SECOND PROGRESS REPORT ON

STRUCTURAL BEHAVIOR OF BATTLEDROSS FLOOR SYSTEMS

by Inge Lyse* and Ingvard E. Madsen**

I. SYMPTOSIS

This report presents the results of a two years investigation of the behavior of Battledrack Flooring. Four one-third size models and one full-size floor panel, designed from the results obtained on the models, were tested under the action of a concentrated wheel load, such as the specifications recommend for H-20 loading. It is shown that the battled Derrick flooring acted as an integral unit distributing the wheel load over various stringers, with the amount of load taken by the several stringers depending upon their spacing. The plate acted with the stringer so as to form a T-beam, which if taken into account in the design, might result in an economy of ten to fifteen percent. The amount of plate contributing to the T-beam action was also found to depend on the stringer spacing. When the stringers were coped in on the floor beams, partial fixity resulted with further economy in design. The models were loaded with dead weights, while the full-size floor panel was tested by means of a jack and spring device. The test results gave a basis on which to formulate a rational design method for battledrack floor systems.

* Research Associate Professor of Engineering Materials
Lehigh University, Bethlehem, Pennsylvania

** American Institute of Steel Construction Research Fellow
Lehigh University, Bethlehem, Pennsylvania
in immediate charge of battledrack investigation
2. INTRODUCTION

The American Institute of Steel Construction through its Technical Research Committee, sponsored this investigation of the action of concentrated loads on battldeck flooring in order to obtain information for design purposes. A research fellowship supported by the Institute was established at the Fritz Engineering Laboratory of Lehigh University and the investigation was carried out under the Committee's guidance.

Experiments were made on four one-third size models, based on a prototype bridge floor consisting of two panels twenty feet long and ten feet wide. The first model represented a floor with 3/8-in. plate on stringers spaced at 24 in. The tests showed that this floor was not capable of supporting an 8-20 loading. Consequently the second model had stringers welded in between those of the first model making the prototype a floor with 3/8-in. plate on stringers spaced 12 in. center to center. This model proved adequate in supporting the load, so that the next point in the investigation became a study of the more economical design. Comparative cost data indicated that although a widening of the stringer spacing might increase the weight of the floor slightly, the decrease in welding cost would more than offset the gain in weight. Thus, for the third floor model, a prototype was selected which consisted of a 3/4-in. plate laid on stringers spaced at 30 in., and for the fourth model a 9/16 in. plate on stringers spaced at 24 in.
The results of the model tests showed that the floors behaved according to certain relationships. Design methods and procedure as established from these results, served for the construction of the full-size floor panel. The agreement between the design stresses and the measured stresses in this full-sized floor indicated a check on the design assumptions. The full-size floor consisted of 12-in. standard I-beams spaced on 26-in. centers with a 11/16-in. plate. The floor was 16 ft. 9 in. in span and 9 ft. 5 in. wide. This span length was adopted because the full-size panel was tested as a simple beam with the stringers resting on the floor beams, representing the distance between the points of contra-flexure of a 20-ft. panel length bridge floor with the stringers coped into the beams.

3. ACKNOWLEDGMENT

The investigation was carried out under the direction of the Technical Research Committee of the American Institute of Steel Construction. Acknowledgment is due all members of this Committee for their active interest in the work and their advice and guidance. Acknowledgment is also due to the members of the Fabricating Division of the Bethlehem Steel Company for constructive criticism and valuable suggestions during the investigation, and to Mr. H. J. Bowles, Welding Supervisor, Bethlehem Steel Company, for advice and assistance in all the construction work, and to Mr. C. C. Keyser, instructor at the laboratory, for his assistance in the construction and testing.
4. The Problem

The problem of determining the behavior of battledeck flooring divides itself broadly into two parts, (1) the stresses in the plate, and (2) the action of the stringer, that is, the amount of load carried by each stringer and the interaction of plate and stringers in resisting flexural stresses. The investigation was limited to the study of these conditions in relation to battledeck flooring for highway bridges subjected to concentrated loads. It was necessary for an adequate solution of the problem to determine:

a. The strength and deflection of battledeck flooring under concentrated loads.

b. The properties of the floor plate in distributing the load over various stringers.

c. The amount of plate acting with the stringers as the compression flange of a T-beam.

d. The length of plate under concentrated load affected by the load.

e. The effect of changing the distance between the stringers.

f. The fixity of the ends of the stringers.

g. The fixity of the ends of the plate.

Very little work had previously been done in this field. Some mathematical studies have been made on the amount of plate acting in T-beam under various loading conditions*, and even less is known of the distribution of load amongst the various

* Die Mittragende Breite by Th. V. Karman, in Beiträge zur Technischen Mechanik und Technischen Physik, August Hoppe Festschrift, Berlin, 1924.
stringers of the floor. For uniform loads over a floor simple relationships obtain, but for concentrated wheel loads such as used in this investigation, the problem becomes very difficult.

What actually happens to a stringer floor under load is readily visualized, but a strictly mathematical analysis is practically impossible because the floor is statically indeterminate to a very high degree. As the load is applied the stringer beneath it deflects and the plate deflects with it, acting as a beam to transmit shear to the next stringer. This second stringer will also deflect and carry on the distribution. The distribution will theoretically go to all the stringers, though practically the effect may become so small after being distributed over three or four of them that any further distribution may be neglected. This action is quite different from that usually assumed in design, namely, that the load is spread equally over a certain definite number of stringers. Since the deflection of a beam varies as the cube of the span, that is, the spacing between the stringers, and inversely as the cube of its thickness, a floor having equal spacings between the stringers has a constant proportion of the shear transmitted between each stringer. In other words, the load on a floor is distributed throughout the floor in a geometrical ratio.

The action of the plate under a concentrated load is not readily determined. The plate may be regarded as a rectangular plate supported along the edges, but the behavior is complicated by the fact that the deflection of the stringers varies along the plate, giving it an elastic support, and in addition the
rotation of the stringers makes the fixity of the plate an
uncertain quantity.

