International Journal of Bridge Engineering (IJBE), Vol. 4, No. 2, (2016), pp. 13-27

FRAMEWORK FOR INSTALLATION OF ENABLING GIRDERS FOR BANDEL-NAIHATI BRIDGE USING MARINE BARGE

Parimal Bhattacharya[1], Abhishek Roy[2], Achal Garg[3]

[1]Naval Architect, Consultant
[2]Structural Engineer, Consultant
[3]Structural Engineer, Keppel Offshore & Marine, Mumbai
[1]pbhattacharya1710@gmail.com, [2]abhishekroy1980@gmail.com, [3]achalgarg_1992@yahoo.com

Abstract: Conventional method of bridge construction if adopted would mean long gestation period and ultimately costly. Therefore, it was desired that some alternative scheme must be developed and adopted to overcome the situation. This scheme must be economical, less time consuming, easy to implement and feasible with local infrastructure. In this report such a scheme is outlined for installation of the two enabling girders (total 2 in numbers) on the river Ganges, which will meet these objectives. The feasibility of the scheme has been established with detail engineering calculation based on the practical constraints prevalent at the site.

Keywords: Barge, Bridge construction, Infrastructure, Marine.

1 INTRODUCTION

It is estimated that over 1,000 bridges worldwide have been constructed by the incremental launching method (Gohler 2000), the vast majority of which have been post-tensioned concrete box girder bridges. Their main application has been in Europe, but the method has now spread around the world and the technology has been applied to steel I-girder and box girder bridges as well. An important issue pertaining to launched steel girders is the load carrying capacity due to concentrated forces.

The load on a launched girder is unique because in addition to a bending moment, a traveling concentrated load exists, which is applied by the temporary roller bearing. The concentrated load, also called a patch load, is transferred from the bottom flange of the girder into the web. The support reaction moves along the girder each time the launched segment passes over a pier bearing. It is important that patch loading does not introduce residual deformation or damage to the web plate. The effects of patch loading must be understood in order to know what web thicknesses are required. Even small increases in web thickness can add great weight and extra costs.

Bandel-Naihati Bridge belonging to Indian Railways (Eastern Railway) is an important railway link between Howrah and Sealdah division in the state of West Bengal. The bridge is situated over river Ganges adjoining Bandel and Naihati towns. The entire bridge consists of total 2 girders which will be constructed in situ on two enabling girders of 100.8M and 141.6M long each. The two enabling girders will be removed after the main bridge girder has been constructed.

2 BASIC DESIGN PARAMETERS & SITE CONDITIONS

As described earlier the bridge is an important railway link adjoining the two towns namely Bandel and Naihati. The river bank on the side of Naihati Town is having gradual slope and the stretch is about 200 meters from the main land. The river bank on the other side is however having steep slope with waterfront starting immediately. The main stream is about 500 meters wide near bridge. The site workshop is situated on the Naihati side about 300 meters from the bridge/water front. The course of the river from the worksite to the bridge is more or less straight and uniform. The water depth of the river varies between 3.5 Mt. to 15 Mt. from the shore side pillar to the deepest portion of the river at the site.

Figure 1. Bridge girder installation site

The tidal variation at the river at various months is taken from the data prepared by Kolkata Port Trust (KoPT) as presented in the published “Tide Table”. The relevant data for the daytime where the operation will be carried out is given in Table-I.

Table 1. Tide level records

FEBRUARY-2010					
DATE	**TIME**	**HEIGHT IN M. (HIGH TIDE)**	**TIME**	**HEIGHT IN M. (LOW TIDE)**	**DURATION**
6	6:02:00 AM	4.16	02:25:00 PM	1.49	08:23:00
7	6:49:00 AM	3.68	02:59:00 PM	1.7	08:10:00
8	8:17:00 AM	3.27	04:20:00 PM	1.88	08:03:00
22	5:57:00 AM	4.08	01:59:00 PM	1.34	08:02:00
23	7:00:00 AM	3.71	02:59:00 PM	1.51	07:59:00
24	9:00:00 AM	3.47	05:00:00 PM	1.62	08:00:00

