DESIGN AND CONSTRUCTION OF A MODEL RAILROAD BRIDGE

THESIS FOR THE DEGREE OF B. S.

L. E. West C. D. Harrington

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THESIS

Bridges

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Design and Construction of a Model Railroad Bridge

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By

L. E. West   C. D. Harrington

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THESIS

FOREWORD

During the winter of 1932, the authors visited the National Road Builders Association's exhibit of various road surfaces and road maintenance equipment at Detroit, Michigan. There we saw a miniature Pratt truss railroad bridge exhibited by the Ohio State Highway Department. There was an electric locomotive repeatedly crossing the bridge and the changes of stress in the various members was registered on small dials attached to them.

At the suggestion of Prof. Allen and Mr. Rothgery of this college, the authors decided to design and construct a somewhat larger and more elaborate model for their thesis.

The details of the design and construction are as hereinafter described. The model is presented with our compliments to the Civil Engineering department of Michigan State College with the hope that it may be of some assistance in class instruction in bridge analysis and design.

ACKNOWLEDGEMENT

The authors wish to thank Professor Allen and Mr. Rothgery for their suggestions, and also the Michigan Sheet Metal Works for the use of their shop and equipment.

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MATERIALS USED IN CONSTRUCTION

Lower chord members	1" x 14 ga. band iron
Upper chord members	1" x 14 ga. band iron
Verticals	$\frac{1}{2}$" x 14 ga. band iron
End diagonal (compression)	1" x 14 ga. band iron
Diagonals (tension)	3/16" round rods
Floor beams	$\frac{1}{4}$" round rods
Stringers	$\frac{3}{4}$" I beams, formed from IX tin
Track	00 gauge toy train track
Gauge springs	9/16" x 24 ga. spring brass
Gauge pointers	1/8" copper rods
Gauge dials	IX tin

DESIGN AND CONSTRUCTION

The type of truss chosen was a Pratt truss with tension diagonals, counters being placed in the center panels to take the reversal of stress caused by the live loading.

As a larger bridge than that shown at the Road Show was desired, it was decided to use a light gauge band iron of varying widths depending upon the member under construction.

As far as possible, we made the members of sizes similar to those of a large bridge; however, this was impossible in our case on account of the method used in joint construction. The many members terminating in a lower chord joint near the center of the bridge necessitated a width of about one inch for the lower chord members. By reference to the sketches on page 11, the details just described will be made more clear.

The panels were made 10" center to center - the height 12" center to center. This gave a diagonal distance of 15.62" center to center. The trusses were placed 8" on centers, with the stringers $3\frac{1}{4}$" apart.

The solid truss was constructed first, and the details of the joint connections decided upon as construction progressed. This was found to be the most practical way as difficulties arose during construction which could not be provided for in the design.

We made three jigs for the members; one each for the chords, verticals, and diagonals. This insured that all similar members would be the same length when finished.

These jigs consisted of a flat strip of 1" band iron on which were welded two upright $\frac{1}{4}$" rods exactly 10, 12, or 15.62 inches apart center to center. Each member was constructed and assembled on its respective jig. This gave us a uniform fit and bearing of all members.

A typical chord member consisted of a strip of the 1" band iron about $9\frac{1}{2}$" long, with a set of clips thru which the ends of the floor beams passed soldered to each end. See details on page 11.

The verticals were made in a similar manner. The tension diagonals had a thin strip of sheet metal with a slotted hole in one end, fasted to each end of the diagonal. This was done to ensure that the diagonals would take no compression.

The floor beams consisted of $\frac{1}{4}$" rods 11" long, threaded at each end for a distance of about $\frac{3}{4}$". Washers were soldered $1\frac{1}{2}$" from each end so that the trusses would be 7" apart in the clear. The members of each truss were slipped on from the outside toward the center, and then held in place by means of a washer and nut at each panel point.

The stringers were made by forming two $\frac{3}{4}$" channels, placing them back to back, and soldering. The stringers were designed so that they were free to pivot on the floor beams. This was effected by slotting the end of one stringer and soldering two rods $\frac{1}{4}$" apart on the end of the next stringer. Sidewise movement was prevented by soldering narrow clips on to the floor beams next to the rods.

