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Autor: Wenzel, Helmut

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Verifying Computer Models of Bridge Foundations

Helmut WENZEL
Dr.-Ing.
Vienna Consulting Engineers
Vienna, Austria

Helmut Wenzel is a member of WC V of IABSE. He earned a Ph.D. in Bridge Construction from the University of Vienna in 1978 and is the Managing Director of VCE, with offices in Vienna, Taiwan and Korea. Dr. Wenzel also teaches Bridge Design and Construction at the University of Vienna.

SUMMARY
The results produced by Computer Models are governed by the boundary conditions introduced by the Engineer. It is common practice to define springs that describe the behavior of the foundation. In most of the cases it is assumed that the foundation is rigidly connected to the ground. Actually soil structure interaction practically occurs in every project and may change the results considerably. To verify a computer model monitoring of the vibrational behavior of the structure might be applied. By the application of System identification technologies the real behavior of the structure is determined and information on the acting boundary conditions is achieved. This state of the art technology has been developed recently. One example of application is provided in this paper.

1 KAO PING HSI BRIDGE

The Southern Second Freeway, which extends from Kaoshiung to Ping Tung crosses the Kao Ping River along it's route. A major bridge project is required to span this wide and, under Typhoon conditions, violent river. The total length of the required bridge is 2600 meters with a major span crossing the river bed. The proposed **Kao Ping Hsi Bridge** was designed to fulfill the traffic requirements in an environmentally sensitive way.

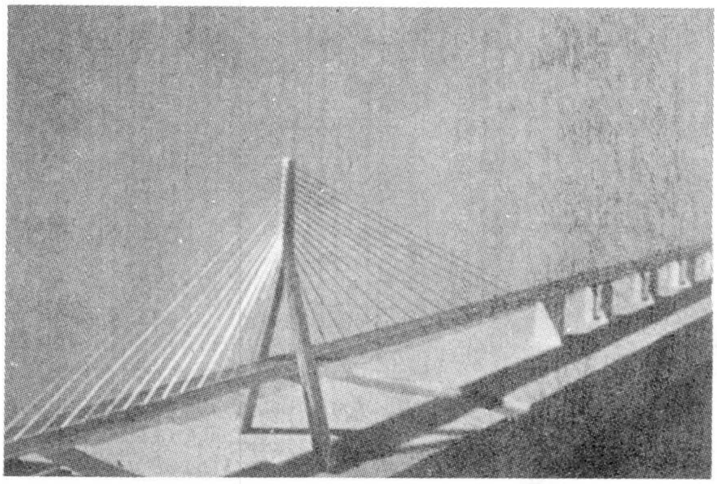

Fig.1 Kao Ping Hsi Bridge

The proposed structure is a cable stayed bridge with an unequal span arrangement. The best location for the pylon was determined with respect to geometry and the relation of the structure to the natural environment. This produces a final side span length of 186 meters. For a perfect geometrical balance the main span was chosen to be 330 m. This is also appropriate relative to the height of the structure, which is an average of 45 meters above the ground.

The height of the pylon was fixed at 180 meters. For aesthetic and balancing reasons, it was decided not to use anchor piers in the side spans. This makes the structure unique and one of the largest asymmetrical cable stayed bridge in the world.

To help balance the span, it was decided to use a concrete deck for the side span and the steel deck for the main span. Fourteen pairs of cable support the structure in a semi-fan arrangement. The cables are anchored on both ends and the distance between cables was chosen to maximize utilization of the deck's bending capacity and optimum stabilization of the pylon.

