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Sustainable Construction of Grade Separators at Mukarba Chowk and Elevated Road Corridor at Barapulla, Delhi

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Abstract

For the last several billion years, nature has nurtured the planet evolving complex Eco-systems that conserve and recycle energy and materials. Climate change is the most visible result – storms, droughts, floods and the like are rising in frequency and severity and the consensus is that we are to be blamed. Civil constructions in urban areas are essential for overall development and benefits of the community, but, it is more important that every such activity be environment friendly as the Environment too has a right to remain protected from any kind of damages. We are, however, the agents of our own eventual doom. We are gradually choking and poisoning ourselves.

This paper covers the attempt in sustainable designing and construction of series of flyovers, Underpasses, River Bridges and other infrastructure projects taken up in the new millennium in New Delhi, the capital city of India. The successful efforts in achieving sustainability are discussed specifically in case of Mukarba Chowk Grade Separator and Barapulla Elevated Road projects.

To assess the amount of the degradation and attempt for sustainable construction, it is essential to understand the environmental characteristics of the area in which structure is taking birth. Once a sincere assessment is done, then it is the core part of ethics of any Engineering to mitigate the degradation and achieve sustainability.

1. Environmental Characteristics of Delhi

Delhi being the capital city is the center of socio-economic, cultural and political activities of the country. The city has become an important center of trade and commerce and for international events, (Commonwealth games 2010), thus desiring a continued and sustained effort to maintain the transport system most effective, direct and fast at internationally acceptable standards. The city also acts as a major center of trade and commerce and is the nodal point for five national highways and intercity rail corridors, carrying large volumes of heterogeneous passenger and goods traffic. The national highways and other major road network carry intracity and intercity traffic traversing to and from the different parts of the country.

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1.1 Geographical Characteristics of Delhi

National capital territory, Delhi is located in northern India between the latitudes of 28°-24'-17" and 28°-53'-00" North and longitudes of 76°-50'-24" and 77°-20'-37" East. It has an area of 1,483 square kilometers. It shares borders with the States of Uttar Pradesh and Haryana. The Yamuna River and terminal part of the Aravali hill range are the two main geographical features of the city. In the 22 km stretch of Yamuna River within Delhi territory, there are 22 drains flowing into the river from upstream of Wazirabad and extending to the Okhla barrage.

Situated on the banks of river Yamuna, Delhi is considered to be a part of the Aravalli Range, major part of Delhi is a plain area or Bhangar which is very fertile. The plains can be divided into Delhi, New Delhi and Delhi Cantonment. The other regions of Delhi namely the Yamuna plains are flood-prone while the ridge which is the most dominating feature in this region is surrounded by the Aravallis. Yamuna is an important river in Delhi which fertilizes the

alluvial soil.

Owing to its location, and good connectivity with the neighboring states, it is being used as a corridor for a large volume of the vehicular traffic travelling within these two states and beyond them also to Punjab, Rajasthan etc. etc. Thus the amount of traffic moving in Delhi has generated many folds.

1.2 Transport and Traffic Characteristics of Delhi

Delhi has the most extensive road network in India - 21% of its geographical area is just motorways. Yet, there is not enough space for the traffic.

Delhi had just five flyovers at the end of Asian Games it hosted in 1982. Today, the number has increased to 74. In last three decades, Delhi's vehicle stock has increased 51 times. 10% of the country's vehicles are registered in Delhi. 17% of country's all private vehicles run on Delhi's roads.

Ten flyovers between Ashram crossing and Dhaula Kuan (2 important junctions in Delhi) could not ease the traffic gridlock along the Ring Road. It often takes 45-50 minutes to cover a distance of 5 Kms from Maharani Bagh to South Extension during peak hours. It is the same story in most of the parts of the city. Flyovers at Modi Mills, Mayapuri, Rao Tula Ram Marg, Azadpur, Seelampur and many others have decongested intersections, but escalated the problem at the next one. Others split the traffic and merge the same at the end of the flyover.

The number of vehicles is growing at 10% every year. According to a Centre for Science and Environment projection, the daily trips are expected to explode from 15 million today to 25 million in 2020. The road spaces have been increased to decongest the existing traffic. But new roads end up attracting more traffic which is explained as the "induced traffic" phenomenon. The studies on traffic concluded that half of the increased roadway capacity is consumed by added traffic in about five years, 80 % of increased capacity is eventually consumed by induced traffic.