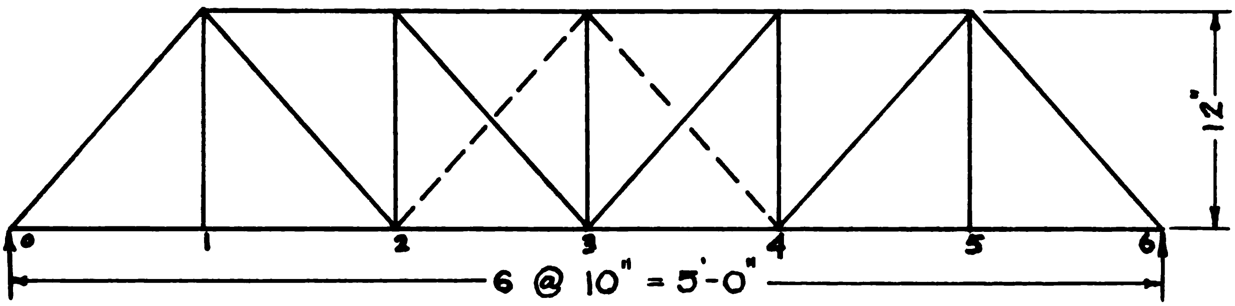
The track used was of the wide gauge used for toy trains. The sections were not of the proper length, however, and had to be cut off to size. The track as purchased had three rails. This center rail was removed from each section and used in the construction of additional sections. This called for additional ties which were formed out of IX tin. The ties were soldered directly to the stringers. There was a small space left at each panel point to allow the floor beam to deflect without causing any binding of the track or stringer.

The springs used in the split members were made by forming semicircular loops of the strips of spring brass. Two of these sections were bolted back to back at each split to prevent the members from buckling under compression.

The pointer of each gauge was pivoted at the end of a narrow strip of metal which was bolted to one part of the member and projected out into the middle of the circular loop. From the other part of the member a flat notched strip engaged the pointer near the pivot. By the principle of the lever, the movement in the springs was greatly magnified out at the end of the pointer. For a more complete description of these gauges, see details on page 12.

After final assembly, the bridge was weighed and the dead stresses computed as described on the following pages:

DEAD LOAD STRESSES IN TRUSS MEMBERS



Dead load of bridge equals 18#

Dead load per truss equals 9#

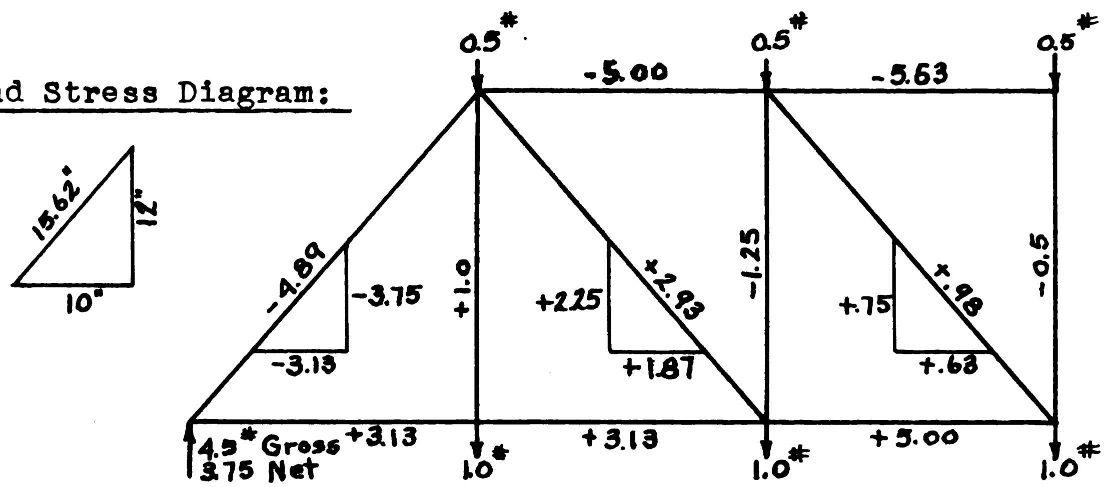
Dead load per panel equals 9/6, or 1.5# per panel

Distribution of dead load:

Upper chord takes 1/3 of 1.5#, or 0.5# per panel

Lower chord takes 2/3 of 1.5#, or 1.0# per panel

Dead Stress Diagram:



Sample Computations:

The stresses were computed by the index stress method, the index of stress in a diagonal being the vertical component of stress therein. In order to obtain the true stresses, the individual index stress must be multiplied by the ratio of bar length to vertical projection for the diagonals, by the ratio of panel length to truss depth for the chords.

