(I2) RESEARCH AND CONSTRUCTION DEVELOPMENTS ON HYBRID APPLICATION OF FRP TO BRIDGES IN JAPAN

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Application of FRP in Japan as a structural material for construction was started from the application of FRP cable or bar to PC tendon in 1980s. Then, research activities were spread to all FRP footbridges, and these activities were extended to the first all-FRP footbridge in Japan constructed in 2000 in Okinawa Prefecture. These outlines will be reported including current ongoing research projects of FRP bridges. Each project is focusing in more efficient design, easier construction and better structural performance. For the application of FRP to bridge decks, some FRP hybrid deck systems have recently been developed in Japan and have some experience of adoption in bridge construction or repair. Also some research activities on FRP deck in Japan will be summarized in the present paper. The Task Committee on FRP Hybrid Bridges is now working to make a draft for the standard design guideline of FRP bridges. We will finally discuss these activities including the future of FRP bridges in Japan..

Key Words : *hybrid, FRP, bridge, deck, research, development*

1. Introduction

Application of Fiber Reinforced Polymers (FRP) which has some excellent properties such as high corrosion resistance or high strength with light weight, to bridge structures will solve some of the problems that we are facing such as corrosion of steels or RC rebar, and is expected to reduce maintenance of infrastructures. Moreover, FRP's possibility is also expected to enable new structures or new functions, such as new retrofit method or new diagnosis method for structures.

Based on these view points, many kinds of research and construction developments on FRP hybrid bridges in Japan have been conducted including feasibility studies, construction technology of FRP bridges and the associated fundamental technology. In this report, we will introduce the outlines of those activities in Japan including the presently conducted ones.

2. Research on FRP in infrastructures in early stage

(1) FRP cable or bar to PC tendon

Application of FRP in Japan as a structural material for construction was started from the application of FRP cable or bar to PC tendon in 1980s. Many researchers in Japan carried out some important research topics such as anchoring methods for FRP cables, durability of FRP cables under continuous tensile load, etc. In 1989, the first Japanese PC bridge with FRP tendons was constructed in Ishikawa Prefecture. In 1996, a code for design of construction was established by JSCE. The development of FRP tendon shows FRP's feasibility as a structural materials in early stage, however its application for PC tendons is not spread widely yet. Other application such as ground anchor becomes more to

be focused recently.

(2) Continuous fiber reinforcement

Research on the application of continuous fiber sheet as a concrete strengthening method was started in Japan since early 1990s; it started a little later to FRP cable. This method was continuously focused because of its outstanding, easy construction, and many researches. This technique was specially spread in Japan after the strong earthquake in Hyogo, 1995. Now this technique is one of standard methods for strengthening of concrete structures. Application of this technique to reinforced steel structures is now focused in Japan and researches are being carried out.

3. Research on FRP footbridges

(1) FRP bridge in early stage in Japan

Research on application of PC tendon and spread of continuous fiber sheets were expected the further feasibility of the application of FRP to structural materials. In Japan, unexpected damages of RC structures because of salt or ASR were focused and became a social problems in 1980s. Increase of maintenance cost of steel structures was also focused. More positive application of FRP as the main structural material was expected to be one of the solutions of these situations. Japanese activity of the research on FRP bridges was started based on these situation.

Public Works Research Institute was started their research activities on the application of FRP to main structural materials in 1993. Their research was started from the FRP's mechanical properties and feasibility of FRP bridges. Feasibility of FRP cable stayed bridges, FRP arch bridges, etc, were studied. In 1996, real size all FRP cable stayed bridge was constructed as a demonstration project, and feasibility of FRP bridges was confirmed through the project including loading test. A FRP truss bridge was also studied considering to apply to a emergency bridge since 1997, and real sizes performance was evaluated through the experiment.

(2) Okinawa Road Park Bridge[1)]

PWRI's studies in 1990s suggested FRP bridge's high feasibility, and as the next stage, real test construction was expected to study if FRP bridge shows really good durability under severe corrosive environment in Japan. The test construction was carried out in Okinawa Prefecture in 2000. This is the Japan's first all-FRP pedestrian bridge and named "Okinawa Road Park Bridge". As shown in Figure 4, it is a 2-span continuous girder bridge with total length of 37.76m and width of 3.5m.

