Elevated Roads for Sri Lanka

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Abstract: *The development of roads and highways related infrastructure has picked up significantly in the recent times along with a significant increase in the vehicle ownership and also the number of larger and heavier vehicles on the road network. With the proposed expressway system being gradually completed, a new requirement has risen. It is the need to come to the capital of the country, Colombo, with a reasonably short time once a vehicle leaves the expressway. Since the roadside developments are high and the land acquisition for new roads would be difficult, one option is the use of elevated expressways constructed above the existing highways. This paper presents some structural aspects that can be effectively used to create a well planned and robust elevated highways banking on the experience on design and construction of existing elevated structures that have been built in recent times in Sri Lanka.*

1. INTRODUCTION

Sri Lanka has not undertaken the development of expressways as a matter of higher priority until the recent times. As shown in Figure 1, there are only a few expressways that have been planned and the design and construction of them are gradually in progress to improve the mobility within Sri Lanka. The main expressways can be identified as Southern Expressway (Figure 1), Outer Circular Highway (Figure 2), Colombo Katunayake expressway (Figure 1), and the proposed expressway to Kandy/north (Figure 1). With the completion of these expressways, it is expected that higher volumes of traffic would need to gain access to the city of Colombo. However, the present road infrastructure from the proposed expressway boundaries to the city center appear to be already saturated and hence would take a significant time for a vehicle taking exit from an expressway to reach Colombo.

This is not a desirable situation and could negate the benefits that are achieved with time and fuel savings by using the expressways for which a toll also would need to be paid. In this context, it would be a need of the hour to upgrade the connectivity from the expressways to the city center though it would offer significant challenges to find space for increasing the number of lanes that will provide the access. In this context, elevated highways can become the preferred option though the general perception is that elevated highways could be having higher costs of construction. This paper looks at various options available for Sri Lanka with respect to the selection of routes, materials, design methodologies, construction techniques to realize the an effective elevated road network that could bring significant economic benefits.

2. THE PROPOSED EXPRESSWAYS

The proposed expressways of Sri Lanka can be seen on Figure 1. Sri Lanka being an island with a length of about 430 km and a width of about 225 km, it would be sufficient to have a reasonable expressway network for mobility by linking the major cities. This network can then be supplemented by the normal roads that are maintained in a good condition.

This concept can be viewed from the needs of the country as well. Sri Lanka is a country with a GDP of about Rs 6000 Billion (1 US $ = Rs 120/=). The agricultural sector contributes to about 14% and the industrial sector contributes about 26%. The services sector accounts for the rest and stands close to 60%. The exports stand at about Rs 1200 billion.

For the sustaining of the industrial sector, a good road network is necessary with adequate connectivity to Colombo. It will be essential for sustaining the export sector and also supporting the service sectors like tourism. This is the link that can be considered as inadequate with the current road network that provides access to the capital city.

