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New Composite Slab System by Large Scale PC Panel Cast in Site

Fabrication locale de plaques composites utilisant
un panneau en béton préfabriqué de grande dimension

Neues Verbundplattensystem aus grossen Betonfertigteilplatten und Ortbeton

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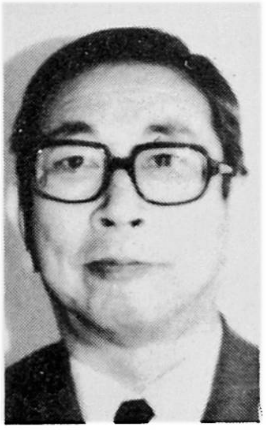

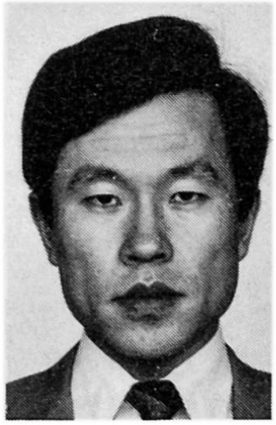

SUMMARY
A new slab system whereby a concrete composite slab is constructed by placing concrete on a large scale PC panel cast on site allows the reduction of the construction period, saves manpower, and reduces the amount of temporary materials used thereby resulting in a great improvement in the economy of the work. This report describes the structural experiments required in order to design the composite slab, the creep of the concrete composite slab, software for making an optimum construction plan for the system and examples and effects of applications on site.

RÉSUMÉ
Un nouveau système de fabrication locale de plaques composites en béton consiste à couler le béton sur un panneau en béton préfabriqué de grande dimension. Ce système permet de diminuer le délai des travaux, d'économiser la main d'oeuvre et de réduire la quantité des matériaux provisoires. Il en résulte d'importantes améliorations en terme d'économie de travail. Ce compte-rendu décrit les expériences nécessaires à la mise au point de la plaque de béton, les caractéristiques de fluage, le logiciel permettant de réaliser une construction optimale du système ainsi que des exemples et des possibilités d'application concrètes.

ZUSAMMENFASSUNG
Ein neues System, bei dem eine Betonverbundplatte vor Ort hergestellt wird, indem Beton auf eine Grossplatte aus Betonfertigteilen gegossen wird, ermöglicht eine Verkürzung der Bauzeit, hilft Arbeitskräfte sparen und verringert den Aufwand an eingesetztem Baugerät und führt so zu einer wesentlich verbesserten Wirtschaftlichkeit bei der Arbeit. Dieser Bericht beschreibt die bautechnischen Versuche, die für den Entwurf der Betonplatten erforderlich sind, die Dehnung der Betonverbundplatten, die Software zur Erstellung eines optimalen Systembauplans sowie Anwendungsbeispiele und Erfahrungen auf der Baustelle.

1. INTRODUCTION

Large scale constructions are increasing in Japan but skilled laborers are in short supply and construction periods are shortened. Therefore, the development of advanced and reasonable technologies for construction work is an urgent theme. The authors have developed a new slab system (a precast and in-situ placed concrete composite slab system, PICOS System) and applied it to buildings on the premise that the system of formed slabs and computer aided engineering (CAE) is the key technology for increasing the economy of construction work.

2. OUTLINE OF THE PICOS SYSTEM

The main features of the PICOS System are as follows:
1) The large scale precast concrete panels are approximately the size of a grid surrounded by girders on four sides and are more than 70mm thick.
2) The precast concrete is cast on a horizontal concrete bed in-situ and is manufactured at the rate of one panel per day by multi-layer casting.
3) The precast concrete panel is combined with in-situ placed concrete by shear keys on each side in several lines. PICOS resists load as a composite structure and is designed as two-way slabs. The shear keys are 80mm square and have a depth of 8mm.
4) The PICOS System has a CAE sub-system as a useful tool for calculation, graphics and drafting to design the optimum conditions for construction planning. This results in economy.

3. EXPERIMENTAL RESEARCH

The following research and development work was performed in order to establish the standard specifications for the design and construction of the PICOS System.