Dead Stress Computations (cont):

With the panel loads written on the diagram, the stresses were written by inspection as follows: Starting with joint U3, the stress in the center vertical is -0.5# (minus indicating compression). At joint L3 the tensile vertical component in each diagonal equals one-half the sum of vertical stress and panel load, this joint being at the center of the span. This gives a V component of stress in diagonal U2-L3 as (1.0 plus 0.5) / 2, or plus 0.75#. At joint U2 there is a downward load of 0.5 and a downward vertical component in the diagonal of 0.75 to be balanced by the compression in the vertical U2-L2, or this compression is equal to their sum, or -1.25#. Thus the work proceeded to joints L2, U1 etc. in turn, a check being afforded at L0 by an independent computation of the reactions. Next the horizontal components of the diagonals were written down and then the chord stresses, proceeding joint by joint toward the center, first on one chord, then on the other.

The first check for the chord stresses was the requirement of equal stress in bars diagonally opposite as U1-U2 and L2-L3. The second and positive verification was the independent computation of the stress in the top chord at the center, which equals the bending moment at the center of the span divided by the truss depth. After this check, the actual stresses in the diagonals were added to the diagram.

We experimented with live loads of different weights until a load was found which was heavy enough to cause a reversal of stress which would be taken by the counters in the middle panels. A special car was designed to carry this weight across the bridge. The weight selected was a piece of steel shafting 3" in diameter and 10" long which weighed 20#.

The maximum swing of each pointer was marked on each gauge and this point marked with the maximum live stress as computed on the following pages:

After final adjustments were made using the live load selected, the bridge was sprayed with aluminum paint, the gauges calibrated as above described, and the completed model presented to the Civil Engineering department of the Michigan State College.

LIVE LOAD STRESSES IN TRUSS MEMBERS

Live Load Data:

Live load consists of a single 20# weight.

Therefore the weight per truss is 10#

Sample Computations:

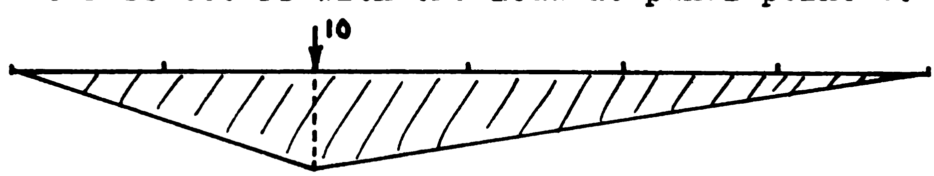
To determine the position of the load for the maximum stress in each bar required the drawing of an influence line for stress in that bar.

While in this particular method of loading, the effect of a concentrated load is not obtained, yet as this is only a relative measure of stress, the maximum stresses were computed on the basis of a 10# concentrated weight.

Following are the computations for maximum live stress in one each of the different types of members:

CHORD MEMBER U1-U2

Maximum stress occurs with the load at panel point 2.



Sum M about L2:

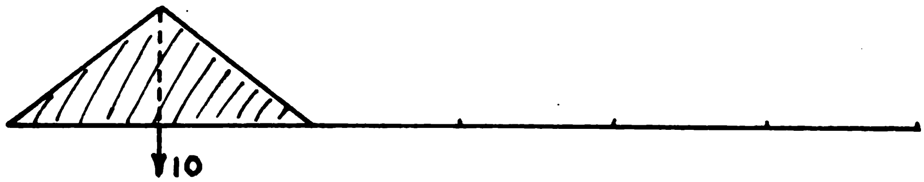
$$(2/3 \times 10) \times 20 = 12\ S$$

$$12\ S = 400/36$$

$$S = \underline{\underline{11.1\#\ \text{Comp}}}.$$

VERTICAL MEMBER U1-L1

Maximum stress occurs with the load at panel point 1.



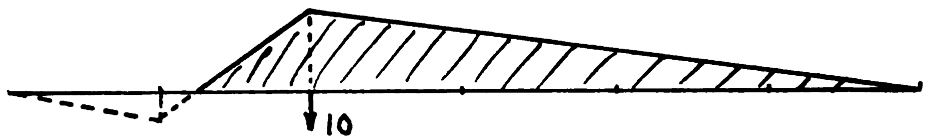
Taking the joint L1, and Sum V equals 0:

$$S - 10 = 0$$

$$S = \underline{\underline{10\#\ \text{Tension}}}$$

DIAGONAL MEMBER U1-L2

Maximum Stress occurs with the load at panel point 2.



