Research on High Speed Maglev Guideway System

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Abstract: In the preliminary study of the potential maglev project, the alignment conditions are mainly divided into two types, underground type and elevated type. As to the former, in order to determine the arrangement of the tunnel and corresponding girders, we should focus on the aero dynamic effects when the maglev train passes through the tunnel, treatment measures to the settlement, emergency plan etc. As to the latter, new practical elevated guideway system should be designed based on the following principles: optimization of the maglev system arrangement, high escape efficiency, economic use of land and better environment protection, etc. The study progress on the above two aspects by Shanghai Maglev Transportation Engineering R&D Center are introduced in this paper.
Key Words: Maglev alignment, Tunnel, Aerodynamic effects, Treatment measures to the settlement, Safe escape, Elevated guideway system

1 INTRODUCTION

Shanghai Maglev Demonstration Line is the first commercial operation line with conventional-conductive maglev technology in the world. Its guideway system is based on the elevated hybrid girder, which ensures the successful construction and safe operation of Shanghai Maglev Demonstration Line. Since the line was open to the public, it has been operated safely and timely for more than 8 years. According to the feedback from the operation & maintenance department, the line is in stable statement. With the development of the research on the potential project, the existed guideway system will not be completely suitable for the complicated condition of potential maglev projects in the future. Therefore, corresponding maglev guideway systems are necessary. Researchers in Shanghai Maglev Transportation Engineering R&D Center have done series of research work on the maglev tunnel and the elevated guideway system according to the requirements of the potential project.

2 RESEARCH ON MAGLEV TUNNEL

In the preliminary study of the project linking two airports in Shanghai, the way to pass through the Huangpu River was designed as underground tunnel, with length of 2.8km， with maximal depth of about 60m, and with designed speed of 250km/h. For the lack of similar experience in maglev tunnels, we carried out series of key researches on the Huangpu River tunnel project. Based on these researches, we optimized the layout, guideway structure, and the engineer treatment of the maglev tunnel project.

The tunnel was designed as double-track tunnel, as shown in Figure 1. The tunnel section is divided into upper and lower space. The upper space is for train operation and equipment installation. The lower space is for evacuation, rescue and the installation & maintenance of some equipment.

The train’s operation space is designed to meet the required clearance envelope limit. The space from the limit to the tunnel lining is for equipments installation. The maintenance power box and wireless control junction box are fixed on the sidewall. The top space of the tunnel is set as the flue partly along the tunnel. The basic and emergency lighting, monitoring camera, speaker, leakage cable and the maglev train special instruments are arranged along the lining. Hydrants (every 50m) and the inspection manholes are arranged between the two tracks.

Under the traffic lane slab, the space between the two tracks is set as the overhaul path along the tunnel to the working wells at two ends. The cable trays, equipment boxes and rainspouts are arranged on the side wall of the overhaul path. The space inside the two apron pieces supporting the tracks is used as the tunnel of traffic cables, and there is an access gate linking with the overhaul path every 100m. Cable channels lie at each side out of the apron pieces, doubling as the gully.

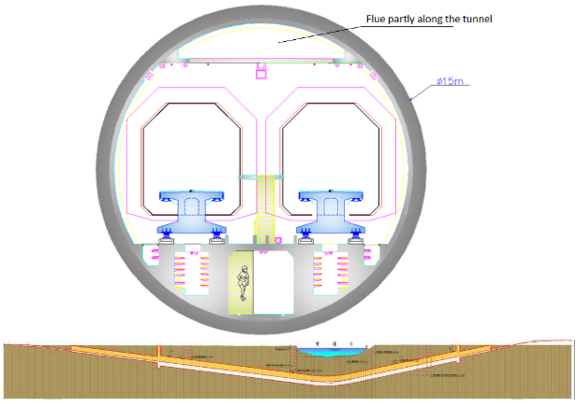


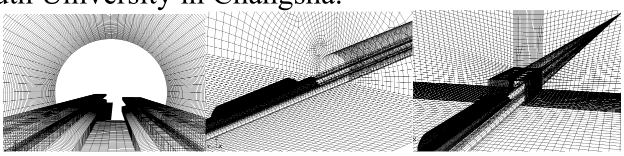
Figure 1 Layout of the Huangpu River Tunnel.