MAY-2010					
DATE	**TIME**	**HEIGHT IN M. (HIGH TIDE)**	**TIME**	**HEIGHT IN M. (LOW TIDE)**	**DURATIO N**
6	5:54:00 AM	3.87	01:40:00 PM	2.03	07:46:00
7	7:24:00 AM	2.56	02:56:00 PM	2.13	07:32:00
8	9:04:00 AM	3.8	04:49:00 PM	2.08	07:45:00
9	10:25:00 AM	4.06	06:15:00 PM	1.92	07:50:00
21	6:48:00 AM	4.44	02:56:00 PM	1.88	08:08:00
22	8:12:00 AM	4.43	04:21:00 PM	1.93	08:09:00
23	9:35:00 AM	4.6	05:43:00 PM	1.9	08:08:00
SEPTEMBER-2010					
DATE	**TIME**	**HEIGHT IN M. (HIGH TIDE)**	**TIME**	**HEIGHT IN M. (LOW TIDE)**	**DURATIO N**
3	7:02:00 AM	4.91	03:29:00 PM	2.84	08:27:00
4	9:09:00 AM	5.02	05:37:00 PM	2.61	08:28:00
5	10:32:00 AM	5.43	07:08:00 PM	2.26	08:36:00
16	5:26:00 AM	4.79	02:35:00 PM	2.95	09:09:00
17	8:22:00 AM	4.6	04:55:00 PM	2.81	08:33:00
18	10:07:00 AM	4.78	06:18:00 PM	2.45	08:11:00

The variation of height of water due to tidal effect is plotted against time interval as well as against height interval based on procedure indicated in Tide Table published by KoPT (Kolkata Port Trust), proper correction has been applied to get accurate figure at Jubilee Bridge site. The variation follows harmonic nature and thus can also be defined mathematically. But since the height and duration varies on daily basis we have considered the values given by KoPT which will be further corroborated by actual observation at the site. This data will then be plotted in graphical form and the maximum time window available for keeping the Barge in between the pillars will be estimated. This will also be useful to determine the time at which we should start the job. It is to be ensured that the Barge will have to be shifted out from the pillar location before this time window is exceeded.

It may be noted that in general during the months of 1st week of October for every 100mm rise in water time gap will be 28 minutes. Tidal current is present in the river all the time even though the magnitude recedes considerably near the worksite near Bandel. The current of the river stream, varies between 3 knot to 5 knots during rainy season (July to September) and about 2 to 3 knots during winter season (between November to March). Similarly the wind speed varies between 30 km/hr. to 40 km/hr. over the years except during stormy condition (Monsoon period) when it may exceed 50 Km/hr. The truss type construction has enabling girder I which is 100.8m long and 9.15m high, 9.15m wide, weighing 1484 tons, and enabling girder II which is 141.6m long, 9.15m high, 9.15m wide, and having weight of 1762 tons. The pillar on which the girder is to be placed is about 6.2 M above reference level (RL). Thus it is concluded that the enabling girder is to be transported over a distance of approximately 600 m. from the work site for installation purpose.

