IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684, p-ISSN: 2320-334X.
PP 01-13
www.iosrjournals.org

Common Problems in Bridges on Baddi-Nalagarh-Swarghat Road

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Abstract: *Though bridges generally have a design life of 75-100 years, there have been incidences where strengthening or rehabilitation of the bridges is required before their designed life span. The reasons may be many but in the case of Balad bridge, which is located on the National Highway no.21A near Baddi (Himachal Pradesh), the rehabilitation of the bridge was required due to deep scouring and lowering of the bed at one of the pier location. As the bridge was designed for the maximum anticipated discharge and corresponding scour depth such a deep scouring was never expected. Such an unexpected deep scouring forced to explore in detail any other possible reasons for the scouring. After gathering the information from the local people regarding similar problems in nearby other bridges, it appeared that there may be other factors associated with the problem and this necessitated the detailed investigations not only for the Balad bridge but also for other nearby bridges. Detailed investigations were therefore done to identify the root causes of the problem and suggest the rehabilitation measures accordingly. The investigations and findings along with the methodology used for the rehabilitation and proposed bed protection works for the Balad bridge have been discussed and presented in the paper.*

Keywords: *Bed protection, foundation settlement, grouting below foundation, mining, scouring*

I. INTRODUCTION

The Balad bridge which is located at km17/561 on NH21A, Himachal Pradesh was constructed in the year 1998. The total length of the bridge was 282.65m which consisted of 29 spans (9.565m+27@9.76m+9.565m) of simply supported solid slab type superstructure resting over the wall type piers and isolated footings (Photo 1, Fig.1 & 2).

