Bridge Accessories

Nr. 34
VLE / VBA
11 / 2000
1 / 7

Head Office
P.O. Box 440145, D-80750 München
Frankfurter Ring 193, D-80807 München
Phone (089) 3 23 94-0
Fax (089) 3 23 94-329

Branch Office
P.O. Box 63 40, D-44520 Lünen
Zum Holzplatz 2, D-44536 Lünen
Phone (0231) 4 34 01-0
Fax (0231) 4 34 01-11

Subsidiary Plant
P.O. Box 55, D-02992 Bernsdorf
Kamenzer Str. 4 - 6, D-02994 Bernsdorf
Phone (035723) 237-0
Fax (035723) 237-20

MAURER Info

Description of two Seismic Protection Systems at Bridges

In the field of seismic engineering, in the last 25 years considerable progress was made. On the one hand, this progress is based on newly developed construction methods, and on the other hand on suitable seismic devices.

Particularly to be mentioned as construction methods are the seismic isolation of bridges and the energy concept.

The 2 case studies described below serve as typical examples for the successful application of the respective construction method applied.

LOCICA VIADUCT

1) General

The Locica Viaduct near Ljubljana in Slovenia represents the first application of a total seismic protection system for bridges that was provided by MAURER SÖHNE.

The expression *Seismic Protection System* hereby comprises the total of the bridge accessories employed (expansion joints; bearings and / or isolators; dampers; shock transmitters). The appropriate selection and dimensioning of these seismic devices as well as their proper location are set to prevent damages of the bridge structure in case of the design earth quake.

2) Bridge Structure

The Locica Viaduct consists of 2 separate and nearly straight bridge decks with a length of 849 and 869m. The bridge decks are subdivided in 11 segments of a length between 50m and 125m. The variable height of the piers lies between app. 15m and 39m (see fig. 1).

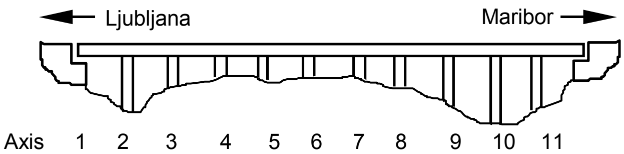


Fig. 1: Schematic Side View of Locica Viaduct

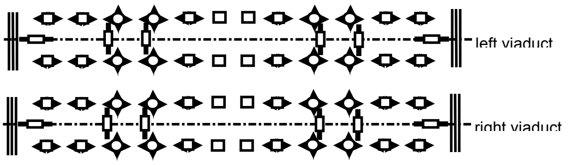
MAURER SÖHNE
Innovations in steel
Since 1876

The superstructure consists of a hollow segment made of prestressed concrete, at a total width of 13m and a height of 3.50m to 6.50m.

3) Arrangement of the Seismic Devices

The seismic devices that were proposed by MAURER SÖHNE and were accepted by the client use the particularities of the Locica Viaduct in an optimal way. These particularities are represented in the fact that the lowermost piers are situated in the centre of the bridge structure (see Fig.1), whereas the abutments employ a relatively weak load carrying capacity.

As for the arrangement of the seimic devices, see Fig.2.



Elastomeric Bearings sliding in longitudinal direction, and deforming in cross direction, Type VGE2

Elastomeric Bearings deforming in all directions, type V2

Pot bearings sliding in all directions, Type TGa

Hydraulic damper Type MHD

Expansion Joint Type Swivel Joint

Fig. 2: Arrangement of the Seismic Devices

The 4 basic functions of a seismic protection system were realised as follows:

- Transfer of the vertical forces and cross resilience by means of horizontally deforming (central piers 6 and 7) as well as longitudinally sliding (abutments plus piers 2, 5, 8 and 11) elastomeric bearings to be used as isolators plus multidirectionally sliding pot bearings (high piers 3, 4, 9 and 10);

- Isolation of the bridge deck from the substructure by means of the bearings mentioned above;
- Restoration of the location of the bridge deck during and after an earth quake by means of the elastic reaction forces that are activated in the elastomeric bearings when they are subject to shear deformation.