Left Reaction $V_L = 4/6 \times 10 = 40/6$

Sum V equals 0:

$$V - 40/6 = 0$$

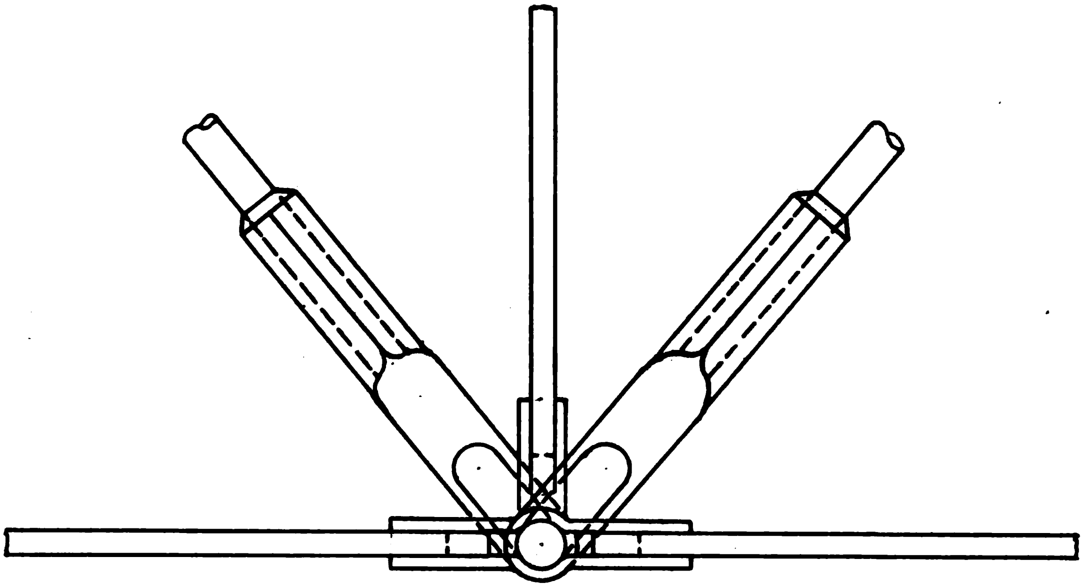
$$V = 40/6$$

$$S = 40/6 \times 15.62/12$$

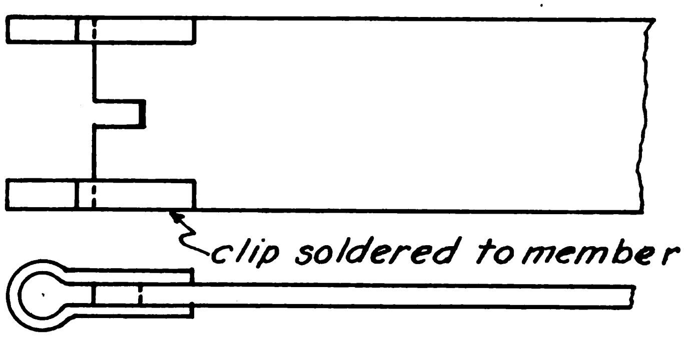
$$S = \underline{\underline{8.75\#\ \text{Tension}}}$$

