BRIDGE PIER SCOUR IN BOULDERY BED - A CASE STUDY

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INTRODUCTION

1. Scour depth estimation is a challenging assignment for bridge engineers, specially when there are no exact formulae available. Due to uneven and haphazard bed stratification, behaviour of bed material in all plane is difficult to assimilate for hydrological requirement. There are cases when scour profile of the river is under estimated or over estimated which presented its effects in all direction, subsequent to failure of structure due to excessive scour. In fact most of the bridge sites on bouldery rivers need observation for hydrological behaviour after construction. Behaviour of scour in alluvial soil and bouldery bed posses different characteristic due to available particle size in respective beds. The sediment carrying capacity of any river depends upon its velocity of water and pattern of flow which leads to gain and dissipation of its energy during flow. With higher velocity, higher size of sediment will be picked up and shifted to down stream.

SCOUR AN OVERVIEW

2. The design and construction of foundation of bridges is linked to realistic assessment of scour depth, both global and local. The foundations are generally designed to withstand the loads and moments transmitted by other components of the bridge. They are also designed to have a minimum grip length below deepest scour level, which is usually calculated based on various parameters. The best way of assessing the depth of scour in a river is to observe the same during the highest flood period. Unfortunately with the methods available it has not been possible to approach the intended pier location during high floods and observe deepest scour. Thus the Design Engineer generally rely on the use of formulae for calculation of scour depth. While the various available formulae have been known to give reasonable results in respect of sandy strata, the results have been erratic in other cases. Various formulae have been originally evolved based on the study and observation of particular types of strata, soil classification and water flow regime. Over the years there has been a increasing tendency to apply the same formulae for other types of harder strata including conglomerates, large boulders and soft rock. This has resulted in skewing of results and totally unrealistic scour value in extreme cases. While fortunately in India there has not been many cases of failure of foundations due to scour, a large number of bridges are required to have their foundations taken deeper than necessary depth due to the above referred approach. Because of this, the time overruns in many cases have been more than double with corresponding cost

overruns. In a number of well foundations, steinings have been damaged due to extensive blasting necessitating extensive repairs. In a few cases the wells had to be rejected because of extensive damages. The situation is acute while dealing with conglomerate strata, particularly encountered in the rivers flowing through the foothills of Himalayas. The substrata may consist of boulders, shingle, gravel etc. either in loose form or cemented by a matrix, which may be calcareous in nature. Such heterogeneous combination of materials with individual particle size upto two or three meters does not easily lead itself to any logical assessment or interpretation of scour using available tools. Substantial reliance needs to be placed on observation of behavior of structures built in the past coupled with reasoned judgement of the decision makers in each individual case. Similar situations may also arise in other parts. Conglomerate strata are known to have been encountered in the plains in various locations leading to dilemma in the matter of proper assessment of scour.At the outfall end of the river, the tidal effect needs to be considered. Here fine suspended sediment deposits are common. The deposition process as well as scour if any is also affected by changes in the density of water due to salinity. If these aspects are not considered, scour depth is generally assessed on conservative basis, resulting in wasteful design. In such cases, the assessment of scour needs entirely different perspective. The South Indian peninsula is geologically more stable. The bed and banks of the river are generally highly resistant to erosion. The tendency for a gradation or degradation is insignificant with such a diverse scenario concerning the characteristics of rivers flowing through the different parts of the country, it is no wonder that diverse problems are being faced by the Engineers.

BRIDGE PIER SCOUR

3. Scour is the erosive action of water in excavation and carrying away material from the channel bed. An obstruction such as a bridge pier causes interference in the flow of stream, which changes the flow pattern at obstruction. This is commonly termed as local scour. The flow around the bridge pier is complex. As the stream flow approaches the pier, adverse gradient caused by the pier, drives a portion of the approach flow downwards the just ahead of the pier. **A change in the downward flow, velocity has a direct effect on the rate of scour and thus on the depth of scour hole**.

3.1 **Local Scour** : Local scour is the local lowering of the bed in the near vicinity of a hydraulic structure such as bridge pier, spur, guide bund etc. Bridge pier locally distorts the flow pattern by increasing local velocities or by inducing whirls, eddies and vortices etc. which results in increased sediment transporting capacity of the stream. The bed particles are lifted up and carried away with the current. This process continues till the normal transporting capacity of the channel is restored. This stage of dynamic equilibrium may also be achieved when the armouring of the bed reaches a limit. Where upper particles of the bed can no more be dislodged by the stream action, further development of scour ceases. The finally attained scour depth is known as maximum or limiting scour. The phenomena of local scour is very complex due to large variations in the field conditions, besides numerous variables describing the flow, fluid and sediment characteristics, the channel and the pier geometry etc., which have their own effects on this phenomena

