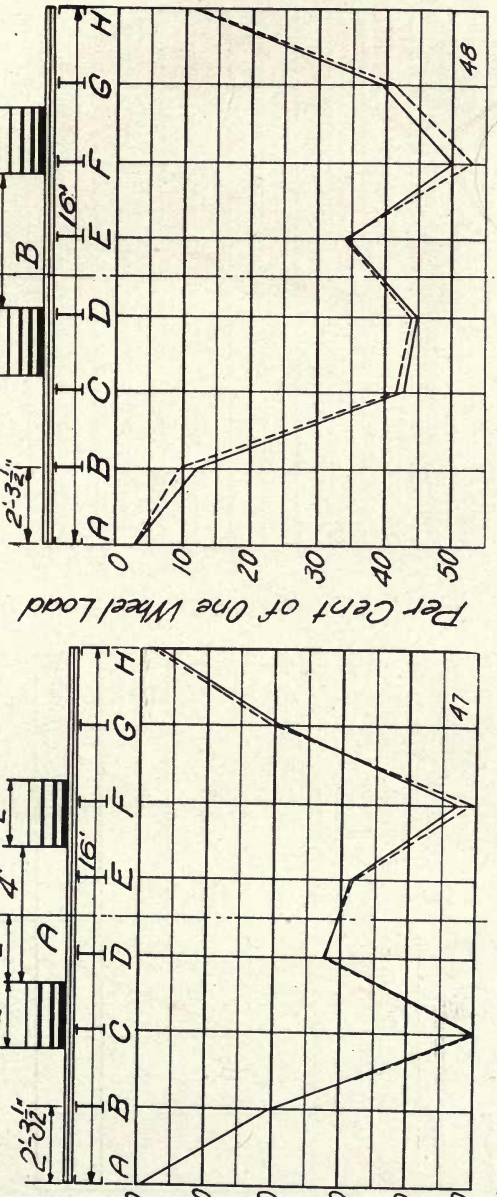


Fig. 16. Floor system consisting of six 9 in., 21 lb. I-beams and two 9 in., 13¾ lb. channels. Floor of commercial 3 by 12 in. fir laid transversely and fastened to nailing pieces on the channels over which commercial 2 by 12 in. y. p. was laid at 60° to center line of bridge with ends fastened to nailing pieces on the channels. Solid lines connect points showing concentration for load of 14,900 lb. at each wheel and dotted line connects points showing concentration for load of 18,900 lb. at each wheel. Positions A and B in this figure.