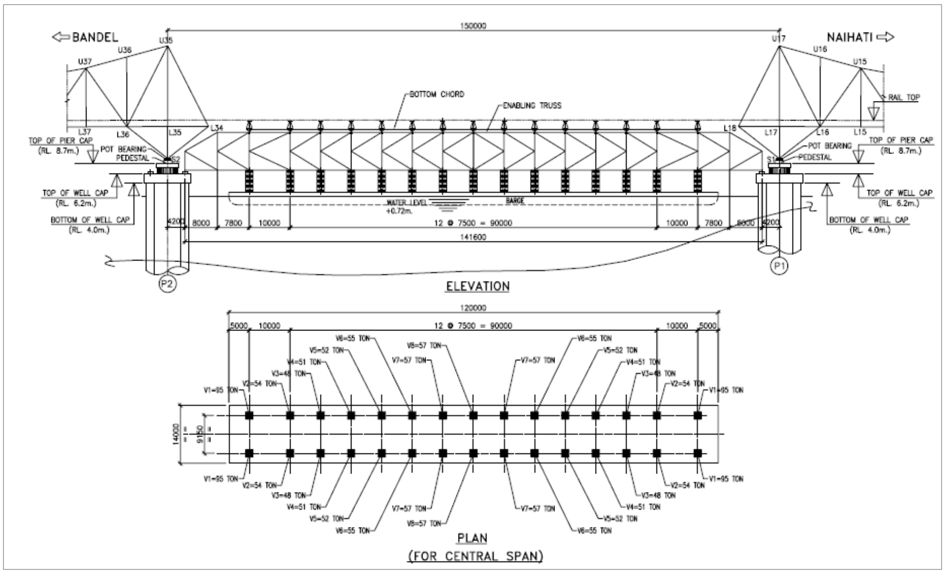

Figure 2. Bridge section

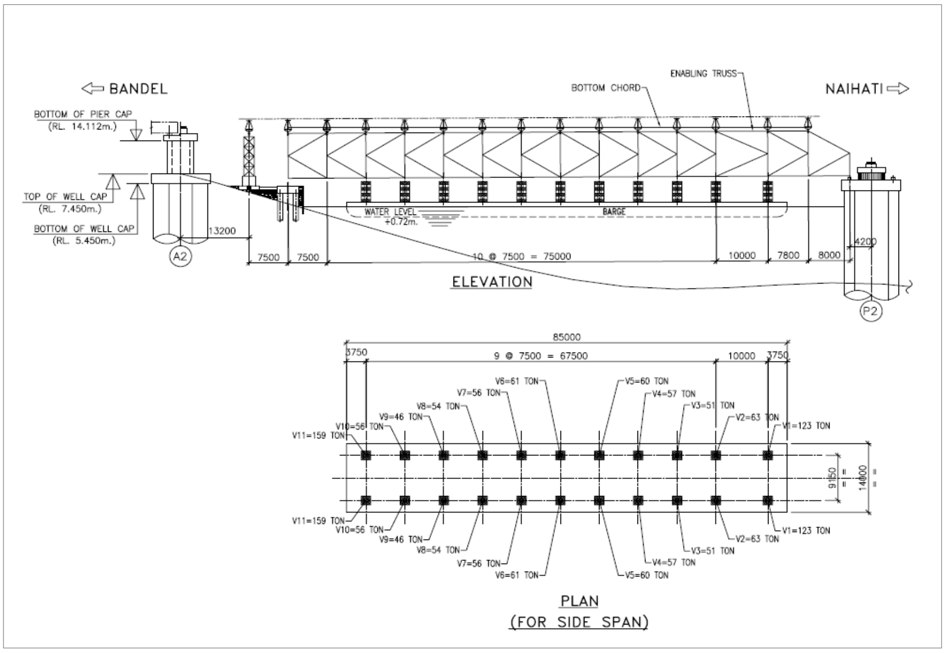

Figure 3. Bridge section

3 METHODOLOGY & OBJECTIVES

Two different non self-propelled barges; one having dimensions as 77M Long and the other 118M long, having other proportional dimensions, will be mobilized to carry the 1484 tons and 1762 tons enabling girders respectively. The enabling girders will be assembled span by span on the barge at the required height near shore. The shore mobile crane will be used for constructing the enabling girders. Necessary trestles up to suitable height will be erected on the barge and the enabling girder will be constructed on top of the trestle.

After assembly of the enabling girder is completed, the barge will be towed by means of anchors or tug near the bridge site and finally position it just at the center position, in between the pillars. By carefully choosing the time of operation, tidal effect can be utilized to effect movement of the barge up & down (similar to that can be achieved by ballasting i.e. pumping in water and de-ballasting i.e. pumping out water). In this way the enabling girder will be placed on its pillars and when the job will be over it will be removed. Assistance of small tug will be required for some finer adjustments near the pillar site and bring the empty barge back to the work site.

As briefly described earlier, the proposed method should fulfill the major objectives. The enabling girder should be transported at site and installed on the pillars in the most economical way. It should be safe i.e., there should be no loss of life/material due to accident etc. The entire operation of installation/

removal of the enabling girder must be done within 2 hours in order that the operation is carried out within existing tidal time slot and river traffic is not disrupted. After the enabling girder is placed on the pillars, it must be released from the pillars situated on the barge and the barge will be pulled back immediately before the water starts receding. In order to account for the natural condition of tidal variation in the river, efforts should be made to use this phenomenon for the up and down movement. The scheme as proposed here fulfils all the above objectives.

4 COMPARISON WITH OTHER ALTERNATIVES

The first alternative suggests that one self-propelled barge of 77M long capable of displacing about 2500 tons will have to be mobilized, equipped with two 1000 tons capacity 40 m. long derricks with associated winches. The completed enabling girder will be placed on the deck of the barge. The barge will then be transported near the site and the girder will be picked up by the derricks and installed on the pillars. While this method is technically feasible, it was soon found out that the cost is too prohibitive and mobilization of self-propelled barge fitted with two 1000 tons derrick winch system with 40 m. long boom, along with its own power pack will involve long time and will delay the project considerably. The delay in the project completion and additional financial implications were not acceptable to the Owners. In addition the stability and heeling of the barge will have to be carefully controlled while the 1484/1762 tons girder will be swung out for installation purpose. Due to higher risk of operation, increased time for regirdering and high cost of operation this method was not considered acceptable. The second alternative is to carry out the operation in the usual way i.e. installation of the enabling girder piece by piece and also dismantling each span in the same way. This is not favorable, as it will take a long time and still a smaller crane barge will be required for material handling.

