The New Steel Guideway

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ABSTRACT: The new steel guideway is improved for the new Transrapid vehicle generation (TR09). This Maglev – vehicle is conceived for urban projects with a higher load capacity (8 passengers per m² standing area). Therefore the vehicle live load on the guideway increased. The new steel guideway is designed according to the new specifications of the TR09 based on the experience of the existing steel guideway development. The steel guideway is designed and tested for an automated manufacturing process. The handling of high quantity steel constructions in a short time is a challenge for the steel construction companies. New automatic production process for logistic, assemblage and welding were developed and tested by prototypes. The new design is already approved by the German Railways Authority (EBA).

1. GENERAL REQUIREMENTS

Automatic controlled transport systems require own guideway with integrated guidance, propulsion and support elements.

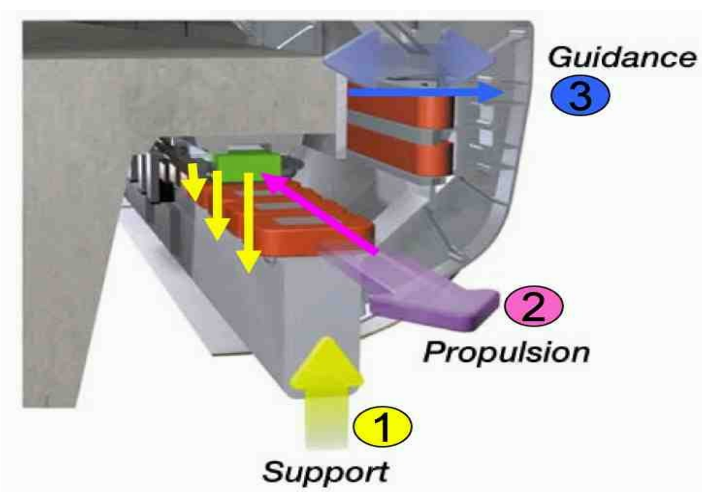

Fig. 1: Transrapid guideway system elements

The riding comfort of high speed systems depends on the guidance quality of the guideway. Therefore live load deflections, temperature movements and the construction deviation tolerances are limited to few millimeters.

For example Transrapid:
(L: span length)

Permissible live load deflection:	L / 4800
Permissible deformation due to temperature:	L / 6500
Tolerance of the stator packages:	± 1 mm
Tolerance of the guidance rails	± 2 mm
First natural frequency bridge	> 5 Hz
First natural frequency stator cantilever	> 450 Hz

The challenge for the guideway designer is to integrate the system elements as a part of the carrying structure, in order to get the required rigidity of the structure and to realize an economical guideway. Any not integrated system element is only providing more dead load and brings in addition more cost intensity in to the guideway.

The designer has also to pay carefully attention to the production of serial parts (e.g: guideway girders), in order to fulfill the tolerance requirements with a reproducible and economical process. The assemblage of system elements (Stator packs, cable windings, power rails, positions marks, etc.) must also be integrated in the whole production process.

The guideway is playing a mayor roll in the inversion cost of the automated transport systems. Between 60 – 70 % of the project cost are determined by the guideway constructions. The safety is also getting more importance for the guideway due to the integration of vital control elements in to the guideway.

The guideway designer has not only to bring theoretical acknowledgment, but also manufacturing experience, in order to obtain a guideway with economical results fulfilling the system requirements.

2. LOAD AND FATIGUE REQUIREMENTS

The new automated guided transport systems are bringing the dynamic loads directly in to the guideway construction. Any rail sleepers or ballast are used for damping of the dynamic effects or for adjusting the rails. Therefore the guideway structures have to be rigid enough to avoid any vibration of any part of the guideway creating noise and additional dynamic actions, which cause fatigue in to the material and disturb the environment with noise impact.

The Maglev system loads are continuously distributing along the long stator means of vehicle electrical magnets in comparison to the concentrated wheel loads by the railway systems. Therefore the Maglev guidance and supporting elements are not to heavy punctually loaded. On the other hand the regulation forces of the electrical machine are applied directly in the guideway elements. When supporting elements are weak and creating unwanted deflections, electrical regulation forces and dynamic load factors are increasing.

In terms of fatigue, the guideway has to be designed for a life time of 80 -100 years. Depending on the application of urban or intercity transport system the load interval varies between 1 and 10 minutes.

Supporting and guidance elements are always loaded more then 10 x 106 cycles under the cut of limit for fatigue strength. The main structure (Girder, bridges) are loaded 2 – 10 x 10^6 cycles.