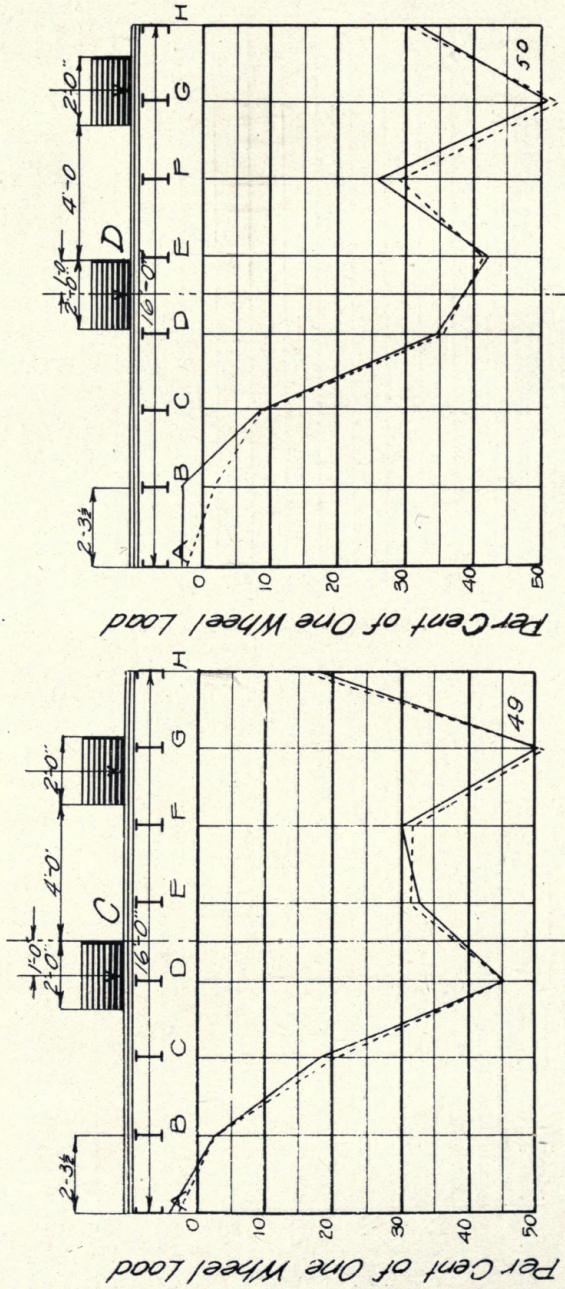


Fig. 17. See note for Fig. 16. Positions C and D in this figure.

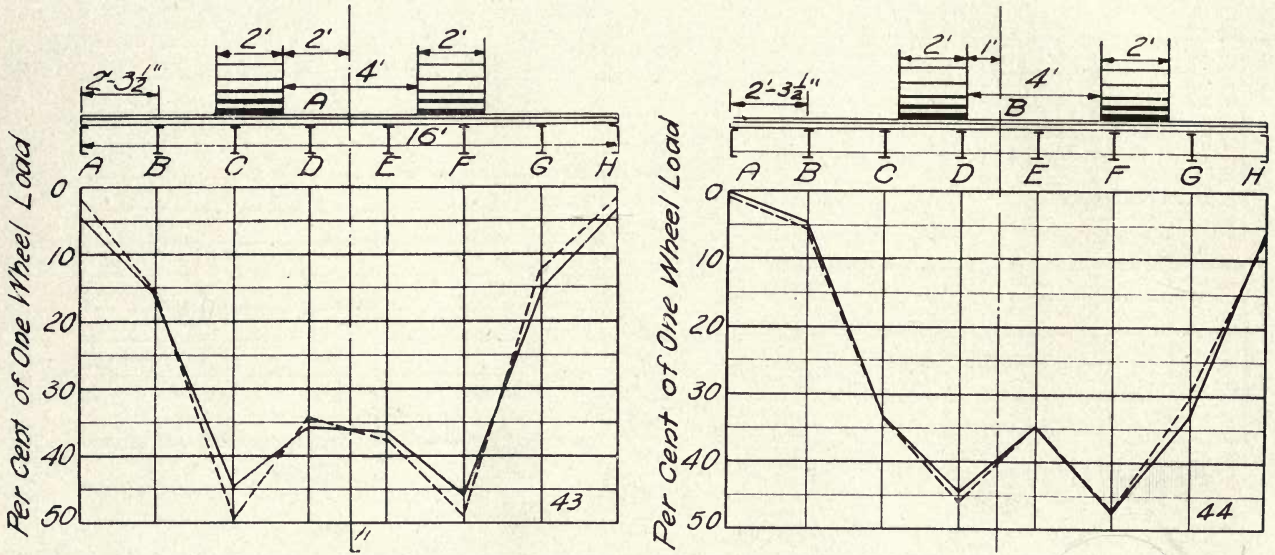
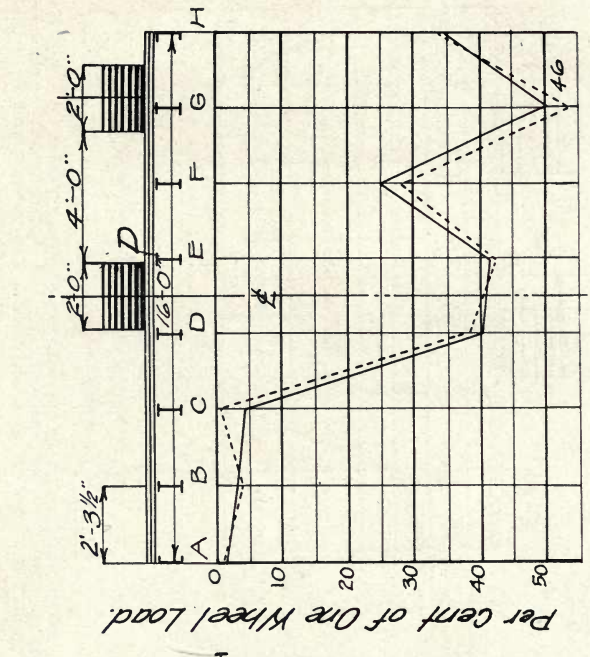


