The Institution of Structural Engineers

Possible solution to past CM examination question

Question 3 - January 2015

Temporary pedestrian bridge

by Saprava Bhattacharya

Question 3. Temporary pedestrian bridge

Client's requirements

1. A temporary pedestrian bridge is required to provide access from the shore to an existing jetty serving passenger ferries: see Figure Q3. The temporary bridge is needed while the jetty is extended, putting the permanent access bridge out of use. Access for fishermen's boats is required under the temporary bridge.
2. The tidal range is 2.0m, from +0.5m high water to –1.5m low water. Datum is Mean Sea Level (MSL). The bridge is to be 150m long and to provide a 4.0m clear width for pedestrians. The jetty is 100m away from the shore at low water. A minimum clearance of 3.5m is required under the bridge at all states of the tide, over an uninterrupted length of 50.0m and a second uninterrupted length of 20m within the 100m distance between the jetty and shore.
3. No temporary or permanent foundations may be installed closer than 75.0m to the jetty. The client advises that the existing jetty is capable of supporting unfactored loads of 500kN vertically and 250kN laterally in both horizontal directions from the temporary bridge. The existing jetty deck level is +4.5m above MSL.
4. In the 50.0m length of bridge over the tidal zone of the shore, no construction may leave any footprint after the bridge is removed.
5. All existing services should remain uninterrupted during the construction, use and removal of the bridge. There is a 30.0m-high electricity transmission tower and line close to the proposed bridge which will remain live throughout the construction, use and removal of the bridge.

Imposed loading

6. Live load on bridge deck. 5.0kN/m^2

Site conditions

7. The site is located in the open sea. Basic wind speed at sea level is 46.0m/s based on a 3-second gust; the equivalent mean hourly wind speed is 23.0m/s.
8. Ground Conditions
   Sea bed – 30m below datum — Stiff clay, C = 200kN/m^2
   30m - depth — Rock, characteristic compressive strength 1,000kN/m^2

Omit from consideration

9. Longitudinal imposed loading.

SECTION 1 (50 marks)

a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)

b. After the completion of the design the client advises that a mistake was made in the calculation of the jetty load capacity, and the correct values are 50% of those previously advised in both the horizontal and vertical directions. Write a letter to your client advising of the implications this would have on your design and ways in which the design could be modified. (10 marks)

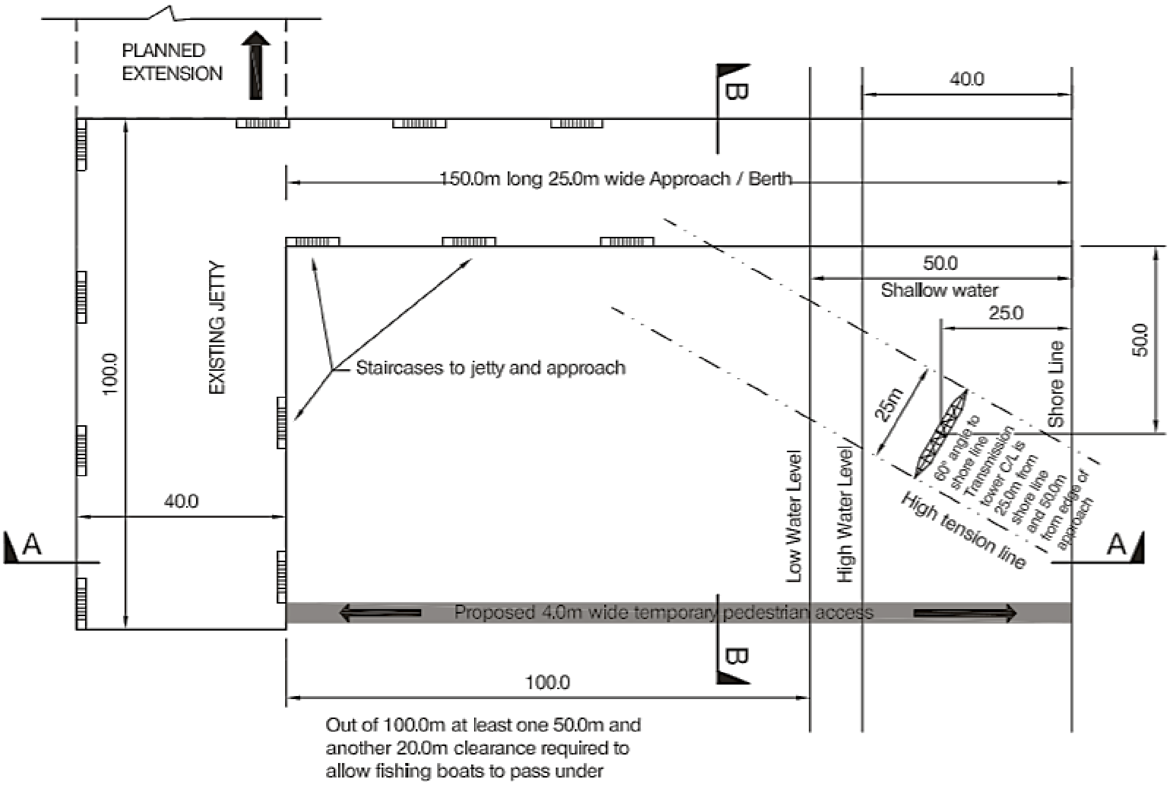
SECTION 2 (50 marks)

For the solution recommended in Section 1(a):

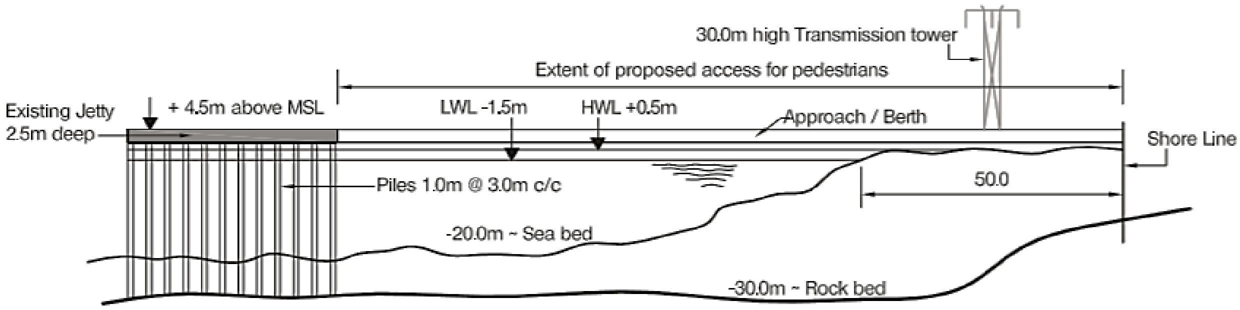
c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)

d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. (20 marks)

e. Prepare a detailed method statement for the safe construction of the works and an outline construction programme. (10 marks)

