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Design and Fabrication of Bascule Bridge Case Study on Vashi Bridge

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Abstract: *During the fast paced civilization and development throughout the world and an increased rate of trade shares among states and countries, various air and sea routes are being discovered quite frequently. In order to optimize the transportation process intricate routes are being used which at time require a ship or boat to cross a special movable bridge connecting two land masses. In time such as these, there comes a need for special movable bridges, for example bascule bridge; A bascule bridge (sometimes referred to as a drawbridge)is a movable bridge with a counterweight that continuously balances a span, or leaf, throughout its upward swings to provide clearance for boat or ship traffic. It may be single or double leafed. This research is focused on designing a bascule bridge by taking the Pamban Bridge, the bridge that connects the town of Rameshwaram on Pamban Island to mainland India, as reference and conducting a study on the stress and strain acting on the bridge along with the total deformation analysis. A comparative study is also conducted between stainless steel and structural steel used for it's construction and the various parameters found for both the materials to decide which material is safe for the construction.***.**

Keywords: Bascule Bridge, Clearance, Stress, Strain

I. INTRODUCTION

The florida department of transportation (FDOT) owns and operates one of the largest number of movable bridges in the U.S. According to national bridge Inventory [1] there are 146 movable bridges (3 lift type, 133 bascule type, and 10 swing type) in florida and these are complex structures utilizing machinery to open a portion of the bridge allowing for the passage of waterborne traffic. The majority of the movable bridges in Florida are of the bascule type, having interior spans called "leaves" that rotate upward and away from the centreline of the waterway thus providing clear passage. Movable bridges are commonly used over the waterway especially in flat terrain.

A bascule bridge is a type of drawbridge that pivoted around a horizontal axis located in the line of supports to allow boat traffic to pass underneath .bascule is a French term for seesaw and balance. The counterweights help balance each side of the bridge during the upward swing, which assists in the lifting motion. Bascule bridges are the most classical type of movable bridges and those most used in the world, most likely because they open quickly and easily once established, and operate on very little energy.

The bascule bridge was originated in medieval Europe to help defend castles and towns. These first movable bridge were operated by men using a winch and counterweight. One portion of the Old London Bridge was actually a bascule drawbridge, and it was lifted occasionally to allow ships with tall masts to pass through. However, it wasn't until the 19th century that these bridges became popular for aiding the navigation f large ships. The first large bascule bridge, The Blagoveshchensky Bridge, was built in St. Petersburg in 1850.

The constant improvement of technology gives people a better place to live . technology development knows no boundaries and ushers in a new era. In the modern world the transportation system is crucial in enabling the communication system. In todays transportation system the importance of the movable bridge can not be overstated. A structure with at least one span that may be instantly moved by mechanical device mounted on it is referred to as a movable bridge. The idea of a movable bridge is advantageous for smart cities since it makes ship and car transit management easier. Additionally, some specialized locations, like the Suez canal, call for the use of movable bridge technology to allow ships to pass through many gates. To prevent the bridge structure from suffering severe earthquake damage, a better seismic design method for simply supported girder bridges has been developed.

The planned study so seeks to close the gap. Additionally most movable bridges currently in use are operated by people. Early arriving ships must dock until the designated opening time of the day which takes time and patience. The movable bridge has existed since prehistoric times, but there are several obstacles to automating mechanism, thus it is currently run by humans. It can be difficult to gauge control when ships are approaching quicker and closer while a vehicle is still on the bridge.

Future study is steel needed on ship sensing and automated operation of this enormous structure. With the development of maritime control technology, some automated control system are now being incorporated to movable bridges in an effort to eliminate the need for the human labour. However, it extends the duration of the bridges operations, and much more study is steel needed to increase the security of the navigation system. In this work, a small demonstration model of an automated bascule-type movable bridge with an on-off control scheme is developed. This model will serve as a platform for demonstrating the use of control engineering in the field of transportation and as a kit for students to conduct and comprehend multiple control system and electrical machine experiments using a single system. An automated moving bascule bridge with a truss construction will be visible in real time thanks to the suggested small model for demonstration. The kit shows how smooth vehicle passing is accomplished on a moving bridge in real-time. Overall, the suggested small model for demonstration will offer a platform to demonstrate how system integrate is built in order to design a robust system.

