Production and Examination of Prestress loss of Precast Prestressed Concrete Bridge Girder Using Self-Compacting Concrete in Cambodia

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ABSTRACT: Cambodia post civil war has demanded immediate rehabilitation of infrastructure including hundreds of bridges and road network for revival and development of economy. To make it possible to produce required human resources and technology domestically in Cambodia, Kochi University of Technology (KUT), Japan and Institute of Technology of Cambodia (ITC), Cambodia have established collaboration to implement "Integrated System for Human Resources and technology Development in Cambodia". Under this collaboration, the authors have developed a design method and shapes of the PC girder which are appropriate for the Cambodian local situation. Further, a PC girder specimen of 20 m span using SCC was produced in Phnom Penh, Cambodia in April 2006. The success of the specimen production has shown the possibility of mass production of high strength PC girder in Cambodia to achieve quick rehabilitation of the existing bridges as well as development of new infrastructures. This paper provides the design method, imported and local materials used for producing SCC, required quality and cost management method, design mix proportion and creep measurement methods used for production of the PC girder in Cambodia.

KEYWORDS: Prestressed Concrete, Precast , Prestress loss

1. INTRODUCTION

A large part of infrastructure including road network had been damaged by the civil war in Cambodia for about 20 years from 1970 to late 1980s. Some bridges which avoided destruction in the war had been remained without enough maintenance for a long period. After Paris peaces deal in 1991, a lot of bridge collapse have been reported which were caused by the overloading and increase of traffic. In Cambodia, for recovery of the economy and the development of traffic networks, it is required for immediate maintenance of traffic networks and rehabilitation of bridges. Over 20,000 small bridges with 15m to 20m span length are needed to rehabilitate in Cambodia.

2. REHABILITATION PLAN OF CAMBODIA

2.1 Integrated system for human resources and technology development

Niraula, R. 2005 argued that it is important to bring up a local engineer necessary for autonomous development of a developing country and has proposed an "Integrated system for human resources and technology development". In this study, it was proposed to establish NPO (Non Profit Organization) in university of developing countries, and to carry out the following with a fee. "Education and supply of human resources who are necessary for construction and maintenance of infrastructure in a developing country", "Production and supply of material" and " Technological assistance". Autonomous technical establishment of continuation of a developing countries are brought by this project incorporating above-mentioned duties was designed for the development of appropriate technology and human resources in autonomous entity at university of developing countries. In the future, various construction companies become independent from a part of NPO and enlarge the field of local construction industry. A conception diagram of this study is shown in Fig.1. Rajendra Niraula and authors have already started preparations to establish NPO in Institute technology of Cambodia.

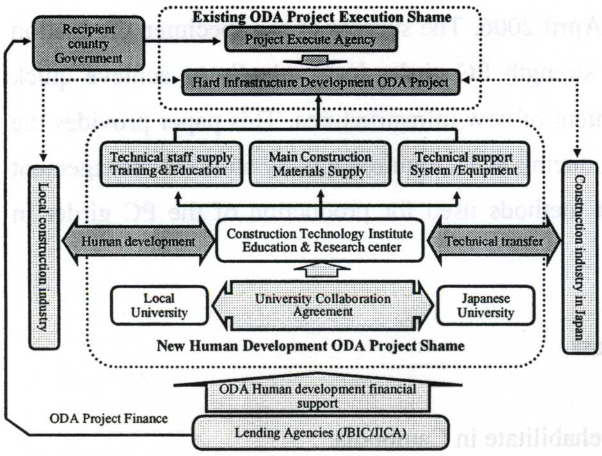

Fig.1 Integrated system for human resources and infrastructures development in Cambodia

2.2 Rehabilitation of bridges by PC girder

For immediate construction of traffic networks with low cost, it is extremely important to build up a system as shown in Fig.1 and design standards which shall be carried out by local engineers and incorporating their own techniques. Although Cambodian design standards have already been built up under the Australian ODA scheme, it is still not suitable for local conditions. Therefore, authors have proposed design methods which are suitable for local condition in Cambodia. At first, we explain about Cambodian situation and then, explain about design methods in this chapter.

