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A Quality Control Method of Concrete of Tall Composite Pier Construction

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Summary

The steel pipe-concrete composite pier exhibits not only high seismic performance in effect of ductile steel pipes and spiral high strength strands, but also a rapid construction method. In concrete works such as high pier construction, the quality control for the mass concrete is necessary. Especially in the steel pipe-concrete composite pier, it is important to control thermal cracks caused by section characteristics, and the curing is also important after placing concrete, because curing period is very short for rapid construction. As for materials of concrete, usage of low heat cement is effective to reduce the thermal stress due to the temperature rise. In this paper the concept of construction method (Hybrid-Slipform Method), the quality control method and requirements for mass concrete are described.

1. Introduction

The recent lessons of structural damages occurred to the number of bridge substructures during 1995 Earthquake in Kobe make a new bridge construction more expensive and time consuming because of the high standard of earthquake resistant design. The construction of Yamagata Expressway in the northern part of Japan includes Ouami River Bridge (544m) and Koami River Bridge (627m), where the Ouami has two tall piers of 60.5m and 47.5m high, and the Koami has five piers of 37m, 75m, 70.5m, 48.5m, and 36m high. (see Fig. 1, Fig. 2)

Those two bridge piers are required to be built within a reduced schedule in the heavy snow country. Snow closes the site 5 months, and it usually starts in the beginning of December and melt in the end of April. In order to speed up the expressway service earlier, the jobs on the critical path, which means the bridge construction, are needed to reduce the construction period. Additionally, the other issues promote a drastic improvement of pier construction in the both of design and site operation, such as :

- Structural reinforcement to improve the shear strength and ductility against

earthquake shaking

- Safety protection of the site operation at high position
- Reduce the number of skilled labor

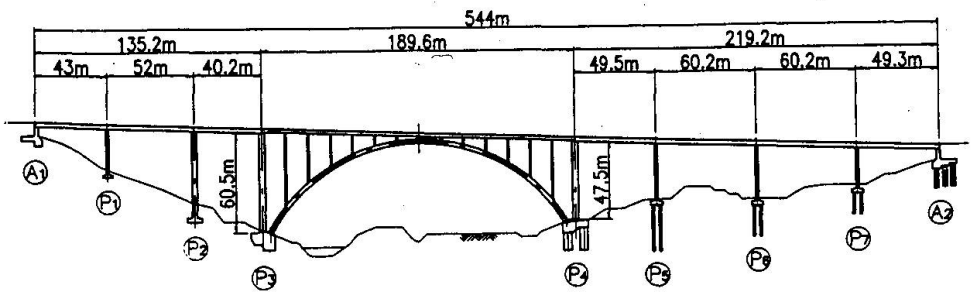


Fig.1 General Plan of Ouami River Bridge

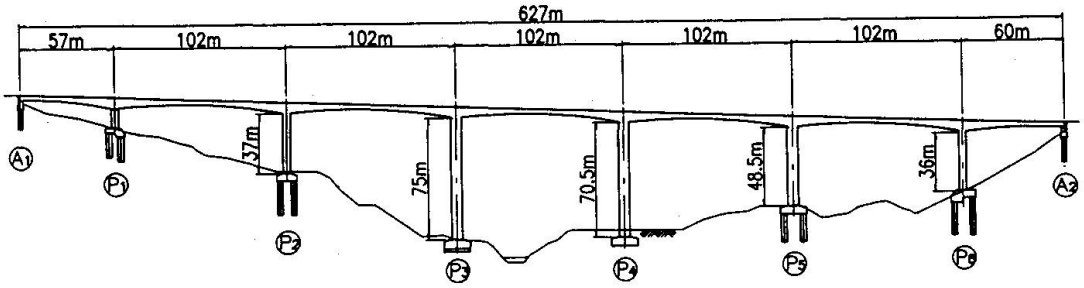


Fig.2 General Plan of Koami River Bridge

2. Concept of Hybrid-Slipform Method

The design of a conventional reinforced concrete pier may be an appropriate solution in terms of material efficiency and cost, while the overall construction cost as well as the construction period may not be optimum. The left hand side of Fig. 3 shows a typical configuration of the conventional hollow type structure, which has one- or two-boxes. The right hand side of Fig. 3 illustrates a typical cross section of the Hybrid- Slipform design, which is a composite structure of the steel pipe and the minimum amount of reinforcement.

A long term social trend in labor market is the shortage of skilled labor and the decrease of annual working hours. This trend enhances the engineering development for a drastic improvement of construction time and labor force required for the bridge construction. The constructor's goal of Hybrid-Slipform method is one half in construction time and one third in labor input compared to the conventional design and jump-form construction. Fig 4 illustrates the equipment and structural arrangements of the new method.