In fact in many cities in the West and also in US, dismantling of flyovers and expressways is taking place. Delhi may not need to take such extreme steps yet, but soon it will be impossible to keep adding to infrastructure beyond its physical limits.

2. Impact Of Construction Activities On The Environment

In India, the importance of Environmental Impact Assessment for sustainable development was recognized in the early nineteen eighties. However, it was only by mid-eighties that Environmental Impact Assessment was introduced as a necessary step for the clearance of various developmental activities under the Environmental Protection Act 1986. Since the start of new millennium, the city has seen mega construction projects especially due to the commonwealth games organized in this city in 2010. The construction industry is a major source of pollution, responsible for around 4% of particulate emissions, more water pollution incidents than any other industry, and thousands of noise complaints every year. Although construction activities also pollute the soil, the main areas of concern are air, water, land and noise Pollution.

Construction and operation are the two major activities in which the project interacts physically with the environment and as a result of which the environmental deterioration occur. In assessing the effects of these processes therefore, all potential impacts of the project should be identified, and attempt to replenish is taken to mitigate the adverse impacts.

Following sections evaluate the impact of the Infrastructure Projects on Air, water and land, three major components of the environment.

2.1 Air Pollution

Construction activities that contribute to air pollution include land clearing, operation of diesel engines, demolition, burning and toxic materials.

1. Earthwork excavation, refilling, handling and transportation of construction materials (like sand and aggregate), and construction of earthen ramps produce large volumes of dust if it is not done properly. This dust can carry for large distances over a long period of time. Construction dust is classified as PM10 - particulate matter less than 10 microns in diameter, invisible to the naked eye. Research has shown that PM10 penetrate deeply into the lungs and cause a wide range of health problems including respiratory illness, asthma, bronchitis and even cancer.
2. Another major source of PM10 on construction sites comes from the diesel engine exhausts of vehicles and heavy equipment. This is known as diesel particulate matter (DPM) and consists of sulphate and silicates, all of which readily combine with other toxins in the atmosphere, increasing the health risks of particle inhalation. Diesel is also responsible for emissions of carbon monoxide, hydrocarbons, nitrogen oxides and carbon dioxide. Noxious vapors from oils, glues, thinners, paints, treated woods, plastics, cleaners and other hazardous chemicals that are widely

used on construction sites, also contribute to air pollution.

3. Because of sheer volume, cement concrete is the major contributor to embodied energy in most structures, hence contributes most to carbon emission in the initial stages

2.2 Water Pollution

Sources of water pollution on building sites include diesel/ oil, paints, solvents, cleaners, other harmful chemicals and construction debris/dirt. When land is cleared, it causes soil erosion that leads bearing run-off and sediment pollution.

1. Silt and soil that runs into natural waterways turns them turbid and when runs into city drainage system cause silting of drains.
2. Surface water run-off carries pollutants from the site, such as diesel and oil, toxic chemicals, and building materials like cement. When these substances get into waterways they cause water pollution.
3. Pollutants on construction sites can also soak into the groundwater, a source of human drinking water. Once contaminated, groundwater is much more difficult to treat than surface water.

2.3 Land Pollution

Construction activities that contribute to land pollution include uprooting of trees, excavation of foundations, land clearing.

1. Invariably any construction activity of a grade separator requires uprooting of number of trees thus disturbing the ecological balance in the project environment. It is observed that for a project comprising of 10000 sqm area, around 200 trees are removed from the construction site.
2. Excavation produces large quantity of waste soil, which needs proper disposal. This however is utilized in construction earthen ramps, so that the surplus soil that requires proper disposal is minimal.
3. During deep excavation for pile foundation, water gets collected in the void, needing disposal. Indiscriminate disposal of this silt – laden water may choke drains, lead to water accumulation etc. Also, existing drains in the ROW gets disturbed.
4. Excavation has a potential of causing damage to the existing infrastructure/utilities. There is always number of various utilities like electric poles, transformers, water lines, drainage lines, Telephone cables, Gas lines etc. within the ROW, which needs to be relocated.

3. Impact of Construction Activities on the Society

In Urban Environment, the disturbance caused to the public residing in vicinity is to given due regard and the inconvenience of any kind or sudden disturbance on their life style due to taking up of any project in their vicinity is an area of concern.

