System for launching erection method of steel box-girder bridges

Autor(en): **Nishido, Takayuki / Itoh, Yoshito**

Objekttyp: **Article**

Zeitschrift: **IABSE reports = Rapports AIPC = IVBH Berichte**

Band (Jahr): **72 (1995)**

PDF erstellt am: **25.04.2024**

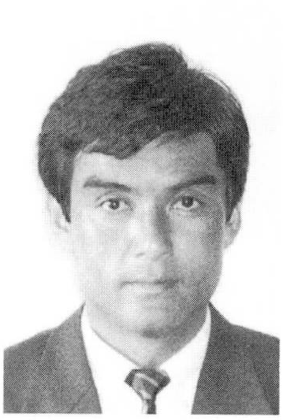
Persistenter Link: https://doi.org/10.5169/seals-54649

System for Launching Erection Method of Steel Box-Girder Bridges

Système expert pour le lancement de ponts-caissons métalliques

Ein wissensbasiertes System für das Taktschieben von Stahlhohlkastenbrücken

Takayuki NISHIDO
Dr Eng.
Kawada Techno-System
Tokyo, Japan



Takayuki Nishido, born 1957, received his Dr. of Eng. degree from Nagoya Univ. in 1992. He is currently manager of the Development Div., Kawada, Inc. His research interests includes knowledge advisory systems and economy and safety of bridges.

Yoshito ITOH
Assoc. Prof.
Nagoya University
Nagoya, Japan

Yoshito Itoh, born 1952, received his Dr. of Eng. degree from Nagoya Univ. in 1985. He is currently Assoc. Prof. of Civil Eng. at Nagoya Univ. His research includes knowledge-based systems and ultimate strength of structures.

SUMMARY

The authors have proposed a new knowledge approach for the launching erection method to automatically decide the erection steps, decreasing the number of stiffeners required to avoid web buckling. The knowledge of expert design engineers is embedded into the system. The approach considers the stress conditions of a bridge as well as the geometrical conditions, for example, a yard length where blocks of a bridge are joined. The usefulness of the proposed knowledge-support system is demonstrated in application examples.

RÉSUMÉ

Les auteurs proposent un système expert pour la construction de ponts par lancement, afin de déterminer les phases de construction minimisant le besoin en raidisseurs d'âme. Les règles appliquées dans le système sont basées sur les connaissances acquises par des ingénieurs expérimentés. Le système tient compte des conditions de contrainte dans le pont ainsi que des conditions géométriques, comme par exemple la longueur des éléments poussés. La valeur du système expert est démontré par quelques résultats d'application.

ZUSAMMENFASSUNG

Für das Taktschiebeverfahren wird ein wissensbasiertes System vorgeschlagen, das die Verschubzustände im Hinblick auf eine Minimierung notwendiger Stegaussteifungen bestimmt. Die verwendeten Regeln wurden aus den Kenntnissen erfahrener Entwurfsingenieure gewonnen. Sie berücksichtigen die Spannungszustände der Brücke und geometrische Bedingungen wie z.B. die Schusslängen mit der Lage der Konstruktionsfugen. Die Brauchbarkeit des wissensbasierten Hilfsmittels wird anhand einiger exemplarischer Anwendungen demonstriert.

1. INTRODUCTION

In the launching erection method of bridge construction, the bridge superstructure is fabricated in successive segments at one end of the bridge. The completed section of the bridge is launched one stage forward and the procedure is repeated. Fig.1 shows one stage of the erection method. As the support condition in the girder always changes during the erection, the stress condition in the bridge also change.

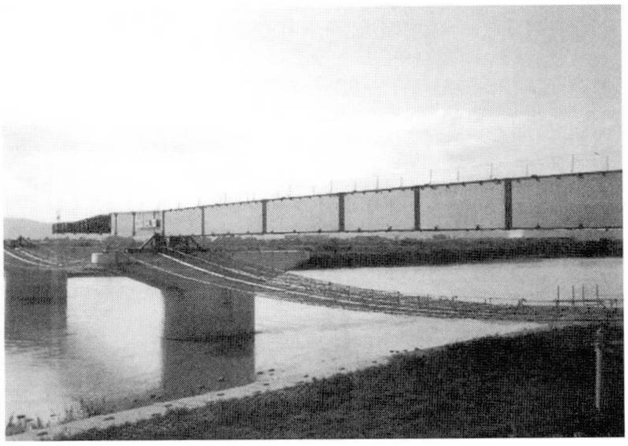


Fig.1 One stage of the launching erection method

Therefore an expert design engineer has to perform many calculations for safety checks in order to adopt this erection method. This erection method is often applied to steel box girder bridges[1], when it is difficult to employ other erection methods because of lack of space in the site.

