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Elevated Guideways of Systems for Tracked Transport

Voies de circulation à guidage imposé, élevées sur piliers

Aufgeständerte Fahrwege für spurgeführte Verkehrssysteme

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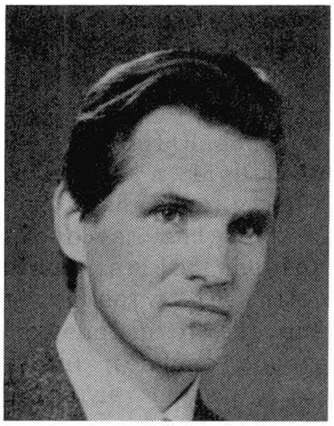

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SUMMARY

Elevated guideways are proving more and more to be the only possibility for building new sections for tracked transport systems. The requirements and their effect on the design and construction methods are explained with the help of several examples of elevated guideways for magnetically levitated transport systems and railway systems.

RESUME

La surélévation des voies de circulation est très souvent la seule possibilité pour réaliser un nouveau projet de transport à guidage imposé. Les exigences et leurs incidences sur l'étude et les méthodes de construction sont illustrées par quelques exemples de voies surélevées construites pour le système de transport magnétique et le chemin de fer.

ZUSAMMENFASSUNG

Die Aufständerung des Fahrweges ist immer häufiger die einzige Möglichkeit, eine neue Strecke für spurgeführte Verkehrssysteme zu bauen. Die Anforderungen und deren Auswirkung auf Entwurf und Bauverfahren werden an einigen Beispielen aufgeständerter Fahrwege für die Magnetbahn und die Eisenbahn erläutert.

1. INTRODUCTORY REMARK

More than 150 years ago the development of the railway as a large scale transportation system was begun, an important prerequisite for industrial progress. In those days the tracks were laid as far as possible on ground level or on embankments, and bridges were only built to overcome such obstacles as roads, rivers or deep valleys. Nowadays, however, it is often found that the only possible means of building a new transportation route is to elevate the whole line, i.e. to raise the track to a higher level. This insures unimpaired use of the terrain below and avoids the severing of the landscape by the traffic line.

In order to compete with the automobile and the airplane a tracked mass transportation system must operate at high speeds. For this reason, along with the further development of the wheel-on-rail system, the magnetic high-speed system with contact-free levitation technology (MagLev) was developed, which is currently being examined at test facilities under realistic conditions. (Fig. 1)

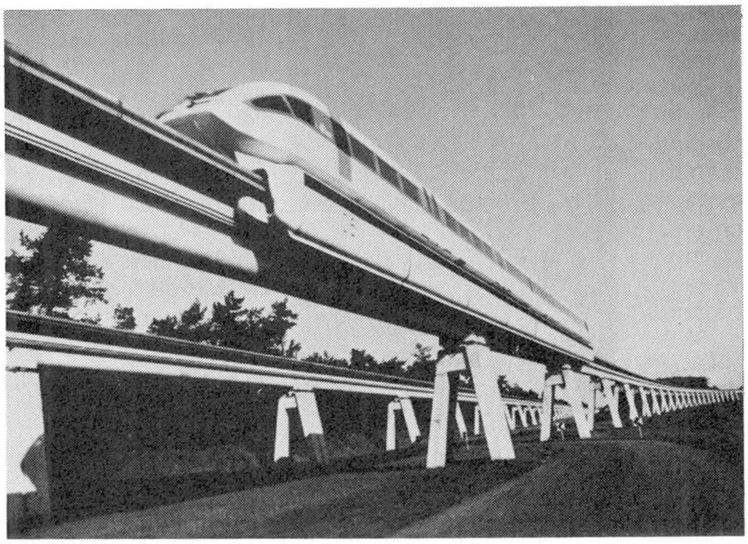

Fig. 1 Concrete guideway for the TRANSRAPID Test Facility Emsland, 1st construction phase with MagLev vehicle

2. GUIDEWAYS FOR HIGH-SPEED MAGLEV TRANSPORTATION SYSTEMS

2.1 System-specific requirements

Such transportation systems place specific demands on the guideway, which are determinative for its design as well as its construction methods:

* Structural system of the guideway in form of a girder, which is embraced by the vehicle and to which the functional components (in place of conventional rails) are fastened.
* A positional accuracy of the functional components unusually high for structures must be guaranteed.
* The structural system must possess a high rigidity and be insensitive to vibrations.