Fig. 1Bascule Bridge

BASCULE BRIDGES

Bascule strictly applies only to those bridges that consist of a single moving element, which pivots about a horizontal line near its centre of gravity so that the weight on one side of the pivot axis nearly balances the weight on the other side. The balance is usually not exact. If the bias is towards keeping the bridge closed, it is referred to as span heavy. If the bias is towards keeping the bridge open, or causing it to open, it is called counterweight heavy. Many bridges pivot about horizontal axis, but do not take the configuration of a seesaw; these bridges are generally all called bascule bridge as well, and accepted usage allows the term to encompass all the variable types that pivot in the same manner.

The deck section or span of a bascule bridge that moves is referred to as a "leaf''. Leaf can also be called a "span'', but that term applies to any movable bridge section, such as the full swinging length of a swing bridge or the lifting portion of a vertical lift bridge. The term span also applies to any length of a double leaf bascule or fixed bridge between supports, such as in "a three-span continuous bridge''.

The outer end of the bascule leaf is called the toe of the leaf. The inner end, at the part of the leaf nearest the pivot point adjacent to the approach span or abutment, is called the heel of the leaf. The heel of the bridge leaf is supported on the pivot pier, also called the bascule pier, and the toe of a single leaf bascule bridge is supported on the rest pier. Many bridges are pivoted on a shaft, called a trunnion. The term applied to the various parts of the bridge are generally considered standard.

TYPES OF BASCULE BRIDGES

According to the number of leafs Basule Bridge can be classified as single leaf and double leaf. Some bascule bridges, single and double leaf ,are twinned by having two parallel spans across the navigation channel. Some of these are connected so that the pair of leaves on one side of the navigation channel acts as one, and some are left independent so that each leaf acts separately. Some act as arch bridges, such as the Tacony -Palmyra bascule span over the Delaware River which was designed to act as a three- hinge arch when carrying traffic. If is a double leaf rolling lift bascule bride with shear lock. The bascule span is to the right of the arch bridge. It acts as an arch to carry live load, with compression joints at the upper chords at the centre of the span. Vary rare is the asymmetrical double leaf bascule ,in which one leaf , usually the shorter, acts as a cantilever and the toe of the other leaf rests on the first, so that the second leaf acts, when carrying traffic, as a simply supported span. The railroad bridge at Boca de Rosario, Uruguay , is an example of this variation, with the short span cantilevered by being supported by cable stays, and the long span a simple span with its toe resting on the short span. There are some types of bascule bridge designs according to the counterweight locations required to balance a bascules span. They may be located either above or below the bridge deck.

TRUNNION BASCULE BRIDGE: One is the fixed- trunnion bascule design, which is where the bridge rotates around a large axle, called a trunnion , to raise.This bridge type is sometimes called the Chicago bascule as this type was developed and perfected there and is used for many of that citys river crossing. Joseph Strauss was a key person who worked on improving the trunnion bascule bridge. This type of movable bridge is perhaps the most common. Moreover,

some authors divide the fixed-trunnion bridge type in Simple trunnion, Heel trunnion and Articulated counterweight.

Simple trunnion bascule bridge:

A simple trunnion bascule bridge consists of a unitary rigid displaceable structure supported on a horizontal pivot. This pit must be large enough to contain the rear, or counterweight, end of the bridge, and allow it to drop below the water level without dipping into the water as the bridgeswings open. If the counterweight enters the water, even to a small extent, operating difficulties occur, as the bridge balance is changed because of the buoyancy effect of the displaced water. Occasional immersion can also accelerate deterioration of the steel and concrete components of the counterweight, particularly if the water is saline.

