Earthquake Design of an ISAF-Bridge in Afghanistan

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Abstract:

In the framework of the ISAF-Engagement in Afghanistan a new bridge over the River KOKCHA, near FEYZABAD in the BADAKHSHAN district, was built in order to provide a bypass access from the military camp to the local road network in the eastern valley. A military recce team proposed to build the substructure with local contractors and to erect the logistic and support bridge elements with German military personnel. The chosen bridge type is a modular bridge system, call compact 200 and was produced and delivered by Mabey & Johnson in Great Britain. This bridge model is often used and approved in military missions abroad. The total length of the bridge is 150 meters subdivided into three spans. The superstructure features one lane and is constructed as a trough with two sidewise truss girders connected by transoms. The principle design procedure for that bridge system is based on table works referring to military load classification but covering public traffic as well. Researches concerning the reaction of the superstructure caused by earthquakes had not been carried out yet. However the bridge is located in a region with high seismic activity. Therefore a design review had to be done applying full dynamic calculation methods. Finally some modifications on components of the modular bridge got necessary in order to ensure safe support for all calculated horizontal dynamic reaction forces that were significantly higher than wind forces and forces from acceleration and breaking. All constructive supplements were focused on horizontal fixture and damping without restraining thermal dilatation and without replacing original bearings of the bridge system that anymore provide required vertical support. Military specialists from German Engineers Scholl made the necessary adjustments and ensured the correct installation.

Keywords:

Earthquake, Bridge, Afghanistan, Mabey&Johnson

1. Introduction

In the framework of the ISAF-Engagement in Afghanistan a new bridge over the River KOKCHA, near FEYZABAD in the BADAKHSHAN district, was built in order to provide a bypass access from the military camp to the local road network in the eastern valley.

Figure 1 Construction foundation piers

Figure 2 Construction abutments

Figure 3 View of substructure, abutment WEST and EAST, and the two pier basements, End of March 2009

The substructure was planned and executed by the leadership of the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) with local companies located in the area around FEZAYABAD. End of works on the abutments and base piers was by end of March 2009.

The further schedule was, that after arriving of the superstructure, transported in 46 20" Containers, German engineer forces will erect the bridge parts on the construction site and launch the 150,516 m bridge. The bridge type is mostly used for temporary logistic bridging, although the durability is comparable with permanent bridges. The bridge components consist of few single parts as shown in Figure 4.

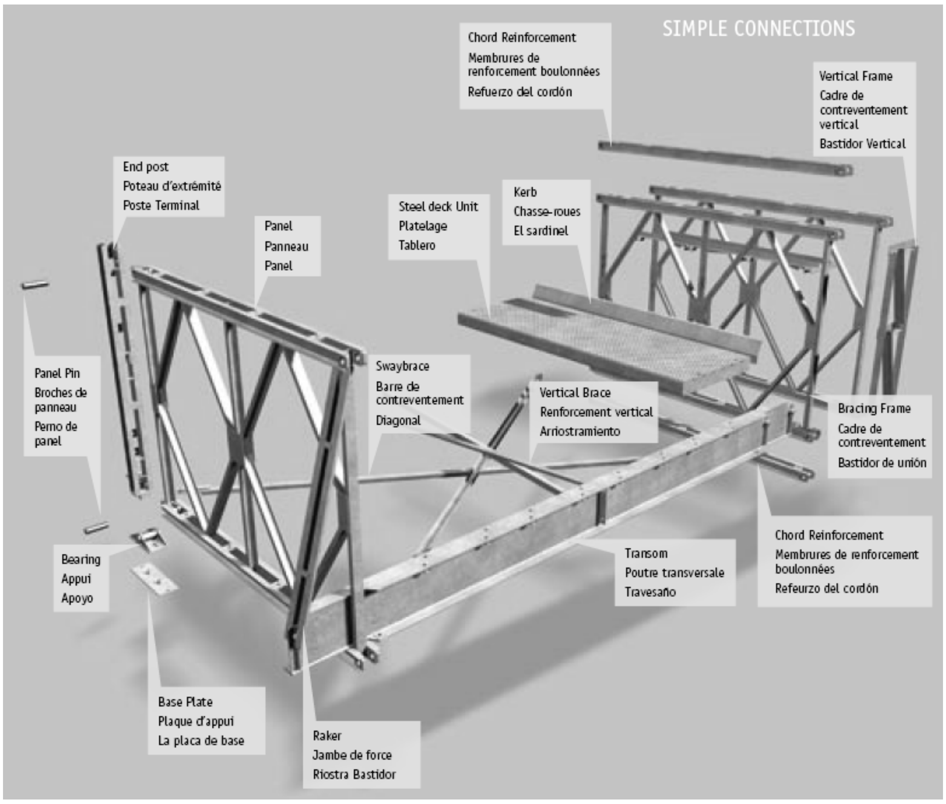

Figure 4 Part list of compact 200 bridge system

The modular system allows different configurations always depending on the width of the span and which traffic load will cross the bridge. The chord profile, chord reinforcement profiles and the transoms are produced of a material S460, while the remaining components are made of materials S355.

