1916

A study for comparative costs of flat, short span, concrete steel highway bridges

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A STUDY FOR COMPARATIVE COSTS OF FLAT, SHORT SPAN, CONCRETE STEEL HIGHWAY BRIDGES.

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A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

DEGREE OF

BACHELOR OF SCIENCE IN CIVIL ENGINEERING

Rolla, Mo.

1916

Approved by Elmo G. Harris

Professor of Civil Engineering.

Thesis. Comparative Costs of Concrete-Steel Highway Bridges. McCague. 1916

For years it was only considered necessary for the larger streams, or streams that could not be forded to have bridges, but with the advance of road building the highway engineers have realized that the small streams and drains should have culverts or small bridges.

The principal requisites of a material used in building various structures forming the necessary parts of a well constructed, modern highway are cheapness and durability. Wood, steel, stone and concrete are in general the principal materials used in the construction of highway culverts and bridges. Of these four materials wood is usually the cheapest in first cost for small structures and is the least durable of all as the life of the bridge is short, being from nine to twenty years, and there is always a high cost of upkeep as the bridges must be inspected and repaired rather often; and of late there has been a number of failures of wooden bridges due generally to the deterioration of the wood, or to the bridge not being built strong enough for the loads of the present time.

Stone is generally a durable material, but it's first cost, and in many places it's scarcity tend to limit it's use for highway purposes. It is also difficult and expensive to shape stone into desired forms which in many cases are required to secure the best results.

The importance of steel in the construction of long span highway bridges is well understood, but it's cost and the constant heavy maintenance charges, or it's rapid deterioration, if not properly maintained, have caused builders of bridges to seek some other material, which is low in first cost and which will not require constant painting.

So we consider concrete and concrete steel. Concrete can be made at small expense in practically any locality and can be molded in any desired shape or size. Concrete and concrete steel requires practically no cost of maintenance and can be placed in position with very little skilled labor. So we find that concrete or concrete steel is the material above all others that combines the advantage of cheapness and durability.

In addition to natural permanence and low first cost concrete bridges are proof against tornadoes and fire and there is very little danger from high water.

In combining concrete and steel as a building material we find that if the concrete contains a good aggregate and is well mixed that the combination of concrete and steel make a combination that is very satisfactory as the coefficient of expansion is about the same so there is no danger of the breaking of the bond between the concrete and steel due to temperature changes.

Also concrete is low in tension and high in compression while steel is high in tension and low in compression so combining the two and placing the steel in the proper place and amount we get the good qualities of both.

We find there is a natural classification of concrete bridges, the flat and arch bridges. This thesis is devoted entirely to the flat type of bridge. This type is suitable for and is generally used in level countries for short spans, seldom exceeding forty feet, and for locations where the foundation is of soft material.

In designing this bridge I have tried to keep in mind the idea of comparison so the amount of steel and concrete is just about that necessary for the bridge and if any of these bridges were to be built a little more concrete should be used to help the looks of the bridge and this amount would vary as the length of the span. Prices of material were adopted that correspond to present market prices plus the cost of putting the material in place but not assuming any cost for haulage of materials. The type of labor required would be about the same in all cases but it would take more forms and time to place forms in some types than it would in others, but there is little difference in cost of form work. "Turnaure and Maurier" was the reference book used for this study. The approximate formulas found therein were adopted as they shortened computation and give results that are perfectly safe. The rules for loading and allowable stresses are those used and recommended by "Iowa State Highway Commission" and the concrete and steel should come up to their specifications (See page 11 for most important stresses and rules for loads). All slabs are treated as independent beams, one foot wide. The floor girders or beams were treated as T beams and the width "b" of the T was figured by a formula found in "Reid's Concrete and Steel Construction".

In Type I the load is carried by the floor to side girders and by the side girders to the abutments.

In Type II the load is carried entirely by floor from abutment to abutment. The guard rail is of concrete and hand rail is of 1" iron pipe.

In Types III, IV and V the load is carried by the floor to cross girders and by side girders to abutments or piers.