Fig. 18. Floor system identical with that shown in Figs. 16 and 17, except that in this case the ends of the plank were **not** fastened to the nailing pieces on the channels. Solid line connects points showing concentration for load of 14,900 lb. at each wheel and dotted line connects points showing concentration for load of 18,900 lb. at each wheel. Positions A and B in this figure.



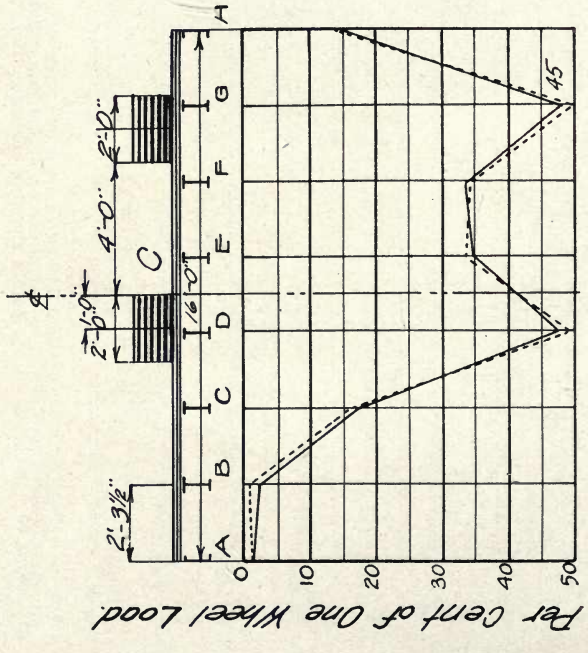


Fig. 19. See note for Fig. 18. Positions C and D in this figure.

