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THESIS BEAVER BRIDGE McGRATH 1878

METALLURGY

MSM HISTORICAL COLLECTION SSOURISCHOOLOFMIN SSOU

BEAVER BRIDCE.

A Thesis

For the Degree of C.E.

7530

BY J.E Mª GRATH

Class 76

MISSOURI SCHOOL OF MINES AND **METALLURGY**

BEAVER BRIDGE

A Thesis

For the Degree of C.E.

by

J. E. McGrath

Class '76

There is no agent more active in the gle at work of civilization than the "wad". It binds mankind as with a chain over it Commerce flows exchanging to mutual advantage the products of one clime for those of another. But Commerce is not the only veneficiary as experience has laught us, the arts, seconce and in fact every civiliz ing agent is indebted to it, for it is the channel by which their discoveries andis tributed over the earth, and it is to our poods we own the fact, that the existence of mecountry in a high state of civilization while its pier. ghbors languish in barbarism, (as was the case when Athens and Egypt ware at the Benith of their poner) is in our age an impossibility. The Romans wall kenends power and the wisdom of introducing Their wads where ar their disso had ben etrated, after times fully approved; for in addition to the civilizing officet they be oduced, they (particularily the Appian May), by Their my pustige preserved the Empire from dismemberment years after its mili tary stringth had departed fromt. Among the many other essentials of a good road, there is none of more impor-

There is no agent more active in the great work of civilization than the "road." It binds mankind as with a chain, over it Commerce flows, exchanging to mutual advantage the products of one clime for those of another. But commerce is not the only beneficiary, as experience has taught us. The arts, science, and in fact every civilizing agent is indebted to it, for it is the channel by which their discoveries are distributed over the earth, and it is to our roads we owe the fact that the existence of one country in a high state of civilization while its neighbors languish in barbarism (as was the case when Athens and Egypt were at the zenith of their power) is in our age an impossibility. The Romans well knew its power, and the wisdom of introducing their roads wherever their arms had penetrated, after times fully approved; for in addition to the civilizing effect they produced, they (particularly the Appian Way) by their very prestige, preserved the Empire from dismemberment years after its military strength had departed from it. Among the many other essentials of a good road, there is none of more

tance than the bridge; it is the most im portant of all its adjuncts. Without it the rapid torvent, yawning chasmor un fordable siver, all offer insubinable obst. acles; and its universal existence bears suff. icient testimony of its importance. The construction of a bridge, in consequence of the nature of its office, is an underta. king demanding the most painstaking and careful consideration upon the part of the Engineer and me may obtain a fair idea of the skell required from the med of praise which is everywhere conferred on the successful bridge builder. It was not until within the last lemtury (for lowil Engineering as a distinct for fission is no older! That bridge build ing became a science; fine bridges where exected previously, but king built by Architects, Carpenters, Masono and others who had no special training to qual My themselves for this department, the In work was not distinginished for the design and perfect adaptation of the material to the strain to be borne which characterizes the work of our modern Engineus. The Railwad introduced a new consideration into bridge building,

importance than the bridge; it is the most important of all its adjuncts. Without it the rapid torrent, yawning chasm, or unfordable river, all offer insuperable obstacles; and its universal existence bears sufficient testimony of its importance. The construction of a bridge, in consequence of the nature of its office, is an undertaking demanding the most painstaking and careful consideration upon the part

of the nature of its office, is an undertaking demanding the most painstaking and careful consideration upon the part of the Engineer and we may obtain a fair idea of the skill required from the need of praise which is everywhere conferred on the successful bridge builder. It was not until within the last century (for Civil Engineering as a distinct profession is no older) that bridge building became a science; fine bridges were erected previously, but being built by Architects, Carpenters, Masons, and others who had no special training to qualify themselves for this deportment, their work was not distinguished for the design and perfect adaptation of the material to the strain to be borne which characterizes the work of our modern Engineers. The Railroad introduced a new consideration into Bridge Building,