5 PROJECT COMPONENTS & DETAIL

5.1 Basic dimensions of barge

It was soon found out that suitable barges of required dimension are not readily available for long duration. Thus it was decided to design and construct new barge for the job. The basic design for the barge was done considering the site data and the data of the enabling girder. Drawing was prepared after taking measurement from the site and the acceptable length was determined after plotting the site data in the form of a drawing. The dimensions of the two such barges to carry two different girders are given below:

	Dimensions	
	Barge B-77	**Barge B-118**
Overall Length	77.0 Mt.	117.8 Mt.
Breadth (mld)	20.0 Mt.	20.0 Mt.
Depth (mld)	3.5 Mt.	3.5 Mt.
Draft (Approx.)	2.35 Mt.	2.35 Mt.

5.2 Installation of 100 m girder

Initially the barge B-77 is properly tied up with the pier at shore on one side and anchored on the other side. The empty barge B-77 will be fitted with trestles at pre-determined positions and suitably fixed on the deck of the barge. Proper foundation will be made on the barge deck on which the trestle supplied by the manufacturer of the bridge will be fixed. Certain tanks as decided from structural considerations will be filled with quantity of ballast water (as required). After the enabling girder has been constructed and suitably secured with the trestles, all non-essential items are cleared off from the barge. The barge is now ready for movement and further operation. The draft reading will be taken and general survey regarding safety aspect will be done. The barge will now proceed towards the bridge site by the pulling of the anchors. Initially the barge will be pulled to a distance of about mid-length of the river. Then the anchors will be changed over and further pulled towards the opposite bank of the river. When the barge is near the opposite shore it will be turned by changing anchors methodically. At a suitable tide condition the barge will be brought near the pillars and properly positioned about 10M away from the pillars. In the proposed way of shifting the barge, most of the time the river current will work along the length of the barge which is actually desirable. If the barge is brought while the side of the barge is facing the flow, it is susceptible to turn due to river current and that will render difficulty to control the barge as there is no powered steering gear fitted to the barge. During movement of the barge all six anchors will be used. In addition one standby tug will also be mobilized to assist the barge during initial movement and during positioning in between the pillars. All the winches will be powered winches which should be controlled remotely from a central position. Separate single lever control for each winch will be required and will be fitted. The barge is now ready for operation.

The actual operation will start just about 30- 45 minutes before the start of the low tide. In other words the barge will be moved between the pillars at the highest water level. At this time the barge will be moved and brought under the pillar. She will be positioned between the pillars and the barge will be tied up tightly with the anchors and kept in position. During this time all the fastening of the enabling girder with the trestles will be removed. Slowly the low tide will set in, and water will start receding and the barge will slowly come down.

Slowly the girder will sit on the pillars and after some time the barge will be free from the girder. The height of the trestles will be adjusted in such a way that this will occur about 2 hours after the start of the low tide. When sufficient gap is created by the receding water level, the barge will be pulled by the anchors away from the pillars by about 10M. At this time if necessary high capacity pumps will be used to make sufficient workable gap between the trestles and the enabling girder which is now sitting on the pillars. Thereafter the barge will be brought back to the jetty by the similar procedure as was applied while taking it with the girder from the jetty.

The exact parameters of operation will depend on the day and month when the actual procedure will be carried out. As an example let us consider that the operation will be done on 2nd/ 3rd October. The plot of tidal variation, based on the tide data available from KoPT document, is presented in this document. Let us say that we have positioned the barge 30 minutes before start of low tide i.e. at 7:20 AM the condition of the barge B-77 at that time is given below:

Displacement	2477 Tons.
Draft Ford	1.8 Mt.
Aft	1.8 Mt.
Clearance of bottom of girder from top of pillar	500 mm

Due to onset of low tide the barge will slowly go down. The bottom of girder will touch the top of pillar after the barge goes down by 500mm and this will occur at 9:35 AM. i.e. after two hours and fifteen minutes. The girder is not yet fully borne on the pillars. Slowly the due receding tide the barge will go down and the enabling girder load will be taken up by the pillars. During this time the ballast water will also be discharged systematically from the tank so that no unfavorable trim occurs. A chart is prepared for such tank water discharge and the pumping out will have to be done following this chart. Total 206 tons of ballast water will have to be discharged. At about 1:20 PM water level will recede by 1.14 m. at which time the entire girder load will be supported by the pillar. By 1:49 PM the trestles will be clear of the girder by 400mm. At that time the barge will be slowly pulled out of the pillar position by 10M. This will take about 15-30 minutes by which time the clearance will further increase as the low tide will continue up to 5:20 PM. Thus the entire operation can be done very safely within about 4 hours. Therefore we shall take actual measurements two three days before the actual operation and decide the operation timings.