2.2 Elevated Guideway

2.2.1 General Remarks

The requirements stated above can be satisfied both economically and aesthetically by the use of freely spanned girders with a span of 25 to 35 m, which are mounted on piers of sufficient height to ensure the uninhibited use of the underlying terrain.

Because of the required rigidity and insensitivity to vibration of the structural systems prestressed concrete for the girders and reinforced concrete for the substructures as construction materials have proven advantageous.

Needed is a highly economical assembly procedure which satisfies strict tolerance requirements and a design whose longterm deformations are about zero and which allows unavoidable soil settlement to be quickly compensated.

This is achieved by the use of prefabricated girders, which ensures fast construction progress without regard to weather conditions, high accuracy and controlled quality of the materials.

Dyckerhoff & Widmann AG planned and, together with partners, built a guideway based on the above principles for the TRANSRAPID Test Facility Emsland (TVE) in northwestern Germany, which was erected in several construction phases between 1980 and 1987. This guideway, which is elevated along nearly its full length, has in general a clearance of 4.70 m above ground level and is single-track in compliance with the needs of the test facility. By the summer of 1990 the TRANSRAPID MagLev vehicles had covered more than 100,000 km on the test route achieving speeds up to 435 km/h.

The guideway, consisting of a straight-away and two turning loops, has a total length of ca 31 km. Besides the concrete guideway, a description of which follows, the test course also contains sections with girders of steel, [1], [2].

2.2.2 Design of the concrete guideway for the TVE

In order to fulfill the extremely strict requirements for positional accuracy of the functional components, the design is based on a strict separation of the two installation phases erection of the supporting structures and mounting of the functional components (Fig. 2). This allows greater tolerances in the supporting structures, which can be compensated for later by adjustments made when the functional components are installed. Thus initial deformations in the green concrete of the girders have no influence on the positional accuracy of the functional components.

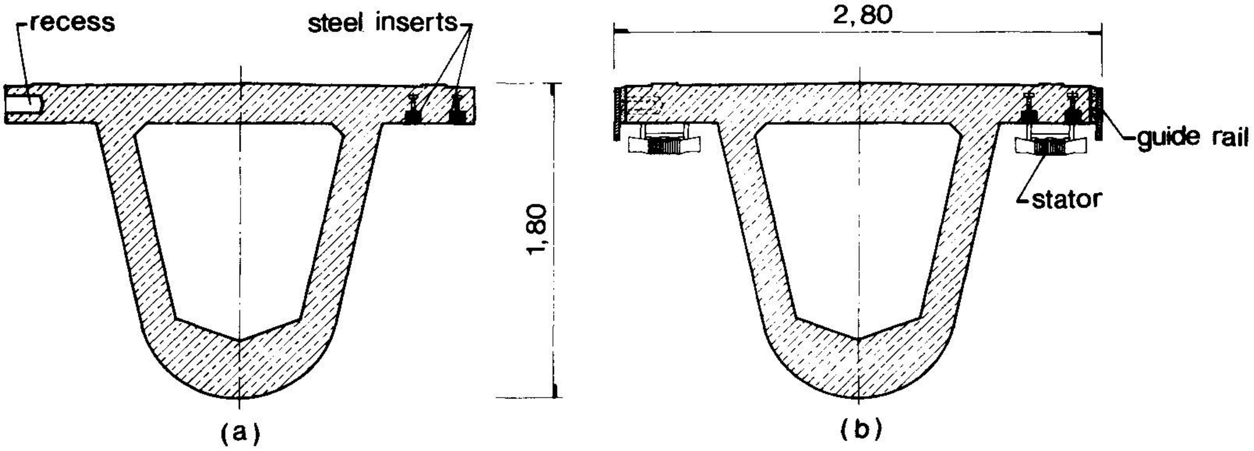

Fig. 2 Girder cross section TVE, 2nd construction phase
(a) before, (b) after installation of the functional components

The hollow-box girders of the guideway are of prestressed concrete and have a cantilevering deck slab. As single-span girders they have a span of ca 25 m with a structural height of 1.80 m. There are also spans of ca 31 m at a structural height of 2.40 m as well as a few other spans.