that of stability under a rakidly moring load; In the old countries of Europe where a heavy traffic soon remarded the Railroad for its invisionent they ware enabled to provide Themallows with iron and stone bridges, which rendered the consideration of the best means to produce stiffness in Their hidges, of but little moment in consequence of their quat strangth. The contrary was the case here; in America while timber was abundant won was wetly, the country was but thinky settled, as compared with England or France, and the small traffic they could obtain Inbade anything like the first class equip ment of the foreign roads and except in very few cases the were compelled to weet wooden midges. The old bridges whi le perfictly adapted for ordinary traf. (fic ware soon found to be utterly unfit for railway busness. Among the many devices presented, the Howe mins bridge 1 I which the hidge to be described is an example), was found to supply almost kerfectly the want they created. Is sim dicity, correct adaptation of the parts to the trains they ware to pustain soon made it an almost universal favorte with American

that of stability under a rapidly moving load; In the old countries of Europe, where a heavy traffic soon rewarded the Railroad for its investment they were enabled to provide themselves with iron and stone bridges, which rendered the consideration of the best means to produce stiffness in their bridges, of but little moment in consequence of their great strength. The contrary was the case here; in America while timber was abundant iron was costly, the country was but thinly settled, as compared with England or France, and the small traffic they could obtain forbade anything like the first class equipment of the foreign roads and except in very few cases they were compelled to erect wooden bridges. The old bridges while perfectly adapted for ordinary traffic were soon found to be utterly unfit for railway business. Among the many devices presented, the Howe Truss bridge (of which the bridge to be described is an example), was found to supply almost perfectly the want they created. Its simplicity, correct adaptation of the parts to the strains they were to sustain soon made it an almost universal favorite with American

Railwad men The main princifele which governs The How Thus bridge is, that the com pressiva strain will be borne by east iron for while the tensile strain is to be sustained by the wood. Thus the greatest economy is prescised for the two materials are arranged so as to bring the quatest strength of each into play; this anangement and the lase with which the bridge can a exected and repand have but little to be desired. The Little Beaver Bridge is situated on the AY S. R.R., 33/4 S. Vr. M. Rollait is built on the Howe Imas plan and sp. and a valley through which flows the ditt. le Bearen Creek "_ it has two approaches (stringers supported by hestlis), the length of the northern one is 38 ft. while that of the fouthern one is 35'5" The bridge is composed of 5 spans and is supported on le purs; the length of the bridge proper is 68% 2" with the abutments it is y60'7." The piers are of sandstone and have a bat in from about one half of their hight to the top of one inch to the foot. In consequence of the comparatively small sizz of the used in their construction, the

Railroad men.

The main principle which governs the Howe Truss bridge is that the compressive strain will be borne by cast iron rods while the tensile strain is to be sustained by the wood. Thus the greatest economy is exercised for the two materials are arranged so as to bring the greatest strength of each into play; this arrangement and the ease with which the bridge can be erected and repaired, leave but little to be desired. The Little Beaver Bridge is situated on the A. & P. R. R., 3 ³/₄ S. W. of Rolla it is built on the "Howe Truss" plan and spans a valley through which flows the "Little Beaver Creek" -- it has two approaches (stringers supported by trestles), the length of the northern one is 38 ft., while that of the southern one is 35'5". The bridge is composed of 5 spans and is supported on 6 piers; the length of the bridge proper is 687' 2", with the abutments it is 760'7". The piers are of sandstone and have a batir, from about one half of their height to the top, of one inch to the foot. In consequence of the comparatively small size of the used in their construction, the

Railroad leompany has commenced to tear them down in order to erect larger piers the dimensions of the new piers for the bottom course) will be 13'1" & 30' instead of 7'6" x 24'3" as in the old one - The batir will honaver in the new piers start from the second course, All the timber used in this bridge (except the ties which are vake) is white kine. Date length of 1st Span -- ---- 149'6' 37 11 4th 11 -----149'10 1 5th 150'4" No of panels in first span 9 15 Sistance between Wall plates Width from out to out of chords " in clear between " 10'6" 2'6" 4' 19' 14' Hight of trues pomout to out of " 21' 10"

