RECENT DEVELOPMENT OF PRESTRESSED CONCRETE BRIDGES IN VIETNAM

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Abstract

The prestressed concrete structure has been successfully applied in Vietnam more than 40 years. The prestressed concrete bridges were built in various periods with different design standards. In Vietnam, a number of innovative technologies have been applied not only in construction the new bridges but also in repairing and upgrading the old prestressed concrete bridges. These include the development of novel structural systems (external prestressing, extradosed prestressing, cable-stayed bridge) and the new technologies in repair, strengthening old bridges (shotcrete technology, FRP material, external prestressing tendons). This paper presents an overview of such achievements as well as some problems in the development and application of modern technologies in the construction and repair bridges in Vietnam.

ベトナムにおける近年のPC橋の発展

要　旨

ベトナムにおいて，プレストレストコンクリートが利用されるようになってから40年以上が経過している。ベトナムのPC橋は，様々な時代に異なった基準に従って建設されてきた。ベトナムにおいては，数々の革新的な技術が新たなPC橋の建設にばかりではなく，既設PC橋の補修・補強にも適用されている。革新的な技術として，外ケーブルやエクストラドーズドプレストレッシング，斜張橋のような新たな構造形式が挙げられる。同時に，既設橋の補修・補強に適用するショットクリートやFRP材料，外ケーブル補強といった新技術も挙げられる。

本文では，ベトナムにおけるこれまでの技術的発展を概説するとともに，革新的な技術を開発・適用するうえでの課題について述べる。

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1. INTRODUCTION

In recent years, prestressed technology has been applied successfully in Vietnam and countries around the world. In Vietnam, prestressed technology was first applied in the 1970s. In 1975, Institute of Transport Science and Technology (ITST) researched to design the template of prestressed concrete I beam with the span length from 21m to 24m. Since then, the number of prestressed concrete bridge has grown rapidly (Fig. 1).

Currently, Vietnam highway network has 93 national highways including 4.239 bridges with total length of 144348m. It has 558 prestressed concrete (PC) bridges with a total length of 45239m; 2591 reinforced concrete (RC) with a total length of 56099m, 746 steel bridges with a total length of 38966m, 344 others with a total length of 4044m [1]. The bridges were built in various periods with different design standards: France, USA (AASHTO), the Soviet Union, China, Japan and Vietnam (18-79 22TCN, 22TCN 272-05). In addition, the design load of the standards are different.

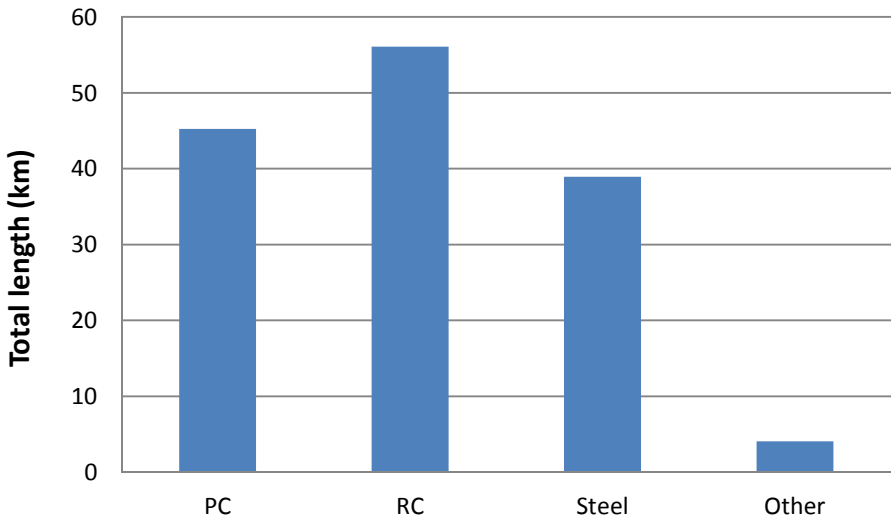

Fig. 1 Trend of construction of different types of bridges in Vietnam [1]

Besides the development of innovative structure and technology in the design and construction new bridges, maintenance, repair, strengthening for old bridges is big problem that needs to be paid attention. After approximately 40 years, with some different reasons, many bridges have been deteriorating and reducing the load capacity. Some of them are now being investigated to rebuild a new one. Due to limitations of the state budget, the old bridges should be repaired and upgraded. Therefore, the research and development of new technologies in repair, strengthening have always been the concern of engineers in Vietnam.