Figure 5 TSHR3H Boxes are connected

The cross section has one lane (width 4.2 m) and is constructed as a trough with two sidewise truss girders connected by transoms. The so called box consists of up to three panels on each side of the lane and a transom which holds the two boxes of panels together, that is a bay. The decks are bolted on top of the transoms. By connecting bay after bay with pins, the bridge is erected and gets it design length according to the gap and required load class. Figure 5 shows soldiers connecting DSHR2H boxes with pins.

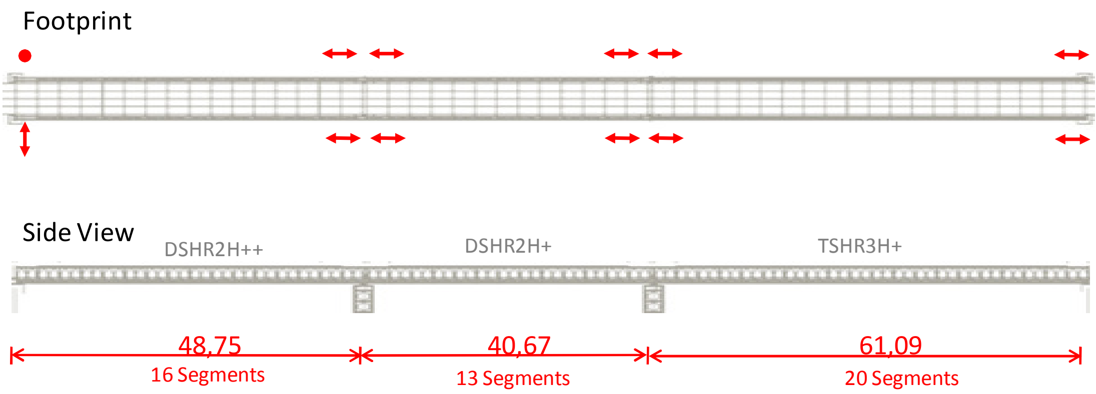

Figure 6 Top view and elevation KOKCHA Bridge

The principle design procedure for that bridge system is based on table works referring to military load classification but public traffic is covered as well; more information is shown in Figure 16. The superstructure of the bridge across the Kokcha has three single spans with lengths of 41.75m (16 bays), 40.67m (13 bays) and 61.09m (20 bays) (Figure 6), only during the launching phase the three spans are connected at span junctions in order to have the necessary stability on the top and bottom chords (Figure 7 and 8).

The piers are fitted together with the same elements as the main girder. Four panels are used to build one segment of a single pier (Figure 9 and 10).

Figure 7 Span junction fixed

Figure 8 Span junction after jacking down the bridge

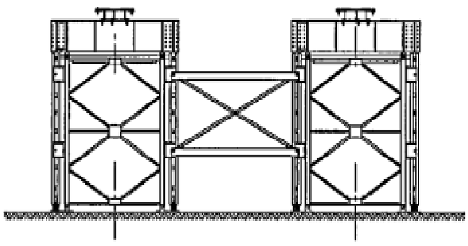

Figure 9 Pier construction

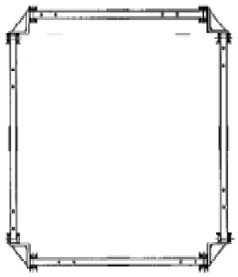

Figure 10 horizontal pier

Figure 11 MABEY & JOHNSON piers at their position on foundations

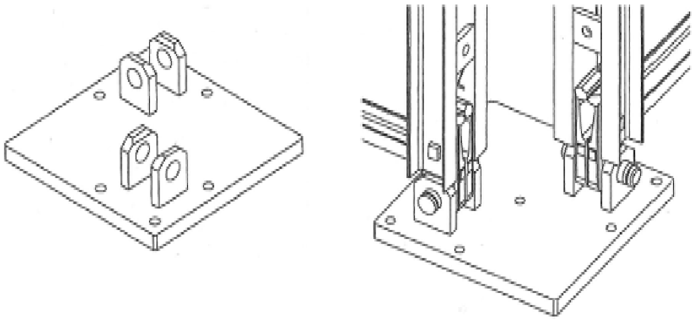

Figure 12 Base plates of piers

The bearings are constructed as rocker. They are placed under the bottom chord of the panels (Figure 14). The sliding bearing reacts with the base plate by contact steel on steel (Figure 13) activating effects of friction. Uplift reaction forces are not considered and so a system to prevent the bridge from jumping out of the bearing is not in place.