3.1 STRUCTURAL EXPERIMENT

The following experiments were carried out in order to investigate the transfer mechanism of horizontal shearing force at an interface between precast concrete and in-situ placed concrete.

3.1.1 Bearing and Shearing Strength

Shallow and concave shear keys are made on the surface of the PC panel in place of protruding reinforced trusses in order to form a concrete composite slab.
Experiments are carried out to study the effect of the shallow and concave shear keys in transferring the shearing force occurring at the interface between the PC panel and the in-situ placed concrete. A release agent is applied over the total surface of the PC panel in order to release it from the bond strength and

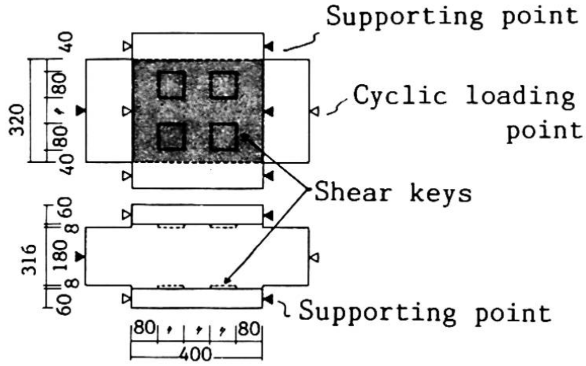

Fig.1 Shear key specimen for bearing and shearing test.

Shape of the shear key (mm)	Depth	30	4	8	30
	Width	80×80	80×80	80×80	80×80
Pieces of keys		2	8	8	2
PC panel surface finish		Finish by steel trowel Release agent applied			Finish by wood trowel
Condition at failure		Shear failure	Bearing failure		Shear failure
Maximum load (N)		76.5	72.5	141	642
Effective area (cm^2)		128	25.6	51.2	2560
Stress (MPa)		5.65	28.4	27.6	2.50

Table 1 Details of the experimental results.

to clear the shear key effect. The loading method applied is alternative loading. The structural specimen is shown in Figure 1 and the details of the experiments and the experimental results are shown in Table 1.
The experimental results allow us to design the size and number of shear keys. The bond strength is regarded as reserve strength.

3.1.2 Flexural and Shearing Strength
Short-term loading experiments are carried out in order to study the strength, deformation capacity and failure conditions of the composite slab. The results are studied by comparing them with those of a monolithic slab. A release agent is applied to the surface in order to clear the effect of the shear keys and also assume the case where there is no bond strength between the joint surface after a long period of time.
The effective span is shortened by assuming a case where large shearing force is applied. The loading method applied is 2-point line loading.
The structural specimens are shown in Figure 2 and the details of the experiments and the experimental results are shown in Table 2 and Figure 3. The experimental results prove that the shear keys to be made on the surface of the PC panel allow the construction of a composite slab with strength nearly equal to that of a monolithic slab.

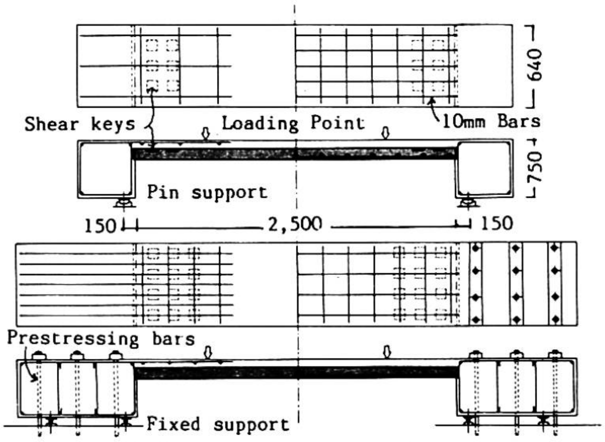

Fig.2 Slab specimen for flexural and shearing test.