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Fig. 2Simple trunnionbascule bridge

Heel Trunnion Bascule Bridge

The counterweight of a heel trunnion bascule is mounted separately, on its own pivot parallel to the pivot of the bridge span, but is located at a higher elevation so that as the counterweight swings down when the bridge span swings up , the lowest part of the counterweight will be above the water surface. The counterweight is connected to the bascule leaf by links, so that the counterweight and bridge leaf operate together. The connection is usually arranged so that the span and counterweight remain exactly parallel to each other and the links remain parallel to lines running from the centreline of the main trunnions to the centreline of the counterweight trunnions.

The heel trunnion bascule bridge has a simple bridge span that is hinged at one end, on a horizontal axis at right angles to the roadway, and supported by some means at the other end.

None are known that are cantilevered on live load shoes, as the far forward position of the main trunnion makes this construction virtually impossible.

Fig. 3Heel Trunnion Bascule Bridge

II. LITERATURE REVIEW:

Sr. No	NAME OF PAPER	AUTHOR NAME	YEAR	CONCLUSION
1.	Design and analysis of a bascule bridge using finite element method.	A.B.krishna, A.P.Pawgi, S.Gupta et al.,	7 July 2017	The study hence proved that bascule bridges when designed with appropriate counter balance mechanism and proper material, they can withstand high loads even such of trains. The study here proves structural steel to be better material for the construction of the bascule bridge as it does not deform as

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				much as stainless steel.
2.	Rebuilding Bailey bridge to bridge with bascule span-A case study.	AndrzejAmbroziak, Maciej Malinowski, Miroslaw Walega		The structural analysis and proof load tests confirmed the validity of the adopted design solutions.
3.	Analysis of different bascule bridge Architectures.	Mootaz E Abo-Elnor	17 Dec 2022	As a conclusion bridge leaf mechanism in pull arrangement architecture provide redundant safety in design and operation with lower stress of operating structure components and this is an advantage over the push arrangement architecture one.
4.	Bascule leaf fabrication and erection tolerance: Where structure meets machine.		6-9 Nov 2006	Knowledge of the various fabrication and erection tolerance for a bascule span is also needed in the design of the structure.
5.	Design of automated bascule bridge and collision avoidance with water traffic.	MdMostafizurRahmanKomal, A. N. M. MizonurRahman, AmitKumer Podder et al.,		The movable bridge under consideration is of the bascule type. Mobile bridges protect trade- critical areas like ports and the Suez Canal. Marine traffic management is crucial to ship and product mobility in important places.
6.	Heavy Movable Structure Health monitoring: Case study on a bascule bridge in ft. Lauderdale.	F. NecatiCatbas, Alberto O. Sardinas, Mustafa Gul, H. BurakGokce		The structural health monitoring system presented in this paper serves as a demonstration of an integrated system that is designed to monitor structural, mechanical and electrical components of a movable bridges. Such an implemented offers promise for improved condition assessment and can complement current bridge management system.
7.	Structural design and lifecycle analysis of an orthotropic steel deck bascule bridge.	Emanuele Maiorana, Angelo Alosio, Adrian BognouFofouet al.,	May 2024	Concurrent assessment of these factors enables designers to make balanced decisions considering structural needs and environmental impacts.
8.	Sensitivity Analysis of design parameters for Trunnion-Hub Assemblies of bascule bridges using finite element method.	Jai.P. Paul	2005	It can be concluded that the AASHTO standards are safer than the current practices used in the manufacturing of trunnion-hub-girder assemblies for bascule bridges. If employed the AASHTO standards will yield higher critical crack length and stress ratio. It can also prove out to be more economical during the manufacturing process by educing the failure and hence savings hundreds of thousands of dollars.
9.	The Belidor Bascule Bridge Design.	FabrizioBarpi, Michael AB	2012	The classical solution of an idealized model in term of potential energy is presented. At

