THE CONSTRUCTION OF A MODEL PLATE GIRDER RAILROAD BRIDGE.

A Thesis Submitted to
The Faculty of
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By

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THESIS

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INTRODUCTION.

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The need of a model plate girder railroad bridge was very apparent in the course in Civil Engineering 8b given during the winter term of 1917. At that time the class designed and made a general drawing of an 70'-0" deck plate girder railroad bridge.

Such a bridge was built in 1915 by members of the Engineering Society. But this model perished in the fire of March 5th, 1916. It was deemed advisable to build any future model out of more substantial material however so that the general appearance of an actual bridge would be more clearly shown.

With this in view, one of the writers of this thesis together with Mr. F. W. Stafford, who later went to Fort Sheridan, thus necessitating a general rearraggement whereby Mr. Stewart became the other partner, consulted with the faculty upon the suitability of the construction of this bridge as a thesis subject. Before the final acceptance several materials were suggested as suitable for the various parts. The first model was built of a stiff roofing paper. This was not stiff enough however, and no provision having been made in the was of camber,the bridge sagged greatly because of its own weight.

Cost was one of the prime factors in determining the materials to be used. Steel could not be used for the web because of excessive cost and laak of proper machinery for punching. For the same reason steel angles could not be used. Wood was of course, the natural material to consider next. But the impracticability of securing web plates of sufficient width became appar-

ent so a material used in place of wood, Beaver Board, was substituted. While this did very well for the web, the angles had to be of a closer grained or else a more flexible stronger material, so wood was used here. The remainder of the parts such as gusset plates, splice plates, fillers, etc. were best made from Beaver Board.

Along with the question of material was the question of a substitute for rivets. Actual rivets could not be used because wa had no riveting machines and the web would not stand such usage. It became evident that a bolt would be the most satisfactory, as stove bolts were ordered.

Much credit for the success and final completion of this model is due to Mr. Stafford who made most of the original estimates. This included a thorough examination of the drawing and a listing of all of the parts needed together with a reduction of the measurements to the scale used.

We also wish to thank the members of the Mechanical Department, Mr. Krentel and Mr. Evans for their kindness in loaning us tools without chich we could not work and which would have coste considerable had we been required to purchase them.

Since the time alloted for this work would not permit the design of the bridge in addition ti the construction, the model was constructed according to the design of the American Bridge Company. This bridge is an 80'-0" Deck Plate Girder made for the C. & N. W. Ry., Northern Iowa Division at Gary Plant of the American Bridge Company. The plans for this bridge were loaned by the Civil Engineering Department.

It was feared that continual handling of the plans would render their future use doubtful so photographs of the plans were taken. These photographs were not clear enough for ready use in the shop. By a careful use of the originals they are still intact and ready for future use.

The scale decided upon was 1/4 actual size. This gave a model 20'-0" long and also permitted an exact reproduction of the original without any crowding of rivets or the omission of important details. In addition, this size made the reduction of the dimensions quite simple.

CONSTRUCTION.

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After the material had arrived and the rights to use the necessary machines and buildings were secured, the actual construction of the parts of the bridge began.

Web Plates.

The Beaver Board from which the web plates were made came in strips 7'-0" long and 33" wide. This was very convenient, for the web plate of the bridge was in three sections and was 25 1/2" deep. These plates were quickly cut to size on the circular saw. All parts were clearly marked with their mark to facilitate the assembling.

Flange Angles.

The angles presented the most difficult part of the preliminary work. The angles of the top and bottom flanges had to be 20'-0" long. Of course it was impossible to secure material of that length, so white pine boards about 10 or 12' long were selected. These were run thru the planer to get them as near the desired thickness as possible. It was found expedient to deviate slightly from the actual 1/4 size in this respect for all angles were made the same thickness, namely 5/32". This prevented the endless confusion which might have ensued had we tried to distinguish between 1/2" and 5/8" angles. After the boards were planed they were edged on two sides, and strips of the desired width were taken off on each side. The remaining edges were again jointed and the process repeated. This only one edge of the board had to be planed by planer. Equal leg angles were made by allowing for thickness of the wood.