Essential for a long-term maintainance of the original high positional accuracy of the funtional components is the non-distortional prestressing of the track girders, which ensures that practically no plastic deflection occurs. This is achieved by the radial forces of the curved prestressing tendons counteracting the dead load and providing average compensation for this load.

Because of the strong eccentric loads carried by them, especially in curves with max. 12° cant, the piers are A-shaped, as seen in Fig. 3, with two slender, slanting slabs set in the connecting slab of the piles and running together at the pier head, upon which the structural bearings of the track girders, laterally spread, are positioned.

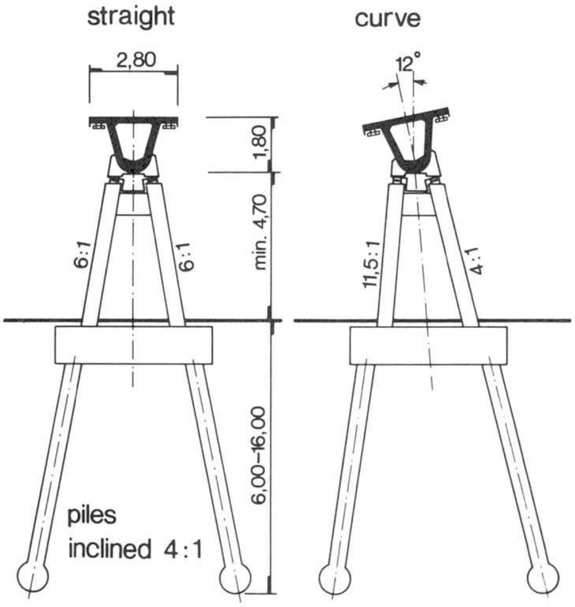

Fig. 3 Cross section of the TVE guideway, span 25 m

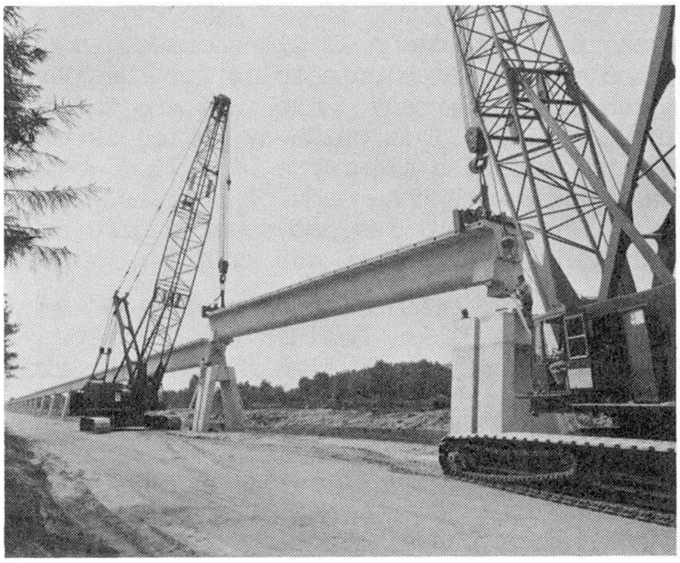

Fig. 4 Installation of the track girder TVE, 1st construction phase

2.2.3 Construction procedure for the TVE concrete guideway

- The foundations and piers were erected in concrete cast in-situ by means of a wandering construction site, which progressed at an average of three piers per day, ca 75 - 90 m.
- The track girders, altogether about 800 in number, were produced as prefabricated prestressed concrete elements in a field factory at the rate of one girder per day in each of two, and at times three, moulds operating simultaneously. The fast rate of production was made possible by prefabricating the mesh of reinforcing steel and heating the green concrete, [1].
- The installation of the track girders at the construction site was accomplished by use of mobile cranes with caterpillar drive (Fig. 4).
- With the help of hydraulic jacks the girders were finely positioned and then set on the bearings by filling in with mortar.

2.3 MagLev guideways for public service

The cost of the guideway and its compatibility with the environment are decisive factors for the realization of new transportation routes. For this reason there was an early activity in Germany starting route studies for MagLev systems and setting up a basic design for typical guideway constructions.