In this investigation strain readings were taken before
and after loading to determine the stresses. Slope readings
were also taken along the stringers before and after loadings.
These were plotted, and the resultant curves were differenti-
ated once to obtain the moments, and then a second time to ob-
tain the shears. They were also integrated to obtain the de-
lections, and the deflections were also measured directly for
a check. From mechanics, the slope curve, differentaited twice,
and multiplied by EI gives the shear. Since the sum of all
the shears of the stringers must be equal to the applied load,
the value of the moment of inertia I was so selected that this
became true for the experimental results. Knowing the value of
I, it was easy to determine how much plate was acting with the
stringer as a T-beam. The values of the shears on each string-
er indicated how much load was carried by the various stringers.
Also when the T-beam action of the stringer was known, the sec-
tion modulus could be computed, and the stress could be deter-
mined from the moment curves which had been computed. These
stresses were compared with the measured stresses, and their
agreement served as a check on the work. The stresses in the
plate were determined by means of Huggenberger tensometers.
5. PROGRAM

The investigation was carried on, as stated before, by tests on four models and one full-size bridge floor panel. The models were tested with the dead loads in various positions. In what is called a typical run, strain readings were taken along the stringers, transversely between the stringers, and level bar readings were taken along the stringers both before and after the load was applied. The difference between the initial and final readings was the effect due to the applied load. The strain multiplied by the modulus of elasticity gave the stress at any point in the stringer, and the difference in the level bar readings gave the slope due to the applied load. Such tests were made on the models with the load in all parts of the floor. However, the load in the middle of the stringer caused the larger stresses and therefore governed the design. In the full size panel, tests were made only with the load in the middle of the floor.

For these tests, the sum of all the slope readings along a stringer at any point would give the deflection of the stringer at that point. However, this was supplemented by tests in which Ames dials were placed along the stringers to actually measure the deflections. These results agreed quite closely with the integration of the slope readings and served as a check on them.
The plate stresses were obtained by measuring the strains in the plate with Huggenberger tensometers. The load was placed in various parts of the plate, and Huggenberger's were located at all points where any effect was noticed, thus recording the distribution of the plate stresses.

In making some of the models, strain measurements were also taken on the stringers before and after welding to get an idea on the amount and effect of the welding stresses.

6. TESTING

The models were made out of standard rolled steel sections and plate. They were constructed on the basis that the model should be one-third size. However, since the prototype could not be reduced in all proportions without expensive machining, the stringers were machined so as to keep the clear spans of the plate in proportion, and they were designed so that the stresses in the model would be approximately the same as in the prototype. This could not be quite attained since the smallest I-beams rolled gave about a twenty-five per cent excess over the computed section modulus. The panels in the model were eighty by forty inches. The first two models consisted of two panels welded together. The last two models consisted of but one panel each, but they were welded in the same frame and their floor beams consisted of channels. After the testing of the last two models was completed, a filler plate was put between the two adjacent channels and weld metal deposited so as to make an I-beam and cause the panels to be continuous. A picture of the first
two models is shown in Fig. 1 and 2. All the models had the same type of stringers but the stringer spacing and the plate thickness varied. The plate in the first two models was steel metal sheeting of a low strength and yield point. This type was selected because the uniformity of thickness which sheeting possesses was an important factor in the 1/8-in. plate thickness used in these models. The 1/4 and 3/16 in. plates in the third and fourth models were regular structural grade and passed the specifications.

Great care was necessary in welding the models in order to avoid warping, particularly in the first two where the plate was so thin. They were fabricated by first tacking the stringers onto the plate, and then the weld metal was deposited, alternating from one spot to another on the floor so as to minimize the heat and thus decrease the tendency to warp.

The models were loaded by a dead weight loading rig which is shown in Fig. 1. The United States Bureau of Public Roads has approved a loading area of twenty by ten inches for the rear wheel of an H-20 loading. This assumes a 20-in.-wide tire with a pressure of 112 lb per sq in., giving 10 in. of longitudinal bearing.

The loading rig consisted of a cast iron block to which a frame was fastened to carry the additional dead weight. The initial weight of the rig was four hundred pounds. Additional load was applied by adding fifty-pound weights. The load was applied through a steel bearing plate which was one-third size or 5-2/3 by 3-1/3 in. Under the bearing plate was placed a
piece of soft rubber 1-1/2 in. thick to keep the load constant-
ly uniform as the plate deflected, and a piece of cellotex was
placed under the rubber to keep the area in contact with the
plate constant.

A load of 2499 lb. should cause the same stresses in
the model as would the rear wheel of a H-20 truck in the full-
size panel. A load of 2500 lb. was used in the model tests.

In order to show that the loading rig gave a uniform
load distribution on the plate, and in order to compare its
action with that of a tire, comparative load tests were made.
The floor was tested by means of/looding rig and strain meas-
urements were taken around the load at a number of critical
points. Then the floor was tested by means of a tire as shown
in the photograph of Fig. 3. The results of these tests were
compared and found to be equal within the limits of experiment-
al error, showing that the loading rig gave essentially the
same results as an actual wheel load.

The full-size floor panel was fabricated in the shops
of the Bethlehem Steel Company. No trouble was experienced
with warping due to welding so that it was unnecessary to go
through any special welding procedure. The plate was so thick
it dissipated the heat rather quickly. Structural grade steel
was used in the floor.

The floor was set in a frame as shown in Fig. 4. It
was tested by means of jacks as is shown in Fig. 5, the load
being measured by means of the deflection of calibrated springs.
It was possible to ascertain the load on the floor by this method to within one per cent. In order that the pressure on the floor be uniform as the plate deflected, the deflection of the plank on which the spring set-up was placed was computed and the plank made of such a thickness that its deflection would be approximately equal to that of the plate. The deflection of the plank was computed on the basis of a beam on a yielding foundation under uniform pressure.

The models were held in a frame consisting of vertical posts made up of eight-inch channels braced with angles (see Fig. 1 and 2). The floor beams of the models were welded to the vertical channels to simulate the connections of beams to hangers in an actual bridge construction. The full-size panel was held up in a truss made up of beams and angles, the details of which are shown in Fig. 4.

The strains in the stringers were measured by means of a fulcrum type Whittemore strain gage, equipped with a 0.0001-in. Ames dial. It is accurate to about six hundred pounds per square inch, as a tolerance of 0.0002 was allowed in repeating a reading. Since temperature changes cause strains in a structure which would be measured by the gage, the observations were made when these changes were at a minimum. Usually therefore, temperature could be neglected, but when variations occurred, corrections were applied to the strains from observations on mild steel standards.
The Huggenberger tensometers which were used in the plate tests had one-inch and one-half inch gage lengths. They are accurate to within about five hundred pounds per square inch, depending on the gage length.

Two level bars were used. The one employed in the model tests had various gage lengths from one to six inches. However, the five-inch gage length was used practically exclusively. It was fitted with a very sensitive bubble so that readings could be repeated to 0.0001-in., if the point hit the same spot on the floor. Hitting the exact spot was practically impossible, and so the accuracy was limited by the irregularities in the plate surface. For the full-size model, the bubble was mounted so that the level bar had a fifteen-inch gage length. This would make the instrument three times more accurate than it was on the five-inch gage length, but here again the accuracy was limited by the irregularities in the plate surface. These irregularities were worse in the full-size plate than in the models. In all cases the spots, where the micrometer point of the level bar rested, were ground smooth and polished with an emery cloth.

