

Public Works (1896) Department.

SERIAL
No. 40

G.O., No. 806 R

DATED 22nd Sept 1896

[Despatch Abstract.]

"Strengthening of Bridges". Letter to the Govt of India forwarding a copy of the report by Mr. Hayter on the subject of —, Madras Rail-
way with copy of certain other documents on the same subject.

P. W. D.
1,000-2-10

3/10

are as follows

BACK PAPERS.

[illegible]

FURTHER PAPERS.

G.O.	No.	Department.	Date.	G.O.	No.	Department.	Date.

№ 0/1201

Indian Railway Company

Chief Engineer's Office.

Madras 5th Oct-1895.

The Agent and Manager

Dear Sir

Dear Sir

Strengthening fiber bridges

It is I think desirable for convenience of reference to review very briefly the history of this question, and to show what has hitherto been done, before stating its present position. Attention was first drawn to the subject by Mr Stoney in 1880 who showed how extremely weak the girders then in use on the Cairney Bridge were, and these were soon after replaced by new ones designed by Messrs. Hawkshaw and Hayter.

2. In August 1880 Messrs Hawksshaw and Telford sent out drawings for strengthening small spans, and since that time the work of strengthening girders on this Railway has been steadily proceeded with, by bringing them up to the standard laid down by the Board of Trade rules for English bridges which are as follows:

In a Wrought Iron or Steel Bridge the greatest load which can be brought upon it added to the weight of the superstructure should not produce a greater stress on any part of the material than five tons where wrought iron is used, or six tons and a half where steel is employed per square inch.

3. Attention was again drawn by the Chief Engineer in May 1890 to the subject of the weakness of the large girder bridges and since that time a good deal has been written on the subject.

In Government of India letter No. 1369 R-C of 13th December 1892 forwarded with your No. 7759/451 of 21st January 1893, new draft rules were promulgated for determining the strength of girder bridges, which differ altogether from those issued by the Board of Trade, and which need considerably greater sectional area in the various members of a girder bridge for any given span, these rules are briefly as follows: -

Draft Rules

1. For any member of a Railway bridge of wrought iron or steel, the total working load is to be taken as the 'greatest moving load' multiplied by a co-efficient and added to the 'actual' fixed load.

2. The co-efficient to be used for this purpose is 2.0 in all cases except for the upper and lower booms of triangulated girders, for which a co-efficient of 1.5 may be used.

3. The stress per square inch, either in tension or compression, due to the 'total working load' thus calculated, is not to exceed the following: -

	Tons
wrought iron	7
steel	9

4. The working stress per square inch given above, whether for tension or compression, is to be taken on the net available area at the weakest part of the member of the structure to which it is applied, after deducting all holes for rivets, pins, bolts &c.

5. For members in compression the working stress given above is subject to such reduction of the $\frac{1}{2}$... according to Column

6. For the purposes of this rule "fixed load" is to be taken to mean the weight of the structure itself, with roadway, flooring, ballast, permanent way or complete (see also wind pressure below.)

"moving load" is to be taken as follows:—

(a) A train load for each line of rails, calculated as specified under "train load" below.

(b) If there be a road or foot way in addition to and distant from the railway, an additional moving load 4 tons per 100 square feet of such load, or foot way.

Train load.

1. Type train. For the purpose of calculating the train load to be allowed for on each line of rails, the "type train" is to consist of two engines on the specification given as Appendix A with a train of loaded wagons taken at a uniform weight per foot as follows.

5 ft 6 in gauge	Tons
	1.2
metre gauge	0.8

The engines are to be taken as

either in the ordinary way or coupled head to head, and occupying any position in the train.

2. Type engine. To facilitate the determination of the stresses which may be produced by the "type train", a diagram of a "type engine" is given as Appendix B. It is to be understood that this diagram does not represent any actual engine, but an imaginary engine so designed as to produce on a bridge the most severe effect practicable under the specification given as Appendix A.

Wind pressure.

1. The amount of wind pressure on a railway bridge is to be calculated on the assumption that the maximum normal pressure may be one and a half tons per 100 square feet of surface exposed. The surface exposed to be reckoned as follows:—

(a) A train surface calculated on a height of 13 ft 6 inch on the 5 ft 6 inch gauge, or 16 ft 0 inch on the metre gauge, multiplied by the total length of the girder—

(b) The actual surface (as seen in elevation) of that portion of the girder which may be below rail level, or at a height above rail level of more than 13 ft 6 in on the 5 ft 6 in gauge, or 11 ft 0 in on the metric gauge also

(c) In the case of triangulated girders, the actual vertical surface (as seen in elevation) of that portion of the leeward girder which may be below rail level or at a height above rail level of more than 13 feet 6 in on the 5 ft 6 in gauge, or 11 ft 0 in on the metric gauge.

2. The total wind pressure thus calculated is to be provided for by a proper system of wind bracing or floor-plateing and its effect taken into account as forming a part of the stress on the chords of the main girders.