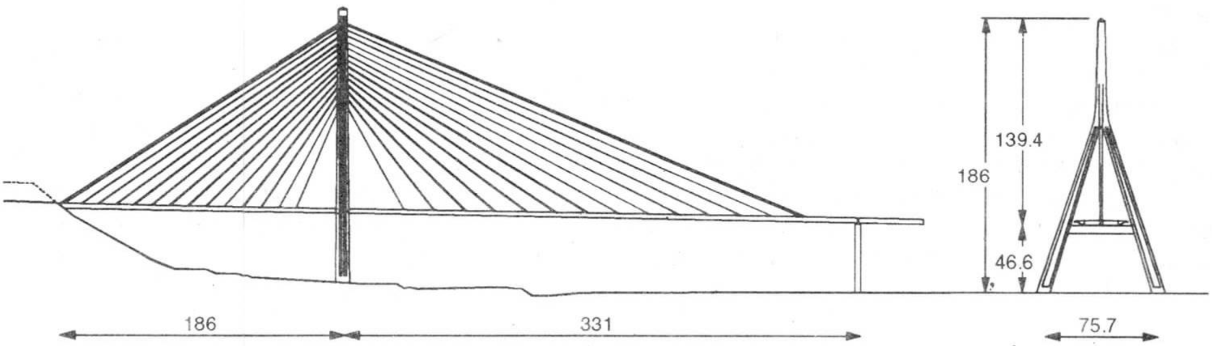

Fig.2 Bridge Elevation

2 PYLON FOUNDATION

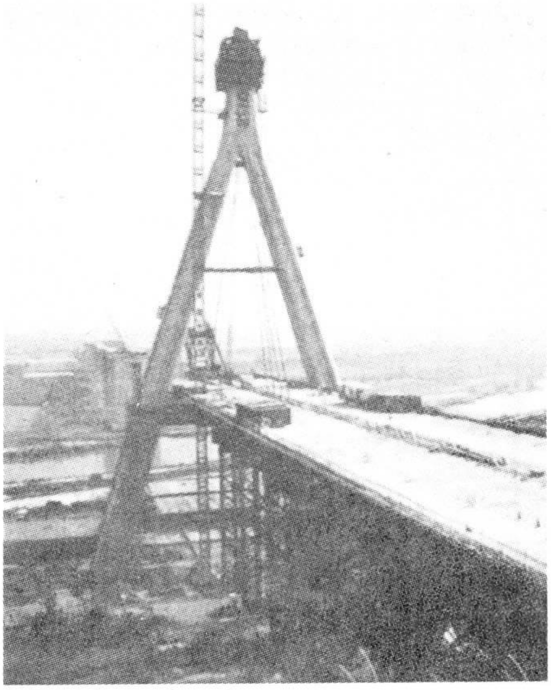

Fig.3 Kao Ping Hsi Pylon

In the course of the preliminary design, two variations were considered for the pylon foundation; one foundation with slurry walls and the other with piles of ∅ 1.50 m. Under the observance of the dispersing forces, as well as the scouring, an efficient comparison of both variations was executed, whereby it was shown that a slurry wall foundation is the more favorable solution from the economic point of view. Additionally, this system results in a substantially greater security of the foundation elements.

The basic principle of the foundation in the presence of the soil types as determined by the borehole samples, is that:
The soil within the foundation elements is enclosed through the slurry wall, the normal forces are dispersed correspondingly during lateral friction, and, through the corresponding stiffening of the slurry wall elements, as also through structural design of the individual elements, an optimal dispersal of the horizontal forces in a normal loading condition, as well as in an earthquake loading condition, is secured.

There are two proposals: one for slurry walls with a diameter of 0.80 m, and the second for slurry walls with a diameter of 1.20 m.

2.1 Basic Concept

Normal forces and both shear forces and bending moments each acting in the longitudinal as well as the lateral direction of the bridge, occur at the underside of the foundation slab.

2.2 Normal Forces

The dispersal of the normal forces results during lateral friction, whereby the lateral friction begins at a level of +11.0 m. This measure takes under consideration complete scouring in the event of a catastrophe. The lateral friction itself is applied internally and externally, whereby the spacing of the individual elements amounts to a minimum of three times the width of the element's cross section. The value of the lateral friction amounts to 65 kN/m^2. This value follows from accumulated values based on borehole samples and results of the Standard Penetration Tests.

Fig.4 Foundation

2.3 Shear Forces – Longitudinal Direction

Shear forces in the longitudinal direction of the bridge are dispersed over an elastic bedding at the base. For the normal loading condition, a bedding according to the figure below is considered. Additionally it is important that above all a corresponding safety factor is given for the earthquake loading condition in relation to the possible passive soil pressure. For the earthquake loading condition itself, a full scouring must not be considered alone. Moreover, the possible passive soil pressure at total scouring plus earthquake loading was also analyzed, thereby showing that nevertheless the second degree safety factor is still present.

