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Structural Design of Liyutan Railway Bridge

Conception du pont ferroviaire de Liyutan

Projektierung der Liyutan – Eisenbahnbrücke

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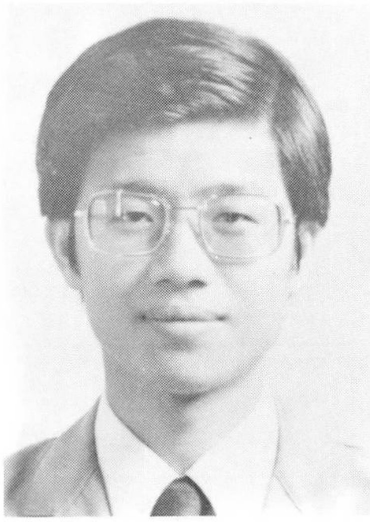

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SUMMARY

The Liyutan Railway Bridge, a continuous four-span, reinforced concrete bridge with an inverted Langer arch, will be the longest continuous rigid frame railway bridge in Taiwan after its completion. This paper describes such technical information as the member arrangement, structural analysis, seismic response and construction method for the bridge.

RÉSUMÉ

Le pont ferroviaire de Liyutan, un pont arc en béton armé continu sur quatre travées, sera le plus long pont continu sans appui glissant. Cet article décrit le système statique, le dimensionnement, le comportement au séisme et l'exécution de l'ouvrage.

ZUSAMMENFASSUNG

Die Liyutan-Eisenbahnbrücke, eine über vier Spannweiten durchlaufende Bogenbrücke aus Stahlbeton, wird bei ihrer Vollendung die längste festgelagerte Eisenbahnbrücke Taiwans sein. Der Beitrag beschreibt das Tragsystem, die Berechnung, das Erdbebenverhalten und den Bauvorgang.

1. INTRODUCTION

Liyutan Bridge, the main bridge in the extension project of the Taiwan Railway is located in the hilly region of central Taiwan. It crosses over a valley 740 meters in width and connects two tunnels one on each end. A design elevation with a value of about 40 meters across the width of the valley with a range of 400 meters will be used to design the bridge

In addition, the bridge is surrounded by beautiful, calm and peaceful mountain scenery. The construction of the arch bridge will attract more tourist to enjoy the scenic beauty of this region. At a distance of 4.5 kilometers from the bridge in this valley, a reservoir is being built. The region around the reservoir will also be developed into a recreational and tourist area.

During the planning stage, five types of bridge alternatives were proposed, as illustrated in Fig. 1. But after investigation and comparision with regard to structural appearance, durability, economic feasibility, construction method, etc. Type 1, the continuous, reinforced concrete, inverted Langer arch bridge, was chosen.

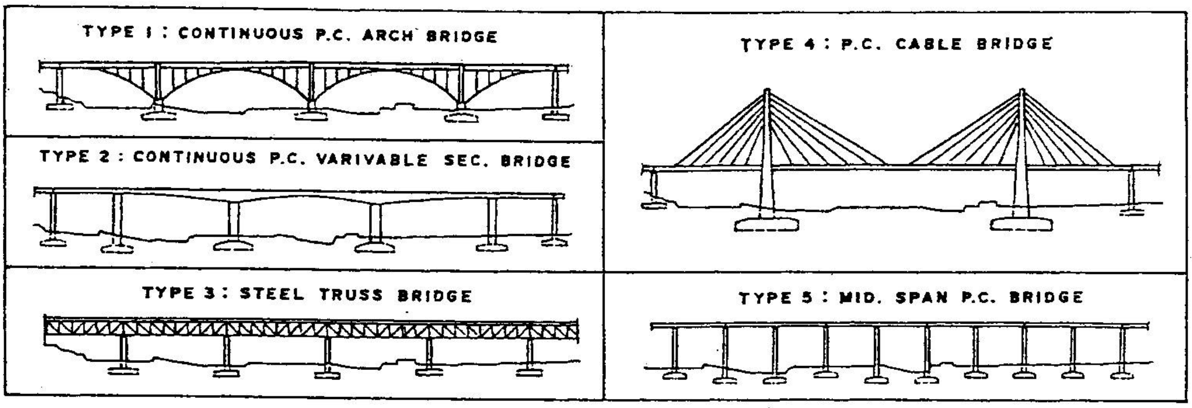

Fig. 1 Five bridge alternatives during the planning stage.