The edges were than glued and the strips nailed together and clamped. At the end of 24 hours the clamps were removed and the angles were ready. Because the parts of the angles were not entire pieces further stiffening was thought necessary. This was done by means of linoleum glued on the backs of the angles. The linoleum was first cut into strips of the proper width which was the sum of the two dimensions plus a small amount for trimming. These strips were then placed under the angles on a long board and glue was applied to the strip. As fast as possible the linoleum was pressed against the back of the angles and held there by strips of wood and clamps. In some cases two angles were placed back to back and nails were driven thru both. Thus each angle helped to hold the linoleum on the other and strips or clamps were not necessary. The chief value of the linoleum lay in the fact that it

held the two parts of the angle together and prevented splitting, when holes were bored. Where the linoleum stuck the angles were undoubtedly stiffened; but thwre were many places where the linoleum did not stick. In addition to that, the additional handling given severely injured the glued and nailed joint between the two pieces composing the angle.

Stiffener Angles.

These were made in the same was as the flange angles. Of course no linoleum was necessary. The question of crimped stiffeners presented an additional difficulty.At first soaking the wood and bending it to the proper form was tried. But this proved unsatisfactory so the part of the angle which lay flat against the web was sawed enough on each side to permit the necessary bending. The parts were then glued and nailed.

Cross Frames and Laterial Systems.

These angles were also made in the same was as the flange angles.

Bottom and Side Plates.

All of these plates were made from Beaver Board. Of course the board was not long enough so splices were made. These were made as follows: The joints were first cut at a bevel and the pieces were laid flat on the floor, each joint resting on a small block as wide as the strip. Glue was then put on the joint, another block put on the top, a couple of nails driven thru and the clamps applied. A couple of layers of paper were put between the blocks and the Beaver Board so that the blocks would come off easily.

Gusset Plates, Splice Plates,Fillers,etc.

All of these parts were quickly and easily cut from the Beaver Board.

Assembling.

The first step in the assembling was the establishing of gage lines and the making of templates to secure the proper rivet spacing. The angles were then cut to the proper length and the actual assembling began. The girders were assembled separately. Four saw hourses were secured to set each girder on. A saw horse was placed under each end. The bottom angles and lower side plates were put in place and the bottom flange fastened in place by clamps until a few bolts could be inserted. The same plane was pursued with the top flange just enough bolts being inserted to hold the parts in place.

To keep the bridge from sagging because of its own weight, about an inch camber was placed in it. This was accomplishdd by raising the web at the joint so that there was a larger opening at the top of joint, than at the bottom. This required a change in the rivet spacing on the splice plate. The top rivets on one side of the center line were moved over accordingly on a line connecting this top rivet with the bottom rivet, which was not moved. The results obtained were highly satisfactory for there is absolutely no sag; in fact there

is a slight upward bow which will be entirely removed when the weight of the track is added.

After the bottom and top flanges were fastened the splice plates and stiffeners were put on with just enough rivets to hold? After all of these parts had been put on,the routine of boring holes began. All of the spaces were laid off on the various parts so that the only thing to do was to bore holes and insert bolts.

From the outset the question of boring the six thousand or more holes and putting in the bolts was our chief worry. An ordinary brace and drill was used. But its slow revolution split many of the thin pieces so it gave was to a faster breast drill. An electric drill, which would have been most desirable, could not be obtained. We found the best was to be that of having one man turn the drill while the other held it. A Yankee screw driver and a brace and a screw driver were used to fasten the bolts. The bolts were pushed thru the holes, then the nuts put on by one man while the other turned the bolt.

Splitting of the angles by the drill when holes were drilled near the end, also caused much trouble and delay. The further splitting was finally prevented by clamping the end while boring the holes. All of this required considerable time and patience.

As has already been stated some of the dimensions were not exactly 1/4 actual size. This was true in the case of the Beaver Board which should have been 7/64 inch for the flange and 3/32 inch for the side plate. Its actual width is nearly 3/16. This fact was overlooked

when the cover plates were made. Consequently the angles project beyond the edge of the cover plates instead of the reverse. This can easily be remedied by the aid of a plane.

These cover plates were the last of the larger parts that were put on. This was done by laying the girder on its side upon the floor, clamping the side plates which had been marked for the bolts. Then the clamps were removed and the remainder of the bolts were put in.

CONCLUSION.

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The greatest damage has been caused by the boring of holes. Of course the kind and grain of the wood made a great deal of difference. In some cases there was very little splitting even though considerable pressure was applied. There is probably no way that splitting could be avoided without the use of a different drill. It is probable that a higher speed drill might have a tendency to go thru plates without requiring such a great amount of pressure.

