論　文

[2112] Strength and Structural Performance of Deteriorated Reinforced Concrete Bridges in Korea

Keun-Joo BYUN*, Young-Jin KIM*, Kee-Sung LEE* and Sang-Min LEE*

1. INTRODUCTION

A series of static and live load tests are performed on two deterio-rated RC bridges (slab and T-beam bridges :constructed in 1920 and 1949) in Korea to evaluate the degree of deterioration,the strengths of mater-ials, the ultimate strength and load-carrying capacity of bridges, and structural performances such as the deformation and cracking behavior, the location of neutral axis and the transverse load distribution [1]. And also, the evaluation technique which is capable of predicting the responses of existing RC bridges is proposed.

2. BRIDGE CHARACTERISTICS

As the tested bridges are deteriorated ones which are over 40 years old,then any drawings do not exist. So, the section properties and steel areas are made out by direct and indirect ways as shown in Fig.1.

Table 1 Bridge Characteristics

Item	Tee-type Bridge	Slab Bridge
Bridge Type	simply supported	6-span continuous
Length of Bridge	48.00 m	71.48 m
Width	7.55 m	4.00 m
Built Year	1949	near 1920
Design Method	working stress design	working stress design

3. MEASUREMENT OF MATERIAL STRENGTH AND DEGREE OF DETERIORATION

The strength of concrete is estimated using the Schmidt Hammer and the cores(ϕ 10x20cm), and the yield strength of reinforcing bar is measured. For the purpose of measuring the degree of deterioration of concrete surfaces due to weathering and salt water, 1% phenolphthalein solutions are sprayed on the concrete surfaces. In spite of the severe cracking of concrete surfaces and corrosion of reinforcing bars, the neutralization did not occur in Tee-type bridge.In case of slab bridge it proceeded to the depth of 3cm into the upper part of bridge deck, and to 4cm into the lower part from the bottom surface. But the decr-ease in strengths are not measured.

*Department of Civil Engineering, Yonsei University, Korea
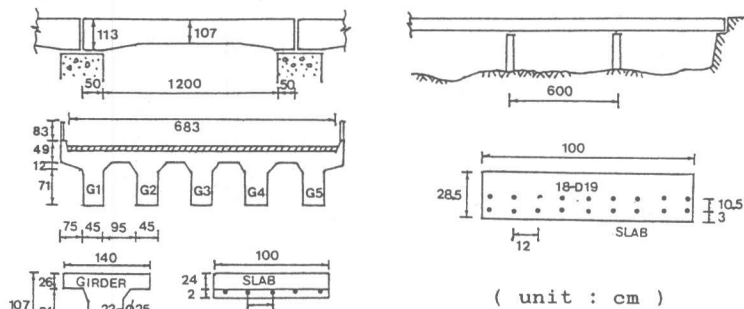
(a) Tee-type bridge   (b) Slab bridge

Fig.1 Cross sections of test structures

Table 2 Results of Material Tests

Material	Test Item	Tee-type	Slab
Concrete	Compressive Strength of Core(σco) Nondestructive Strength(σsh) σco / σsh Modulus of Elasticity	243.6 392.9 0.62 2.34×10^5	169.4 292.1 0.58 1.95×10^5
Steel	Yield Strength Modulus of Elasticity	3500 1.98×10^6	3200 1.90×10^6

(unit : kg/cm^2)

4. TRANSVERSE LOAD DISTRIBUTION

4.1 Tee-type Bridge

The response of the bridges to static load test are assessed through measurement of the induced tensile strain in the reinforcing bars. As shown in Fig.2, the test vehicles are successively positioned at a series of transverse locations to permit evaluation of the mid-span influence lines for each girders.
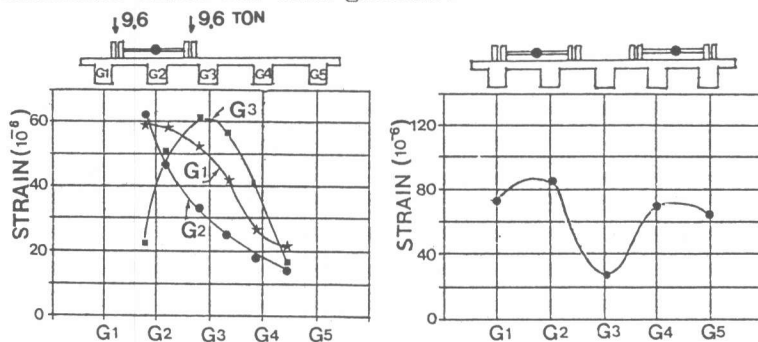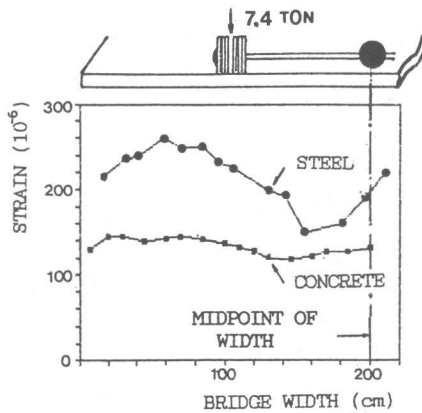

Fig.2 Influence lines for girder 1,2,3,4 and 5 (Tee-type bridge)

4.2 Wheel Load Distribution on Slab Bridge

To investigate the distribution of wheel load, test vehicles are positioned to cause maximum positive moment at the midspan.

