A new guideway for Transrapid – The Munich girder

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ABSTRACT: Based on lessons learned from the know-how transfer of the 'Hybrid girder', combined with continues development in high precision 'tuning' and advanced Precast-prestressed manufacturing methods, a new and even more economical girder was recreated: an all-concrete girder. Self-developed software enables us to accomplish an optimum in standardisation of girders. With a length of 9.3 m the 'external' track geometry is perfectly reproduced. By grinding the surfaces for the lateral guidance plates, high precision 'internal' track geometry is pictured. The steel functional units of Hybrid girders are key elements in economics of the guideway. Converting steel parts into concrete sections simplify the design and not only reduce significantly the production cost, but also LCC. The glide surface, also being grinded for highest accuracy, on top of the concrete superstructure was modified based on new coating technology by ThyssenKrupp. The cant of the girder is accomplished by individual units with integrated elastomer bearings. For transport and erection those units are pre-attached to the all-concrete girders. Last but not least, the new development required a high-dense concrete microstructure, accomplished by the use of self-compacting high-strength concrete and special formwork and production methods. The new all-concrete guideway by Max Bögl is perfectly suited for at-grade applications and allows later adjustment, but also construction on bridges and in tunnels (e.g. mass-spring-system). All tests at the Laathen test track have been highly positive.

1 REVIEW

It is generally known that the first Transrapid section was officially opened for operation in Shanghai in 2003. The track system technology for this double-tracked 35 km section originates from the MAX BÖGL Company in the Upper Palatinate. A modified further development of the hybrid guideway was manufactured and assembled in Shanghai with the aid of consultation and guidance from our company, to take account of the national conditions there.

The hybrid guideway was selected by the Chinese because at that time it represented the most efficient and technically advanced solution.

The idea behind the hybrid construction method was to manufacture the function levels in short steel modules and then attach these to robust prestressed concrete girders. A connecting piece which was cast in concrete and later mechanically processed using drill grinding equipment was needed between the concrete girder and steel module in order to comply with accuracy criteria

The experiences and observations we made in Shanghai did not prevent us from developing even more efficient guideways for future sections. When we focus on the sections to be realised in Europe in particular we see a range of new problems that could be or were disregarded in Shanghai.

2 CONCLUSIONS FROM SHANGHAI

The successful commissioning of the Shanghai section with the MAX BÖGL group's guideway technology led to the following fundamental conclusions:

- The polygonal arrangement of the function levels does not produce any systematic motivation of the system.
- The cross-sectional form selected there permits the use of single field girders (where climates are comparable to Shanghai). Both the 25 m long girder with box girder profile and the 12.40 m long girder with a solid cross-section comply with the strain requirements. A coupling of the girders is not necessary.

- The accuracy achieved in Shanghai facilitates a reduction in the air gap during operation of between 10 to 20 % (8 – 9 mm, instead of 10 mm previously), and thus a reduction in energy requirements. The concept of docking precise component elements on to no distorting main girders via mechanically processed surfaces produces functional guideways which are in harmony with system specifications.
- The measurements of the airborne sound level produced somewhat higher values and a different distribution of the sound propagation than conclusions from Emsland had previously indicated.
- Observations of the oncoming traffic in Shanghai have shown that the aerodynamic effects of this may be disregarded in the girder dimensioning.
- We are not aware of any shortcomings which are attributable to the production concept or the calculation or load assumptions.

The abovementioned facts apply to the elevated guideway with single field girders in Shanghai.

The subject of noise control or winter operation have either not yet been satisfactorily resolved in Shanghai, or are not relevant. The same applies to sections in tunnels or on bridges where there are no solutions ready for production on the market.

Knowledge of ground level guideways only stems from short partial sections which until now have been tested in Emsland.

3 CONSISTENT DEVELOPMENT

At the beginning of 2004, independent of the federal program for further development (WEP), the MAX BÖGL group began to find solutions to the problems alluded to above. An advantage was and is that we were involved in the Shanghai section, thus in our company we did not simply have theoretical engineering knowledge of the guideways, but also had the experience of practically-oriented ways of thinking by craftsmen as well as the day-to-day contact with the production of prefabricated parts.

But it was not only the knowledge from China, but also the experience gained during the development and building of our fixed track system for high speed trains, the FF-BÖGL, which favoured the fast development of the guideway for the Transrapid.

What has been changed in comparison to the guideway in Shanghai?

3.1 Reduction of the regular field width

The regular length of the Shanghai girders is 25 m. It is necessary to manufacture variable cantilever widths or girder shaping in order to be able to model the railway line within the limits of permissible tolerances – the term used here is “external geometry”. This means that flexible formwork is required which can be individually adjusted. Individual girder moulds however also mean greater measuring costs and therefore higher initial costs. This concept will have to be retained in elevated areas with greater field widths.

For ground level areas we have consistently reduced the girder lengths to the extent that the stipulated external geometry can be reproduced without adjusting the formwork. Independent of the line routing, identical girder moulds are produced which are oversized in the area of the cantilever, and these are then later given the appropriate “internal geometry” through mechanical processing. The parts processed in this way are strung together and produce the guideway with an extremely accurate external geometry.

The main girder consists of a single field girder with a span of 9.30 m and cross-section which resembles a π slab, constructed using the prestressed concrete method. It is pre-tensioned with directly bonded lengthwise lacing. Due to the stiffness, ratio garland-shaped pre-stressing similar to that for the long girders is not necessary.