Fig.1 Okinawa Road Park Bridge

(3) Task Committees in JSCE

After the construction of Okinawa Road Park Bridge, research on FRP bridge became more active. Structural Engineering Committee of JSCE sets the Task Committee on Research on FRP Bridge in 2000, and their activities for development and diffusion of FRP bridge was started. The first chairman was Prof. Ohshima of Kitami University of Technology, and technical information was exchanged in the committee, including the carrying out of the first national symposium on FRP bridge. The chairman from 2002 to 2004 was Prof. Maeda of Tokyo Metropolitan University, and the book, "FRP bridge" was established as a state of the art of this technology during this duration.

As making progress of the research of FRP bridges, the absence of the suitable standard code for FRP bridge became the obstacle of the spread of FRP bridges. The activities of the task committee of JSCE also shifted to establish the standard design method. The task committee for design of FRP bridge was set in 2004 as the post activities of the Task committee for research on FRP bridge. The chairman was Prof. Yamada of Toyohashi University of Technology, and now continuing their activities to establish the guideline for FRP bridge describing standard of design.

4. Research on FRP decks

(1) FRP-concrete hybrid deck[3)]

In Japan, all-FRP decks was also studied during the last decade, however its application was not spread like that of United States, Europe or Korea, however, the various FRP-concrete hybrid decks, shown in Fig.2, have recently been constructed; they have applied totally to seven bridges.

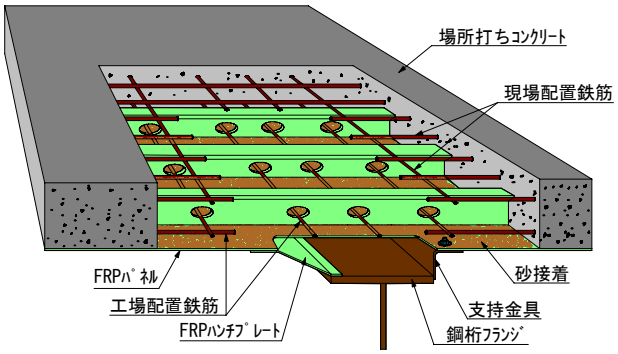

Fig.2 An example of FRP-concrete hybrid deck systems

(2) Steel-FRP/concrete hybrid deck [4)]

The FRP-concrete hybrid deck was improved to apply to a existing concrete deck's rehabilitation The frame has hybrid structure with FRP combining with steel squire pipes as shown in Fig. 3, and obtained light weight and high corrosion protective performance. Its wheel loading test was already carried out and showed a good fatigue performance.

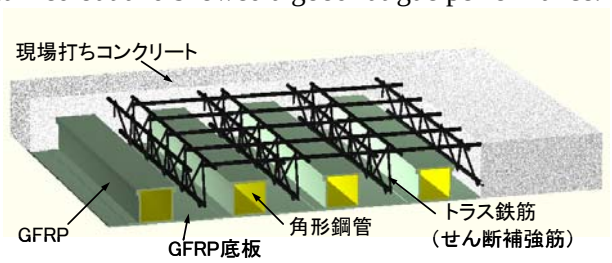

Fig.3 Steel-FRP/concrete hybrid deck

(3) Research in PWRI[5)]

PWRI also carried out a research on an all-FRP deck, shown in Fig.4, subjected to large scale wheel loading tests shown in Fig.5. No remarkable deterioration was observed after 700,000 times cyclic wheel load at 100kN. After that for the same all-FRP deck, the same step-up loading procedure which is used for RC decks was performed until 255kN, any remarkable decrease of durability as well as any large remaining deflection was not observed. This result suggests that all-FRP decks have good performance for design, but traditional RC decks have still an advantage in economic view points. This cost performance is now the main obstacle for all-FRP deck in Japan.