2. DESCRIPTION OF BRIDGE

The four-span bridge comprises two 134-meter central spans and two 70-meter side spans. Its general configuration is shown in Fig 2. Its box girder, supporting two railway tracks, will be supported by spandrel struts and arch ribs.

The box girder, besides resisting design moment after completion, is also designed with some prestressed tendons to satisfy the requirements in the segmental construction method. To reduce stress from creep and shrinkage and to increase the ductility of the bridge, the ratio of prestressed tendons will not be large. In addition, top slabs are prestressed transversely to reduce the self-dead load. To resist the shear and increase the durability during earthquake, the web thickness near by the pier column will be made larger than that in the center of the bridge.

Generally, a circular arc has been adopted for the arch rib as its fundamental configuration. However, curvature near by the pier column was modified following detailed analysis and comparison to reduce the moment and self-dead load in the arch rib and to exert the mechanical advantage of the arch bridge as a pure compression member.

In consideration of stability, spandrel struts are designed not only to satisfy all mechanic requirements, but also to fulfil the consideration of slenderness effect.

For increased durability, the outer bridge areas exposed to weathering will be painted with a layer of protective painting. In addition, a concrete strength higher than that of ordinary bridges will be adopted.

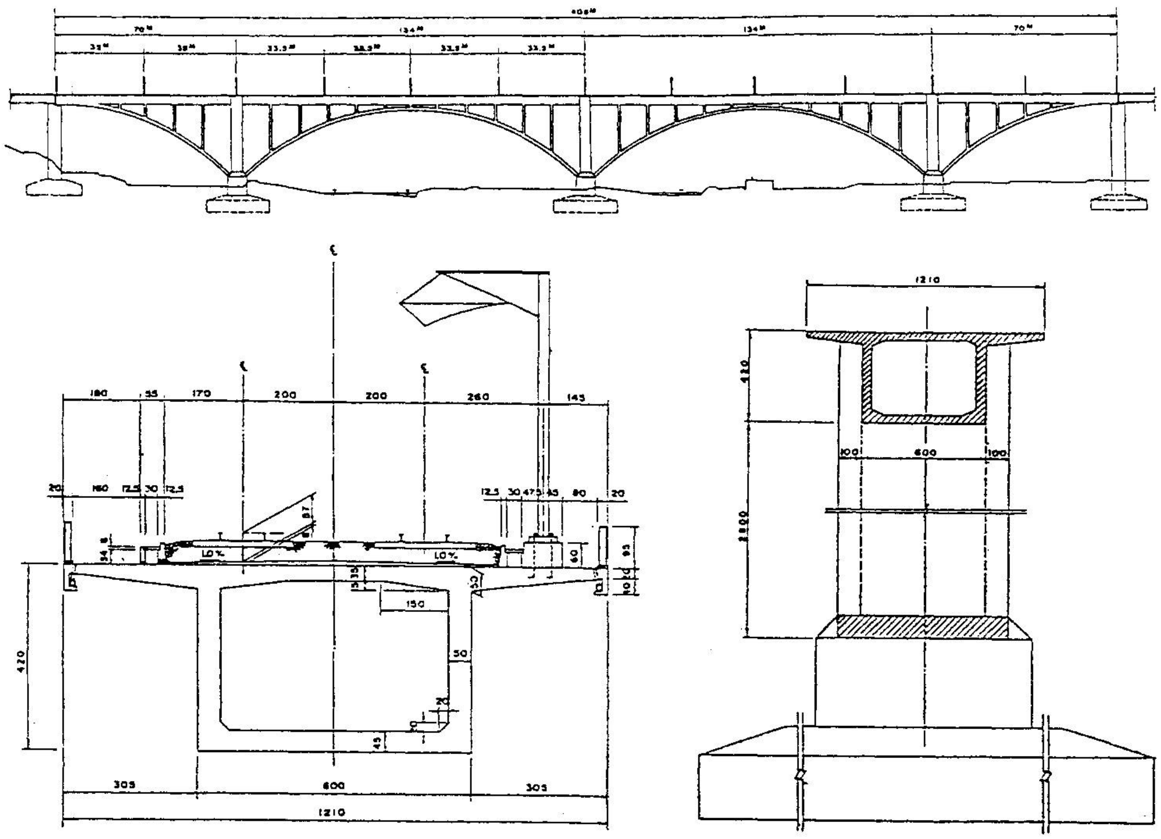

Fig. 2 General configuration of the bridge (Type 1).