		Beakin		the end, the equation of a cardioid is derived.
10.	Sensitivity analysis of cooling methods and geometric parameters in the assembly procedure of bascule bridge fulcra.	C. Nguyen, AK. Kow, J. Paul	2007	This shrunk trunnion is then inserted into the hub and allowed to warm up to ambient temperature to develop interference fit on the TH interface.
11.	Controlling motion of metal bascule structures by fluid power system (exemplified by lifting of bascule bridge span)	AV. Ashcheulov	2021	Conventional relay control of motion speed of the heavy metal structure of the bascule type results in increased dynamic of the process, since acceleration coincide with overriding of maximum loads.
12.	Design of a double Leaf bascule highway bridge “Simple trunnion-Deck Truss Type”.	John Harry Stamataky	1953	Dead weight of all members including rivets, connection angles, gusset plates, bracing and miscellaneous items which add to the dead weight of the movable leaf.
13.	The design of a Double Leaf Simple Trunnion Highway Bascule Bridge.	Anthony M Luciano Jr.	1956	There is no necessity of interrupting water traffic until the more or less completed structure is lowered into its level position to permit the addition of the roadway, sidewalks etc.
14.	Design of a Double Leaf Simple Trunnion highway Truss Bascule Bridge.	Stephen Pavelka	1955	For this problem the double leaf bridge is used with a span of 300’ from trunnion to trunnion.
15.	BASCULE BRIDGE MACHINERY Rehabilitation at Hutchinson river parkway bridge.	C. Birnstiel	2014	The overall objectives of bridge management in terms of such risk considerations, the tools necessary to carry out the tasks effectively.
16.	Movable bridges: Condition, modelling and damage simulation.	F. NectaiCatbas, HasanBurakGokce, Mustafa Gulet al.,	2011	From these damaged and undamaged models, it is shown that distinct dynamic and static response changes can be observed. These changes of behaviour can be tracked by mean of appropriate monitoring systems providing timely information to bridge engineers and owner.
17.	Smart condition monitoring of a steel bascule railway bridge.	J. Nyman, P. Rosengren, P. Kool et al.,	2023	Observing and investing within year data has been beneficial to understand the bridge and its behaviour.
19.	Full-scale testing of procedures for assembling trunnion-hub-girder in bascule bridge.	G. Bester Fied, S.Nichoni, Autar K. Kaw et al.,	2003	The hoop stress on the inner diameter of the hub developed during both these assembly procedures is shown in Fig. 9 and 10.both plots have been marked into the four steps of the assembly procedure.