2.1 Research on aerodynamic effect of tunnel

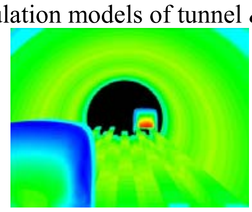
Numerical simulation and scale model test were both carried out to examine the aerodynamic effect when maglev train passing through the tunnel with the speed of 200km/h and 250km/h. The research focused on the train surface pressure, the pressure variation in carriage, the pressure on tunnel and the micro pressure wave at the tunnel opening caused by the train passing through the tunnel or rendezvous in the tunnel. The influence to the aerodynamic effect caused by the tunnel shaft, the tunnel opening buffer structure and the septum (if designed) is also examined.

In simulation, we use FEM sliding mesh to describe the relative movement between the train, the tunnel and the air. The tunnel pressure wave was imitated in 'One-dimension compressible isentropic flow model'. Loss coefficients of some special structures was got from 3d calculation of the software FLUENT.

In the model test, 1/25.4 scaled models of the train and the tunnel were produced according to the similarity criterion. The test was carried out at the Key Laboratory of Traffic Safety on Track of Central South University in Changsha.



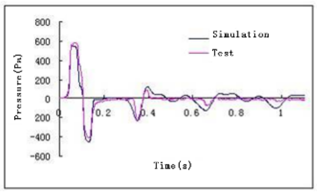
a) Simulation models of tunnel & tracks



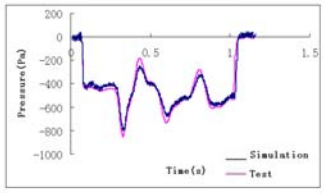
b) Simulation pressure

Figure 2 The simulation model of maglev tunnel for aerodynamic research

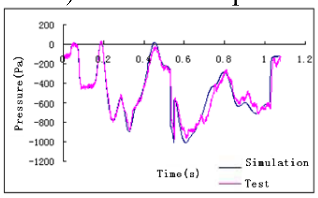
Figure 3 the model test of maglev tunnel

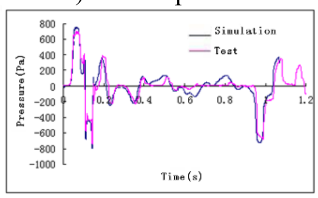


a) Train surface pressure



b) Tunnel pressure





c) Pressure of train surface and tunnel in rendezvous

Figure 4 The contrast between simulation and test on the aerodynamic effect of maglev train in tunnel

From the simulation and model test, we got some conclusions about the aerodynamic effect of maglev tunnel, which have helped the tunnel project design and optimization.

1) The tunnel buffer structure can evidently reduce the micro pressure wave at the opening, and can reduce the variation of the train surface pressure and the tunnel pressure. For example, when the train runs through the tunnel at the speed of 200km/h, the train surface pressure reduces about 100 Pa, and the tunnel pressure reduces about 150Pa.

2) The shaft can evidently reduce the micro pressure wave of tunnel. When there are buildings near the opening, shaft is necessary to the tunnel.

3) Rendezvous has little effect on the rate and the amplitude of the pressure variation in the train. With speed of 250km/h, the max variation rate is about 322Pa/3s, and the max amplitude is 960pa. If septum is designed, the variation rate becomes 529Pa/3s and the amplitude becomes 1588Pa, and this will make the ride uncomfortable.

4) When the trains run or meet in tunnel with speed of 200km/h~250km/h, the max amplitude of the train surface pressure is from -3500Pa to 2700Pa, which is permitted by the structure.

5) When train runs in tunnel in speed of 250km/h, the max tunnel pressure is about 3200Pa.

6) With the research conclusions, the clearance area value and the blockage ratio of maglev tunnels with different speeds are suggested in Table 1.

Table 1 Suggested values for maglev tunnel sections

Speed (km/h)	Clearance Area(m^2)		Blockage Ratio		Comments
	Single-track tunnel	Double-track tunnel	Single-track tunnel	double -track tunnel	
200	52	69.4	0.240	0.18	
250	60	73.5	0.208	0.17	
300	60	86.1	0.208	0.145	
350	70	100	0.178	0.125	
400	80	110	0.156	0.114	
450	100	110	0.125	0.114	No rendezvous in tunnel is suggested when speed is higher than the value of the first column.
500	110	120	0.114	0.104	
550	120	130	0.104	0.096	

2.2 Research on tunnel settlement and treatment measures

Due to the soft soil in Shanghai, the tunnel construction method is mainly shield-driven. The longitudinal uneven settlement of the tunnel during long term operation is mainly caused by 6 factors, as follows.