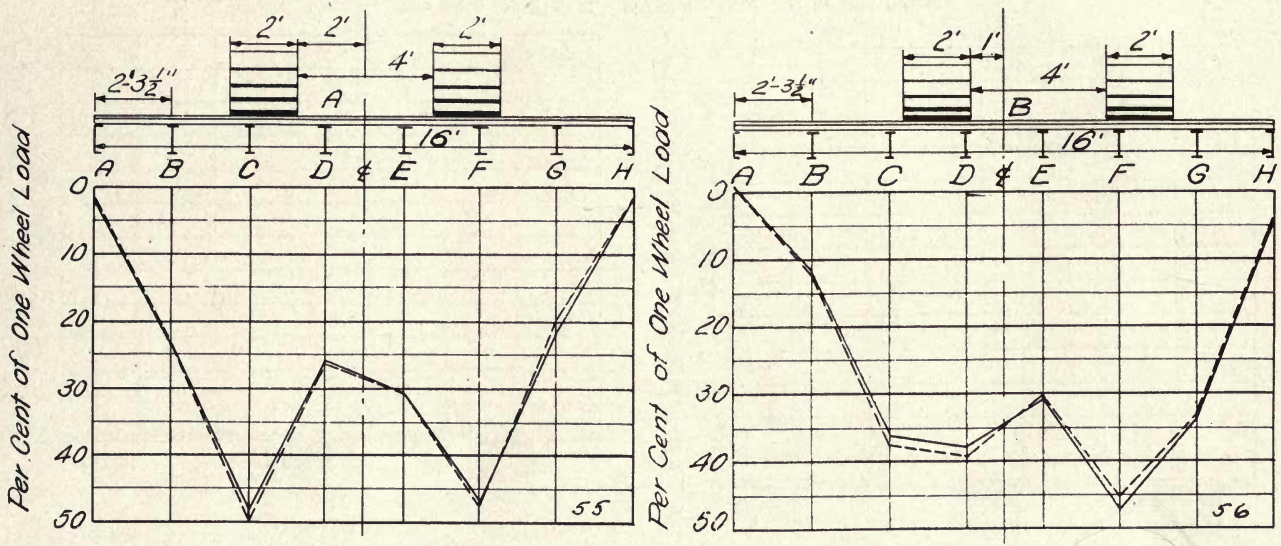
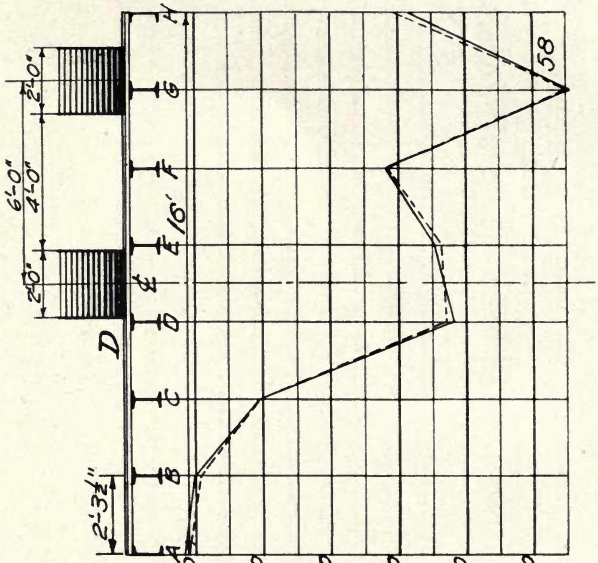


Fig. 20. Floor system consisting of six 9 in., 21 lb. I-beams and two 9 in., 13¼lb. channels. Floor consisting of commercial 3 by 12 in. fir laid crosswise and fastened to nailing pieces on the channels, over which commercial 2 by 12 in. y. p. was laid lengthwise of the bridge, but were not fastened. Solid lines connect points showing concentration for load of 14,900 lb. at each wheel dotted line connects points showing concentration of 18,900 lb. at each wheel. Positions A and B in this figure.



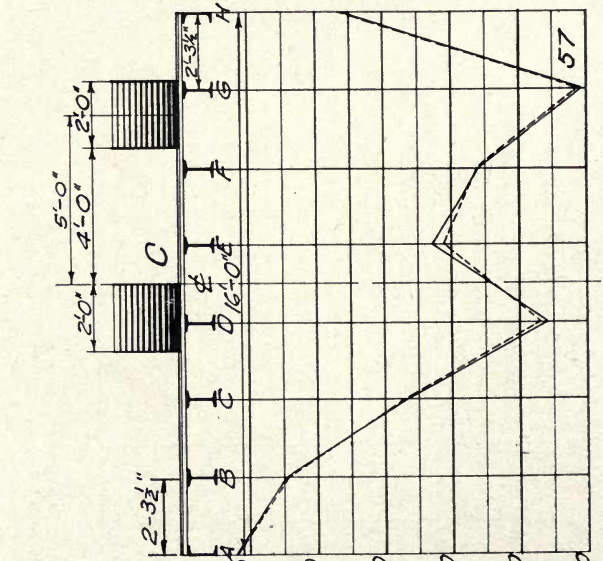


Fig. 21. See note for Fig. 20. Positions C and D in this figure.