2.3.1 The alignment of MagLev lines

Because of the derailment-proof clasp of the track combined with great cant a MagLev line can be aligned with comparatively small radii of curvature and because of the great climbing ability of the long-stator propulsion it can be aligned with steep gradients. As a result it can be favorably adapted to the terrain through which it passes.

The limiting alignment elements (for instance for speeds of 400 km/h and 500 km/h respectively) are

	400 km/h	500 km/h
Maximum cant	12°	12°
Minimum radius of curvature (plan)	4 180 m	6 530 m
Minimum vertical radius for summits	24 700 m	38 580 m
Minimum vertical radius for sags	12 350 m	19 290 m
Maximum gradient	10 % (1:10)	10 % (1:10)

2.3.2 Typical guideway constructions

For public service lines double-track guideways are generally needed which can either be elevated or constructed on ground level or, depending upon the terrain, be continued over bridges or through tunnels. For example Fig. 5 shows an elevated double-track guideway built of prestressed concrete. It consists of two separate girders set side by side on a common substructure. The girders can be designed to span 35 m at a construction height of 2 m. The substructures consist of slender double columns adaptable to differing clearances. The girders are prefabricated and then installed by means of mounting devices. In difficult terrain special devices can be moved along on the already available supports.

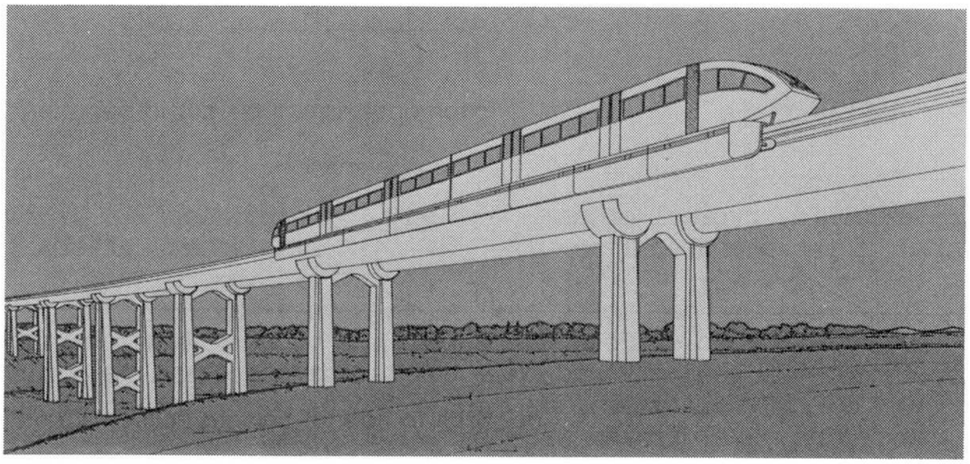

Fig. 5 Elevated double-track guideway, drawing in perspective

3. ELEVATED RAILWAY LINES

As already mentioned a lack of necessary space for the construction of a new railway line can also lead to a decision to elevate the track. A good example of this is the urban rail system Metro Medellin now under construction in Columbia, which will connect the suburban areas with the city center, [3]. Since an underground line would have been too expensive, the only other possibility to realize an intersection-free route over a length of about 11 km within the inner city area was to raise it 7 to 19 m above street level. The rest of the Metro Medellin network, which has a total length of about 30 km and which was planned and built by a Spanish-German consortium, is located on the outskirts of the city and runs on ground level.

Within the consortium Dyckerhoff & Widmann AG was responsible for the design work for the 11 km of elevated track, including 13 elevated stations. The superstructure for the double-track elevated line with ballast bed, as shown in Fig. 6, consists of prefabricated post-tensioned concrete girders, each generally 30 m in length with a weight of 2300 kN, supported by a number of center piers of concrete cast in-situ, which usually follow the median strip on main thoroughfares. Under each track is a seperate girder.

To allow for clearance and for architectural reasons the girders are shaped at both ends to rest on hidden hammerheads on the piers. Thus the elevated railway appears as a light and well balanced structure (Fig. 7).