Proper arrangements must also be made at the girder ends to secure sufficient stiffness to resist racking action where diagonal stiffeners are not used.

3. Wind pressure is to be treated as

'fixed load', and its effect on the different members of the structure is to be allowed for as provided in the rule for 'maximum permissible stress'.

4. The above rules which were then provisional were confirmed in F.O. No. 1255 R of 26th September 1893 forwarded with your Endorsement No. 7759 of 13th October 1893. After the receipt of your No. 7759/451 of 21st January 1893, this office letter No. 162 of 14th February 1893 was written in which certain definite information as to the application of the above rules was asked for.

5. The last para: 5 clauses a, b, c, d asking how the effects of wind pressure was to be dealt with have never been answered though a reminder was sent in this office letter No. 450/248 of 7th March 1893, in reply to which the Consulting Engineer stated in his letter No. 312 of 8th April 1893 that the questions had been referred to the Technical Section, Girders, and that the effect of wind pressure on girders below 150 feet might be neglected.

6. The Government of India in their letter P.W. D. no 551 R.C. of 1st June 1893, embodied in G.O. no. 1255 R of 26th September 1893 state that the draft rules referred to in their letter no. 1369 R.C. of 13th December 1892 have been finally approved of, and request that these rules may form the basis of investigation regarding the strength of girder bridges. Further instructions were given in Consulting Engineer's letter no 7 dated 3rd January 1894, and a telegram was sent by him on the 2nd of June 1894 stating that the total horizontal wind pressure as found by the Government rules was to be added as a dead vertical load, as follows: — Total pressure on elevation of girder clear span, plus half pressure between top of girder to top of carriage taken as 13 ft 6 inches. The inclusion of wind pressure and the method of calculating its effects adds greatly to the stresses produced and consequent

11 sectional area required in every part of a girder beyond that necessary under Board of Trade rules. The type engine also imposes a heavier load than our heaviest engines doubling that which can be brought on the cross girders of the Chittravati type.

7. All the girders on the Railway have been it is understood from Mr Hayter's reports designed by Board of Trade rules, which do not include wind pressure or multiply the Rolling load by any factor in order to convert it into an equivalent dead load, while in the Government of India Rules the Rolling load is doubled and wind pressure is also included, though a higher working stress is used.

8. All girders hitherto strengthened, with the exception of those recently done as shown in table No 1 have been calculated to conform to Board of Trade requirements and are consequently too weak if judged

by the new Government of India Rules.

9. Before any further outlay is incurred in strengthening girders on this Railway, I desire to know if Government will insist on the application of their new rules to the calculations of the strength of all our girder bridges, as if they do all girders above 4 feet span as shown in Table No 2, with the exception of the Penner, Chitrawati, Sankarni, Kallangi and Ferok Bridges and a few others shown in Table 1 will be found too weak so that all these including most of the bridges already strengthened and such new girders as those of the Cauvery and Thootta need to be dealt with in the most suitable manner to conform to the new Government Rules at an enormous cost, and I presume, the Board and their Consulting Engineers consent to the enforcement of these rules if insisted on would be needed.

10. I beg that an early reply may be given to

to Para 5 of this office letter No 162 of 14th February 1893 as in the absence of clear instructions showing how wind pressure is to be dealt with, it is impossible to design girders to meet the Government requirements, or to say exactly which of those now in use do so.

Their rules merely show how to find the horizontal wind pressure on a girder with given data, but give no instructions as to how this is to be provided for or how its effects on the structure are to be calculated. The calculations now made are according to the directions given in the Consulting Engineers' telegram of the 2nd June 1894.

11. These give such large sectional areas for 64 feet girders as to render it practically impossible to bring up any existing ones to the requisite standard, their flange area being less in most cases than half what is requisite, as shown by table No 3 so that the only way in which they could be made suitable would be by building piers under their centres where possible, thus reducing each 64 feet span to two 32 feet spans, for which spans the flange areas of the present girders would suffice, as

per table No. 4. Another way, and the cheapest, where foundations suited, and waterway and other circumstances permitted, would be to alter 64 feet girder bridges into 30 feet span arches, the girders being then available for sale.

12. Girders of 50 feet span can generally speaking be best dealt with by building a pier under the centre of each span, table No. 5. The smaller spans i.e. those between 9 feet and 30 feet could be easily dealt with, and I would propose in all of these where the headway was sufficient, to replace the girders by brick or stone arches; which could be cheaply done without interruption to traffic, the girders so released being used to pair with others of the same type, to strengthen other bridges of the same span, in the manner shown in the accompanying drawing, which shows these girders arranged in pairs connected at the bottom by N bracing, and at top by transverse T bars, the rails being placed midway over each pair of girders, this arrangement would make a very good

and

and stiff bridge, and the girders would be open to examination and easily accessible for scraping and painting.

13. Personally I consider arch bridges much superior to girders, and far more easily maintained and recommend their being substituted for steel girders in all cases where circumstances allow, of this being done.

