# I -A214 Effectiveness of Pultruded GFRP Beams in Strengthening of Steel I-girder bridge with Damaged RC Slab

Kyushu University, Student Member, Basem ABDULLAH, Takahiro KITAMURA
Kyushu University, Members, Shinichi HINO, Toshiaki OHTA
Mitsubishi Heavy Industries Erection Co, LTD. Member, Hisao KATSUNO

## 1. Introduction

The use of pultruded glass fiber reinforced plastic (GFRP) in structural engineering has been rather limited compared to the use of steel and concrete, and it is mostly confined to special applications where resistance to highly corrosive environments, electromagnetic transparency, or a low weight-to-strength ratio is required. In this study the usage of pultruded glass fiber reinforced plastic I-shaped beams in strengthening the RC slabs of steel I-girder bridges is introduced. Analytical results for both stages viz., the pre-strengthening stage and the post-strengthening stage are presented.

## 2. Back ground

Steel I-girder Bridge with RC slab in Fukuoka prefecture was chosen to be a study case. The non-continuos three spans bridge has total length of 67 m and width of 12.6 m. The bridge consists of RC slab and six fully composite steel I-girders with variable sections. The design of the bridges was completed in 1956 and the bridge was under service in 1960. A look to the lower face of the RC slab shows the longitudinal and transverse distribution of the cracks inside the concrete. The main reasons for the occurrence of the cracks is the insufficient amount of the distribution steel reinforcement, which was used according to the specification for highway bridges of Japan Road Association in 1956. Also the increase of the truck loads by about 20% since the construction time has negative effectiveness on the behavior of the bridges' structural members.

## 3. Strengthening process

Based on the aforementioned problems an analytical study was completed to check the effectiveness of strengthening the damaged RC slab by GFRP I-beams (Fig.1) to enhance its stiffness and flexural capacities. The suggested GFRP strengthening system consists of longitudinal and transverse beams, which has exactly the same cross section. The longitudinal beams were connected with the extended gusset plate by steel angles and were rest over the transverse GFRP beams. The transverse GFRP beams were connected to the stiffeners of the main steel I-girders.
Also to enhance the strengthening process, the RC slab were vertically supported by the retrofitted existing steel cross frames. Figure 2 shows a plan of bridge after strengthening.

## 4. Analytical Study

Analytical studies were completed using FE package (LUSAS Ver. 12.3) to simulate the behavior of the cracked and the retrofitted bridges.

### 4.1 Analytical Assumption

**(1) Assumptions**

It is worthy to list in brief the general assumptions, which were considered to simplify the analytical modeling.

(A) Full composite joints (rigid joint) to connect the GFRP I-beams with the stiffeners of the steel I-girders.

(B) Full composite joints to connect the transverse and longitudinal GFRP beams.

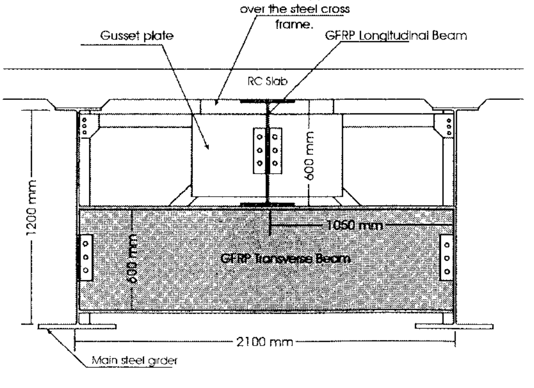


Fig.1 GFRP Strengthening System

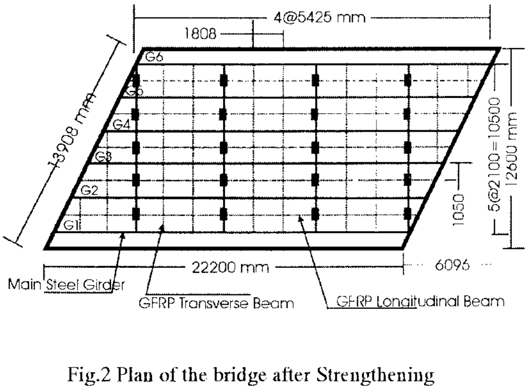


Fig.2 Plan of the bridge after Strengthening

**Key words:** Steel I-girder Bridge, GFRP Beams, Strengthening System.
**Address:** 6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581 Tel: (092) 641-3131 Ext.8677 Fax: (092) 642-3306

(C) Partial composite joints to connect the RC slab with the upper flange of the longitudinal GFRP I-beams.
(D) Spring supports to replace the steel cross frames.
(E) GFRP beams behave elastically under loading.