5.3 Removal of 100 m girder

The removal procedure is more critical as at this time the bridge is constructed and the gap between the enabling girder top and the bottom of the bridge is limited to about 560mm. This puts a constraint in the sense that the barge while picking up the enabling girder should not at any time rise more than 560mm as then it will put an upward force on the bridge bottom girder. The empty barge B-77 with trestle fitted and water filled in designated tanks will be positioned below the enabling Girder and in between the pillars. The barge will be positioned about 1:30 hrs before the on-set of low tide. As the river level will increase due to tide it is expected that within 30 minutes the trestles will touch the enabling girder. Within 45-60 minutes the barge will take the entire load of the enabling girder and will raise it by about 350mm. Within the next 45 minutes while no change in water level is expected (slack period) the barge will be brought out of the pillar site and slowly brought near the jetty. This operation however will be done after the 118M enabling girder has been removed. Since powered winches will be used it is expected that operation can be done within the desired time interval. The exact parameters of operation will depend on the day and month when the actual procedure will be carried out. As an example let us consider that the operation will be done on 3rd October. The plot of tidal variation, based on the tide data available from KoPT document, is presented in this document. The condition of the barge B-77 at that time is given below:

Displacement	787 Tons.
Draft Forward	0.66 Mt.
Draft Aft	0.66 Mt.
Clearance of bottom of girder from top of pillar	560 mm
Safety clearance upwards as well as downwards	100 mm

Let us say we start the operation at 5:30 AM when the minimum low tide is just over and the high tide has started. At around 7:40 A.M. the water will rise by about 1.14 m. and the weight of the enabling girder will just be taken up by the barge. During this time at selected tanks water will be filled in so that undue trim is avoided. About 206 tons of water will have to be pumped in. After this time at 7:50 AM the girder will be clear of the pillar by 300mm. At that time pulling out operation will start and should be completed by 30 minutes. Within this time the barge will further rise by 100 mm and hence clearance from pillar will be maintained as well as the clearance from the bridge will be 560-(300+100=400) =160 mm. Thus by 8:20 AM the operation will be over and the barge will be clear from the pillars by 10M. At that time onset of low tide will slowly begin and so barge will never touch the bridge. This procedure is safe with enough safety margins. Therefore we shall take actual measurements two three days before the actual operation and decide the operation timings. From the analysis of the development of tide discussed earlier in the section it is observed that the time duration for the entire operation will be 2 hours 50 minutes. Thus within this time the barge with the enabling girder has to pulled away from the pillar location.

5.4 Installation & removal of 118 m girder

Barge B-118 will be used for installation of the 118M enabling girder. In order to reduce cost it has been decided that B-77 barge will be lengthened and converted to a 118M barge by adding two separate units on forward and after ends. This will not pose any hindrance to the project schedule as removal operation of the 100M will be necessary only after the complete bridge is finished. The joining will be carried out in floating condition. Special structure has been designed at the joining face so that adequate strength is maintained. The remaining procedure to be followed for installation of the 118M enabling girder will be similar to that for installation of 100M girder. The procedure to be followed for removal of the 118M enabling girder will be similar to that described for removal of 100M girder.

5.5 Handling of barge

The proposed barge is non propelled dumb barge. The movement of the barge is controlled by anchors and Tug will be standby to make way course correction etc. Thus the anchor sizing and its shape are very important parameters. Detail calculations have been done to determine the required size of the anchor for holding the barge while under tow. The calculation is based on estimation of forces acting on the barge and then its effect on the anchor holding capacity. The anchor holding capacity of the soil near the work site is known from past design data as such was not repeated. The loads acting on the barge during movement is very difficult to calculate as it does not reflect a typical ship or an offshore structure. The various types of forces which are acting are buoyancy at centre of buoyancy, weight at centre of gravity, hydrodynamic force at centre of pressure, current uniform at the underwater body, wind force on the above portion of barge, wave draft force on underwater body, and anchor force on deck points. We are interested in forces acting Y (Transverse) and X (Longitudinal) directions, but mostly in Y direction as that affects the stability also. In order to determine the anchor size the load acting on the barge at fully loaded condition i.e. with the enabling girder perked on the trestles; calculations have been performed by making some assumption to simulate the actual condition. The calculations have been carried out according to Lloyds classification rules for determining the size of the anchors for the proposed barge and the displacement, resistance estimation method by following normal procedure at a barge speed of 4.0 knots. The assumption is that the holding power of the anchors should withstand the resistance force. The calculations also carried assuming the barge structure to be stationary and find the force acting on it by Morrison's equation considering water speed of 4 knots and by taking into account the Wave drift force for low velocity case. The sizes of anchors have been thus decided considering the results of above calculations. It is proposed to use six anchors with partial chain and ropes for doing movement operations of the barge.

