

Review on the Scour Management to Alleviate the Bridge Failure

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DOI:- <https://doi.org/10.47531/SIC.2022.33>

Abstract

The bridge is a crucial aspect for transportation in marine and land. The safety of the bridge is crucial for the safety of humans. Local scouring affects the safety of the bridge structure immensely. Scour depth estimation is done by the years-old method such as the Lacey-Inglis method in India, which only yields effective results for coarse sand. Codes provide overestimated depth for scouring, which increases the cost of construction. This review paper studies various methods to effectively estimate the scour depth. Scour monitoring is also a necessary aspect, and this paper studies various monitoring devices which can be used according to different sites and economic conditions. The most important condition is to minimize the scouring, and devices used to reduce scouring are classified in the paper. Scour monitoring and reduction, if done effectively, increases the bridge's life span and hence increases the safety of life.

Keywords: - Scouring, Bridge, Lacey-Inglis method, Scour depth, Sensor, Sonar, Fibre Bragg grating, Countermeasure, Slot, Collar, Riprap, Guiding vanes

INTRODUCTION

The bridge is a prominent structure used both for marine and land transportation purposes. Safety of the bridge structure is so necessary due to the human traffic that bridges carry during their life span. Bridge life affects the safety of humans using the bridges [1] [2]. Failure of the bridge structure is caused by several reasons, including natural hazards, design error, human error, overloading, etc. [3]. Natural hazards being the most affecting cause includes phenomena such as storms, explosions, earthquakes and flooding or

scouring[4][5]. Among all natural hazards scouring is the most affected reason for the failure of bridge structure as shown in Fig.1 (chart)[4][6] scouring in consideration of bridge structure is mainly of two types. General scouring deals with bigger aspects such as river cross-section, river dimensions and properties [7][8]. Another kind of scouring is local and focuses on the local elements, such as scouring around the bridge pier and abutments [9]. Factors that affect local scouring are geometric properties of the river cross-section,

water current characteristics, type of flora and resistance in the current path, etc.[8][4].

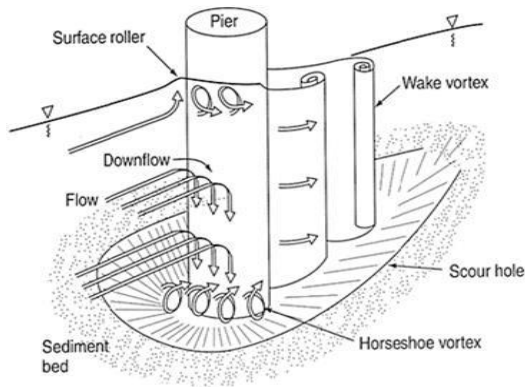


Fig.1 chart representing total bridge collapsed by natural hazard[8]

Local scouring phenomena consists of two complex behaviour of water current due to the obstruction of the pier. As the pier obstructs the water current, water gets stagnant at the pier surface, and following water pushes down the stagnant water and creates down flow. Water current on the downstream due to turbulence creates a horseshoe vortex [10][11][12]. Fig.2. shows the behaviour of down flow and horseshoe vortex [13]. Due to these two complex behaviours scouring around the pier increases [14]. To minimize the scoring and avoid the bridge's failure, first, we have to look into the aspect of scouring estimation and management by monitoring the scouring [4].

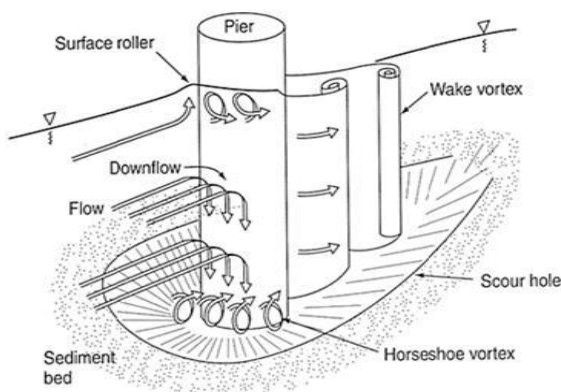


Fig.2 downflow and horseshoe vortex[13]

METHODS TO CALCULATE THE SCOUR DEPTH

Conventionally, many experimental and theoretical methods give an empirical formula to calculate the scour depth for a particular set of data[15]. In India, we mainly consider the Lacey-Inglis method, which is too old to consider [16]. These two scientists have considered only seventeen on-site data and developed the empirical equations to calculate the scouring depth, which works only for soil type which comes under sediment size between 0.15mm to 0.43mm, which is mostly coarse and sandy soil[16][17][7].

$$D_{LQ} = 0.47(Q/f)^{\frac{1}{3}}$$

$$P = 4.75\sqrt{Q}$$

$$f = 1.76\sqrt{d}[16]$$

Here D_{LQ} is normal scour depth, Q is river discharge, f is lacey's factor, P is the perimeter of the river cross-section, and d is the water depth.

$$D_{se} = KD_{LQ}[16]$$

Here D_{se} is a high flood level scour depth, and K varies between 1.76 to 2.59.