The theoretical live load moment 4.64 t-m by the vehicle is assumed to be distributed over 1.56m of width of wheel load distribution given by bridge design specifications. When the experimental live load moment 3.43 t-m is compared with the theoretical one, the former is less than the latter by 26%.

Fig.3 Wheel load distribution (slab bridge)

5. TESTING METHOD

5.1 Loading System

Section profiles cut out of the existing bridges, loading systems and gage locations for bridge tests [3] are shown in Fig.4. Loading and reloading cycles are applied by the hydraulic jack in increments of every 10ton gradually increased up to failure and the bridge decks are loaded through two I-beams in transverse direction at the midspan.
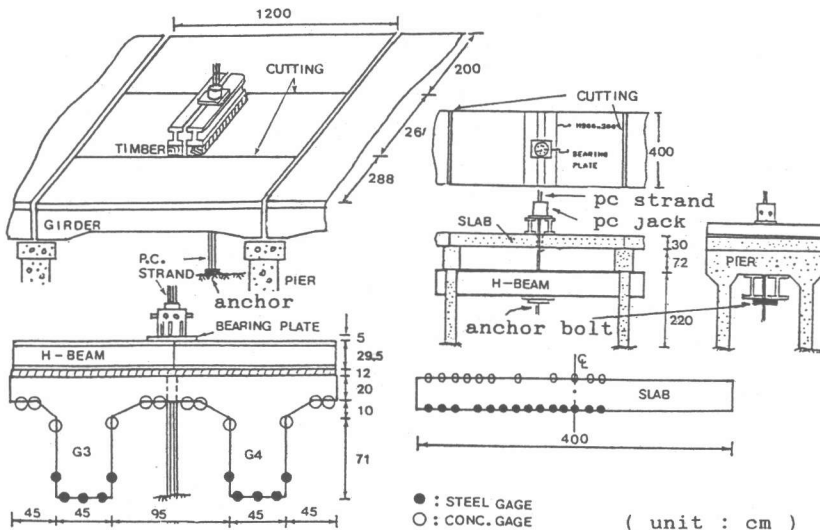
(a) Tee-type bridge   (b) Slab bridge
Fig.4 Test bridges and loading systems

5.2 Testing Procedure

(1) Static loading tests over whole bridge width using test vehicles.
(2) Cutting of girder and slab.   (3) Rock bolting and grouting.
(4) Installing of strain gages and displacement transducers.
(5) Setting of loading system at midspan.   (6) Loading tests.

6. STRUCTURAL BEHAVIORS OF BRIDGES

6.1 Load-Deflection Relation
   The results show that the deflection behaviors are close to the un-
cracked theory up to the service load level, whereas deflections are
rather close to the cracked theory beyond this load level.
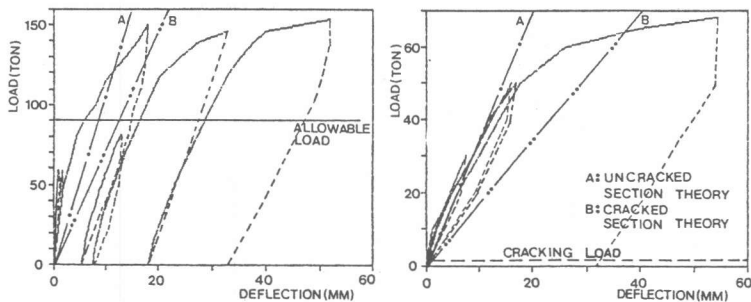
(a) Tee-type bridge   (b) Slab bridge
Fig.5   Load-deflection relation

### 6.2 Load-Strain Relation
   The results show that the relations are close to the uncracked
theory up to the service load level, whereas the relations are rather
close to the cracked theory beyond this load level.
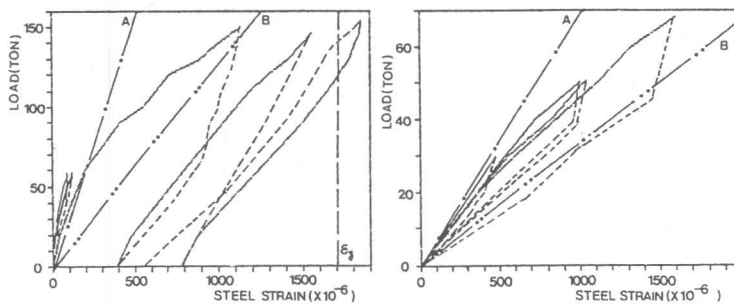
(a) Tee-type bridge   (b) Slab bridge
Fig.6   Load-strain relation