14. Table No. 6 is a summary of all girders on this Railway, showing those which are strong enough and those not strong enough if judged by Government of India rules; information as to headway, foundations, &c is now being collected and drawings are being made to enable this office to estimate the cost of altering all girder bridges on this Railway in such manner as shall appear cheapest, in the event of the Government of India insisting on their new rules being applied without exception.

15. I may state under these rules, assuming the type engine for purposes of calculation, that the cross girders of the Chitravati, Penner, Dampalni and Kellegi bridges would be

found too weak; while simply strong
for our heaviest engines.

Yours faithfully

(Sd) E. W. Stoney M.C.E.

Chief Engineer

(True copy)

(Sd) Louis S. Moss

Agent & Manager

Table No 1

Madras Railway

List of Girder Bridges from 6 feet to 131 feet spans which are strong enough
according to the new Rules issued by the Government of India.

Position of Bridges		Description of Bridges		Number of spans	Remarks.
Miles	2 P				
		6 feet spans			
		All spans of 6 feet	297		Being strengthened by doubling
		20 feet spans			12170 are already finished
275	2-9	Single 20 feet openings	1		Strengthened by adding extra plate
216	7	Two 20 feet openings	4		to the planges.
244	9	Single 20 feet openings	1		Being strengthened by - do - do - do.
		22 feet spans			Strengthened by - do - do -
192	3	Two 21 feet openings (skew)	2		Being strengthened by - do - do -
		23 1/4 feet spans			
174	4-5	Two 20 feet openings (skew)	2		Being strengthened by - do - do

Agent Manager.

Location of Bridges			Description of Bridges	Number of spans	Remarks.
Miles	2 P		6 feet spans		
			All spans of 6 feet	297	Beins strengthened by doubling
			20 feet spans		No 170 are already finished
275	2-9	N.W.Z	Single 20 feet openings	1	strengthened by adding extra plate to the planks.
216	7	N.B.L	Two 20 feet opening	4	beins strengthened by - do - do - do -
244	9	N.W.Z	Single 20 feet openings	1	strengthened by - do - do -
			22 feet spans		
182	3	N.W.Z	Two 21 feet openings (skew)	2	beins strengthened by - do - do -
			23 1/4 feet spans		
94	4-5	N.W.Z	Two 20 feet openings (skew)	2	beins strengthened by - do - do
130	7-8	N.W.Z	Single 22 feet openings	1	do - do - do -
			24 feet spans		
140	12-13	N.W.Z	Four 24 feet openings	4	strengthened by inserting new girders made from old pieces of old runner girders at known spot.
			30 feet spans		
97	8-15	N.W.Z	Single 20 feet openings	1	Girders being 4 ft deep are strong enough.
106	2	N.W.Z	Single 30 feet openings	2	9 feet spans recently enlarged to a double 30 ft opening and part of an old runner girder for 14 ft span 4 feet deep used.
258	11	N.W.Z	Single 30 feet openings	1	Girders being 4 feet deep is strong enough.
			50 feet spans		
70	2	N.W.Z	Single 50 feet openings	1	strengthened by inserting central masonry pier.
79	1-14	N.W.Z	Single 50 feet openings	1	do - do - do - do -
95	13	N.W.Z	Single 50 feet openings	1	beins - do - do - do -
			60 feet spans		
			Two 60 feet openings	3	strengthened by inserting central masonry pier.

Table II

Madras Railway

List of girder bridges too weak by the Government of India Rule

Spans of bridges	Number of spans weak by Govt. of India Rule	Method proposed by which these can be brought up to Government of India Rule
9 feet	231	By building arches where headway re allows and taking the girders released to duplicate these remaining spans.
12 feet	268	
15 feet	37	
18 feet	10	
20 feet	177	
22 feet	36	
23 1/4 feet	1	
30 feet	141	By masonry piers under the centre of each span or using arches where this can be done with advantage.
34 feet	6	
39 feet	2	
43 1/2 feet	17	
50 feet	14	
64 feet	243	

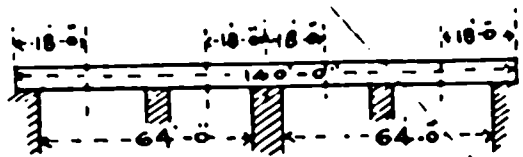
(Sd) E.W. Stoney

List of Bridges of
 1st Class Rule.

Type of Bridges	No. of Bridges
1	1

used by
 1st Class Rule.

sectional area required at centre of small spans of 30 feet if made by building
 and pressure as compared with available net sectional areas of girders at centre of



Available net area of flange of
 centre of small spans if pier built
 in two ft spans.

18 feet from
 end of continuous
 girders

18 feet from centre
 of continuous
 girders

Net area required by the
 formulae in Rule.
 The required area
 pressure.