A convenient program, which is called the checking program here, has been developed for the erection method to easily check the safety of steel box girder bridges. The checking program can consider support conditions during all erection steps. It can automatically make new nodal points for the positions of all supports at calculations. It is written in FORTRAN language and works on a personal computer.

Webs are usually stiffened with horizontal stiffeners to avoid buckling during the erection. The expert design engineer should decrease the number of the stiffeners for the web buckling by selecting the optimum erection steps. The optimum erection steps can not easily be determined because the procedure is very complicated. Expert systems in construction have been developed to resolve unknown or complicated factors[2]. Therefore the authors proposed a knowledge approach method to automatically decide the erection steps decreasing the number of stiffeners required to avoid web buckling. The method considers the stress conditions of a bridge as well as the geometrical conditions, for example, a yard length where blocks of a bridge are joined.

The proposed knowledge support system that is now applied to actual design problems as a prototype uses production rules to embedded the knowledge from expert engineers. The knowledge support system is consists of the checking program and the production rules and works on a personal computer. This paper describes the procedure and features of the proposed method and its usability is demonstrated by some examples.

2. OUTLINE OF THE CHECKING PROGRAM FOR THE LAUNCHING ERECTION METHOD

The launching erection method uses a thin teflon plate and a stainless plate on each support as shown in Fig.2[3]. The teflon plate is put in between a bridge and all supports except a roller one. The bridge is launched using a center-hole type jack and a steel bar at the speed of about 3 mm/sec. The friction coefficient between stainless steel and teflon plate is less than 0.05. Therefore the bridge can be launched with low horizontal force. This is one of

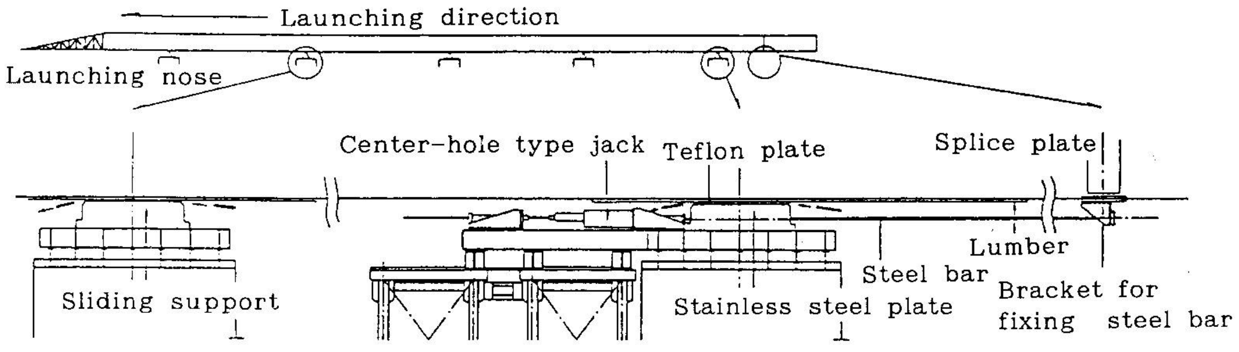


Fig.2 Launching erection method by using teflon plate

the main advantages for this erection method.

In this erection method, the support conditions always change during the erection because the support location moves and the girder length changes. Expert design engineers have to calculate reaction and internal forces at all erection steps by modifying the skeleton data in order to assure bridge safety during the erection. The authors have developed a checking program to determine automatically the whole process.

This program has the following features:

(1) A box girder bridge is idealized by beam elements.
(2) The locations of supports and block joints during the erection steps are automatically made as nodal points in the stress analysis.
(3) Maximum and minimum internal forces at every nodal point through all erection steps are automatically divided.
(4) Safety checks for bending moments and shear forces are done by using the maximum and minimum internal forces.
(5) Required stiffnesses of vertical stiffeners at upper and lower flanges are checked[4].
(6) Webs are checked against buckling.