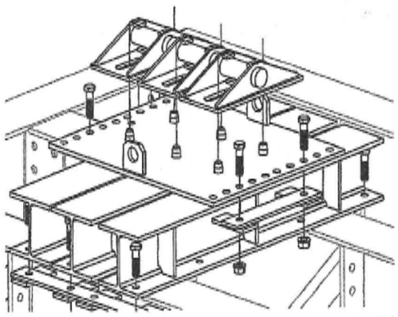

Figure 13 Connector on the stock pier head

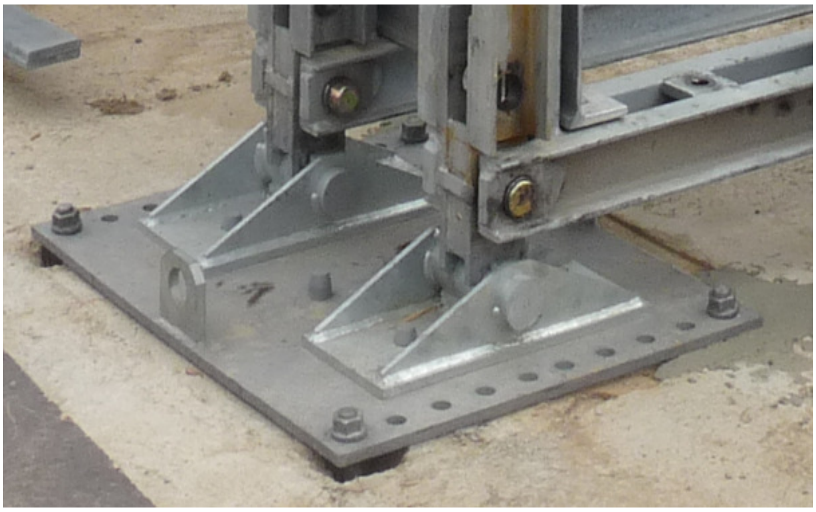

Figure 14 Abutment WEST with fixed bearing

A survey report for building and foundation specific for the area around the camp Feyzabad is available [10].

2 Load assumptions

The bridge is usually constructed for military vehicles of load class MLC 50. Due to the roadway width less than 4.50m, a classification in MLC70 is not possible. Because of the span length vehicles in mid-span positions are relevant for the bending moment, while for the shear forces the vehicle positions close to abutments are assumed as the dominant load position. The masses and dimensions of the vehicles normally used for the design of military bridges and gap crossing equipment are shown in Figure 15.

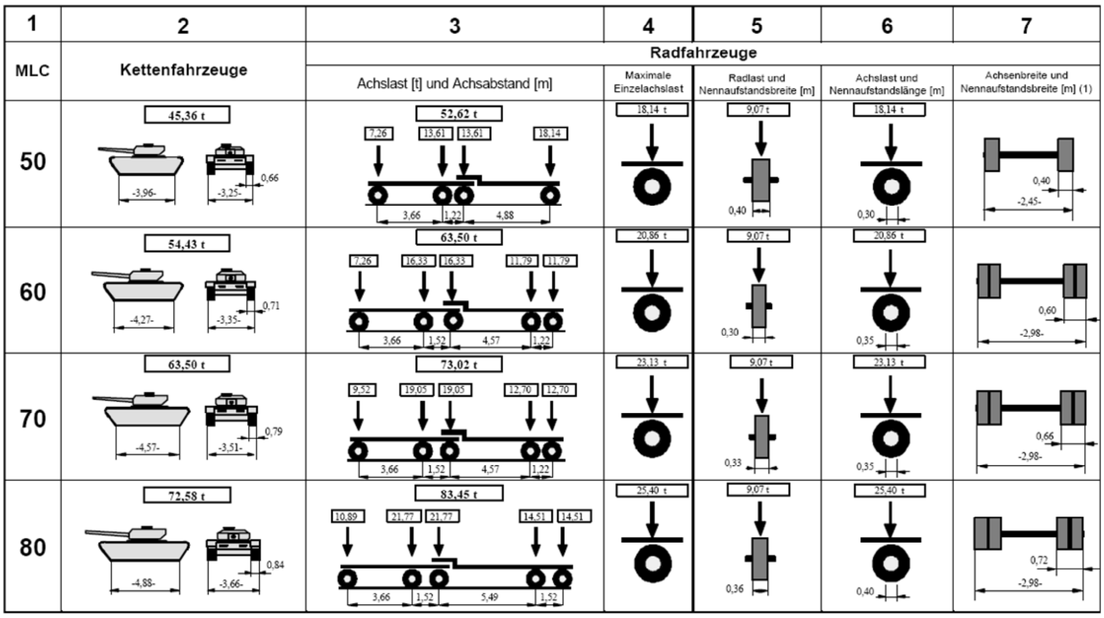

Figure 15 Rule vehicles acc. STANAG 2021 (6th edition)

The design of modular military bridges is generally based on tables created by the manufacturer (Figure 16). The calculations contain dynamic effects and additional loads like soiling on the surface of the lane.