Type of girder	Position of bridge			Name of bridge	Number of spans	18 feet from end of continuous girders	18 feet from centre of continuous girders
	Mile	S.P.					
Old runner Type III	403	5	S.W.	Kadaliundi	12	14.28	14.28
	403	4	-	do	8	do	do
	232	3	N.W.	Portom	4	do	do
	232	10	-		2	do	do
	240	9	-	Conavonka	4	do	do
	240	15	-	Chinnavonka	2	do	do
	250	11	-	Krasnapalikonka	4	do	do
	263	3	-	Lingalonka	4	do	do
Metaspalli Type IV				Nil			
Old Chayor Type V	387	12	S.W.	Tirur	5	11.87	11.87
	142	10	N.W.		2	do	do

11.50 sq inch area required at centre of new pier
 9.32 - area required at centre of small spans

Table No. 11
Madras Railway

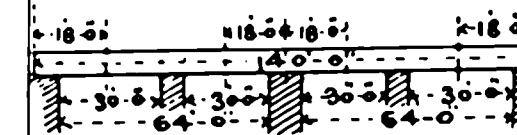
List of Bridges of 64 feet spans, (girders, continuous, over, box spans) showing net sectional areas as compared with that required by the Govt of India Rule.

Type of Girders	Position of Bridge			Name of Bridge	No. of Spans	Available at center of Girders	Net Sectional areas			
	Miles	Lat	Long				Required by Govt of India Rule	Available at joint nearest to center of Girders	Required by Govt of India Rule	Available at joint away from center of Girders
New Curvey Type A New Girders	241, 373, 165	8-11, 12, 15	80-2, 80-2, 81-2	New Curvey, Thoratha, Rallavomka	22, 12, 9	30.625, do, do		23.75, do, do		23.75, do, do
Bridges strengthened by duplicating girders Type A ₁	135, 6136, 162, 106, 333, 405	8, 3, 5, 4-7, 3, 12-14	N.W., -	Chayan (double), Konga (double), Palar (double), Dalpatu (double), Varakemund	6, 22, 8, 5, 4, 4	37.36, 36.36, 36.36, 34.30, 32.24, 32.24		24.74, 23.74, 23.74, 22.12, 20.50, 20.50		24.74, 23.74, 23.74, 22.12, 20.50, 20.50
Strengthened Pinner Girders Type A ₂	180	15	N.W.	Meatagapalli	4	35.70		24.89		24.89
New Chayan Type I	135, 5, 136	8, 3	N.W.	New Chayan	22	22.50		16.50		16.50
Jungabhadra Type II	333, 0, 307, 200, 312, 313, 314, 321	12, 14, 17, 7, 13, 12, 10, 13	N.W., 80-2	Jungabhadra, Lochranes Canal, Bilghiri Branch	50, 4, 2, 2, 2, 4, 2, 4	22.68, do, do, do, do, do, do, do		15.375, do, do, do, do, do, do, do		15.375, do, do, do, do, do, do, do
Meatagapalli Type IV				Nil						
Old Chayan Type I	387, 142	12, 10	80-2, N.W.	Chayan	5	18.10		37.10, 37.39, 27.06, 20.29		37.10, 37.39, 27.06, 20.29
Old Curvey Type III	403, 403, 232, 232, 240, 248, 250, 260	5, 11, 3, 10, 9, 15, 11, 0	80-2, do, N.W.	Kadavundi, do, do, do, Conavomka, Chinnavomka, Annasapallavomka, Lingalavomka	12, 8, 4, 4, 4, 2, 4, 4	21.60, do, do, do, do, do, do, do		14.28, do, do, do, do, do, do, do		14.28, do, do, do, do, do, do, do
Meatagapalli Type IV				Nil						
Old Chayan Type I	387, 142	12, 10	80-2, N.W.	Chayan	5	18.10		37.10, 37.39, 27.06, 20.29		37.10, 37.39, 27.06, 20.29

(Signed) E. W. Porey

List of bridges of the feet spans (girders continuous over two spans) showing net at central masonry pier) as per Govt of India Rule with Type Engine including small spans.