Detail list of anchors, mooring fittings etc. have been discussed in succeeding paragraphs. In order to carry out the installation operations successfully it is very important to handle the barge in a controlled manner. Six anchors already grouted at predetermined location according to drawing will be connected with the winches on the barge. With the help of the winches and pull provided by the anchors the barge along with the enabling girder will be taken out of the jetty and turned around and finally brought just between the pillars. The slow pull by the anchor winches will inhibit large movement of the barge in any direction as the pull of the six winches can be easily be controlled by winch control. Further, handling the barge near the pillars of the bridge during installation/ removal of the enabling girder must be done very accurately with utmost precautions as otherwise accidents might occur resulting in financial loss. Even though handling of the barge will be done by certified masters and marine operators, who know their job best, a proposed method for accurate positioning of the barges, turning of the barge etc. is indicated in a drawing which should be followed. The most critical parameters are the presence of river current and very narrow manoeuvring space available between the pillars. The narrow space between the pillars is a design constraint as smaller length of barge will not be able to carry the entire length of the girder. Keeping in mind the above site parameters, it is proposed to employ one tug as standby vessel which will assist in accurate positioning the barge within the tolerance.

5.6 Tug and its sizes

In order to accomplish the task of shifting the barge to the bridge site with the new enabling girder and bring the barge back to the work site, assistance of proper Tug will be required in accomplishing initial movement and in emergency situation. The Tug will push the barge and also help in finer positioning between the two pillars. Minimum one Tug will be required while taking the barge. During positioning phase the tug will provide necessary help in a proper manner to maintain the position during installation or load out of girder. The schematic drawing which is prepared for such purpose is enclosed with this report. However, during unloading operation the Tug will acts as stand by and will only assist to maintain its position during actual unloading operation, the basic parameters of the Tug which shall be able to handle the barge will be as follows:

Type	Pusher/side towing type with shallow draft
Bollard pull	15-20 Tons.
Horse power	1200 - 1800 H.P.
No. of propellers	2
Length	20-22 Mt.
Draft	Not to exceed 2.5 Mt.

5.7 Design, calculations & criticality check

Proposed method is not a common design issue and various design aspects are required to be checked and confirmed by calculations (with adequate factor of safety), before undertaking any operations, in order to establish the soundness of the method.

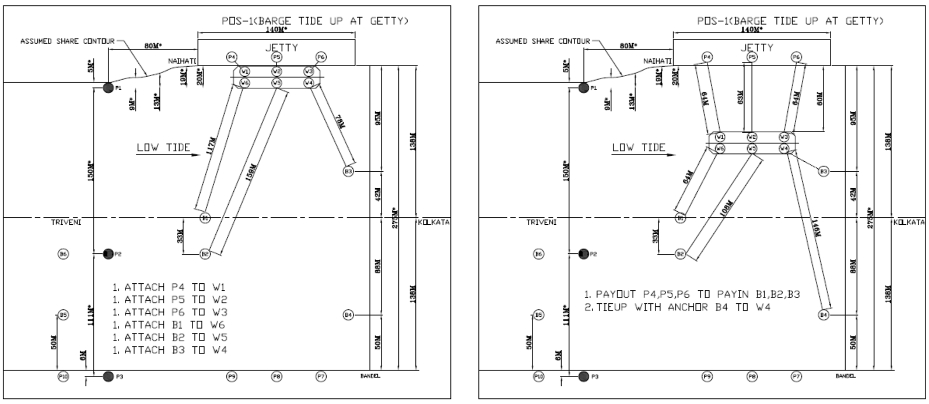

Figure 4. Position 1 (Barge Tide up at Getty in Low Tide)