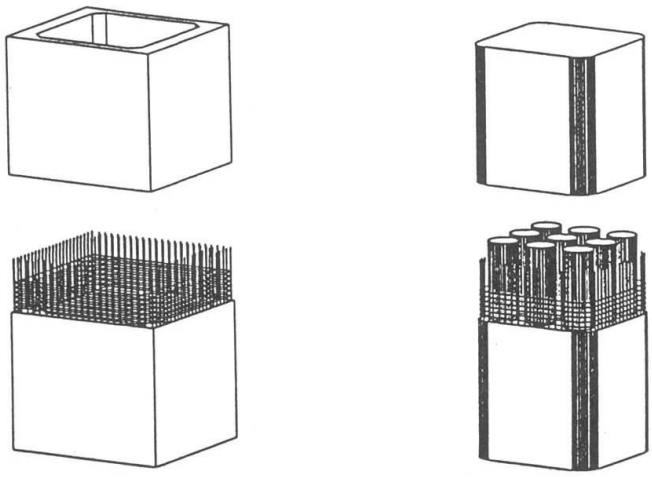
The construction sequence of the method is described in Fig. 5. The first step of construction is the erection of prefabricated segment of steel pipes, which length is about 10m long each. Those erected steel pipes have the structural stability against the wind load until the concrete

is placed. At every 10m of the pipe segment erection, the group of steel pipes is strengthened by bracing, connecting each pipe together. When the erection reached to the pier top, a reaction frame is installed and fastened at the pipe head. The reaction frame supports the vertical slipforming load transmitted through the vertical tension wires made of the standard strands.

The second step follows the assembly of slipform, working decks, scaffold and jacking system(6 center hole jacks). The slipform system has four working decks. The top deck has a loop of rail track where the automated pc strand feeder runs on the track. The main deck is used for the jobs of formwork, re-bar installation, concerning and jack operation. The lower decks are for the removal of Sheet-in-Form and the work of concrete curing. In stead of a sophisticated computer control for jacking system, the manual operation is used to lift the scaffold up 2.7m every day.

Once completed the slipform installation, the highlight of Hybrid-Slipform Method begins with the pier construction by the daily repetition of jobs sequence. The cycle consists of the jack up of the slipform system, the placement of Sheet-in Form, the concrete work, and the re-bar installation. The height of concrete placed by each daily cycle is planned to be 2.7m for this project.(see Fig.6)

The old Sheet-in-Form persists its position and is remained at the old position of concrete placed on the previous day. As soon as the scaffold is settled to the new position, the new Sheet-in-Form is placed for the next concrete pouring. The advantages of utilization of the sheet-in-form are significant : a smooth surface finish of concrete as same as the fixed form, a drastic change of the slipforming procedure from continuous from lifting to at once lifting at any time, a better curing protection to the concrete surface, and more easier positioning of the slipform. (see Fig.7)



A. Conventional B. Hybrid-Slipform Alternative

Fig.3 Structural Concept of Conventional and Hybrid-Slipform Alternative

The horizontal reinforcement of pc strand is spiraled along the vertical reinforcement by using the automated strand feeder. The placement takes one and a half hour by a few workers, which is needed for fastening the strands to the vertical re-bars. When the slipform has reached to the final elevation of pier structure, the working decks and scaffolds are easily lifted down together to the ground by the reversal use of jacking system. During the down ward process, any necessary finishing job for the concrete surface of pier can be done by using the working decks. (see Fig.8)