These procedures are automatically done after inputting the data. Input data include length, weight, sectional properties, support locations and block joints locations at each step. Fig.3 shows the stress patterns of σ_{xb}, σ_{xc}, σ_{yc} and τ by acting forces on the web. The possibilities of buckling are checked at each panel of a web by using Eq.(1)[5].

$$\left(\frac{\sigma_{xb}}{\sigma_{xbcr}}\right)^2 Fs^2 + \left(\frac{\sigma_{xc}}{\sigma_{xccr}}\right) Fs + \left(\frac{\beta_{yc}}{\sigma_{yccr}}\right)^2 Fs^2 + \left(\frac{\beta\,\tau}{\tau_{cr}}\right)^2 Fs^2 = 1.0 \qquad (1)$$

Where, β is a coefficient considering the unbalance in reaction forces on the left and right webs of a box girder bridge. σ_{xbcr}, σ_{xccr}, σ_{yccr} and τ_{cr} are critical buckling stresses obtained by multiplying the buckling factors K_b, K_x, K_y and K_τ by the basic elastic buckling stress σ_e. The Eq.(1) is follows DIN[6]. The web is safe against buckling when the safety factor Fs is more than 1.36 according to the Japanese specifications[5].

3. RULES FOR AUTOMATIC DECISION

Rules are used to automatically decide the erection steps. Fig.4 shows an example of launching erection by expressing the rules. These rules reflect expert design engineers' knowledge and experience. A procedure for automatic decision of erection steps is added to the checking program.

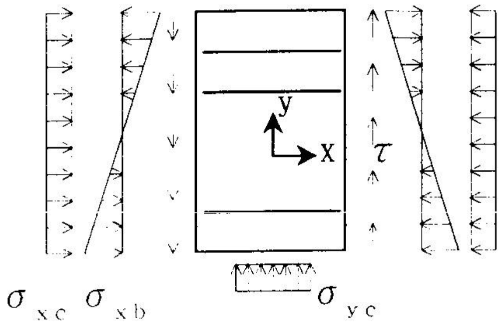


Fig.3 Stress patterns on a web plate

Some of the main rules are as follows:

Rule 1 : As many blocks as possible of the bridge are joined in the yard.

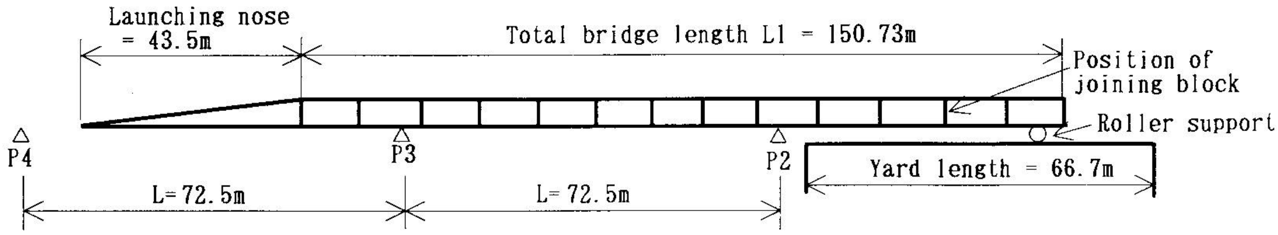


Fig.4 An example of launching erection - Case 1

This erection repeats launching and joining within the yard. The total time of joining blocks takes half of the erection. Of course, a truck crane and impact wrenches need to join blocks. If the bridge is always launched after joining one block, this erection work is inefficient. The collected launching erection can be done according to this rule.

Rule 2 : The roller support is basically located below the diaphragm of the last block.

Only the location of the roller support to the bridge does not change till the joining of new blocks. This rule is considered to avoid the web buckling over the roller support.

Rule 3 : The roller support is replaced when the length to move in a new position is more than 10m.

The reaction force of the first sliding support P3 may decrease by changing the position of the roller support. When the roller support is replaced, the last block must be suspended by the truck crane. If the work of replacing the roller support increases, this erection procedure is not appropriate.