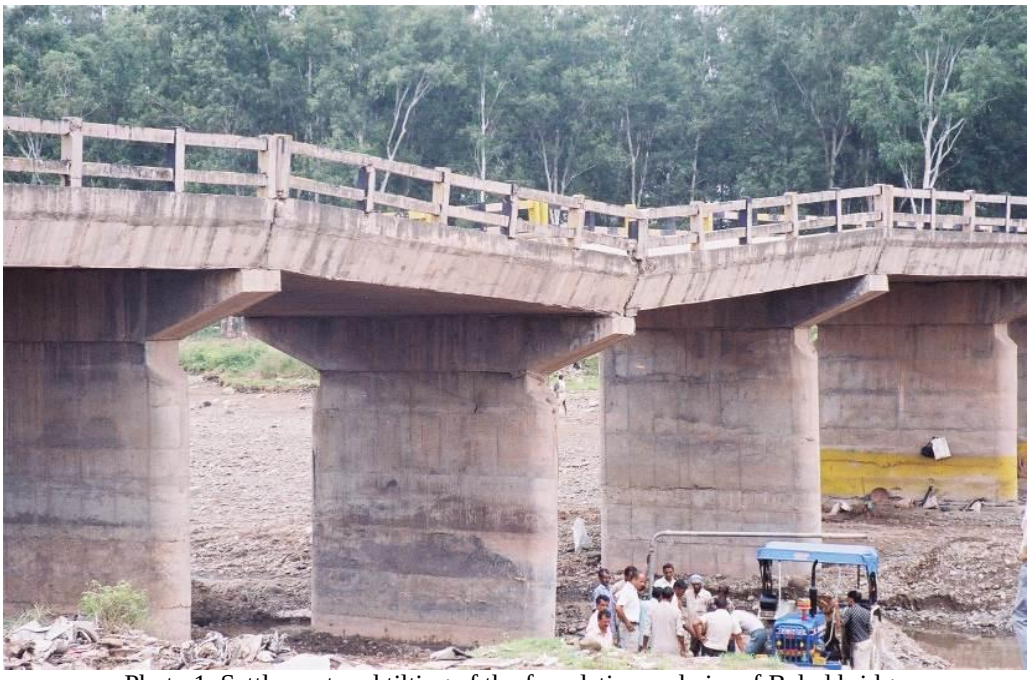

Photo.1. Settlement and tilting of the foundation and pier of Balad bridge

Photo.2. Close view of the settled pier at deck level

Total width and thickness of deck slab was 8450mm and 720mm respectively to accommodate the carriageway width of 7500mm (Fig.2). Width and thickness of wall type pier was 5200mm and 700mm respectively which was supported over 5000mm wide x 7500mm long x 750mm thick open foundation (Fig.1 & 2). The formation level and founding level of the bridge of was +100.50m and +92.00m respectively. The original bed level (at the time of construction of bridge) was +95.93m i.e. about 3.5-4m above the founding level. Though the bridge was serving to the traffic without any sign of distress, during one of the high floods in 2007, one of the piers & supporting foundation (sixth from one end) settled by about 750mm and tilted by 1-2 degree (Photo 1, 2 & Fig.1). As the bridge was designed for maximum anticipated discharge of 2024 m^3/sec & corresponding scour depth and because similar problems occurred in last 5-10 years in the nearby old and new bridges, detailed investigations were done to know any other possible reasons of scouring. These have been discussed and presented below in the paper along with the findings, methodologies, proposed protection works and actual site photographs.

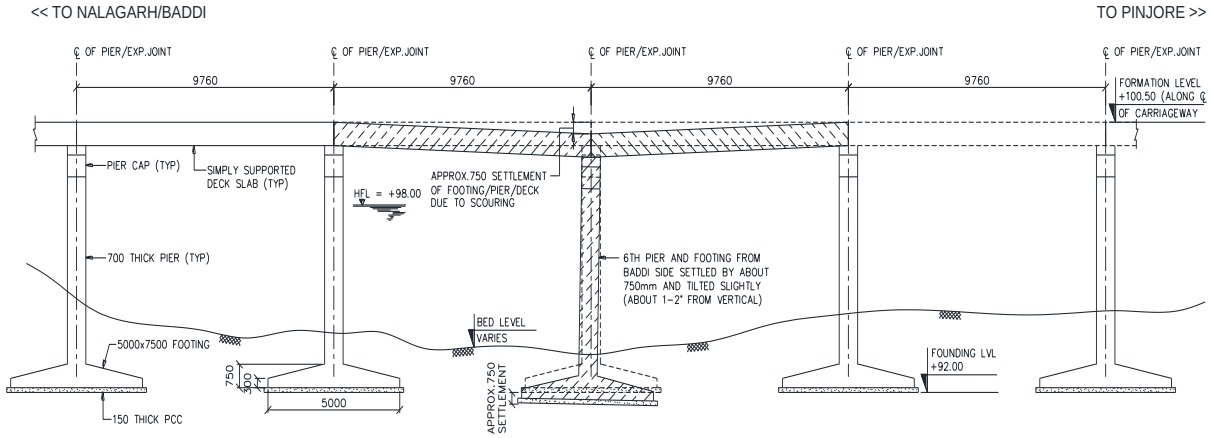

Fig.1. Typical elevation of Balad bridge adjacent to settled pier and foundation

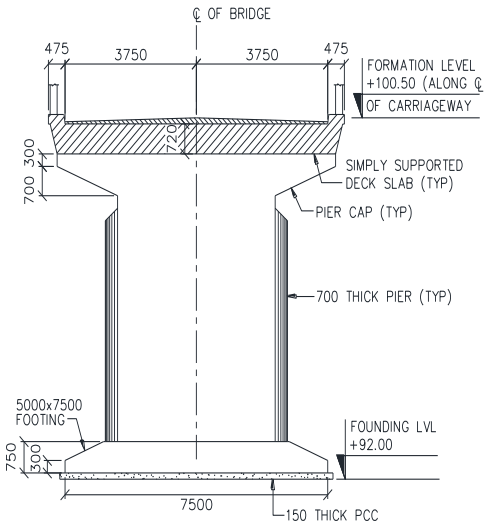

Fig.2. Typical cross-section of the Balad bridge

II. INVESTIGATIONS AND FINDINGS

In order to have full understanding of the problem, Balad bridge and seven other nearby bridges were inspected carefully before going for the rehabilitation of the Balad bridge. Out of the seven bridges, one bridge was located across the same river at a distance of about 2km on the upstream side of the Balad bridge and other six bridges on the same national highway within a distance of about 40km. The investigations and findings along with the site photographs are presented below:

2.1. Balad bridge under consideration at km17/561 on NH21A

In addition to the deep scouring and sunken/tilted pier & foundation (Photo 1 & 2, Fig.1), the following were noticed at the bridge site:

- No bed protection works as the foundations were taken below the calculated scour level.
- Bed level was found almost same on the upstream and downstream sides of the bridge.
- Presence of densely spaced trees just on the upstream side of the bridge (in about 40m length of the bridge, Photo 3).
- Mining taking place adjacent to the bridge site (Photo 4).
- Presence of wide crack/gap at base of the one of the piers (Photo 5).