6.3 Cracking Behavior

The results show that the cracking behavior is close to ACI code up to the service load level, whereas the crack widths are rather close to the limiting crack width of ACI or exceed the limiting widths beyond this load level. Test bridges failed in a typical flexural failure mode.
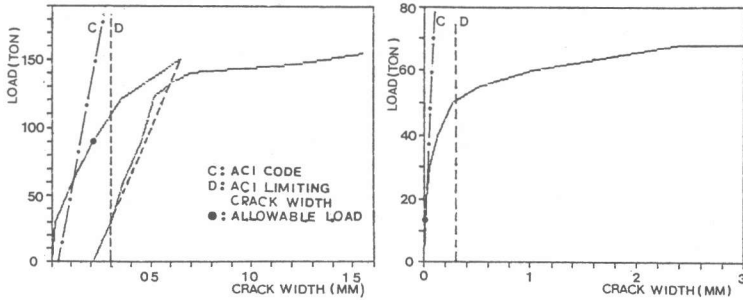
(a) Tee-type bridge   (b) Slab bridge
Fig.7   Load-crack width relation

6.4 Location of Neutral Axis

The results show that the neutral axis has moved according to the areas of reinforcing bars. In case of the tested bridges, the Tee-type bridge behaves as an underreinforced beam and the slab bridge as an overreinforced beam. This results coincide with the theoretical results.
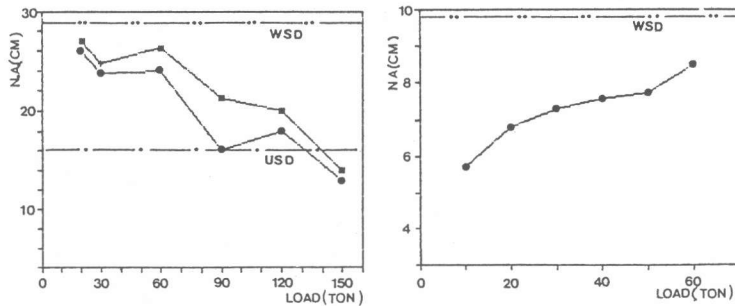
(a) Tee-type bridge   (b) Slab bridge
Fig.8   Location of neutral axis

6.5 Comparison of Theoretical and Experimental Strengths

The experimental moment strength (478.1 ton-m) of the Tee-type bridge is shown to be less than the theoretical ultimate strength of the double T-section at the midspan as shown in Fig. 4(a) by 24.4 % and in slab bridge the experimental value is larger than the theoretical one by 24.6 %.

6.6 Load-carrying Capacities

Load-carrying capacities of test bridges are as follows.

Table 3   Load-carrying Capacities* of Test Bridges

Type	Theoretical Load Capacity	Permissible Load Capacity		
		WSD	USD	Bridge Test
Tee	78.5	142.6	125.2	56.9
Slab	12.5	14.0	27.8	38.0

* Equivalant standard truck load   (unit : ton)

7. CONCLUSIONS

On the basis of the results obtained from the field testing of two deteriorated RC bridges, the conclusions are as follows:
1) It is necessary to make an exact investigation on the presence of drawnings, the strength of materials, and the sectional area of reinforcing bars for the structural evaluation of existing RC bridges.
2) According to field investigations the superstructures of these two bridges are highly deteriorated in appearance, but significant losses of strength and load-carrying capacities due to carbonations are not seen.
3) The core strength of concrete is within the range of 58 % to 62% of the nondestructive strength by the Schmidt hammer, and the yield strength of reinforcing bars is within the range of 3200 to 3500 kg/cm² .
4) The bridges are seen to behave like the uncracked section up to around the service load level, but its behavior is similar to the behavior of cracked section beyond the service load level.
5) The load-carrying capacity of the existing RC bridges is shown to depend primarily on the amount of reinforcing bars.
6) It is recommended that the load-carrying capacity of the RC bridges is derived from the ultimate strength theory.
7) It is concluded that the slab and Tee-type bridges have enough load-carrying capacity to carry the present Korean highway design load (DB-24).

8. REFERENCES

1) Beal,David B.,"Strength of Concrete T-Beam Bridges", ACI SP-88,1985, PP.143-163.
2) Oshiro,Takeshi and Hamada,Sumio,"Structural Performance and Bending Test of Deteriorated Reinforced Concrete Bridges", ACI SP-88, 1985, PP.39-58.
3) ASCE, "A Guide for the Field Testing of Bridges", ASCE,1980,pp.2-50.