Design Criteria for Maglev Structures

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Abstract: Maglev systems represent an entirely new concept in transportation. They will not operate on nor share the right-of-way with any other system. It is important, therefore, that the guideways be designed and constructed so as to be economical, constructable, durable, adaptable, reliable, and readily maintained. Comparisons should be made with the current transportation systems, especially highways and railroads. Since most of the guideway will be elevated, the comparison should be with the bridges. The object of the comparisons should be to avoid the shortcomings of the other systems while building on their strengths. This paper develops in some detail design and construction criteria that will ensure a good, long-lived performance of the maglev guideway. The importance of beauty should have a low priority in comparison to the other design criteria. Clean, simple details meeting other criteria will ensure an acceptable appearance. These criteria were used in evaluating the four maglev concepts developed for the National Maglev Initiative.

INTRODUCTION

Maglev should be looked at as a new system having both advantages and disadvantages when compared to the other forms of transportation: air, highway, waterway, and railroad. The state-of-the-art of these systems developed over many years and, in some cases, is still developing. The designers of a maglev system must examine the strength and shortcomings of the other systems, and profit by them.

Examples of shortcomings are readily found in the highway system. In "Status" (1995) 14% of the 576,000 bridges were classified as functionally obsolete, and 19% were classified as structurally deficient. Some of these bridges are less than 20-years old. The designers failed to foresee the increased requirements that would drastically impact these systems.

Railroads have fared better. Most railroad bridges are of modular construction using simple spans and readily replaceable track components. A significant number of these bridges are still performing satisfactorily after 100 years. The use of simple, noncomposite spans and standard track components permits timely repairs and restoration of rail service when damage occurs.

DESIGN CRITERIA

The high cost of constructing a maglev system demands that special attention be given to planning for future growth. It also demands that the system be

1. Constructable
2. Reliable
3. Maintainable
4. Adaptable
5. Durable

These criteria should be developed in detail and used to evaluate any proposed system. The following are some thoughts on these criteria.

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Constructable

These structures should be constructed of readily available materials. They should be capable of being readily built by any heavy construction contractor. Elements should fit the capabilities of existing fabricating plants. Standard shapes and structural systems already proven in highway and railroad construction should be considered. Proposed innovative shapes and construction techniques should be studied in-depth to ensure an economical buildable structure.

The most constructable structure is one with the simplest, most direct load path. Given the constraints of reliability, maintainability, and adaptability, the load path from application to foundation should involve as few members as possible.

Reliable

To be successful any transportation system must have an acceptable degree of dependability. If the cost of a trip is low, the user will accept a low degree of dependability. If the cost is high, the user will demand that the system be reliable. Inclement weather, whether snow or rain, hot or cold, foggy or windy, must not impact the reliability of the maglev to meet its schedule. Any flaw, however minor, that would shut down the system would have a major impact. Maglev provides no opportunity to bypass a section, as does a highway or even a railroad. The system must lend itself to rapid replacement of any questionable element.

Reliability also means safety, both actual and perceived. Accidents on highways [although the most dangerous method of transportation—National Transportation Safety Board (1996)] have been accepted by the user. Accidents on railroads are not considered unusual. By contrast, the safest method of transportation (the airlines) receives special attention on all their accidents and even near-accidents. Maglev will share the airlines' problem because it is seen as an uncertain if not unknown element.

Maintainable

Any system requires maintenance to keep it in top operating condition. The ease of making adjustments as well as inspection to detect the need for adjustments is critical. All structures are subject to geometric variations during construction, operation, and changes in climactic conditions. If adequate tolerances are not provided during construction, the cost of construction will greatly increase. All structures deform or deflect under load. The amount of deflection that can be accepted during operation must be reasonable. If deflection is a controlling factor in design, the cost of construction will be greatly increased. The amount of tolerance for longitudinal thermal movement and the bending of a member due to temperature differentials must also be reasonable.