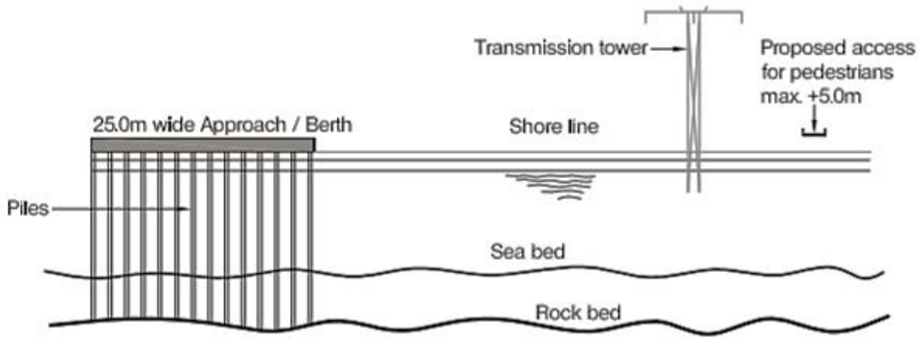


PLAN OF EXISTING JETTY AND APPROACH



SECTION A - A

(Piles under Approach not shown for clarity)



SECTION B - B

NOTE: All dimensions are in metres

FIGURE Q3

Question 3. Temporary pedestrian bridge

Question 3

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Introduction: *Figures 1 and 2 show the site in three dimension*