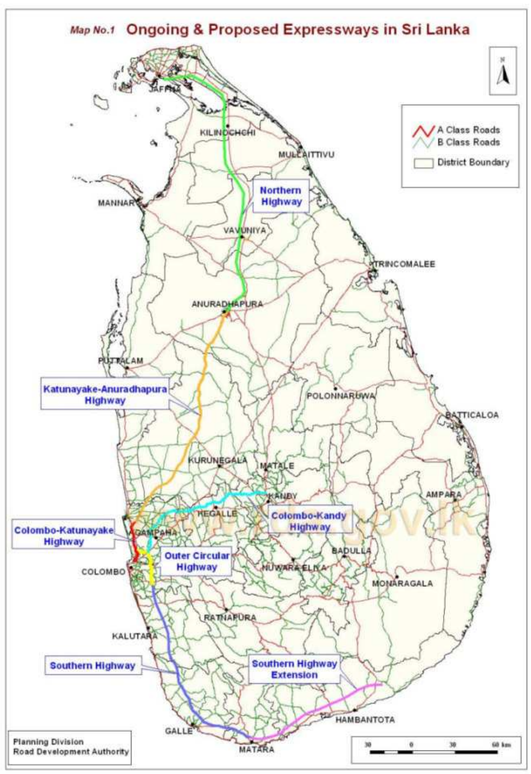

Figure 1 The expressways in Sri Lanka

3. THE POSSIBLE SCENARIOS FOR CONNECTIVITY

The road network to Colombo and within Colombo is generally considered as congested. The implementation of the one way route network in the recent times have reduced the delays within the city of Colombo. One of the reasons for slow moving traffic is the model mix that can be seen that consists of many motor cycles and three wheelers. The separation of faster moving traffic from the motor cycles, three wheelers and slow moving buses is considered as a reasonable solution. Since land acquisition could be a difficult task, elevated highways constructed above the existing four lane main roads could be a viable solution.

Generally, elevated highways are considered as an expensive solution. When, elevated highways are constructed through congested cities, it is possible for those to become a source of noise pollution at a higher elevation thus affecting the medium rise buildings to a greater extent (Mutasem *et al* 2001 and 2002). This could reduce the land value on either side of the road with elevated highway option.

However, the situation in Sri Lanka can be considered as much more favourable. The main highways that would need the construction of elevated expressways above are A1 and A4 for about a distance of 20 km from the city center, up to the boundaries of the proposed expressways as shown in Figure 2. In both these highways, upgrading to 4 lanes from 2 lanes have taken place only in the recent times and hence the large scale roadside developments are yet to happen except within the Colombo city limits and the immediate boundaries. This means that the impact of elevated option could be managed at a reasonable level. This could become an attractive option when the cost of land acquisition and connectivity issues are considered that could arise with alternative solutions.

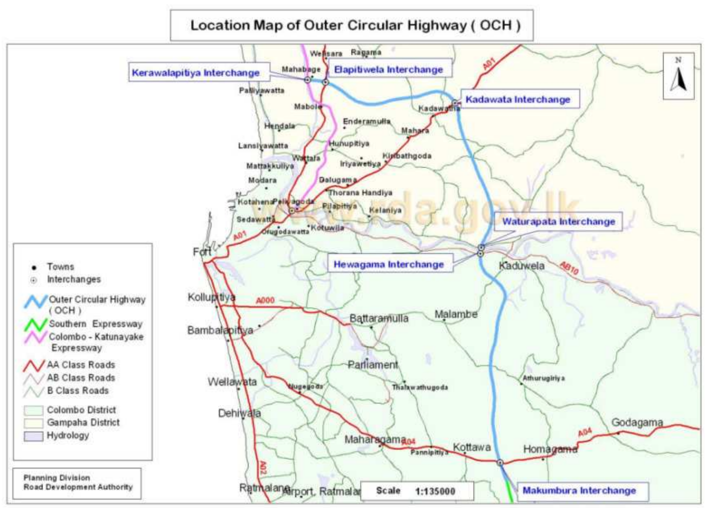

Figure 2 The main roads that would connect the expressways to Colombo

4. THE OPTIONS FOR STRUCTURAL FORMS

It is indicated that elevated expressways with toll charges could be a viable solution for improving the connectivity of the proposed expressways to Colombo. In this context, the selection of an appropriate construction material and methodology will be of primary importance for the successful implementation. One of the greatest challenges will be the construction of an elevated expressway over the existing highway that has to be used on daily basis.

When the future traffic demand is considered, the minimum number of lanes in each direction will be two and it could preferably be three. These details could be finalized with the completion of the feasibility studies that have already been initiated. When the number of traffic lanes are determined, it would be possible to use toll charged as a basis for controlling the number of vehicles so that an adequate level service with appropriate speeds could be maintained. In addition, many other measures will also be necessary to control the number of vehicles such as improvement of rail based passenger services, development of alternative routes, etc. Thus, the elevated expressways will finally become a part of a comprehensive traffic management plan that can sustain the development activities at an appropriate level while ensuring easy access to the city of Colombo from expressways.
An elevated structure can be divided into three main components. They are the foundation, sub-structure and the super-structure. The main material for foundation of this type of large structures will be the reinforced concrete. The sub-structure that consists of pile caps and piers can be out reinforced concrete though piers can be constructed with steel as well. The superstructure will need special attention and the structural forms can be of composite construction of various materials. The use of these are discussed in detail with specific issues addressed.