21.	Performance evaluation of a highlight epoxy asphalt mixture for bascule bridge pavements.	ZhendongQian, Leilei Chen, Chenlong Jiang et al.,	2011	This paper proposes a new asphalt mixture for pavement on bascule bridge, i.e., lightweight epoxy asphalt mixture, and presents a performance evaluation program for the LEAM based on the laboratory tests and 3D FE numerical analysis.
23.	Monitoring of a bascule bridge during rehabilitation.	Matthew Yarnold, Jeffrey Weidner	2016	A case study was presented for monitoring of a rolling lift bascule bridge throughout construction.
24.	Rebuilding Bailey Bridge to Bridge with Bascule Span-A case study.	Andrzej Ambroziak, Maciej Malinowski, Miroslowwalega	2024	The Bailey- type steel bridge is successfully rebuilt to a bridge equipped with a bascule span. The investigated bridge is in operation serviceable and fulfils imposed requirements for traffic road and sailing serviceability.
25.	Assembly procedures of trunnion-hub-girder for bascule bridge.	G. Bester Field, Autar Kaw, S. Nichani et al.,	2003	The trunnion is shrunk by immersing in liquid nitrogen.
26.	A twin leaf bascule bridge for Calcutta.	J.B. Talati, BGR Holloway, R.G.Chapman	1971	The Calcutta Port Commissioners decided, therefore, to replace it with a new opening bridge capable of handling considering higher traffic densities.
27.	Icons of movable bridges utilizing orthotropic bridge decks.	Carl Huang, Alferd R. Mangus, Craig Copelan	2010	This paper describes existing movable bridges in service with orthotropic steel decks that have not only performed well but are considered icons.
28.	Hills brough river bascule bridge Vibration and rehabilitation.	Dongzhou Huang	2016	This paper presents a reliable procedure for dynamic analysis of bascule bridges subjected to moving vehicles.
30.	Congress street bascule bridge reconstruction.	Stan-Lee C Kaderberk, Joseph Quattrochi, Luis Benitez, Michael Haas	2012	The rehabilitation of an existing movable bridge poses unique challenges to the contractor and the contractors Construction Engineer not found on more traditional bridge construction projects.
32.	The Belidor bascule bridge design.	FabrizioBarpi, Michael AB Deakin	2012	The paper discuss the so-called Belidor bascule drawbridge.
34.	La portad Europe bascule bridge in Barcelona, spain	Juan Josu Arenas de pablo	2018	The movable bridge in its closed position has a clearance of 22m, which allows smaller ships to pass underneath.
35.	Composing os extensions safely and efficiently with bascule.	Andrew Baumann, Dongyoon Lee, Pedro	2013	Bascule shows that it is possible to support lightweight yet safe OS extensibility as well as composition of extensions by running them in a shared address space and exploiting interposition on a common

				binary interface of primitive OS abstraction.
36.	Simulation study on an ICT-based maritime management and safety framework for movable bridges.	MdMostafizurRahamanKomal, Md Samiul Islam Sagar, Jack Pinnow	2021	A compressive theoretical framework and logarithm for movable bridge maritime automation have been proposed and simulated in this research.
39.	Determination of design moments in bridges constructed with a movable scaffolding system (MSS).	Hyo-GyoungKwak, Je-Kuk Son	2006	The design moments for a dead load at any construction step can be determined on the basis of an elastic analysis considering the construction sequence only.
40.	Mechanism and functionality of mobile bridges case study: bascule bridge at the Viareggio harbour in italy.			The maximum negative values of those solicitation at ULS are observed when the bascule bridge is opened at around 30 degrees with respect to the horizontal.
42.	Gatun River Bascule Bridge Panama Railroad.	PL Kaufman	1915	The Panama railroad has played an important part in the construction of the great canal and will continue to serve as a necessary and useful adjunct to its operation in the future.
44.	Acoustic Emission monitoring of bascule bridge components.			It is the primary obstacle to conducting such tests using conventional AE equipment and technique.
47.	A design of experiments study of procedure for assembling bascule bridge.	Cuong Nguyen	2006	To open and close the girder (that is the leaf) of the bascule bridge, power is supplied to the THG assembly by mean of a curved rack and pinion gear at the bottom of the girder or by hydraulic system.
50.	Health monitoring of bridge structures and components using smart structure technology.	Brent M Phares	2005	It is unclear if these system will, indeed possess all of the characteristics to be considered truly "smart".
51.	Wireless sensor network- Based system for monitoring a lifting bridge.	Gokhan Kilic	2024.	The wireless presented combines different monitoring system in a GSM and LAN based environment.
52.	Performance evaluation of a lightweight epoxy asphalt mixture for bascule bridge pavements.	ZhendongQian, Leilei Chen, Chenlong Jiang, Sang Luo	2011	This paper proposes a new asphalt mixture for pavement on bascule bridge etc.
54.	Risk-based management guidelines	Stuart Stein, KarstenSedmera	2006	Performance based methods offer increased flexibility in the design process and

	for scour at bridges with unknown foundation.			contribute to cost efficiencies in a design that meet facility specific requirements and desired performance goals.