1) The difference in consolidation characteristic of the soil layers lying under the tunnel,

2) Constructions near the tunnel,

3) The addition of ground load above the tunnel,

4) The variation of water level in the tunnel layer,

5) The subversive longitudinal deformation caused by the soil erosion in soil layers under the tunnel, and

6) The differential settlement between the tunnel and the working well.

According to the 2D settlement calculation of the typical tunnel section and the 3D settlement calculation of the total tunnel model, the maximal settlement of the tunnel can be controlled within 50mm, 80 percents of which completed in the construction period. Usually tunnel will not be put into operation until half to one year after shield work done, by when the initial settlement and the consolidation settlement will have almost completed.

Some practical engineer measures are suggested to control the maglev tunnel settlement, as follows.

1)The construction quality control standards are produced to control the longitudinal deformation of the tunnel, so as to meet the requirement of the maglev train operation.

2) With consideration of the tunnel property and the girder arrangement, the short π-shaped hyper beam with span of 12.384m is suggested as the major girder beam used in tunnel.

3) Adjustable bearings are set under the girder ends, which can be adjusted from upward 40mm to downward 20mm,so as to adjust the alignment when necessary.

4) In the operation of long maglev tunnel, some special control measures are suggested:

(1) Any construction near the tunnel must be at least 3m away from the tunnel outline.

(2) The additional load value to the tunnel wall can't be more than 30kPa, caused by side building (including foundation basement) or some construction factors like precipitation or grouting, etc.

(3) The additional curve radius should be no less than 15000m, caused by the tunnel deformation curve.

2.3 Research on fire protection and rescue escape in maglev tunnels

The fire protection mainly aims at the tunnel fire. Based on the principle of "Rely mainly on prevention, together with extinguishing, and controlled in the tunnel", reliable disaster proof measurements are taken to provide a safe and economically rational tunnel.

The design is on the assumptions as follows,

1) only one place fires in tunnel at one time,

2) the scale of the fire is no more than 10.5MW,

3) taking the escape efficiency and the reliability of rescue into account.

In maglev tunnel structure design, a layer of 20cm thick in-situ concrete floor is set inside the segments, doubling as the fire proof inner lining of the segments, so as to protect the segment structure when fired.

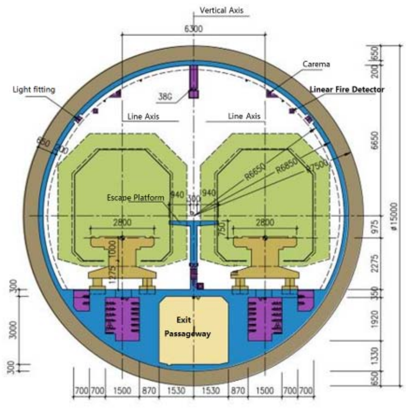


Figure 5 means of escape in maglev tunnel

The escape plan of maglev passengers in tunnel is designed as, the equipment mainly include escape platform in tunnel (usually used as maintenance platform), escape way in tunnel and the escape stairs set in the working well and the middle well. When got fired, the train stopped at the accident rescue point firstly, then passengers escaped through the escape platform to the escape way, and then escaped to the nearest working well or middle well, finally passengers escape to the ground through the escape stairs set in the well.

