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Construction Control System for Cable-Stayed Bridges

Système pour le contrôle de la construction des ponts haubanés

Baukontrollsystem von Schrägseilbrücken

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SUMMARY

In the case of long-spanned bridges such as cable-stayed bridges, it is very important to fulfil the criteria of construction accuracy both during construction and at completion. In this paper the authors present a new methodology to execute systematically the control of construction accuracy, which consists of measurement, identification, prediction and modification.

RESUME

Dans le cas de ponts de grande portée, par exemple pont haubané, il est très important de respecter le critère de précision au cours de la construction et à l'achèvement des travaux. L'article présente une nouvelle méthodologie permettant d'exécuter systématiquement le contrôle de la précision dans la construction, dépendant de mesure, identification, prédiction et modification.

ZUSAMMENFASSUNG

Für weitgespannte Brücken wie Schrägseilbrücken ist es von grosser Bedeutung, Kriterien der Baugenauigkeit sowohl während des Montagezustandes als auch im Endzustand einzuhalten. In diesem Beitrag ist eine neue Methodologie zur Durchführung der systematischen Kontrolle der Baugenauigkeit dargestellt. Sie setzt sich aus Messung, Identifikation, Vorhersage und Ausführungsänderung zusammen.

1. INTRODUCTION

Bridges are completed through construction processes of designing, fabrication and erection. In those processes many kinds of error arise for various reasons. From the standpoint of treating accuracy control analytically, we need to classify these errors into error factors and resultant errors. The formers are difined as origins of the latters, and reversely the latters are defined as configuration and stress errors in the consequence of the formers.

The authors previously conducted theoretical investigation in relation to the prediction of resultant errors and the identification of error factors [1-3]. The prediction is defined here to obtain what errors of configuration and stress the error factors generate. On the other hand the identification is defined to obtain the error factors included inside the structures from the measured data of resultant errors of configuration and stress at each stage of erection.

In this paper first a new control procedure by combining the identification and the prediction is proposed for keeping construction accuracy of cable-stayed bridges.

Second the method proposed here is compared with the conventional try-and-error method in the actual case of Bannaguro Bridge, which was completed at 1990. The compared results are considerably satisfactory in that these are obtained more rationally and speedily than from the conventional method.

2. METHOD OF CONTROL

Here we present a new method to control construction accuracy by using the flow-chart shown in Fig. 1.

2.1 In process of designing and fabrication

First the designed values of the configuration and stress at each stage of erection are calculated by the backward procedure of structural analysis. But actually the deviations from the designed values arise at each stage of erection. Therefore in designing the deviations should be considerd, but in the convetional method the basis of magnitude of the deviations has not been clarified. Here through the stochastic investigation of various error factors and the analysis of influence of the error factors for the resultant errors, the magnitude of the deviations and the accuracy allowance are decided. Adding to it, the primal error factors are classified among the error factors, and the measurement terms which are needed to identify the primal error factors are selected [2, 3].

2.2 In process of erection

First at each stage of erection we can obtain measured data such as the configurations of girder and tower, the cable tensions, the reactions of pier and bent. The measured data must be corrected considering the temperature. Next from the obtained resultant errors the primal error factors are identified by the least squares method. In this case to use together the resultant errors at the preceeding stages is effective for compensating the shortage of the data and cancelling the measurement errors, and Kalman's filtering theory is applied.

Next from the primal error factors the resultant errors at the succeeding stages are predicted by the stochastic finite element method to grasp what influence the present errors give. If the resultant errors at the present stage