4.1. The foundations

The soil conditions along the existing highways can be highly variable. One of the solutions that can be successfully adopted in variable ground conditions is large diameter bored piles. Piles can be constructed with diameters up to 2.2 m and the load carrying capacities can be in the range of 15000 kN per pile when the piles rest on bed rock that is at a reachable depth in many locations in Sri Lanka. The advantage of pile foundations is that they can be constructed along edge of the existing highways and the pile caps can be completed below the existing road levels.

4.2. The superstructure

There are two very popular solutions for the superstructure. One is the use of steel beams with insitu cast reinforced concrete acting as a composite material. The other is the use of prestressed concrete beams along with insitu cast deck. In both these, it is possible to have the beams being completed away and then to be placed as the construction progresses. In the Sri Lankan context, prestressed concrete has remained as a preferred material for bridges due to many advantages such as a good durability record with minimum maintenance and the use of locally available or manufactured materials.
There are many issues that need to be addressed with respect to the super-structure. They can be identified as follows:

1. The number of lanes – This will be a critical issue and will depend on many other factors as indicated in BS 5400: Part 2: 1978 or the bridge designers manual of the Road Development Authority of Sri Lanka. However, the width of the existing road is only about 13-14 m and hence the maximum number of lanes will have to be restricted to about 6 with a center median of reasonable width to separate the traffic. An elevated expressway will need a hard shoulder of at least 2.5 m also three lanes of 3.5 m. The other alternative will be to have a wider lane (3.8 m) as the left lane for heavy vehicles and buses and to have two more narrower lanes of 3.2 m for lighter vehicles. This means a width of about 26 m above road of having a width of 14 m. This means the need of cantilevers of about 5.0 m from each pier of about 2.0 m x 2.0 m where the cantilevers will have to act as post tensioned beams.
2. The use of a suitable precast prestressed concrete beam to act as the pier capping beam to support the bridge beams
3. This means that a pier capping beam of suitable shape with two cantilevers on either side that can be post-tensioned to ensure one continuous beam that is connected with post tensioning of the tendons in the ducts
4. A beam of suitable length and shape that can be used to support the insitu cast deck. For this, prestressed concrete I shaped beams of 30-35 m length would be needed since longer spans would need more piles at each pier for which there may not be adequate space
5. An extra-wide pier capping beam that could be used to accommodate changes in slopes and directions while using straight beams of standard section

6. A specially formed precast panel that can be placed on the precast beams so that the insitu cast concrete slab could be constructed only with overnight closure of two lanes of the four lane highway beneath.
7. An expansion joint of suitable type that can ensure smooth ride for the vehicles using this elevated expressway and travel a substantial distance and the special joint that has been applied with a significant level of success is shown in Figure 3 along with the appearance of the completed bridge in Figure 4.
8. Few intersections that will allow vehicles to reach the highway located below via which they will be able to reach their destinations.
9. This indicates a considerable challenge imposed on those involved in the preliminary designs and detailed designs if the elevated highway option has been selected as the preferred option among the alternatives.