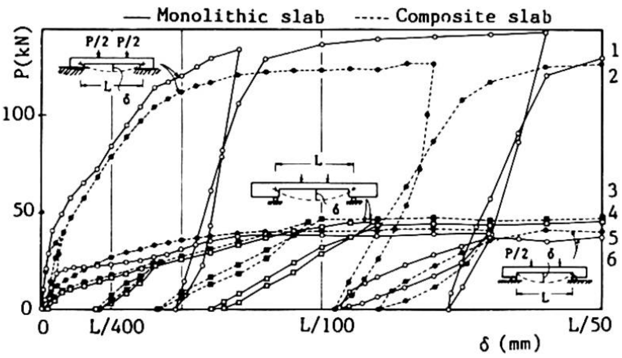

Fig.3 Load-deflection curves

Slab specimen	Effective span (L:mm)	Maximum load (N)	Fig.3
Monolithic slab	2,500	39.3	6
Composite slab(A)	(pin supports)	42.6	5
Monolithic slab	2,500	145	1
Composite slab(Ā)	(Fix supports)	127	2
Monolithic slab	4,500	38.3	4
Composite slab	(Pin supports)	40.5	3

(A): The surface of PC panel was finished by steel trovel and applied release agent.

Table 2 Details of the experimental results.

3.1.3 Creep Behavior
Long-term loading experiments are carried out in order to study the creep behavior of the composite slab and the long-term reliability of the shear keys.
The results are studied by comparing them with those of a monolithic slab. The loading method applied is uniformly distributed loading.
The specimens and loading method are shown in Figure 4 and the details of

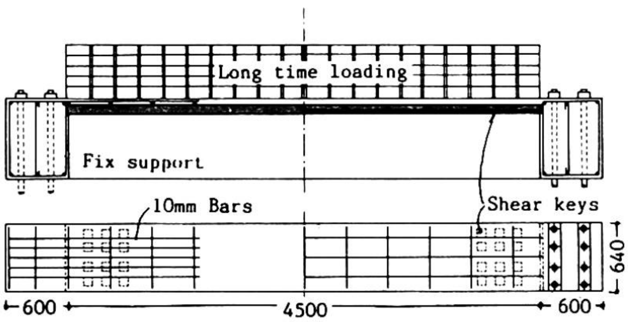

Fig.4 Slab specimen for long-term loading test.

the experiments and the experimental results are shown in Table 3 and Figure 5.
The experimental results show that the composite slab behaves similarly to a monolithic slab until the joint surfaces are completely separated and that no large deflection appears even if the separation proceeds.

Slab specimen	Effective span (mm)	Deflection (mm)		
		Loading	1Year	Ratio
Monolithic slab	4,500 (Fix supports)	1.70	14.4	8.47
Composite slab(B)		2.70	24.0	8.89
Composite slab		1.82	11.5	6.31

(B) : The surface of PC panel was finished by steel trowel and applied release agent

Table 3 Details of the experimental results.