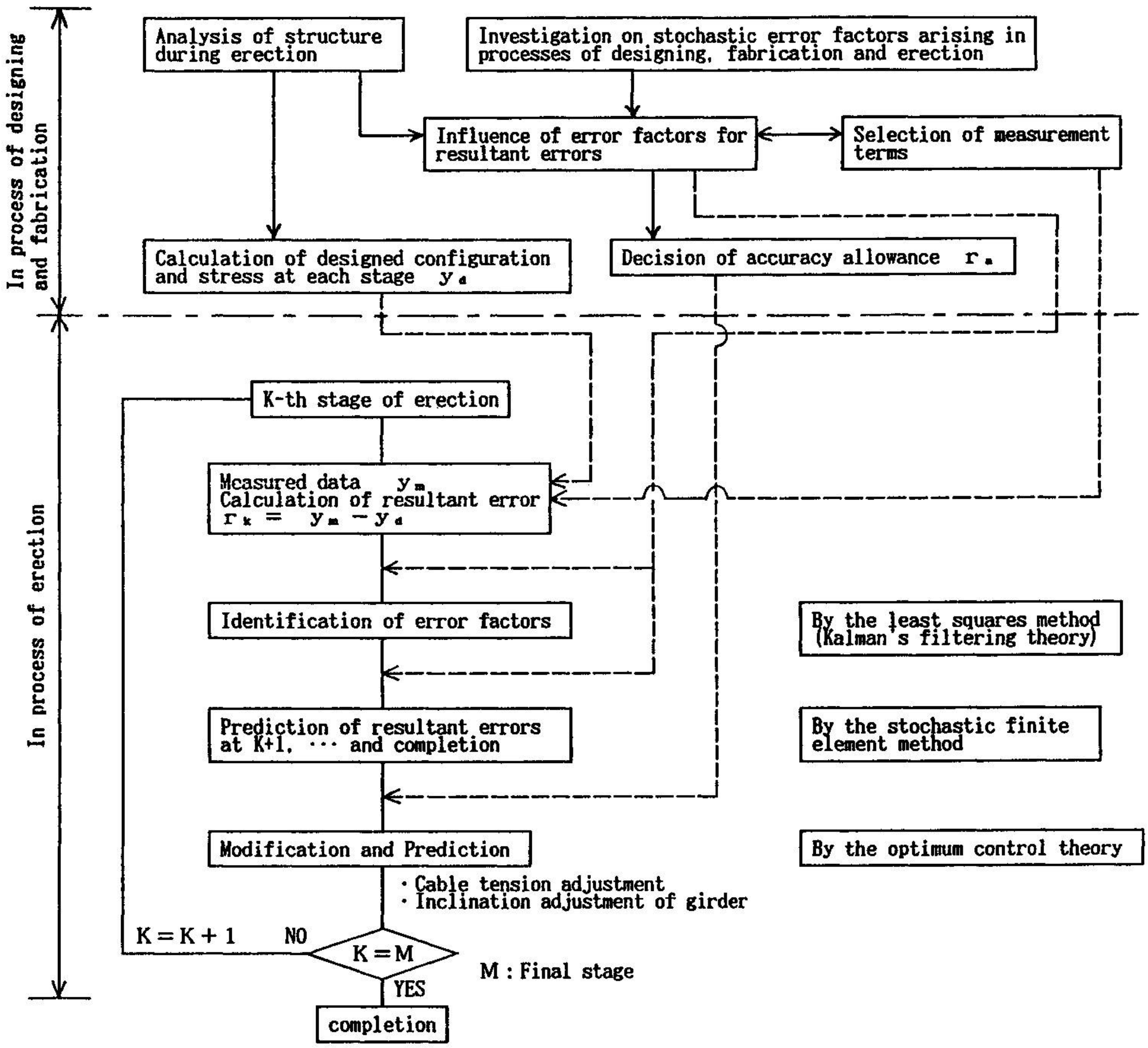


Fig. 1 Flow-chart of method for accuracy control

or the succeeding ones are greater than the allowance, some modification of configuration and stress is needed. For the modification the adjustment of cable tensions or joint inclinations of girder is conducted. In this case the optimum control theory is applied to determine the optimum adjustment for the objective stage.

3. ACTUAL CASE OF BANNAGURO BRIDGE

The method was actually applied to the erection of Bannaguro bridge shown in Fig. 2, which is a two span continuous cable-stayed bridge with single-plane multiple cables. The erection started in May 1988 and finished in December 1989.

3.1 Erection procedure

Frist the side-span was constructed, and the tower was erected with a truck crane on it. Next the construction of the main girder proceeded by the cantilever erection method. One segment was installed with the truck crane and supported by two cables as shown in Fig. 2. This procedure is repeated fundamentally.

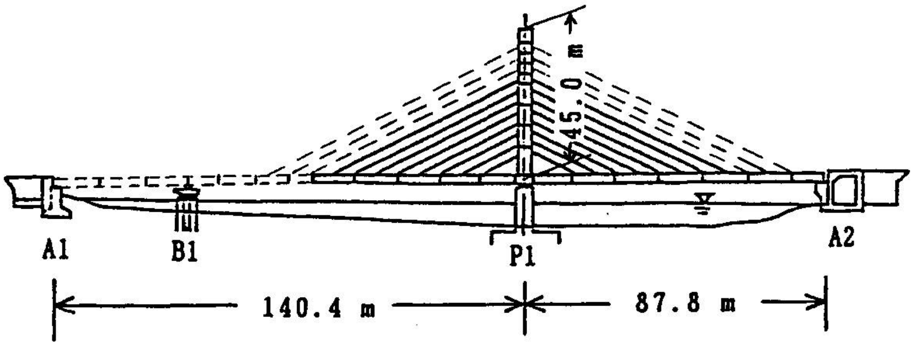


Fig. 2 Erection of Bannaguro Bridge (13th and final stages)

3.2 Results

As an example let us explain the control of construction accuracy after the 13th stage of erection shown in Fig. 2.

