DISCUSSIONS ON THE PAPER
"SILT FACTOR FOR SCOUR CALCULATION AROUND BRIDGE FOUNDATION"

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Published in 'INDIAN HIGHWAYS', Vol.47, No. 10, Oct. 2019

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Author of the paper has recommended use of 'Silt Factor' method of scour calculation around bridge foundation with silt factor (K_{sf}= f) up to maximum value of 8 and he has strongly recommended it for use in bridge projects by Border Roads Organisation (BRO). Currently, IRC -78(2000) and IRC -5 (1998) recommend silt factor method of scour computation up to a maximum value of silt factor f=1.50 corresponding to a mean sediment size d_{50}=2mm for cohesion less soil. Silt factor method of scour calculation was introduced by IRC based on Lacey's(1929) regime theory as follows:

$$P=W=4.75\ Q^{0.5} \tag{1}$$

$$R=D_{sm}=0.475\ (Q/f)^{1/3} \tag{2}$$

Where, P is Lacey's regime perimeter which is almost equal to regime width (in wide stream only) in m, Q is the design flood discharge in m^3/sec, R is the regime depth in m unit and f is the silt factor given by the relation:

$$f=K_{sf}=1.76(d_{50})^{0.5} \tag{3}$$

where $d_{50}=d_m$=mean size of sediments.

When waterway under a bridge, W=P, it can be proved that

$$R=D_{sm}=1.34\ (D_b^2/K_{sf})^{1/3} \tag{4}$$

where, D_b=q=Q/W= discharge intensity in m^3/sec/m.

IRC recommends maximum scour depth at the nose of pier as 2R below design flood level. In other words, maximum scour depth below river bed is R. It is based on scour measurement by Inglis (1949) in piers in 17 railway bridges (CWPRS, 1944) - all of which were constructed on very fine and uniform alluvial soil (d_{50} varying from 0.17 to 0.37 mm). All the piers had well type foundation. There is no other field data in India to verify the above hypothesis based on which relevant IRC codes were framed.

After going through research study made in India (mostly in laboratory flumes) and data collected from both laboratory flumes as well as field data (collected in rivers abroad) and his own research study (Mazumder et al -2005,2014; Mzumder-2007,2009,2016) discusser concluded that the regime scoured depth (d_{sm}) equation may be adopted for finding depth of flow (general scour) above the mean bed, only when the river runs in fine (d_{50}<2mm) and uniform alluvial soil with low geometric standard deviation [σ_g= $(d_{84}/d_{16})^{0.5}$] less than 1.3.

For gravelly/bouldery soil (d_{50}>2mm) which has very high degree of non-uniformity (σ_g>1.3), Lacey's regime depth equations (2,3&4) are not at all applicable (Mazumder,2009). As regards maximum scour level (MSL) at pier nose is concerned, the IRC recommendation for MSL at pier nose is $2D_{sm}$ below HFL or D_{sm} below mean bed level. It is not at all scientific, since the Lacey's regime depth ***above river bed*** has no bearing with scour ***below river bed***. Scour below river bed is governed by several parameters e.g. geometry of pier, type of foundation, obliquity of flow, size and non-uniformity of sediments, geometry of approaching flow, flow depth, duration of scour(t) with respect to time to attain equilibrium scour (t_e) i.e. t/t_e etc. In IRC equation for scour, none of these parameters other than Q (or q) and d_{50} are considered.

It is now universally established that scour depth below river bed (d_s) in bridge piers attains a maximum value (d_{smax}) at threshold condition when V/V_c=1 as shown in Fig.1. Here V (=q/y) is the mean flow velocity and V_c is the critical velocity when the river bed sediments just start moving. Value of V_c is determined by the mean size of sediments in the river bed i.e. d_{50}. V_C-value can be determined from Shield's (1936) function for both non-cohesive and cohesive soil and other methods (K-G-R, 1992). Once the mean flow velocity (V) exceeds the critical or threshold value (V_c), scour depth (ds) reduces due to deposition of incoming bed sediments in the scour hole. With further rise in V, scour depth increases again and it attains an equilibrium value (d_{se}) at V/V_C=4 as shown in Fig.1. It has been found that the equilibrium scour depth d_{se} (at V/V_C=4) is always less than the threshold value of scour depth d_{smax} (at V/Vc=1). Thus, it will be always safe to design bridge foundation for a maximum scour under threshold condition. Several mathematical models [Blench,1997; Bruessers et al,1991 (IAHR); Dey,2005-06;Kothyari-Garde-RangaRaju (K-G-R),1992; Mellvile & Kolemam,2000; Richardson &Davis,1995 (HEC-18)] have been developed in India and abroad over the years for finding maximum scour depths of foundation by using the threshold scour concept as discussed above.