7. TEST DATA AND RELATIONSHIPS

A large number of tests were made on all the models and on the full-size panel. It is impossible, however, to describe all these tests and only the results of the significant and important runs will be given.
a. Tests on First Model of 84-in. Stringer Spacing -
A series of nine runs were made on the first model. Some of the load positions included the quarter points of the stringers, the center of the span, and adjacent to the floor-beams. As far as stringer stresses are concerned, the load in the center of the span caused the critical stresses.

In Series 16 (see Fig. 6), the load was placed between stringers E and G, in the middle of the first panel. In Table I, are shown the results of the test. It is seen that the two adjacent stringers E and G took eighty per cent of the load, while the two next ones took about ten per cent. It is also noted that the stringers, which were away from the direct influence of the load, carried over about twenty-five per cent of their load to the adjacent stringer. The beams acted as if they were partially fixed, the average fixity factor on the left being about fifteen per cent and that on the right about thirty-nine per cent. Due to this fact the left shear was less than the right. These fixity factors were the ratios of the moments at the supports to those of a fixed end beam.

In order that the shears should equal the applied load, the moment of inertia of a stringer had to be 3.54 in$^4$. This required 3-1/2 in. of plate acting in the compression flange. With these values the computed center moment was found from the slope curves, and the fibre stresses were computed. The measured stresses did not agree with the computed as well as expected, and the reason for this will be discussed later.
The center deflection was computed from the formula
\[ d = \frac{E}{192EI} \left( -4 + 2K_1 + K_2 \right). \]
This formula was derived from moment area theorems, and while approximate is good within a few per cent, if the fixity factors do not differ by more than fifty per cent.

The deflection was obtained by summing up the areas underneath the slope curve. The agreement between the observed and measured deflections served as a check upon the accuracy of the differentiation and the computations.

In Table II are shown the results of Series 17A on the first model. In this run the load was placed directly on stringer 2 at its center. However, the loading area was so wide that the bearing block lapped over the plate and some of the load was transferred directly through the plate to stringers 5 and 6. The ratio between the shear carried from one stringer to another in the direction away from the load, is seen to be 0.84. The average left fixity factor was 23 per cent and the right 35 per cent. The value required for the moment of inertia of the stringers to make the shear equal to the load was 3.35 in\(^4\) for the interior stringers, and 2.84\(^4\) in\(^4\) for the exterior stringer A. These values for \( I \) were worked out as follows: First the shears were computed using a value of \( I \) corresponding to full T-beam action, that is, using eight inches of plate for the top part of the T in the interior stringers, and four inches for the exterior stringers. This made the value of the shears too large. Next, the values for the moment of inertia were multiplied by a factor
so the shears would equal the load, and then the width of plate required for this value of the moment of inertia was computed.

The left reactions were again found to be less than the right, as would be expected, since the left fixity factor was smaller. It is seen that Stringer E directly beneath the load took fully fifty per cent of the load.

In Series 19, the load was placed on Stringer C, which was next to the exterior stringer. Consequently, the load could not be distributed so widely. In this case, the loaded Stringer C carried fifty-five per cent of the load or five per cent more than in the former series.

The worst loading condition for the floor occurred in Series 21 when the load was placed directly over Stringer A, an exterior stringer. The results for this test are given in Table III. It is noted that Stringer A took 63 per cent of the load. However, this loading would not be attained in an actual bridge, since in order to place the wheel directly over an exterior stringer, a good deal of the wheel would be projecting out beyond the floor. When the load was placed as close to the exterior stringer as is practical, it took about fifty per cent of the load, and its design would be about the same as that of an interior stringer.

Referring to the stringer stresses of Series 21, the measured stress gave values which would require much more plate in T-beam action than the total plate width between stringers. This shows that there were other stresses in the
stringer besides bending stresses. The observed slopes of Stringer A during this test are shown in Fig. 7, and the corresponding stresses in Fig. 8.

The results of quarter point loading on the floor were quite interesting. The amount of plate in T-beam action was the same as that in the corresponding center of span loadings, but the amount of shear transferred from one stringer to another was only 0.08 the shear in the stringer, instead of the 0.25 which occurred in the former cases. This agrees with the fact that the shear transferred from one stringer to another depends on their relative deflection, and since the stringers deflected less at the quarter point, the difference in deflection between two adjacent stringers was less. Carried to the extreme, when the load is at the end of the stringer, one stringer will take the whole load and must be designed for such.

Supplementary tests were also made on this model. In Fig. 9 the deflection of Stringer E is plotted against the load. The load was placed in a position corresponding to Series 18. It is seen that the load-deflection relation is a straight line which would be expected, showing that the amount of plate acting as a T-beam was constant and did not vary with the load.

The center deflection diagram for the plate is also given in Fig. 9. The curve slopes upward to the left showing that the load required for equal increments of deflection increased with the increase in load on the plate. In other words, catenary action helped to support the plate.
In Fig. 10, the deflections of the plate and Stringer E are plotted against the longitudinal axis of the stringer for a 2500-lb. load. The deflection curves for quarter point loading are also given. In the stringers, there is a slight initial reverse curvature of the deflection curve at the ends of the span. This shows slight partial fixity.

The curve for the plate, in sharp contrast to that of the stringers, slopes gradually and then ballys down quite sharply underneath the load.

In all these tests the stringers rotated a good deal. However, the top of the stringer showed little or no rotation which indicated that the stringers must have rotated about the plate. This rotation is at least partly due to the deflection of the floor plate. Evidently, the stringers were subjected to torsional forces and thus contributed to the load distribution.

b. Tests on Second Model of 18-in. Stringer Spacing

The second model, as has been said before, was the same as the first, except that the stringers were spaced four inches center to center instead of the former eight inches. The test results were similar to those of the first, but due to the decreased stringer spacing, the floor was stiffer so that the load was distributed over more stringers.

In Table IV, are shown the results of Series 32 (see Fig. 6), in which the load was placed directly on top of stringer F. The width of the loading area was so large relatively to the stringer spacing that when stringer F was loaded, the area
lapped over onto the two other stringers F and G. Full T-beam action was present in this series. Stringer F took the largest proportion of the load or about thirty per cent. The ratio of shear carried from one stringer to another in the direction away from the load was about 0.43, instead of the 0.25 found in the first model. The average fixity factor was about 12 per cent at the left and about 35 per cent at the right.