In Vietnam, a number of innovative technologies have been applied not only in construction the new bridges but also in repairing and upgrading the old PC bridges. These include the development of novel structural systems (external prestressing, extradosed prestressing, cable-stayed bridge) and the new technologies in repair, strengthening old bridges (shotcrete technology, FRP material, external prestressing tendons). This paper introduces an overview of such achievements as well as some problems in the development and application of modern technologies in the construction and repair bridges in Vietnam.

2. DEVELOPMENT OF NEW PC BRIDGES

Design state is the first and important step in construction of bridge. The quality of each project depends on the quality of design stage. Many Vietnam consulting companies has a team of professional engineers. This team is trained from projects with foreign capital. After participating in this project, the Vietnam engineers will learn a lot of knowledge and experience from foreign experts to apply for the same work.

In addition, some Vietnam consulting companies have invested professional software such as overall analysis software for cable-stayed bridge, cantilever bridges, prestressed structures (Rm 2000-2006, Midas Civil); local stress analysis software (Ansys), foundation analysis software (Fb Pier, Plaxis, Geoslope). A lot of innovative structures and modern construction technology have been successfully applied by the Vietnamese design consultants and contractors of Vietnam such as cable-stayed bridge (My Thuan Bridge, Dakrong Bridge, Rach Mieu Bridge, Kien Bridge, Bai Chay Bridge, Can Tho Bridge,...); suspension bridge (Thuan Phuoc Bridge), the extradosed Bridge (An Dong Bridge), the external prestressing (Thi Nai Bridge) PC box girder (Song Gianh Bridge, Phu Luong Bridge,...) Super T girder, steel pipe pile, pneumatic caisson [2]...

Appraisal of design is also interested. Most of the complex, large-scale projects will be examined carefully as Bai Chay cable-stayed bridge, Nhat Tan cable-stayed bridge, Thuan Phuoc suspension bridge, Pa Uon Bridge... Many technical problems have been detected and solved after evaluating.

The modern construction technology was successfully applied in Vietnam is balanced cantilever technology, balanced cantilever assembly, launching method, movable scaffolding system technology, construction technology of steel pipe piles, large diameter bored piles from 2m to 2.5m. The innovative technologies have been studied to improve the quality, in accordance with the specific conditions of each project such as construction technology of high pier of Pa Uon Bridge (about 100m); cantilever construction technology for long span of Ham Luong Bridge; external prestressing technology of the Thi Nai Bridge; climbing formwork technology construction for pylon, technology to adjust internal tension of Rach Mieu cable-stayed bridge...

In addition, testing of new material, new structures are also interested. The new materials (prestressed tendon with 21.8mm of diameter, the couple of rebar with 51mm of diameter, high strength concrete (80 - 120Mpa), pregrouted prestressing tendon, high load pot bearing) are tested in Vietnam. The fatigue test for strand of cable-stayed bridge, wind tunnel testing are tested in China or Japan.

The results of these efforts are many high quality and large-scale bridges, as follows:

- My Thuan Bridge (Fig. 2) is the first cable-stayed bridge in Vietnam. The bridge length is 1.535m. Main span length is 350m. The width of the bridge is 23.6 m. The bridge height is 116m.

- Rach Mieu Bridge (Fig. 3) was opened in 2009 connecting Tien Giang Tien river to Ben Tre. This is the first cable-stayed bridge designed and constructed by Vietnamese people. The bridge length is 2.868 m. Main span length is 270m. The width of the bridge is 15 m. The bridge height is 117m.

Fig. 2 My Thuan Bridge

Fig. 3 Rach Mieu Bridge

- Bai Chay Bridge (Fig. 4) is the world's longest span of any single-plane, cable-stayed, prestressed concrete bridge. Main span length is 435m. The bridge length is 1.106m. The width is 25.3 m. The bridge height is 137m.
- Can Tho Bridge (Fig. 5) is the cable-stayed bridge with the longest main span in Southeast Asia. Main span length is 550m. The bridge length is 1.010km. The width is 23.1 m. The bridge height is 175m.

Fig. 4 Bai Chay Bridge

Fig. 5 Can Tho Bridge

- Song Han Bridge (Fig. 6) is special cable-stayed bridge which can turn around its axis to allow shipping traffic to pass along the river. The bridge length is 487.7 m. The width is 12.9 m.
- Thuan Phuoc Bridge (Fig. 7) is the longest suspension bridge in Vietnam. The bridge length is 1.856m. The main span length is 405m. The width is 18m. The height bridge is 92m.