BED MATERIAL CHARACTERISTIC OF BOULDERY BED AND INTER RELATED FACTOR FOR SCOUR

4 The size of the channel material is important at low velocity, the scour depth is less for a bigger size boulder since it is difficult for slow moving water to pick up and carry the larger size. This may eventually result in an armoured bed within the scour hole, slowing or stopping of erosion process until higher velocity scours the armored layer. Soil strata generally available in bouldery bed is indicated in Fig1 &2

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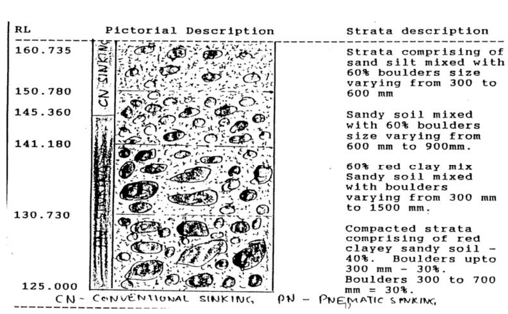

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Figure 1 & 2 soil strata in bouldery bed

various interrelated important parameters, which affect the type and depth of foundation are type of strata, design discharge, silt factor and formulae for scour depth calculations are discussed as under:-

(a) **Type of Strata** : Erodible/nonerodable beds leads to adopting foundation based on scour/non scour criteria and also an entirely different philosophy in planning and designing of bridge foundation. The aspects of weathered/fissured rocks, further add to the uncertainty in branching out to the two approaches described above. In addition to the type of strata encountered during the actual execution is invariably at variance from the one catered during the planning process. Thus owing to partially/entirely different strata at the execution stage at time necessitates in redoing the entire Sub Soil Investigation (SSI), and/or also adopting an entirely different type of foundation on the other extreme besides causing exceptional delay in order to ensure safety of structure. On the moderate site, it tantamounts to raising/lowering the foundations, the effect of which however becomes quite substantial incase there is a significant raising/lowering of the founding levels.

(b) **Design Discharge** : The design discharge for the foundation design is done based on various empirical/rational formulae. The applicability of these formulae is best suited for rivers flowing in the plains. It is seen from experience that these empirical relations are not entirely dependable/reliable in estimation of discharge for hilly regions of the Himalayas and NorthEastern Region.

(c) **Silt Factor** : Silt factor plays a significant role in finalising the scour depth and also the founding levels for the foundation of the bridge structures. Due to lack of adequate borehole data and also various uncertainties associated, the bridge engineers are confronted with a difficult job of choosing an appropriate value of silt factor. This has importance because IRC Code caters for a maximum silt factor of upto 2.42 (Applicable for heavy sand) only. Though IS 7784(Pt-I) gives a increase beyond the range of 2.42 is in discrete jumps of 4.75, 9, 12, 15 & 24 rather than a continuous spectra. However, in absence/identification of correct silt factor for boulderly bed there is a problem where in the selection of this important parameter is left to the judgement, discretion and experience of the designer. Also result obtained by the above formulae for bouldery bed are erratic and impracticable. In addition to the various unknown parameters and uncertainties mentioned above the problem assumes a bigger dimension because of lack of appropriate formulae for finalising the scour depths. Various reasons connected with it are enumerated as under :-

(i) The type of strata/bed ie erodiblity or nonerodibility has a direct impact on deciding whether to finalise a foundation based on scour/non scour criteria, and also to decide whether an open foundation would suffice, or a deep foundation would have to be catered for. It would be in order to state that this significant difference/in adopting different philosophies and depth of two types of foundations have direct impact on the economic of the structure.

(ii) Scour depth calculation significantly depends on the design discharge to be adopted for foundation design. Since the formulae for design discharge are by themselves not applicable, the reliability of scour depth calculations is thus questionable.

(iii) IRC 78 : 2000 also clearly states that these formulae are not applicable to rivers with flashy nature.

(iv) A close scrutiny of the formulae indicates that the uncertainties associated with the selection of strata, design discharge and silt factor as pointed out above gets further substantiated for various anomalies in the adoption of these formulae for various reasons stated in above referred paragraph.

(v) Structures designed for scour consideration on the basis of above formulae on boulder bed had led to unnecessary time and cost over the particular job.

CASE STUDY

5 Ranga river is basically a tributary of the Brahmaputra river. Ranga-I bridge is located on Kimin-Ziro road in Arunachal Pradesh. Bridge was made during 1968 on bouldery strata. The salient features of the bridge are as under (fig 3):-