2.2.1 Traffic in Cambodia

After Paris peaces deal in 1991, there were many bridges collapsed due to the overloading and increase of traffic. Therefore, Sub-decree on Maximum Weight of Transport Vehicles Circulating on National Roads was enforced from Ministry of Public Works and Transport (MPWT) for dangerous prevention from overloading of the truck in September, 1999. But after the traffic law, the overloaded trucks still have be causing damage on many roads and bridges. There is less traffic volume of most roads in Cambodia comparing with the traffic in the industrial area of developed countries. In other words, the characteristic of traffic load in Cambodia is large traffic load by overloaded trucks and little traffic volume.

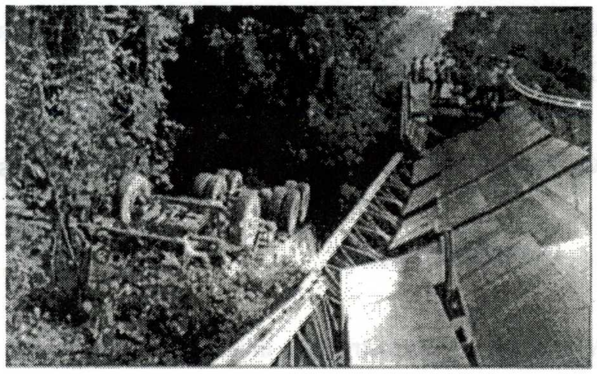

Fig.2 the collapse of a bridge on the road from Siem Reap to Bantey Srey temple on April 10, 2004

2.2.2 Climate in Cambodia

Cambodia belongs to the tropical monsoon climate that is high temperature and humidity. One year is divided into wet and dry season, and wet season is from the end of May to the end of October. In wet season, it does not continue to rain all the time for 24 hours either. There is a strong squall of one or two hours every day at about the same time. It does not rain from the beginning of November to the middle of May in dry season. Annual average temperature is 27.6 degrees Celsius and it is the hottest in April just before beginning of wet season throughout the year.

2.2.3 Pretension PC girder

Most of bridges in Cambodia were built by conventional reinforced concrete (RC) with multi-short span of about 5m for each span as shown in Fig.3, and steel bridges are shown in Fig 4.

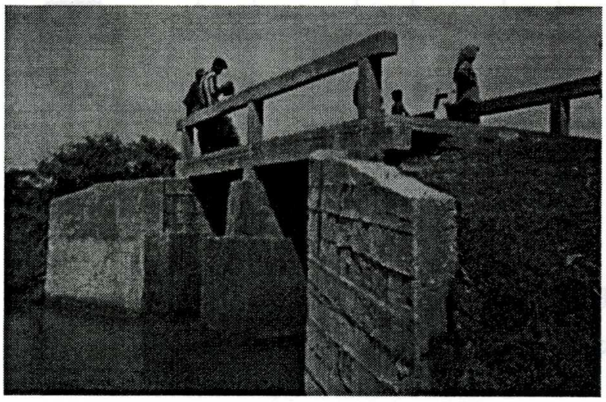

Fig.3 Reinforced concrete bridge

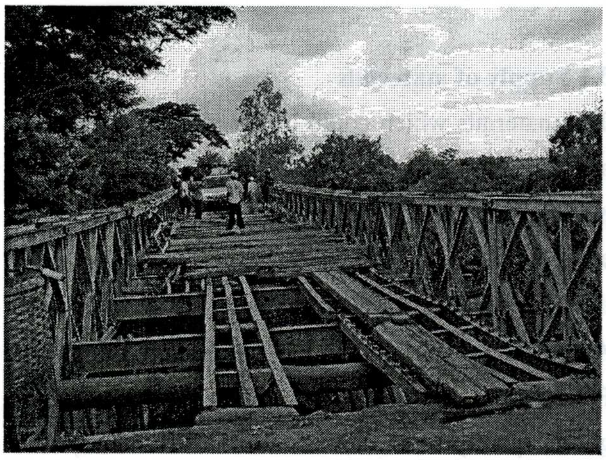

Fig.4 Steel bridge

Steel bridges and timber bridges can be easily constructed and took short time, but the bridges were damaged after about 5 years due to insufficient maintenance. Good quality of steel bridges are cost expensive because all construction materials have to be imported (there is no local production of steel) and it requires the good quality of painting for the long term protection against corrosion. Bridges made by reinforced concrete require little maintenance from compared to steel bridges. But it has been observed that RC bridge took long time for the construction work and a lot of materials were used. As to this problem, it can be solved by making a bridge member the pre-cast. PC girder is more dominant than steel bridges and RC bridges considering the life cycle cost for the durability, maintenance, and repair. Furthermore, PC girder is suitable for the Cambodian situation which is lacking deficiency of skilled workers.