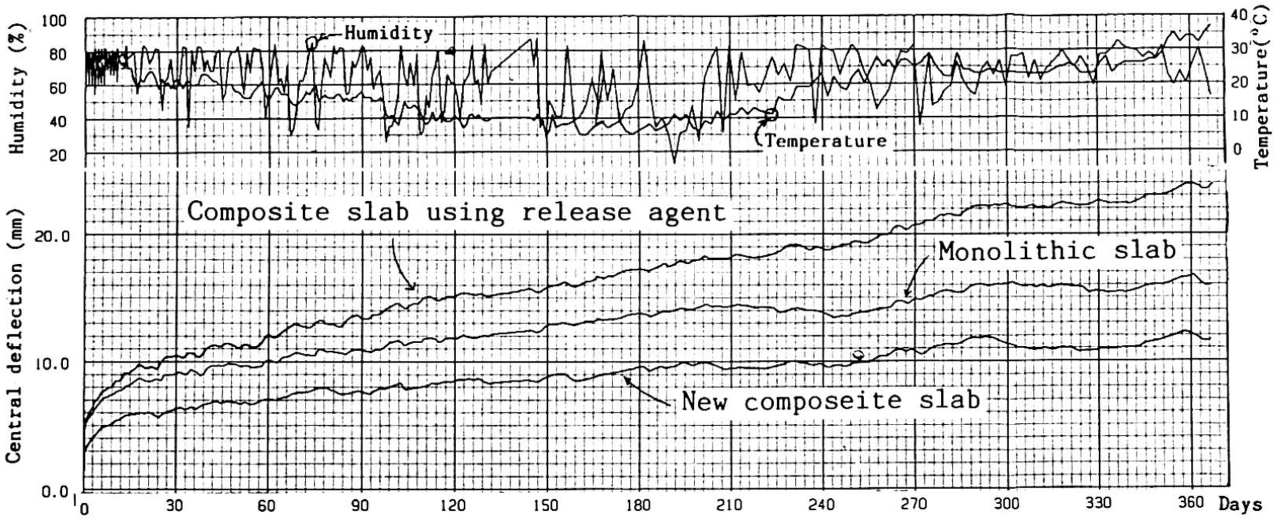

Fig.5 Changes in the central deffection of slabs by long-term loading test.

3.1.4 Drying Shrinkage

It is expected that the in-situ concrete may crack after a long term when concrete is cast in-situ on a PC panel because of the differences in dry shrinkage between the two. Experiments are carried out by changing such conditions as the thickness of the PC panel and the in-situ placed concrete, the composing period and the number of reinforcing bars.
The test results nearly agree with the corresponding values calculated by CEB/FIP. It is understood that no cracking occurs if the PC panel or the in-situ placed concrete is 50mm or more thick.

3.2 CAE SUB-SYSTEM

The logistics of minimizing manpower, temporary materials and other resources for prefabrication and erection in-situ were studied for the CAE sub-system of the PICOS System.
The logistics were based on the following ideas:
1) A crew composed of a fixed number of people repeats the same work every day.
2) Temporary materials and machines are reduced to as small a number as possible. Concrete for constructing the composite slab is cast directly from a truck mixer. Therefore, the total height of the composite slab cast by multi-layer casting is limited. The number of beds used for manufacturing PC panels is reduced to as few as possible.
3) The schedule for manufacturing PC panels is decided based on such conditions as the sequence of lifting the PC panels, the concrete strength appearance, the number of PC panel and the number of blocking construct areas.
4) The PC panel drawing is made by CAD. Some examples of the output from the CAE sub-system are shown in Figures 6, 7, and 8.

