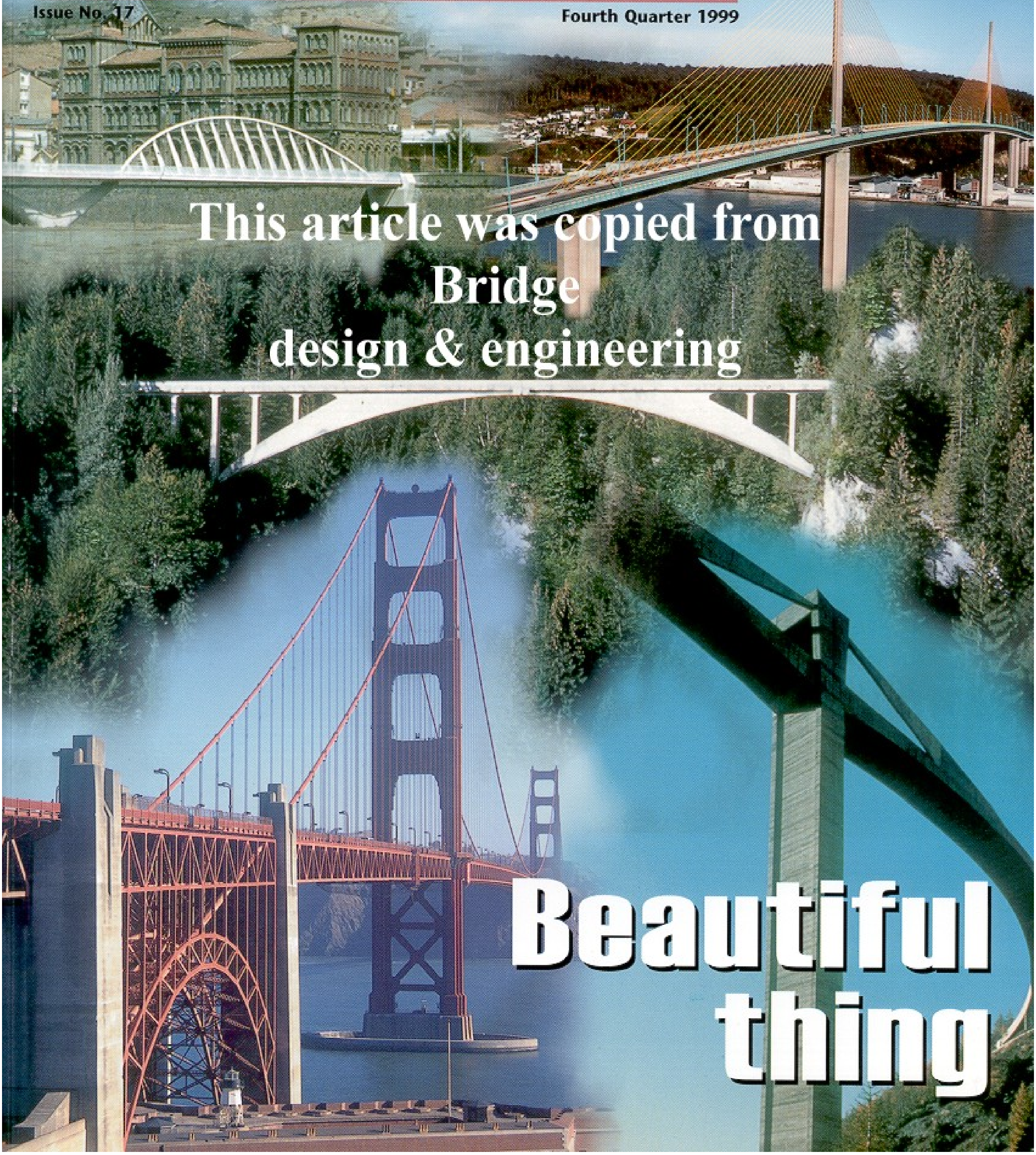
THE DEFINITIVE PUBLICATION FOR BRIDGE PROFESSIONALS WORLDWIDE

Bridge

design & engineering

Issue No. 17

Fourth Quarter 1999



Beautiful thing

Fast forward

The bridge will carry the new freeway which runs between Taipei and Kaohsiung

Detailed design Analysis on a new cable-stayed bridge just completed in Taiwan was carried Out in only two and a Half months, reports *Heinz Pircher*

A new freeway is being built from Taipei to Kaohsiung in Taiwan, and some 35km from Kaohsiung the road will run across the Kao Ping Hsi Bridge. Central to the crossing is a cable-stayed bridge with a main span of 330m, served by approximately 2km of approach viaducts.

The overall dimensions of the cable-stayed bridge had already been set in the preliminary design, but UK consultant FFF-3F Engineering and German specialist TDV were employed by the contracting consortium to carry out the detail design, the structural analysis and address all construction stage and erection issues arising during construction.

The final stage structural analysis, for both the cable-stayed bridge and the approach viaducts, was performed using the software system RM-Spaceframe. Construction stage analysis also used this system, and the effects of any variations in the loading conditions during construction were continually monitored using the system. Construction has just been completed.

The main bridge has a single pylon 183m high, with a two-span girder of lengths 330m and 183m and two lots of 15 pairs of stay cables. The two spans of the box girder bridge deck are 34m wide; the main span is a multiple cell steel box girder, and the back span is made of pre-stressed concrete. The difference in weights means that the two spans are balanced.