1. Generally there exists a commercial area including road side vendors along the roads, shops and other business loose income due to impeding of costumer's access.
2. Large scale disturbance to moving traffic is caused due to construction activities at site as well as off side in casting yard like carrying of RMC or precast segments in case of segmental constructions etc. Even there is a general increase in traffic due to trucks carrying construction material and heavy equipment to site.
3. Workers and public at construction site as well as the public at large passing nearby the construction sites in Urban Environment are always subjected to a risk of accidents or life from accidents on site
4. Construction sites produce a lot of vibration and noise, mainly from vehicles, heavy equipment and machinery, excavation for casting piles, braking up pile heads, road surface but also from people shouting and radios turned up too loud. Excessive noise is not only annoying and distracting, but also lead to sleep disturbance and extreme stress. Even during the operation stage, lot of noise is produced by the fast moving vehicles on flyovers, which is an area of concern in urban environment

4. Sustainable Solutions in Practice during Construction

Good construction site practice can help to control and prevent pollution. The first step is to prepare environmental risk assessments for all construction activities and materials likely to cause pollution. Environment Agency and other government bodies are putting increasing pressure on construction companies to reduce pollution and conform to environmental regulations. In the past the pollution fines have been low and environmental regulations slack, and it could have been perceived as cheaper to pollute than to prevent pollution. This situation is now changing, and enforcement of environmental regulations is not only very expensive but can be irreversibly damaging to the reputation of a firm. Measures to reduce and control pollution are relatively inexpensive and cost-effective, and the

construction industry needs to incorporate these into an environmental management strategy. By employing these practices, the construction industry is well positioned to clean up its act. Measures can then be taken to mitigate these risks.

4.1 Erosion of Soil and Run-off

1. Land disturbance is minimized and maximum vegetation cover is left. Dust is controlled through fine water sprays to dampen down the site and the surface of the developing ramps any soil stockpiled on site by spraying with water, when necessary during dry weather. Trucks loaded with loose construction materials are covered using tarpaulins. Materials are brought as and when required. While unloading the material, particularly aggregate, at the site dust generated is controlled by sprinkling water and ensuring the unloading in a barricaded area. Water is sprinkled in truck after downloading material or covered with tarpaulin to avoid dust raging from the truck while it is moving.
2. Piles of building materials like cement, sand and other powders are well covered and regularly inspected for spillage. These are located where they will not be washed into waterways or drainage areas. Toxic substances are segregated, tightly covered and monitored to prevent spills and possible site contamination.
3. Surplus soil is utilized for beneficial purposes such as in construction activities elsewhere and filling up low lying areas.

4.2 Drains Contamination

All drains in the construction site are covered up properly and protected from all possible contamination. Any wastewater generated from site activities like Bentonite from the piling activity are collected in settlement tanks, screened and re-circulated or disposed off according to environmental regulations.

4.3 Uprooting of Trees

Whenever trees are removed to make the site clear for taking up the construction activities, it is ensured that 10 times the trees removed are planted as compensatory plantation measures according to the A forestation Policy under Forest Conservation Act-1980. While trees are uprooted, best efforts are made to keep the bulb of roots intact and replant the same at other location. It is experienced that 60% of the trees replanted continue to survive.

4.4 Shifting of Infrastructure/Utilities

Location of underground infrastructure/utilities is done before start of work by physically excavating the earth and by collecting the required information from all the utilities owing departments. Proper planning is done to shift these utilities in safe corridors either through the utilities owners or by construction agency itself. Sometimes shutdown is required in case of essential services like water lines or electric lines. In such a situation, prior public information is provided about the likely disruption of services. It is ensured that alternate arrangements like water tankers are provided during the relocation period.

4.5 Social Aspects

1. Resident Welfare Associations (RWAs), public in general and business establishments in particular are taken into the confidence by consultation with them and informing them of the nature, duration and likely effects of the construction work and the mitigation measures in place
2. At the work site, public information/caution boards are provided with information of project name, cost and schedule executing agency and contract details, nature and schedule of work, traffic diversion details, if any, entry restriction information, competent official's name and contact information for public complaints.
3. Alternative traffic arrangement/detours are provided so that traffic can be distributed and move on different roads and it is ensured that public is informed about such traffic diversions through media – daily newspapers and local cable television (TV). Service roads and pedestrian walks are maintained in good condition to allow smooth traffic movement. Necessary personnel /Marshalls are provided to guide and control the traffic.