These equations are too old, and still, in India, we have used them for many years.

$$Z = 1.11b\left(\frac{y}{b}\right)^{0.5}[18]$$

$$Z = 1.4b[11]$$

$$Z = 1.84b(y/b)^{0.3}F_{rc}^{0.25}[11]$$

Here Z is scoured depth, y is water depth, and b is pier dimension and F_{ranc} is Froude number for the water current

Theoretical aspect can also be used to scour depth which varies with actual scour depth with certain percentage errors. Scientists like baker have given the theoretical approach to calculate depth.[11]

$$\frac{d_{se}}{b} = (a_1 N - a_2) \tanh(a_{3b}^h)$$

$$a_1, a_2, a_3 = f_n(h/D, G)$$

Here variables a_1, a_2, a_3 are a function of river water depth and pier dimension and depend on river water's resistance.[16][11]

SCOUR MONITORING DEVICES

Scour monitoring is a dynamic process that requires devices to monitor the phenomena for real time analysis[19]. We can only monitor the scouring for a particular time interval manually. Still, with the instruments developed under structural health monitoring, we can continuously monitor the scouring for an extended period. Also, we can record the data on a computer to use it afterwards[20]. Scour monitoring can be done by methods such as using a single device, using electrical rods, pulse, sound waves, fibre bragg grating device, etc.[21].

Single-Use Devices

Single-use devices are installed beneath the river bed to a certain level decided previously. When the scouring, which happens due to the water current, erodes the river bed material up to the level where the device is located, the device will get out of the river bed material. It will float on the water surface, and thus we can monitor the scouring for the river. This device is costly to install, can be used only once, and cannot give the data for maximum scouring in the river.[21][22]

Electrical Rods

Electrical or magnetic rods can be installed beneath the river bed material to a certain level. This type of device works on the principle of gravity. As the scouring occurs in the vicinity of the device and bed material gets displaced, the

device receives below the fabric and gives the data to the computer. These devices are easy to install, provide data with like maximum scouring, and be used more than once[23][24].

Radar or Sonar

Sonar is a type of device which generates the pulse waves which travels through the water medium and, after reflecting from the river bed material, comes back. The transducer in the sonar receives the reflected waves and generates the data of the depth of river bed material from the water surface. These types of devices are also easy to install and give continuous monitoring data [20][6].

Fibre Bragg Grating

Fibre bragg grating is a device that is made of piezoelectric material. Piezoelectric material has the characteristic of producing electricity when applied by any mechanical strain. When installed, this device proves to be very economical and provides real time continuous monitoring to the connected computer and gives maximum scouring data [25][26]. Fig.3 shows all the devices discussed above. [21]

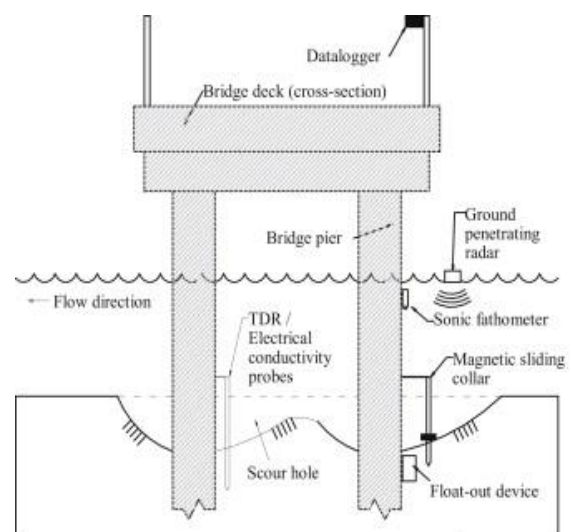


Fig. 3 different devices to monitor scouring in

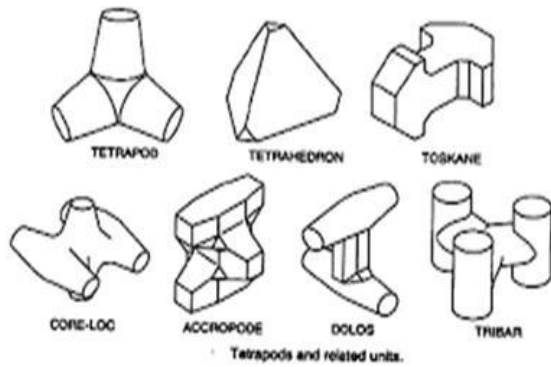


Fig.4 artificial Ripraps[28] real time situation[21]

COUNTER MEASURES FOR SCOURING

Scour depth estimation and monitoring can be effectively looking upon and to reduce the scouring certain counter measures are developed since several years. Counter measures are the devices which helps reduce scouring. Scouring can be effectively reduced either by strengthening the river bed material or by altering the river flow. Thus, counter measures are also device in two types which are device to strengthen the river bed and device to alter the water flow [27][1][28].