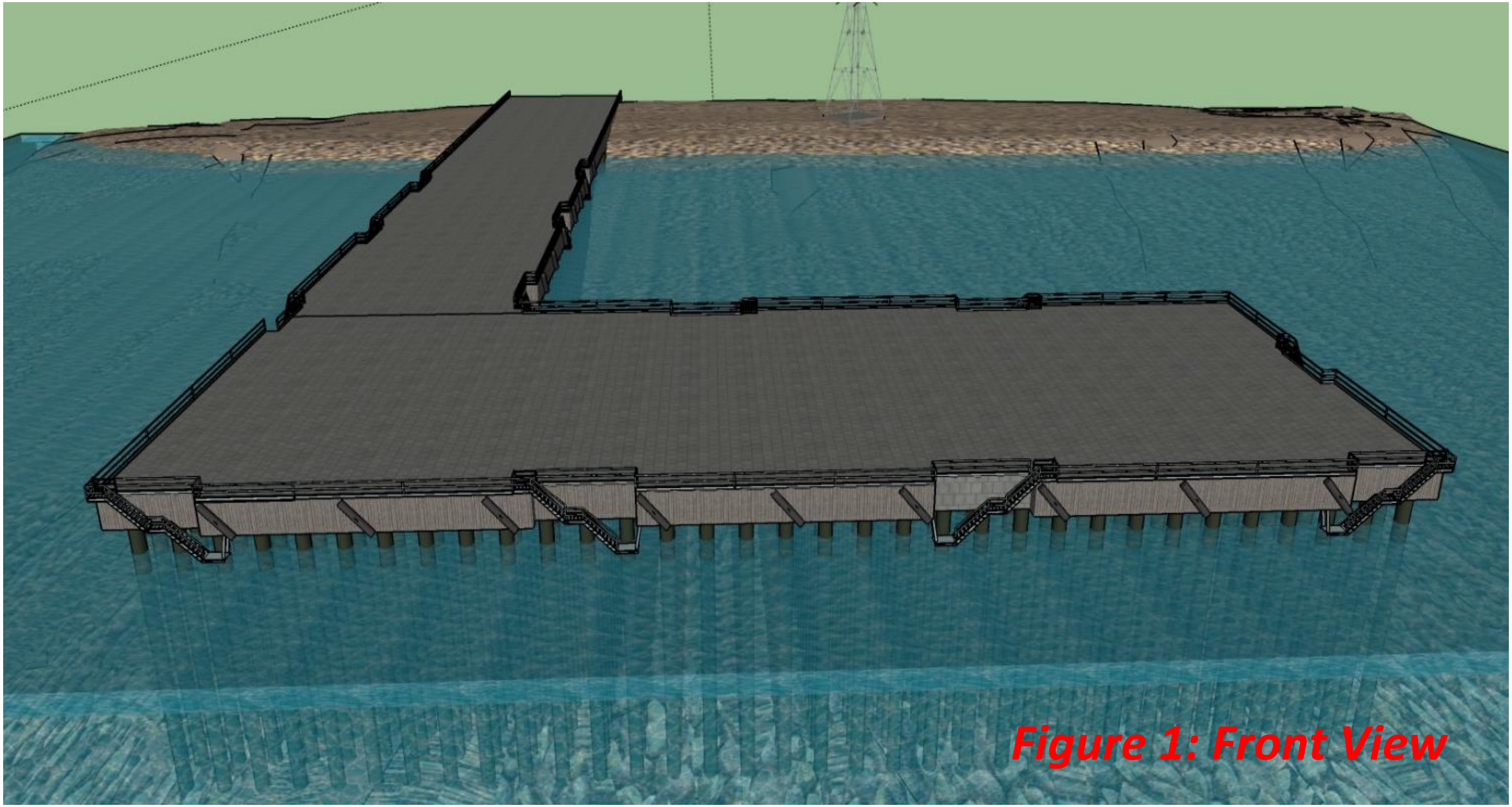


Figure 1: Front View

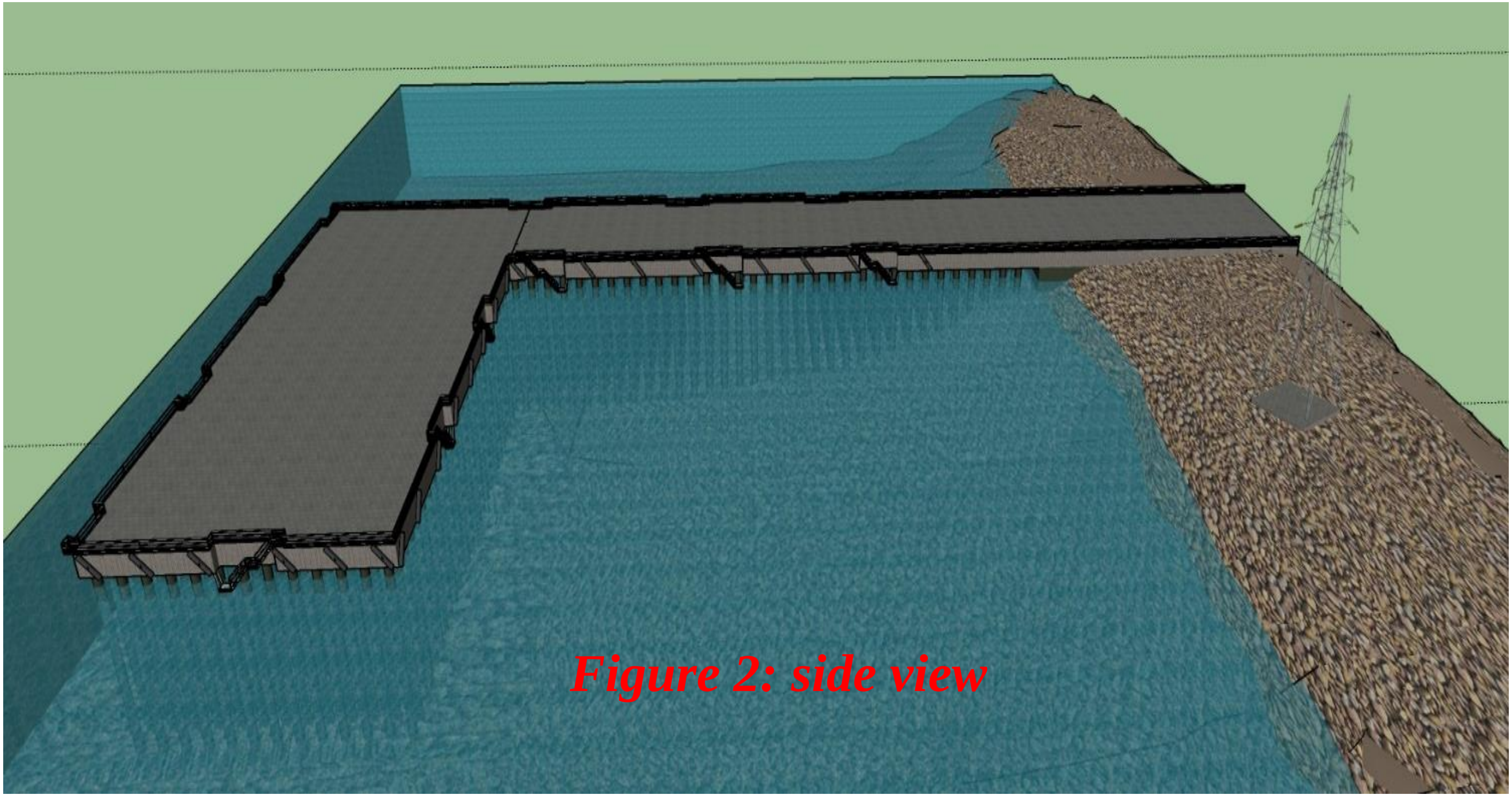


Figure 2: side view

This is a question where engineers are expected to think outside the box to come up with a very simple solution for a complicated problem and not the other way round. This was a real life problem. There are plenty of jetty out there for which similar situation could arise at any point of their service life.

Looking at the client's requirements and the description of the site the only simple solution to the problem is nothing but a pedestrian walkway supported by floating barges at appropriate distance. One of the well-known examples of floating bridge is the temporary bridge prior to construction of present Howrah Bridge at the capital city of Bengal state of India named Kolkata (Figure 3 and 4).

Figure 3

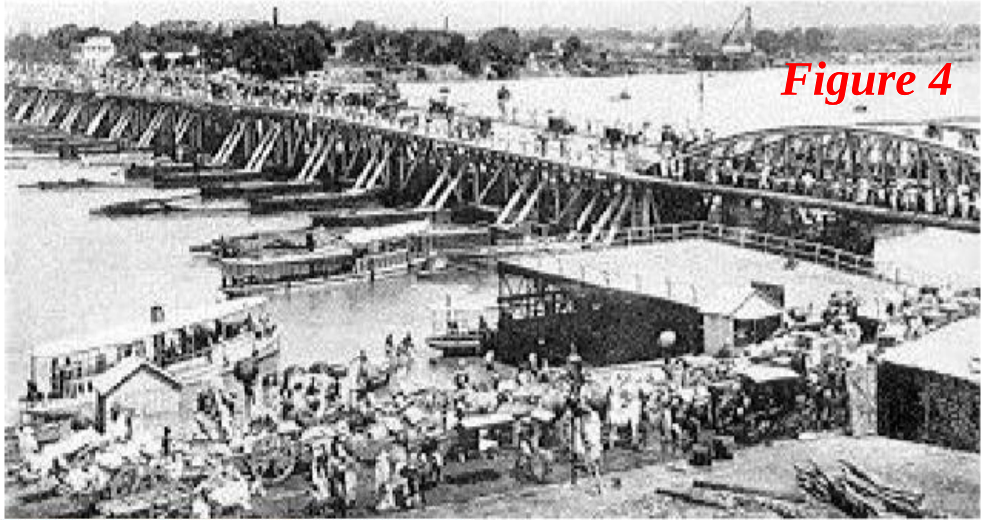


Figure 4

Figure 5

Another example of an existing Floating foot bridge is Canary Warf Bridge (Figure 5)

A simple pedestrian access to a small jetty is a possible way to join two approach trusses to overcome such problem as shown in Figure 6 below. This type of structure could be a joiner of two Trusses from either end as shown in the solutions shown through figure 7 and further.

Figure 6

Solution 1

Simple truss bridge dropped on top of Pontoons (spans 25m 55m & 25m) resting on Jetty on one end and on temporary embankment at the other end.

This solution is the easiest. Simply supported truss bridges supported on pontoons / floating barges with appropriate overhang to support a simply supported dropping span in between, the basic cantilever bridge concept. Span adjustment could be such that the clearance envelops are compiled, as well as the reactions on the existing jetty never exceed as mentioned in client's brief. 3D model in figure 9 to 12 as well as sketches in figure 7 & 8 is self- explanatory to demonstrate the simplest possible solution to this particular problem. If required these floating pontoon / barge can be tied back to some form of anchors on seabed. This particular will be the only solution which can really be considered as a pure temporary solution.