Dimensions of the guideway structures are determined by fatigue stress and serviceability requirements for deflection.

3. THE NEW TRANSRAPID VEHICLE TR09

The new Transrapid vehicle TR09 is in comparison to the intercity version TR08 designed for urban transportation with areas for standing passengers and wider entrance doors. The new vehicle TR09 increases the passenger transport capacity of the system and causes a higher level of live loads and a higher numbers of intervals on the guideway.

The live loads on the guideway of TR09 vehicle are in comparison to the TR08 approx. 10 % higher and the load interval for urban transportation is shorter. (e.g.: for intercity transportation are assumed 70 – 100 cycles per day and per urban one 130 – 200 cycles per day).

4. THE STEEL GUIDEWAY

In the last 25 years the steel guideway as well as the Transrapid vehicles have been developed to new state of the art technology

The first generation of steel guideway was built in 1982 at the test facility (TVE). 10 km steel guideway girders were installed. The 50 m girder (2 x 25 m spans) were manufactured separately (each of the two 25 m straight main girder and the 50 m system elements) and on a special jig assembled. Drilling holes for bolted connections of the system elements the required alignment was achieved; this method of manufacturing was not too efficient, but the required system geometrical tolerances were fulfilled.

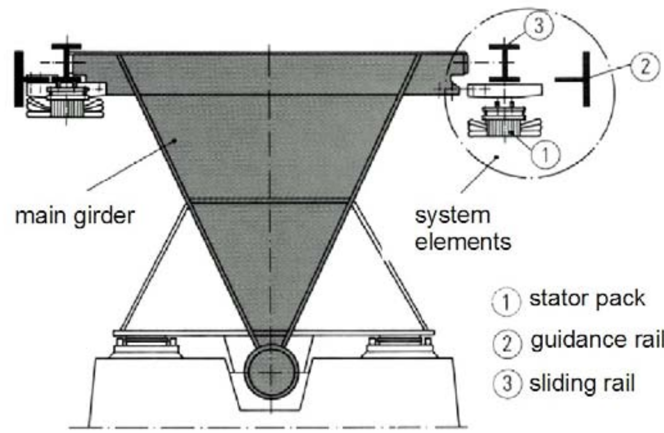

Fig. 2: Steel guideway first generation (TVE 1982)

The second generation of steel guideway was erected in 1986 at the south loop of the TVE (5 km). System elements were fully integrated and welded to the main girder as a carrying part of the structure. The main box girder (25m single span) is also a straight element. Only the girder upper flange and the system elements were cut according the alignment parameters and welded on a jig. The designed rigidity (live load deflection l/200, 12 mm) and temperature deflections by single span girders were not optimal for a high speed system.

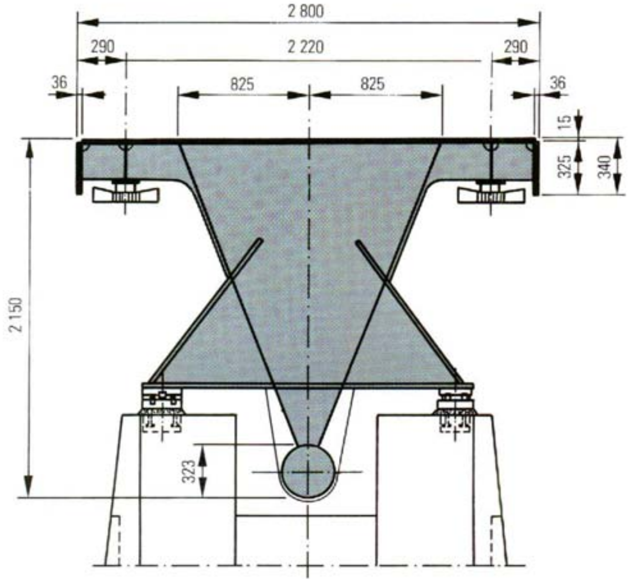

Fig. 3: Steel guideway second generation
(TVE 1986)

The third generation steel guideway was tested as a prototype at the TVE (1990). The 50 m girder (2 x 25 m) was a full welded structure with integrated system elements. Stator packs were fixed to cross plates, each 0,35 m without a longitudinal beam. Low rigidity at the stator pack connection caused non-tolerable vibrations on the interaction vehicle-guideway.

