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Investigations for Road Connectivity Across Chaliyar Estuary

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***Abstract*—Due to the increasing urban population, the cities and suburbs are facing severe traffic congestion. In this case the utilization of underground space in the form of tunnel construction has become an effective way to solve the traffic congestion. Despite the huge construction costs and complexities in design and construction, the ever increasing needs of human race has driven tunneling technology to its pinnacle. This review paper presents a framework for the investigations done for suggesting a suitable tunneling methodology for road connectivity across Chaliyar estuary in the Malabar region of Kerala**

Keywords—Tunnel, Investigations, estuary, tunneling methods

I. INTRODUCTION

History has seen the evolution of tunnelling starting with cave formation, for water management, underground transportation, mineral extraction and for warfare purposes. Tunnels have played a vital role in the evolution and sustenance of man-kind through the ages. Despite huge initial costs and extreme precision engineering for the design and construction of a tunnel, selecting a tunnel solution may be justified on new routes under densely developed urban areas where land acquisition costs are high, where clearance requirements or land use prevent the construction of bridges

II. SCOPE OF THE WORK

A. Objectives of the Project

The report focuses on the applicability of a suitable tunnelling technology for road connectivity of two coastal reaches Beypore and Chaliyam across Chaliyar estuary in Malabar region of Kerala. The report states the need of explicitly choosing a tunnel over a bridge for interlinking of the reaches after analysing the inland navigation traffic. An overall perspective and broad guidelines are given for selecting a suitable tunnelling technology at the proposed location after analysing the location data, the topography of the site, the available geological parameters, favourable geometric design. The basic idea of the scheme is to link the northern (Beypore) and southern (Chaliyam) part of the estuary with a tunnel across and beneath River Chaliyar. Providing a road connectivity across Chaliyar estuary would reduce the distance between Beypore and Chaliyam by more than 9kms, which is the present road network connecting the two reaches. It would also facilitate the coastal highway network connectivity from aligned along the Malabar region of Kerala.

B. Background Information of the Locality

Beypore has a medium port, situated on the banks of Chaliyar estuary. Two breakwaters constructed at the Chaliyar estuary guarantees round the year operation of the port. Vessels of 3000 DWT operates from the port presently. Proposals are therefore the development of the port to cater to ships of 8000 DWT and more. Beypore also has a fishery harbor, situated further upstream of the cargo port. Kerala's coastal regions are the most densely settled with population of 2022 persons per square km, 2.5 times the overall population density of the state, leaving the eastern hills and mountains comparatively sparsely populated. This factor point out to the necessity of development and construction of new road network in the coastal region. A hindrance to construction of such a road network is the presence of large number of rivers that drain to Lakshadweep Sea. Beypore is where the River Chaliyar meets the Lakshadweep Sea. The road network breaks on either banks of the river owing to the ship movement. Distance between Chaliyam and Beypore is about 2km aerially, but people have to travel a distance of more than 9km to reach the other bank as shown in figure 1.

Due to the ship and vessel movement across Chaliyar estuary, the idea of constructing bridge across the river have been shelved out by the authorities.

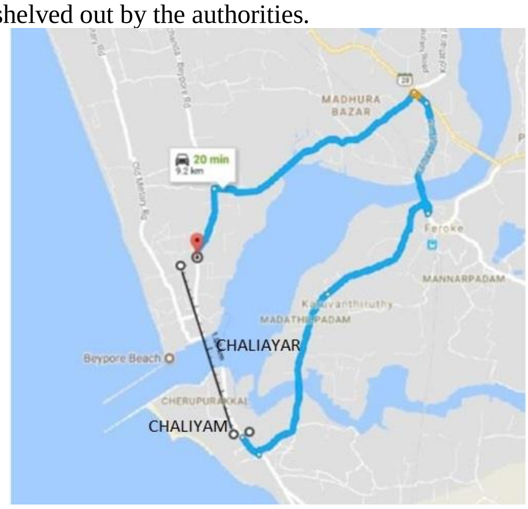

Figure 1 Beypore Chaliyam map

III. TUNNELS VERSUS BRIDGES

Broadly speaking, two options are available for Beypore Chaliyam crossing. First one is the construction of a large span bridge whose deck slab is sufficiently clear from water level to allow the movements of vessels at present and in future, with due consideration to the expansion for