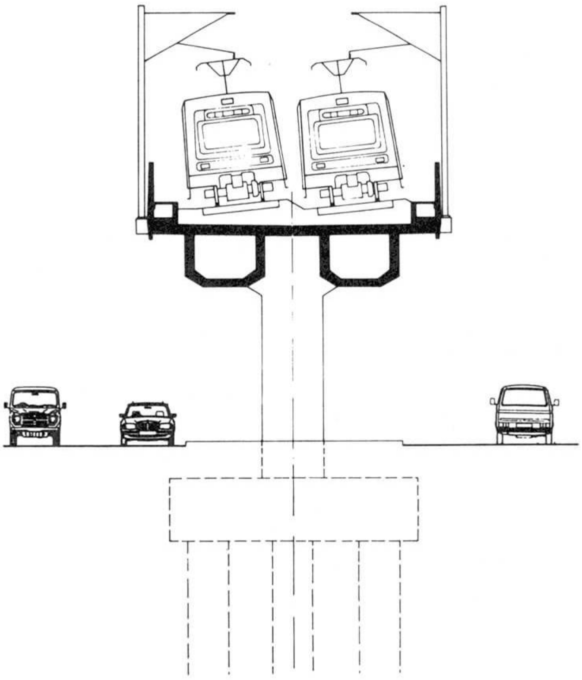

Fig. 6 Metro Medellin, typical cross section of the elevated line

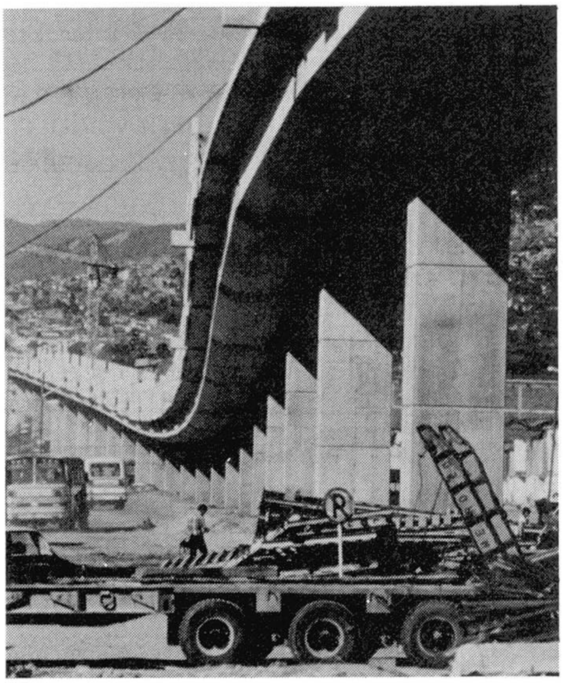

Fig. 7 Metro Medellin, elevated line under construction

The construction procedure had to be planned in such a way as to hinder the traffic as little as possible. For this reason the girders were prefabricated in field factories outside the city and then mounted by a special launching truss, which can travel along the hammerheads of the center piers leaving the finished superstructure behind. The girders were delivered to the launching truss by trucks designed for this purpose, which can travel along the already finished superstructure. The maximum transport distance was about 4 km.

4. CONCLUSION

With prestressed concrete elevated lines for tracked high-speed transportation systems can be constructed in an economical as well as aesthetically satisfying manner. High standards are required for accuracy of execution and long-term maintainance of the specified form. When design and construction are in the hands of an experienced company with high technical standards, the prerequisites for an optimal realization of this type of structures are assured.

REFERENCES

1. LÖNNECKE K.-H., STÜBEN H.-H., Bauausführung des Betonfahrweges der Transrapid Versuchsanlage Emsland. Bauingenieur 58, 1983, No. 4, p. 129 - 134.
2. HILLIGES D., Aufgeständerte Betonfahrwege für Magnetschwebefahrzeuge. Vorträge Betontag 1983, publisher: Deutscher Beton-Verein e.V., Wiesbaden, 1983, p. 107 - 113.
3. SCHAMBECK, H., Metro Medellin - eine Paketlösung für Finanzierung, Planung und Bau eines neuen Verkehrssystems. Vorträge Betontag 1989, publisher: Deutscher Beton-Verein e.V., Wiesbaden, 1989, p. 397 - 411.