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Deterioration and Evaluation of Chien-Kou Viaduct in Taipei

Détérioration et évaluation du viaduc Chien-Kou à Taipei

Schäden und Zustandsbeurteilung des Chien-Kou-Viadukts in Taipei

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SUMMARY

Chien-Kou Viaduct was the first urban expressway built in Taiwan in 1983. The traffic growth increased rapidly since then. Traffic volume of the viaduct had already reached its capacity, and some damages were observed in the past years. This paper focuses on the damage assessment and the safety evaluation of the viaduct, especially, the non-destructive test for the investigation of corrosion rate of steel rebar.

RÉSUMÉ

Le viaduc Chien-Kou a été la première autoroute urbaine construite à Taiwan, en 1983. La croissance du trafic a depuis rapidement augmenté. Le volume du trafic sur le viaduc ayant déjà atteint la capacité du pont, certains dégâts ont pu être observés ces dernières années. Cet article fait le point sur l'évaluation de ces dégâts et de la sécurité du viaduc. L'essai non-destructif pour l'estimation du taux de corrosion de l'acier est exposé.

ZUSAMMENFASSUNG

Die Chien-Kou-Hochstrasse war die erste, 1983 in Taiwan gebaute Stadtautobahn. Seither ist das Verkehrsaufkommen rapide gestiegen. Da die Verkehrsbelastung der Hochstrasse bereits ihr Mass überschritten hatte, kam es in den letzten Jahren zu deutlichen Schäden. Der Beitrag konzentriert sich auf die Schadensaufnahme und die Beurteilung der Tragsicherheit. Insbesondere wird die zerstörungsfreie Prüfung des Bewehrungsstahls auf seine Korrosionsrate hin geschildert.

1. INTRODUCTION

Chien-Kou Viaduct was the first urban expressway built in Taiwan. It was completed in 1983. The total length of the viaduct was more than five kilometers. The viaduct is the main traffic route passing through the north and south parts of the Taipei city, and is connected to the No. 1 National Freeway. The open space under the viaduct was utilized for multi-purposes. It was designed to be gas stations, parking lots or ground roads. The design criteria of structural system of the viaduct were concerned not only the economics and safety, but also the aesthetics and uniformity. The clearance under the viaduct has to fulfil the usage requirements, and also minimize the elevation of viaduct to ease the traffic.

The superstructure of viaduct was continuous prestressed concrete box girders. The standard deck width was 22.6 meters. Two single-cell box girders connected with deck slab were used and transversal prestress was adopted in the deck slab. The construction schemes were ground staging and precast segmental free cantilever methods depending on the traffic detour plan. The ground staging parts were two to four span continuous P. C. box girders with constant cross section as shown in Figure 1. The segmental free cantilever parts had a maximum span length 60 meters and various cross sections as shown in Figure 2. All piers were designed to be single column type without pier caps.