- Energy dissipation by means of hydraulic dampers, which act in longitudinal direction at the abutments, and in cross direction at the high piers 3, 4, 9,and 10.

In addition, the hydraulic dampers had to accomplish the following functions:

- those situated at the abutment will additionally perform as shock transmitters for the service loads, which means that the superstructure will not move in longitudinal direction due to braking forces, and movement only will occur in case of earth quake,

- those situated at the piers will act as a stiff support in cross direction up to a certain limiting force. Which means that the superstructure will not move in cross direction due to wind loads, and movement will occur only in case of earth quake.

- in addition, all dampers act as load delimiters, which means that the restraining moment at the foot of the piers as well the strain at the abutments will be exactly defined, to be independent from the actual seismic strain.

4) Description of the individual seismic devices

Description of two Seismic Protection Systems at Bridges

The individual seismic devices mentioned above lead to an effective seismic protection of the bridge structure, which is achieved by their cooperation in case of an earth quake, and their location.

Bridge bearings to be employed were conventional pot bearings, elastomeric sliding bearings and elastomeric „fix" bearings (i.e. deformation by shear). Loads were between 4,100kN and 25,500kN.
The elastomeric pads of the (elastomeric) deformation bearings were made of high quality natural rubber, being additionally coated by a layer of ageing-resistant chloroprene rubber. Damping effect of the elastomeric bearings was assumed to be 5%.

The pot bearings are multidirectional sliding and were preferred to the elastomeric bearings because of the high vertical loads at the axes 3,4,9, and 10.

At the axes 1, 3, 4, 9, 10 und 12 MAURER SÖHNE employed specially developed hydraulic dampers, which are connected to the bridge deck at one side, and with their other side at the piers, or at the abutments respectively. These dampers transform the energy strain of an earth quake that is introduced into the bridge structure into heat. Thus, this dissipated energy is kept away from the bridge structure, preventing damages.

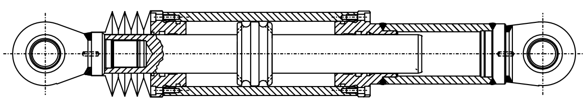


Abb. 3: MHD Hydraulic Damper

The dampers at the abutment consist of a tube in which a piston can move. The spaces before and behind the piston are filled with silicon oil. Both spaces are connected by means of openings. In case very slow movements will occur between substructure and superstructure, e.g. due to shrinkage, creep or temperature changes, the piston will be moved in the damper, and the silicon oil can flow without resistance from one side of the piston to the other side. (=> see part 1 in Fig. 4). The damper will not return noticeable reaction forces. However, if movements occur of more than 0.1 mm / s, not enough silicon oil will stream from one side to the other, which results in the formation of compression in the damper (=> see part 2 in Fig. 4), because the piston wants to move, but is prevented to do so by the silicon oil.

In case a certain predefined compression force is surpassed, again silicon oil will flow from one side of the piston to the other, resulting in a movement of the damper. (see part 3 in Fig. 4).

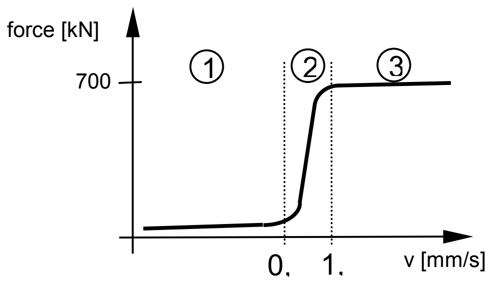


Fig. 4: Force-Velocity-Diagram of an MHD

During the course of the flow of the silicon oil through the openings under high pressure, this silicon oil will become hot. This way, the energy that is imposed on the damper by means of movement of the bridge deck, will be transformed into heat, i.e. dissipated, and thus kept away from the bridge structure.