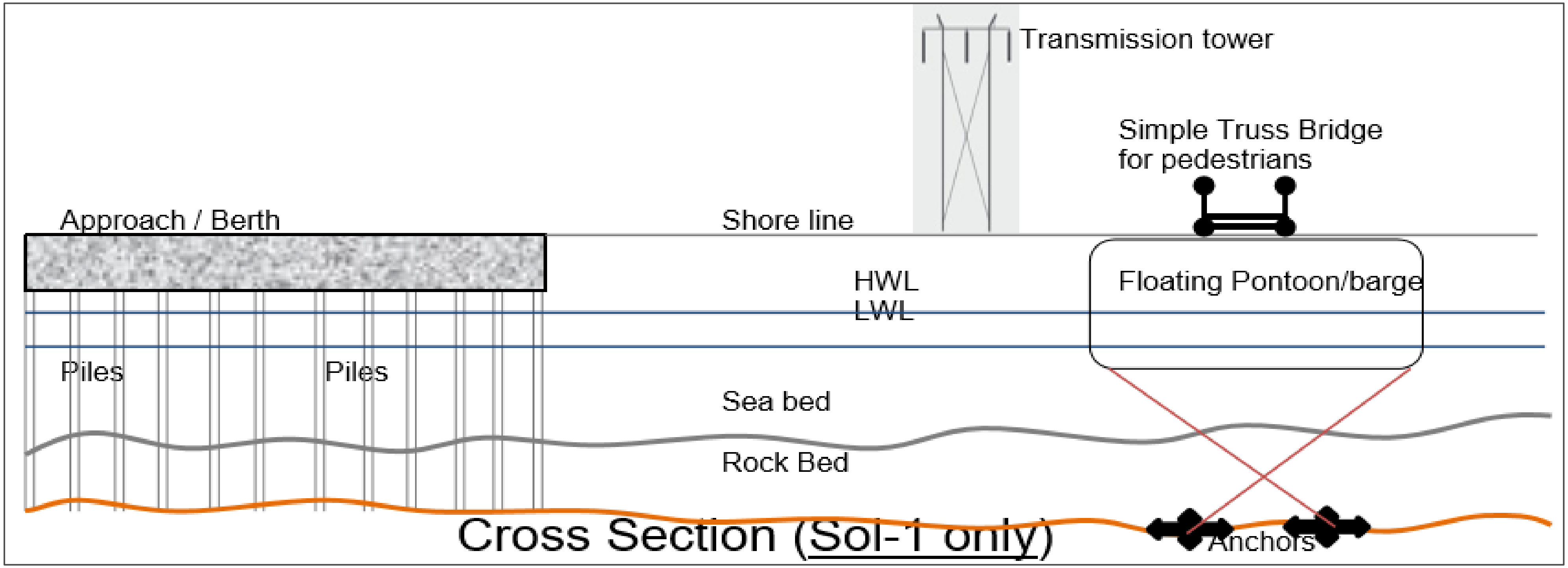
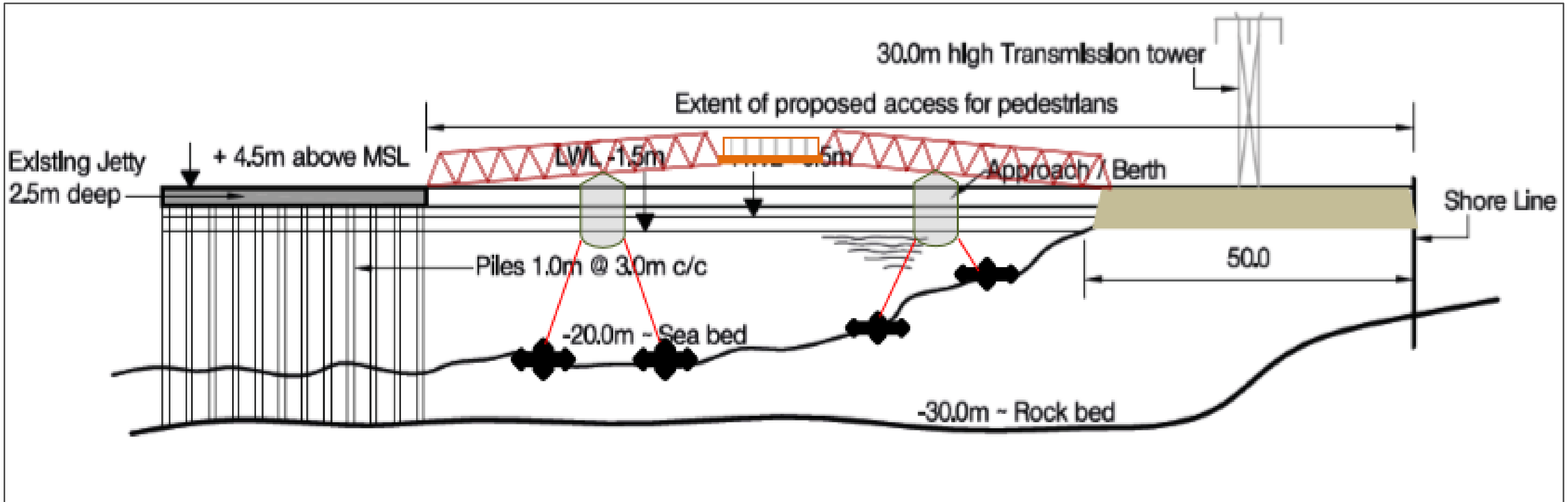


Figure 7 Cross sectional view of the proposed solution 1



SECTION A - A

(Piles under Approach not shown for clarity)

Figure 8 Long sectional view of the proposed solution 1

In the following figures 9 to 12 three dimensional views of the proposed simple solution should be sufficiently self-explanatory to demonstrate its appropriateness.