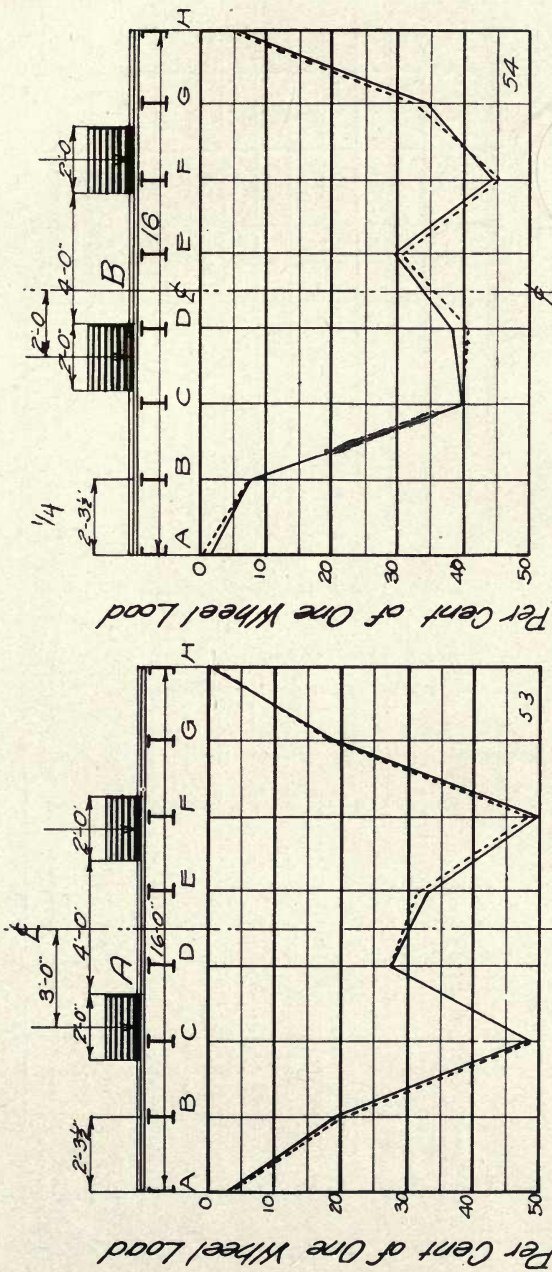
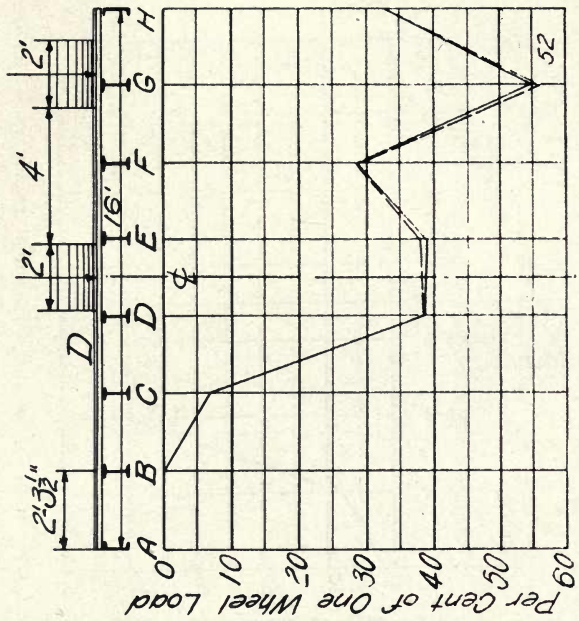


Fig. 22. Floor system identical with that in Figs. 20 and 21, except that in this case the longitudinal planks were rigidly fastened at the ends. Positions A and B in this figure.