Measured data at 13th stage Fig. 3 shows the measured data of configuration and cable tension. From the figure it is found that the values of some cable tensions were 80-100 tons greater than the designed values and the configuration at the cantilever end of the main girder was about 100 mm upper to the designed ones.

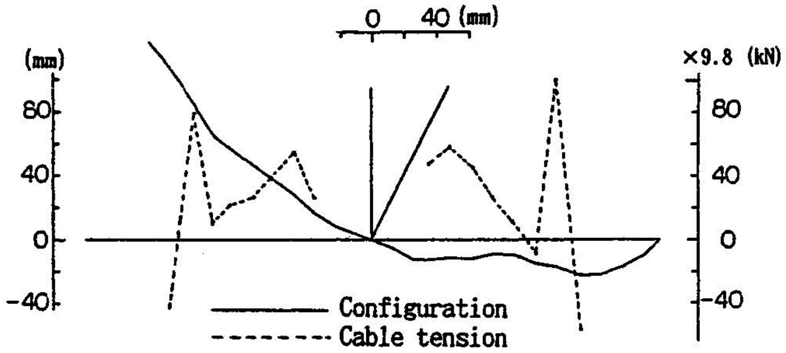


Fig. 3 Measured resultant errors (at 13th stage)

Identification and Prediction From the measured data the primal errors were identified to be the cable lengths and the joint inclinations of the girder shown in Fig. 4. We found that some cables were short and the initial configuration of girder was below the designed values. Next from the results the configuration and the cable tensions at completion were predicted as shown in Fig. 5. Here the error factors at the succeeding stages were considered with some standard deviation. From the figure we grasped that the values of some cable tensions might be greater than the accuracy allowance at completion.

Modification From the predicted results we found some modification of cable tensions is needed to keep the criteria of construction accuracy at completion. Howerer, it was judged that all cables would be still enough safe.

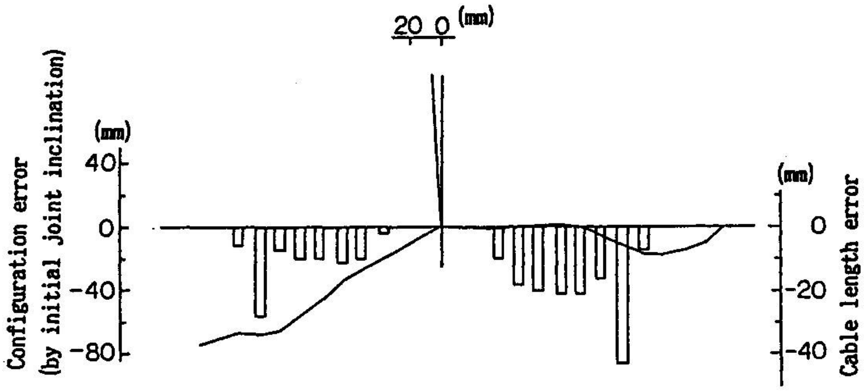
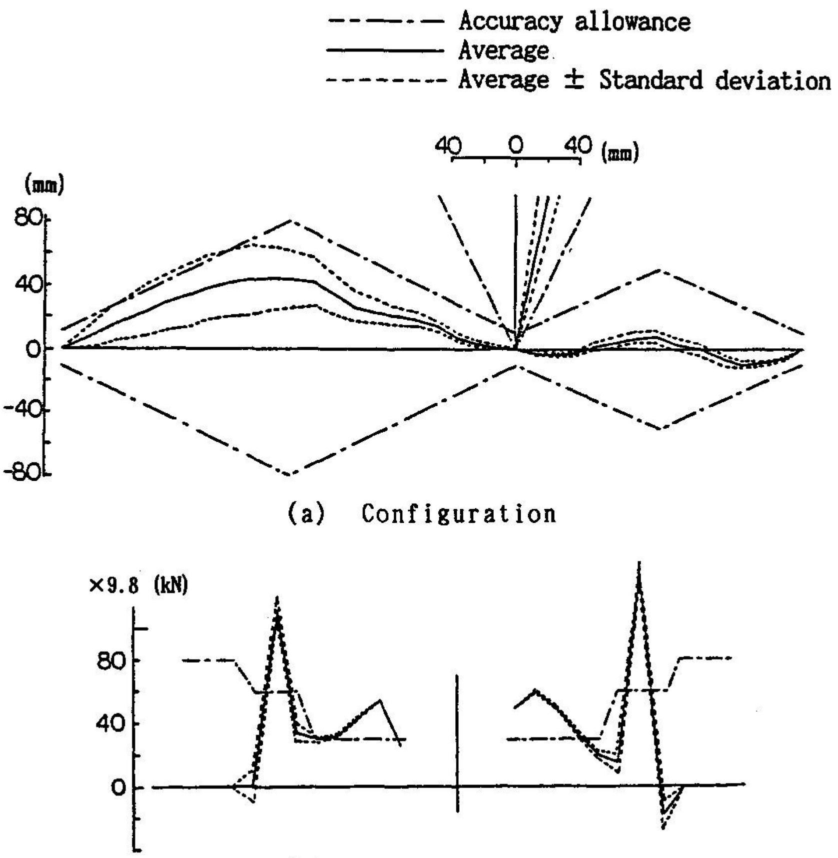