River Bed Strengthening Devices

Devices such as Ripraps and Geobags are used to strengthen the river bed material. Ripraps are a man-made artificial structure. It is made mostly out of concrete and can be of different shapes. It can be placed around the pier in the manner appropriate[29]. Geobags also can be placed around the pier and are mostly made of bags contained with sand. Fig shows artificial Ripraps which can be used[30]. Fig.4 shows artificial ripraps[28].

Flow Altering Devices

Devices which can alter the water flow before the pier will reduce the chances of scouring due to reduced effect of down flow and horseshoe vortex. Various devices can be used to alter the flow before the pier such as Slot, Collar, guiding vanes

etc. as shown in Fig.5. slots provided in the bridge pier can reduce the scouring up to 60-70%[17][29]. Scouring reduction varies according to the shape, size and position of the slot provided. And it varies between 40-80%. As shown in Fig.6. Collar can be provided below the pier and is effective to reduce the scouring in the range of 70-80%[31]. Guiding vanes as shown in Fig.7. can be used alone and also with the combination of slot or collar to reduce the scouring[32].

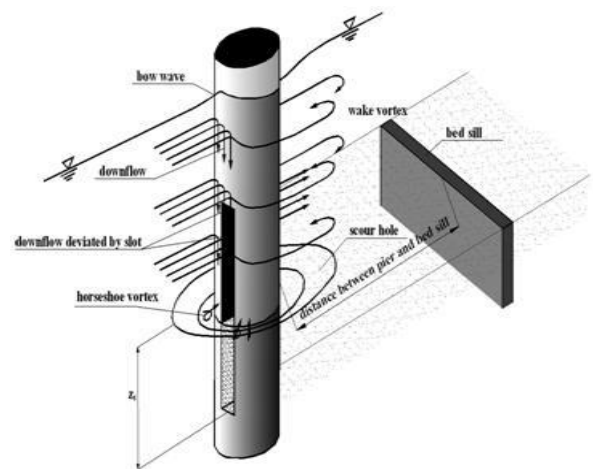


Fig.5 provision of slot in bridge pier [28]

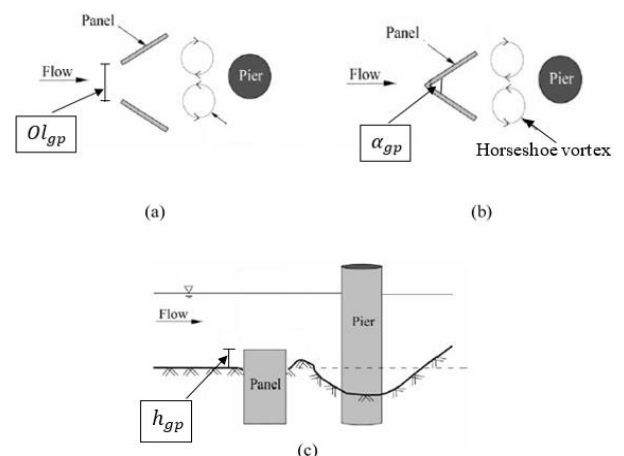


Fig.6 provision of guiding vanes before bridge pier[32]

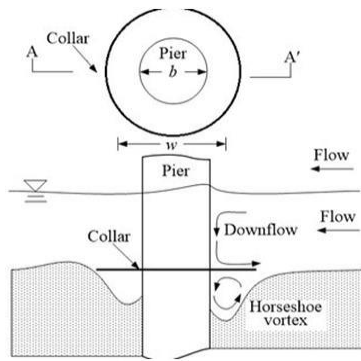


Fig.7 provision of the collar in bridge pier[30]

CONCLUSION

Scouring around the bridge pier is a major issue and should be paid great attention to. As scour measurement is a first step towards minimizing the scouring, methods to calculate scouring vary according to site conditions and other situations in the surrounding environment. India uses a method such as Lacey-Inglis, which is very old and can only be used for coarse sand and is limited due to development by considering only seventeen river site data. Methods like Kothyari can be used to estimate scour depth more effectively. For scouring monitoring, structural health monitoring provides various devices according to economic and site conditions. Single-use, sonar type and electric or magnetic rods can be used effectively for monitoring. Still, the fibre bragg grating device is most effective as it gives continuous real-time observation and keeps track of maximum scouring depth and scour variation with time. After estimating and monitoring the scour, it is necessary to minimize the scour and effectively reduce it using countermeasures. Slots, collars and guiding vanes can be used alone or with a combination of two to reduce scouring. Scouring reduction is in the range of 40-80% according to the combination of devices used. River bed strengthening can also be used to reduce scouring. The use of riprap or geo bags also reduces

scouring in the range of 40-60%. Scouring reduction increases the life expectancy of the bridge structure and guarantees the safety of humans using the bridge.

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