KNOWLEDGE-BASE APPROACH FOR GLOBALLY OPTIMAL PLATE GIRDER BRIDGES DESIGN

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1. Introduction

Optimum bridge design and fabrication need a wide spectrum of knowledge about a varity of fields including structural mechanics and fabrication and construction methods. However, cost estimation of steel bridges in Japan is based only on the steel weight. This results in increasing the number of cross section variation and complicating the bridge structure with large number of welding lines. In addition, because of the shortage of technicians and the increase of labour cost, it is expected that the present design practice will lead to complicate the fabrication process and increase the total cost of the bridge.

2. Suggested New Cost Estimation Method

At present, the work needed in bridge fabrication is estimated according to the number of the operations needed in the fabrication N:

$$N = (A \times a + B \times b + C \times c) \times (1 + \alpha) \times (1 + \beta) \times (1 + \gamma) \tag{1}$$

Where A, B *and* C are the steel weights for 40 k, 50 k and 60 k steels, respectively. a, b *and* c are factors used in the calculation of the manpower needed for the fabrication according to the type of bridge. α, β and γ are correction factors that consider the total weight, the number of similar spans and the curvature or inclination of the bridge, respectively.

In order to develop a practical method for calculating the fabrication cost, directly from the dimensions of the components, the following equation is suggested for calculating the total cost, except the costs of composition and trial erection:

$$total\_cost = \Sigma cost\_of\_steel + \Sigma cost\_of\_cutting + \Sigma cost\_of\_one\_hole + \Sigma cost\_of\_welding \tag{2}$$

The cost of welding is calculated by first calculating the equivalent 6 mm fillet welding length according to the type of the welding and its dimensions. Then, it is possible to consider the cost proportional with the length of the welding. Eq.(2) becomes:

$$total\_cost = \Sigma W \times c_{weight} + \Sigma 2(a + b) \times t \times c_{cut} + \Sigma t \times c_{hole} + \Sigma w \times L \times c_{welding} \tag{3}$$

where W is the steel weight in the bridge (tonf), c_{weight} is the cost of the unit weight of steel (Yen/tonf), a, b and t are the length, width and thickness of one plate (m), c_{cut} is the cost of cutting 1 m of the plate, c_{hole} is the cost of opening one hole, w is the factor for calculating the equivalent 6 mm fillet welding, L is the length of the equivalent 6 mm fillet welding (m), and $c_{welding}$ is the cost of 1 m of 6 mm fillet welding (Yen/m).

The values of the factors c_{cut}, c_{hole} and $c_{welding}$ will differ from one bridge fabricator to another depending on the degree of automation achieved. The cost of composition and trial erection depends on the number of joints. As the number of joints will not change in the new design suggestions, explained later, these items are not considered here.

3. Creating a Knowledge Base of Previously Designed Bridges

The design data of previously designed plate girder bridges are implemented in a knowledge base form. The knowledge base has the data of about 200 I plate girder bridges and 150 box plate girder bridges. All the details related to the dimensions, materials, structural configuration and design parameters are described using the object-oriented approach. The knowledge base is enhanced by adding heuristic design rules that can help in calculating some values that are not included in the knowledge base explicitly. For instance, the method for calculating the fillet welding size and the type of the groove welding is decided according to expert designers' rules.

Using the expert designers rules about welding type and welding size, and the dimensions of the bridge from the knowledge base, the type and length of welding between the web and the flanges and the horizontal and vertical stiffeners can be calculated. All of the variables used in Eq.(2) can be found from the knowledge base. Figure 1 shows the relationship between the total span length and the weight per unit area for the plate girder bridges with three spans.

4. Using the Knowledge Base for Redesign

The previous design Knowledge base can be used effectively for many purposes. One purpose is the redesign of some selected bridges and the calculation of the cost according to Eq.(2). Some of the provisions of the design standards (Doro-Kodan, Ministry of Construction, etc.) may be neglected. However the Specifications of the Highway Bridges [1] are followed. The bridges which have average weight values are chosen for redesign. Three bridges with average weights and different span lengths are selected for number of spans equal 2, 3 and 4. Each of these bridges was redesigned for three cases: Case 1) Make the cross section changes only at the joint position. Case 2) Reduce the number of vertical stiffeners and horizontal stiffeners. Case 3) Combine Case 1 and Case 2. However, eliminating horizontal stiffeners is done only when the increase in the web thickness is less than 5 mm. The number of vertical stiffeners in one panel is reduced from 3 to 1 when possible.

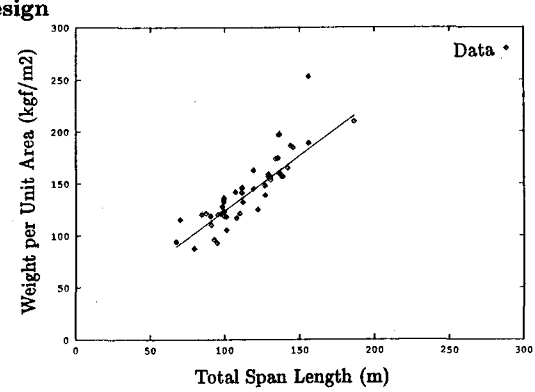

Figure 1: Relationship between Span Length and Weight per Unit Area

Table 1: Basic Data Used in Redesign

Bridge	ns	ng	Length mm	wh mm	wt mm	w0 kgf/m2	w1 kgf/m2	w2 kgf/m2	w3 kgf/m2
2-A	2	2	34200	1000	9	154	158	–	–
2-B	2	5	69124	2000	10	198	204	190	200
2-C	2	5	75668	2200	10	212	220	213	223
3-D	3	5	67080	1600	9	144	151	143	173
3-E	3	4	119083	2050	10	204	208	205	210
3-F	3	4	145627	2600	11	288	298	290	301
4-G	4	5	117842	1700	9	199	197	202	200
4-H	4	4	154090	2300	10	214	211	218	218
4-I	4	5	168998	2000	10	208	220	214	228

Table 1 shows the basic data of the bridges used in the redesign and the results of the redesign. The data include: number of spans (ns), number of girders (ng), total span length (Length), web height (wh), web thickness (wt), weight per unit area for the original design (w0) and the new designs of the three cases (wl, w2 and w3). From the comparison between the original design and the three redesign cases, it is clear that the new cases may result in a design that is more optimal than the original one.

5. Conclusions

In this paper, problems related to plate girder bridges cost estimation were discussed and a new cost estimation method that consider the different factors related to fabrication was proposed. The design data of available bridges were implemented in a knowledge base form and this knowledge base was used to redesign some bridges in a manner that decreases the work needed in the fabrication. The partial results from the redesign show that the increase in the weight is very small and is acceptable considering the decrease in the welding length. Further investigation of the results is necessary to show the effect of the redesign in more detail.

References

[1] Japan Road Association. *Specifications of the Highway Bridges – Superstructure*, 1980.