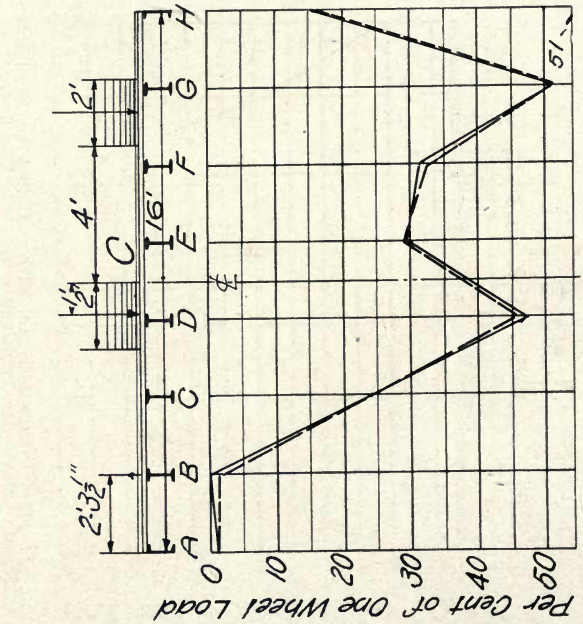


Fig. 23. See note for Fig. 22. Positions C and D in this figure.

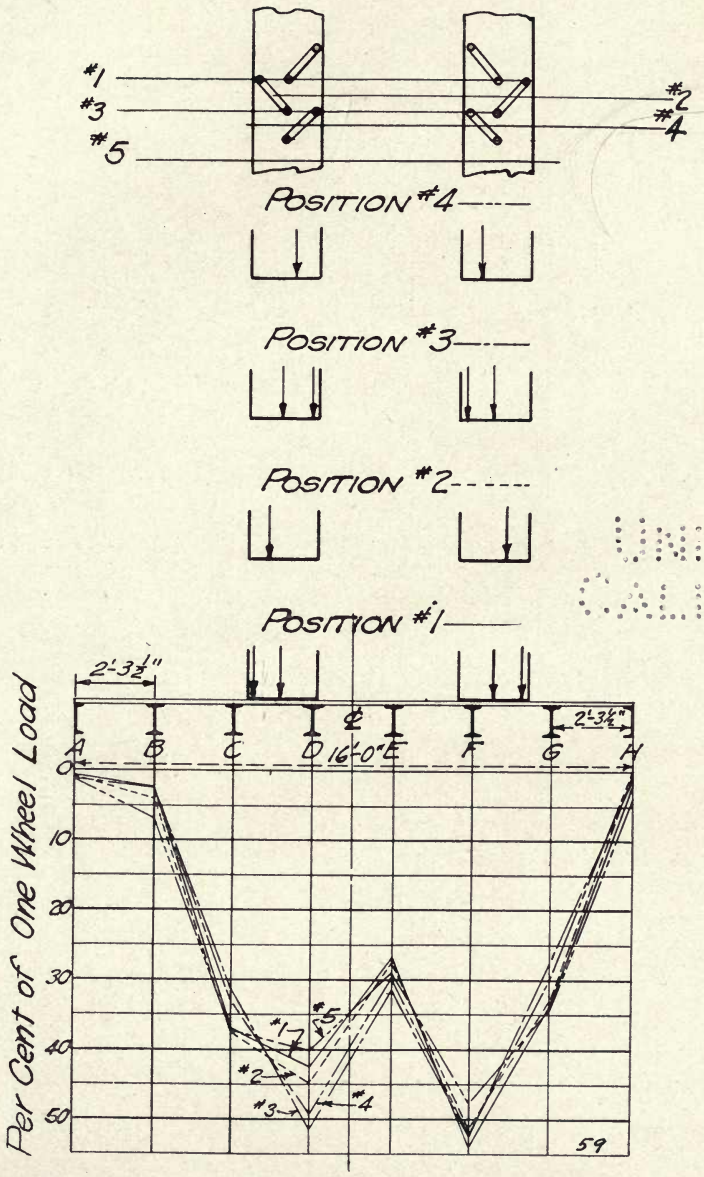


Fig. 24. Showing effect of position of lugs bearing on the floor. Load 18,900 lb. at each wheel. Floor system consists of six 9 in., 21 lb. I-beams and two 9 in., 13¼ lb. channels. Floor of commercial 3 by 12 in. fir, laid transversely and fastened to nailing pieces on channels.

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