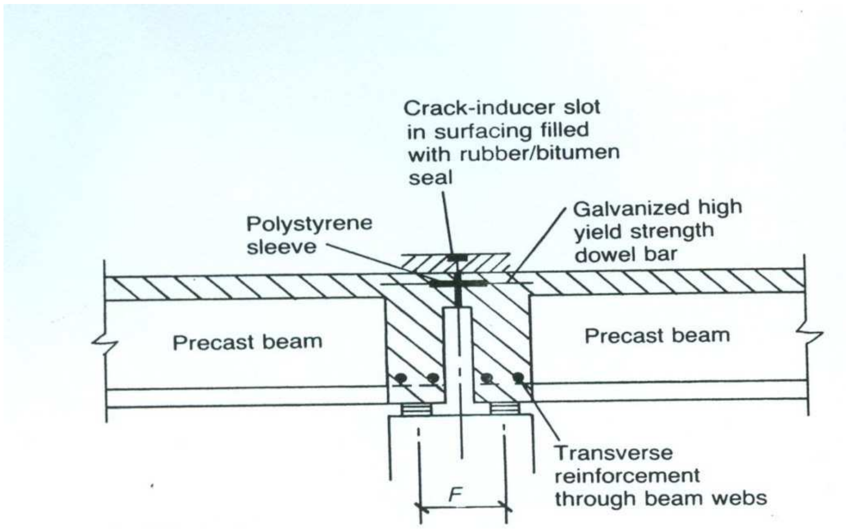

Figure 3 The connection details

Figure 4 The completed expressway without expansion joints

4.3. The sub-structure

The sub-structure will consist of the pile caps and the piers. Since Sri Lanka is a tropical country, it would be ideal to have a good clearance between the existing highway and the proposed elevated expressway such as 7.0 m. In this context, large columns such as 2.0 m x 2.0 m cross sections would be needed for avoiding the slenderness effects and these also would need earthquake resistant details for added safety.

One of the key challenges of the pile caps and pier capping beam will be the durability and the controlling of peak temperatures due to heat of hydration. This will need the use of blended cements that contain pulvarised fuel ash (PFA) along with silica fumes. Due to restricted site conditions that will prevail over the length of the existing highway, high strength self compacting concrete would be needed along with prefabricated reinforcement cages to facilitate the construction at a rapid phase and the post-tensioning operations. The use of latest advances in the concrete technology at its highest level would be needed to ensure the execution of challenging task of this nature.

5. THE EXPERIENCE IN SRI LANKA WITH SIMILAR PROJECTS

A rapid expansion of the highway network of Sri Lanka has occurred in the recent times with many challenging tasks being undertaken successfully. They include the following:

1. Use of 30 -45 m precast prestressed concrete beams for the construction of bridges at a very fast rate as achieved with many concrete bridges and flyovers in Colombo area (Mattakkuliya bridge or Orugodawatta flyover) and the bridges on A4 highway and A15 highway in the eastern province
2. Use of post tensioned pier capping beams with 5.5 m cantilevers at Orugodawatta bridge as shown in Figure 5 and 6
3. Use of self compacting concrete of very low water cement ratio such as 0.25 or less in the toll gates of Southern Expressway
4. Use of blended cements to obtain highly workable concretes that also has high chloride and sulphate resistance as in A32 highway construction (Chindaprasirt *et al* 2005, Neville)
5. Use of water cooling systems in STDP project for preventing the possibility for Delayed Ettringite Formation by controlling the maximum temperatures achieved in the pile caps and other large concrete pores exceeding 700 mm thickness (Bamforth 2007)

Figure 5 A cantilever of 5.5 m with post tensioning ducts in the pier capping beam

Figure 6 The completed bridge with 5.5 m cantilevers supporting the wider roadway

6. CONCLUSIONS

There is a reasonable need to improve the traffic condition of the main approaches to Colombo, especially those serving the gradually updated expressway system. In this context, elevated expressways could offer a viable solution due to various land acquisition problems that are likely to be associated with the new routes. The construction of an elevated highway on a busy road while in use can offer a considerable challenge. The probable need for a six lane highway also could pose a considerable challenge since the width of the existing road is about 14 m at certain locations. The details of all these challenges have been presented in this paper with probable solutions that can be drawn from the past experience in constructing bridges and flyovers in Sri Lanka.

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