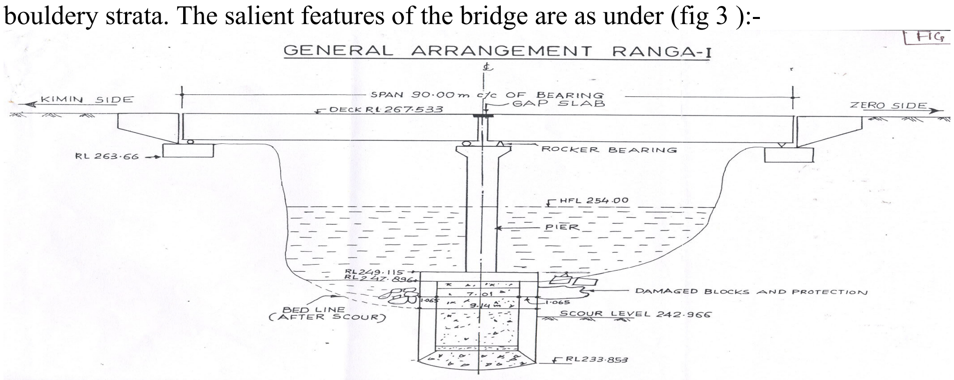

Figure 3 : General Arrangement drawing.(a) Length : 90m (2 Span)

(b) Deck Level : RL 267.53 m
(c) HFL : RL 254.00 m
(d) LWL: RL 250.00 m
(e) LBL : RL 249.115 m
(f) Foundation Level : RL 233.853 m
(g) Type of foundation : Well
(h) Dia of well : 9.14 m
(i) Soil strata : Soil mixed with Boulders
(j) Year of construction : 1968

Well foundation construction planning was done as per codal provision. Based on the construction difficulties faced, the foundation level was reviewed and well was plugged at RL 233.853 m in bouldery packed strata. During construction, the advantage of changed properties of the soil strata was taken in view. Bridge was completed and opened for traffic during Feb 1968. Features of U/S and D/S plan of the bridge scheme and shown in.

OBSERVATION OF SCOUR

6 During Jun (1968) there was heavy flood with increased discharge about 1.6 times the designed discharge, affects the pattern of flow around the pier which was observed as oblique. This enhanced discharge caused heavy scour around the pier of central foundation and reoriented the flow on right channel only. Observations of scour was kept and bridge behaved well but from 1979 onward increased scour had been observed. Rehabilitation measures were taken after examination of the condition to arrest the scour. For this purpose concrete block were laid around the foundation as per practice in vogue. There had been instances when most of the concrete blocks made

around the pier were either washed away or dislocated due to water force. Scour remained with in the designed limit. .

To control the scour damage during past years PCC block were cast during the years 1981, 1984 and 1985. A few of these blocks got dislocated and later on all the blocks were interconnected. Under pining of the blocks was also done. In fact the more damage was noticed due to oblique flow hitting the pier at angle and on left bank there was very less flow. There is sharp turn on D/S leading to sudden change in flow pattern. Detailed examination of the problem was done during 2000 keeping in view the past scour and rehabilitation measurers taken so far. Following were observed (Fig.4) :-

(a) Flow in the channel is oblique and maximum flow is going through the right side of the span.
b) All the PCC blocks need to be made matching with the bed level in order to avoid the obstruction of flow and to avoid formation eddies.

Fig 4 Scour around pier

SOLUTION TO ARREST EXCESSIVE SCOUR

7 Based on the observations of scour in past years, following recommendations were made :-

(a) The river water be made to flow in the both the channel which is not happening at present as maximum discharge is going in the
right side channel. This requires dredging of the river to some extent for left side span to pass the atleast 30% to 40% of discharge.

(b) There is need of repelling type spur on U/S right side to ensure that further water flow stay to left channel equally.

(c) Temporary arrangement made by PCC blocks to arrest scour be made in such a manner that top of block should match with existing bed level so that unnecessary obstruction is not caused to the flow and further scour is arrested.

SCOUR REVIEW OF THE PIER

8 It has been observed that inspite of erratic flow pattern in the channel specially on U/S and the scour had been within limit and the bridge has behaved well so far. However it has been observed that in case of bouldery bed due to large size of particles in the river bed, more force of water is require to lift and carry the material to D/S.

Scour hole observed near the pier in sandy bed condition are entirely different than that of bouldery bed (Fig.12). To have a proper observation in future, the scour record of each bridge before and after monsoon need to be kept. Further result can be derived to correlate the scour with any key factor affecting hydraulic of river. Any damage to pier or excessive scour observed during the maintenance of the bridge should be attended to on priority. More stress to be given to have streamline/smooth flow under the bridge

RECOMMENDATIONS

9 (a) Scour depth in bouldery starta be recorded after construction of bridge as this is required to ensure the serviceability and soundness of the bridge for remaining designed life.

(b) Damages if any be recorded due to excessive scour and should be attended to on priority.

(c) Emperical relationship can be established based on the data collected in respect of bridges made on bouldery bed.

(d) Documentation of the scour data in bouldery bed can save lot of time and money in finalisation and construction of bridges.

(e) Scour record observation at each bridge site be taken judiciously as it will be helpful to optimization of cost of many bridges in future.

CONCLUSION

10 Scour around pier in case of bouldery bed is not erratic in all the cases. There is need to see the flow profile of the bridge in such a way so that water passes smoothly around the pier. This will lead to less scour only. Efforts can be made to keep regular observation so that preventive measures be taken if required without any delay to arrest the scour if any.

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