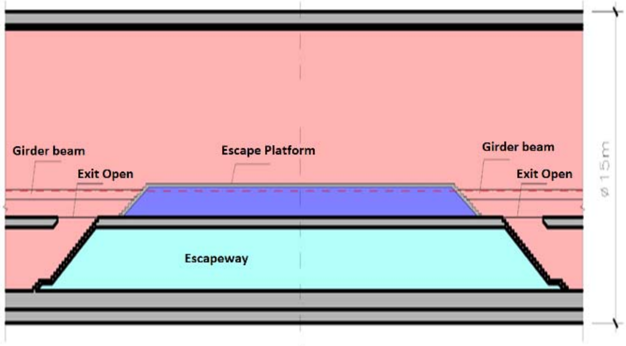


Figure 6 Arrangement of escape platform in maglev tunnels

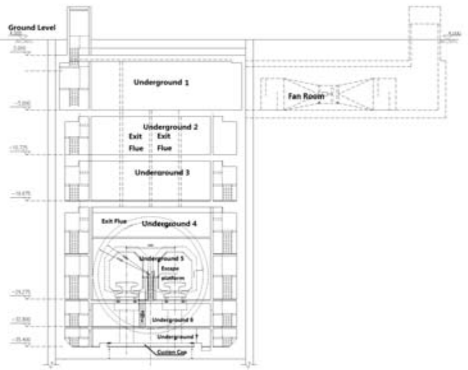


Figure 7 Arrangement of escape stairs in working well

3 RESEARCH ON ELEVATED STRUCTURES

In high-speed maglev line design, usually there will be a lot of existing or planed urban land along the line, which leads to more critical requirement on the escape system and the environmental protection to the maglev transportation system. In urban area, the transportation of girder beams becomes more difficult because of the safety caution to the existing city roads and bridges. In this case, “girder on bridge” system is suggested as the major structure type to overcome the difficulty in line design, so as to improve the availability of the maglev transportation system.

According to the requirements in line design, the design of girder on bridge system should follow some principles as follows.

1)Separate the support bridge from precise machined girder beams, so as to reduce the mass of the precise machined body.

2)The support bridge is designed with the ability to transport girder or bridge with trolley on it, so as to reduce the construction transportation difficulty in urban area.

3)The Precise adjustment of the alignment is set to be done on the girder beams, which are mainly short beams successfully designed before such as slab girder beams (as shown in Figure 8) or π-shaped girder beams (as shown Figure 9).

4)Escape measurement is considered in the new system, taking advantage of the train clearance limit space as the escape way in rescue, which doubles the overhaul path in normal times.

5)Override beams are used at the span end, so as to reduce the effect on the alignment by the uneven settlement of the substructures.

6)The integration layout of the system equipments is improved, so as to save the land occupied.

Figure 8 Slab girder with span of 6.192m

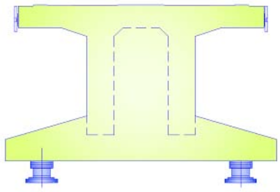


Figure 9 π -shaped girder

3.1 *Girder on bridges system*

According to the chosen girder beam type and the functional needs, ‘Slab-beam on bridge’ and ‘π -shaped beam on bridge’ are optimized as the suggested two forms. The major layout is shown in Figure 10. The support bridge is a prestressed concrete box beam. Two tracks are placed on the top surface of the bridge, and on both sides cantilever of the box beam are cast-in-cite short walls on which cable bearers, noise barrier screens and some other equipments can be fixed.

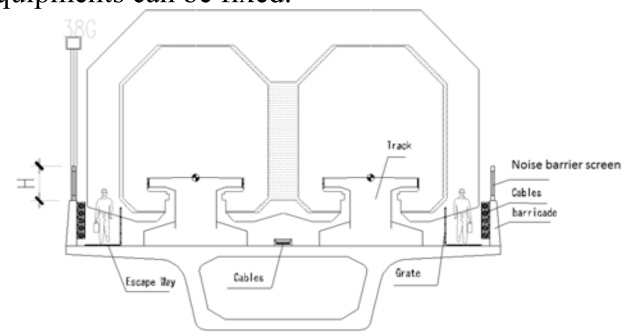


Figure 10 Layout of maglev girder system on bridges

Taking the typical system span 24.768m as an example, the constituents of ‘Slab-beam on bridge’ and ‘π -shaped beam on bridge’ are shown in Table 2.

And the detailed schemes are shown in Figure 11 and Figure 12.