Rule 4 : The roller support is removed within the yard and the distance from the support P2 to the roller one is less than 0.1 times of the completed span length L.

The roller support can not be removed out of the yard. The reaction force of the forward support P2 may be negative when the distance from the forward support to the roller one is too short. The reaction force of the first sliding support may decrease by removing the roller support, but the reaction force of the forward support P2 is critical for its web against buckling when the distance of cantilever is too long.

Rule 5 : Erection steps are always made exactly before and after joining blocks.

The reaction forces of all supports always change after joining blocks. These reaction forces must be calculated to check the safety of the bridge.

Rule 6 : Only the heights of the P4 that is the first sliding support at the final erection step and the roller supports can be adjusted.

The sliding supports except the first one and the roller support are difficult to jack up and down during erection because these reaction forces are large. On the other hand, the first sliding support and the roller support are easy to jack up at joining blocks.

Rule 7 : Erection steps may be made at the intervals of 0.1 times of the completed span length when the bridge total length L1 and the number of supports do not change.

This rule is established from the result of trial calculations. Useless calculations can be removed firing this rule.

These rules are embedded as production rules into the proposed support system. The number of rules is about 30 in the system. The part of knowledge base exists as a subroutine in the system.

4. AUTOMATIC DECIDING METHOD

Figs.5(a) and 5(b) show the flow-charts of automatic decision for the basic steps and for the erection steps except the basic steps respectively. The flow-charts are described by using Fig.6(a) as an example. Initial data for automatic decision are yard length, the possibilities of adjusting the heights of the first sliding support and the roller support, the possibilities of using blocks as counter weights and the position of a diaphragm at each block, and the data for the checking program.

For deciding automatically basic steps as shown in the flow-chart of Fig.5(a), a condition is considered where the tip of the launching nose is immediately before the first support P3 as shown in Fig.6(a). This erection step is called *basic step* here. During this step the web over the forward sliding support P2 is most critical to buckling. The basic step is also most critical for over turning of the cantilevered launching nose.

The checking program has two functions. one is to check against buckling of the web, and another to predict the stability of over-turning of launching nose.

The number of the basic steps is found from the number of all the supports. For example, there are two basic steps in Figs.6(a) and 6(b). At the basic steps, the number of blocks is fixed according to the Rule 1. The position of a roller support is changing within satisfying the Rule 2 and the condition C2 in Fig.5(a). The suitable position of the roller support is that the reaction force of the first sliding support is smallest. Reaction forces at all supports are quickly calculated by using the checking program. The first step from which the launching erection starts is decided in the same way.

If the basic step is decided at this stage, remaining steps would be decided following the rules according to the flow-chart as shown in Fig.5(b). There are some rules in the flow-chart except from the Rule 1 to the Rule 7. Here, L is the completed span length. At joining blocks and setting the roller support, the condition C1, namely the Rule 1, and C2 that is described in Fig.5(a) are used.