Photo.3. Presence of densely spaced trees on the upstream side

Photo.4. Mining taking place adjacent to the bridge site

Photo.5. Wide crack at the base of one of the piers

2.2 Bridge across same river on upstream side

The main findings at the bridge site were deep scouring on the downstream side, failure of the bed protection works & launching apron and no scouring on the upstream side (Photo 6 & 7) of the bridge. It was important to note that the rigid flooring below the bridge remained intact due to the presence of a RCC retaining wall provided as curtain wall and probably having foundation at considerably lower depth (Photo 6).

Photo.6. D/S side of bridge across same river

Photo.7. U/S side of bridge across same river

2.3 Bridges near km15, km24, km44, km49, km52 and km55 on NH21A

In the other existing bridges on the same national highway i.e. NH21A, deep scouring (about 5-8m) was noticed on the downstream side of the bridge. No scouring was noticed on the upstream side of these bridges. The floor protection work of bridges near km15, km24 & km44 appeared to be designed with due attention paid to actual the site conditions and was generally found intact in position (Photo 8 to 12). At the location of bridges near km49, km52 & km55, the floor protection work was found failed or at the verge of failure (Photo 13 to 18).

Photo.8. D/S side of bridge near km15 of NH21A

Photo.9. D/S side of bridge near km24 of NH21A

Photo.10. U/S side of bridge near km24 of NH21A

Photo.11. D/S side of bridge near km44 of NH21A

Photo.12. U/S side of bridge near km44 of NH21A

2.4 Presence of two adjoining states near the bridge sites:

During the investigations, it was found that the bridges were located at the junction of two different states of the country i.e. Himachal Pradesh on the upstream side and Punjab on the downstream side. The Himachal Pradesh is primarily a hilly region where there are uncertainties associated with the rainfall and possibility of cloud bursts.

Photo.13. D/S side of bridge near km49 of NH21A

Photo.14. U/S side of bridge near km49 of NH21A

Photo.15. D/S side of bridge near km52 of NH21A

Photo.16. U/S side of bridge near km52 of NH21A

Photo.17. D/S side of bridge near km55 of NH21A

Photo.18. U/S side of bridge near km55 of NH21A

2.5 Presence of bouldery beds and mining near the bridge sites

Due the presence of boudery beds at all the bridge sites, mining of the granular bed materials could be seen near the bridge sites. Though the efforts were made by the concerned authorities to control the mining, the same could probably not be achieved due to presence of two different states on either side of the bridges.

III. REASONS FOR UNEXPECTED SCOURING

Based on the investigations done, the following reasons could be identified for the deep scouring at the Balad bridge site:

- The prime reason for the scouring appeared to be mining near the bridge sites. As seen above, at the location of other nearby bridges, where protections works existed at the bridge sites, a sudden drop of the bed levels was noticed on the downstream side just after the protection works. On the upstream side of these bridge there were not even the nominal scouring noticed. This was because of the reason that protection works acted as a barrier to hold the bed on the upstream side. At the location of Balad bridge, where no protection work was found, a uniform lowering of the bed was noticed with almost same bed levels on the upstream and downstream sides of the bridge.
- The presence of densely spaced trees just on the upstream side of the Balad bridge also contributed towards the deep scouring as they restricted the available linear waterway resulting into increased discharge per unit length of the bridge and hence into the increased scour depth.
- The discharge passing through the bridge probably exceeded the maximum anticipated discharge due to cloud burst in the hilly region on the upstream side of the bridge.