SPAN		MLC40	MLC60	MLC80 T	MLC110 W
BAYS	METRES	CIVILIAN	NORMAL	NORMAL	NORMAL
5	15.24	SSH	SSH+	DSH	DSH
6	18.29	SSH+	SSHRH+	DSH	DSH
7	21.34	SSHRH+	SSHRH++	DSH	DSH
8	24.38	SSHRH++	SSHRH++	DSHR1H++	DSHR1H++
9	27.43	SSHRH++	DSH	DSHR1H++	DSHR1H++
10	30.48	SSHRH+++	DSHR1H+	DSHR1H++	DSHR2H++
11	33.53	DSH	DSHR1H++	DSHR1H+++	DSHR2H++
12	36.58	DSHR1H++	DSHR1H++	DSHR2H+	DSHR2H+++
13	39.62	DSHR1H++	DSHR1H+++	DSHR2H++	DSHR2H+++
14	42.67	DSHR1H++	DSHR2H+	DSHR2H++	TSHR2H++
15	45.72	DSHR2H+	DSHR2H+	DSHR2H++	TSHR3H+
16	48.77	DSHR2H+	DSHR2H++	TSHR2H++	TSHR3H++
17	51.82	DSHR2H++	TSHR2H	TSHR2H++	(TSHR3H++@C)
18	54.86	TSHR2H+	TSHR2H+	TSHR3H+	X
19	57.91	TSHR3H	TSHR3H	TSHR3H++	X
20	60.96	TSHR3H	TSHR3H+	(TSHR3H++@C)	X

NOTES:

1. "+/++/+++" indicates the number of bays of High Shear Panels required at each end of the span.
2. It is assumed that civilian vehicles of up to 40 tonnes gross weight may cross the bridges as well as those military vehicles specified, hence, constructions tabulated for MLC40 loading are as required to provide a 1.7 minimum "civilian" factor of safety against failure. The constructions tabulated for MLC60, MLC80T and MLC110W loadings, however, are those as required to provide a 1.5 minimum "military" factor of safety against failure.
3. The constructions tabulated for MLC40, MLC60 and MLC80T loadings are adequate to sustain a minimum of 100,000 cycles of the relevant design live loading, however, fatigue has not been considered a criterion when assessing the constructions required for MLC110W loading.
4. All of the design loadings tabulated have been considered as normal crossings in convoy with 30 metre intervals between vehicles and with dynamic impact and eccentricity effects applied as defined in the Trilateral Design and Test Code for Military Bridges and Gap Crossing Equipment.

   Where a construction has been given in brackets and listed as "@C", however, it is only suitable for a "caution" crossing. In such cases, only one vehicle is allowed onto the span at any one time, at a reduced speed, so as to limit the dynamic impact effects to 5% on bending and 10% on shear, and at a limited eccentricity within the roadway of 10%.
5. In addition to the live loading as specified, a superimposed dead loading of 0.75 kN/m² has been applied over the entire roadway to account for potential mud deposits.

Figure 16 Design table for Mabey & Johnson Compact 200 logistic Bridge

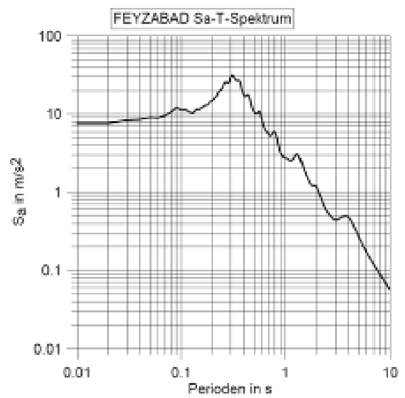

Figure 17 Acceleration spectrum Feyzabad

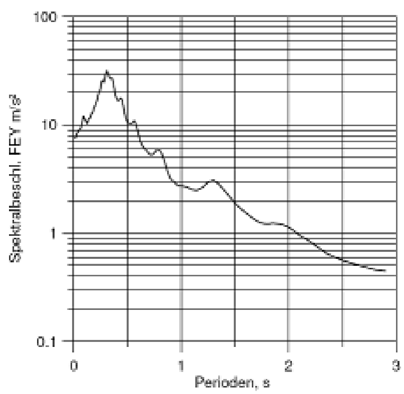

Figure 18 Acceleration spectrum Feyzabad (logarithmic scale)

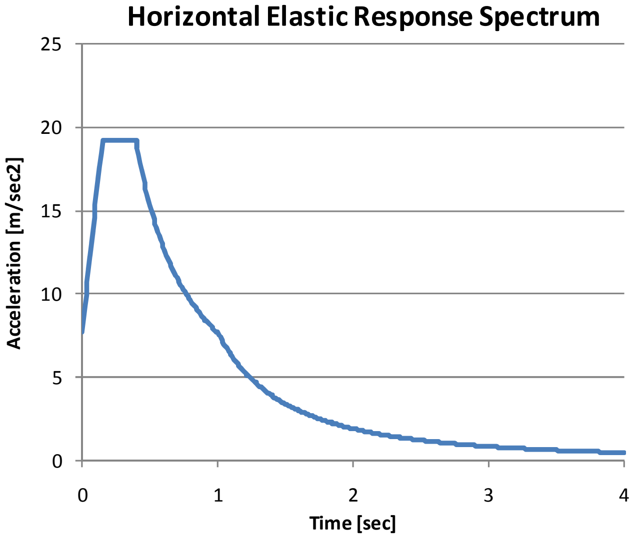

Figure 19 Elastic response spectrum according to DIN EN 199 8-1

The horizontal actions include wind loads, acceleration and braking loads and furthermore bearing friction, activated by thermal expansion. The wind loads are defined by the client with a dynamic pressure of 1.1 kN/m². Information on magnitude of the braking loads is not mentioned in the STANAG 2021. The static calculation value of 290 kN corresponds to approximately 60% of the weight of a heavy vehicle according to DIN EN1991-2. As a basic value for analysis of earthquake effects according to DIN EN1998-1 and DIN EN1998-2, the client set an on-site-specific acceleration spectrum (Figure 17, Figure 18) and a reference earthquake with an average return period of 475 years. The maximum value of ground acceleration reflection influences of soil conditions is 7.65 m/s².