The use of smaller bolts and consequently a smaller drill would have done much to decrease splitting. Smaller bolts would surely do as well as the bolts, used for there is no great strain on the bolts. Case should be exercised, however in tightening such bolts, unless washers are used, for the heads will be drawn thru the material.

Beaver Board and wood are probably the best materials for such a model, everything such as expense, availability of machinery, etc., being considered. But in selecting the wood be extremely careful to

see that good soft wood that will not split is obtained.

It is also suggested for the benefit of those who would build a model similar to this that a part of the bolts be omitted. It is evident that they are not necessary to hold the bridge together solidly. In some instances it would be better without them. Instead we would suggest that about half of the rivets s should be inserted. This would include all of the important joints For the remainder of the places for rivets we recommend that a tack having a head like a rivet be driven. In this way the actual rivet spacing may be maintained and much of the tiresome work of boring holes and inserting rivets may be avoided.

ESTIMATE OF COST.

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All of the wood was secured at the carpenter shop. Only the long pieces for the flange angles were taken from the stock room. The remainder of the parts were made from wood taken from the scrap pile. It is noteworthy of mention that the wood taken from the stock room caused the least trouble.

Beaver Boards were secured direct from the lumber company.

Bolts were bought from hardware companies. Part of these were ordered from the college.

3300 stove bolts @ 65¢ per hundred	$ 21.45
300 " " " 1.08 " "	3.24
2000 " " " .90 " "	18.00
7 pieces Beaver Board 33" x 7'	4.55
85 sq.ft. of " "	3.00
7 yards of linoleum 36" wide	3.50
2 pieces white pine 2"x10"x14'	2.35
	$ 56.09

LIST OF MATERIAL.

Crossframes & Lateral System Angles.						
No	Mark	Dimensions	Width	Thickness	Length	Remarks.
	Cross frame CF1 R/L					
2	aa2	4 x 4 x 3/8 x 7'-4 1/2"	1	3/32 1/8	1'-10 1/8"	
			7/8			
2	ac2	4 x 4 x 3/8 x 7-4 1/2	1	3/32 1/8	1'-10 1/8"	
			7/8			
4	ab2	4 x 4 x 3/8 x 9-0 1/2	1	3/32 1/8	2'-3 1/8"	
			7/8			
	Cross frames CF2		~~7/8~~			
3	ad2	3 1/2 x 3 1/2 x 3/8 x 7-7 1/2"	7/8	3/32 - 1/8	1'-10 7/8"	
			3/4			
3	af2	3 1/2 x 3 1/2 x 3/8 x 7'-7 1/2	7/8	3/32 - 1/8	1'-10 7/8"	
			3/4			
6	ae2	3 1/2 x 3 1/2 x 3/8 x 9'-4 1/2"	7/8	3/32 - 1/8	2'-4 1/8"	
			3/4			
		Top Struts.				
4	S1	3 1/2 x 3 1/2 x 3/8 x 7'-7 1/2	7/8	3/32 - 1/8	1'-10 7/8"	
			3/4			
		Bottom Struts				
4	S2	3 1/2 x 3 1/2 x 3/8 x 7'-7 1/2	7/8	3/32 - 1/8	1'-10 7/8"	
			3/4			
	Top	Lateral Bracing (diag)				
4	T1	4 x 4 x 3/8 x 10'-3 3/4"	1	3/32 1/8	2-6 15/16"	
			7/8			
4	T2	4 x 4 x 3/8 x 10'-3 3/4"	1	3/32 - 1/8	2-6 15/16"	
			7/8			
4	T3	4 x 4 x 3/8 x 10'-7 3/4"	1	3/32 - 1/8	2'-7 15/16"	
			7/8			
4	T4	4 x 4 x 3/8 x 10'-7 3/4	1	3/32 - 1/8	2-7 15/16"	
			7/8			
	Bot.	Lateral Bracing (diag)				
8	L1.	6 x 6 x 3/8 x 10'-7 1/4	1 1/2	3/32 - 1/8	2'-7 13/16"	
			1 3/8			
		Flang stiff clips				
4	aa1	8 x 8 x 1/2 x 0'-2 1/2"	2	1/8	0-0 5/8"	
			1 7/8	"		
16	ab1	8 x 8 x 1/2 x 0'-4 1/2"	2	1/8	0-1 1/8"	
			1 7/8	"		
	Strut Clips & Cross frame clips					
18	ad1	3 1/2 x 3 1/2 x 3/8 x 1'-0"	7/8	3/32 - 1/8	0-3"	
			3/4	" "		
	Lugs on Top Lateral System					
16	lac	4 x 4 x 3/8 x 0'-10 1/2"	1	3/32 - 1/8	0-2 5/8"	
			7/8			