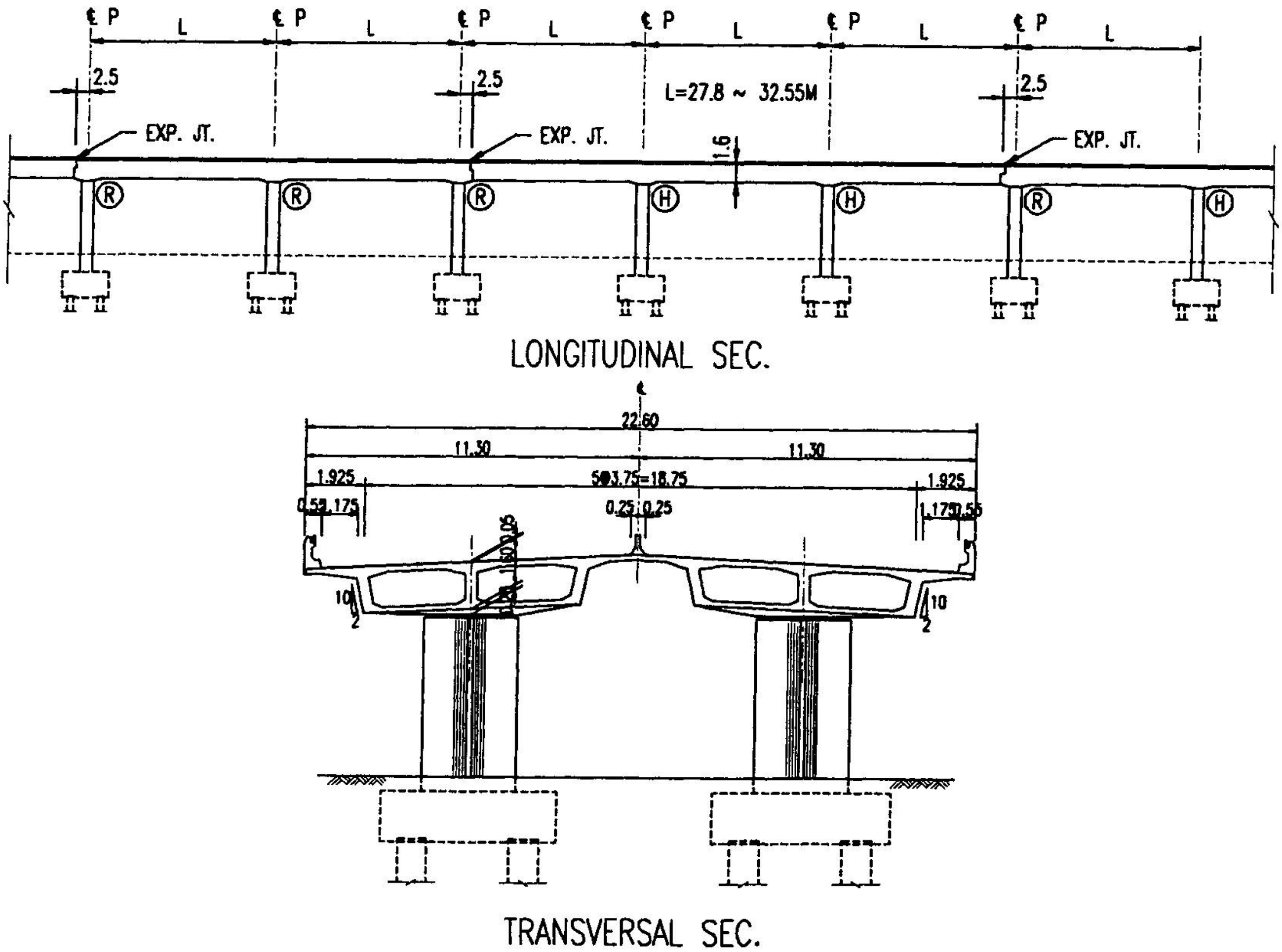

Figure 1. Ground Staging Method

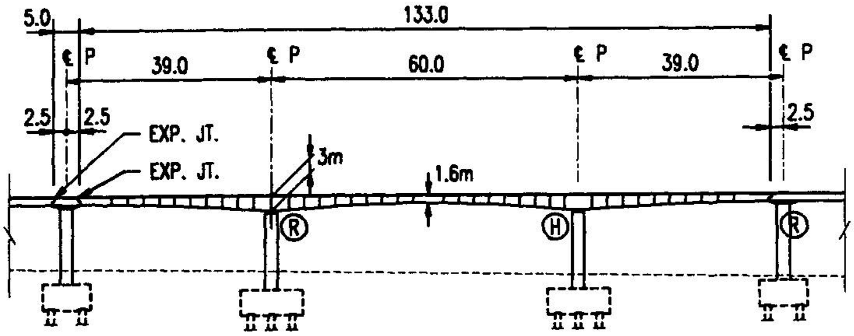

Figure 2. Free Cantilever Method

2. DAMAGE ASSESSMENT

The usage of Chien-Kou Viaduct was already up to its capacity. The traffic volume has reached 7180 PCU per hour which is the highest one of all the viaducts in Taipei. Due to the traffic growth and number increase of heavy vehicles, in addition to occurrences of several earthquakes in the past, there were some damages found in Chien-Kou Viaduct recently. In order to assess the safety and evaluate the remaining loading capacity of the bridge, a series of tests were conducted as listed in Figure 3. The tests included non-destructed test of investigating rebar corrosion and evaluation of concrete protection ability.