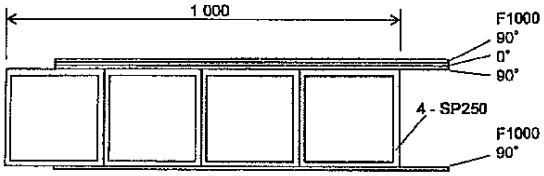

Fig.4 All-FRP deck by PWRI

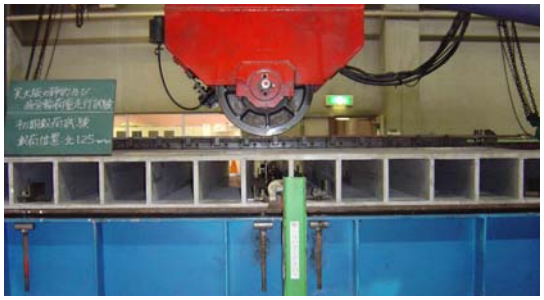

Fig.5 Wheel load test of FRP deck by PWRI

5. Current research activities on FRP hybrid bridges in Japan

(1) CF/GF hybrid FRP beam[6)]

A project to develop hybrid FRP beam member for pedestrian decks is now being carried out by Prof. Mutsuyoshi of Saitama University and his group. The purpose of this research is to develop light weight and strong hybrid FRP beam combining different kinds of materials. The main target is the application of this new beam to reconstruction of infrastructures, for example, pedestrian decks and urban footbridges connecting buildings. An alternative design method using the beam is now studied considering life cycle cost and environmental assessment.

(2) FRP truss bridge[7)]

An all-FRP truss bridge was designed and constructed in the campus of Monotsukuri University, Saitama in 2007, supervised by Prof. Masubuchi and Prof. Maeda. Pultruded GFRP truss members are jointed by blind rivets and stainless steel gusset plates. This new bridge was erected for bachelor course students of this university to learn the skill of manufacturing technology in construction. The bridge is in use as a walkway connecting the university buildings after construction. It is the first real used truss bridge in Japan.

(3) FRP deck bridge[8)]

A research project of deck type FRP footbridge is being studied by Prof. Maeda. The deck member is

made combining pultruded GFRP profile with adhesion. A trial design for 16m span bridge and loading test with several meters members are carried out.

(4) GFRP girder bridge

Research activities of PWRI on FRP bridge are shifted to increase efficiency of the design method based on the method of Okinawa Road Park Bridge. The height of the main girder of Okinawa Road Park Bridge was 1,600 mm, however, this size is to large to apply relatively low cost pultruded FRP. Hence, a research to assemble members with built-up method with pultruded FRP with small dimension profiles.[9,10)]

(5) Walkway for inspection of long span bridges over the sea[11)]

Application of FRP bridge to walkway for inspection of long span bridge is being studied by Honshu-Shikoku Bridge Authority. Inspection bridge for long span bridges connecting Honshu and Shikoku are usually made with steel and protected with galvanizing from corrosion, however, there are some partial corrosion because of severe environment conditions. An FRP bridge is considered to help to solve the problem in the repairing the inspection walkway.

6. Future of FRP bridges in Japan

Now in JSCE, the Task Committees on FRP Hybrid Bridges (chaired by the first author) and on Repair and Reinforcement of Steel and Hybrid Structures using FRP Material (chaired by Professor Hiroyuki Suzuki), are both very active; the latter started to collect data not only domestic but also oversea works and to discuss on the state of arts mainly for FRP-strengthened metallic bridges[13)].

Most interesting action may be on the edition of the guideline for FRP bridges describing standard of design by the Task Committee on FRP Hybrid Bridges which is now working to be completed to make the draft by the end of the next year.

Application of FRP to infrastructures in Japan is in the spotlight and will also be so in the future. Over 50-years bridges in Japan are now in need of renewal or strengthening (and/or rehabilitation) due to corrosion, and the numbers are expected to increase rapidly in near future. Therefore, many advantages of the use of FRP are just with great anticipation to solve these difficult problems. Precise supervising would, on the other hand, be useful both for assessing the damage level and for planning the strategy of the long-life usage of infrastructures. An alternative new monitoring system, “visit monitoring”, has been proposed for steel or all-FRP bridges by the first author[14,15)]. Optical power spectra and the associated strain measurement using innovative optical fiber Bragg grating sensors has been carried out, and the precise data have been obtained, for example, for the riveted joints of GFRP truss members covered by steel gusset plates in Monotsukuri University all-FRP truss bridge. This kinds of low-cost, visit, monitoring would give useful structural health information for various infrastructures in the future.

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