IV. METHODOLOGY OF REHABILITATION

The various steps involved towards the rehabilitation of the bridge were:

- Though the rehabilitation works started after the monsoon when the river bed was almost dry, the first step was to make necessary arrangements to divert any possible flow towards the pier/foundation under consideration due to the uncertainty of rain in the nearby hilly area.
- The foundation bed was although dry, the water table was almost at the ground level. Having adequate number of high capacity water pumps was therefore essential to have uninterrupted rehabilitation works below ground level.
- The next step involved was fabricating and erecting steel portals on each side of the sunken pier/foundation to support and hence release the superstructure loads over the piers/foundations (Photo 19). The portal foundations were placed away from the existing bridge foundation with a clear gap of 2000mm in such a way that difference in the founding levels of bridge and portal foundations is not more than 1000mm i.e. half the clear distance between the two.
- Jacks were placed over the portals (four number jacks over each portal) to lift the slabs and hence transfer the superstructure loads over the steel portals. Intermediate packing were placed between the jacks to have additional supports below the deck slab.
- Excavations were then made very carefully till founding level of bridge foundation to examine and rehabilitate the same.

Photo.19. Erection of steel portals on either side of pier of Balad bridge

- As the settlement was due to scouring below the founding level, there was possibility of sub-surface soil not fully in contact with foundations and hence voids below the founding level. The next step therefore was to drill 25mm diameter holes through the foundation and grout any such voids using free flowing, high early strength, non-shrink cement grout. The grouting was done in the presence of authorized representative of the grout supplier who ensured the effectiveness of the grouting and certified the quality of work. Here it would be worth mentioning that about 1.75m^{3}grout was consumed in this process which shows considerably large size/number of voids below the foundation.
- As there was tilting of the pier/foundation, foundation was therefore extended (all around by 750mm) and shear key formed in the foundation to prevent any possible sliding in the future. The extension of the foundation was done using 12mm/16mm diameter (rebar) chemical fasteners (Fg.3 & 4).