The structure of viaduct was mainly P.C. box girders and R.C. piers. The resisting capacity of the viaduct depends mainly on the strengths of concrete and reinforcement. Therefore, the inspections were focus on the damage assessment of these two materials. The checking items were damage assessment on main structure, evaluation of concrete strength and concrete deterioration, and investigation of rebar corrosion.

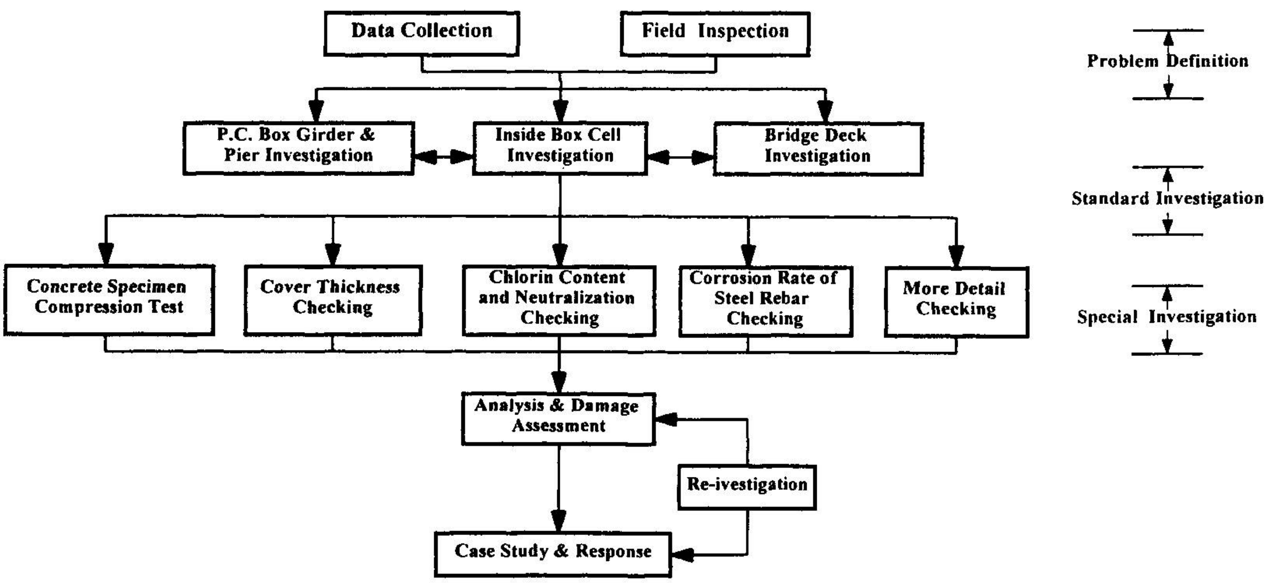

Figure 3. Inpsection of Chien Kou Viaduct

3. INVESTIGATION OF CONCRETE

The take-core tests were done and the specimens showed that there were no deterioration of concrete. There were also no cracks found on the substructure. However, there were several kinds of cracks observed in the superstructure, such as:

(1) Cracks on P.C. box girders : This kind of cracks included three different types - type A crack on the cold joint of bottom slab and web, type B crack on girder web along the strand and type C crack on the bottom slab as shown in Figure 4. There was some water found on type A and C cracks because of the broken drainage pipe. The reason that caused type C crack was related to the service loading.