Railroad Company has commenced to tear them down in order to erect larger piers. The dimensions of the new piers (for the bottom course) will be 13'1" x 30' instead of 7'6" x 24'3" as in the old one -- the batir will however in the new piers start from the second course. All the timber used in this bridge (except the ties which are oak) is white pine.

Data Length of 1st Span ""2nd"..... ""3rd"..... ""3rd".... ""4th".... ""4th".... No. of panels in first span """""the other spans Length of panel """"the other spans Length of panel """pier" Distance between Wall plates Width from out to out of chords "in clear between " Height of truss from out to out of

••••••	. 88'6"
•••••	149'6"
•••••	149'
•••••	149'10"
	150'4"
	9
	15
	10'6"
	2'6"
	4'
	19'
	14'
"	21′10″

In all calculations where the intention is to determine the dimensions fany material to sustain a given strain, to quard against defective workmanship and un forseen makness in the matchal it is the rule to base their calculations on some prace. tion of the known strength as 16 or 110th fit this fraction is known as the factor of safety" the general allowance for the working stringth of wood, por square with of section, is 2000 lbs for its tensile and 1000 lbs for its crushing strangth and for cast iron 25,000 lb is allowed for the erushing strangth. In determining the strain that a cear tain naight I for bridges of part more than 1 Su foot span 1/2 aton per running foot and The waight of the span deelf and Honper. foot for the load, is generally allowed will produce in the chords, we must Treat them as loaded beams supported at both ends. The quatest horizontal strain will be at the centre of the chords. and it decreases there to the abutments where its value should be open; the partical strain on the contrary decreases from the abutments to the centre and in a post disigned bridge This would be taken ad-

In all calculations where the intention is to determine the dimensions of any material to sustain a given strain, to guard against defective workmanship and unforeseen weakness in the material it is the rule to base their calculations on some fraction of the known strength, as $\frac{1}{10}$ of it; this fraction is known as the "factor of safety" -- the general allowance for the working strength of wood, per square inch of section is 2000 lbs. for its tensile and 1000 lbs. for its crushing strength and for cast iron 25,000 lbs. is allowed for its crushing strength.

In determining the strain that a certain weight (for bridges of not more than 110 foot span, ½ a ton per running foot and the weight of the span itself and 1 ton pr. foot for the load, is generally allowed) will produce in the chords, we must treat them as loaded beams supported at both ends. The greatest horizontal strain will be at the centre of the chords and it decreases thence to the abutment where its value should be zero; the vertical strain on the contrary decrease from the abutments to the centre and in a well designed bridge this would be taken

vantage of to make the end panels only on half as wide as the centre ones in order toth To economize timber and lessen the strain on the Graces. From the principles of mechanism we deduce the rule for the strain on the chirds (first premising that the strain will be a tensile one for the low is and a compressive one for the upper chord, J= 4 x in which I represents The strain w The weight and h. The height Instituting in this equation for 11 132. tous - D, 88%" and for h 20'1" and we find The cross section of the lower chord should ta 37 sq. in. whereas in reality it is 336 chowing a most ample allowance for su fity Whe upper chord while being equally trained and having a smaller allowance In stringth demands less of a cross section because as the strain it supports is one of compression the fact of the chord having to be built with goints, which militates most severely against the lowar chord whise strain is one of lencion, this is the reason why they have allotted 252 gg in of cross sutim to the upper chord. The fact of this must excessive allowance of strength in These chirds can only be accounted for by the