**(2) Loading**

Following the Specification for Highway Bridges in design the concrete slab of bridges, the loads of three trucks T20 were applied to the bridge to produce the most severe loading case. Figure 3 shows the applied load.

**(3) Material Properties**

All the materials were assumed to behave linear elastically under loading. Table 1 shows the mechanical properties of the concrete, steel and GFRP.

Table 1 Mechanical properties

| | Young's Modulus(kgf/cm2) | Poisson's ratio |
|---|---|---|
| Concrete | 2.1E+5 | 0.16 |
| Steel | 2.1E+6 | 0.30 |
| GFRP | 3.0E+5 | 0.30 |

### 4.2 Analytical Model

The bridge in both stages viz., pre-strengthening and post-strengthening stages were analyzed by F.E.M. The bridge was distretized into mesh consisting of semiloof thin shell elements, semiloof beam elements and three dimensional joints elements.

The semiloof shell elements were used to model the RC slab. The semiloof beam elements were used to model the steel I-girders also the longitudinal and the transverse GFRP beams. The 3-D joint elements were used to model the connections between the steel I-girders and the RC slab, also the connections between the GFRP longitudinal beams and the RC slab. Figure 4 shows F.E mesh for the bridge.

### 4.3 Analytical Results

Compression between the analytical results for pre-strengthening and post-strengthening stages is shown in Figs. 5 and 6.

It is clear that the new strengthening system was able to reduce the stress in the distribution reinforcement and the main reinforcement of the RC slab by 44%and 41 %, respectively, which make the stress under the allowable stress mentioned in the specification.

## 5. Conclusion

The new GFRP strengthening system is able to enhance the flexural and stiffness capacities of the bridges, which suffers from severe damages due to the insufficient steel reinforcements in the RC slab or due to increase of the live load. The new strengthening system is expected to have the following advantages

(1) GFRP beams with bolted connections are relatively easy to assemble and maintain.
(2) Using the aforementioned strengthening system are expected to be relatively less expensive than other strengthening method such as CFRP sheets.
(3) The proposed system is the most appropriate one for accessing and monitoring to any structural member of the bridge after completing the strengthening process.

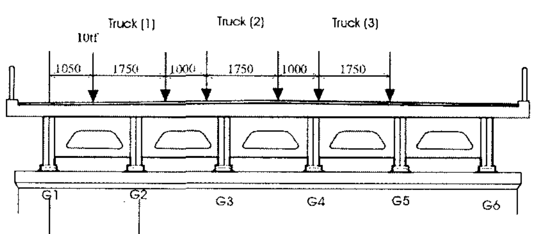


Fig.3 Applied Load

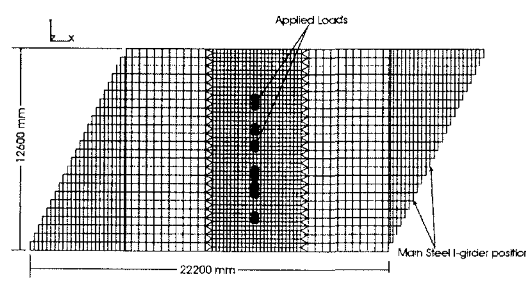


Fig.4 F.E.M Mesh

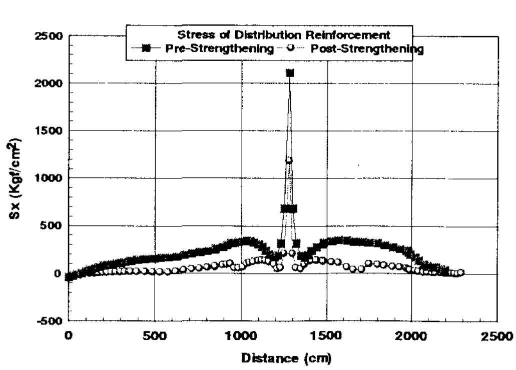


Fig.5 Stress in Distribution steel Reinforcement of the RC Slab

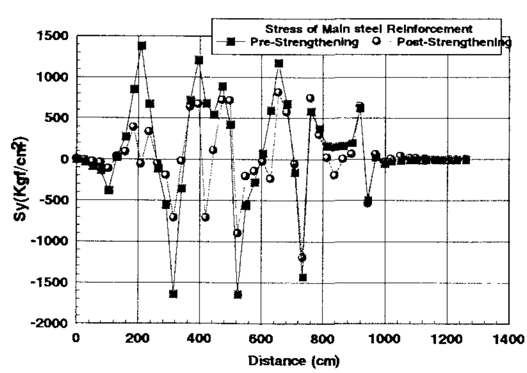


Fig.6 Stress in Main Steel Reinforcement of the RC Slab