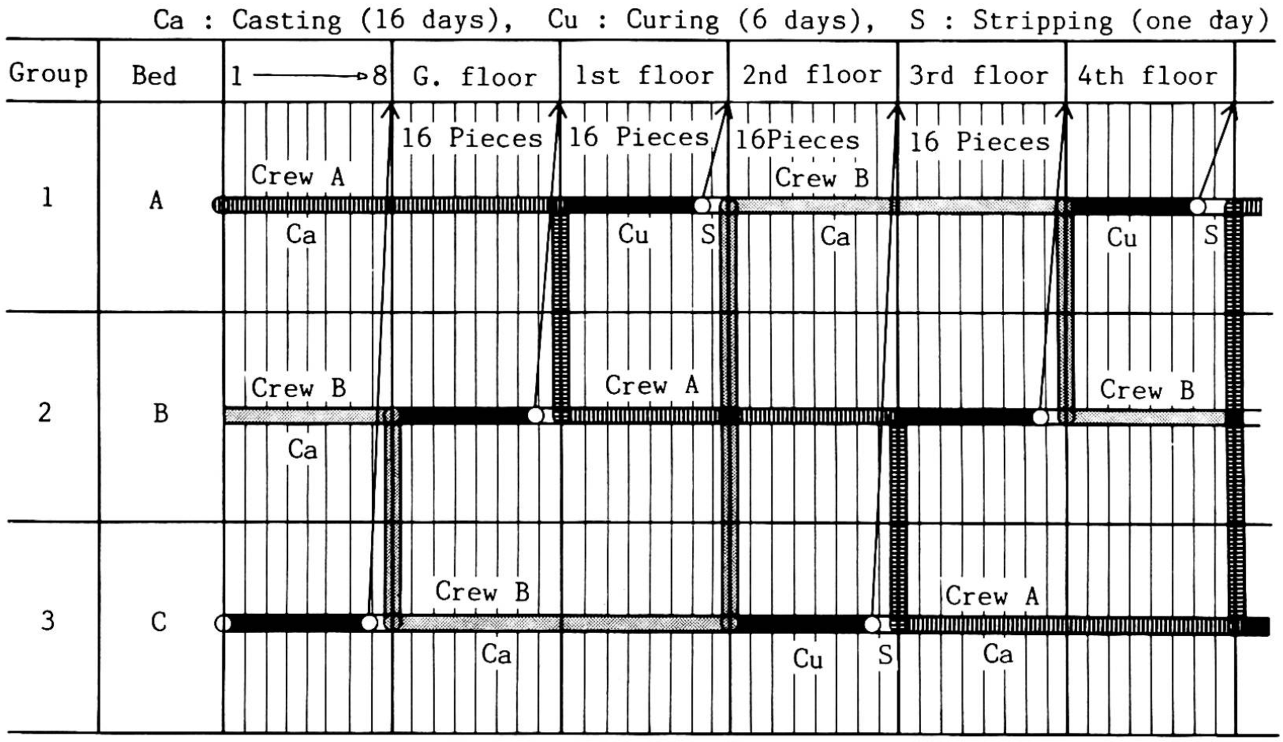

Fig.6 The crew balance chart for multi-layer casting in site.

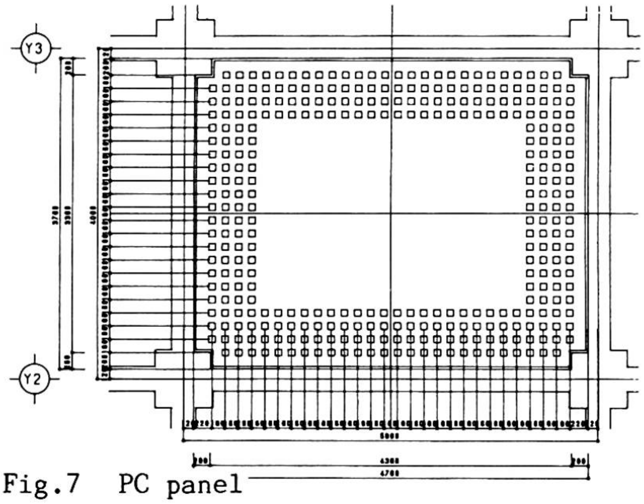

Fig.7 PC panel

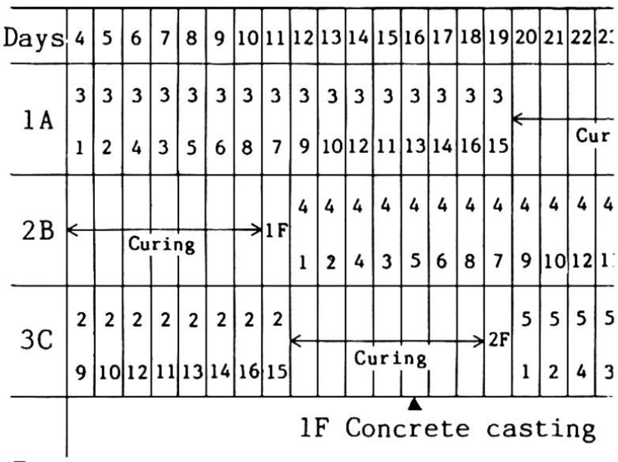

Fig.8 The manufacturing schedule

4. APPLICATIONS

4.1 APPLICATION EXAMPLE

The site plan of the D Building site is shown in Figure 9. The D Building Site is intended for the construction of a multiple dwelling house eight storeys tall. There are 16 slabs per floor and the construction period is eight days per floor. One blocking construct area is taken. The CAE subsystem calculates that the number of

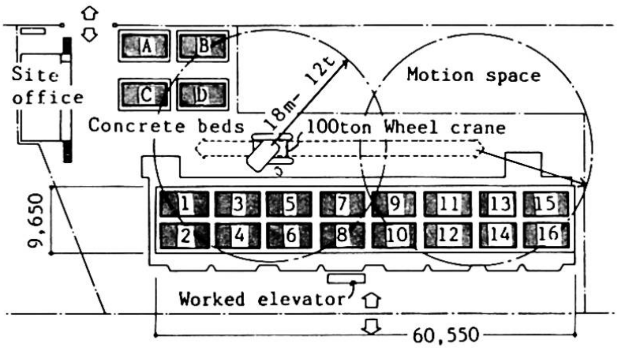

Fig.9 The site planning

beds required is three, the number of days for constructing the PC panels is 64, and the total number of workers is 256. In the actual work, the number of beds used is four , the number of days for constructing the PC panels is 56, and the total number of workers is 292.