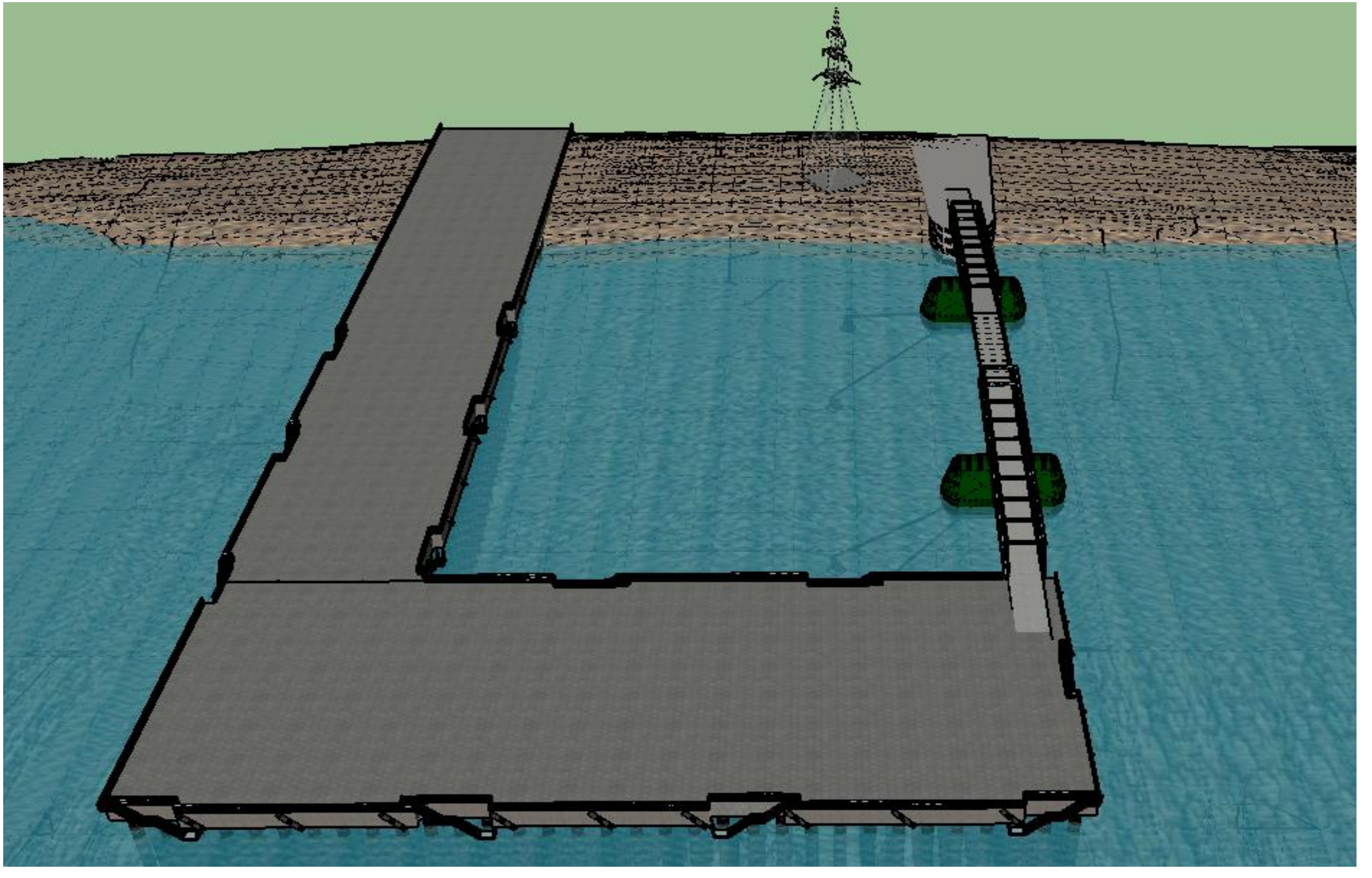


Figure 9

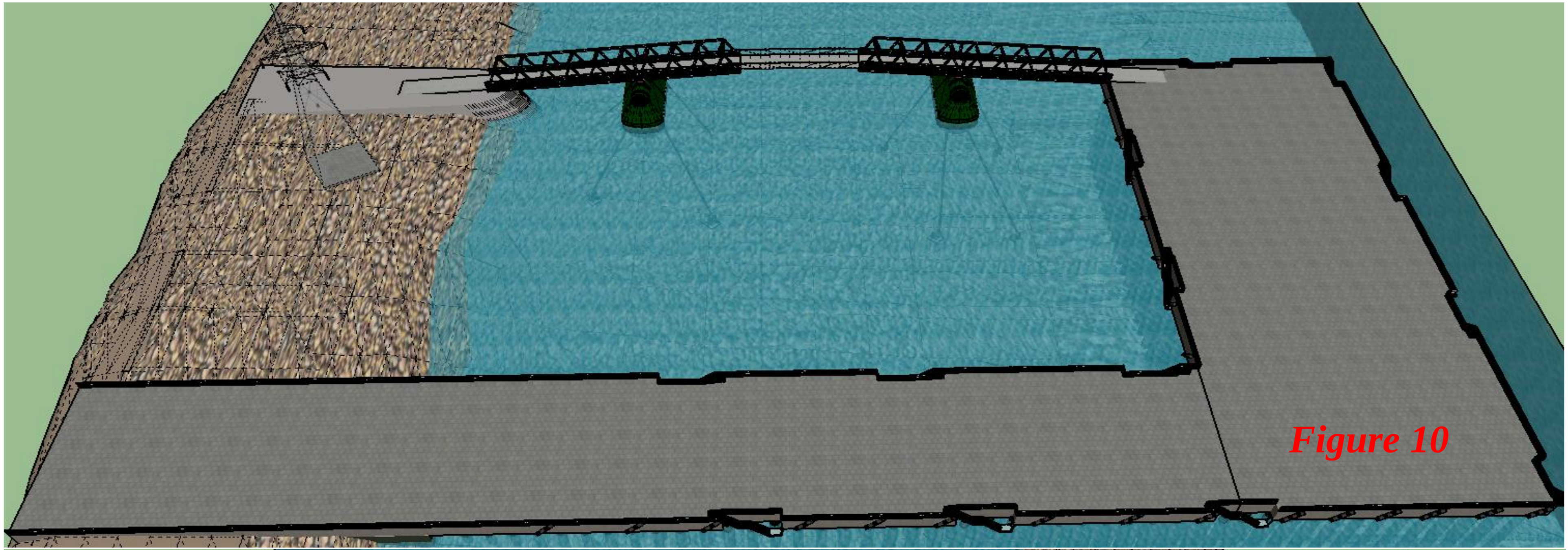


Figure 10

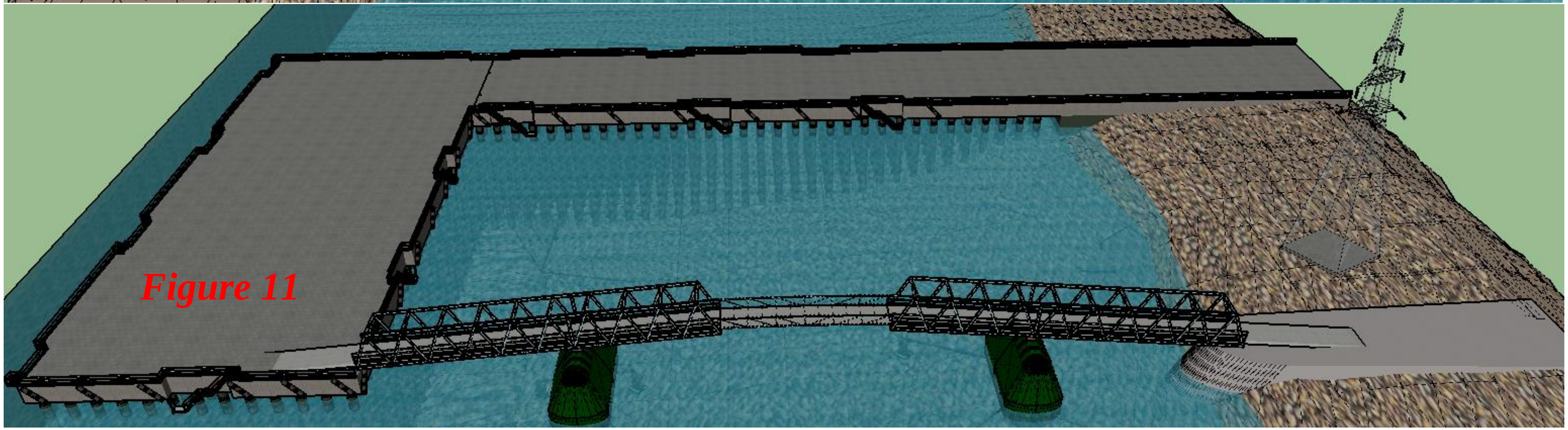


Figure 11

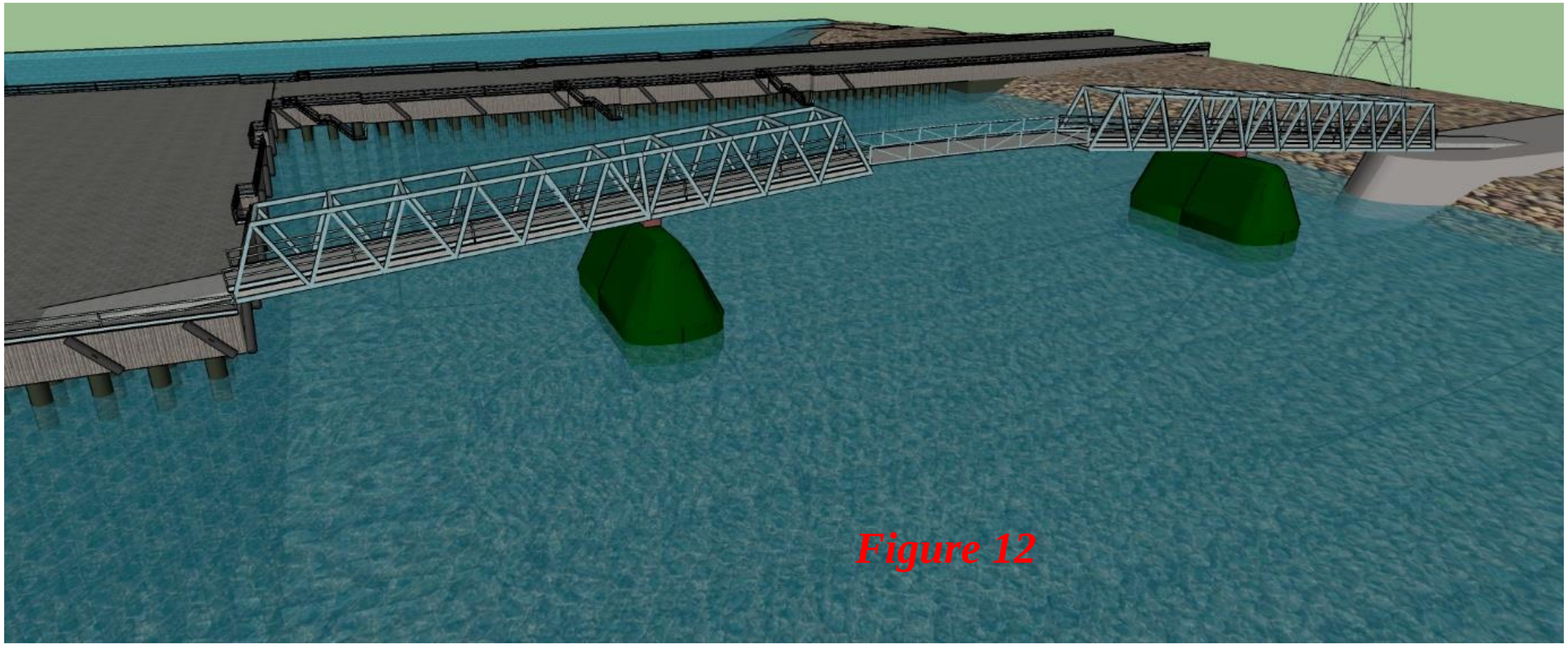


Figure 12

Though the question asks candidates to propose two solutions for a temporary bridge structure, truss superstructure were inevitable. To make them fully distinct from each other, it was essential to propose two truss bridge superstructures whose supporting arrangements are significantly different from each other so that the load path is different.

Solution 2

To be a complete distinct as well a temporary solution - one half of Tokyo Gate Bridge with suspended span can easily be a discarded but feasible solution. The length of the suspended span to be decided based on its reaction to the existing jetty. Precast concrete deck may be used on top of the under slung truss for the approach span to balance some permanent load and avoid any possible uplift at the end abutment when there isn't any live load. Although both the proposed solutions are based on cantilever bridge concept but the load path and structural configuration of both the solutions are totally different in spite of the same material being used. Figure 13 and followed by other figures of three dimensional representations are self- sufficient to demonstrate its appropriateness for this particular problem.