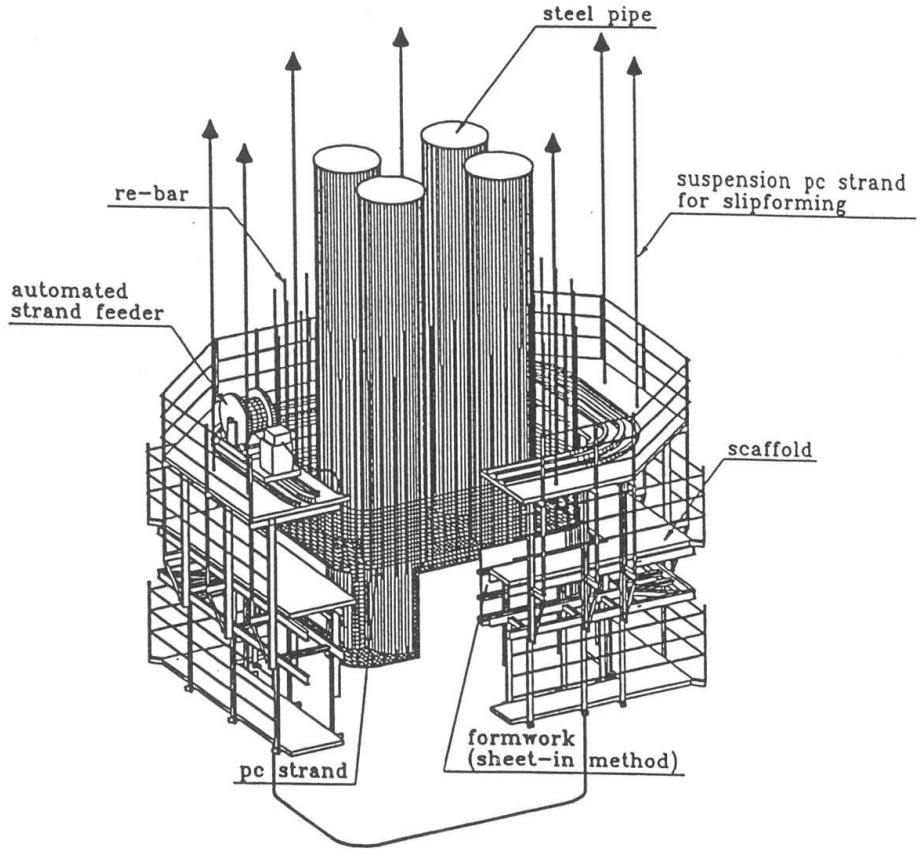


Fig.4 Illustration of Structural System and Equipment of Hybrid-Slipform Method

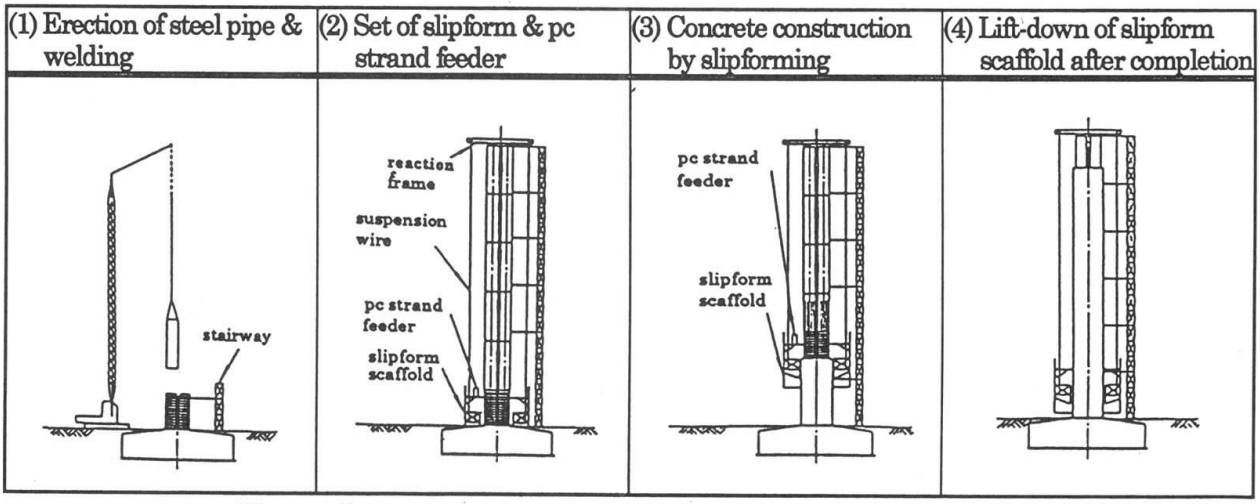


Fig.5 Construction Procedure of Hybrid-Slipform Method

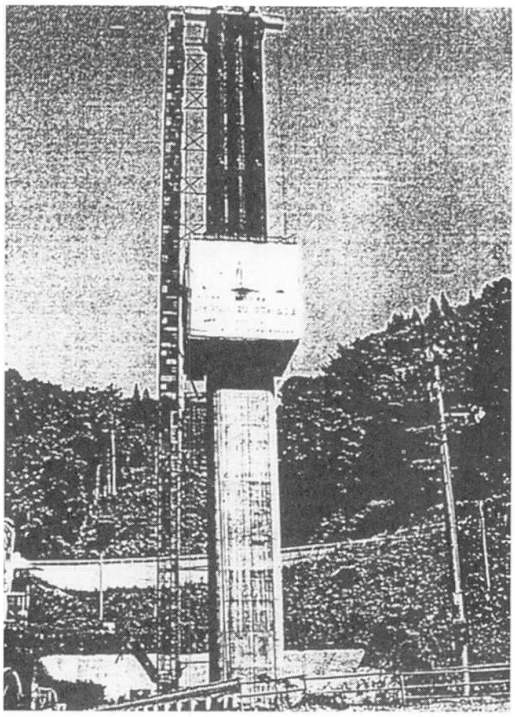


Fig.6 Hybird-Slipform method construction

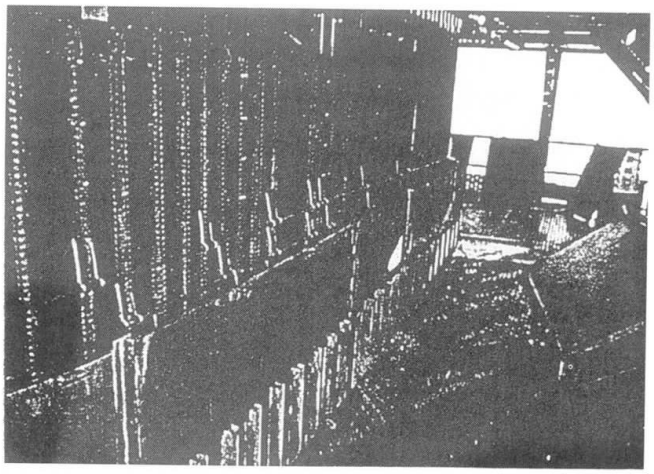


Fig.7 Installation of Sheet-in-form

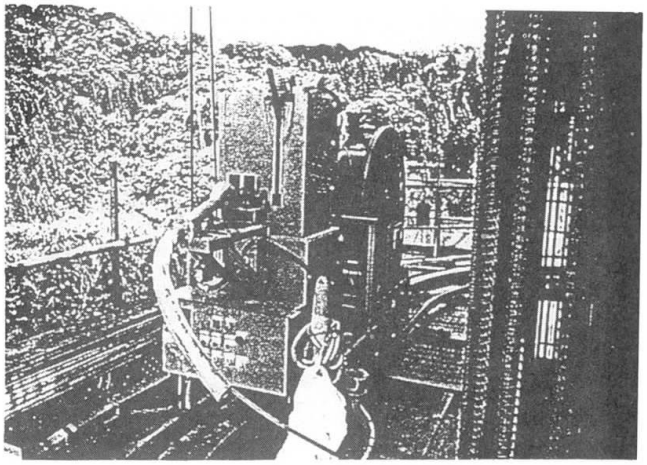


Fig.8 Automated PC strand Feeder

3. Control of cracks by low heat cement

In concrete works such as high pier construction, the quality control for the mass concrete is necessary. Especially in the steel pipe-concrete composite pier, it is important to control thermal cracks caused by structural characteristics i.e. unbalanced section (see Fig.9), temerature difference between surface and core. A possible crack width has been estimated by FEM analysis. The analysis result shows that in the case of using normal portland cement the crack width is possible to exceed allowable width (see Table 1) and usage of low heat cement is effective to reduce the thermal stress due to the temperature rise.

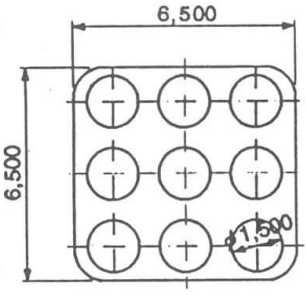


Fig.9 section of composite pier

Table 1 Permisible crack width ωa (mm)

Type of reinforcement	Environmental conditions for corrosion of reinforcement		
	Normal environment	Corrosive environment	Severely corrosive environment
Deformed bars and plain bars	0.005C	0.004C	0.0035C
Prestressing steel	0.004C	–	–

C : concrete cover (in this case = 70mm)

4. Evaluation of concrete strength based on temperature measurement