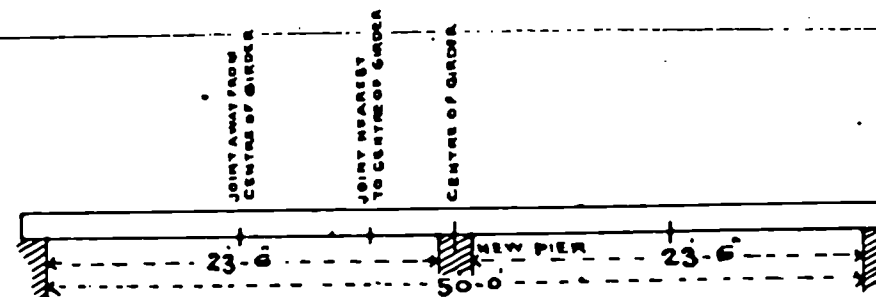
Type of girders	Position of bridges			Names of bridges	Number of spans.	Available net area of flange at centre of small spans of bridge built in two spans.	
						18 feet from end of continuous girders sq inch	18 feet from centre of continuous girders sq inch
New Cauvery Type A	135	11	90	New Cauvery	22	22.375	22.375
	136	12	90	Shoother	12	do	do
	165	15	N.W.	Rothavanka	9	do	do
Bridges strengthened by duplicating girder Type A ₁	135	11	N.W.	Chayan	22	23.74	23.74
	136	12		Aranga	8	23.74	23.74
	106	4.7	90	Salur	5	22.12	22.12
	223	3		Kalpanthi	4	20.50	20.50
	405	12.10		Manakambad	4	20.50	20.50
Strengthened Girder Type A ₂	180	15	N.W.	Matangapalli	4	24.89	24.89
New Chayan Type I	135	15	N.W.	New Chayan	22	15.50	15.50
Tungabhadra Type II	133	12		Tungabhadra	68	15.375	15.375
	0	14	90	Coimbraes Canal	4	do	do
	207	17			2	do	do
	209	7			2	do	do
	212	13			2	do	do
	213	12	90	Mulgaia Branch	4	do	do
	214	10			2	do	do
	221	13			4	do	do



11.50 sq in area required at centre of new pier
9.32 sq in area required at centre of small spans
11.50 sq in area required by the Govt of India Rule with Type Engine

Table No. V
Madras Railway

List of Bridges of 50 feet spans showing available nett sectional area of flange as compared with that required by the Government of India Rule at centre of small span if a central masonry pier be built.



Position of Bridge			Description of Span	No of spans	Nett sectional areas					
					Available at centre of girder	Required by the Govt of India Rule if pier be built at centre	Available at joint nearest to centre of girder	Required by the Govt of India Rule if pier be built at centre	Available at joint away from centre of girder	Required by the Govt of India Rule if pier be built at centre
mile	J.P			sq. inch		sq. inch		sq. inch		
70	2-3	N.W.	Single span strengthened by central pier	1	18.58	16.70	16.70	16.70		
79	13-14	"	Single span do.	1	19.52	17.64	17.64	17.64		
95	13-14	-	single span being strengthened by central pier	1	18.58	16.70	16.70	16.70		
179	1	"	Two spans	5	13.53	12.41	12.41	12.41		
107	10-11	"	Two spans (skew)	5	18.58	16.70	16.70	16.70		
175	5	O.B.L.	Single span	1	15.77	13.89	13.89	13.89		
1	14	R.B.	Cochranes Canal	1	17.37	15.59	15.59	15.59		
175	16	O.B.L.	Two spans	2	17.37	15.59	15.59	15.59		
					9.51 required at centre of girder		4.64 required at nearest joint to centre of girder.		7.0' required at joint away from centre of girder.	

(Signed) R.W. Stoney

Table No. VI

Summary list of girder bridges on the Madras Railway

Spans of bridge	Total number of spans	Number of spans strong enough according to Govt of India Rule	Number of spans weak by Govt of India Rule	Remarks.
6 feet	297	297	.	
9 feet	231	.	231	
12 feet	268	.	268	
15 feet	37	.	37	
18 feet	10	.	10	These spans were already strengthened with extra plates according to the Board of Trade Rule.
20 feet	183	6	177	91 spans were already strengthened with extra plates etc.
22 feet	38	2	36	30 spans - do - do -
23½ feet	4	3	1	This span was strengthened by extra plates.
24 feet	4	4	.	
30 feet	145	4	141	26 spans were already strengthened with extra plates.
34 feet	6	..	6	
39 feet	2	..	2	
43½ feet	17	.	17	
50 feet	17	3	14	
44 feet	246	3	243	{ 65 spans were replaced by new girders { 49 - were strengthened by duplicating { 4 - were replaced by strengthened girders
121 feet	9	9	.	
131 feet	47	47	.	

(Signed) E. W. Stoney

THE AGENT AND MANAGER.

DEAR SIR,

STRENGTHENING OF GIRDER BRIDGES.

1. In continuation of this Office letter, No. C/1281, dated 5th October 1895, I beg to report more fully on the whole question in regard to the strengthening of the Girder Bridges on the Madras Railway, with a view to placing the facts clearly before the Company's Consulting Engineer in London, and I request that you will be so good as to ask the Board to invite from Mr. Hayter an expression of his opinion as to the course which should be adopted.

2. I desire to explain that, ever since the opening of the line for traffic, steps have been taken to secure for the several spans an improved type of girder in compliance with the indents periodically sent home, and in more recent years considerable expenditure has been incurred in substituting stronger girders on many bridges, both of large and small span, in order to meet the heavier loads imposed on them. The Government of India have now promulgated certain rules and regulations for strengthening girders far in excess of the limit which has been hitherto recognized as sufficient, and as compliance with these rules will involve a very large outlay, the subject requires very careful consideration, and the incidence of the cost, whether debitable to Capital or Revenue, is a material factor which demands special attention in the final disposal of the question.