Fig. 6 Song Han Bridge

Fig. 7 Thuan Phuoc Bridge

- Thi Nai Bridge (Fig. 8) is the longest sea-crossing bridge in Vietnam with nearly 7km in length. The bridge has 54 spans. 5 main span are constructed by balanced cantilever method with external cables. And 49 spans are Supper T girders. The width is 14.5 m.
- An Dong Bridge (Fig. 9) is the first extradosed bridge in Vietnam. The bridge length is 1.018m. The bridge will be constructed by cantilever method. The bridge consists of 4 towers.

Fig. 8 Thi Nai Bridge

Fig. 9 An Dong Bridge

- Ham Luong Bridge (Fig. 10) is constructed by cantilever method with the longest main span length in Vietnam. Main span length is 150 m. The bridge length is 1227.2 m. The width is 16 m.
- Pa Uon Bridge (Fig. 11) is constructed by cantilever method with the highest pier in Vietnam. Bridge over Da River near Son La Hydropower. The pier height is designed up to 98 m. The bridge length is 1273m. Main span length is 130 m. The width is 9 m. The bridge was designed and built to withstand an earthquake of 9 on the Ricter scale.

Fig. 10 Ham Luong Bridge

Fig. 11 Pa Uon Bridge

However, the design work has some problem need further consideration to improve the quality and aesthetics, such as:

- The design of some bridges are not focused on the aesthetics. The reason is that bridge aesthetic are not presented in Vietnam University as well as not training in consulting companies.
- A lot of bridges are less emphasis on structure solutions, on the ability to maintain and repair. Some bridges are not designed the position to put the jacks when replacing the bearings. The old Dakrong suspension bridge was collapsed due to corrosion of main cable. Thi Nai Bridge cables were used inappropriate materials, leading to damaged external post-tensioning cables,...
- Some bridges have large vibration, unsafe for traffic due to lack of rigidity (Gian Khau Bridge, Dong Nai Bridge,...);
- The differential settlement between the bridge and approaching road is unsafe for traffic, reduce the exploitation smoothly (Van Thanh Bridge in Ho Chi Minh City);
- The crack near bearing of Super T girder has yet to be overcome. Although this structure has many advantages.
- A number of innovative materials, new technology has not been widely adopted (prestressed tendon with 21.8mm of diameter, the couple of rebar with 51mm of diameter, high strength concrete (80 - 120Mpa), pregrouted prestressing tendon, steel pipe piles);
- A number of modern construction technology has been slowly applied despite successfully used in several projects (automatically tension technology, expanding technology of pile head, movable scaffolding system technology movable scaffolding system technology, ...);
- In the Mekong Delta and some other areas, thickness of soft soil is over several tens of meters. However, no suitable solution of structure and foundation are recommended to replace bored piles, T girder, I girder, Super T girder and the cantilever bridge.

3. APPLICATION OF INNOVATIVE TECHNOLOGIES IN MAINTENANCE AND REPAIR FOR PC BRIDGES IN VIETNAM

3.1 The maintenance work

Maintenance is an important step to ensure that the projects to be exploited effectively, durably. Every year, the state invests a lot of funds for the maintenance work as well as specialized testing equipment. A number of new technologies and equipment in the assessment, maintenance operators have been applied.

Since 1995-1996, the Ministry of Transport carried out the transfer of technology "Bridge Testing and Evaluation" with the ODA funded by the United Kingdom. The program trained and transfer the good technical knowledge for Vietnam Engineers. Some modern equipment for testing, evaluation and Bridgeman software were invested. Since 2000, MOT continued to make a number of projects to enhance capacity in the field of management and maintenance of the road network, including VBMS software (improved from Bridgeman 2.2). Through it, the bridge management has been done and obtained some positive results. most important in the management system is the VBMS bridge management software with 4 main modules of Statistics, inspection, planning and finance. However, the database of

statistical and inspection module is updated slowly, so implementation of the planning and financial module has some difficulties and lack of precision.

The inspection work was carried out according to the current standards (22TCN 243-98, 22TCN170-87), the manual for bridge inspection (issued by Directorate for Road of Vietnam). The inspection work is done by the qualified consultant companies such as the Institute of Transport Science and Technology, University of Transport and Communication, University of Civil Engineering, Technical Center of Directorate for Road of Vietnam. The inspection results are basis for management, operation and repair of bridges.