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accommodation of vessels of more DWT. The second option is to have a tunnel beneath the river with approach gradients on two banks of the estuary. From the economical point of view a bridge is preferred with respect to a tunnel in many locations. But providing a beam, truss or girder bridges or Arch bridges requires supports like heavy piers to support the deck slab. The width of navigation channel is 380m. Hence providing a beam or girder bridges with high deck slab height will reduce the width of navigation channel, restricting the movement of ships. Providing moveable bridges like a swing bridge or a bascule bridge or a draw bridge can be another option , which would swing or tilt or lift up to facilitate the vessel movement. But a moveable bridge has usually weight restrictions and requires high operation and maintenance cost. Also it can create congestions to the road traffic when the bridge will be closed for allowing vessel movement. A suspension bridge is also not suitable owing to the restrictions for heavy traffic and its high susceptibility to wind. A cable stayed bridge can be a more feasible option in this case. Where the bridge has one or more towers from which the cable supports the bridge deck. This solution could be more explored considering the inland navigation traffic. Beypore is the only port in Malabar area of Kerala. 50% of its vessels traffic are from Lakshadweep. To accommodate vessels of 8000DWT, which require a draft of 7m and an air draft of more than 25m, a cable stayed bridge if provided should have a deck slab of 30m above water level, and the approach gradients for the bridge would require an acquisition of land of more than 1km on either side of estuary which is an impracticable solution considering the population density of the locality. Hence a tunnel could be the suitable solution for the road connectivity across Chaliyar estuary. A detailed topographical survey would be required to finalize the alignment of tunnels, location of shafts or access portals if any.

IV. DATA COLLECTION

Especially for a tunnelling project, data from multidisciplinary sources are required for deciding on to the appropriate methodology. To develop a conceptual tunnel model, it is required to estimate the range of ground conditions, geology, geotechnical information, hydrogeological data, behaviour for excavation support, ground water control**.** Selection of the alignment, cross section, and construction methods is influenced by the geological, geotechnical conditions as well as site constraints. Tunnel alignment is sometimes changed based on the results of geotechnical to minimize the construction cost or to reduce the risk. Topographic maps and aerial photographs that today can be easily and economically obtained are useful in showing terrain and geologic features (like faults, drainage channels etc.). Data collected specific to the site are

A. Traffic Studies

Recent Traffic study details of the site are collected to know the traffic pattern. Traffic data collected include traffic volume counts, parking studies, speed studies, intersection volume counts etc. The trends in traffic growth over the past 10 years had also been collected to know the projected traffic volume in the upcoming years. The probable traffic pattern that could be deviated along the proposed road is also analysed.

B. Topographical Survey Details

Data of available maps, the contour of the site, the elevation difference between the access portals and the summit of tunnel are required to decide the tunnel alignment. Contour survey with total station is conducted on both sides of the Chaliyar estuary for a distance of more than 1km, along the probable tunnel alignment. Contour map and longitudinal sections of ground are plotted to fix the tunnel alignment.

C. Navigation Survey Details of the Locality

The existing port The Existing Beypore Port is located on the south western coast of India (latitude 11°10' 0" N and longitude 75° 47' 59" E) which is midway between two major ports of Cochin and New Mangalore. The information regarding the berthing facilities of existing port and the requirements for the proposals are collected. The draft and air draft requirements of present and proposed vessels based on the dead weight tonnage are analysed. Beypore port is presently handling vessels of 3000 dead weight tonnage, which needs a draft of 4m. For the proposal to accommodate vessels of 8000 dead weight tonnage, draft of 6m is required, for which the river bed has to be dredged for a distance more than 7m. Even though there is no specific norms for the air draft of vessels, it is expected to have an air draft of 10-25m. The navigation survey details collected aided in listing out the difficulties in construction a bridge across the river.

D. Bathymetry Data

Bathymetric surveys allow us to measure the depth of a water body as well as map the underwater features of a water body. Multiple methods can be used for bathymetric surveys including multi-beam and single-beam surveys, ADCPs, sub-bottom profilers and the Eco mapper Autonomous Underwater Vehicle. The details of hydrographic survey carried out by Global Positioning system and sounding rope to measure the water depth are collected. The appropriate tidal correction was incorporated to the water depth values, which were obtained from the tidal values. The bathymetry covers up to the water depth of 5.5m from shore line. Bathymetry data can be analysed for plotting the river cross section. Since the tunnel alignment below the river bed cannot be omitted, bathymetry surveys are essential to determine the probable alignment below the river bed.