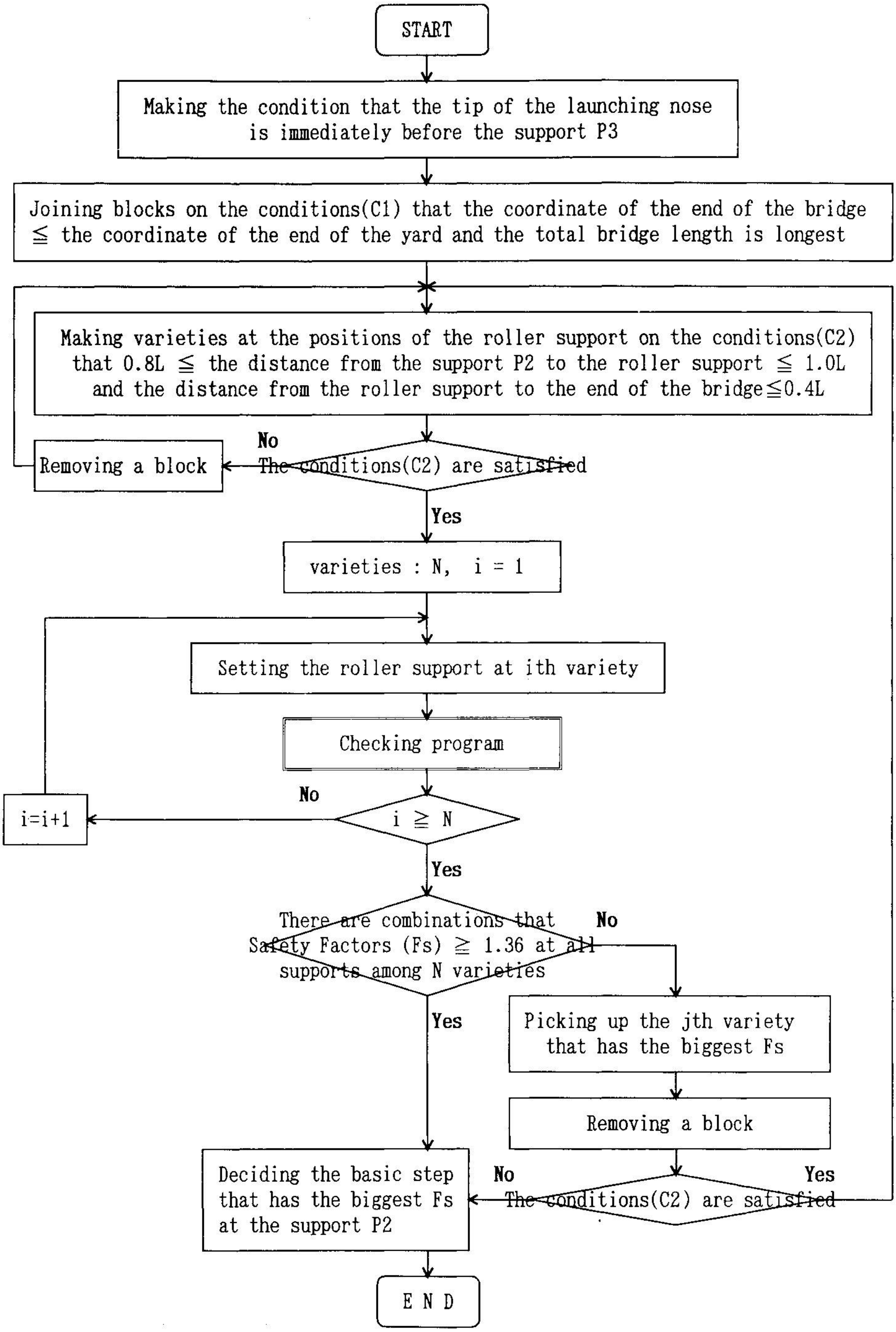


Fig.5 (a) Flow-chart of automatic decision for basic steps

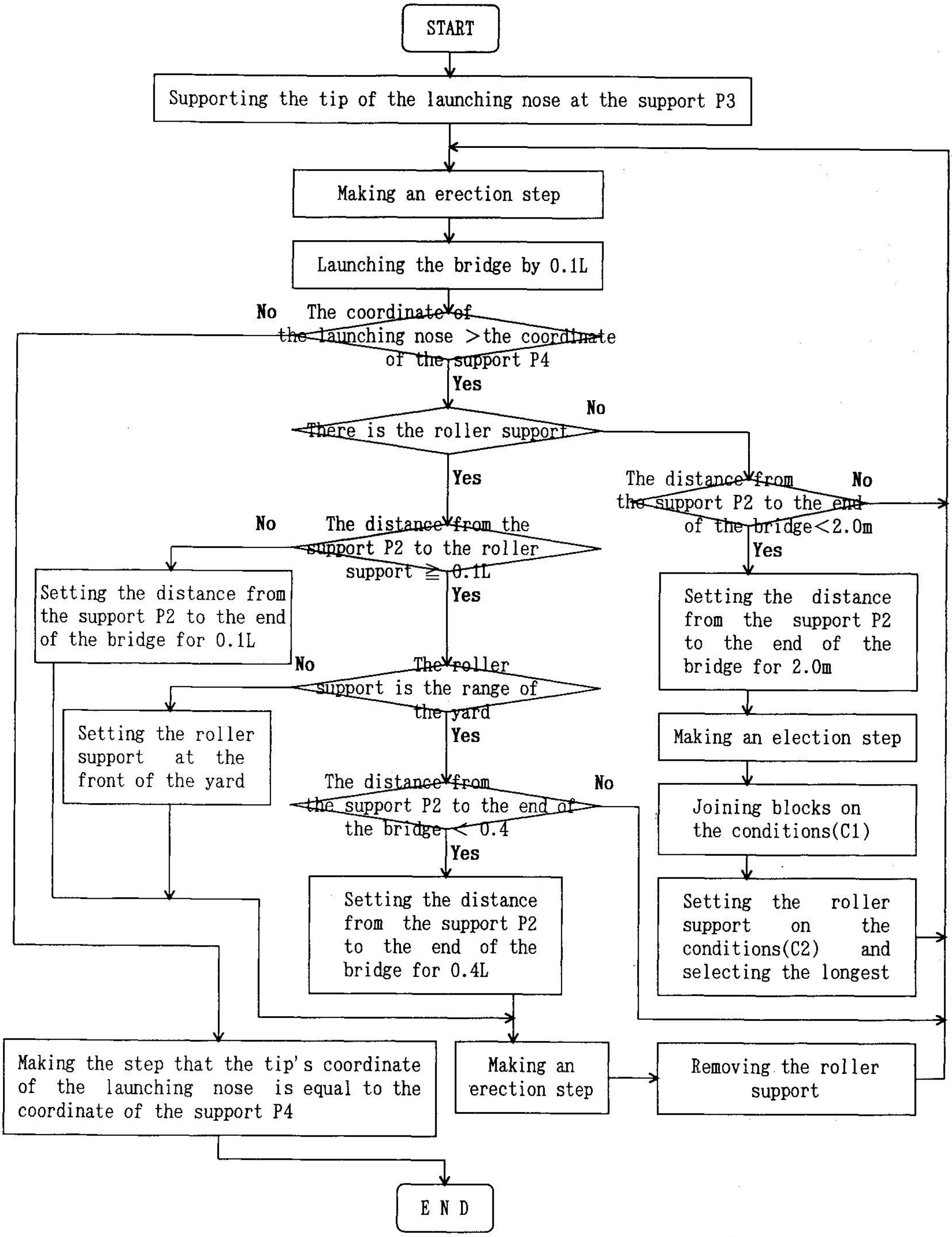


Fig.5 (b) Flow-chart of automatic decision for erection steps except basic steps

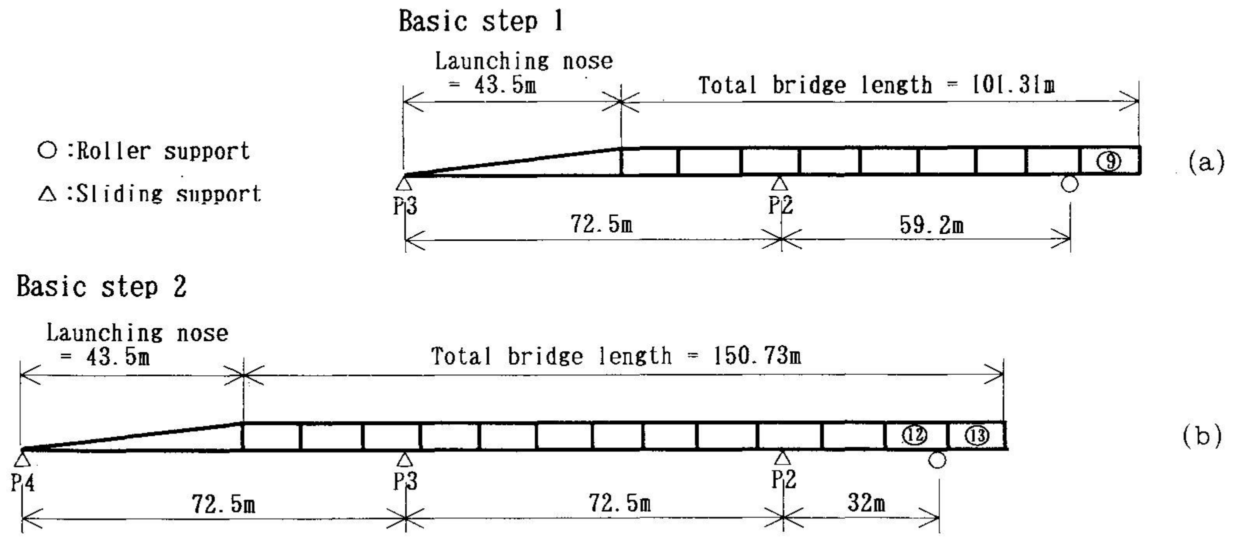


Fig.6 Basic steps in Case 1

Then, the erection steps except the basic steps and the first step are modified to decrease the number of the stiffeners for the web buckling by using the results of buckling analysis. The modification of erection steps ends when the number of stiffeners for the web buckling at the erection steps of the ith variety is less than the number of stiffeners at the erection steps of the (i-1)th variety. The part of knowledge base that is a subroutine uses FORTRAN language because almost production rules can be expressed with the flow-charts in Figs.5(a) and 5(b) by elaborating the procedures of expert designer engineers.

The reaction force of the support before the roller one can be decreased by using a block as a counter weight and increasing the length of cantilever at one end of the bridge. If the first sliding support is jacked