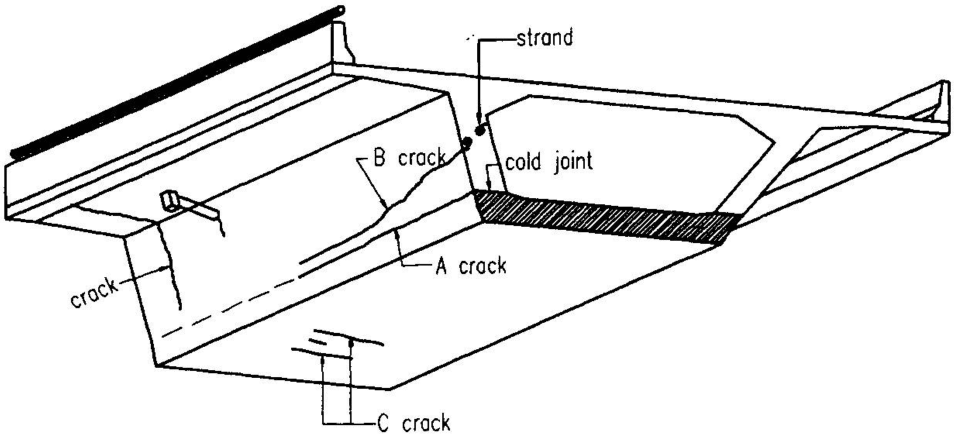

Figure 4. Cracks on P.C. Box Girder

(2) Cracks on connection joint: The main crack on side face of connection joint was alone point a to point b as shown in Figure 5. This kind of crack was caused by differential shrinkage and creep of two different age or strength of concretes. There were also cracks on bottom face of connection joint as shown in Figure 6. This kind of crack was caused by principal stress of bearing reactions as shown in Figure 7. There were no cracks observed on the corner of girder or anchor zone of strand since a detail study was done for the reinforcement design of the connection joint.

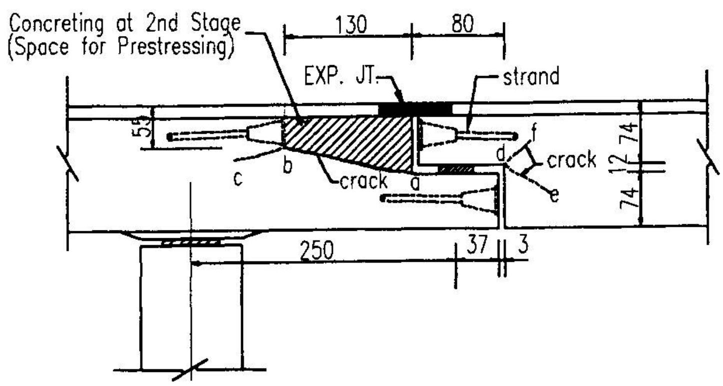

Figure 5. Cracks on Connection Joint

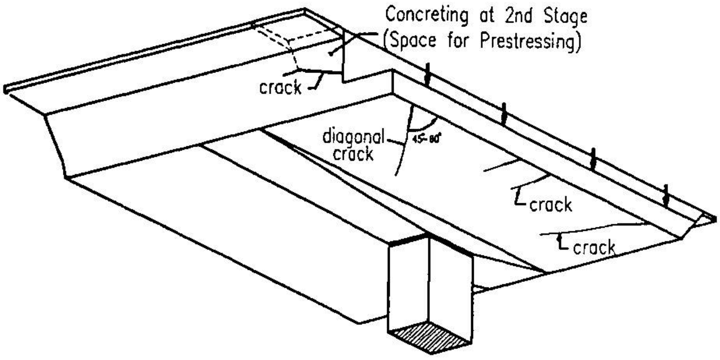

Figure 6. Cracks on Bottom of Connection Joint

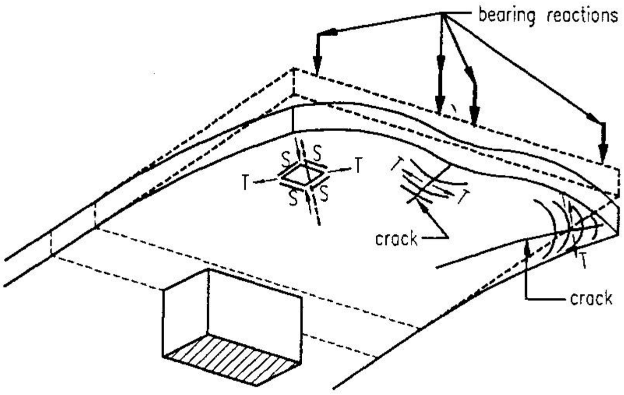

Figure 7. Cracks Caused by Principal Stress of Bearing Reactions

(3) Cracks on diaphragm: There were cracks on the bottom of girder diaphragm as shown in Figure 8.