advantage of to make the end panels only one half as wide as the centre ones, in order both to economize timber and lessen the strain on the braces. From the principles of mechanism we deduce the rule for the strains on the chords (first premising that the strain will be a tensile one for the lower and a compressive one for the upper chord), $y = \frac{W \times S}{8h}$; in which y represents the strain, w the weight and h the height. Substituting in this equation for w, $132 \frac{1}{2}$ tons - S. 88'6" and for h 20'1" and we find the cross section of the lower chord should be 37 sq. in., whereas in reality it is 336 showing a most ample allowance for safety. The upper chord while being equally strained and having a smaller allowance for strength demands less of a cross section because as the strain it supports is one of compression the fact of the chord having to be built with joints, which militates most severely against the lower chord whose strain is one of tension, this is the reason why they have allotted 252 sq. in. of cross section to the upper chord. The fact of this most excessive allowance of strength in these chords can only be accounted for by the

necessity of making these chords windorm with those of the larger span the length of this span being but little more than half as long as that of the others. Substituting in the equation already given the values of those terms for the 2nd Span (S= 149'6", h= 20'1" and W= 22313 tons, wa obtain for the clover chord the cross section, 104" pyin and for the app er one 208 sq, in, this although a closer result shows that still they are unnece parily long. I h unsequence of the abutments and kins being finally compelled to sustain the whole load, it is evident that the end braces and pods will have the whole weight throw on them; in This calculation we will confine ourselow, to the larger pan is it is a better type. The weight of trush whose length is 149'6" together with its maximum load will be 446, 666 73 lbs, this will thom 223 3331/3 lb on each end or 111, 6666 for each panel but as the braces are ananged in pairs the strain upon each brace will ti 55, 8331/3, The braces being diagonals of the parallelogram formed by the panel the strain will be increased on then in the

necessity of making these chords uniform with those of the larger span -- the length of their span being but little more Substituting in the equation already given the values of those terms for the 2nd span (S = 149'6", h = 20'1" and w = 223 $\frac{1}{3}$ cross section, 104" sq. in. and for the upper one 208 sq. in., this although a closer result shows that still they are unnecessarily long. In consequence of the abutments and piers being finally compelled to sustain end braces and rods will have the whole weight thrown on them; in The weight of truss whose length is 149'6" together with its maximum load will be 446,666 ²/₃ lbs., this will throw 223,333 ¹/₃ lbs. on each end or 111,666 ¹/₃ for each panel but as the braces are arranged in pairs the strain upon each brace will be 55,833 ¹/₃, the braces being diagonals of the parallelogram formed by the panel

than half as long as that of the others. tons), we obtain for the lower chord the the whole load, it is evident that the this calculation we will confine ourselves to the larger span as it is a better type.

the strain will be increased on them in the

Natio of the value of their length over that I the perfendicular high botwan the Trusses, This gives as for the strain 66,508 Us and as the trace is in compussion it will necessitate a cross section of 64 squ the section used is 8914 eq. in; to ascertain whether there is any danger of the beam wielding by flexun an substitute, in the empiril formula for white fine 12 goverde and got a value of 30 ft (ml), and as the brace is only 21'T" we see it is amply sufficient. In each of the pods, for the same rea pon these will be a strain of 55 833/3 Us these thing natical the strain is die. set and for this weight a cross section of 2/15 Rgin which would be that I fa pod while diam is 13/4" The diameter of these in use. The counterbraceing on account of its object (giving stiffues to the trues) will never have to sustain only the quatest Nariable loved which would be 289000th. by pules arready adverted this would meessitate a cross section 371 sq in. or a ham of the dimension 6'x 6", The dimension of the one in use are 73/4" X7." The diagonal braceing, which is alway