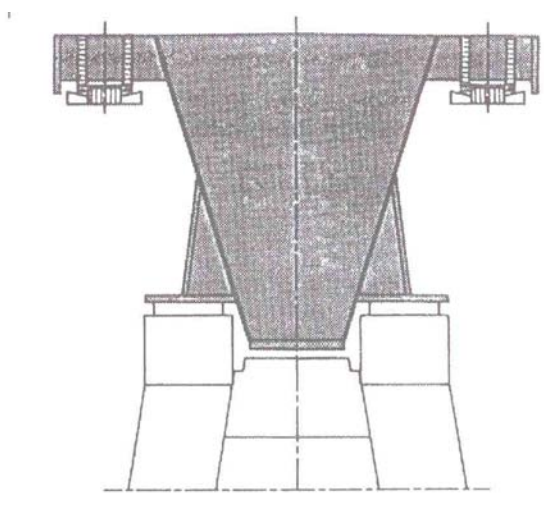

Fig. 4: Steel guideway third generation
(TVE 1990)

The fourth generation of steel guideway (1992 -1999) was developed in an extensive program, in order to avoid any unfavorable vibration and to improve the cost efficiency of the guideway. Beginning with vibration analysis at stator pack interfaces, design of redundancy stator pack connection, fatigue test on laboratory of the stator pack and guidance rail connection and the related steel girder local structure a complete new steel guideway was developed.

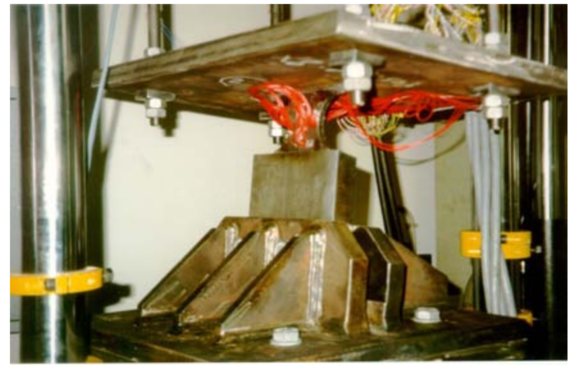

Fig. 5: Fatigue test system elements connection

By the development of the fourth steel guideway was particularly paid attention to the automation and rationalization of a serial production. Thereby one the alignment following cross section was selected, which creates equal cross section and cross beam as series production parts. The open shape of cross section permitted further the unrestricted use of welding robots.

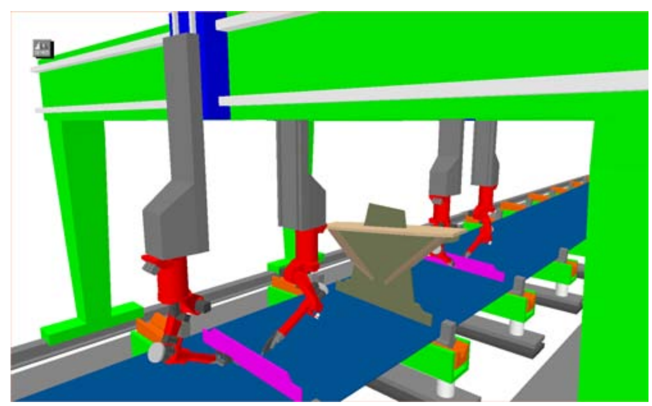

Fig. 6: Assembly Jigs with welding robots

The assembly sequence was arranged in such a manner that the functional components with restricted manufacturing tolerances are inserted at last. The patented guidance rail attachment makes the exactly positioning of the side guide rail, by means of adaptable horizontal connectors, possible.

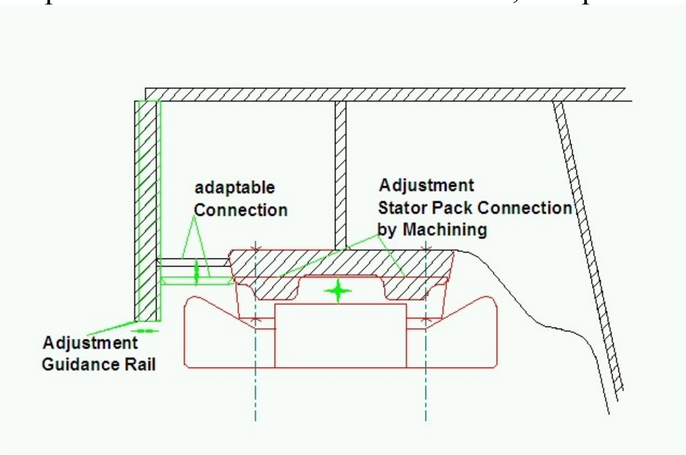

Fig. 7: Adjustable Guidance Rail

By the measurement of the steel guideway girder a digital industrial photogrammetric system is being used. Those by the measurement determined geometrical deviations are re-used as default for the pre-setting manufacturing process as well as basic data for the machining of the stator package attachment.