On the other hand, it is necessary to extend a section to assume a span the bridge which can cope to around 20m, and increased weight. And to solve lack of skilled workers and to improve the durability, PC girder made of high strength concrete using Self-Compacting Concrete (SCC) is the most suitable.

Standard girders using in developed countries such as Japan, the weight of 20m of girder is about 20tons. However, it is difficult to use in Cambodia because of existing conditions of transportation (roads and bridges). The weight of precast girder is limited to 12tons for the present time due to the conditions of existing roads and bridges for transporting the girder for construction.

2.2.4 Proposed design standards

For a condition explained in previous chapter, authors proposed design methods and standard shape of PC girder which is suitable for local situations in Cambodia. This design method considered live load, prestress loss by creep and shrinkage in Cambodia and adopted live load of "The Specification for Highway Bridge in Japan". They consider 2 situations. One is B live load which assumes the situation with many run frequency of a large-sized car. The other is A live load which assumes the situation with few run frequency of a large-sized car.

Each of A and B live loads were divided into T load which is "concentric load" and L load which is "distributed load". T load and L load is the load which considered influence by a span of a bridge. T load and L load are shown in Fig.5 and Fig.6.

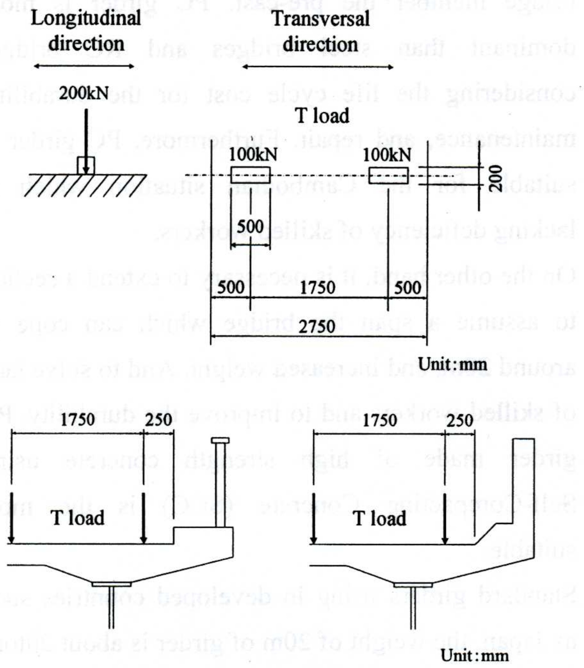

Fig.5 T load

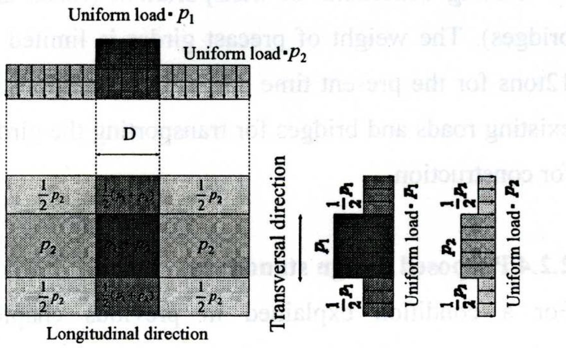

Fig.6 L load

To consider temperature and relative humidity, creep and shrinkage model adopted CEB-FIP90 model. Mean temperature in Cambodia is higher than under climate in European developed countries. Therefore, prestress loss by creep and shrinkage increases in Cambodian climate.

Proposed PC girder of shape for Cambodian standard is prestressd concrete of pretension type. To produce PC girder with rational shape, some PC strands were controlled bond at the end parts of girder. The position of PC strands in section and bond control length are shown in Fig.7.