IRC formula recommends that scour goes on increasing as mean velocity of flow V or discharge intensity q (=Vy) increases which is in contradiction to the above scientific study on scour in bridge foundation made by several gifted research scientists in India and abroad mentioned above.

Table-1 taken from a paper written jointly by the discusser with the author of the present paper gives a comparison of the observed maximum local scour depths in a bouldery river and scour predicted by different mathematical models (including Lacey's Model adopted by IRC). Figures in bracket indicate y_s/R-values where ys=ds is the maximum local scour depth and R is Lacey's regime depth.

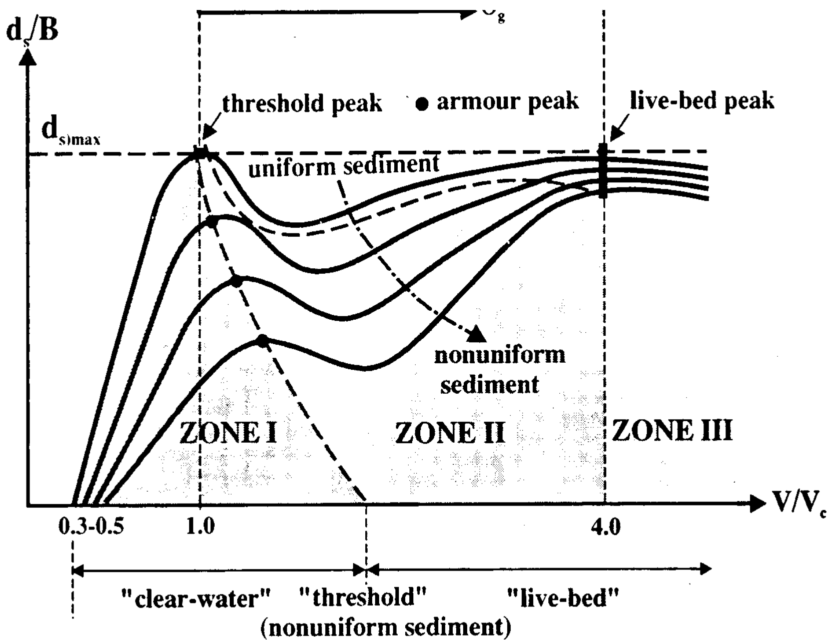

Fig.1 Variation of Scour Depth (ds) With Mean Flow Velocity (V)

Note: B is pier Thickness; Peak scour occurs at Threshold stage; ds reduces with σ_g

Table-1 Observed and Predicted values of Maximum Scour Depths by Different Models

Bridge Site	Observed Scour Depth (y_s' in m)	Predicated Scour Depth (y_s in m)					
		Lacey(R)	Blench	HEC-18	Melville & Coleman	IAHR	K-G-R
1	0.35 (0.15)	2.29 (1.00)	2.29 (1.00)	0.69 (0.30)	0.57 (0.25)	0.43 (0.19)	0.46 (0.20)
10	0.24 (0.25)	0.98 (1.00)	1.22 (1.24)	0.76 (0.77)	0.99 (1.01)	0.38 (0.39)	0.90 (0.92)
11	0.42 (0.42)	1.44 (1.00)	1.44 (1.00)	0.98 (0.68)	1.27 (0.88)	0.33 (0.23)	1.02 (0.71)
16	0.63 (0.12)	4.85 (1.00)	4.85 (1.00)	1.44 (0.29)	1.70 (0.35)	1.39 (0.28)	1.34 (0.27)
22	0.91 (0.25)	3.69 (1.00)	5.27 (1.43)	2.21 (0.60)	2.19 (0.59)	0.90 (0.21)	1.67 (0.45)

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