The center moment, stress, and deflection, were computed for the second model in the same manner as for the first. The slope readings checked the deflection. However, the ratio between the various stringers did not stay quite as constant for the shear, moment, and deflections as they did in the first model. This shows that the slope curves were not exact second-degree curves, although they were so assumed, and consequently, a slight error occurred with the differentiation and integration.

The load on the other sections of the floor gave results similar in nature to those shown for Series 32.

After the regular runs had been made on the second model an attempt was made to test it to destruction. The model was loaded by means of a 30-in. I-beam cantilevered out from a 800,000-lb. testing machine. It was first loaded to 15,710 lb., which is more than six times the design load, at which time the deflection under the load was 0.531 in. The load was released to 4700 lb. and the deflection was 0.340 in., of which 0.118 in. was permanent set.
The model was loaded again to 28,510 lb., when the testing had to be discontinued due to the incipient yielding of the loading beam and the bowing of the vertical legs of the frame holding the floor. At this load the total deflection was about one inch. The stringer under the load had yielded and thrown much of the load onto the two adjacent stringers which were also starting to yield. Upon removal of the load a permanent set of about one-half inch was present.

There was no sign of yielding of the plate, and the only sign of failure was scaling of the whitewash in one of the welds holding the floorbeam in the supporting frame.

c. Tests on Third Model of 30-in. Stringer Spacing

The third model was based on a prototype with a 3/4-in. plate welded to stringers spaced on 30-in. centers. This model, as well as the fourth, consisted of but one span, and since the stringers were coped into the floorbeams there was a partial fixity present. In these models, the plate was carried out to the center of the exterior Stringer A, whereas it lapped out two inches from the center of the exterior Stringer E. This was done to see if the overlapping plate was efficient in T-beam action.

The results of the tests on the third model were very similar to those of the first two. In Table V, are given the results of the case in which the load was placed on top of Stringer C. Stringer C took 59.4 per cent of the load which is a greater proportion than in the first two models. This
was due to the greater stringer spacing. For a similar reason, the amount of plate in T-beam action was not as large as in the first two models. The fixity factor for the loaded stringer was small as would be expected. For the other stringers the fixity factor is negative. A negative fixity factor denotes an applied moment at the end of the stringer. The reason for this is as follows: Due to the partial fixity of the loaded stringer, the floorbeam rotates and puts applied moments on the adjacent stringers.

A number of tests were made in a study of the plate stresses in the third and fourth models. Similar tests were made on the full-size floor and since these were more complete and gave essentially the same results as those on the models, only the results on the full-size floor plate are given in this report. Full T-beam action was not present in these models. Accordingly, the compression in the top part of the T-beam would be expected to decrease away from the stringer. This decrease was found to be linear as shown in Fig. 11 for the variation of the compression in the plate between Stringers C and D when the load was placed between them.

Cross bracing was welded between the stringers in one of the bays of this model. It consisted of 1/4 by 2-in. plates welded to the stringers and the plate at 12-in. intervals. Although the secondary bracing was spaced this closely, the plate stresses were reduced but very little.
d. Tests on Fourth Model of 34-in. Stringer Spacing

The fourth model was based on a prototype with 9/16-in. plate welded to stringers at 34-in. centers. In this model, an attempt was made to evaluate the welding stresses. Strain readings were taken on the stringers and on the portion of the plate over the stringers before and after the floor was welded together. The welding stresses were largest in the plate because most of the welding was done there. The longitudinal welding stresses in the plate varied from about 4000 over the exterior to 9000 lb per sq in. compression over the interior stringers. The stress along the bottom of the stringers was about 2000 lb per sq in. tension. The transverse welding stress in the plate between the stringers varied from fifteen to twenty thousand pounds per square inch compression. These stresses did not seem to affect the test results.

The results of the various tests of the fourth model were similar to those of the previous models. Table VI gives the results of the case in which Stringer C was loaded. Stringer C is seen to take 48 per cent of the load.

After the regular runs had been made on the third and fourth models, they were welded together to form a two-panel floor. A run was taken similar to that in the third model for which the results are given in Table V and the results for the two-panel model were very similar to those for model three except that the fixity factor at the intermediate floorbeam was
increased to fifty per cent. The stresses and deflections in
the floorbeams were found to be smaller in accordance with the
increased fixity factor.

Both the third and fourth models were tested to destruc-
tion. They were loaded in a manner similar to that used
for the second model, that is, cantilevering out from the big
testing machine. The third model was loaded up to 26,744 lb.
and the fourth to 27,911 lb. In each case, the testing had to
be discontinued due to incipient yielding of the loading beam.
At these maximum loads which were about eleven times the design
load, large deflections were present although nothing broke.
The large reserve strength is due to the fact that as one
stringer yields, the increase in load is taken by the adjacent
stringers while the original stringer still holds its yield-
point load. This process continues until all stringers have
yielded.

In the third model the load was placed on the plate be-
tween Stringers B and C. Fig. 12 shows a diagram of the load-
deflection and permanent set curves of the stringers and the
plate. At the maximum load, the deflection was two inches and
the permanent set was one inch.

The fourth model was tested with the load directly
over Stringer C. The results were about the same as for the
third model. In Fig. 13 is given a diagram of the deflection
of the centers of the stringers under various load increments.
e. Tests of Full-Size Floor Panel - The full-size floor panel was built according to a design procedure, determined by a study of the results of the model tests. The panel was 18 ft. 9 in. long center to center bearing and 9 ft. 5 in. wide. This floor was built with the object in view that it was to act as a test on the design procedure, and to serve as a check on the model tests. How well it did this is illustrated in the comparison of the design values with the measured values of stress and deflection for the critical sections of the floor, shown in Table VII. The check is very good considering that the properties of structural sections may vary as much as five per cent. The tests on this full-size floor were similar to those of the models. Table VIII gives the results when the load was on top of Stringer C.

Because of the large dimensions of the full-size floor, it was possible to get more data on the stresses in the plate than had been possible in the models. A large number of Huggenberger readings were taken in order to obtain the stress distribution in the plate. Fig. 14 shows the distribution of the transverse stress in the plate along the length of the floor. This stress is the largest in the plate since it lies along the short span between the stringers. It is seen to have a peak of 26,000 lb per sq in. at the center of the load, rapidly decreases asymptotically along the plate. The compression in the top of the plate is seen to be similar to the tension in the bottom. Complete readings could not be obtained for the compression side
since the load was in the way. In Fig. 15 is shown the distribution of the transverse stress in the bottom of the plate across the width of the floor. In the loaded span, the stress in the plate was zero at the edges of the stringer flanges. The stress changed to compression along the flange, and rapidly dropped off to zero at the next stringer.