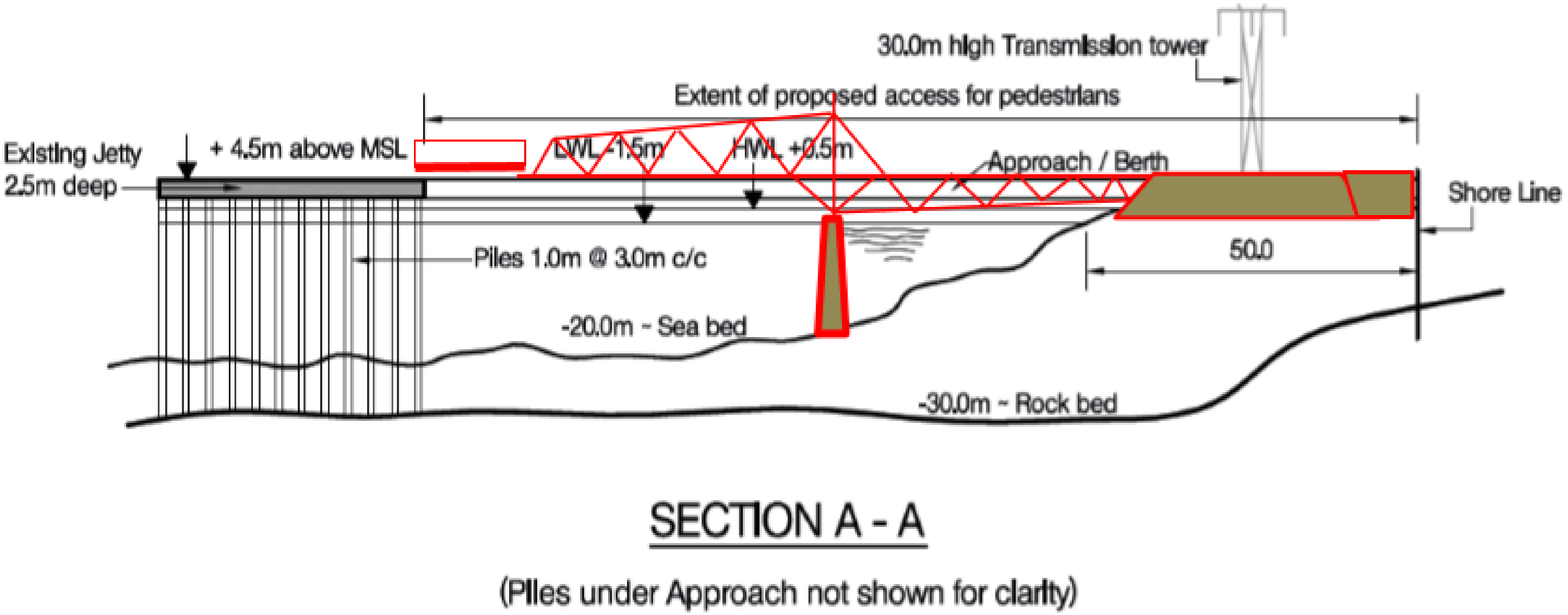


Figure 13 Long sectional view of the proposed solution 2

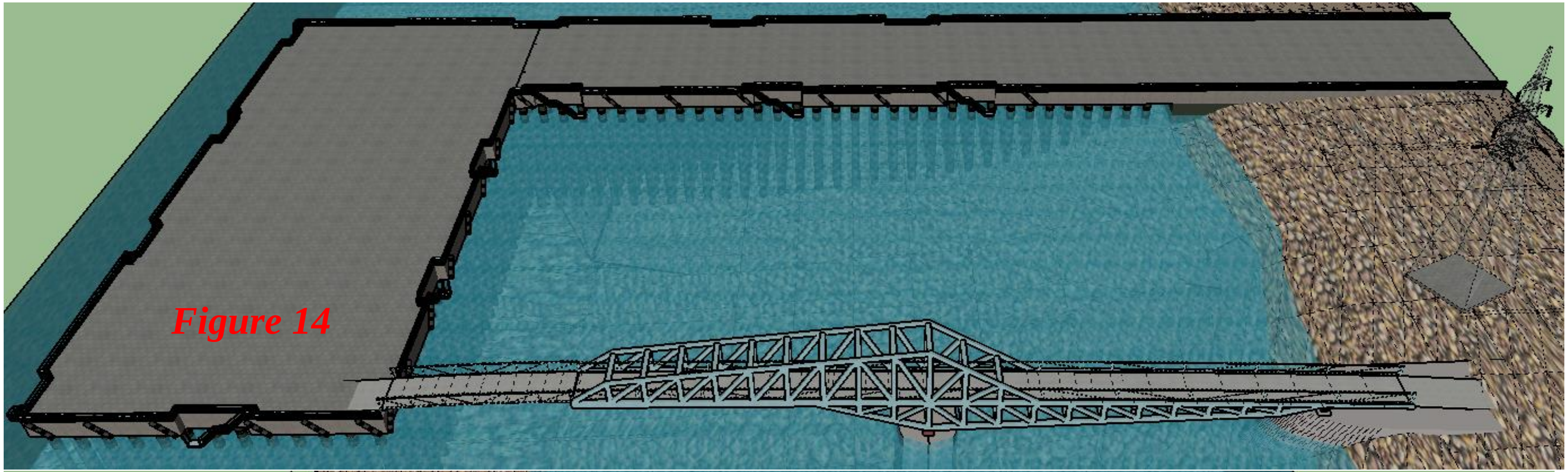


Figure 14

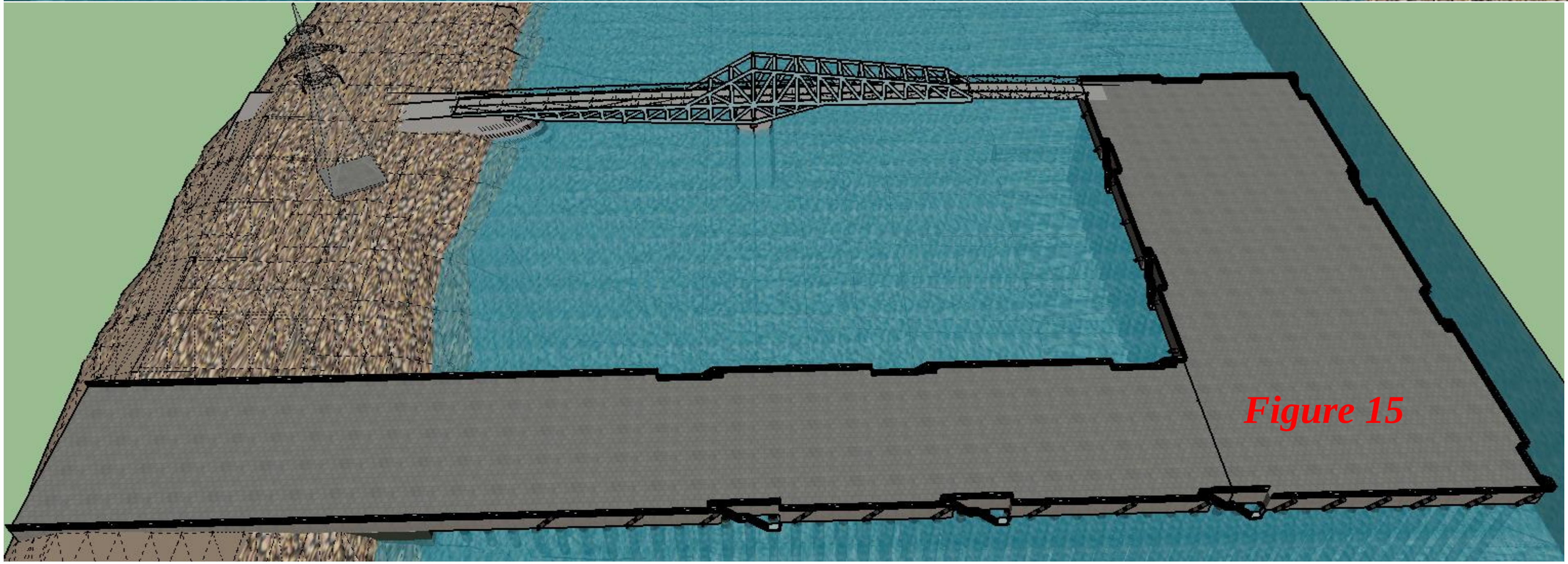


Figure 15

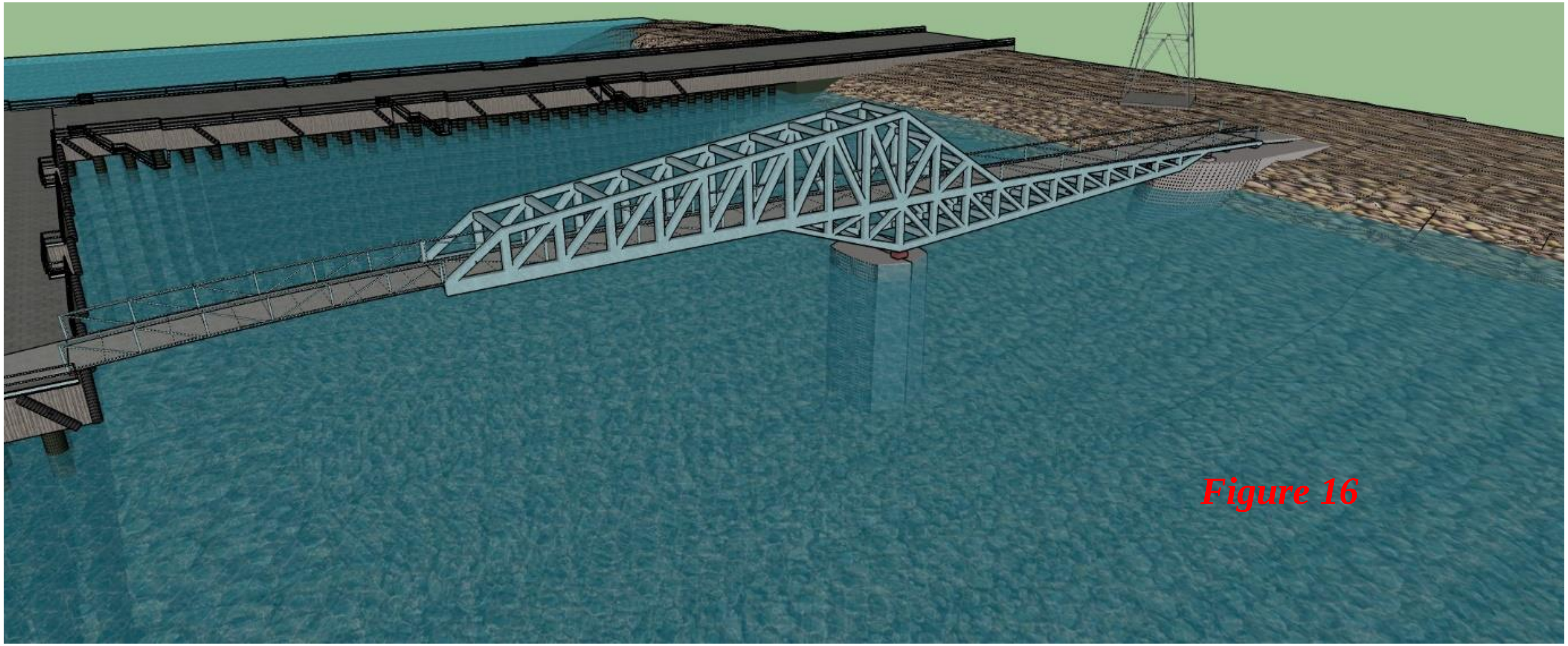


Figure 16

Comparison of two options:

Looking at the two proposals it is obvious that the first solution is much more appropriate to the problem for many reasons.