3. The documents accompanying this letter are:—

- (1) Government of India letter with enclosure No. 1369, R. C., dated 13th December 1892.
- (2) Statement A, relating to girder bridges of from 9 ft. to 43½ ft. span.
- (3) Statement B, relating to bridges of 64 ft. span (girders continuous over two openings).
- (4) Technical section paper No. 44, } on the effect of wind pressure on
- (5) Technical section paper No. 44A, } bridges.
- (6) Drawings of heaviest Madras Railway Engine and Government of India Type Engine.
- (7) Elevation of Tungabhadra Bridge (fifty-eight 64 ft. spans).

4. In statement A, column 1 gives the list of bridges spanned by the several types of girder for the same span; in column 2 is given the sectional area at the centre of the existing girder; in column 3 is shown the section required by the English Board of Trade rules excluding wind pressure; in column 4, the sectional area demanded by the Government of India rules including wind pressure computed in accordance with Technical section papers Nos. 44 and 44A, and in column 4A taking the heaviest Engine on the Madras Railway; in column 4B, the sectional area calculated as detailed for column 4A, but taking the type Engine suggested by the Government of India; columns 6 and 9 show the proposed method of carrying out the strengthening for each group of girders; columns 7 and 10 give the estimated cost of the increased sections entered in columns 4A and 4B respectively, and it will be seen that the difference between the figures in these two columns is considerable.

5. Statement B gives precisely the same particulars for all girders of 64 feet span continuous over two openings, and as the sectional area at three points of the span has to be considered in dealing with this class of girder, the figures in each column will have to be compared throughout the statement. It will be observed that in the case of girders of the

Tungabhadra Bridge type (contract drawing No. 3, dated 14th June 1866,) duplicating the existing girders will scarcely furnish the desired increase of section entered in columns 4A and 4B.

6. As the present condition of exchange largely influences the cost of imported iron work, it has been suggested by Mr. E. W. Stoney, when Officiating Chief Engineer, that many of the single small spans might be converted into arches, if the headway be sufficient to admit of this being done; but I fear that the number capable of this treatment is too insignificant to materially affect the estimated figures, although I recommend this course being adopted wherever it be practicable. In regard to the larger bridges, of which the Tungabhadra Bridge (fifty-eight 64 feet span) may be taken as a typical example, (vide drawing attached), Mr. Stoney proposes the conversion of each of the 22 land spans into a double 30 feet arch, thus releasing a corresponding number of girders for duplicating those over some of the remaining spans. This scheme, however, involves the insertion of abutment piers at every sixth arch, and the obstruction thus offered in both waterway and headway combined appears to me undesirable in a river subject to such high floods. The alternative which commends itself as preferable would be the introduction of central piers for supporting the existing girders over the 22 shallow land spans, and substituting new and stronger girders for the remaining 36 deep spans, as it is presumed that duplicating the existing girders will not afford the desired remedy; but in this case there will be a serious loss in discarding the present girders of the 36 deep spans, inasmuch as it is almost impossible to realize a fair price for such iron material in this country.

7. I would here point out that in regard to the latest improved design of girders sent out, viz., for the Cauveri, Rallavonka and Thootha Bridges (contract drawings No. 1, dated 31st July 1880 and 27th May 1891,) the sectional area scarcely complies with that required by the Government of India standard (vide column 2 in statement B).

8. In the girders also of the double system Whipple-Murphy type for 130 ft. and 140 ft. span adopted for the Feroke, Kallai, Penner, Chittravati and Papaghni Bridges (contract drawings No. 1, dated 29th May 1885, 18th November 1885, and 29th July 1887 respectively,) the computations made in this Office would appear to indicate that the cross girders in these two types are slightly deficient in section if the Government of India standard is to be accepted, although they are sufficient for carrying the heaviest engines at present on the Madras Railway.

9. That the greater portion of the girder bridges on the line require to be strengthened in order to efficiently carry the enhanced loads now imposed upon them is admitted, but to what extent the sectional area is to be increased is the question which presents itself for solution. This mainly rests on the treatment of wind pressure, the theoretical application of which, as prescribed in the Technical Section Papers Nos. 44 and 44A, appears to be questionable from a practical point of view; and the Consulting Engineer for Railways to the Madras Government has urged that the calculation for wind pressure should be made in accordance with the rules embodied in these Papers.

10. The estimated cost of strengthening the existing girders to conform to the section calculated as necessary under the Government of India rules, taking the heaviest type (K A₂ class) of Engine on the Madras Railway is—

For bridges from 9 ft. to 50 ft. span, as per statement A	... Rs.	5,30,869
For bridges of 64 ft. span, as per statement B		17,50,656
Total Rupees	...	22,81,524

and the cost taking the Government of India type Engine—

For bridges from 9 ft. to 50 ft. span, as per statement A	... Rs.	6,32,126
For bridges of 64 ft. span, as per statement B		18,68,322
Total Rupees	...	25,00,448

The points therefore submitted for Mr. Hayter's consideration and decision are, first, whether the outlay represented by the higher figure is imperative, and secondly, whether the expenditure embodied even in the lower figure is absolutely necessary. If both these points be decided in the negative, his opinion should be invited as to what extent the expenditure should be limited, and to what corresponding extent the proposed strengthening should be reduced. In any case the outlay on this work will have to be spread over several years, so as not to cause too excessive a burden on the Company's revenue in each half year, as it is feared that only a very small proportion of the charges will be debitable to Capital.

