MODEL VALIDATION FOR AN AGED GERBER TRUSS BRIDGE

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1. Introduction

With the rapid increase of aged bridges, in japan as well as in other developed countries the maintenance and rehabilitation of old steel bridges are fields of growing relevance in terms of economic impact. A case study of an aged Gerber Truss bridge was conducted for this research. The case study bridge carries the National Highway No.351 over the Shinano River, the longest river in Japan, between the east and west regions of Nagaoka city, located in the central part of Niigata Prefecture. The structure was built between 1934 and 1937, and was opened to the traffic in 1938. After more than 75 years of service, fatigue crack, degradation and corrosion had become prominent in the course of aging. For this reason a tool that accurate simulates the actual behavior of the bridge to help with its condition assessment is needed.

2. Objectives

The purpose of this research was to perform a field load test and a detailed structural analysis of the case study bridge. With the intention to collect the necessary data that allow a better understanding of the structural behavior of the bridge to validate a model capable of accurately simulate the bridge structural response in the current operating conditions.

3. Background

The case study bridge is considered as steel through Gerber truss (cantilever) bridge. A Gerber truss consists of introducing hinges in a continuous beam to make it isostatic so that it becomes a series of simply supported beams extended at their ends by cantilevers in alternate spans that are linked to each other by beams supported on the cantilever ends. This system gives the advantages of the continuous beam and of the isostatic structure.

4. Bridge Testing

Field tests involved measuring strains and deflections while trucks of known weight crossed the bridge. The bridge was instrumented with 100 strain gauges on 25 truss members in addition to thirteen displacement transducers placed at the center of each span along the bridge. The bridge response was monitored under two different loading scenarios, namely static and dynamic. Static load case data was recorded continuously and reduced to member forces for model validation comparisons. Vertical displacements at each bridge's span were also recorded for model validation purposes. The purpose of driving the truck at a higher rate of speed on the dynamic load case was to investigate the effects an impact load had on the instrumented members. Minimum and maximum values from the high speed measured results were compared to quantify the effect that dynamic loading had on strains and movement.

5. Finite Element Analysis of the Bridge

The model validation process began by developing eight simple truss models, each reflecting different expected restraint conditions, in the hopes of replicate data from recorded results at field load test. Models were refined to frames, and then frames including stringers for greater accuracy. Finally, the most accurate model in simulating the overall structural response to static vertical loads taking into account both member force and span vertical displacement was selected.

6. Analysis of the results

6.1 Static Load Test Results

It was found that there were very little amounts of bending effects in the north-south direction or out of plane of the truss as well as in the east-west direction or in-plane with the truss in the order of 0.1% of the measured axial strain (see Fig.1).

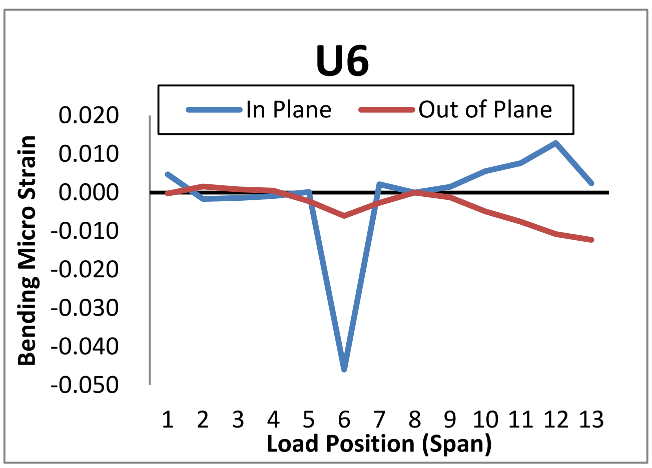

Fig. 1 Bending Strain in Top Chord Member at Span 6

6.2 Dynamic Load Test Results

The truss member strains showed a difference in strain between static and dynamic loading. The dynamic loading results measured an increase in maximum and minimum values on average of about 15%. From Fig.2 it can be seen that the dynamic effect is much evident in the movable diagonal.