4.2 MEASUREMENT OF WORKING HOURS

The results of the measured working hours for manufacturing PC panels at the D Building site are shown in Figure 10. The results of the average measured working hours for the A, B, C, and D Building sites are shown in Figure 11. The system is improved every time it is applied to construction and the skill of the workers is also improved. As a result, the quantity of work is now about eight worker-hours per PC panel and thus the economy is greatly improved.

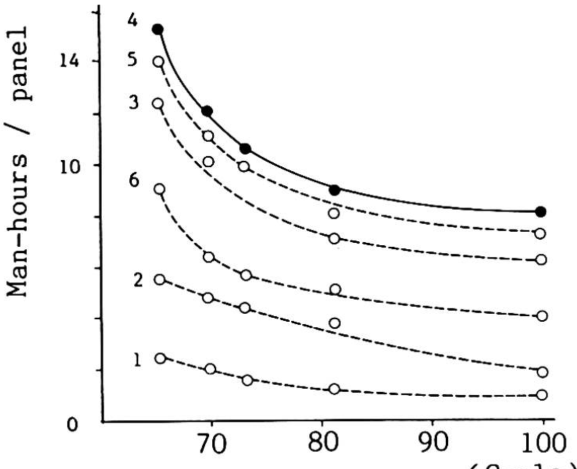

Fig.10 Man-hours (D Building Site)

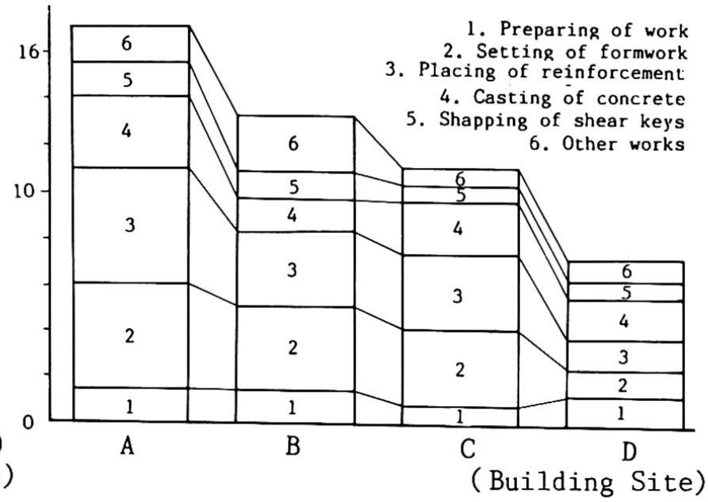

Fig.11 Total man-hours per panel

5. CONCLUSION

The PICOS System is now popular in Japan and has been applied to many construction buildings in a relatively short time. The PICOS System makes it possible to complete construction work satisfactorily and successsfully in a shorter period and thereby to save manpower and conserve materials.

The effects of the PICOS System on the economy of the construction work were examined in-situ as follows:

1) The labor productivity ratio of PICOS to the traditional method was 2 to 1. PICOS required repetitive and unskilled labor and had a more effective learning curve than did the traditional method.

2) The site management productivity ratio of PICOS to the traditional method was approximately 3 to 2.

3) The construction period required for PICOS was approximately half as long as that for the traditional method.

4) The weight of the temporary materials required by PICOS was one-eighth that of the weight required by the traditional method.

5) PICOS excelled the traditional method in terms of accurecy of concrete strength , thickness of slab, placement of the reinforcing bars and smooth-faced ceilings.

6) The PICOS System can be of great use for the systematization of construction methods, that is for the separated horizontal-and-vertical construction system, for the blocking construct area method, etc.