Primary constructions for traversing traffic routes with the maglev train

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**ABSTRACT:** Principles, requirements and examples of primary constructions – planning of the high speed magnetic-elevation train Munich Main Station – Munich Airport Lot 3 (link flood plain (Isarauen) to Munich airport).

**GENERAL**

Sometimes common roadway load-bearing structures are not sufficient to traverse roads or water with the maglev train due to diverse route constraints.

Therefore, portal frame methods, e.g. primary constructions have to be used. In Lot 3 (PFA 31 + 32) of the maglev train route three situations to traverse roads and water are faced. These points include traversing the river (Isar) and the motorway interchange “Munich airport” (BAB A 92) as well as the single lane track to the maglev maintenance centre. This central service point is located south of the main maglev train track and south of the metropolitan railway track.

The following individual load-bearing structure solutions to traverse with the maglev train different conditions and urban difficulties were identified:
Primary constructions face extremely high demands in regards to driving comfort and cruising speed. If the primary engineering structure is connected to the superstructure, which results in bending resistance, specific rescriptive limits have to be taken into consideration. These limited values include the following measures: limits for the vertical bending resistance and deformations in traversal direction, as well as the angle at the edge of the bridge. Additionally a summary of occurring gaps for lengthwise deformation due to temperature changes, creepings, and shrinkage has to be provided. Based on these the system components of the track have to be designed. This results in a meaningful arrangement of traversal gaps in the construction. In addition to that, stiffness of the substructures to carry horizontal acceleration of the rail system has to be proofed.

The design of the supports, bearing the track girder, is designed with regard to the arrangement of the maintenance path between the two track girders. This ensures that in cause of an unforeseen halt the train can be centrally exited. Therefore emergency exits are located in the centre of the track on both sides of the bridge edges.

EXAMPLE: RAILWAY LINE MUNICH MAIN STATION – AIRPORT

Maglev train - Flyover Isar

In the area of traversing the river Isar the double-lined railway line runs north of the motorway Munich –Deggendorf (BAB A 92) closely to the highway.

Target of the design development phase was to build a bridge with balanced proportions in regards to length of span and building height. The following condition had to be met: to traverse the river Isar free of supports. Due to designing and economical aspects, a possibly low gradient and trace in combination with a framed guideway under the condition of a clear height was targeted.

During the design development phase the different variants for the design of the engineering structure had been examined. Included in this examination process were single-span and three-span as well superstructures made out of prestressed concrete, steel composite and steel structures. Due to economical reasons all Maglev train girder variants were built as one superstructure including both traffic directions. The sloped intersection angles of the maglev train with the river Isar (approx.150 gon) acts negatively for single-span superstructures due to the forced right-angled engineering structure finishing at the transition to the next track girder. The reason for this is the length of span of approximately 80 meters, which can only be realized with a large superstructure. To match the design of the neighbouring bridges of the motorway and the metropolitan railway, a prestressed concrete box bridge in form of a 3-span girder (spans = 41,30 m/ 75,30 m/ 41,30 m) had been preselected. Therefore, a bridge family of similar construction types was born.

During the final environment compatibility tests the problems of bat collision parallel to the river were identified by the environment planner. Due to the fact that these are protected animals, prevention measures were defined.

This included for example the integration of additional protection walls (7 meters high) for bats at the bridge borders. Taking into consideration the additional radio technical requirements the result was an engineering construction (box beam and protection walls for bats) with a total height of approx. 12 meters, which was from a design point of view not acceptable.

Therefore, the following primary engineering structure was developed: A 3-span-steel-trussed-bridge including an exterior main load-bearing structure and a thin steel composite plate used as a traversal load-bearing system. Due to the integrated protection walls for bats (made out of laminated safety glass with prints) and the integrated slab track, as well as an optimised gradient, connecting the integrated slab track on the bridge with the alignment, a slim engineering structure could be re-
administrated, with an overall construction height of 8,40 meters. Therefore, this engineering structure was matched perfectly with other bridges in the neighbouring environment.

The gradient of the maglev train is located approximately 8,5 meters over the river foreland and runs in the area of the engineering structure in a vertical curvature, which is balanced by variable support walls of the slab track girder. This track type girder III includes an overall length of 6,20 meters and is due to the continuous bearing situation and its construction height used for primary engineering structures.

The superstructure is virtually horizontal and matches with its clear height the neighbouring motorway bridge. The reason for that is that in the case of high water the flow section of the river Isar is guaranteed.