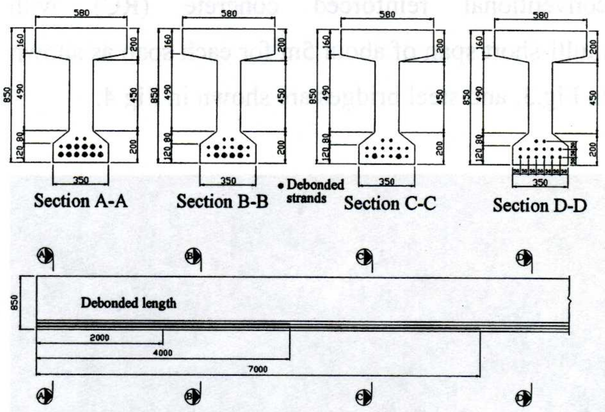

Fig.7 Position of PC strands in section and bond control length

3. PRODUCTION OF REAL SIZE PC GIRDER IN CAMBODIA

3.1 Supply of materials

The materials which could be supplied in Cambodia are only gravel, sand, and water. For the other materials, they have to be imported. Cement, steel, water-reducing agent and so on are importing from the neighboring countries, Thailand or Vietnam. Among the materials, the most expensive one is the PC strands. Although it is possible to import the good quality PC strands from Thailand, the dimension variety of wedge which is necessary for introducing the prestress is few. And the wedge of PC strands for the standard type of PC girder from the proposal could not be supplied this time. Besides, in order to reduce the cost of PC girder, it is preferable to reduce the deployment of the materials imported from Japan. Therefore, as to the sheath, it was replaced by the Flexible pipe which could be supplied in Cambodia. Only for the wedge, since it is impossible to import from the neighboring country Thailand, it was decided to import from Japan. However, considering that the wedge could be recycled to use and the PC could be manufactured continuously, therefore, comparing with the other materials, it would result in the huge influence on cost.

3.2 Mixing

To manufacture SCC, trial mix is necessary on the spot. For the real scale of PC girder this time, in Cambodia, there is the huge forced twin-axial mixer for plant, but there was no experimental level drum mixer. Generally speaking, forced twin-axial mixer is the precondition to manufacture SCC. However, according to the report of Ouchi, there is no problem to manufacture SCC with the drum mixer as well. Therefore, to manufacture SCC in Cambodia this time, drum mixer was employed for the trial mix, and for the real cast of PC girder, forced twin-axial mixer in plant was employed. Considering the influence from different type of mixer, the mixing time was properly adjusted.

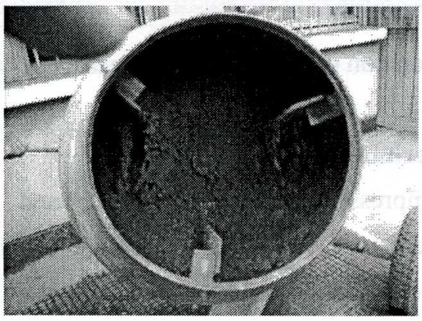

Fig.8 Drum mixer

3.3 Mix proportions

In the case of SCC mix proportion, the larger amount of powder is generally used. Moreover, in order to reduce the temperature rise of concrete, low-heat Portland cement is widely used. However, in Cambodia, there is only normal Portland cement which could be supplied. Besides, although admixtures like Slag fine powder, flyash and silica fume could be supplied from the market, they are very expensive. In the case of limestone powder, since there is the mine in Cambodia, it is the comparatively cheaper material which could be supplied. According to the above conditions, to manufacture SCC in Cambodia, normal Portland cement and limestone powder were used.

As to the high performance AE superplasticizer which is necessary for the manufacture of SCC, the delay type of high performance AE superplasticizer could not be supplied in Cambodia now. The only one which could be supplied in Cambodia is early strength type of high performance AE superplasticizer. In the case of early strength type AE superplasticizer, it is difficult to maintain the flow ability for the long time. However, since the PC girder is generally manufactured in prescast factory, it would not cause big problem in quality. Besides, if it is necessary to add the delay type of superplasticizer, it is also possible to supply in Cambodia in the future.