An overload test was made on the full-size floor. It was loaded up to 56,000 lb., or two and one-half times the design load. The deflection of the floor increased linearly with the increase in load. At a fifty per cent overload, there was an overall permanent set under the plate of 0.005 in. At the maximum load of two and one-half times the design load the permanent set was 0.025 in. No signs of failure or yielding could be determined with the exception of a scaling of the whitewash near one of the welds between the plate and stringer. After the load was removed, the floor appeared just as good as ever, and one could never have told by eye that it had been overloaded. The maximum deflection of the plate had been 0.269 in.

8. DISCUSSION OF RESULTS

The results of these tests show that the battledeck floors acted as an integral unit. The load was distributed from one stringer to another by means of the plate; which acted as a cantilever beam, in proportion to the relative deflection of the stringers. This distribution factor was a constant for a definite stringer spacing and plate thickness. In all cases as shown by the tables, the carryover factor was larger for the
strings close to the load than for those away from the load. Considering the case in which the load was directly over one stringer, the adjacent stringers took not only the amount of load carried over by their relative deflections, but also some of the load itself as the wheel load was so wide that it lapped over the loaded stringer.

In some cases the stresses in the stringer did not check the computed stresses, particularly for the smaller stringer spacings. This is because the computed stresses only included bending stresses. Since the stringers were welded to the floorbeams, direct tension could occur in addition to the bending moments. Four types of stresses are probably added to the simple bending stresses along the tension flange. First, due to the tension in the lower flange, its length is increased, putting compression on the ends of the beam, thus tending to reduce the flange tension. Second, due to the deflection of the beam, the longitudinal axis shortens and causes tension along that axis. Third, due to the rotation of the bottom flange, shortening takes place which causes tension along the gage line. Finally, these effects in any one stringer have a reaction on the floor beam which in turn applies a couple and a tensional stress to the other stringers.

The effect of these stresses is greatest on the loaded stringer as it reduces the compression and increases the tension. This stringer has a large effect on the rotation of the floor beam which in turn tends to offset the secondary stresses
in the adjacent stringers. In the stringers a distance away from the load, the tension is reduced in some cases to zero, and the compression is increased. Table II illustrates this phenomenon.

The amount of plate in T-beam action was found to increase as the stringer spacing decreased, while the amount of load taken by a stringer increased with the increase in spacing. Both these results are logical and Fig. 16 presents the relationships obtained. These relationships are useful for the design of battledeck floors.

A stringer needs be designed only for the effect of one rear wheel load since the usual axle spacing on trucks is so large that the effect of one wheel is not carried over to the other. There seems to be no need of making the exterior stringer larger than the interior stringers since it is practically impossible for the center of the wheel to come over the center of the exterior stringers. Usually, the exterior stringer will not be stressed higher than the interior stringers if of the same size. The stringer next to the exterior will take about five per cent more of the load than any of the other interior stringers, because a full wheel load can rest on it and the exterior will not help support it as much as will the interior stringers. Thus, it will be overstressed about five per cent, if of the same size as the other interior stringers.
The stringers when coped into the floorbeams of a single span gave a fixity factor of about twenty-five per cent. When the spans were continuous, the fixity factor was as high as fifty per cent. A substantial saving in material can be effected if this partial fixity is taken into account in design. The above statements apply to web plate connections while the fixity factors for web angle connections were slightly smaller.

In designing battledock floors the smaller is the stringer spacing, the lighter will be the resultant floor. However, the increased welding cost of the lighter floors will probably in general make them uneconomical unless the importance of light-weight is particularly high, such as in lift spans.

The overload tests showed that the battledock floor had a very large reserve strength and was practically impossible to break. The test on the full size floor panel would indicate that, although the measured stress was fairly high, the plate thickness could be reduced to 5/8 or 9/16 in. and still be amply strong to take an H-20 load.

Most plates in battledock flooring have been designed on the assumption that the plate under the load acts as a fixed end beam. No account has been taken of the longitudinal distribution of the load. Fig. 14 and 15 show the distribution of the plate stress. The longitudinal distribution is seen to extend itself over about four times the clear span of the plate, or about 84 in.
The point of contraflexure of the plate fell close to the edge of the stringer flange. One of two assumptions may explain this: The first assumes that the plate acts as a simple span between the flange of stringers; the second assumes that the plate acts as a fixed beam with the point of contraflexure at the edge of the stringer flange. In either case the result is the same and the first assumption is the easier to use in computation. The second assumption is probably closer to what actually takes place since the plate forms a fixed beam of varying cross-section, the depth between the flanges being the depth of the plate itself, and the depth over the stringer flanges in the thickness of the plate plus the flange. The increased depth of beam at the stringers decreased the stress over the stringer far below what would be expected. The tension stress was larger than the compression stress, probably because a catenary stress of about 1000 lb per sq in. was present.

The curve in Fig. 14 shows that the longitudinal distribution of stress varied from a peak at the center of the load decreasing asymptotically. Neglecting the small curve at the peak, this variation may be assumed to be parabolic. Thus the computation of the stresses in the plate becomes very simple. First, the total moment which the plate must support is computed on the assumption that the plate is a simple beam between the edges of the stringer flanges. Next the average stress in the plate is computed over the length of four times the clear span of the plate, since the load is distributed
over that distance. This gives us for the average stress 
\[ \sigma = \frac{M}{4.3L} \]
where \(M\) is the moment, \(L\) the clear span and \(S\) the
section modulus of the plate per inch of plate. The maximum
stress in the plate will be three times the average since the
distribution of stress is parabolic. This semi-empirical
method of determining the plate stress was used in computing
the stresses in the full-size floor and was checked by the ob-
erved stresses. The values of the stresses in the one-third
size models checked even more closely than those for the full-
sized floor. This method of determining plate stresses may be
expected to give quite accurate results for one-way slabs
under concentrated wheel loads.

9. RECOMMENDED METHOD OF DESIGN

The results of the four models and the full-size floor
panel indicated that battledock floors may be designed by the
following procedure.

(1) When the stringer spacing is determined, obtain
from the graph of Fig. 16 the load taken by T-beam action of
one stringer and its contributing plate width. With this in-
formation, the moment on the stringer is easily found and a
trial stringer is selected. The properties of the T-beam sec-
tion can be determined as soon as the plate thickness is found.

(2) When the trial stringer section has been selected
for the T-beam, the clear span between the stringers is known.
The trial section can be determined quite closely in the first
step since large changes in the top of the T-beam change the
value of the section modulus but slightly.
(3) Using the formula \( \sigma = \frac{3M}{4bh} \), the required plate thickness is determined. This is found directly by changing the formula to \( t = \frac{3M}{2bh-L} \).