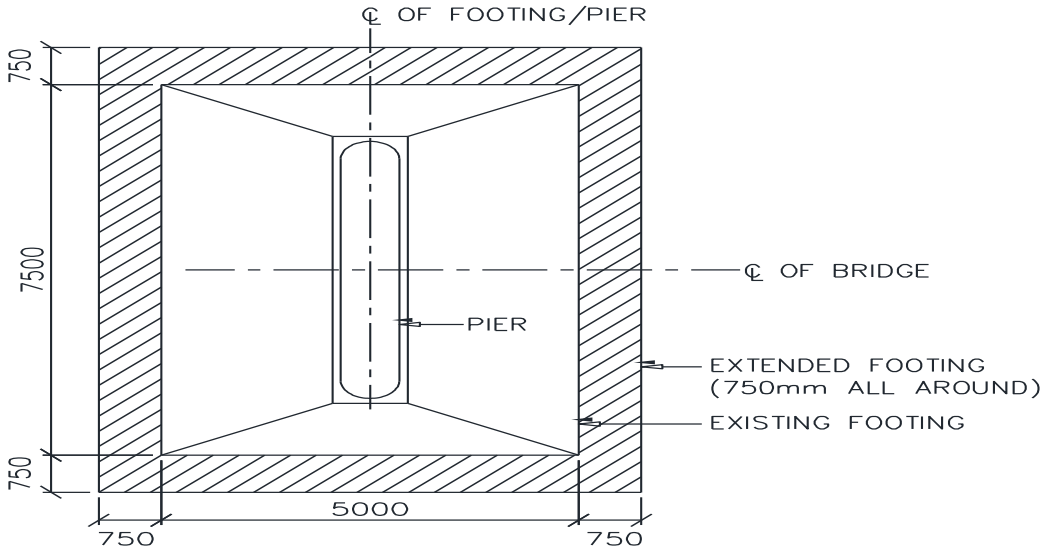

Fig.3.Extension of foundation

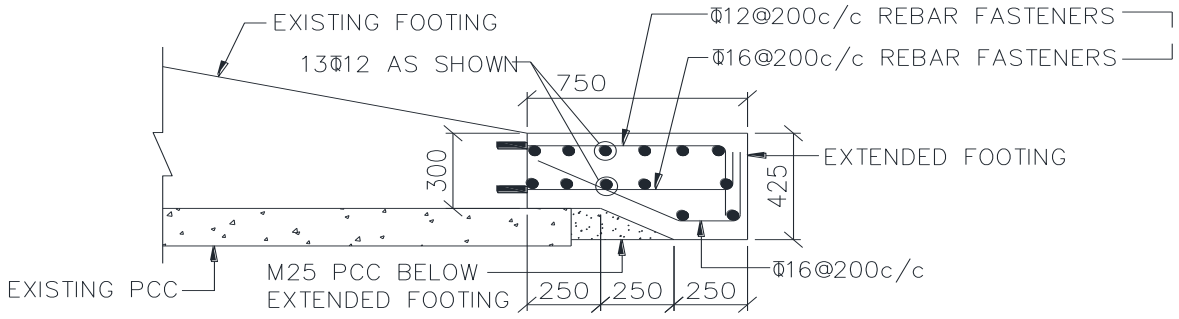

Fig.4. Extension of foundation & formation of shear key

- Once the foundation was extended all around, the same was load tested to ensure the effectiveness of the grouting below founding level. A load of 250t was placed uniformly over the foundation which was about 25% more than the expected load over the foundation in future. Before applying the loads, four number of dial gauges (one near each corner) were placed over the foundation to measure the settlement of the foundation. No settlement at all these corners ensured the effectiveness of the grouting below the founding level.
- After load testing the foundation, traditional method of concrete jacketing was used for pier and pier cap to make the tilted surface vertical (Photo 20 and Fig.5 to 8) and raise the pier cap level. This thickness of pier jacketing varied along the height of the pier (Fig.6) due to tilting of the pier.

- While going for concrete jacketing, attention was paid to have proper joint between the old and new concrete without having any separation between the two. To achieve this, formation of proper construction joint was assured through hacking the old concrete surface by mechanical chisel and using chemical fasteners as shear connectors (Photo 20 and Fig.5 to 8). Use of shrinkage compensating admixture was made to avoid shrinkage of the new concrete.
- The deck slab was finally lowered over the raised and thickened pier cap once the concrete achieved the desired strength (Photo 21).
- The wide crack/gap at the base of the pier was filled with epoxy grouting before allowing the traffic over the deck slab.
- After rehabilitation of the sunken pier and foundation, the next step was to have floor protection works to prevent any further scouring in the future. Typical section of floor protection works proposed for the Balad bridge is shown in Fig.9. The basic differences between the proposed floor protection works as compared to the traditional protection works were: increased thickness and length of protection works on the downstream side (about 15m against 5m), well graded boulder filling below rigid flooring, plum concrete below PCC steps on downstream side, launching apron & curtain wall designed for critical discharge & scour depths considering reduced linear water way (80%), providing 100mm thick rich concrete at the top with nominal reinforcement to prevent any possible damage of the top surface due impact from rolling boulders etc. The bed level on the upstream side was raised with the help of boulders filled in wire crates.

Photo.20. Concrete jacketing of pier and pier cap

- As the traffic was stopped during the process of rehabilitation, wearing coat and expansion joints were also replaced simultaneously with the rehabilitation works.
- As there are no limits of scouring due to mining, it was recommended to take serious steps to stop the mining near the bridge sites and have a dedicated team for close monitoring of the same.