Table 2 Two different types of girder on bridge

Item	Slab beams on bridge	π -shaped beam on bridge
bridge	Prestressed concrete box beam with span of 24.768m	Prestressed concrete box beam with span of 24.768m
girder	Slab beams with span of 6.192m	π -shaped Integrated type girder with span of 12.384m
Straddled beam	π -shaped Integrated type girder with span of 6.192m	π -shaped Integrated type girder with span of 12.384m

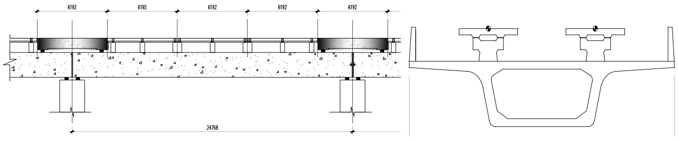


Figure 11 Layout of slab beams on bridges

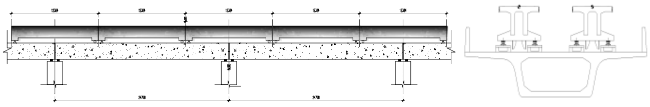


Figure 12 Layout of π -shaped beams on bridges

In order to reduce the land scale occupied by the system instruments along the line, trackside switch cabinets are optimized and placed on the bridge, as shown in Figure 14. The trackside switch cabinet is optimized with size of 1.25m in thickness, 3m in width and 3m in height. Accordingly the cantilever of the box beam will be widen about 1.3m and strengthened where trackside switch cabinets are placed.

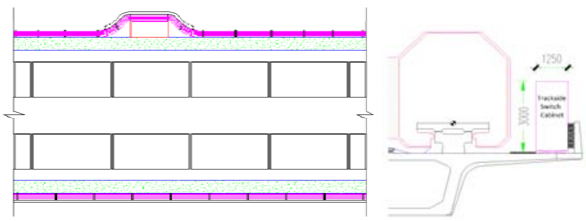


Figure 13 Layout of trackside switch cabinet on bridges

A new adjustable escape style was put forward for the girder-on-bridge system, which includes escape instruments fixed in the train, escape way on the bridge, and escape stair linking the bridge and the ground. The escape instruments fixed in the train include four parts. The first is a telescopic carriage which can reach out of the train in some distance and keep firm linking. The second is an escape air cushion made of light material (like Nylon, etc) which can be overplayed, can be bloomed to fixed shape, and has balance weight at one end. The third is a set of gas generator which can provide gas for the air cushion quickly. And the last one is an instrument cabinet fixed in the train, where the carriage, the air cushion and the gas generator can be placed when not used.

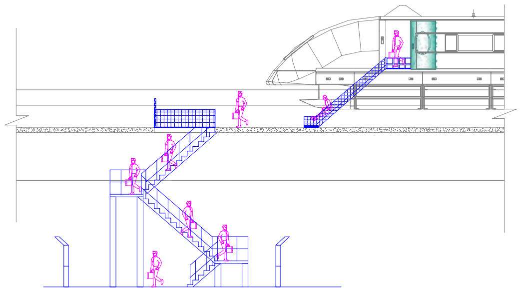


Figure 14 The escape system of girder on bridge systems

3.2 Research on aerodynamic effect of girder on bridge system

In order to test the technique feasibility of the girder on bridge system, the aerodynamic effect of maglev train running on the bridge is examined with the method of both simulation and scaled model test. The scaled model is made as 1/20.4, and the test was carried out at the Key Laboratory of Traffic Safety on Track in Central South University.

Figure 15 model test for aerodynamic effect

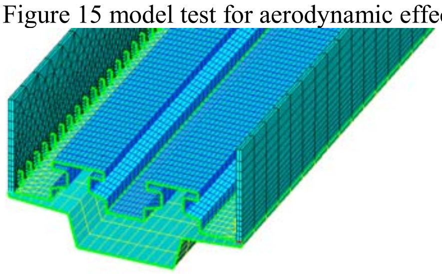


Figure 16 Simulation model for aerodynamic effect

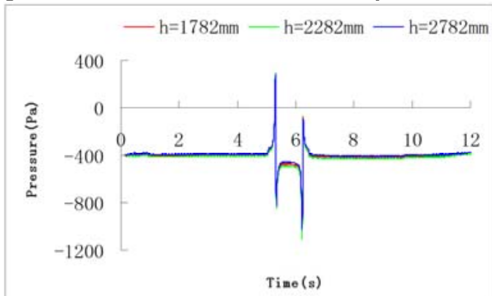


Figure 17 The effect of screen height to the train's surface pressure