SUMMARY OF STRESSES

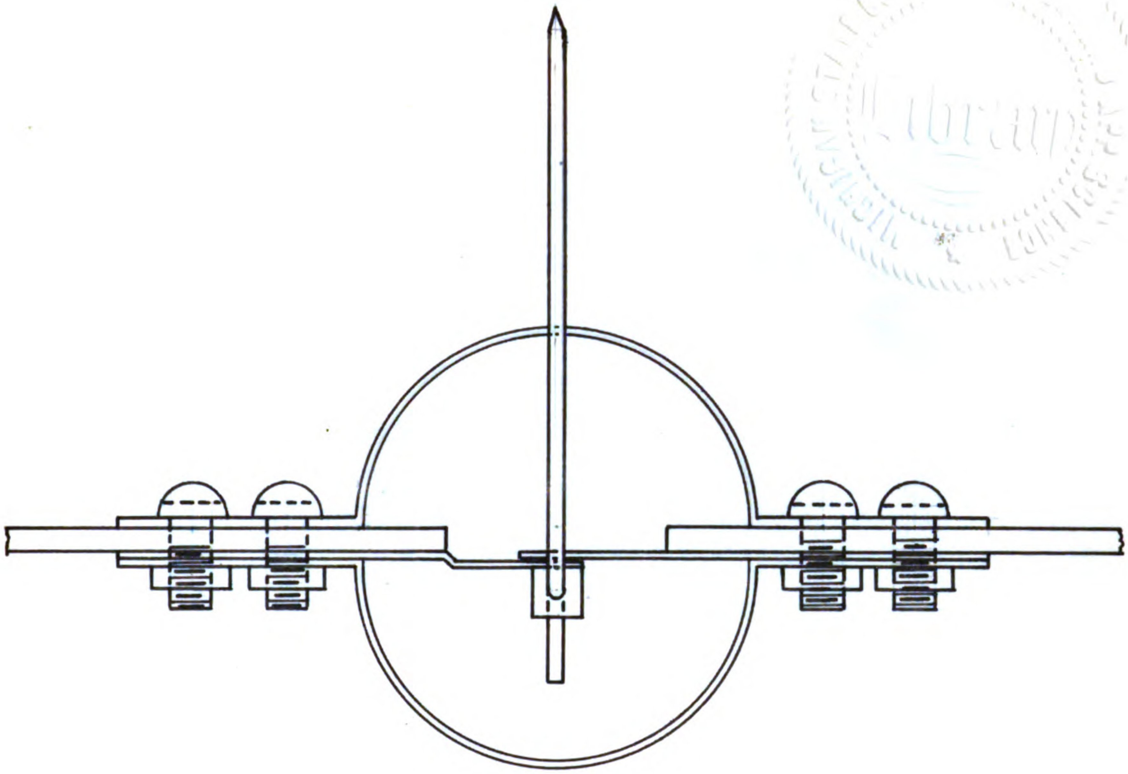
Member	Dead Stress	Position of Load for Max.	Maximum Live Stress
U1-U2	5.00# C	Panel pt. 2	11.11# C
U2-U3	5.63# C	" " 3	12.50# C
L0-L1	3.13# T	" " 1	6.95# T
L1-L2	3.13# T	" " 1	6.95# T
L2-L3	5.00# T	" " 2	8.34# T
U1-L1	1.00# T	" " 1	10.00# T
U2-L2	1.25# C	" " 3	5.00# C
U3-L3	0.50# C	" " 2	3.33# C
U1-L0	4.89# C	" " 1	10.83# C
U1-L2	2.93# T	" " 2	8.75# T
U2-L3	0.98# T	" " 3	6.50# T
U3-L2	0.00#	" " 2	4.33# T