(4) Knowing the plate thickness, the section of the T-beam is determined, and the stresses in the stringer are computed. If the stresses are not satisfactory another section is selected.

(5) Design the stringer connections for the full load in shear.

(6) Partial fixity may be taken into account and resultant economies effected by using a fixity factor of 25 per cent where the span is simple and 50 per cent where the span is continuous.

Wide flange beams in general, will be economical since they reduce the clear span of the plate. However, the lightest wide flange beam may not meet the specification that the web must be at least 3/8-in. in thickness.

In general, lateral bracing should not be necessary for the floor when the stringers are coped in on the floor beams.

When the plate and stringers are selected, the rest of the floor is designed according to the usual methods. The welds between the plate and stringers are designed for longitudinal shear. The resultant welds will also be strong enough to take care of the horizontal and catenary stresses in the plate.
10. SUMMARY

The results of the tests indicated that:

1. Battledock flooring makes a satisfactory and strong bridge floor which acts as an integral unit.

2. Inherent welding stresses may be found in the plate of battledock flooring but they do little harm. Care in welding will minimize these stresses.

3. A tire gives essentially uniform load over the area upon which it rests.

4. The plate acts with the stringers to form a T-beam reducing the stringer stress about fifteen per cent.

5. The amount of load taken by a stringer and the amount of plate acting with the stringer varies with the stringer spacing.

6. The stringers distribute the load in proportion to their relative deflections. Thus the distribution is the greatest when the load is in the center of the panel and it decreases as the load approaches the floor beams. The distribution factor varies with the thickness of the plate and the distance between the stringers.

7. The plate acts as a simple beam between the edges of the stringers. The load is distributed longitudinally over a distance equal to four times the clear span. The distribution is parabolic with the maximum stress three times the average stress.
### TABLE I

**SERIES 16 - FIRST MODEL**

<table>
<thead>
<tr>
<th>Str.*</th>
<th>Shear Left</th>
<th>Shear Right</th>
<th>Ratio to Next Str.*</th>
<th>Per Cent</th>
<th>Total Load</th>
<th>Fixity Factor Left</th>
<th>Fixity Factor Right</th>
<th>Computed Center Moment in-lb</th>
<th>Ratio to Next Str.*</th>
<th>Center Stress Computed Measured</th>
<th>Center Defl. Ratio From to Slope Next Reads, Str.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>101</td>
<td>119</td>
<td>220</td>
<td>0.21</td>
<td>88</td>
<td>13</td>
<td>42</td>
<td>3,790</td>
<td>0.21 + 2,260</td>
<td>0</td>
<td>0.0185</td>
</tr>
<tr>
<td>E</td>
<td>507</td>
<td>555</td>
<td>1062</td>
<td>1.00</td>
<td>42.6</td>
<td>18</td>
<td>34</td>
<td>18,500</td>
<td>1.00 + 10,300</td>
<td>+ 9,500</td>
<td>0.0880</td>
</tr>
<tr>
<td>G</td>
<td>470</td>
<td>438</td>
<td>958</td>
<td>1.00</td>
<td>38.3</td>
<td>15</td>
<td>26</td>
<td>17,250</td>
<td>1.00 + 9,640</td>
<td>+ 10,150</td>
<td>0.0829</td>
</tr>
<tr>
<td>I</td>
<td>122</td>
<td>138</td>
<td>260</td>
<td>0.27</td>
<td>10.4</td>
<td>11</td>
<td>55</td>
<td>4,330</td>
<td>0.25 + 2,430</td>
<td>+ 800</td>
<td>0.0211</td>
</tr>
<tr>
<td>Total</td>
<td>1200</td>
<td>1300</td>
<td>2500</td>
<td>100.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Stringer

**Properties of Section Used in Computation:**

- Plate in T-Beam Action -- 5-1/2 inches
- \( I = 3.54 \text{ in}^4 \)
- \( S = 1.79 \text{ in}^3 \) and \( 3.07 \text{ in}^3 \)
### TABLE II
SERIES 17A - FIRST MODEL

<table>
<thead>
<tr>
<th>Str.*</th>
<th>Shear Left</th>
<th>Right Load</th>
<th>Ratio to Next Str.*</th>
<th>Per Cent Load</th>
<th>Fixity Factor Left</th>
<th>Right</th>
<th>Computed Center Moment in-lb</th>
<th>Ratio to Next Str.*</th>
<th>Center Stress Computed Measured lb per sq in</th>
<th>Center Defl. Computed From Slope Reads. inches</th>
<th>Ratio to Next Str.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>61</td>
<td>75</td>
<td>136</td>
<td>0.23</td>
<td>5.4</td>
<td>27</td>
<td>2,290</td>
<td>0.25 + 1,140</td>
<td>0</td>
<td>0.0135 0.0129 0.30</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- 1,370 - 2,500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>265</td>
<td>315</td>
<td>580</td>
<td>0.47</td>
<td>23.2</td>
<td>38</td>
<td>9,320</td>
<td>0.43 + 5,270 + 5,250</td>
<td>- 3,430 - 2,600</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- 3,430 - 2,600</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>538</td>
<td>699</td>
<td>1237</td>
<td>1.00</td>
<td>49.5</td>
<td>11</td>
<td>21,600</td>
<td>1.00 +12,200 +15,400</td>
<td>- 7,940 - 4,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- 7,940 - 4,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>201</td>
<td>241</td>
<td>442</td>
<td>0.38</td>
<td>17.7</td>
<td>15</td>
<td>7,940</td>
<td>0.37 + 4,490 + 4,500</td>
<td>- 2,920 - 3,100</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- 2,920 - 3,100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>47</td>
<td>58</td>
<td>105</td>
<td>0.24</td>
<td>4.2</td>
<td>23</td>
<td>1,740</td>
<td>0.22 + 980 + 900</td>
<td>- 640 - 900</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- 640 - 900</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>1112</td>
<td></td>
<td></td>
<td>1388</td>
<td>2500</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Properties of Sections Used in Computations:
- Exterior Stringer A
  - Plate in T-Beam Action -- 1-7/8 inches
  - $I = 2.84 \text{ in}^4$
  - $S = 1.67 \text{ in}^3$ and 2.00 in$^3$
- Plate in T-Beam Action -- 4-1/4 inches
  - $I = 3.35 \text{ in}^4$
  - $S = 1.77 \text{ in}^3$ and 2.72 in$^3$