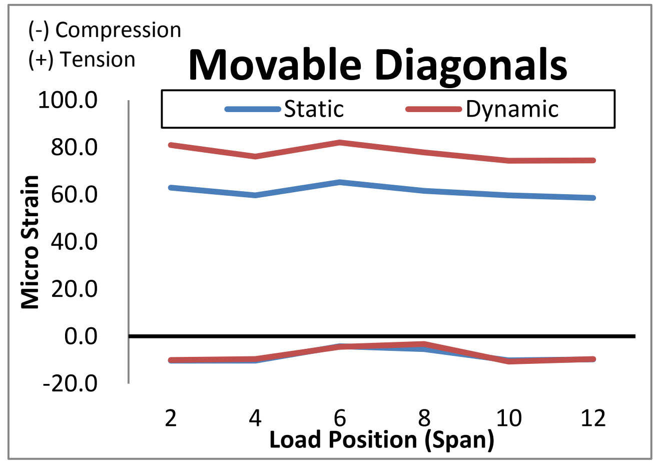

Fig. 2 Peak Strain Comparison of Instrumented Movable Diagonal Members

6.3 Finite Element Analysis Results

There appears to be little advantage in the use of more complex models for computing the truss member forces, but if considering floor system (stringers) in the models an appreciable improvement in the flexural stiffness of the structure was found(see Fig.3).

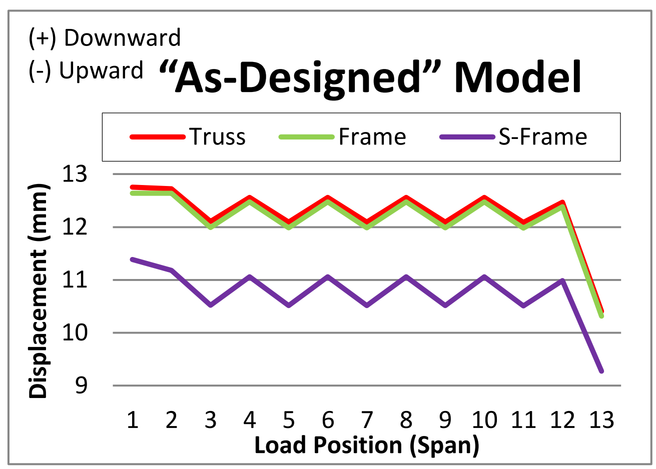

Fig. 3 Comparison of maximum analytical span displacement results obtained from the "as-designed" condition model

6.4 Comparison Of Test Data And Finite Element Analysis

After analyzing the finite-element model with the assumed As-Design bridge properties, it was observed that the theoretical model did not behave in the same way as the actual bridge.

The finite-element model would typically over and under predict values of strain and displacements. For that reason, the model-test comparison was carried out in several progressive steps with varying combination of model properties. The progressive model adjustments did result in improved agreement at each step and reasonably good match at the end of the process as can be seen In the next tables.

Table 1

Comparison of average percent difference between recorded and expected member forces

Bridge Member Forces			
Model #	Model Type (Δ%)		
	Truss	Frame	Stringer Frame
1	10.4%	10.3%	12.2%
2	14.9%	15.0%	15.4%
3	9.4%	9.1%	11.2%
4	11.6%	11.7%	13.2%
5	8.2%	7.6%	10.1%
6	14.3%	14.2%	14.9%
7	9.4%	8.5%	9.9%
8	11.2%	11.1%	12.6%

Table 2

Comparison of average percent difference between recorded and expected deflections

Bridge Span Deflections			
Model #	Model Type (Δ%)		
	Truss	Frame	Stringer Frame
1	44.7%	43.5%	27.0%
2	26.6%	25.2%	12.0%
3	67.5%	66.3%	46.7%
4	35.6%	34.2%	19.3%
5	23.6%	21.1%	13.5%
6	12.1%	11.4%	9.2%
7	33.0%	29.8%	22.4%
8	17.4%	15.4%	9.6%

7. Conclusions

The results have permitted to conclude the following:

- Despite being nominally designed as a truss, the structure did not behave as intended. Probably the existence of rusted pins and damaged members requires the entire bridge structure to behave more like a frame than an ideal truss.
- The dynamic loading had very little effect on the vertical displacements along the spans of the bridge. However, did have a greater effect on the truss members in terms of strain with an average increase in magnitude of about 15%.
- Given that the numerical estimates for the FEM compared well with the experimental results, presenting an average percent difference below 10% for vertical displacement and less than 13% for member forces, it was concluded that the bridge's response to static vertical loads is best simulated as a 2D stringer frame system assuming a fixed restraint condition in all bearing supports and a spring joint condition for the upper west movable hinges on the suspended spans.