The cross section is defined by a centre-to-centre distance of the track with centric aligned maintenance paths and the alignment (a bowing track) in the ground plan. The inclined orientation of the intermediate pillars are from a current point of view optimal located close by the river bank. The motorway pillars were built accordingly. The pillar pairs were enlarged due to design aspects and due to ease the installation of pressings at the head of pillars. The abutments included in the end spans were used as pier discs in a way that the framework superstructure as well as the bordering built on stilts track girder was directly supported.

Changes in length along the longitudinal axis due to temperature changes were optimised with the help of fixed supports in the immediate pillar, which is located at the furthest point north-east. Due to the characteristics of the soil survey, deep foundation with large-diameter piles was used in all cases. These piles reach the tertiary soil with entrapped ground water. Therefore, additional measures have to be taken into account during the pile production.

The geometrical data for the maglev train Isar flyover including protection structure:

- Crossing point: Maglev-km 31,4+32
- Intersection angle: approx. 149,74 gon
- Single support span: 43,40 m/ 78,70 m/ 43,40 m
- Overall length: 167,10 m
- Construction height: 8,40 m
- Clear width between protection walls for bats: approx. 12,0 m
- Building height protection walls for bats: 6,10 m
- Clear height over high water/200 of the river Isar: ≥ 5,90 m
- Clear height over rural roads: ≥ 4,50 m
Figure 6: Flyover the river Isar - view / ground plan / cross section

Maglev train – bridge across motorway BAB A 92

The maglev train track line traverses the existing motorway in a sharp angle in the area of the motorway interchange - Munich airport. The motorway includes in this zone two lanes in each direction and additional lanes for approaching and leaving the airport.

Despite of the narrow situation in between the two motorway lanes a special flyover bridge was efficiently and economically developed. During the construction phase as well as in the final phase the shade of the flyover bridge should impact the motorway as less as possible. Therefore, a low gradient with an inclination based to the ground was targeted.
to minimise the height of bordering built on stilts maglev track and to reduce the dominance of the construction itself.

At first, it was obvious to realize the maglev train crossing with cost effective frame bridges, which are sectioned according to the system of the track slabs. The number of these frame bridges is determined by the required system length of the discreetly supported maglev train track girder type I. The span of this track girder is 24.80 m.

Figure 7: Maglev train track girder type I

Due to technical and route planning difficulties caused by for example horizontal and vertical alignment or by the construction itself, an adaptation of the system length of the regular maglev train track girder is possible. The length can be enlarged exceptionally by up to 31 m. In the case of the flyover over the motorway interchange - Munich airport, both systems with the span of 24 m and 31 m were not sufficient. Due to the required span of the frame bridges a higher construction depth of the transom girder emerged. The bigger construction depth together with the supported maglev girder showed a badly styled configuration. Therefore, a primary construction for further design development was used.

In addition to these problems, the point of support of the maglev girder exocentric on the transom girder caused different temperature affected deformations in the frame bridges with an adverse influence on the supports of the maglev girder in lateral direction. The construction of the frame bridges with the cast in place method additionally would have had a bad intervention on the motorway traffic situation.

As a result of the very slant crossing between the motorway lanes and the maglev train track line, the span of the primary structure was about 50 m, caused by the parallel to the maglev line running abutments of the primary structure. Due to the necessary construction depth of the chosen prestressed box girder and the construction related high level of the gradient, it seemed to be very dominant.

Caused by local necessities the primary structure should has been built in a complex repetition method. Due to economic reasons and the engineering design this solution was not evaluated any further.

As a result for an alternative was searched. A reduction of the span and therefore an optimization of the construction depth could be only reached by using a partially prefabricated superstructure for the bridge deck of the flyover bridge. The superstructure consists of individual prefabricated prestressed concrete girders with a continuous site-placed concrete filling. The prestressed girders were supported with fixed ends on intermediate pillars parallel to the motorway lanes.

Due to the radial maglev train track axis in the area of construction different directions of the girders in reference to the bearing structures for each span occurred. To optimise the bridge the rectangular fixed end bearing was not used, instead a slant arrangement was selected.

In the area of the motorway lanes neither supporting frames nor auxiliary pillars were allowed, the remaining gaps, which were not covered by the prefabricated girders, were closed by using prefabricated concrete girders with a site-placed concrete filling. These prefabricated slabs were designed as broad as necessary for the maintenance paths, parallel to the maglev train track and a continuous blind wall, to keep the bridge construction as narrow as possible.

Figure 8: Portal frame bridge solutions BAB A 92
Due to the continuous screen walls of different heights on each side a clear and uniform view of the five-span superstructure could be realized. On side railings on the bridge borders could be untended from a design point of view. Instead of a continuous supporting wall, several pillars were used. With the arrangement of these pillars on a row of maximum 70 meters length a light construction and a tunnel effect was avoided.