ratio of the value of their length over that of their perpendicular height between the trusses, this gives us for the strain 66,508 lbs. and as the brace is in compression it will necessitate a cross section of 67 sq. in. the section used is 89 ¼ sq. in.; to ascertain whether there is any danger of the beam yielding by flexure per substitute, in, the empirical formula for white pine $2^2 = \frac{9000 \text{ bd}^3}{\text{m}}$ and get a value of 30 ft. for (1), and as the brace is only 21'8" we see it is amply sufficient. In each of the rods, for the same reason there will be a strain of 55,833 $\frac{1}{3}$ lbs. these being vertical the strain is direct, and for this weight a cross section of 2 ¹/₅ sq. in. which would be that of a rod whose diam. is $1\frac{34}{7}$ the diameter of those in use. The counterbracing on account of its object (giving stiffness to the truss) will never have to sustain only the greatest variable load which would be 289,000 lbs. by rules already adverted this would necessitate a cross section 37" sq. in. or

a beam of the dimension 6" x 6", the dimensions of the one in use are $7\frac{34''}{4} \times 7''$. The diagonal bracing, which is always

necessary in a bridge of the character of the one under discussion (i. 2, one in which The roadway runs on top) is intended for The prevention of side motion and as per mile can be laid down for the exact determination of its dimensions, it is the custom to make them 5"x7" which differs but little from the dimensions used in the Bea Nar midge, 6×63/4". The horizontal bracing which is intended to privant lateral flexure in The roadway from the wind and other cause is. (The greatest strain upon) composed I braces and ties differing from those in The truss, in the fact that only how ma ces are used instead of three, but both braces are of equal strength. The gea test strain possible would be, when the sides nave weather boarded, in a strong gale. Allowing 15 lb. per ug. fl for the stringth of the wind we would have 47935 the for the whole strain or 23, 963 lb for each since top and bottom as the brices are diagonals, on reduction we would find 16.8 sq. in poould he what the strain demanded 30 y, in are used in the hold and as it is an open one The waste of material is evident. The "

necessary in a bridge of the character of the one under discussion (i.e. one in which the roadway runs on top), is intended for the prevention of side motion and as per rule can be laid down for the exact determination of its dimensions, it is the custom to make them 5" x 7", which differs but little from the dimensions used in the Beaver Bridge, 6" x 6 $\frac{3}{4}$ ".

The horizontal bracing which is intended to prevent lateral flexure in the roadway from the wind and other causes, is (The greatest strain upon) composed of braces and ties differing from those in the truss, in the fact that only two braces are used instead of three, but both braces are of equal strength. The greatest strain possible would be, when the sides were weather boarded, in a strong gale. Allowing 15 lb. per sq. ft. for the strength of the wind would have 47935 lbs. for the whole strain or 23,963 lbs. for each series top and bottom as the braces are diagonals, on reduction we would find 16.8 sq. in. would be what the strain demanded. 30 sq. in. are used in the bridge and as it is an open one the waste of material is evident. The 1"

Jods in use are amply sufficient. The superstructure consisting of the flooring timbers (21/2' apart, 6"x 14"), the stringers (forming a double built be am 11" x 24"], and the ties (6"x 6"], requ ine no calculation and their dimen. sions are in conformity with the law. laid down by Town and Haupt. From the previous pages it will be readily seen that although the tim Vars pro where are of less dimensions than those required by the strain still the bidge is not a commendable one. most With members possess excessive strigth and this strangth instead of adding to usefullness of the bridge, detracts from it, by adding to its ful fluous weight; the parts are ill an anged and knowing this the constant rebaining this bridge need surprise wone

rods in use are amply sufficient. The superstructure consisting of the flooring timbers (2 1/2' apart, 6" x 14"), the stringers (forming a double built beam 14" x 24") and the ties (6" x 6"), require no calculation and their dimensions are in conformity with the laws laid down by Town and Haupt. From the previous pages it will be

readily seen that although the timbers no where are of less dimensions than those required by the strain, still the bridge is not a commendable one. Most of its members possess excessive strength and this strength instead of adding to usefullness of the bridge, detracts from it, by adding to its superfluous weight; the parts are ill arranged and knowing this, the constant repairing of this bridge need surprise no one.