up, the safety factor of the web buckling on the second support can increase. On the other hand, if the roller support is jacked up, the safety factor of the web buckling on its forward support can decrease. The reaction force of the first sliding support would be less when the number of spans is odd. Moreover, if the roller support is jacked down, the reaction force of the first support can decrease when the number of spans is even.

5. APPLICATION

Here, the comparisons of the number of stiffeners necessary to avoid web buckling from the obtained proposed knowledge support system and from expert design engineers are done on the two launching erection cases. Case 1 is shown in Fig.4. The erection conditions are as follows: the yard length is 66.7m, blocks are not used as counter weights and the first sliding support P4 and the roller support can be jacked up by 10cm.

Fig.6 shows two basic steps. At the basic step 1, the maximum block number is 9 considering the yard length. The reaction force of the first sliding support is minimum at this position of the roller support by applying the Rule 3. At the basic step 2, the maximum block number is 13. The suitable position of the roller support is on the block number 12 firing the Rule 4.

Table 1 shows the safety factors of the web. It is clear for panels which step's reaction forces that influence the buckling of the web panels can be

Web No.	Coordinates of web(m) Left	Coordinates of web(m) Right	Maximum reaction Coordinates(m)	Maximum reaction Value(tf)	Support point of left side of web Step No.	Support point of left side of web Reaction(tf)	Support point of right side of web Step No.	Support point of right side of web Reaction(tf)	Safety factor Fs
1	42.850	43.762	42.850	58.247	15	55.923	15	55.923	1.38
2	43.762	44.886	44.886	58.560	15	55.923	16	65.710	1.32
3	44.886	46.010	46.010	60.131	15	55.923	16	65.710	1.28
4	46.010	47.133	47.133	61.702	15	55.923	16	65.710	1.24
5	47.133	48.558	48.558	63.694	15	55.923	16	65.710	1.04
6	48.558	49.983	49.983	65.687	15	55.923	16	65.710	1.45
7	49.983	51.408	51.408	67.365	16	65.710	16	65.710	1.41
8	51.408	52.833	52.833	69.040	16	65.710	18	73.936	1.30
9	52.833	54.258	54.258	70.714	16	65.710	18	73.936	1.32
10	54.258	55.683	55.683	72.389	16	65.710	18	73.936	1.28