3. STRUCTURAL ANALYSIS

Main design criteria and design data are illustrated in Table 1. Two-dimensional linear elastic analysis was employed to evaluate the sectional forces due to vertical loading, earthquake force, wind loading, creep, shrinkage and temperature changes along the bridge. Besides stress analysis of the bridge subjected to loading after completion, sectional forces from dead load during the process of construction will be calculated. Futhermore, the load carrying capacity of bridge will also be checked.

At present, electrified locomotives are used throughout the Taiwan Railway system. To avoid separation of electric cables from above the train, the railroad bridge must be designed with sufficient stiffness to limit the deflection and sidesway of the bridge. In addition, vertical deflection from vertical loading and horizontal sidesway from horizontal earthquake force as shown in Fig 3 and Fig 4 are limited to 0.84 cm and 9.6 cm, respectively.

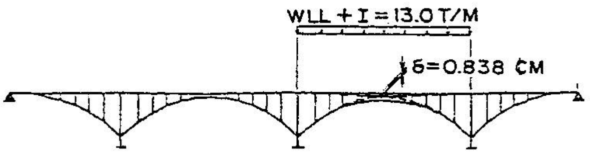

Fig. 3 Vertical deflection due to vertical loading (dead load and live load).

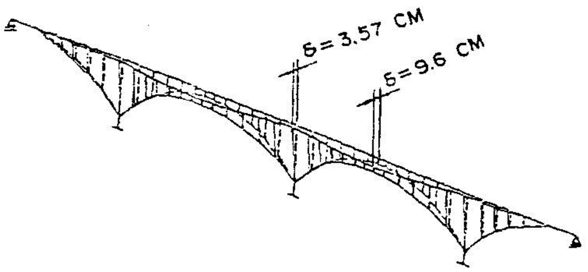

Fig. 4 Horizontal deflection due to horizontal earthquake force.

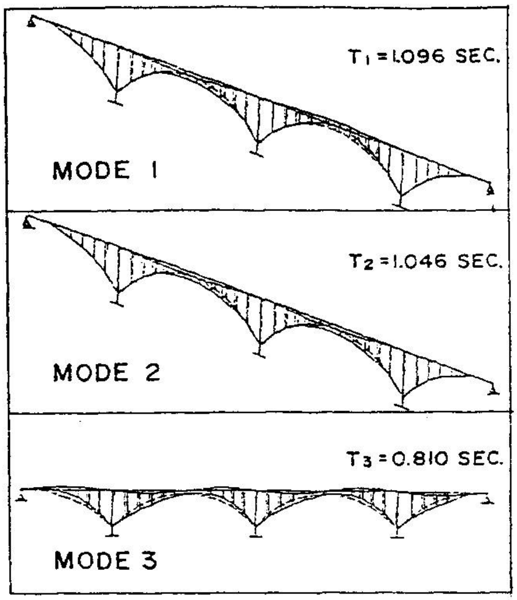

Fig. 5 The first three mode shapes and its natural period in the dynamic analysis.

Design Load	: KS 18	Concrete Strength	: f'c = 350 Kg/cm^2
Seismic Coefficient	: Kh = 0.25	Reinforcement	: fy = 2800 Kg/cm^2
	Kv = 0.10	Prestressed tendon	: f's = 19000 Kg/cm^2
Temperature Change	: ± 15°c	Creep coefficient	: Ø = 2.6
Design Wind Speed	: 65 m/sec	Shrinkage strain	: ε_s = 2.0x10

Table 1 Design data.

4. SEISMIC ANALYSIS

According to seismic records, the proposed site is located in a seismically active region. For example, one destructive earthquake with a magnitude of M 7.2 took place within a distance of 20 kilometers from the bridge site in 1935. In order to study the dynamic behavior of the bridge, seismic analysis was performed. The first three mode shapes and their natural periods are shown in Fig 5. From dynamic analysis, a design seismic force coefficient of 0.25 was decided for the earthquake design.

5. DESIGN OF FOUNDATION

According to the results of geologic investigations, a gravel layer with a thickness of 12 meters underground was found near Liyutan Bridge. Under the gravel layer is a layer of sandstone. Hence, the bearing capacity of the soil in the site is good. Therefore, spread footing is to be used as the foundation for the bridge.

6. CONSTRUCTION METHOD

The Cantilever Segmental Construction method with a moveable wagon mounted on the main girder will be used during erection. Through this method, the main girder, the arch rib, and the vertical struts may be erected without use of support. The erection sequence is shown in Fig 6.