3.4 Quality management

As to the quality control of SCC in flash state, it was as same as the one in the Japan. That is to say that, based on the criteria of JIS, the slump cone with the bottom inner diameter 200mm, top inner diameter 100mm and the height 300mm was employed.

Besides, the flow time based on the V test and the obstacle pass-ability performance based on the box test was employed as well. As to the hardened concrete, the compressive strength test by cylinder specimen with diameter 100mm and height 200mm same as the test in Japan was tested. According to the above quality management methods, the SCC manufactured in Cambodia was assured to have the same quality of SCC which was manufactured in Japan.

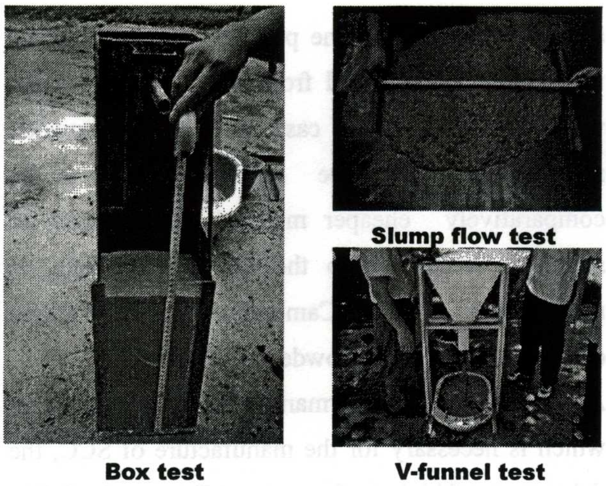

Fig.9 Quality test in Cambodia

3.5 Real size PC girder

Formwork of this experiment was removed after 1 day of casting. This formwork was made with metal for recycling. PC girder was cured for 5 days by water as shown Fig.10.

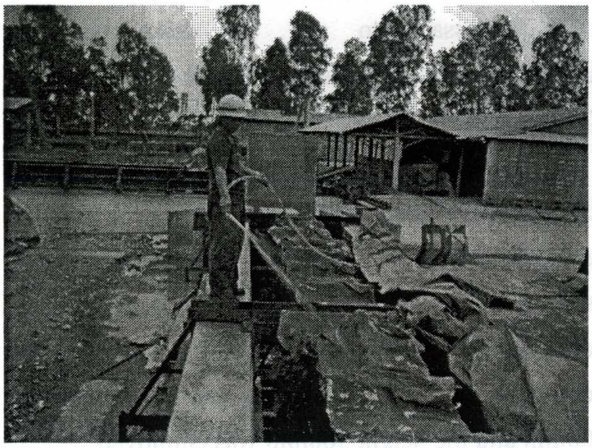

Fig.10 Curing

PC strands were cut at 6 days to transfer the prestress force to SCC girder by releasing method. It means that cutting strands were operated one by one wire each strand composes of 7 wires. By considering the loss at tensioning and the loss at transferring due to elastic shortening, the PC strands were tensioned at total force 2279kN. After loss due to settlement of wedge the total tension force remains 2227kN.

4. EXPERIMENT ON PRESTRESS LOSS

In this chapter, it explains about prestress loss by creep and shrinkage measured real size PC girder which was explained in Chapter 3.

4.1 Measurement

Strains on concrete were measured by ball contacting extensometer based 300mm. Gauge plug were pasted on PC girder surface as shown Fig.11. The measurement was made before cutting strands, just after cutting strands and 1day, 3day, 7day, 14day, 21day, 28day and 56day after cutting strands. At the same time of strain measurement, the deflections were measured on bottom surface of PC girder.