* Stringer
**TABLE III**  
**SERIES 21 - FIRST MODEL**

<table>
<thead>
<tr>
<th>Str.*</th>
<th>Shear Left</th>
<th>Shear Right</th>
<th>Load</th>
<th>Ratio to Next Str.*</th>
<th>Per Cent</th>
<th>Fixity Factor</th>
<th>Computed Center Moment</th>
<th>Ratio to Next Str.*</th>
<th>Center Stress Computed Measured</th>
<th>Center Defl. Computed From Slope Reads.</th>
<th>Ratio to Next Str.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>717</td>
<td>916</td>
<td>1535</td>
<td>1.00</td>
<td>65.4</td>
<td>32</td>
<td>55</td>
<td>25,100</td>
<td>+15,500</td>
<td>-15,500</td>
<td>0.161</td>
</tr>
<tr>
<td></td>
<td>-15,500</td>
<td>-9,200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.149</td>
</tr>
<tr>
<td>C</td>
<td>336</td>
<td>350</td>
<td>686</td>
<td>0.42</td>
<td>27.4</td>
<td>33</td>
<td>36</td>
<td>11,130</td>
<td>+6,550</td>
<td>-5,400</td>
<td>0.062</td>
</tr>
<tr>
<td></td>
<td>-5,400</td>
<td>-5,400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.061</td>
</tr>
<tr>
<td>E</td>
<td>89</td>
<td>86</td>
<td>175</td>
<td>0.25</td>
<td>7.0</td>
<td>51</td>
<td>57</td>
<td>2,500</td>
<td>+1,470</td>
<td>-1,210</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td>-1,210</td>
<td>-2,300</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.011</td>
</tr>
<tr>
<td>Total</td>
<td>1142</td>
<td>1354</td>
<td>2496</td>
<td>99.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>99.8</td>
</tr>
</tbody>
</table>

* Stringer

Properties of Sections Used in Computations:
- Exterior Stringer A
  - Plate in T-Beam Action -- 1/2 inch
  - $I = 2.53 \text{ in}^4$
  - $S = 1.62 \text{ in}^3$ and 1.62 in$^3$

- Plate in T-Beam Action -- 2 inches
  - $I = 2.93 \text{ in}^4$
  - $S = 1.70 \text{ in}^3$ and 2.06 in$^3$
### TABLE IV
SERIES 32 - SECOND MODEL

<table>
<thead>
<tr>
<th>Str.</th>
<th>Shear Str. Load</th>
<th>Ratio to Next Str.*</th>
<th>Per Cent Total Load</th>
<th>Fixity Factor</th>
<th>Computed Center Moment in-lb</th>
<th>Computed Center to Next Str.*</th>
<th>Center Stress Calcd Measured lb per sq in</th>
<th>Center Defl. From Computed Slope Reads, inches</th>
<th>Ratio to Next Str.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>44</td>
<td>52</td>
<td>96</td>
<td>0.37</td>
<td>3.8</td>
<td>6</td>
<td>0.39 990 500</td>
<td>0.0092 0.0089 0.41</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>139</td>
<td>134</td>
<td>263</td>
<td>0.50</td>
<td>10.5</td>
<td>23</td>
<td>0.45 2,590 1,350</td>
<td>0.0226 0.0218 0.44</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>263</td>
<td>258</td>
<td>521</td>
<td>0.68</td>
<td>20.8</td>
<td>7</td>
<td>0.77 5,720 6,300</td>
<td>0.0508 0.0500 0.78</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>352</td>
<td>416</td>
<td>768</td>
<td>1.00</td>
<td>30.7</td>
<td>19</td>
<td>1.00 7,470 9,800</td>
<td>0.0672 0.0659 1.00</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>238</td>
<td>238</td>
<td>471</td>
<td>0.61</td>
<td>18.8</td>
<td>10</td>
<td>0.65 4,870 6,400</td>
<td>0.0440 0.0440 0.67</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>109</td>
<td>124</td>
<td>233</td>
<td>0.50</td>
<td>9.4</td>
<td>18</td>
<td>0.46 2,230 2,500</td>
<td>0.0201 0.0190 0.43</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>49</td>
<td>49</td>
<td>98</td>
<td>0.42</td>
<td>3.9</td>
<td>0</td>
<td>0.45 1,015 800</td>
<td>0.0095 0.0090 0.47</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1,172</td>
<td>1,271</td>
<td>2,450</td>
<td>3.30</td>
<td>3.30</td>
<td>3.30</td>
<td>3.30 3.30 3.30</td>
<td>3.30 3.30 3.30</td>
<td></td>
</tr>
</tbody>
</table>

* Stringer

Properties of Sections Used in Computations:
Plate in T-Beam Action -- 4 inches
I = 3.30 in^4
S = 1.76 in^3 and 2.64 in^3
TABLE V
SERIES 6 - THIRD MODEL

<table>
<thead>
<tr>
<th>Str.</th>
<th>Shear Left Right Load</th>
<th>Ratio to Next Str.</th>
<th>Per Cent</th>
<th>Fixity Factor</th>
<th>K1 K2 per cent</th>
<th>Computed Center Moment lb in-lb.</th>
<th>Ratio</th>
<th>Center Stress lb per sq in</th>
<th>Measured Computed</th>
<th>Deflection Slope Reads.</th>
<th>Ratio to Next Str.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>17 11 28 0.06 1.1 -16 - 5</td>
<td>601</td>
<td>0.06 +</td>
<td>323 + 500</td>
<td>0.0028 + 0.0045 + 0.0037</td>
<td>0.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>220 234 454 0.31 18.5 -38 -27 10,420</td>
<td>0.39 +</td>
<td>5,420 + 5,800</td>
<td>0.0458 + 0.0435 + 0.0450</td>
<td>0.48</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>735 722 1457 1.00 59.4 +27 +24 25,400</td>
<td>1.00 +</td>
<td>13,150 +14,200</td>
<td>0.0944 + 0.0935 + 0.0938</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>234 240 474 0.32 19.3 -47 -36 11,440</td>
<td>0.45 +</td>
<td>5,940 + 6,600</td>
<td>0.0495 + 0.0490 + 0.0497</td>
<td>0.53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>28 15 43 0.09 1.7 + 5 -23 1,207</td>
<td>0.10 +</td>
<td>640 + 1,000</td>
<td>0.0037 + 0.0045 + 0.0038</td>
<td>0.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1234 1222 2456</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Properties of Sections Used in Computations:
Stringer A - Plate in T-beam action = 3-1/4 in., I = 3.92 in^4, S = 1.86 in^3 and 3.20 in^3
Stringers B, C, D - Plate in T-beam action = 6 in., I = 4.43 in^4, S = 1.93 in^3 and 4.62 in^3
Stringer E - Plate in T-beam action = 4-5/8 in., I = 4.15 in^4, S = 1.89 in^3 and 3.90 in^3
### Table VI
#### Series 19 - Fourth Model