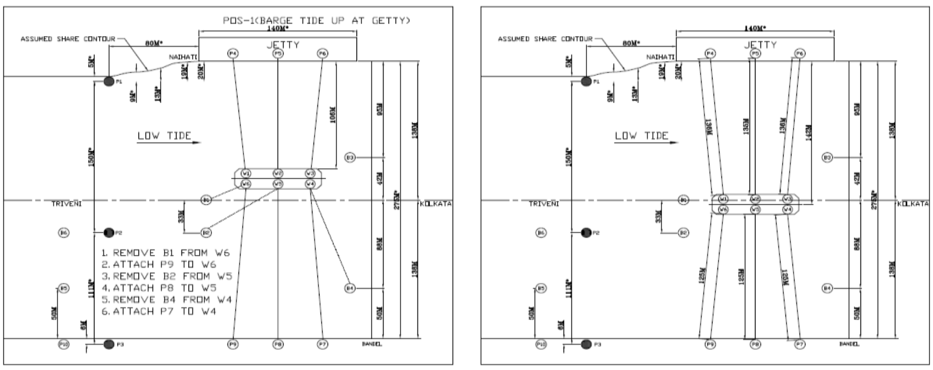

Figure 5. Position 2 (Barge Tide up at Getty in Low Tide)

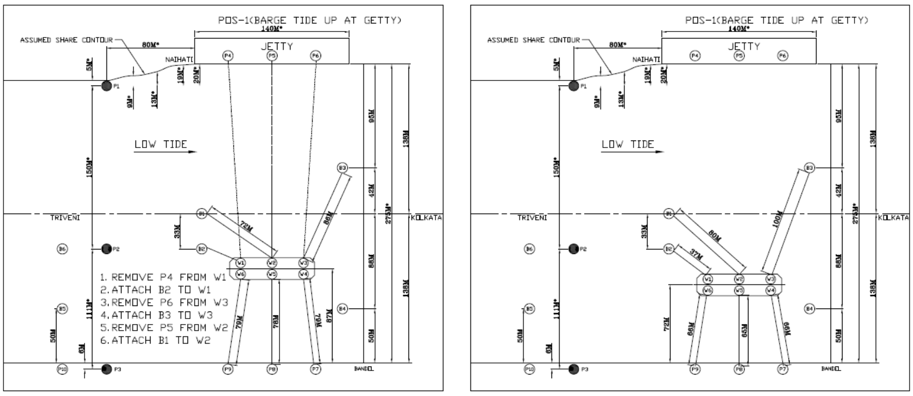

Figure 6. Position 3 (Barge Tide up at Getty in Low Tide)

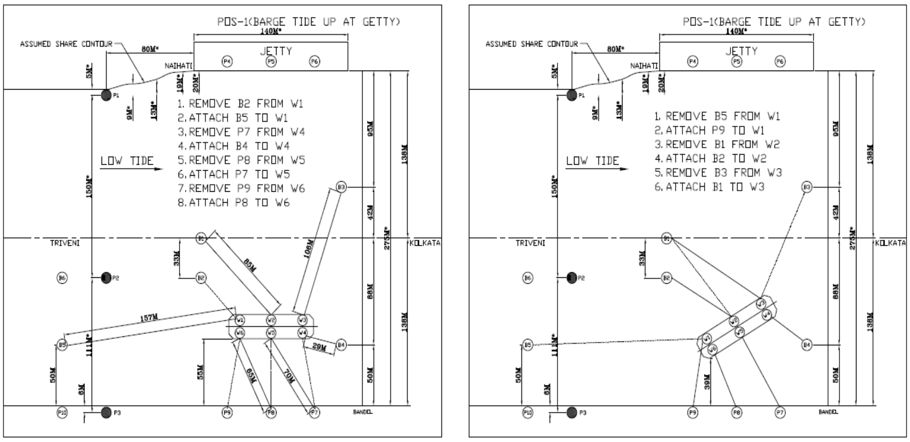

Figure 7. Position 4 (Barge Tide up at Getty in Low Tide)