3 Calculation model

For the implementation of the dynamic analysis by the method of finite elements the superstructure was transformed in a three-dimensional model including structural steel parts of pier sections. The calculation was performed with the software package Bentley StaadPro. All structural elements were considered with their size and their location, taking into account eccentricities. In the overall model of the bridge superstructure and the piers are depicted in Figure 20. The structure geometry is defined by the coordinates of 19740 nodes. For the component modeling 20366 beam elements have been employed. As an example the double-pier structure, consisting of four panel elements, is shown in Figure 21.

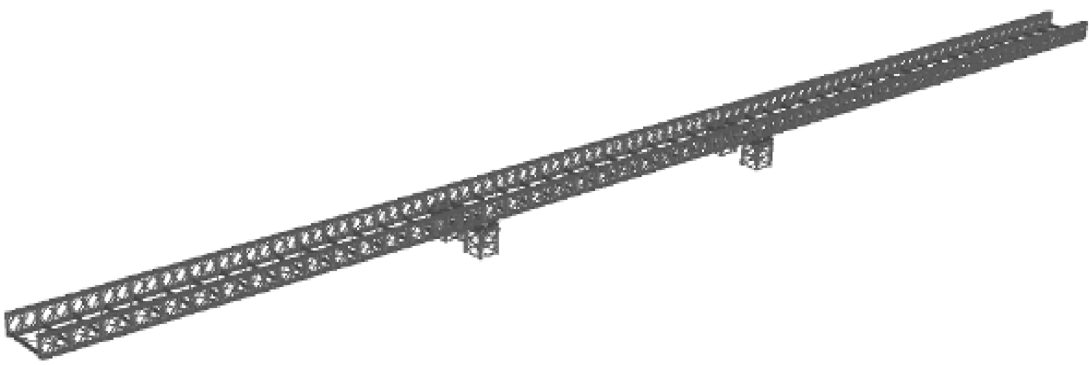

Figure 20 Overview of complete model

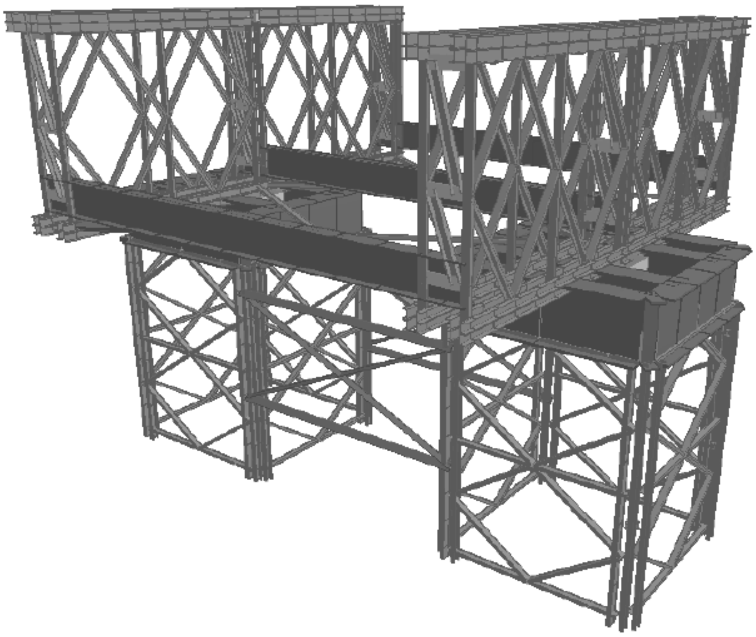

Figure 21 View of piers under DSHR2H construction

4 Calculation results caused by live load MLC 50

Check calculations were carried out for the bridge structure under the influence of vehicles generally MLC 50 in combination with dead load. The dead load was increased by 10 % covering a possible soiling on the lane surface. In the following figures maximum stress in each bridge segment is compared. The evaluated load combination is 1.35 G + 1.50 Q. The unfavorable stresses arise in case of load positions in third section with the largest span. This field has the highest amount of panels and chord reinforcements. This load position without consideration of local stability of the individual elements spends at least 100% of the loading capacity of this segment. It can be immediately concluded that a proof of stability for the load models according to DIN EN 1991-2 and DIN FB 101 is not possible. According to these standards the bridge could be used by public traffic under restrictions only.