Splice Plates - Gusset Plates and Fillers etc.						
No.	Mark	Dimensions	Width	Thick-	Length	Remarks
		Splice Plates				
8	pg1	19 x 3/8 x 6'-3 3/4"	4 3/4"	3/32	1'-6 15/16"	
		End Fillers				
24	fa1	25 x 3/8 x 6'-3 3/4"	6 1/4"	3/32	1'-6 15/16"	
8	fb1	25 x 5/8 x 7'-3 3/4"	6 1/4"	5/32	1'-9 15/16"	
		Int. Fillers				
48	fc1	3 1/2 x 3/8 x 6'-3 3/4"	7/8"	3/32	1'-6 15/16"	
4	fd1	4 x 3/8 x 6'-3 3/4"	1"	3/32	1'-6 15/16"	
	G.P.	Top Lateral Bracing.				
4	pa1	15 x 3/8 x 1'-6"	3 3/4"	3/32	0'-4 1/2"	
4	pc1	15 x 3/8 x 2'-8"	3 3/4"	3/32	0'-8"	
4	pd1	15 x 3/8 x 2'-8 1/2"	3 3/4"	3/32	0'-8 1/8"	
4	pe1	15 x 3/8 x 2'-9 1/2"	3 3/4"	3/32	0'-8 3/8"	
4	pf1	15 x 3/8 x 2'-9 1/2"	3 3/4"	3/32	0'-8 3/8"	
8	pb1	8 x 3/8 x 9 1/2"	2"	3/32	0'-2 3/8	
	G.P.	Bot. Lateral Bracing				
2	pr1	16 x 3/8 x 1'-4"	4"	3/32	0'-4"	
2	po1	16 x 3/8 x 2'-5 1/4"	4"	3/32	0'-7 5/16"	
2	pk1	16 x 3/8 x 2'-5 1/4"	4"	3/32	0'-7 5/16"	
1	pm1	16 x 3/8 x 2'-5 1/4"	4"	3/32	0'-7 5/16"	
	G.P.	For Struts (Top flange)				
4	pp1	9 x 3/8 x 1'-4 3/4"	2 1/4"	3/32	0'-4 3/16"	
8	pt1	9 x 3/8 x 1'-4 3/4"	2 1/4"	3/32	0'-4 3/16"	"
6	pw1	9 x 3/8 x 1'-4 1/4"	2 1/4"	3/32	0'-4 1/16"	"
	G.P.	For Cross Frames				
6	pa2	16 x 3/8 x 1'-4"	4"	3/32	0'-4"	
2	pc2	16 x 3/8 x 1'-4"	4"	3/32	0'-4"	
2	pb2	9 x 3/8 x 0'-9"	2 1/4"	3/32	0'-2 1/4"	
12	pd2	14 x 3/8 x 1'-2"	3 1/2"	3/32	0'-3 1/2"	
3	pe2	9 x 3/8 x 0'-9"	2 1/4"	3/32	0'-2 1/4"	
4	pf2	9 x 3/8 x 0'-9 1/2"	2 1/4"	3/32	0'-2 3/8"	

Web Plates - Lateral Ls - Side Plates - Cover Plates - Sole Plates						
No	Mark	Dimensions	Width	Thick.	Length	Remarks
		Web Plates				
4	aW	102 x 7/16 x 26'-0 1/2"	25 1/2"	1/8"	6'-6 1/8"	
2	bW	102 x 7/16 x 27'-10 1/2"	25 1/2"	1/8"	6'-11 3/8"	
		Lateral Ls.				
4	aTL	6 x 6 x 5/8 x 80'-0"	1 1/2"-1 3/8	5/32"	20'-0"	
4	bTL	6 x 4 x 3/8 x 75'-9 3/4"	1 3/8-7/8	5/32"	18'-11 7/16"	
4	aBL	8 x 8 x 7/8 x 80'-0"	2"-1 7/8	5/32"	20'-0'	
		Side Plates				
4	aTP	8 x 1/2 x 45'-9 1/4"	2"	1/8"	11'-5 5/16"	
4	bTP	8 x 1/2 x 33'-8 3/4"	2"	1/8"	8'-5 3/16"	
4	cTP	14 x 3/8 x 80'-0"	3 1/2"	3/32"	20'-0"	
4	aBP	12 x 3/8 x 80'-0"	3"	3/32"	20'-0"	
		Cover Plates				
2	aCP	18 x 1/2 x 58'-0 1/4"	4 1/2"	1/8"	14'-6 1/16"	
2	bCP	18 x 1/2 x 47'-11 1/2"	4 1/2"	1/8"	11'-11 7/8"	
2	cCP	18 x 7/16 x 33'-10"	4 1/2"	1/8"	8'-5 1/2"	
		Sole Plates				
4	ph1	18 x 3/4 x 2'-5"	4 1/2"	3/16"	0'-7 1/4"	