A particularity of the damper is its damping exponent (α), to be 0.015. In considering the formula for the reaction force of the damper ($F = C \times v^{\alpha}$), it becomes clear that a damper with such a small damping exponent always will provide a nearly constant reaction force, independent of the velocity. Such an optimal functionality to be provided at any velocity, to be added by a high efficiency of up to 96%, guarantees a best possible protection against seismic strains. During an earth quake, all elastomeric bearings will be subject to shear deformation in cross direction, and apart from a resulting isolation of the bridge deck, the activated restoring forces of the bearings due to shear deformation will restore the bridge deck back to its original position.

Description of two Seismic Protection Systems at Bridges

Due to the fact that pot bearings do not provide this functionality, additional dampers were placed on their piers in cross direction. These pier dampers are different from the dampers at the abutment, because they totally block any movement below a defined energy input or external force. In other words, the piston will not move even at velocities below 0.1mm/s. If now within the damper compression will be constituted due to external energy input, as this is the case during earth quake, the hydraulic valves will open, to be similar to the dampers at the abutment, the pistons start to move, and energy will be dissipated.

Fig. 5 shows the reaction force of the damper located at the abutment, as a function of the velocity. The area of the hysteresis loop provides information about the dissipated energy, and the form of the hysteresis loop provides information about the degree of efficiency.

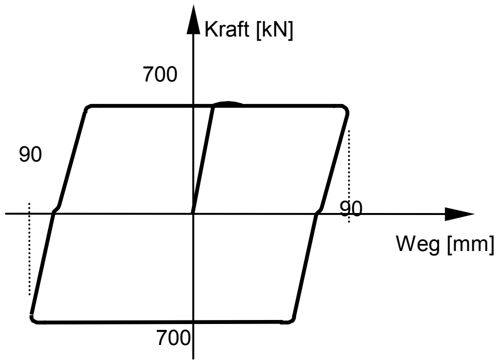


Fig. 5: Hysteresis loop

The consequent application of the isolation of the bridge structure not only in longitudinal direction, but also in cross direction, leads to considerable movements of the bridge structure.

For this reason, at both abutments swivel joist joints were used. Such expansion joints cater for unrestrained and unlimited movement in cross direction, and still be passed by traffic.

5) Structural Analysis

The performance of the bridge structure together with bearings, dampers and expansion joints, was analysed by means of a non-linear finite-element-analysis, with the design earth quake as input. The results have shown that in combining elastomeric bearings and hydraulic dampers, optimal protection against earth quake can be achieved.

In particular, in respect to the critical restraining moments at the foot of the piers, additional safety reserves were created.

The seismic protection system was designed such that that maximum horizontal movements occur almost in same magnitude in all directions (+/- 100 mm), in other words the bridge structure reacts in a very balanced way.

The dynamic structural analysis showed that 2 pairs of elastomeric bearings that deform in all directions and that are located on the 2 central piers, will provide the necessary restoring forces to prevent or at least to limit cumulated translations and maximum movement peaks during and after the design earth quake.

All bearings, dampers and expansion joints are designed in a way that in case of the design earth quake to come, no damages will occur at both the bridge structure and the seismic devices.

Description of two Seismic Protection Systems at Bridges

Fig 6: Locica Viaduct under Construction

METRO BRIDGE OVER SEYHAN RIVER

1) General

A further example of a seismic protection system delivered by MAURER SÖHNE is the Metro Bridge in Adana, Turkey. Also in this case, a very ingenious *seismic protection system* will prevent damages resulting from a design earth quake.

2) Structure

The Seyhan Metro Bridge is a steel bridge with a length of 180m, with 2 railways for the City Metro in Adana. The 3 spans are 50m (at the respective edges) and 80 m (in the centre) . Height of the piers is app. 10m.
The superstructure consists of 4 continuous girders with a height of 2m at the abutments and 4m on the 2 piers. These continuous girders are connected by means of struts. The total width of the bridge is 9.5m.