4.6 Safety Measures for Workers and Public

1. Standard and safe construction practices are followed. Entire construction area that may come under influence in case of accidents is barricaded properly. This is particularly critical during fixing of pre-cast girders or segments using heavy duty cranes. These activities are generally conducted during lean traffic periods and if required traffic is also stopped. Accidental entry of traffic (pedestrian / vehicular) into site is avoided. Warning boards/ sign boards and post security guards are provided throughout the day and night.
2. It is ensured that all workers are provided with and use appropriate Personal Protective Equipment like helmet, hand gloves, boots, masks, safety hoists when working at height or in

foul conditions, etc.

3. Standard practices of safety checks as prescribed are followed before use of equipment such as cranes, hoists, etc. Environmental, Health and Safety (EHS) Expert is employed at site. Health and Safety Training for all site personnel is provided at site. Any accident that happen at site is reported to the authorities promptly and records maintained.

4.7 Noise Pollution

Noise pollution is reduced through careful handling of materials, use of modern, quiet power tools, equipment and silent generators. High noise and vibration generating activities like rock blasting are not permitted involved in the project taken up in Urban Environment and manual methods are only deployed, wherever required. Noise generating activities are avoided in the night and work programme is planned properly so that any particularly noisy activities can be scheduled to avoid sensitive times. Modern vehicles and machinery are utilized with the requisite adaptations to limit noise and exhaust emissions and ensuring that these are maintained to manufacturers' specifications at all times.

5. Grade Separator At Mukarba Chowk

5.1 Location

Mukarba Chowk is located in North Delhi at the junction of Rohini-ISBT axis & NH 1- Azadpur axis. NH1 is part of the Grand Trunk Road. It is amongst the most heavily trafficked junctions in the country. Traffic types is a mixed cocktail of Pedestrians, Two wheelers, Three wheelers, Motor cars, Buses (interstate and local), Trucks etc. etc. Traffic Intensity, based on traffic studies in 2000 at this intersection is 3, 30,000 pcu/day, see fig 1.

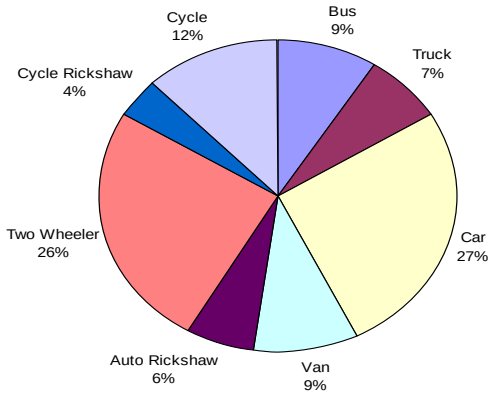

Fig: 1. Composition of Peak Hour Traffic at Mukarba Chowk

The intersection was to be made signal free with provision of full clover leaves, dedicated cycle track both along outer ring road and GT Karnal road, Bus bays at flyover level and road level, Ramps for the safe movement of physically challenged persons from subway to flyover level along with the provisions of lift, escalator and a Subway for crossing of both pedestrian and cyclist, see figs 2, 3, 4 & 5.

Fig: 2. Model of Mukarba Chowk Grade Separator

Fig: 3. Completed View of Mukarba Chowk Grade Separator

5.2 Sustainability Considerations

Apart from traffic challenges, other challenges demanding sustainability were the essential protection of Archaeological (heritage) structure, Graveyard (burial ground), Sanitary landfill and garbage dump of the Municipal Corporation of the city, major Electrical sub-station of 33 and 11 KV existing structures/features at this intersection, see figs 6 to 13. The project was conceived in a manner that all the above could be incorporated into the interchange without demolition or causing any damage to them

1. The Project has been conceived with concrete as main structural material and concrete-steel composite sections for the plate girders supporting the deck slab. It was planned with

more embankments and less structure to reduce carbon footprint. For preparation of the concrete, use of blended cement was another important consideration to reduce carbon footprint. Blast furnace slag was added in concrete design to increase the service life of the structure. Furthermore, slim structures and geo-grids were used for retaining walls of the embankment so as to reduce the use of concrete and thus reducing the material consumption

2. The design and construction technologies were planned in a manner to reduce construction period and minimize works on site

Fig 4: View of Azadpur End

3. Total signal-free movement of traffic in all directions was provided to avoid atmospheric pollution from stationary vehicles
4. Public transport system in preference to personal motorized vehicles has been given due importance and due provisions have been made along with the safe and convenient movement of pedestrians and cyclists. Safety of road users was a paramount consideration during construction period.