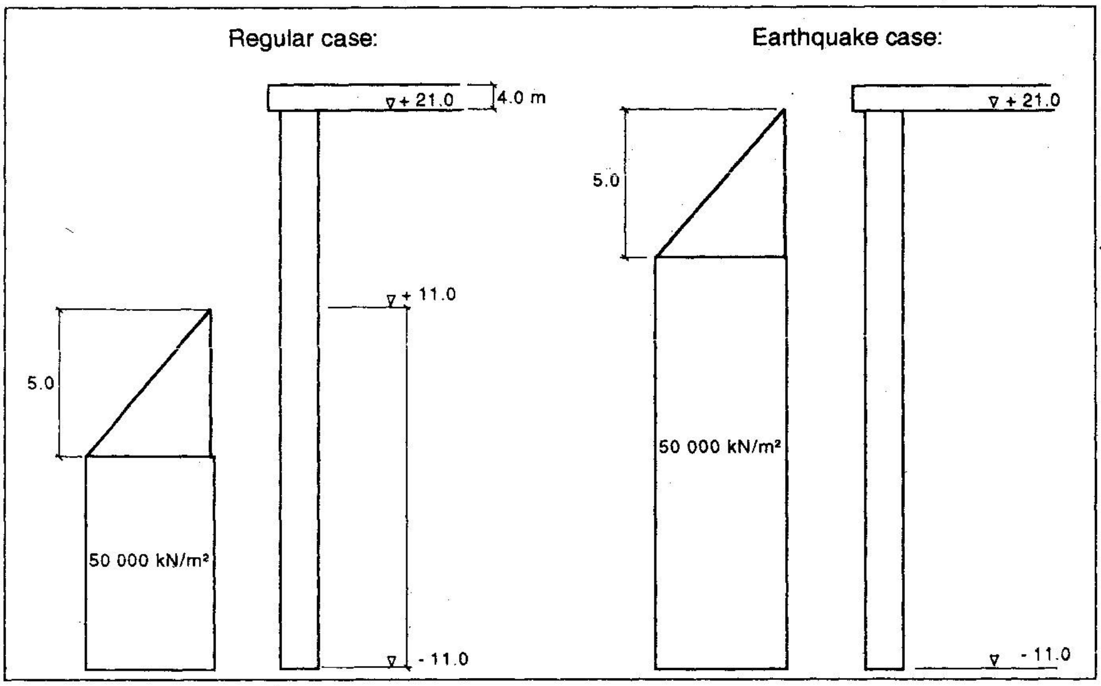

Fig.5 Horizontal bedding – pylon

3 VIBRATION CHARACTERISTIC METHOD

Each structure has its typical dynamic behaviour which may be addressed as „Vibrational Signature". Changes in a structure such as all kinds of damages leading to decrease of load-carring capacity have effects on the dynamic response. This suggests the use of the dynamic response characteristic for evaluation of structural integrity. Monitoring of measurements of the dynamic response of structures makes it possible to get very fast knowledge of their actual condition.

The process of elaborate instrumentation, measurement and analysis of dynamic response data supplemented by immediate or long-term maintenance and rehabilitation programs can be considered as „health" monitoring and diagnostic operations.

The development of a - for the user simple and cheap - method for permanent control of the state of preservation based on the dynamic behaviour of structures makes access to a couple of specialized know-how necessary.

Before the installation of measuring instruments analytic investigations have to be done. Therefore the knowledge of the dynamics of structures is used and adapted to the particular problems. Several dynamic calculations of large complex civil structures especially bridges have been done by many research institutes and are reported in technical journals and on workshops.

The outcome of these calculations is the theoretic dynamic behaviour of the analyzed structures which makes the development of special measuring programs possible. Among dynamic measurement units some measuring instruments for registering environmental influences such as for example temperature will be necessary.

4 INSTRUMENTATION AND MEASUREMENT

Already during design it was decided to instrument the bridge at construction and after completion. This includes a number of strain gages for permanent installation and a number of accelerometers for temporary use and final installation in the structure. The main purpose was quality control and system identification for the calibration of the Computer models.

For the verification of the soil springs in the Computer model the Eigenfrequencies and Eigenmodes of the free standing pylon were determined. The first measurement was taken when an elevation of +45 meters has been reached. At this time the high rigidity of the structure required amplification of the ambient signals for correct computation. Nevertheless the required results could be obtained at the correct spring value could be determined.

Location	Theoretical frequency	Measured frequency	Difference
At level +45 m	5.66 Hz	5.21 Hz	-8%
At level +120 m	1.22 Hz	1.09 Hz	-11%

These values are given for the most effective natural frequency measured. The spring values determined from this measurement has been tried with the Computer model and the real displacement of the pylon under the load of the first cable has been measured. The results matched within 10% accuracy, which is very good.

5 CONCLUSION

System identification technology can help to calibrate Computer models accurately. Particular in case of very flexible structures this tool becomes helpful for the designer to adjust his calculation and detect deviations from the normal conditions. Further development is put into more elaboration of the method by the European Union and tools applicable for everyone will be available soon. In some cases it will lead to cheaper solutions in the foundations because the reserves, not activated until now and covered by high safety factors, might be touched in future.

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