11. In connection with this subject it is suggested that in the event of it being decided to send out any new girders of a stronger type, the advantages and economy of steel, as compared with iron, may be duly considered, as explained by Messrs. Dorman, Long & Co., of Middlesbrough, in the illustrated price list issued by that firm.

12. I desire to add that for all 6 ft. rail girder openings, and a few isolated spans of 20 ft. and 30 ft. in which the girders were found to be undoubtedly overstrained, prompt measures have been taken to strengthen them once for all up to the Government of India standard, and thus dispose of them finally.

13. In conclusion, I regret the delay which has occurred in the submission of this report, but the preparation of statements A and B occupied considerable time owing to the collection of the detail information and the extensive calculations which were necessary for their compilation.

I remain,
Yours faithfully,
(Signed) HENRY C. WEST.

Chief Engineer,
Madras Railway.

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Am

33 Great George Street

Westminster. S.W.

12th May 1896.

Julian Payne Esq.

61 New Broad Street E.C.

Dear Sir,

Madras Railway

Strengthening of Bridges

I instructed in your letter of the 10th March last, I report on the subject of strengthening the bridges on the Madras Railway and reply to the questions raised in the report of Mr. Hobbs the Chief Engineer dated 10th February last.

The subject has to be looked at in two lights that is to say in connection with

Firstly

The proposed rules of the Government of India and

Secondly . The rules of the English Board of Trade.

Thirdly : The proposed new rules of the Government of India.

As far as I can gather these rules are at present only suggested or provisional. They are arrived at by assuming data which would not be favourably entertained here.

Take for instance the locomotive engine given as a type. The weight on any axle limited to 15 tons is in itself a reasonable requirement, but three of the coupled wheels are so close together only 4' 3" apart that the engine could not be used for ordinary running without destroying the road. If it were to be introduced as a type the permanent way would have to be materially increased in strength. If applicable anywhere it could only be on steep gradients where the speed would be slow but even there it is a type which it has been found necessary to abandon for gradients as steep even as 1 in 27 with sharp curves which are much more severe to work than the

Indian Ghat lines of the Standard gauge. I allude more specially to the Government lines of Railway in Mauritius where I have now introduced six wheel coupled engines with a minimum distance between the wheels of 6' 9" to replace eight wheel coupled engines having a minimum wheel distance of 4' 3" like the Government of India type engine. The new Mauritius engines are working most satisfactorily and do not destroy the road like the superseded eight wheel coupled engines.

Further as regards wind pressure there is no doubt there may be a certain increase in the vertical load on the leeward girders due to the horizontal pressure of the wind. But it is a question of degree, and the case has I venture to say been overestimated, the example adduced in Technical Paper No. 44 being an extreme one the girders of the assumed bridge being placed only 4 feet apart. In the case of the Madras bridges the influence of this vertical additional strain on the leeward girders places

8 feet apart is not of importance especially if, as they should be, the overturning moments are taken round a fulcrum lying in the plane of the wind bracing on the top of the girders and not round one in the plane of the bed plates as suggested by the Technical paper in question.

Then as regards the strains per square inch on the girders the Indian proposed rules whilst allowing a working stress of 7 tons due to the dead load, which is reasonable, yet the stress produced in the flanges by a movable load consisting of two of the heavy type engine followed by a train of vehicles is not to be more than $3\frac{1}{2}$ tons per square inch in case of plate girders and $4\frac{2}{3}$ tons per square inch in case of triangulated girders. This differs from the English Board of Trade requirements and as a consequence small span bridges built according to Board of Trade rules are considered too weak by the Government of India whilst

large span bridges on the other hand built according to the proposed Indian rules would be condemned by the Board of Trade as too weak.

Secondly The rules of the English Board of Trade.

These rules form the basis upon which the iron superstructures on the Madras Railway were calculated, and prescribe that the dead weight of the superstructure added to the weight of the heaviest engines and loaded vehicles running on the line together with the wind pressure on large girders should not produce a greater stress in the iron anywhere than 5 tons per square inch.

The Board of Trade rules have been invariably adopted by English engineers in designing not only iron or steel structures in this country but also for India and the Colonies. Hence it follows that if the proposed Indian rules were adopted here almost every

bridge below a certain span in this country in India and the Colonies constituting by far the most numerous, would have to be strengthened or reconstructed.

The Board of Trade rules have been in force for very many years without the Board of Trade seeing any necessity to modify them. They give what has always been regarded as a large margin of safety, and this might be expected considering the purposes for and the circumstances under which they were framed, and the great responsibility attaching to that Government department in connection therewith.