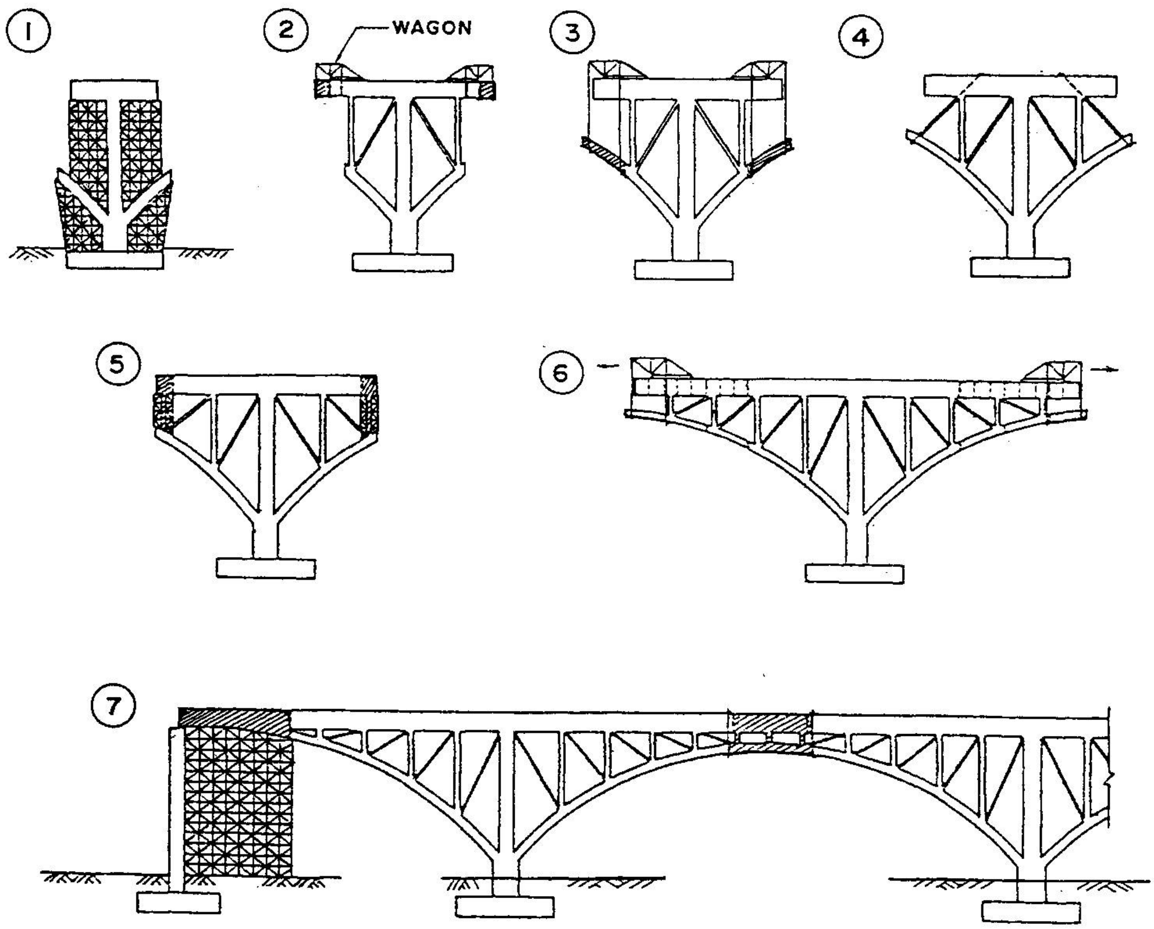

Fig. 6 Erection sequence (1. Erection of pier column and first segment. 2. Erection of box girder with moveable wagon. 3. Erection of arch rib with wagon. 4. Placement of oblique constructional PC steel bars. 5. Erection of spandrel strut. 6. Repetition of process from stage 2 to stage 5. 7. Erection of arch crown section with hanging support and end side section with temporary support.).

7. CONCLUSION

Data collection and planning of this project started in Oct. 1987. The final alternative was selected and designed in 1988. Construction is planned to begin in May 1989 and all works are to be finished within 36 months. Fifteen months were used to complete the design work, from the time of planning to the time of finish. During the design process, all factors such as structural appearance, strength, durability, economic feasibility, construction method,etc. were considered thoroughly.