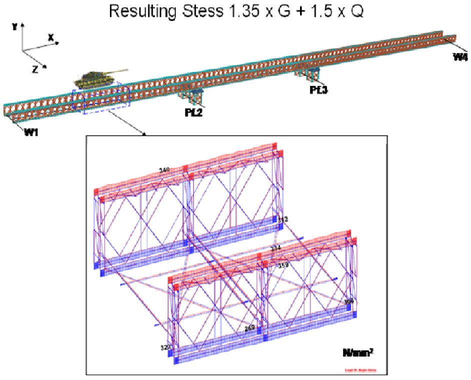

Figure 26 Live load on span 1

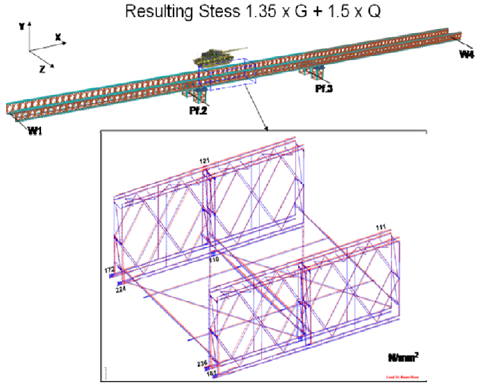

Figure 27 live load on span 2

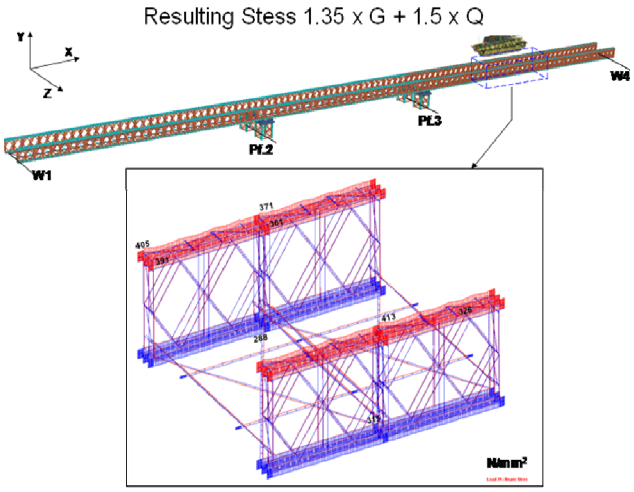

Figure 28 Live load on span 3

5 Earthquake response

Earthquake response calculation is performed throughout the whole domain of natural frequencies and mode shapes. Lower frequencies and corresponding mode shapes are shown in Figure 29 as example. These lower frequencies cover mainly vertical displacements and reveal that each bridge part is largely independent and that all parts of the bridges expose similar characteristics as expected. Higher mode shapes with significant portions of lateral and longitudinal acceleration that are relevant for horizontal excitation are covered through the automatic calculation process.

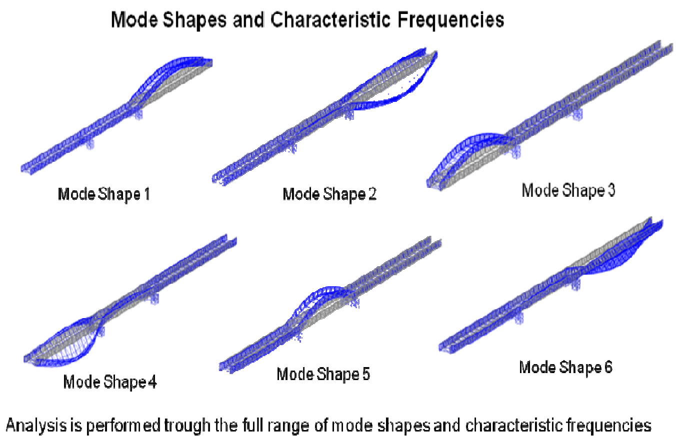

Figure 29 Mode shapes and characteristic frequencies (examples)

Table 1 Lower characteristic frequencies (examples)

Mode	Frequency Hz	Period seconds	Participation X %	Participation Y %	Participation Z %
1	1.059	0.944	0.090	42.140	0.008
2	1.583	0.632	0.001	0.064	12.935
3	1.892	0.529	6.550	18.069	0.000
4	2.681	0.373	0.002	0.001	2.925
5	2.75	0.364	5.455	10.315	0.006
6	2.796	0.358	0.001	0.000	22.051

Reaction forces as result of earthquake load are shown in Figure 30. The noted forces are pure dynamic reaction forces and occur with altering directions. The maximum horizontal support reaction in longitudinal direction of the bridge is approximately 1000 kN and arises when the structure is accelerated parallel to the longitudinal axis of the bridge. The reaction forces in cross direction are about 300 kN (each 2x) on top of the piers and 180 kN (2x each) at the abutments. This earthquake response exceeds all reactions forces due to the regular design. Therefore some safety supports had to be added in order to prevent the structure from sliding in case of damaged bearings or anchors. Furthermore a safe guidance in case of uplift displacements is provided by means of those installations.