Fig: 5. Pedestrian cum Cyclist Subway

5. Total signal-free movement of traffic in all directions was provided to avoid atmospheric pollution from stationary vehicles
6. Public transport system in preference to personal motorized vehicles has been given due importance and due provisions have been made along with the safe and convenient movement of pedestrians and cyclists. Safety of road users was a paramount consideration during construction period.

Fig: 6. Incorporation of Archeological Monument in the Scheme

7. It was essentially required to retain essential cultural and social characteristics of the present environment. Existing structures, utilities, monument, city garbage dump have been made a part of the overall design concept. Simultaneously the aesthetics of structures along with well-planned landscaping all around the Project area have been given due importance for people to "own" the project. Evolving structural shapes that would be aesthetic and enhance the quality of the environment.

Fig: 7. Land Fill

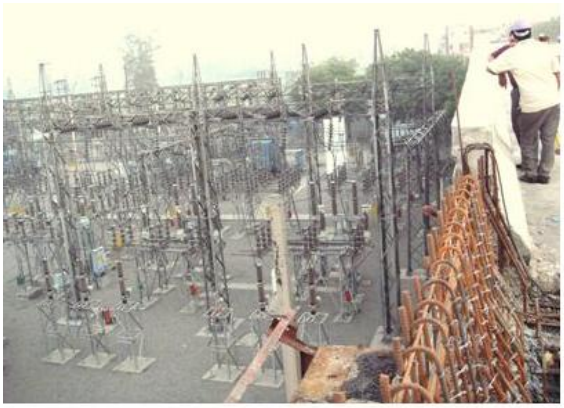

Fig: 8. Major Electric Sub Station

Fig: 9. Archeological Monument

Fig: 10. Burial Ground

8. The space occupied by the city's landfill and garbage dump has been suitably utilized for socially relevant purposes. Nallahs (drains) have been used as an asset and making them part of the overall landscaping.

Fig: 11. Excavation in the Landfill Area

Fig: 12. Landfill Converted into a Green Belt

Fig: 13. Landscaping Around Monument

6. Barapulla Elevated Road Project

Govt. of India had a commitment to common Wealth Federation for connectivity from Games Village to Main Stadium (Jawaharlal Nehru Stadium). Around 10000 Sport Persons had to have unhindered access to Stadium from games village through this corridor.

In spite of many Flyovers Built over Ring Road some sections of Ring Road namely, Maharani Bagh, Ashram, Lajpat Nagar & South Extension was still choked in Peak hour. Ring Road Caters 165000 PCU/Day (Capacity constrained). As per NCRPB report, the projected Traffic is estimated to be 400,000 by 2021. Bhairon Marg had also experienced choking during peak hour which was required to be decongested.

6.1 Location

The Proposed Barapula Nala Corridor was conceived as an East-west corridor as an alternative route to congested section of Ring Road between Sarai Kale Khan and AIIMS that facilitates the immediate need of Commonwealth Games and in long run for the movement of freight, goods, people, and utilities, see fig 14.

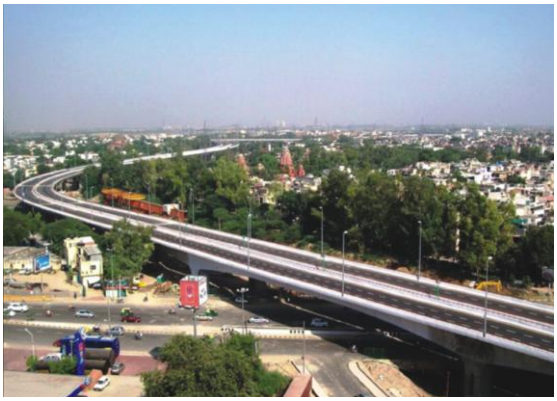

Fig: 14. Barapullah Corridor (upto J N Stadium in Phase 1)

The alignment which is along Barapula Nala drain collects the discharges of other internal, peripheral and trunk drains to further discharge its contents-1,25,000 Kld of domestic sewage into the Yamuna. Barapula Nala in its east west orientation starts from Ring Road to INA, crosses major screen line i.e. Mathura railway track, several Arterial Roads namely Nizamuddin Railway Station Road, Mathura Road near Jangpura, Lala Lajpar Rai near CGO Complex, BhismPitamaah Marg near Sewanagar Flyover, and meeting Aurobindo Marg before being covered under Dilli Haat. The Nallah with a width of 70 m. on an average covers an area of 9.60 Ha. The areas along the Barapulla Nalla include INA, Seva Nagar, JLN Stadium, CGO complex, Jangpura, Nizammuddin, Siddhartha Extension and Sarai Kale Khan Village.