The installation into the guideway girders of the long stator motor consists of three procedures: machining works, mounting of stator packs and windings installation. For fulfillment of required tolerances and creation of redundant attachment of the stator packs, the guideway girders are machined. Hereby T-grooves are milled into the stator beam in transverse direction.

A failsafe connection of the stator packs is manufactured in this manner, which is activated by failure of the bolt connection. The installation of the packs and the windings to the guideway girders takes place by means of automatic manipulators.

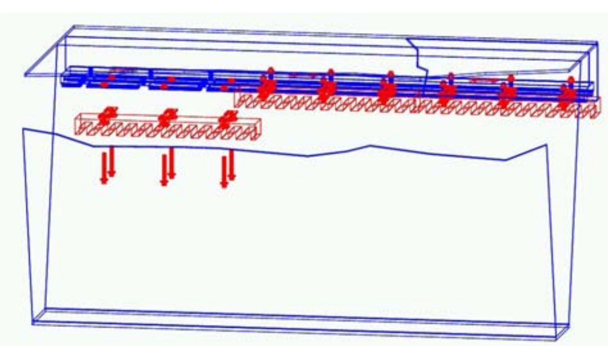

Fig. 8: Stator Pack Connection

For different applications fields (ground level, elevated) and span length (3, 12, 25, 31 m) three main steel guideway types were developed. All types have the same local structure at the connection of the system elements and have different girder height depending on the span length. The girders are designed as two span beams, in order to minimize the temperature deflection due to sunshine in summer or cold ground in winter. To reduce the noise emission the girders are half filled with lightweight expanded clay aggregates.

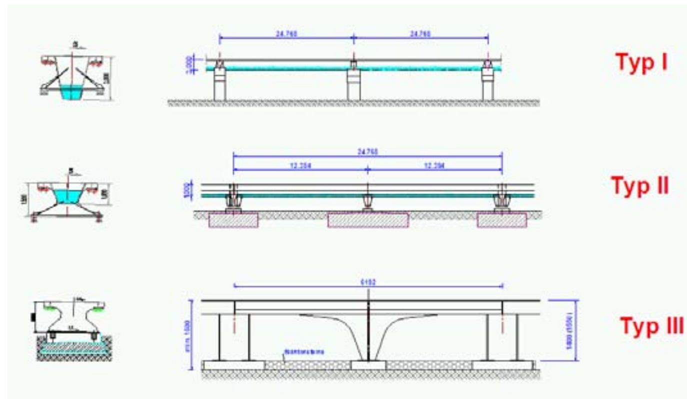

Fig. 9: Steel guideway Types (I, II, III)

The theoretical static and dynamic calculations for the different types were done using finite element methods (FEM) according to the Eurocodes standards based on the system specification for dimensioning of guideway./1/

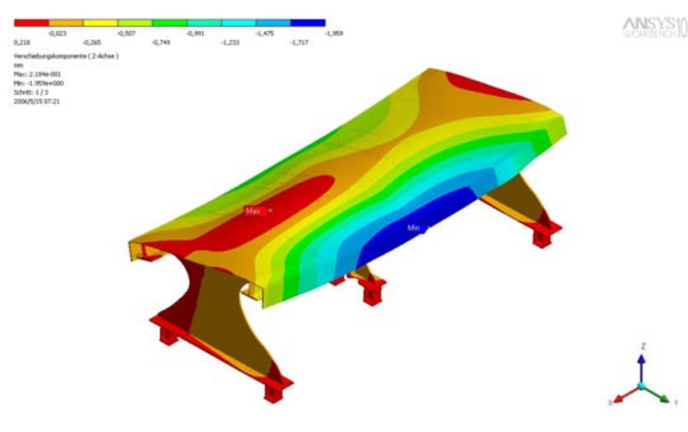

Fig. 10: Static and Dynamic Calculation

The successful conclusion of the development program was the installation of the prototypes (I, II, III) into the TVE test facility, in order to analyze the stress and dynamical response of the guideway by means of strain gauge measurements. Here closes the circle with a comparative analysis between the measured stress and dynamic behavior data at the prototypes on one side and theoretically and/or labor-test-technically determined data on the other side.

Fig. 11: Installation of prototypes at the TVE.

5. THE NEW STEEL GUIDEWAY

Based on extensive development of steel guideway the task for the fourth generation was now to expand the application field of steel girders for any possible alignment parameters, accelerations and speed situations for any project.