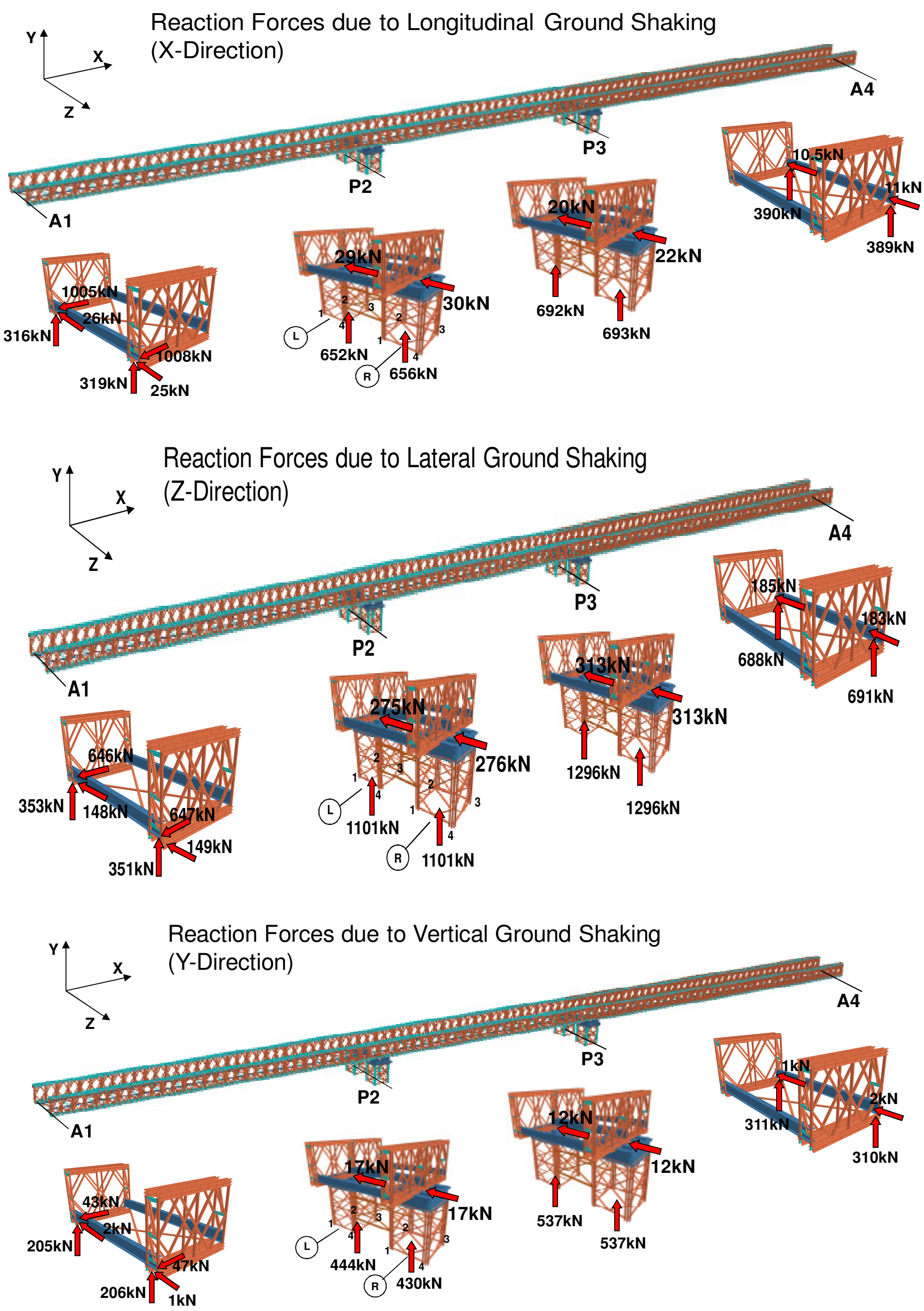

Figure 30 Maximum support reaction of the unloaded bridge due to an earthquake

7 Executed methods to prevent negative earthquake effects

In addition to the original design for standard applications of the modular bridge the complete construction on the WEST and EAST abutment was improved. The fixed bearings in the longitudinal direction of the bridge are located on the WEST abutment. The bottom chord of the bridge in this area is placed on two rocking rollers. Arrangements to prevent uplift movement that likely come up during earthquake events are not in place. Furthermore anchoring of bearing base plates is planned with 4 anchor bolts M24 in the standard configuration obviously not sufficient for the calculated horizontal forces of maximum 1000 kN (Figure 31). In the project-specific implementation plan vertical steel profiles have been provided for this purpose (Figure 32) acting in a cantilever fashion. The dimensions of the abutment bodies have also been enlarged additionally for the same reasons. Since safety supports in longitudinal direction could not be placed in close contact with the super-structure due to thermal dilatation, which must not be significantly restraint, safety supports will be fitted with elastomeric bearings acting as bumpers in order to avoid very large forces caused by hard impact (see Figure 34). Preparations for safety supports on site are shown in Figure 33.