In Hybrid-Slipform method it is necessary to check the real time concrete strength in an early age for rapid construction. For this purpose the estimation method which is calculated by integrated temperature (maturity) has been used. A temperature of concrete is measured by thermos-sensor. The checked strength of concrete are as follows:

- Concrete strength at the lift up time of slipform
- Concrete strength at the end of curing
- Concrete strength at 91 days (design strength)

Table-2 shows the tolerance of concrete strength for each step.

Table 2 Quality control of concrete

Items	Minimum compressive strength (N/mm^2)	Evaluation method
lift up of slipform	$\sigma \geqq \alpha\ \omega\ h$ α : safety factor (=2.0) ω : unit weight of concrete h : hight for each lift	measurement by thermos-sensor
Removal of forms (end of curing)	ordinary weather 3.5	measurement by thermos-sensor
	cold weather 5.0	
Design strength	30 (in this design)	test on specimens

5. Conclusions

The Hybrid-Slipform method provides an appropriate solution not only for rapid construction, but also for the ductile structural performance suitable for the tall bridge pier particularly in a highly seismic region. In this new construction method it is important to control and check the concrete strength at early ages. The strength evaluation method by temperature measurement using thermos-sensor is available for this purpose. And also low heat cement is quite effective in controling thermal cracks of mass concrete.

References

1) Standard Specification for Design and Construction of concrete Structures, 1996, JSCE