After the analysis of the characteristic of the guideway for realized or planed projects (Shanghai, Berlin-Hamburg, Munich), the maximal used parameters were defined in order to cover more than 98 % of any guideway case. The 2 % remaining guideway are areas with narrow radius, which are handled as special cases.

Following design parameters were determined:

Hor. Radius > 1000 m
Vert. Radius > 600 m
Cant / Superelevation: +12 ° < α < -12°
Long. Inclination: +10% < β < - 10%
Max. Level above ground: 13 m
Max. overspeed: 550 km/h
Max. cruise Speed: 520 km/h
Max. Lateral acceleration: 1,5 m/s²
Max. Vertical accel.: +1,2 < a_z < -0,6 m/s²
Max. Fatigue cycles: 3,8 x 10^6

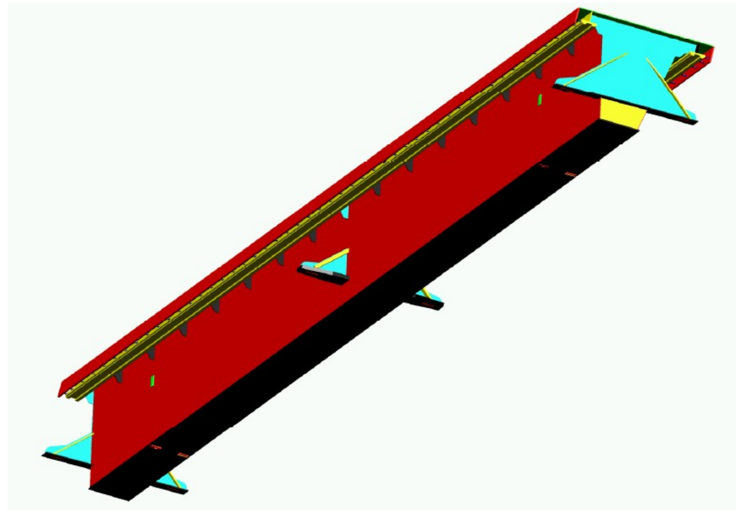

Fig. 12: The new steel guideway

For each steel guideway type, for the vehicles TR08 and TR09 and the design parameters static and dynamic calculations were done and final design drawings have been made. These papers were proofed and certified by the German Railway Authority (EBA) as a safe product ready to use for any Transrapid project in Germany.

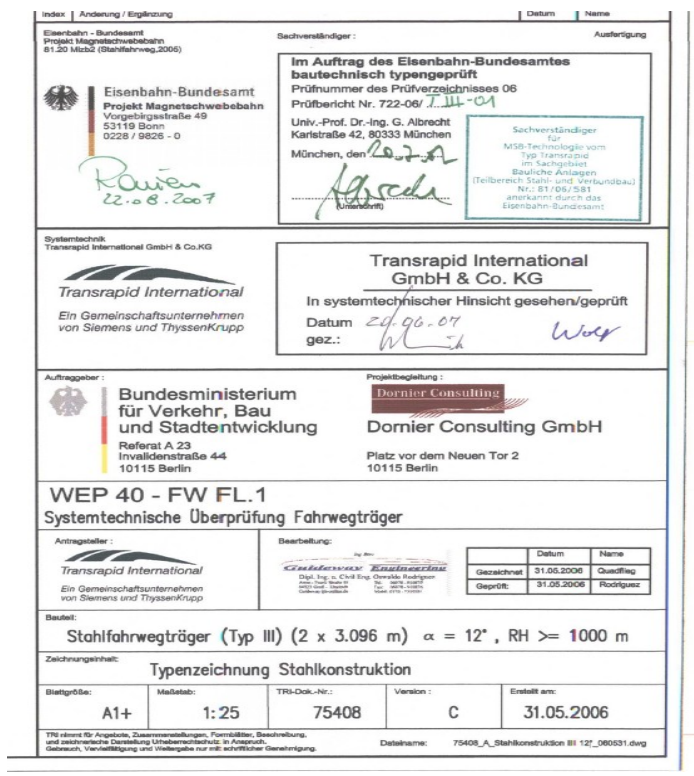

Fig. 13: Example of EBA Type Certification

6. OUTLOOK

The development experiences of more then 25 years are integrated into the new steel guideway. The steel guideway for Transrapid intercity or urban transportation are ready to be built in Germany. The design can be easily adapted to any local requirements and standards of other countries and the technical know-how can also be applied for any kind of transport system guideways.

7. REFERENCES

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