For Example: Purely temporary structure, least construction period and disruption to the users, much more economical, and many more.

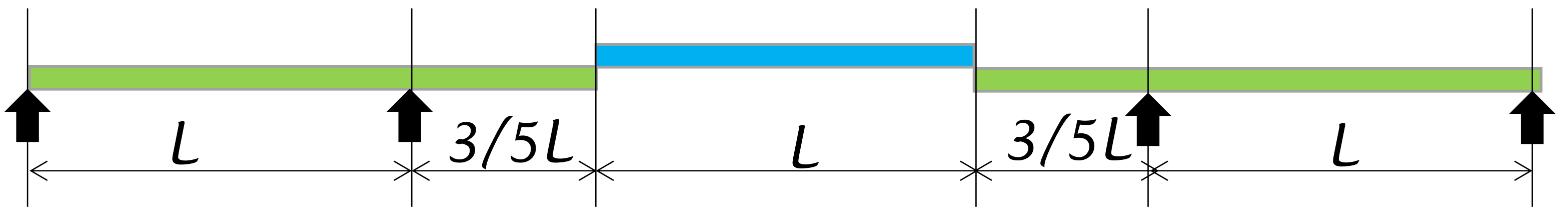
Letter writing:

Controlling support reactions to the given value itself is one of the major challenges for this question. Unless span and structural arrangements are appropriately proposed like the above two solutions it is impossible to meet the given criterion. Therefore it is inevitable to come up with an arrangement which will comply with allowable reaction forces. For the chosen solution it is essential to establish what could be the reactions on the existing Jetty with different patterns of live loading. As per the question, the restriction is on vertical positive reaction, but not on the negative reaction. Letter criterion is also in the same line, hence should be dealt accordingly.

Calculation:

First aim of this part should be to demonstrate the vertical reaction on the existing Jetty

4m wide 5kN/m² LL => 20kN/m. Considering, a conservative approach all other possible vertical loads add up to another 20kN/m allows maximum span of 25m simply supported. For any overhang superstructure for a cantilever bridge arrangement as considered, the reaction at the support on top of the existing jetty can never reach 500kN. In fact an Influence line diagram for the end support reaction will confirm that.



The main trusses at either end will have bottom cord in compression whereas in the top cord of the suspended span. The compression force in them can easily be worked out from the BMD of the above idealised single line beam model and designed accordingly. Use of RHS could easily be adopted.

Drawings

Further improvement in figure 7 and 8 and adding few cross sections of the bridge superstructures could be sufficient as general arrangement drawing for the chosen solution.

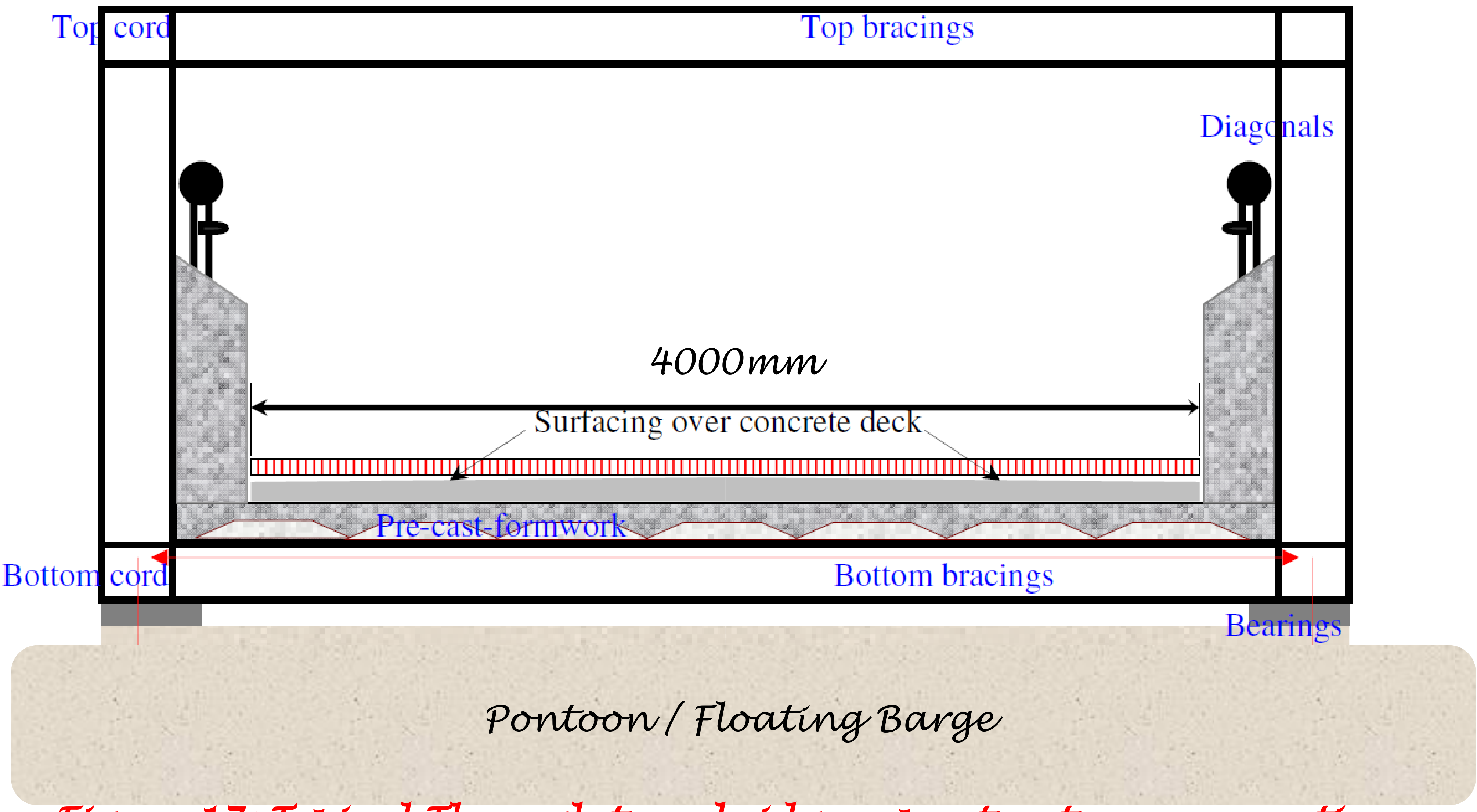


Figure 17: Typical Through truss bridge superstructure cross section

Method of Statement:

For the chosen solution, construction activity at site is negligible. Other than the construction of approach embankment there is hardly any construction activity left for this. However fabrication, transportation and erection of truss bridge superstructure especially on top of pontoon or floating barge should be highly important aspect of this method of statement. Hence the Bar chart on construction programme must be prepared with extra amount of care.