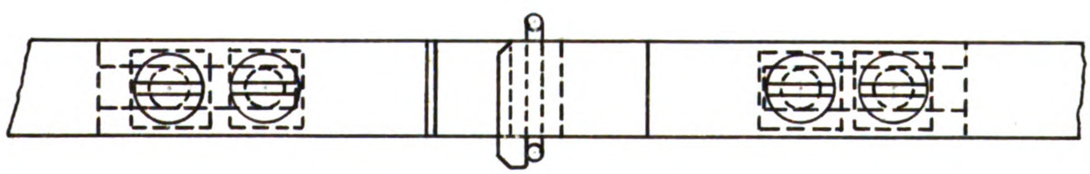
TYPICAL JOINT



TYPICAL CLIP CONNECTION

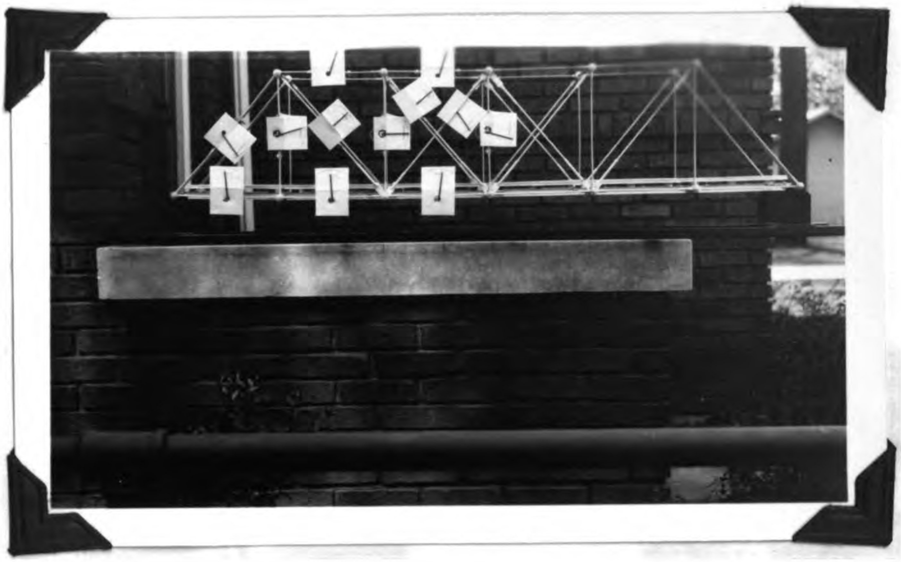


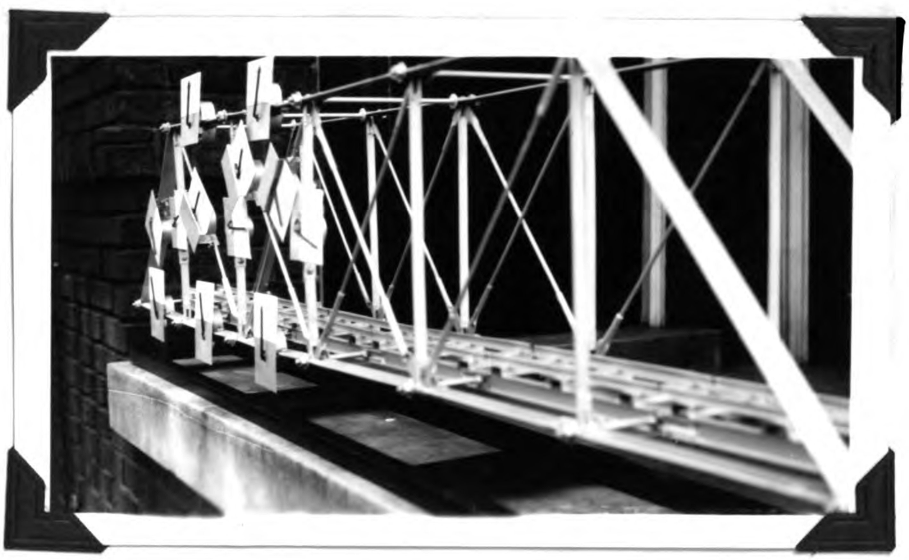
FRONT VIEW OF GAUGE WITH DIAL REMOVED



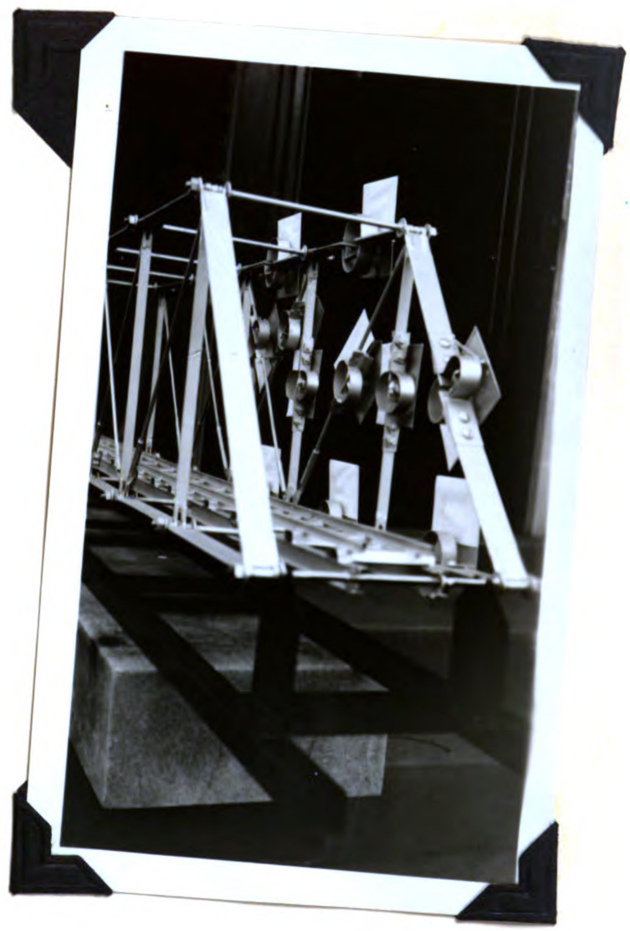
TOP VIEW OF GAUGE WITH DIAL AND TOP SEMICIRCULAR SPRING REMOVED

PHOTOGRAPHS





PHOTOGRAPHS



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