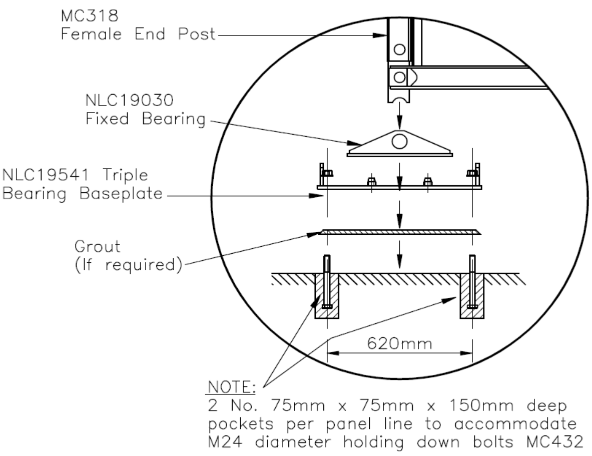

Figure 31 Fixed bearing

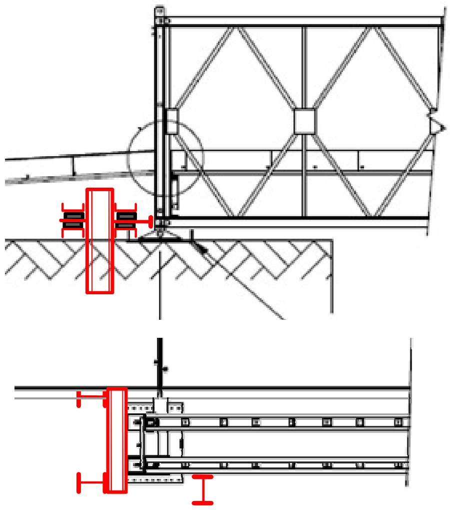

Figure 32 Fixed bearing with safety support

Figure 33 Fixed bearing and anchoring (WEST)

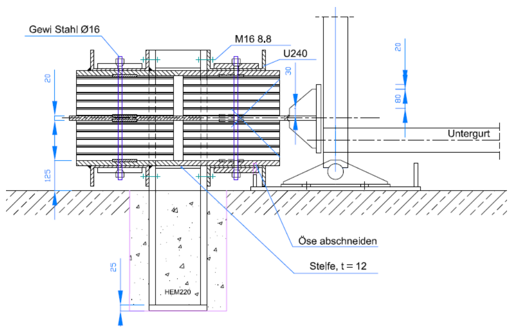

Figure 34 Fixed bearing and

Piers are built as mentioned in chapter 1. The male part of the panels is fitted to the base plate with thread rods, shown in Figure 35. Each main girder rests on a separate pier. Both towers are tied together with sway braces in order to provide sufficient capacity against lateral displacements. The originally purposed anchors with a depth of 200 mm and a diameter of 20 mm were replaced by reinforcement bars terminated by crew connectors at top foundation surfaces delivered from Halfen DEHA HBS-05-SB-20 (Figure 35 and 36) in order to reliably control tensile forces at foundations. The screw connecters are an officially approved system often used to back fitting of existing concrete structures. Reinforcement bars are anchored in a screw whole 500 mm deep and fixed with an injection mortar from HILTI Company.

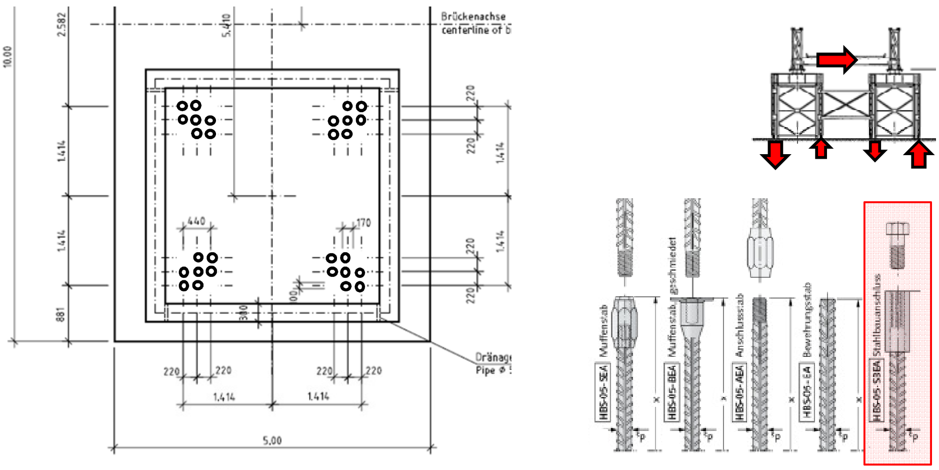

Figure 35 Halfen-Deha Screw Connection

Figure 36 Drilling of holes

Figure 37 Base plate fixed with bolts and nuts

8 Planning Fundamentals

[1] DIN EN 1991-2:2004 Traffic loads on bridges, Beuth-Verlag, Berlin 2004
[2] DIN 101:2003 FB Influences on the bridges, Beuth-Verlag, Berlin 2003
[3] DIN EN 1998-1:2006 interpretations of structures against earthquakes
[4] DIN EN 1998-2:2006 interpretations of structures against earthquakes - Bridges
[5] TDTC Release 2005 Trilateral Design and Test Code for Military Bridging and Gap-Crossing Equipment
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[11] PRT Kunduz, Ltr EinsGeolTrp Newly built bridge north PRT FEYZABAD, December 2007
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