In Type III the distance between cross girders is three feet and assuming the roller over one cross girder and the floor being a continuous slab, we assumed the load to be two thirds of the rear wheel load. In Type IV the distance between cross girders is five feet and we assumed the greatest load to be four fifths the rear wheel load; and in Type V it is 7 feet between centers and we assumed total weight of rear wheel load on cross girder.

In Type VI the load is carried by floor to beams which convey the load to the pier or abutment. There is one T beam in the center of road way and a girder guard rail on each side. I assumed the side girder to carry four fifths the live load of the center girder.

Types VII and VIII are designed in same manner as type VI but in type VII there are two inside T beams and in type VIII there are three inside T beams.

Type IX is the same as type VII only load is carried by four beams underneath the floor and we have an iron pipe hand rail.

In the table attached will be found the loading, dimentions and amount of concrete and steel necessary for bridges of different designs and different spans. In type I the floor is very thick and more concrete and steel used than in other bridges of this length span.

The 12 and 16 foot span of type II are not bad designs but they require a little more concrete and steel than other design but the forms are easier built and the estimate does not include the cost of hand rails.

Types III, Iv and V are of a good design and I would recommend type IV as it has a 6" floor, which I think is almost necessary, but the "Iowa High Way Commission give minimum floor thickness as 5½" ;

also type IV costs very little more than type III. Type V is alright and could be recommended but it costs more than type IV. In these three types of bridges the cost of 35 and 40 foot spans are high because of necessary compression steel. Types VI, VII and VIII are all of a general class and all are of a good design; but we find that in type VII we have a design in which there is less material used, except in spans of 12 and 16 feet, than in any of the other designs, and even with the 12 and 16 foot spans the only type that is cheaper is type VIII and it has a floor that is only $5\frac{1}{2}$" thick, so we would recommend this type above all others as the only draw-back to this type is that in the longer spans the depth of the T beams is rather deep but it is hard to remedy this fault without adopting other designs which are a great deal more expensive, or else place some steel in the top of the T beam to take compression and increase the area of the tension steel and we find that this change increases the cost very rapidly. In type IX we used more material than in type VII and have an iron hand rail and this type costs more than type VII and does not look as neat.

So I would recommend the use of designs like type VII in flat bridges of spans from twelve to forty foot unless there is some good reason for using a different design. I have also found that this is the most economic design for an eighteen foot roadway; but with a twenty foot roadway I find the most economic design is like type VIII with a six and one half inch floor.

Any person studying this subject realizes that a great deal depends upon the place the bridge is to be built and especially is this true of a bridge of more than one span as the cost of the aggregate and the design of the pier necessary for the place has a great deal to do with the cost of the pier; also the length of the span depends somewhat upon the length of the bridge.

Assuming the cost of concrete as $5.50 per cubic yard and using the design of pier shown on the next page, I have come to the following conclusion in regard to the economic length of spans. For five ft., pier or less use 25foot spans and from five to nine foot piers use thirty foot spans and for pier over nine to fourteen feet in height it varies between thirty-five and forty foot spans, for over fourteen pier use forty foot span, but an arch bridge would generally be used where a fourteen foot pier is neccesary.

L O A D I N G .

Dead loadings:

Earth filling	120 lbs. per cu. foot
Concrete	150 lbs. per cu. foot

Uniform Live Load:

Not less than 100 lbs. per square foot

Concentrated Uniform Live Loads

Minimum concentrated load consisting of a 15 ton traction engine. For heavy slabs the distribution is as follows:

20,000 lbs. on rear wheels.

10,000 lbs. on front wheels.

11' 0" between axles.

6' 0" center to center of back wheels (width of wheels 22".)

Each back wheel load is assumed to be distributed 9'0" transversley and 6'0" longitudinally. For thin slabs on girders the same wheel load is assumed to be distributed 4' 00" longitudinally and 4'0" transversley.

Permissable Stresses.

The Stresses used in designing slab and girder bridges shall not exceed the following:

Concrete in compression--	600 lbs. per square inch.
Concrete in tension	0 lbs. per square inch.
Concrete in Shear	100 lbs. per square inch.
Steel in tension	16000 lbs. per square inch.
Steel in Compression	15 times the surrounding concrete.