However, there are some problems as follows:

- There is not enough reliable equipment to evaluate the effectiveness of prestressed beams remaining in the old PC beams.
- The assessment of the condition of the old bridge in case lack of record documents is a difficult task for inspection companies.
- Design standards and inspection, evaluation standards are inconsistent. Currently, the new design is based on AASHTO standards. However, inspection, evaluation is based on Soviet Union standards (22TCN 170-87, 243-98 22TCN).

3.2 The development of new technologies for bridge repair work

3.2.1. Shotcrete Technology [3]

Shotcrete is concrete casting technology by spray drying or wet aggregate concrete through nozzle using compressed air. Normally, with of repair and strengthening work, dry spray technology is used to ensure the bonding with the old concrete.

The advantages of shotcrete technology:

- Flexible and fast execution, without formwork, ensure the bonding, easy to create and control the thickness of the concrete;
- Shrinkage of shotcrete can be adjusted and optimized the water for hydration of concrete.

Principles of Technology

Initially, fine-grained components are bonded with the old concrete surface. The large energy particles pop out and at the same time acts as compaction for the bonded fine particles. Then, when fine-grained layer is thicker, large particles will sink into fine-grained layer to create concrete structures (Fig. 12).

The scope of application

Shotcrete technology is very effective solution for repair and strengthening works. However, the construction and quality control is complicated and requires skilled worker. Shotcrete technology is applied when cross section is not enough; rebar of structure up to yielding stress; old concrete is damaged, need to remove and replaced by shotcrete.

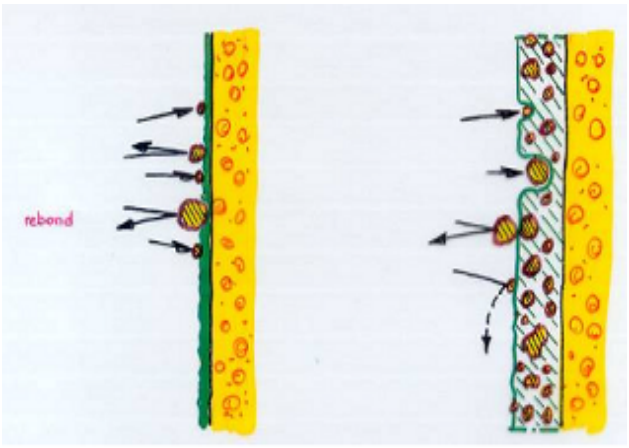

Fig. 12 Shotcrete Technology

Fig. 13 Repair Y Bridge

3.2.2. Strength by FRP Material

FRP (Fiber Reinforced Polymer) usually consists of 2 main components including fibers with high tensile capacity and adhesive glue to create the bonding between fibers and concrete. FRP Material commonly used in three forms: woven fabrics, sheets and bars (Fig. 14).

The advantages of FRP Material:

- High tensile strength and high modulus of elasticity;
- Lightweight, good fatigue resistance, abrasion resistance, easy to strengthening in every shape;
- High corrosion resistance with acid, salt,...

Principles of Technology

FRP material is stuck on the tensile part of structure to increase the bearing capacity. Ability to work simultaneously of the structure depends on the tensile strength of the material surface, bonding capacity and penetration of adhesive glue.

The scope of application

FPR technology is used effectively when strengthening structures not be damaged at the critical state even if completely lost the ability to stick of FRP layer. FRP technology is not applicable in case missing the cross section of structure; concrete surface is in poor quality. Do not use FRP material when the structure has high risk for fire.

Fig. 14 FRP Material

Fig. 15 Strengthening by FPT Material

In Vietnam, FRP material has been applied since 2010. Up to now, FRP was developed over 80 bridges. In 2011, 72 bridges were upgraded by FRP. FPR were used for many kinds of structure such as PC girders, RC beams, PC slab, RC slab, piers, piles,…

3.2.3. Strength by external prestressing

External prestressing is a prestress that introduced by high strength tendons, in which the external tendons are placed outside the cross section of a concrete beam. The tendons are connected to the beam at several anchorage blocks and deviators distributed along the concrete beams. The anchorage blocks and deviators are attached to main girders through PC bars or monolithically cast to main girder.

The advantages of external prestressing:

- Can be constructed in terms of the normal traffic on the bridge. No need to stop the vehicle;
- Can be restored, enhanced load capacity and extend the life of the project;
- Do not increase self weight of structure.