E. Seismic Data

.As per IS 1893-1984, “Criteria for earthquake resistant design of structures”; the proposed location of the berth lies in Zone III. The seismic forces for design of the structure are considered as per this standard

F. Geology of the Locality

Geological maps and geological profile of the area is collected which shows the coastal geology is of marine formation and Gururvayur formation, which is a strand line deposit of paleomarine origin and mostly comprises fine to medium sand. Pebble bed on the coast is associated with grit and clay and is lateritised. It comprises well rounded pebbles of quartz, granite, quartzite and granulite. The bed rock is of charnockite formation which is a moderately jointed rock. The

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riverine alluvium contains moderate organic matter, nitrogen, phosphorus and potassium.

G. *Geo Hydrology*.

The narrow coastal belt with alluvial deposits is a highly potential aquifer with depths of ground water ranging from 0.5-5m below ground level with yields up to 50lps. The ground water in alluvial deposits occur under phreatic condition. The ground water levels over the past decades in the nearby wells of the locality is also studied, which gives information about the seasonal variation of water table. The seasonal variations shows the ground water levels are at 0.5m below the ground level during the months of August and September and it has fallen up to a depth of 5m below the ground level during the months of April and May. The extreme variations in water table should be analysed for deciding the hydrostatic pressure head variations.

H. *Geotechnical Data*

Geotechnical, geological and hydrological data form the most crucial factors in deciding the tunnelling methodology. And hence detailed geotechnical data like bore logs, soil profile, index properties, penetration values, depth of bed rock, hydrogeological data like ground water levels, pore water pressure etc. are required. Bore log samples from the site are collected and a sample bore log is shown in Table 1. Each borehole was tested for soil support strength using the Standard Penetration Test (SPT), an in-situ dynamic penetration test designed to provide information on the geotechnical engineering properties of soil.

TABLE I. BORE LOG

Depth in m	***Soil Characteristics***	***SPT Value***
2.8	Loose sand	8
2.8-4.5	Soft silty clay with sand	3
4.5-5	Medium dense coarse sand	12
5-7.3	Hard laterite	>100
7.3-8.5	Medium dense lateritic sand	23
8.5-10.2	Very loose lateritic sand with clay	4
10.2-16.3	Stiff to hard lateritic clay	15 to 31
16.3-19.5	Medium stiff lateritic clay	8 to 16
19.5-20.9	Dense coarse sand	79
20.9-23.6	Medium stiff lateritic clay	10 to 12
23.6-27.8	Stiff to hard lateritic clay	24 to 38
27.8-29.3	Hard silty clay with weathered rock	>50
29.3-29.5	Soft rock	>100
29.5-32.5	Hard rock	CR 57.33%

The coastal sediments have poor foundation characteristics and have low compressive strength of 1-2 kg/cm^2. The lateritic sand and with clay contents at greater depth have varying permeability moderate compressive strength. The bed rock of charnockite formation of low permeability and have strength of 1000-2000kg/cm^2

I. *Field Geologic Mapping*

Detailed geologic mapping of the locality which shows the possible faults, folds, shears and alteration zones will give information about the support measures for the tunnelling operations.

J. *Subsurface Explorations*

Sub surface explorations include conventional drilling, test pits, determination of index properties of soil, Cone penetrometer testing, geophysical methods like electrical resistivity methods, seismic refraction and reflection methods, ground penetrating radar etc. is to be carried out to get more geotechnical details of the area. A typical drill log should contain various parameter of soil like lithology, soil type, density, grain size distribution, moisture, cementation, plasticity, clay content and rock parameters like rock type, rock quality designation, structure, degree of weathering, texture, strength, hardness, degree of weathering, discontinuities, spacing of joint sets etc.

K. *Water Quality Analysis*

Chemical quality of the ground water samples of the locality were analyzed. pH of the water samples collected lies between 8-8.5. And the electrical conductivity is approximately 600 micro Siemens/cm. Water quality parameters like Chloride, fluoride, nitrate, bicarbonate contents were also analyzed. Water quality analysis is essential to know the chloride intrusion and other chemical attacks on to the underground structures.