III. METHODOLOGY

The study began by conducting a literature survey on the various type of movable bridges, specifically the bascul bridge. Pamban bridge was chosen as the reference and detailed study on its dimentions along with the materials used for its construction was conducted. The various parts of the bridge were first modelled in solidworks and were then assembled in the same. Conclusions were done with regards to the loading condition of the bridge at closed position and as well as for the various open positions. Weight of the engine of the train along with its bogeys for Indian railway was found online. At closed position, the load was calculated according to the self-weight of the leaf of the bridge along with the weight of the train passing over the bridge. In the open position the load only included the self-weight of the leaf of the bridge. The final assembled bridge was then imported in analysworkbench and a stress, strain and total deformation analysis was conducted on the same using the load values as calculated from the calculations. The material chosen for the bridge was first chosen as structural steel and then stainless steel and the results for both were compared. This way the study on the stresse, strain and the total deformation on the bascul bridge was conducted successfully between the two materials.

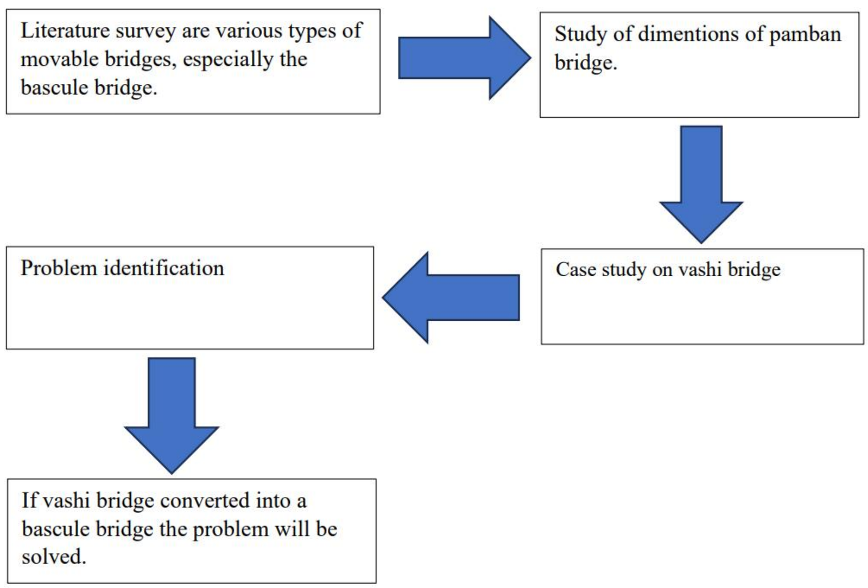

Fig. 4Methodology

Case study:

The Vashi Bridge, also known as Thane Creek Bridge or the Second Thane Creek Bridge, is a road bridge across Thane Creek, which connects the city of Mumbai to the Indian mainland at Navi Mumbai. Opened in 1997, the bridge links the suburb of Mankhurd in Mumbai with Vashi in Navi Mumbai, the satellite city of Mumbai. It is one of four entry points into Mumbai (the other three being the Airoli Bridge upstream across Thane Creek, Mulund, and Dahisar), and handles traffic directed towards the region to the south and east of Mumbai.

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Vashi Bridge

Fig. 4Vashi Bridge

Attribute	Details
Name	Vashi Bridge
Other Name(s)	Thane Creek Bridge, Second Thane Creek Bridge
Coordinates	19.061226°N, 72.971612°E
Carries	SionPanvel Highway
Crosses	Thane Creek
Locale	Mankhurd, Mumbai – Vashi, Navi Mumbai
Official Name	Vashi Bridge
Preceded by	Airoli Bridge
Followed by	Mumbai Trans Harbour Link
Total Length	1837.5 meters
Constructed By	U. P. State Bridge Corporation Ltd.
Opened	1997
Replaces	First Thane Creek Bridge

The bridge replaces the first Thane Creek Bridge, built in 1973, which still stands to the north of the current bridge, but is closed to traffic. A third bridge is currently under construction and is expected to open in August 2024.
There is also a railway bridge to the south of both road bridges.