Due to the right-angled connection of the built on stilts tracks, the deep founded abutment, made out of three single cylindrical columns and tie beams, have also to be right-angled to the maglev train axis. The superstructure takes the forces to the intermediate supports and precast concrete beams like a continuous slab. The maglev track girder is fixed directly at the monolithic concrete supplemented.

The alignment runs in a vertical curvature. This is balanced with the variable height of the bearing shear walls of the slab track. The superstructure marginal rises from west to east.

A specific difficulty is the arrangement of joints in the superstructure. Therefore they have to meet the production requirements of the precast concrete beam as well as meeting the expectation of a fixed ended and restraint superstructure. Additionally they should not be congruent to the track girder edges.

The geometrical data for the flyover bridge – Motorway BAB A 92:

**Crossing point construction** 1-5: MSB-km 32,6+32/ - / 32,7+08/ 32,7+51/ 32,7+95

**Intersecting angle construction** 1-5: ca. 172 gon/ - / ca. 179 gon/ ca. 175 gon/ ca. 176 gon

**Clear width construction** 1-5: min 11,41 m – max 15,69 m

**Total length:** 229,10 m

**Construction height:** 1,60 m

**Clear heights over BAB A 92:** \( \geq 4,70 \text{ m} \)
Maglev track – Flyover – Maintenance centre

While approaching the airport of Munich the double-tracked maglev track runs from the motorway junction onwards closely between the motorway and the double-tracked metropolitan train system. To reach the central maintenance centre the maglev track traverses single-laned the double-tracked maglev track and the metropolitan train. Due to the fact that this flyover bridge is located near by the airport at the portal of the entrance it has to be very well designed. Additionally, the main target was to build an engineering construction, which could be built with minimum influence to the rest of the train operations. Due to design and economical reasons, a low gradient to connect the track girder at the bridge edge was targeted. In the area of the crossing a switch system of the metropolitan train is located.

During the pre-planning phase different variants for the crossing were analysed.

Due to the cramped circumstances and the curved intersection angle, portal frame constructions with added maglev track girder were not used. The reason was that the maglev track girder would have been extremely high, which would have resulted in great spans and therefore resulted in disproportional heights of the transom.

As second variant, a slim, dovetailed prestressed box girder as continuous girder with protective steel constructions for collecting snow and water was developed. This variant met the expectations of the box beam of the first requirement level. The secondary requirement level with more detailed track fittings would have been added separately at the upper boom. The superstructure should have been supported and fixed in the pillar axis of the engineering construction. No technical permission was approved for this specific girder with integrated track line despite design advantages and requirement fulfilling due to high risks.
To be on the save side, the following preferred third variant was selected: A five-span prestressed concrete structure in form of a curved trough represents the primary load-bearing structure with added slab track.

Due to the ground plan showing an alignment in a bow an approximate symmetric arrangement of the immediate centric pillars was used. The fixation of the superstructure took place only in two of the centric pillars. The clear width between the through walls of the superstructure results due to the maglev train structure gauge. Maintenance paths were not included due to the fact that the maglev train usually drives to the maintenance centre without passengers and therefore evacuation does not have to be taken into account.

The gradient of the maintenance centre lane runs in the area of the construction in a crest, which is realized by the arched superstructure. The thick of the superstructure slab varies and has to be strengthened in the area of the immediate pillars. Directly on the superstructure the slab track hast to be positioned. Additionally, the overhead catenaries of the metropolitan train have to be taken into account due to the fact that primary in the area of the bridges centenary poles with chain hoists are located.

The geometrical data for the maglev train flyover bridge – maintenance centre:

- Crossing point: Maglev-km 33,9+94
- Maintenance centre lane: Maintenance centre-km 0,3+93 – 0,5+79
- Intersection angle: 184,1 gon
- Single support span: 30,96 m/ 51,57 m/ 21,67 m/ 50,54 m/ 30,96 m
- Total length: 185,70 m
- Construction hight: 3,80 m
- Maximal width superstructure: 7,00 m
- Clear hight over: ≥ 4,50 m
- Clear hight over metropolitan train: ≥ 6,20 m
SUMMARY

Primary constructions of the maglev train have to meet technical requirements as well as requirements in regards to the bridge cross sections. Additionally, restrictions of urban situations and possible construction services have to be taken into account. Finally, the economical and efficient aspect of an optimal design and limit state as well as the best preconditions for the future maintenance has to be included. That is the reason why no standard solutions for the maglev train crossings can be applied. Individual constructions have to be developed. A good example is the Lot 3 of the maglev train route Munich main station – Munich airport.