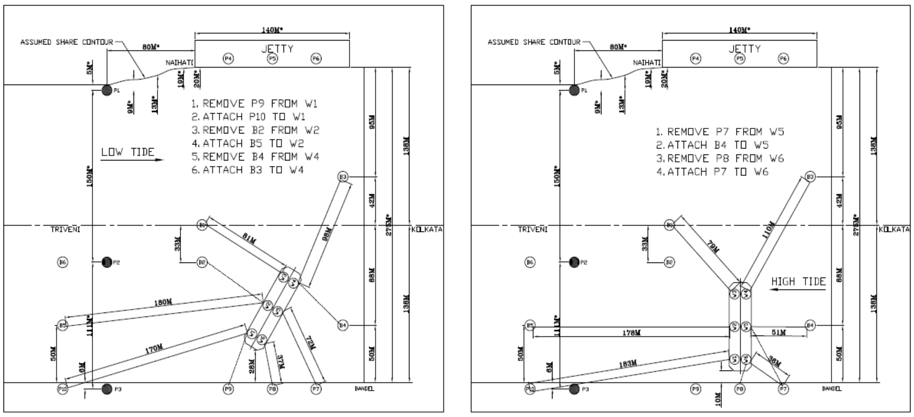

Figure 8. Position 5 (Position of Getty in Low Tide)

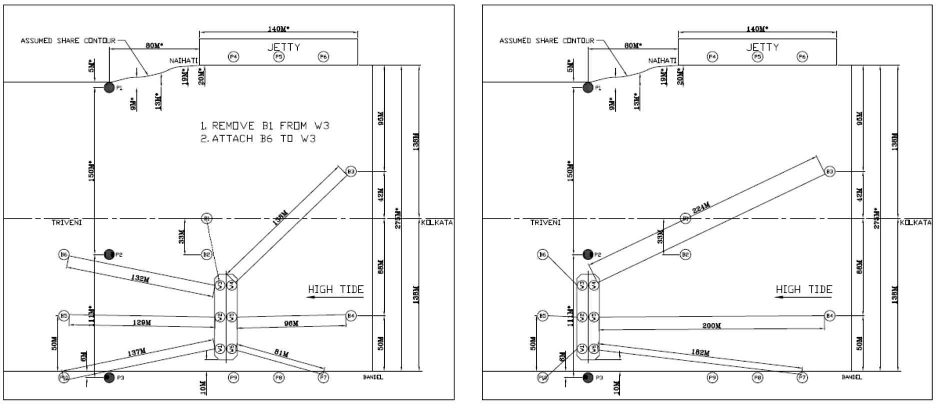

Figure 9. Position 6 (Position of Getty in High Tide)

The basic scantlings of the main structural members and the joints were carried out based on rules of Lloyds Classification for river coastal operation. Local strength calculations have been done to design the foundation of the trestles on the barge, ballast tanks, structure under towing winch, pumps, miscellaneous seats of various fittings, and estimation of weight and centre of gravity. Naval Architectural calculations include Hydrostatic calculation which will form the basis of all future calculation of a floating body, stability calculation in normal weather, and stability calculation in moderate wind condition. Miscellaneous calculation includes calculation for portable diesel driven pump, and mooring fittings.

6 CONCLUSION

A detailed technical appraisal has been presented in this report regarding installation of enabling girder and removal of old girder by deploying floating barge. From the study it is found that the proposed method is technically feasible and operationally safe under the present site condition and dimensions of the girders. Situation may have to be reviewed if the design parameters and site parameters are drastically changed/ reversed. Till such reversed occurs the proposed method is safe and least expensive if the operation is done as per instructions contained in this report. It is also recommended that close monitoring and supervision will be necessary during this operation. Strict adherence to the stability booklet and all pre-trials will ensure safe operation for this novel project.

REFERENCES

[1] Det Norske Veritas: “DNV Hull Structural Rules: Development, Background, Motives”, Report Number 95- 0389.

[2] Health and Safety Executive: “Offshore Installations: Guidance on Design, Construction and Certification” January 1990.

[3] Comstock, J. P.(ed): Principles of Naval Architecture, SNAME, New York, 1957.
[4] Naito S., Yamauchi H., Tomita M., Tomiogi K.: Design and construction of prestressed concrete barges for Yokohama Bay Bridge foundations. Proceedings of the 10th International Congress of the FIP, New Delhi, India, 1986, and FIP Notes 1987/2, p. 3-8.
[5] Eddie A.: Off-shore structures, Hay Point, Queensland. Concrete Institute of Australia, 7th Biennial Conference, Melbourne, August 1975.
[6] Hyde R.: Floating Concourses - Brighton Marina, Sussex. Paper presented at the 8th International Congress of the FIP, London, UK, 1978.
[7] Yee A.A., Masuda F R., Nai Kim C., Doy D.A.: Concrete Module for the Global Marine Concrete Island Drilling System. FIP Notes 1985/2, p. 16-19. Federation Internationale de la Precontrainte (FIP), London, UK.

Received: Nov. 2, 2015 Accepted: Dec. 23, 2015