<table>
<thead>
<tr>
<th>Str.</th>
<th>Shear Load</th>
<th>Ratio to Next Str.</th>
<th>Per Cent Total Load</th>
<th>Fxity Factor</th>
<th>Computed Center Moment</th>
<th>Ratio to Next Str.</th>
<th>Center Stress</th>
<th>Center Deflection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
<td></td>
<td>K1</td>
<td>K2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>92</td>
<td>82</td>
<td>174</td>
<td>0.30</td>
<td>6.7</td>
<td>+16</td>
<td>6</td>
<td>3,270</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>K1</td>
<td>K2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>238</td>
<td>301</td>
<td>589</td>
<td>0.47</td>
<td>22.8</td>
<td>-16</td>
<td>-10</td>
<td>12,570</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>K1</td>
<td>K2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>625</td>
<td>1250</td>
<td>1</td>
<td>0.00</td>
<td>48.4</td>
<td>+23</td>
<td>+24</td>
<td>22,150</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>K1</td>
<td>K2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>235</td>
<td>314</td>
<td>449</td>
<td>0.36</td>
<td>17.4</td>
<td>-4</td>
<td>-13</td>
<td>9,340</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>K1</td>
<td>K2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>63</td>
<td>126</td>
<td>0.28</td>
<td>4.9</td>
<td>7</td>
<td>+7</td>
<td>7</td>
<td>2,430</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>K1</td>
<td>K2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>K1</td>
<td>K2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>K1</td>
<td>K2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1303</td>
<td>1235</td>
<td>2588</td>
<td>100.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Properties of Sections Used in Computations:
- **Stringer A** - Plate in T-beam action = 3-1/4 in., I = 3.51 in^4, S = 1.80 in\(^3\) and 2.82 in\(^3\)
- **Stringers B, C, D, E** - Plate in T-beam action = 5-3/4 in., I = 4.02 in^4, S = 1.87 in^3 and 3.86 in^3
<table>
<thead>
<tr>
<th></th>
<th>Design Value</th>
<th>Measured Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Maximum stress in plate</td>
<td>27,900 lb/sq in.</td>
<td>26,000</td>
</tr>
<tr>
<td>2. Maximum deflection of plate</td>
<td>0.113 in.</td>
<td>0.111</td>
</tr>
<tr>
<td>3. Maximum stress in loaded stringer</td>
<td>13,300 lb/sq in.</td>
<td>13,900</td>
</tr>
<tr>
<td>4. Maximum deflection of loaded stringer</td>
<td>0.169 in.</td>
<td>0.170</td>
</tr>
<tr>
<td>5. Percentage of wheel load taken by loaded stringer</td>
<td>53 per cent</td>
<td>56</td>
</tr>
<tr>
<td>6. Amount of plate in T-beam action</td>
<td>17-1/2 in.</td>
<td>17-1/2</td>
</tr>
<tr>
<td>7. Weight of floor (stringers and plate)</td>
<td>44.0 lb per sq ft.</td>
<td></td>
</tr>
</tbody>
</table>

---
### TABLE VIII
SERIES 31 - FULL SIZE FLOOR

<table>
<thead>
<tr>
<th>Str.</th>
<th>Load</th>
<th>Ratio to Next Str.</th>
<th>Percent Total Load</th>
<th>Computed Center Moment in-lb.</th>
<th>Ratio to Next Str.</th>
<th>Computed Measured Center Stress lb per sq in.</th>
<th>Center Deflection From Measured Slope Read. Inches</th>
<th>Ratio to Next Str.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>405</td>
<td>0.08</td>
<td>1.6</td>
<td>16,800</td>
<td>0.07</td>
<td>+ 390</td>
<td>0.006</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- 160</td>
<td>- 300</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>4,950</td>
<td>0.37</td>
<td>20.8</td>
<td>250,000</td>
<td>0.41</td>
<td>+ 5,600</td>
<td>+ 5,400</td>
<td>.066</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- 1,800</td>
<td>- 1,600</td>
<td>.075</td>
</tr>
<tr>
<td>C</td>
<td>13,120</td>
<td>1.00</td>
<td>56.2</td>
<td>610,000</td>
<td>1.00</td>
<td>+13,600</td>
<td>+13,900</td>
<td>.179</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- 4,450</td>
<td>- 2,100</td>
<td>.170</td>
</tr>
<tr>
<td>D</td>
<td>4,820</td>
<td>0.37</td>
<td>20.6</td>
<td>252,000</td>
<td>0.41</td>
<td>+ 5,650</td>
<td>+ 5,200</td>
<td>.066</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- 1,800</td>
<td>- 1,300</td>
<td>.080</td>
</tr>
<tr>
<td>E</td>
<td>199</td>
<td>0.04</td>
<td>0.8</td>
<td>12,300</td>
<td>0.05</td>
<td>+ 280</td>
<td>0</td>
<td>.003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- 120</td>
<td>- 300</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23,394</td>
<td></td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stringers A and E  Plate in T-Beam Action = 12 in.
\[I = 392 \text{ in}^4, \quad S = 48.6 \text{ in}^3 \text{ and } 106 \text{ in}^3\]

Stringers B, C, D Plate in T-Beam Action = 17-1/2 in.
\[I = 427 \text{ in}^4, \quad S = 44.7 \text{ in}^3 \text{ and } 137 \text{ in}^3\]
Fig. 1 - Photograph of Floor Model and Load
Fig. 2 - Bottom View of Second Floor Model
Fig. 4 - Photograph of Full-Size Floor
Fig. 5 - Photograph Showing Jack on Full-Size Floor
Loading Positions for First and Second Models
Fig. 7 - Slope Observations of Stringer A.
Fig. 8 - Stress Distribution in Stringer A
Fig. 9 - Load Deflection Relations for Center Stringer and Plate
Fig. 10 - Load-Deflection Relations for Stringer E and Plate
Fig. 11 - Stress Distribution in Floor Plate when Load is Placed between Stringers C and D
Fig. 12 - Deflection and Permanent Set of Plate and Stringers B and C. Breaking Test.
Fig. 13 - Deflection Curves for Center of Stringers
Breaking Test, Model #4
Fig. 14 - Transverse Stress in Plate of Full-Size Floor
Fig. 15 - Transverse Stress in Plate of Full-Size Floor
Fig. 16 - Amount of Plate in T-beam action and Load taken by Stringer