3.2 Modification of the function levels

The connecting pieces, the so-called brackets and the steel function level modules determine the price of hybrid guideway girders. Both costly welding work during the module’s manufacture and also its corrosion protection account for over 60 % of the price of hybrid guideways. To this must be added the costs of maintaining and servicing the delicate filigree steel pieces.

Each module is fastened to four brackets with 12 screws and 6 bolts. This kind of fastening is relatively expensive, and requires exception quality control during the production process and must be continually inspected during operation.

Similar factors apply to the manufacture and monitoring of the brackets themselves.

Savings on steel and reduction in fastening materials were targeted to achieve a cost-effective solution in the function levels area.

Everywhere that steel was not necessary for the operation of the Transrapid, it was substituted with concrete.

Thanks to new developments by ThyssenKrupp, the slip plane could be replaced by coated concrete. This has a width of approx. 18 cm, and runs continually over the whole length of the girder. The slip plane is ground into the concrete, and is primed and coated three times after the grinding process.

The side guide rails still consist of 3 centimetre thick sheet steel, which is screwed onto the cantilever of the girder in lengths of approx. three metres and is abrasion-resistant. It rests on concrete humps which are similarly mechanically processed. The screws are twisted and prestressed into concrete-embedded long nuts. Two opposite long nuts are each connected to one another by a thread rod, so that the pre-tensioning force achieved is effective across the whole width of the girder.

The stator cores are connected to the cantilever in an abrasion-resistant manner, whereby 3 transverse beams each are screwed onto anchors built into the structural concrete.

On each girder side of the underneath of the cantilever two over-dimensioned parallel concrete ledges running lengthwise are arranged, which ensure the exact position of the stator cores after the grinding process.

The slip planes, the plant surfaces for the side guide rails and the stator cores, are, as has been alluded to already, mechanically processed. This means an adjustment to the railway line geometry is achieved in an efficient manner, which was not possible with earlier methods. The comfort of travelling is therefore improved enormously. The computer-controlled grinding equipment guarantees reliable, constant quality without the need for extensive monitoring. Defects due to faulty measurement are thereby excluded.

This technology has already been tested in by Bögl. The inner geometry of the so-called track-supporting layers of the FF-BÖGL was produced using it, and it delivered an outstanding, previously unseen track bed on the newly-built Nurnberg – Ingolstadt stretch.

3.3 Bearing and foundations concept

The foundations should be measured in accordance with the given geology, so that greater subsidence and differences in subsidence are improbable. Depending on the soil conditions, spread foundations or pile foundations are produced at span intervals.

The foot support at the end of each girder consists of a concrete prefabricated part, the so-called support wedge with an integrated lower bearing plate. Using these prefabricated parts the cross incline of the girders can be adjusted. Here too efforts have been made to ensure cost-effective production. There are a small number of diverse models with differing cross inclines, which suffice to represent the possible parameters of the railway line.

The girders are connected to these support wedges via simply constructed Elastomer bearings. The bearings are economical to manufacture and monitor. They permit readjustments using a chuck flange and may be completely replaced if necessary.

3.4 Assembly and adjustment

Before delivery the girders are connected tightly with two support wedges. These units have been constructed so that they can be brought to the stipulated site without the need for special means of transport.

Here the approx. 45 ton heavy girders are placed on the prepared foundations using lifting gear and adjusted with hydraulic presses. The planned remaining gap between the foundation and support wedge is later grouted with erosion and frost resistant solid concrete.

This method has also been tested and has been well proven during the assembly of FF BÖGL track supporting layers.

A separation might later take place at this grouting layer. Then the girders could be readjusted again by grouting with concrete. In this way one has a simple concept for undertaking corrections in the event of unplanned settling that can no longer be adjusted via the bearings themselves.

3.5 Further novelties and improvements

The surfaces to be ground require an absolutely leak-proof concrete structure, and this is achieved unerringly using self-compressing concrete and the application of special formwork and concreting methods. Here a multitude of trials have taken place in the prefabricated parts works of the MAX BÖGL company group.

The dense concrete similarly improves endurance strength and serviceability.

Results from our own formwork inspections have been entered into the moulding of girders. The compact girder surface and the fillet on the underside of the cantilever have delivered a fundamental improvement in comparison with the noise emission of the hybrid girders. However, during these noise reduction tests we noticed disturbing influences that could not be eliminated through the construction of the girders, and which must either be considered in different ways or have already been considered.

A further advantage of the compact concrete surface is also the greater suitability of the guideway during winter operation. Snow clearing vehicles are able to drive on the girders easily. Additional trials with heated cantilevers also brought promising results and may be used in the future where conditions are extreme.

For prototypes installed in Emsland the long stator winding was pre-fitted in the factory and assembled together with the stator cores for the first time. Once the assembly of the girders had taken place, the windings were connected with couplings on site. The extent to which price or technical advantages can be derived from this must still be evaluated.

4 FINAL CONSIDERATION

This generation of girders is optimally suited to guideways at even levels. It can equally be used on bridges on in tunnels. There the use of a mass-spring system is also possible. Corresponding ideas and preliminary inspections already exist.

Four of these new “Munich girders” as we have christened them, were installed and commissioned in July of this year in the southern loop of the Emsland test stretch.

Previous knowledge from diverse commissioning trials and vibration measurements as well as the inspection of the position accuracy has, without exception, delivered positive results. The exact evaluations will be presented by the end of the year.

We are convinced that at the start of the Munich project we are presenting the new generation of authorisation ready girders which we can produce efficiently.

Finally we would, however, like our work - which includes our new developments, ideas and the product which has arisen from them - to contribute to making the Transrapid in total more efficient and thus more competitive when compared to other transport systems.