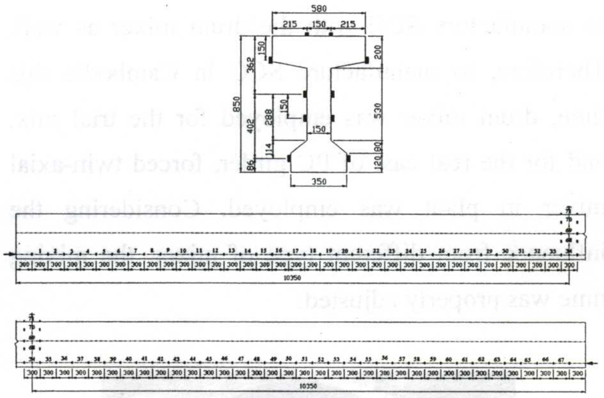

Fig.11 Position of gauge plug and measured camber

4.2 Experimental result

The compressive strength of SCC used in this experiment was 72.4MPa at the age of 28 days. Measured strain of concrete at the location of PC strands just after transfer and 56 days are shown in Fig.12. Measured camber at mid-span is shown in Fig.13. Solid lines in figures are calculation result and points in figures are measured data. Calculation result in figures are included effect of temperature and humidity for consider correct value of shrinkage and creep. Furthermore, it were considered adhering force and friction force between the bottom of formwork and PC girder which appear at the transferring time and friction forces at the end of supports which appear at after transferring.

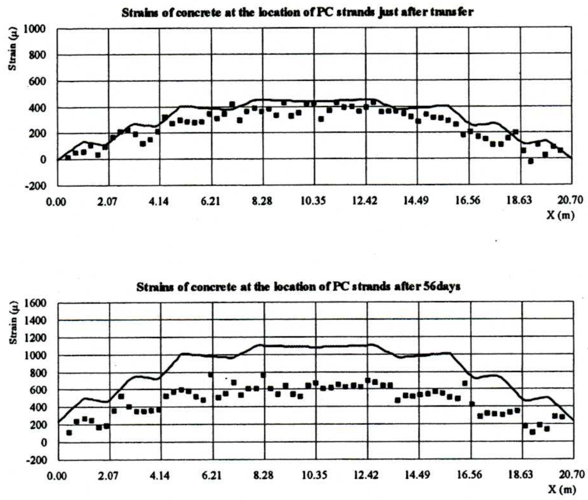

Fig.12 Experiment and calculation result of strain

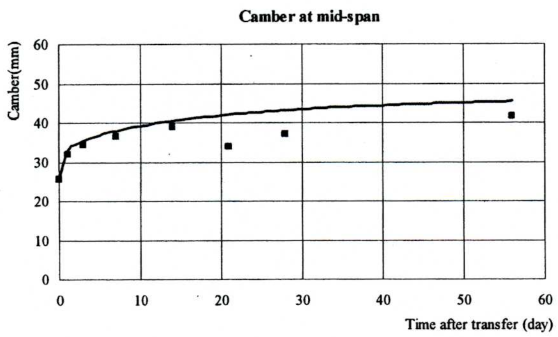

Fig.13 Experiment and calculation result of camber

This experimental result shows that PC girder is in the safe condition. Therefore, it is able to apply proposed model of shrinkage, creep and prestress loss to PC girder design using self-compacting concrete in Cambodia. This experiment clarified the possibility of producing good quality prestressed concrete girder with Cambodian local materials and the design of PC girder presented in Chapter 3 and 4.

5. CONCLUSIONS

(1) It is adopted that Japanese quality control management of self-compacting concrete for Cambodia. Therefore, it is shown that good quality concrete using Cambodian local materials is able to produce in Cambodia.

(2) Real scale prestressd concrete girder was produced and measured for experiment of prestress loss by creep and shrinkage in Cambodia. As a result, prestress loss was less than calculated value by proposed design method. And it is shown that proposed design method is suitable in Cambodia.

(3)The production of real scale prestressd concrete girder using self-compacting concrete in Cambodia has shown the possibility of producing good quality prestressd concrete girder with Cambodian local materials.

REFERENCES

Rajendra Niraula, 2005, Development of Integrated System for Human Resources and Infrastructure Development in Developing countries, Kochi University of technology, Japan

VONG Seng, 2006, Design of Prestressed Concrete Bridge Girder Using Self-Compacting Concrete for Cambodian Rehabilitation, *Kochi University of Technology*, Japan

The Specification for Highway Bridge, *Association of road*, Japan, 2002

Model Code1990, *CEB-FIP Thomas Telford*, 1993

Kazunari MINABE, Kohei TSUTSUI,Masahiro OUCHI, Yoshimitsu NAKAJIMA, Production method of SCC which put in admixture later, *JSCE annual conference Vol.61*, Japan, pp. 391 - 392, 2006