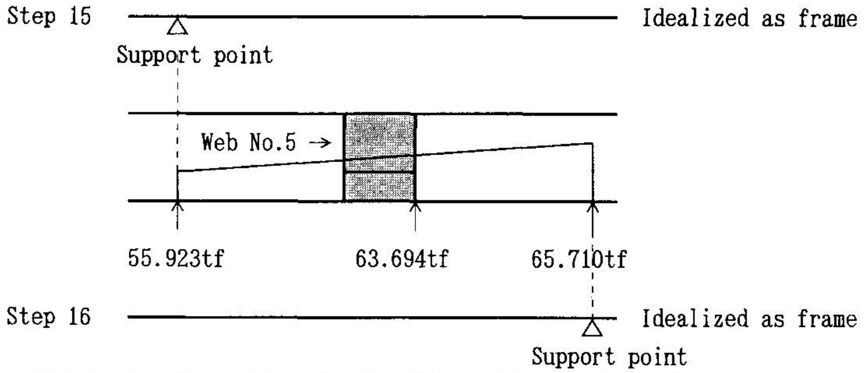


Table 1 Results of checking the web safety

found from this table. For example, at the fifth web, there is no support point in the web. Therefore, the reaction force is calculated to interpolate by using reaction forces outside of both vertical stiffeners, namely, 55.9tf at the step 15 and 65.7tf at the step 16. Although the safety factor of the web is less than 1.36, the factor may be improved by rearranging the position of the roller support and the number of joining blocks on the step 16 according to the rules.

Table 2 shows the number of stiffeners required to avoid web buckling. The number of erection steps is also shown in the table. The number of stiffeners decreases by using the present method even if the heights of the first sliding support and the roller support are not jacked up. The present method can also reduce the number of total erection steps.

Items	An expert planning designer	Present knowledge support system The height of supports: No adjusting	Present knowledge support system The height of supports: Adjusting
Number of stiffeners for the web buckling	44	37	34
Total number of erection steps	36	27	27

Table 2 Number of stiffeners and steps for the web buckling - Case 1

Case 2 is shown in Fig.7. The erection conditions are as follows: the yard length is 130m, blocks are not used as counter weights, and the first sliding support P6 and the roller support can not be adjusted. As shown in Table 3, similar conclusions can be drawn from this example. The present knowledge support system iterates very complicated calculation and many judgments.

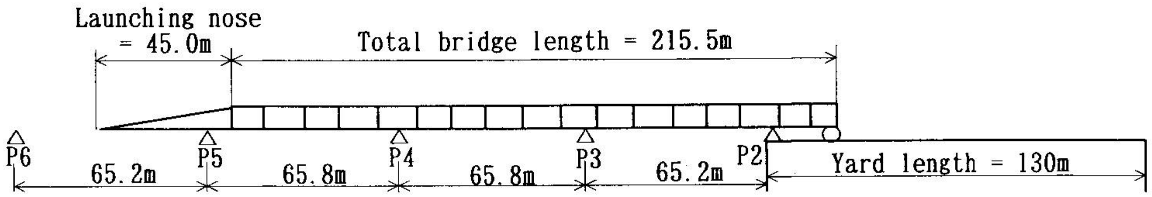


Fig.7 An example of launching erection - Case 2

Items	An expert planning designer	Present knowledge support system The height of supports	
		No adjusting	Adjusting
Number of stiffeners for the web buckling	33	23	—
Total number of erection steps	61	40	—

Table 3 Number of stiffeners and steps for the web buckling - Case 2

6. CONCLUSION

The following main conclusions can be drawn by applying the proposed knowledge approach to the two erection examples.

(1) The proposed knowledge support system including checking program is useful for the actual planning of the launching erection method to steel box girder bridges which requires numerous calculations to assure safety.

(2) Not only the number of horizontal stiffeners required to avoid web buckling, but also the member of total erection steps can be reduced by using the proposed knowledge support system.

(3) Although the weight of all stiffeners to avoid the web buckling at the launching erection is very small compared with the total weight of a bridge, the economy achieved by eliminating the complicated work of attaching horizontal stiffeners is considerable.

REFERENCES

1.Durkee J L., Railway Box-Girder Bridge Erected by Launching. ASCE, ST, No.7/1972.

2.Maher M L., Expert Systems for Civil Engineers - Technology and Application. ASCE, 1987.

3.Maeda K., Nishido T. and Honda S., Study on Reaction Force Control of Launching Erection Method for Steel Bridges by Using Concentrated System. Proc. of JSCE No.415/1990 (in Japanese).

4.Japan Road Association, Specifications for Highway Bridges - Super-structures. 1980.

5.Japan Road Association, Steel Road Bridge Erecting Manual. 1985, (in Japanese).

6.DIN 4114 Blatt 2, Stahlbau, Stabilitätsfälle(Knickung, Kippung, Beulung), Berechnungsgrundlagen, Richtlinien, 1953.