History

Fig. 5 Vashi Bridges, old (TCB-1) and new (TCB-2)

First bridge

In 1959, a study group for Greater Bombay, headed by S.G. Barve, proposed constructing a rail-cum-road bridge over the Thane Creek in order to expand industrial development areas and accommodate the.city's growing population. In the 1960s, civil engineer Adi Kanga and others proposed building Navi Mumbai to help decongest Mumbai.

The first bridge, conceived by Adi Kanga, was opened in 1973. The two-lane road bridge named Thane Creek Bridge 1 (TCB-1) is 1,837 metres (6,027 ft) long. The bottom side of the prestressed girders of some spans developed corrosion cracks within two years of the bridge opening to traffic.This led to a series of extensive repairs including external prestressing. The railway bridge was opened on 9 May 1992.

The first bridge is currently closed to traffic.

Second bridge

The Thane Creek Bridge 2 (TCB-2) was proposed in 1987 to replace the first bridge. The bridge was built by the U.P. State Bridge Corporation and opened to traffic in 1995. It is a box girder bridge, carrying a 6-lane dual carriageway, with a length of 1,837.35 metres (6,028.1 ft). It has several unique features in its construction and design, with emphasis on durability and a formal QA/QC programme.

Proof Consultants were appointed to oversee each aspect of planning, design and construction. Open foundations were taken into the bedrock with foundation concrete being laid in the dry, with the sea water being pumped out using submersible pumps. The piers in the intertidal zone were protected by epoxy coal tar paint painted on 6 millimetres (0.24 in) thick m.s. plate which was considered as a lost shuttering.The superstructure was a P. S. C. box girder, one for each carriageway, constructed using balanced cantilever cast-in-situ segments. It was constructed by U. P. State Bridge Corporation Ltd., and won the most outstanding concrete structure award.

NRS AS, a manufacturer specializing in comprehensive bridge construction equipment, provided the U.P. State Bridge Corporation Ltd. with a total of 12 pairs of 'BRIDGEBUILDER' FORMTRAVELER (BB FT) equipment specially designed for Free Cantilever Construction. These supplied BBFT units belonged to the 'Type II-A12-51' category, boasting impressive specifications:

Load Capacity (Tons): 156

Maximum Road Width (meters): 3.35

Maximum Box Width (meters): 7.5

Maximum Segment Length (meters): 5

Third bridge

The Thane Creek Bridge 3 (TCB-3) was proposed in 2012. It will consist of two separate 3-lane bridges constructed on either side of TCB-2. The third bridge will have a 1.837 km (1.141 mi) main span and 1.25 km (0.78 mi) of approach roads. The project will be executed by the Maharashtra State Road Development Corporation (MSRDC) and the City and Industrial Development Corporation (CIDCO), with MSRDC being the nodal agency. Larsen and Toubro was awarded the contract to build TCB-3 in September 2018.

Work was scheduled to begin in September 2018, however, it was delayed by permissions required to cut down an estimated 430 mangroves across 1.5 hectares (3.7 acres). The Bombay High Court granted permission for construction in January 2020.Works were also delayed by the COVID-19 pandemic. Construction began on 29 October 2020. Around 15% of the total project work had been completed by April 2022, and 33% by November 2022. Around 51% of the work had been completed by June 2023. The bridge is expected to open in August 2024.

IV. CONCLUSION

The importance of Vashi bridge is that there is a large amount of traffic of boats on one side. If Vashi bridge is constructed as bascule bridge, the road will be clear without boat traffic their will be boat traffic from both sides. The distance between Pamban bascule bridge and Vashi bridge is 2 km .

Also, if the span is done on the Vashi bridge the water traffic will be smooth. According to research Vashi bridge is now 6 lanes, so their will be no road traffic but water traffic will be obstructed the only solution is like the Pamban bridge in Tamilnadu if that bridge converted into a bascule bridge the problem will be solved.

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