Construction of the superstructure began with simultaneous construction of the concrete pylon legs and the pre-stressed concrete girder. The latter was built over seven temporary piers in a span by span process; the central box being cast first and the cantilever slabs added later. Once the back span was complete, the structural steel sections were erected in 20m long segments. These were assembled close to the pylon and then raised and transported to the front end of the cantilever and lifted into place. Cables were installed at this stage and the upper half of the pylon was built at the same time.

The pre-stressed concrete deck is essentially a composite structure due to the fact that it was built in two stages; the effects of creep and shrinkage had to be considered as a redistribution of the forces would have been induced between the box section and the cantilever slab. Both external and internal pre-stressing tendons were required - the former for construction, the latter for the final stage requirements.

Many different locations for the temporary steel towers had to be investigated in the analysis of the construction stages to find the best solution for reducing impact on the existing road below. A decision on the final position of the towers was not made until seven on the after the start of construction. Once this had been made, the final construction analysis could be carried out - it had to be done in just two and a half months.

The lower part of the pylon was erected at the same time as the pre-stressed concrete deck and when they had been connected the erection of the upper pylon could be synchronised with the cantilevering of the steel deck and the application of the stay cables. This process involved a sequence of 42 stages which had to be simulated in detail by the software; such detailed analysis was necessary to get complete information about the pre-camber requirements during construction.

Each stage in the steel deck erection sequence had to be precisely defined for the construction stage analysis. Once a segment had been erected, the derrick crane which had lifted it into position was moved to the end of the new segment. Stay cables supporting the new segment were tensioned, then the next segment was brought from the pylon by the hanging carrier and was lifted into place by the derrick crane. The same sequence of events was repeated for each segment.

Once the entire steel deck was in position, the derrick crane and hanging carrier had to be removed, as did the temporary steel towers supporting the concrete back span.

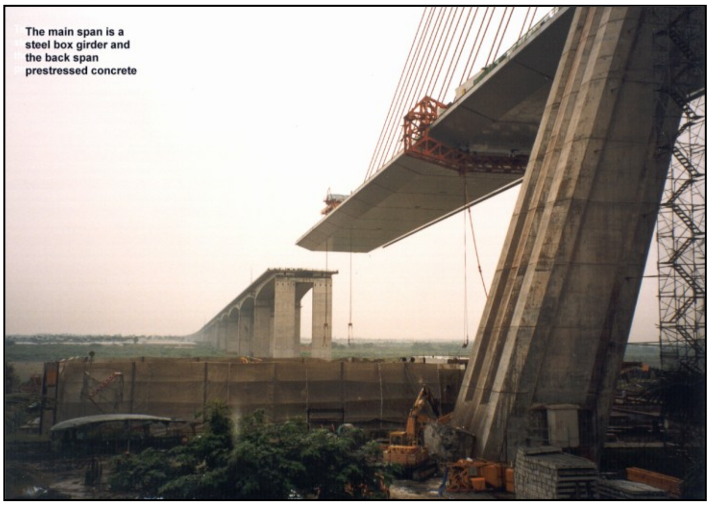
CLIENT:
Second Freeway Bureau Taiwan

PRELIMINARY DESIGN:
CECI, VCE

CONTRACTING CONSORTIUM:
Taisei, Kawada, Pan Asia, Raito

CONTRACTORS CONSULTANTS:
FFF-3F Engineering Consultants, TDV

CABLE SUPPLIER:
Vorspann Technik Austria



The main span is a steel box girder and the back span prestressed concrete

Additional permanent loads had to be applied, temporary pre-stressing of the concrete back span removed, and concrete deck diaphragms pre-stressed. As well as all these construction stages, the effects of creep and shrinkage to infinity had to be considered in the analysis.

In defining the tensioning strategy for the stay cables, one important issue was to find a sequence which would result in similar internal forces in the deck and pylon structures to those achieved in the preliminary design. Large differences would have forced considerable modifications to the dimensions of the structure defined in the tender design. The solution to this problem was implemented in the RM computer program. In a non-hybrid structure considering first order theory only, this process would lead to a straightforward solution of a set of linear equations. But the Kao Ping Hsi bridge is a hybrid structure and so creep, shrinkage and second order theory had to be taken into account, resulting in a non-linear problem requiring a highly sophisticated iterative solution process. The final computer solution verified that a one-stage stressing sequence was possible; and a check of all intermediate stages verified that no unacceptable conditions such as compressive cable forces, excessive uplift forces at the supports, or excessive stress levels would occur.

Possible effects of creep and shrinkage were of utmost importance and took two forms. The first is the initial stress/strain and time dependent stress redistribution for all concrete and composite sections, mainly in the concrete backspan and the pylon anchorage zones.

Due to the change of the statical system during the construction process, creep and shrinkage also have a considerable influence on the overall structural system including all the steel parts. A powerful time-stepping algorithm was implemented in the software to simulate all these phenomena in a very detailed way.

An economic design of a cable-stayed bridge requires that the bending stiffness of the bridge deck is used to achieve an efficient distribution of the loading to the stay cables. On this bridge it was achieved by imposing an appropriate pre-deformed shape to the whole bridge deck.

This aspect was included in the pre-camber calculation. The final result of this analysis was in three parts. The first part was the camber diagrams, showing the pre-camber for the whole structure and the actual position of all segments in each individual construction stage. Secondly the detailed geometry of all segments was carried out taking into account and compensating all deformations arising between the assembly of the segment and the final stage. Finally the stress-free prefabrication shape was built up from the above fabrication shapes for the individual segments.

Heinz Pircher is a partner at TDV