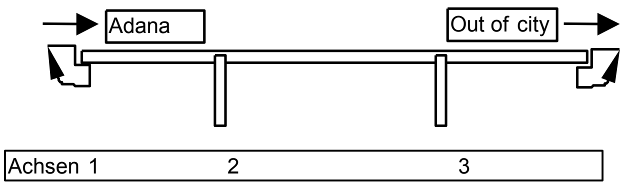
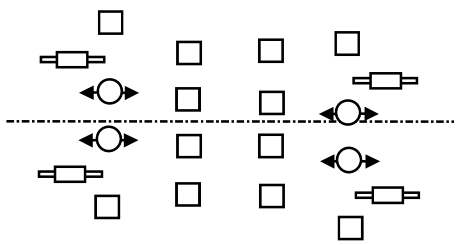


Fig. 7: Statical system of Seyhan Metro Bridge

3) Arrangement of Seismic Devices

The seismic isolation system employed was fine tuned to the requirements of the bridge structure in many sessions with the design engineers, and finally approved by the project owner.



Elastomeric bearings deforming to all directions

Pot bearing sliding longitudinally – fix in cross direction

Hydraulic damper

Fig. 8: Seismic Protection System

The 4 basic functions of a seismic isolation system were realised for the Seyhan Bridge as follows:

- Transfer of the vertical forces and resilience in cross direction to be accomplished with deforming elastomeric isolators on the 2 piers, as well as 2 longitudinally sliding pot bearings plus deforming elastomeric isolators on the 2 abutments;
- Isolation of the bridge deck from the substructure by means of the bearings described above. However, the longitudinally sliding pot bearings prevent a movement in cross direction at the abutments because in consideration of the rail tracks this would not be acceptable;
- Restoring of the bridge deck into its initial position during and after an earth quake by means of the elastic forces that are activated when the elastomeric bearings are subjected to shear deformation.
- Energy dissipation by means of 2 hydraulic dampers at each abutment, acting in longitudinal direction.

The Hydraulic Dampers were designed to additional functionalities, which were requested by the client:

- all dampers also react as shock transmitters for service loads, which means that the superstructure will not move due to braking and acceleration forces of the trains, and only in case of earth quake the damper will be subject to movement;

- all dampers additionally serve as load delimiters, which means that the load impact upon the abutment is exactly defined to an upper limit, and independent from the magnitude of the earth quake.

4) Description of the individual seismic devices

Like in the case of the Locica Viaduct, the aforementioned seismic devices guarantee an effective seismic protection of the Seyhan Bridge.

The bridge bearings applied were designed for vertical loads of 1,400kN at the abutments, and 5,700kN at the piers. Also in this case, the elastomeric bearings made of natural rubber were coated with an additional layer of ageing-resistant chloroprene rubber.

Similar to Locica Bridge, both abutments were provided with dampers of a maximum of 780kN reaction force. They were connected with the abutment at one side, and with the bridge deck at the other side. Function and characteristics of the Seyhan dampers correspond to the aforementioned longitudinal dampers at the Locica Viaduct.

Fig. 9: Installed MHD in Seyhan Bridge

Due to the rail tracks, the Seyhan Bridge could only be consequently isolated in direction of the bridge axis, because the project owner did not tolerate movements in cross direction of the bridge. For this reason, the pot bearings were designed to horizontal loads of 1,400kN per bearing.

The project owner did not wish to use an expansion joint in this case, and covers the structural gap with a steel plate.

5) Structural Analysis

The behaviour of the bridge structure was analysed by means of a non-linear finite element analysis, and also in this project the results have shown that the applied seismic isolation system will comply to indispensable requirements of railway briges, in particular to mention the maximum movement of the bridge deck in longitudinal direction of +-5 cm

Description of two Seismic Protection Systems at Bridges

The installed seismic devices very effectively limit the movement of the bridge structure in case of earth quake to +/-35 mm, with considerable amounts of energy to be dissipated in the dampers, taking care that during an earth quake both the Seyhan Bridge and a train passing the bridge will not suffer damages.

Thus, after a design earth quake no repair of the bridge will be required.

The 2 aforementioned case studies were followed by additional numerous projects that employed seismic devices, posing even bigger challenges to MAURER SÖHNE in respect to the seismic isolation of a bridge. However, in all cases the 2 basic principles „Seismic Isolation“ and „Energy Dissipation“ were the key to success.