6.2 Sustainability Considerations

1. The feasibility study of alignment connecting Ring Road at Barapula Nala and INA near Dilli Haat demands most direct, economical, aesthetic, traffic worthy intersections and interchanges and its speedy constructability. The project must enhance the visual quality of the urban space. Interventions adjacent to historic monuments should be sensitive. The work was to be executed without disrupting the traffic by careful planning the sequence of operations so that the traffic moves unhindered at all times.
2. Noise barriers were to be provided at all sensitive receivers. Removal of bottlenecks and relieving congestion in constricted sections through improved design was aimed at. A proper mix of indigenous species comprising of broad-leaved evergreen and deciduous species will be planted along roadside. The deciduous species to be planted on slopes. The inhabited locations shall be bypassed as far as possible such that the road does not pass through any critical areas.
3. The Barapulla Bridge (see fig 15) is aesthetically visible while driving from Sarai kale khan to INA on new Elevated Corridor.

Fig: 15. A View of Barapullah Nallah

4. The alignment of the road with reference to Khan-e-Khana's Tomb should be as far as possible, even more than 100 meters boundary away from the notified monuments designated as Prohibited Area within which no construction is permitted. Archeological Survey of India (ASI) suggested engaging a heritage consultant for Khan-e-Khana's Tomb and Barapulla Bridge. It was found that the earlier preferred alignment option is contrary to the stipulations of the Ancient Monuments and Archeological Sites and Remains Act 1958. Alignment was shifted towards east to provide 107 mts distance between the Monument and structure soffit level was

raised from 5.5 mts to 12 mts above Mathura Road Level, see figs 16 & 17.

Fig: 16. Planning of Khan-e-Khana's Tomb

5. The Archaeological Beauty of the area has been restored by landscaping the area. Edge Alignment is 107m away from Khan-e-KhanaMirzaAbdurRahims khan Tomb (Protected Monument) with vertical Clearance of 12 m from Mathura road to ensure visibility of Khan-e-khana Tomb. Elevated Road provides unhindered visibility to Old Barapulla Bridge compiling with ASI observations.

Fig: 17. Khan-e-Khana's Tomb in View

6. In order to safeguard the disturbance to road and rail traffic, segmental construction was planned and the sequence of operation were such that the road as well as rail traffic moved uninterrupted at all times of construction, see figs 18 & 19.

Fig: 18. No Disturbance to Road Traffic during Precast Segmental Construction

7. Turfing has been done on embankment Slopes as per the recommended practice for treatment of embankment slopes for erosion control. Trees have been planted on both sides of the road and in the island formed near rotary species.
8. No disturbance has been caused to the existing drainage pattern. Side drains have been provided with its connectivity to main outfall drain. Sections of the corridor have been modified suitably along with the cross drainage structures.
9. Safety of workers during construction was ensured by providing helmets, masks, safety goggles, etc. Adequate signage, barriers and persons with flags to control traffic had been provided during construction. Adequate drainage, sanitation, and waste disposal facilities were provided at work places. Proper drainage was ensured around the sites to avoid water logging leading to disease. At every workplace, potable and sufficient drinking and washing water supply is maintained to avoid water-related diseases and to secure the health of workers.

Fig: 19. No Disturbance to Rail Traffic during Precast Segmental Construction

Fig: 20. No Physical Disturbance to Heritage Structure

7. Conclusions

1. It is true that civil constructions in urban areas are essential for overall development and benefits of the community, but same is successful only if equal importance is given to the environment and it is given due care for a sustainable development.
2. It is essential that every construction activity should be environment friendly as the Environment too has a right to remain protected. Engineering solutions to minimize the Environment impacts and for adopting the mitigation measures are available.
3. Many times it happens that planning a Project requires disturbance to heritage structures existing in the vicinity of the scheme. In such a situation, it requires the consultation with heritage experts. Solutions are available under such circumstances, but these may be more challenging for Engineers to plan and construction besides the cost factors. But importance of heritage structures, their restoration is essential and has to be given due importance, see fig 20.
4. Adoption of standard and safe construction practices is very much essential particularly in urban environment. It must be ensured in all times that all workers adopt best safety protections in their own interest. Protection of Health, Safety and Environment should always be kept as the prime goal.
5. The right of respectful living of the residents residing around the construction sites should not be jeopardized. This should be given due regarding without compromising on their comforts, safe movements and safe livelihood.

8. Acknowledgement

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