It would therefore be altogether out of the question and unnecessary to adopt the new rules proposed by the Government of India for iron or steel superstructures already erected as it is the large bridges recently designed (the Chittavratti, Benner, &c) are if braced against wind strong enough according to the proposed Indian rules and more than strong enough taking the Board of Trade rules.

Taking the Board of Trade rules, the only bridges requiring to be strengthened are the following:-

span feet	Type	net area at centre	area required excluding wind	estimated cost
20	A	6.14	8.34	Rs
20	B	6.75		3,416
22	A	9.61	10.06	2,160
64	New Chayan	26.50	26.96	177,188
	Jungabhadra	22.68		628,212
	Old Benner	21.60		322,160
	Old Chayan	19.18		56,378
				<u>11,89,514</u>

The cost of strengthening these bridges according to Mr West's estimate will therefore amount to Rs 11,89,514 or less than one half of the outlay that would be required if the Government of India rules were in force.

And as regards the bridges in the above list it has been contemplated for years, at the time Sir John Hawkshaw was Consulting Engineer to strengthen the 64 feet span types following as far as may be the plan adopted in the case of the 64 feet spans already strengthened. It will be seen that the above estimate is

nearly all for these 64 feet span type of bridges as only a sum of about Rs 5600 is required for the small spans of 20 and 22 feet. These bridges were all quite strong enough for the requirements of the line when first designed, as the Railway was not of the same heavy character as at present, being only a light railway with 65 lbs rails and light engines instead of as now as substantial a railway as any in India designed for the heaviest loads and with a heavy permanent way.

Of course in future every new bridge that may have to be designed could if required be made strong enough to comply with the proposed Indian data if in force.

Yours truly

(Signed) Harrison Hayter

P.S.

I notice that in statement B Col 2 headed "available not sanctioned area" the area of the "new Cauvery type" of bridges

is given "at centre of girder" as 30.625 but this is a misprint for 34.625.

(True copy)

(sd) Henry C. West

Agent Manager

30-7-56.

Extract from letter from the Agent and manager,
Madras Ref. No. $\frac{7759}{658}$ of 30-7-96 to The
Consulting Engineer for Railways, Madras.

3. With reference to the Chief Engineer's
Report No. C/450 dated February 1896, the
Chief Engineer writes as follows: —

With reference to para: 6 there would
be no necessity for inserting abutment piers
at every 6th arch, and Mr Stoney did not propose
doing so, the end pier of the series only needs
to be an abutment one.

While the arches were being turned
every 6th span might be temporarily filled with
earth to resist the thrust of the arches while
being turned, or temporarily tie rods be used.

Since the bridge was opened no flood
has ever, it is believed, flowed through the land
spans, and there is I consider no objection to
reducing the area of these by central piers pro-
posed to be used under the girders would be the
same as those for arches.

If Government rules are enforced new
guides will be needed for the central spans
of the Tungabhadra.

The great advantage of a stone arch structure is that it is permanent, and when once built gives little trouble in maintenance, and that the 30 feet land arches could be built on the double line side of the bridge, and the new girders be then built on these and rolled out, and the entire new bridge constructed without any risk by floods, or interruption to the traffic over the existing one, a very important advantage.

If central pier be used a very expensive diversion would be needed to carry out the work and this diversion might be injured at any time by a sudden flood, and thus interrupt through traffic with Bombay.

B. Form No. 12

No

Government of Madras.

PUBLIC WORKS DEPARTMENT,

RAILWAY BRANCH SERIAL

No. 40

To

THE SECY. TO THE GOVT. OF INDIA,

P. W. DEPARTMENT.

Octy. 22nd September 1896.

HIR

In compliance
with your letter No. 1062.P.C.
dated 18th July 1896, I am di-
rected to forward herewith
a copy of the report dated
12th May 1896, by Mr. Hayes
on the subject of "Strengthen-
ing of bridges" &c.

2. A copy of the under-
noted document is also
forwarded for information.
(a) Letter from the Chief Engineer
to the Agent & Manager, B.R.
Madras Ry. No. C/450 dated -
10.2.96 with statement for
same referred to therein
copies of documents Nos. (2) (3)
(6) and (7) referred to therein
(4) Letter from the Chief
Engineer to the Agent
and

Manager, Madras by No
C 1281 of 5.10.95 which
contains a brief history of
the whole subject.
(C) Extract from (3) of letter
No 7751 of 30.7.96 from the
Agent's Manager, Madras,
to the Comy Secy of the Madras.

11/8/96

OR.

Documents accompanying:-

1. Copy of Mr. Hayter's report
2. Chief Engr's letter No. C
of 10/2/96 with copies of
certain documents
referred to
3. -- Chief Engr's letter No.
C 1281 of 5/10/95
4. Extract from letter 7751
of 30th July 1896

Rf No 806. D dated 22.9.96

Rf 4/9