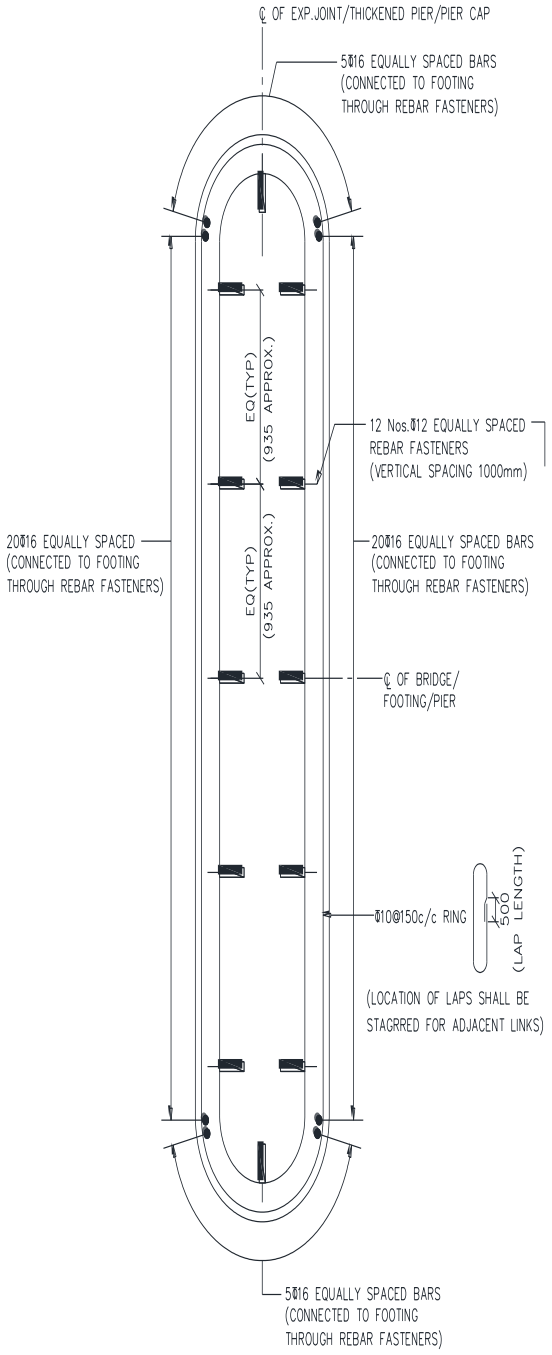

Fig.5. Typical plan of pier jacketing

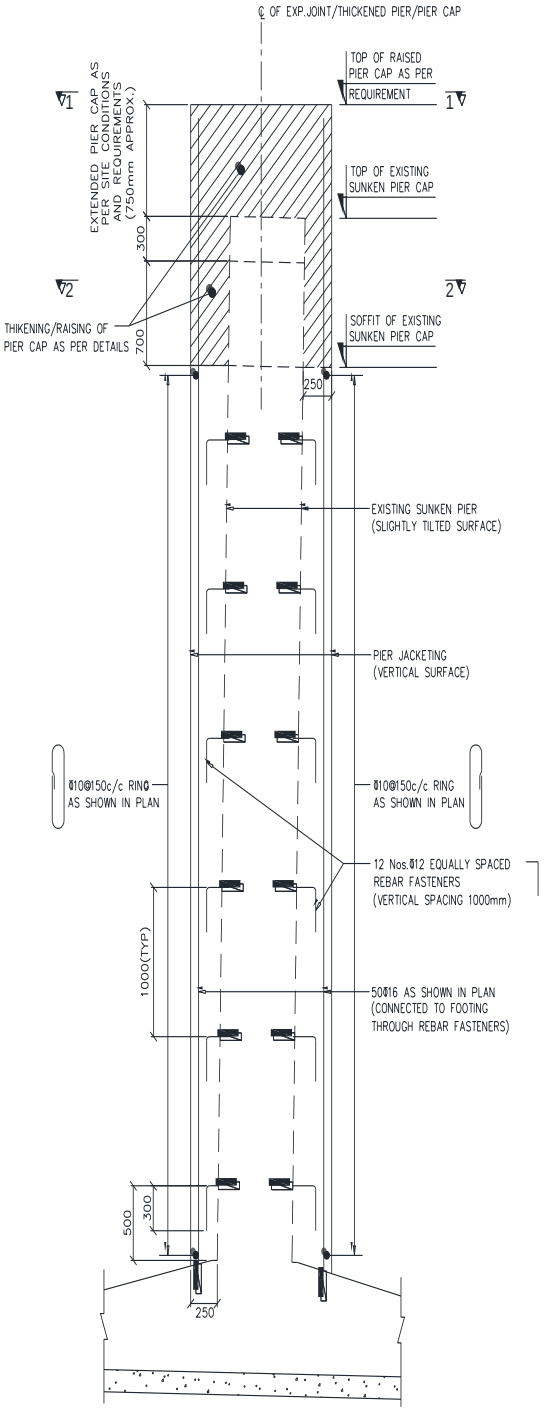

Fig.6. Typical section of pier jacketing

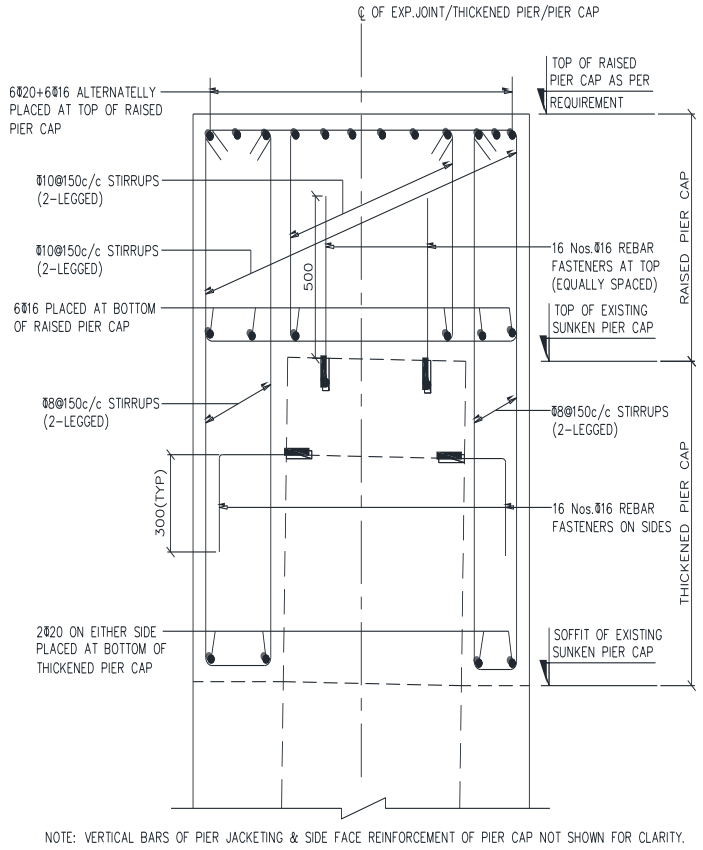

Fig.7. Typical section showing pier cap jacketing

Photo.21. Balad bridge after completion of the rehabilitation works

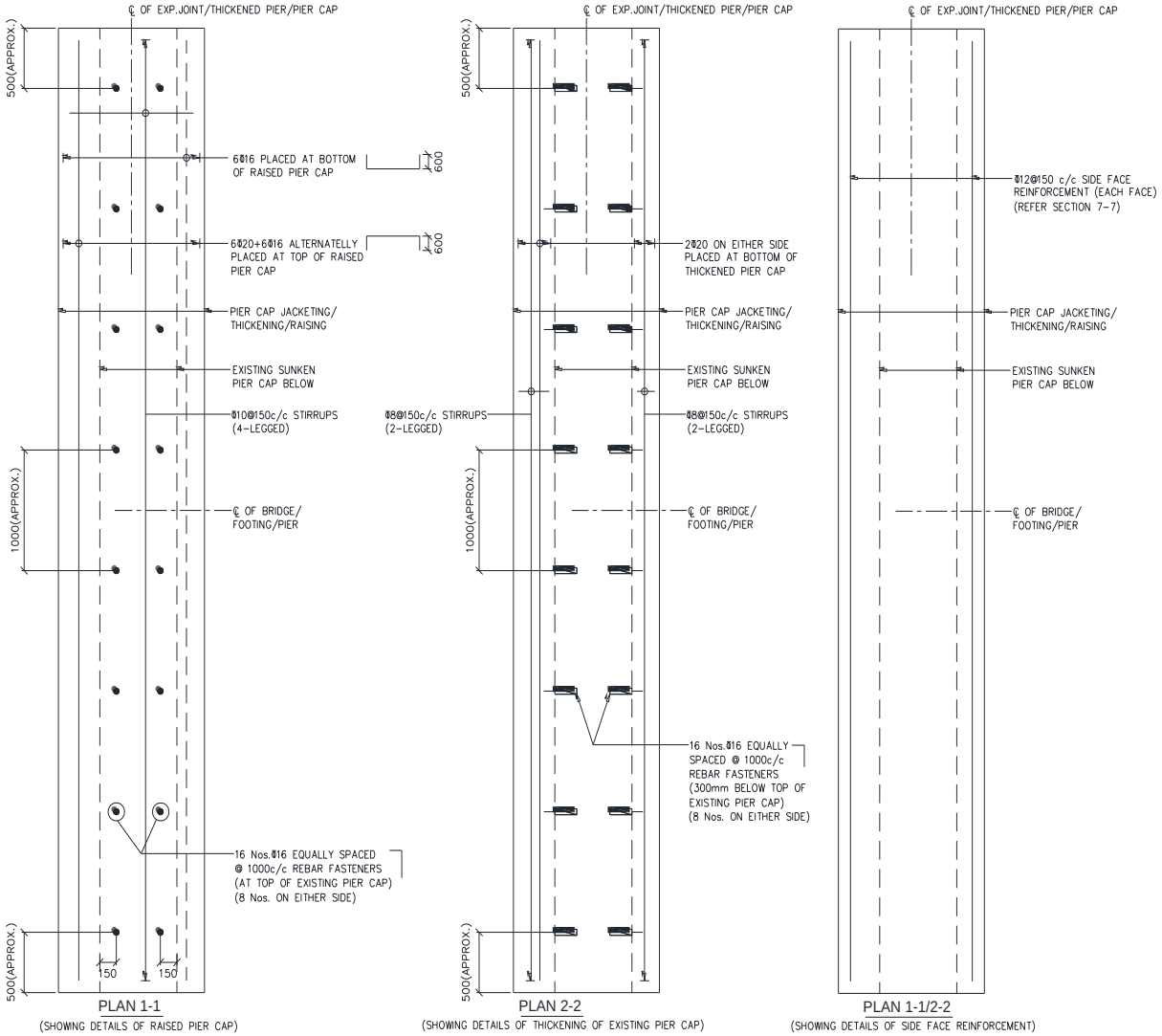

Fig.8. Typical plans of pier cap jacketing/raising

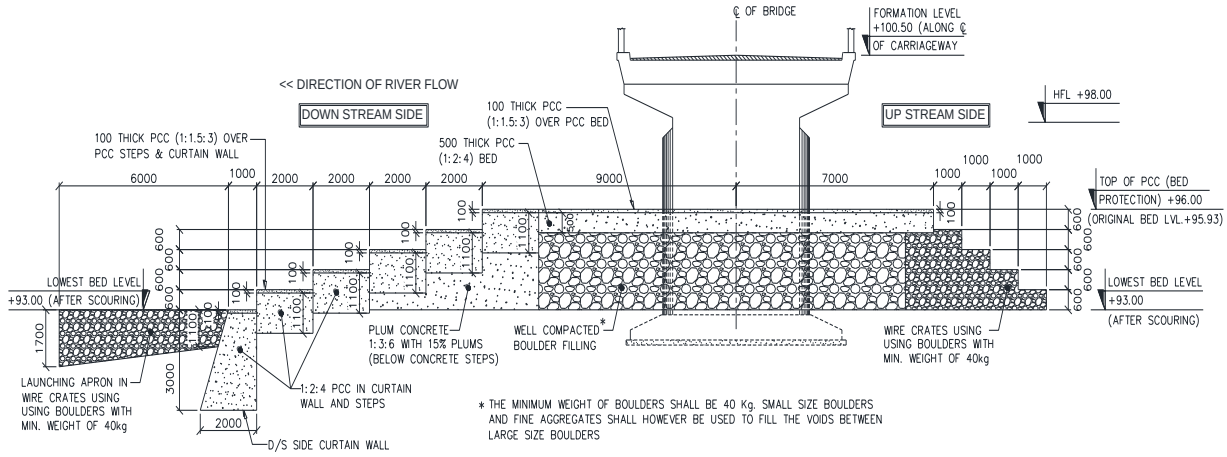

Fig.9. Typical section of floor protection works

V. CONCLUSIONS

The scouring at any bridge site is generally calculated based on the maximum anticipated discharge per unit length of the bridge (based on the rainfall data) and silt factor of the bed materials. Though it may be a correct practice, there may be sometimes other factors also which may result into the increased discharge and scour depths. As it can be seen from the discussions above, sometimes the discharge may be increased by presence of any obstruction which may restrict the area of flow or divert the flow towards any specific part of the bridge. Sometime, the flow itself may be concentrated in any specific length of the bridge i.e. flow of a meandering river. It is therefore necessary to take reduced length of linear waterway into account in such cases to get the possible increased discharge (and hence the increased scour depth) per unit length of the bridge. In the present days of large scale infrastructural developments, mining seems to be a very critical aspect which lower downs the entire bed bodily. Necessary checks are required to control the mining of the river beds which may otherwise result into the serious consequences as seen above. In general, the hydraulics of any bridge should be taken as one of the key factors while deciding the bridge type and lengths. Bridge sites should be inspected at least once before the monsoon and once after the monsoon to ensure the healthy condition of the bridges while serving to the traffic.