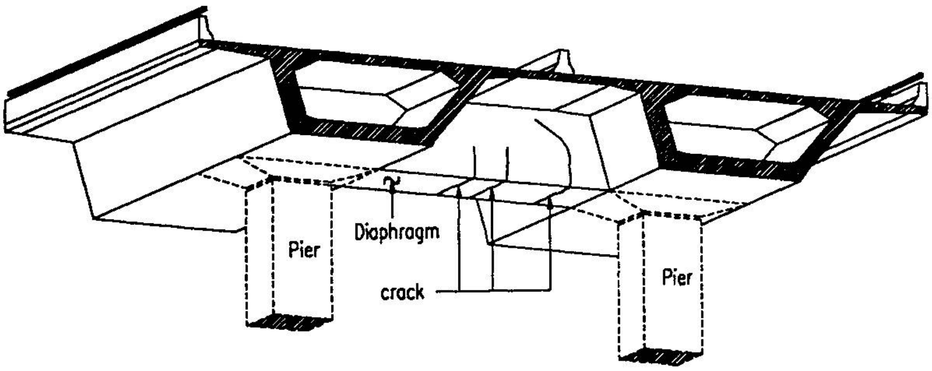

Figure 8 Cracks on Diaphragm

4. INSPECTION OF STEEL REBAR CORROSION

In general, the concrete is an alkali material, the rebar within the concrete should not be corroded unless the concrete is neutralized or the thickness of cover is not enough. The test results showed that the concrete of Chien-Kou Viaduct had a PH value around 10 and the average content of chloride was below 0.01%. No neutralization was observed and the concrete was sufficient to protect the reinforcement. However, there were still some minor corrosions found on the structure surface. They were summaried as follows:

(1) There were corrosions observed on the parapet and central barrier which and resulted in the concrete deterioration. According to a detail investigation, it can be concluded that the corrosion were caused by no enough cover thickness. One other possible reason was that it might be caused by the exhaust from the vehicles .

(2) Few rebars located on outer edge of bottom slab or middle web were exposed, but they were not serious corroded.

(3) There were large area of corrosion spots observed in the bottom slab of some box girders. An electromagnetic test was conducted to examine the thickness of concrete cover. The test results indicated the thickness was still sufficient to protect the rebar and there was no corrosion developed. The smear might be come from the formwork dirt in construction.

5. EVALUATION OF CORROSION RATE OF REINFORCEMENT

A specially designed corrosion monitoring probe was used to measure the corrosion rate of steel rebar within the concrete. The test was using a special device to measure the electricity in the rebar, and established the deterioration rate of rebar R (μm / year) to electricity I (μA) relationship as shown in Equation 1. Another one was established by using the take-core specimen. The rebar in the specimen was electrified to increase the corrosion rate and observed the crack propagation on the concrete cover. From those experimental data, the relationship among the corrosion quantity Q (μm) which caused the crack on concrete cover, cover thickness C and rebar diameter D can be determined as in Equation 2. According to these two equations, it can be estimated that there will be only few corrosions occurred in next ten years. Especially, no crack will be found in the high stress zone.

$$R = X * I \quad \text{(1)}$$

$$Q = Y (C / D)^m + Z \quad \text{(2)}$$

where X, Y, Z and m are constants

6. CONCLUSION

A series of comprehensive tests were performed to assess the safety and serviceability of Chien-Kou Viaduct. The test results showed that the concrete strength on the main structure was still fulfil the requirement and no severe corrosion was detected. Only some minor damages were found which can be easily repaired and the repairing work is under going now.

The corrosion spots observed on the structure surface was thought as a severe corrosion problem at first time. But after a further investigation, no corrosion was actually found. The test results could clarify the suspicious from the public.