Stiffeners for 2 Girders						
No	Mark	Dimensions	Crimp	Width	Thickness	Length.
16	Sal^{R}	$6 \times 3\frac{1}{2} \times \frac{9}{16} \times 8'-5''$		$1\frac{1}{2}''$	$\frac{1}{8}$ +	$2'-1\frac{1}{4}''$
16	Sal^{L}	"		$\frac{3}{4}''$	"	"
8	Sel^{R}	$6 \times 3\frac{1}{2} \times \frac{9}{16} \times 8'-5''$	$1\frac{1}{2}''$	$1\frac{1}{2}''$	$\frac{1}{8}''$	$2'-1\frac{1}{4}''$
8	Sel^{L}	"	$\frac{3}{4}''$	$\frac{3}{4}''$	"	$2'-1\frac{1}{4}''$
20	Skl^{R}	$4 \times 3\frac{1}{2} \times \frac{3}{8} \times 9\frac{1}{4}$		$1''$	$\frac{1}{8}''$	$0-2\frac{5}{16}''$
20	Skl^{L}			$\frac{3}{4}''$	"	"
46	sdl^{R}	$4 \times 3\frac{1}{2} \times \frac{3}{8} \times 7'-7\frac{3}{4}$	Crimp	$1''$	$\frac{1}{8}$	$1-10\frac{15}{16}''$
46	sdl^{L}	"	"	$\frac{3}{4}''$	"	"
8	sel^{R}	$5 \times 3\frac{1}{2} \times \frac{3}{8} \times 7-7\frac{3}{4}$	crimp	$1\frac{1}{4}''$	$\frac{1}{8}''$	$1-10\frac{15}{16}$
8	sel^{L}	"	"	$\frac{3}{4}''$	"	"
4	shl^{R}	$4 \times 3\frac{1}{2} \times \frac{3}{8} \times 9\frac{1}{4}$		$1''$	$\frac{1}{8}''$	$0'-2\frac{15}{16}''$
4	shl^{L}	"		$\frac{3}{4}''$	$\frac{1}{8}''$	$0'-2\frac{15}{16}''$
8	sml^{R}	$4 \times 3\frac{1}{2} \times \frac{3}{8} \times 9\frac{1}{4}$		$1''$	$\frac{1}{8}$	$0-2\frac{9}{16}''$
8	sml^{L}	"		$\frac{3}{4}''$	"	$0-2\frac{9}{16}''$
2	sfL^{L}	$5 \times 4 \times \frac{3}{8} \times 7'-7\frac{3}{4}''$	Crimp	$1\frac{1}{4}''$	$\frac{1}{8}''$	$1'-10\frac{15}{16}''$
2	sfL^{R}	"	"	$\frac{7}{8}''$	"	$1'-10\frac{15}{16}''$
2	Sml^{R}	$4 \times 4 \times \frac{3}{8} \times 9\frac{1}{4}$		$1''$	$\frac{1}{8}''$	$0'-2\frac{5}{16}''$
2	sml^{L}	"		$\frac{7}{8}''$	"	$0'-2\frac{5}{16}''$
4	sql^{R}	$5 \times 3\frac{1}{2} \times \frac{3}{8} \times 7-7\frac{3}{4}$	crimp	$1\frac{1}{4}$	$\frac{1}{8}$	$1'-10\frac{15}{16}''$
4	sql^{L}	"	"	$\frac{3}{4}$	"	$1'-10\frac{15}{16}''$
		Angles to be crimped				
		Crimp $\frac{5}{16}$"