Fig. 4 Identified error factors

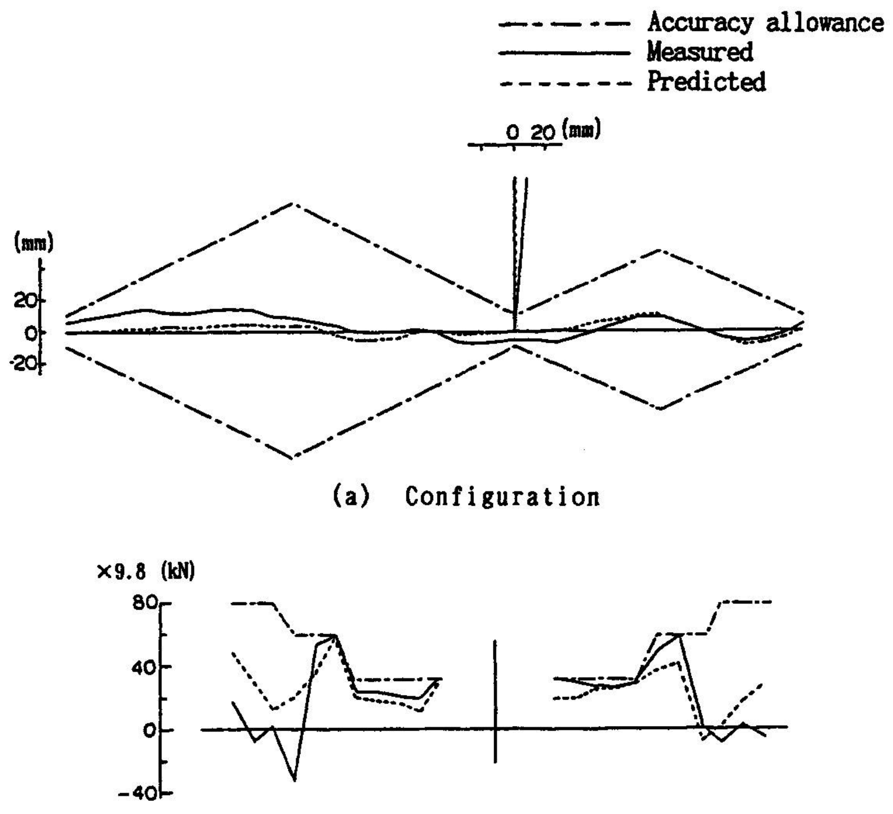


(a) Configuration

(b) Cable tension

Fig. 5 Predicted resultant errors (at completion)

Therefore in actual no modification was conducted at the 13th stage, and after finishing the erection of cables the adjustment of cable tensions was done at the 18th stage, at which the girder reached the bent B1. To determine the adjustment of cable tensions, we applied the optimum control theory. After modification the succeeding girder erection was done to reach the pier A1. Fig. 6 shows the measured and predicted values of configuration and cable tensions at completion. From the figure it can be seen that the resultant errors at completion are within the accuracy allowance, and that the predicted values are almost similar but a little different compared with the measured ones. The difference seems to be caused by the error factors at the girder erection of the succeeding stages.



(a) Configuration

(b) Cable tension

Fig. 6 Resultant errors (at completion)

4. CONCLUSIONS

In this paper the authors presented a new methodology to excute systematically the control of construction accuracy. A routine of measurement, identification, prediction and modification, which is iterated at each stage of erection, is utilized for improving the accuracy of the succeeding stages. The method was applied to the erection of Bannaguro Bridge and compared with the conventional one. The results could be obtained more rationally and speedily than from the conventional method.

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