Principles of Technology

The loading transmission into structure is made by the tension of external tendons via the anchorage blocks and deviators. These forces are opposite vertical load so reduces stress in the structure caused by the vertical load. Thus, external forces can improve the load capacity (Fig. 16).

The scope of application

External prestressing technology is used effectively to strengthening or bridge widening. However, the application of this technology is limited by concrete strength. So external prestressing technology is effectively applied to the old bridge with concrete in good condition. In the case of the old structures were weathered; concrete, rebar in poor condition, the concrete should be treated by shotcrete technology to improve the efficiency of repair works.

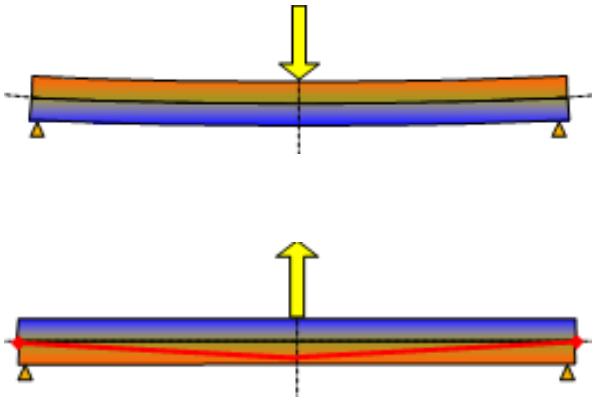

Fig. 16 External prestressing

Fig. 17 Strengthening Saigon Bridge

In Vietnam, external prestressing was firstly applied in repair of Saigon Bridge (Fig. 17), Y – shaped Bridge (in Ho Chi Minh city), An Duong and Niem Bridge (Hai Phong city), in which the prestressing was carried out by Freyssiner company. In the 1980s, external prestressing had already been studied in ITST for the application in bridge rehabilitation. Firstly, ITST together with Freyssinet carried out the repaired work in project of Saigon Bridge and An Duong Bridge, in which ITST played role in inspection the construction work. After that, the external prestressing has been used not only for repair PC bridges but also upgrade of RC bridge such as Vinh Dien, Chau O Bridge (in Quang Nasm province), Da Phuc Bridge (National Highway No.3, Thai Nguyen city), Tram Bridge (National Highway No.37, Tuyen Quang province), Doan Hung Bridge (National Highway No.2, Phu Tho province) [4],…

Repair, upgrade projects for existing bridges that have been carried out by ITST until present are met the desirable requirements, and highly evaluated by the Owners. At present, many weak bridges have to be repaired or upgraded in Vietnam. The external prestressing is one of most advantage technologies. Together with the experiences and computer program developed by Engineers of ITST in order to satisfy the society needs in the filed of transport engineering in Vietnam.

4. CONCLUSIONS

The recent development of new PC bridge and the innovative technologies in repair for old PC bridge in Vietnam were introduced in this paper. The modern construction technology was successfully applied in Vietnam is balanced cantilever technology, balanced cantilever assembly, launching method, movable scaffolding system technology, construction technology of steel pipe piles, large diameter bored piles from 2m to 2.5m. The new materials such as prestressed tendon with 21.8mm of diameter, the couple of rebar with 51mm of diameter, high strength concrete, pregrouted prestressing tendon, high load pot bearing are also presented. The results of the application of innovative structure and new construction materials are many high quality and large-scale bridges in Vietnam. However, the design work has some problem need further consideration to improve the quality and aesthetics.

The innovative technologies in repair and strengthening PC bridge in Vietnam, the application of Shotcrete Technology, FRP material, external prestressing were discussed. Shotcrete technology is very effective solution for

repair and strengthening works. However, the construction and quality control is complicated and requires skilled worker. Shotcrete technology is applied when cross section is not enough; rebar of structure up to yielding stress; old concrete is damaged, need to remove and replaced by shotcrete. FPR technology is used effectively when strengthening structures not be damaged at the critical state even if completely lost the ability to stick of FRP layer. FRP technology is not applicable in case missing the cross section of structure; concrete surface is in poor quality. Do not use FRP material when the structure has high risk for fire. External prestressing technology is used effectively to strenthening or expanding bridges. However, the application of this technology is limited by concrete strength. So External prestressing technology is effectively applied to the old bridge with concrete in good condition. In the case of the old structures were weathered; concrete, rebar in poor condition, the concrete should be treated by shotcrete technology to improve the efficiency of repair works.

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