V. TUNNELLING METHODS

Tunnels are constructed in a wide range of physical and operational circumstances that will determine the type of tunnel used. Tunneling methods include

A. *Drill and Blast method*

This method is suitable for the weak strength rocks (like chalk, clay, marl) as well as for the rocks having high strength (such as quartz, basalt, gneiss, granite). Drill and blast method is the most often used method for underground excavation and tunneling purposes, which consist of several steps such as drilling of blast holes, charging of boreholes, tamping, blasting, fumes extraction by ventilation, mucking and support installation. This method is a very flexible and adaptable process with respect to the excavation of intermediate or any shape-size cross sections and it has advantages to install the various types of primary rock support such as shotcrete, wire-mesh, rock bolt and fore poling.

B. *New Australian Tunneling Method (NATM method)*

This method is based on the idea to stabilize the tunnel itself by using the surrounding rock mass geological stress. In NATM method, during the excavation process of tunnels a flexible, thin and closed shell shotcrete is applied on to the walls of tunnel after excavating a tunnel cross section. In this method hand-mining equipment is used for excavation purpose and shotcrete uses as pre-support in order to stabilize the tunnel walls and roof. Sprayed concrete, anchors and other support e.g. rock bolts/dowels, wire mesh, lattice girder are used to stabilize the tunnel perimeter in NATM method.

C. *Cut and Cover method*

Cut-and-cover method is frequently used for the construction of several shallow depth tunnels such as rapid transit tunnels, vehicular tunnels and sewer tunnels. Construction of tunnel is termed as “cut-and-cover” when a trench is excavated (“cut”) at the shallow depth and then backfilled (“covered”) with the

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combination of a support system which has enough strength to carry the load of the structure to be built on the ground surface above the tunnel. This method is divided into two basic forms- bottom up method and top down method. In bottom up conventional tunnelling method, tunnel construction takes place in a trench which is excavated from the ground surface at the shallow depth and subsequently back filled and supported with the necessary support system. In top down method, side walls are constructed with diaphragm walls or slurry walls and the ground is excavated at shallow depth for the construction of tunnel roof. Then the ground is reinstated for the traffic and the excavation of ground beneath the roof slab is done for tunnelling purpose.

D. Jacked Box Tunnelling Method

Jacked box tunnelling method based on the basic concept of the use of a single piece site-cast box structure which is constructed in a jacking pit situated on the site of tunnel. A tunnelling shield and hydraulic jacks are provided respectively at the front and rear end of the box.

E. Immersed Tunnelling Method

The immersed tunnel, also called Sunken Tube, is a tunnel construction method commonly used for crossing a body of shallow water. In this method, casting basins are constructed near the location and the tunnel elements are fabricated. The basins are then flooded and the elements are immersed into the final location.

F. Tunnel Boring Machine (TBM)

TBM (Tunnel boring machine) is used for the excavation of tunnels with a cross section of circular as well as rectangular shape through the different types of rock and soil strata. Anything from sand to hard rock can be bored by using the tunnel boring machines, therefore nowadays TBMs are using as an alternative to drill and blast methods in soil and hard rock mass. Modern TBMs consists of several systems such as a boring system which includes the disk cutter and cutter head, followed by a thrust system that provide forward movement and the gripper shoes that are pushed against the sidewall, muck removal system which removes the muck from the bottom of the cutter head and using the conveyor, transport the muck to the rear of the machine and support system which consists of the roof shield and drills for installing.

VI. SELECTION OF PROPER TUNNELLING METHOD

Suitability of the appropriate tunneling method specific to the site requires careful and detailed analysis and monitoring of the various parameters affecting the ground settlements. Apart from the geotechnical and geological aspects, the environmental impacts should also be analyzed for the selection of an appropriate tunneling methodology for the site.

CONCLUSION

With the latest tunnel construction technology, engineers can bore through mountains, under rivers, and beneath bustling cities. Before carving a tunnel, engineers investigate ground conditions by analysing soil and rock samples and drilling test holes. In tunnelling projects, it is essential to control and predict the ground surface settlements observed during and after the excavation process that may cause damage to the structures present on the earth surface. The prediction of surface settlements ought to be done independent to the tunnel excavation method, and safety measures against any damage to existing structures should be taken before the construction.

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