To keep these factors from unduly impacting the structure, a system of adjustments must be provided. The adjustments must accommodate vertical, horizontal, and torsional corrections. The means of making these adjustments must be simple and readily accessible.

Adaptable

A prime example of adaptability is the ease with which the early railroads were able to change from wide or narrow gauge to standard. In 1881 the Illinois Central Railroad changed (880 km (550 mi) of wide gauge track to standard gauge from Cairo, Ill., to New Orleans. This was done in less than 24 hours using more than 3,000 workers (Corliss 1950). In a similar manner, sizes of rails and changing of ties from timber to concrete have been readily accommodated. Maglev designers must anticipate major and even drastic changes in future vehicles and methods of propulsion and guidance. To as great an extent as possible, the supporting structures should be capable of carrying all possible modifications.

To achieve this goal the functions of propulsion and guidance should be separated, as much as possible, from functions of support and resistance of forces. A comparison of maglev with a railroad illustrates the importance of this separation. A train is driven by the friction between the driving wheels and the rail. The rail also guides the train by contact of the flanges and the inside of the rail. The rail provides direct support of the wheels over only a short span. The main support of the wheels is the ties. These distribute the wheel load to the ballast or to the deck of the structure. The two elements (the rail and the tie) are easily removed and a better rail or tie is installed. This makes the railroad track very adaptable. In contrast, the maglev systems proposed combining the propulsion, guidance, support, and resistance functions into one element. Advanced technology, which is certain to come, would thus require removal and replacement of a major element rather than a simpler minor one.

Any proposed system should be evaluated on the ease or difficultly of removal and replacement of the "rail" element. This is important not just for technological advances, but even more important as the replacement of any malfunctioning element. Ideally, rail elements could be stockpiled and, in the event of a malfunction, could be inserted in the system while the malfunctioned element is repaired.

Durable

To meet the expectations of the public the maglev structures must be durable. High-performance materials must be used. These materials must also have proven themselves in other installations such as highways and railroads. Relatively new materials, unproven by long time everyday use, should only be used where necessary. Such uses should also be limited to small, readily replaceable elements.

Of equal importance to the high performance materials are the details. Great care must be taken to ensure that secondary stresses are minimized, that continuity of reinforcement is ensured, that congestion of reinforcement is avoided, that bolts and welds are more than adequate, that fatigue-sensitive details do not exist, and that critical areas are readily accessible for inspection and maintenance. Redundancy must be built-in to as great a degree as possible so that even if a partial failure occurs between inspections, there will be no unexpected disruptions to service.

Another aspect of durability is the capability of a structure to carry loads that exceed the design loads. This was discussed under reliability as a need to forecast future requirements. Here it is seen as a need to ensure that loads even greater than those forecasted can be supported. The longevity (durability) of railroad structures can be attributed to a large degree to the low stresses used by the designers. These low stresses were used because of the concern of the designer for unknown or uncertain properties of the materials. In these days of quality control, this doubt has been removed. However, do we know enough about the durability of materials subjected to large loads applied and removed instantaneously? Our methods of analysis are based on static loads with an empirical "guess" for the force we call impact. We should profit by the experience of the designers at the start of the 20th century so that our entry into the 21st century is as successful as theirs.

SUMMARY AND CONCLUSIONS

Some of the concepts presented in the National Maglev Initiative tended to give a great weight of importance to appearance and to the use of high-strength materials to achieve a lighter structure. New materials, namely fiber reinforced plastic, were also used.

The combination of these tendencies produced structures that would be highly stressed under service conditions. Long-lived structures having low maintenance are generally structures with low service load stresses.

The effect of maglev loads, the sudden application, and short duration on actual structures are not yet fully understood. Structures supporting loads that are significantly different than those of highways or railroads should be designed conservatively.

Pleasing appearance can be achieved at small cost by clean lines, simple details, symmetrical spans, and an absence of discontinuity—all of which increase the constructability and maintainability of the guideway. Shapes and details that add members to the load path decrease the constructability and maintainability.

APPENDIX. REFERENCES

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