

## Erosion of Underlying Soil

Birendra Kumar Singh\*

### Abstract

*To protect underlying soil erosion on which foundation base is provided like apron provided in water retaining structure like dam, weir etc. In flood zone area this apron is provided at foundation base of building, near village which is situated near bank of river underlying soil erosion will be prevented when apron is provided. Near bank of river (village situated) for protection of village near bank of river analysis is done as follows: Erosion of the underlying soil is one of the most critical challenges in civil engineering as it directly threatens the stability and service life of structures. Continuous scouring caused by river currents, floods, and seasonal variations in water flow gradually weakens the foundation soil, leading to settlement, tilting, or even collapse of the superstructure. To mitigate this risk, the provision of aprons at the foundation base has proven to be an effective protective measure. Acting as a shield, the apron resists hydraulic pressure and reduces direct contact between water flow and soil, thereby minimizing erosion. In this study, the concept of apron protection is examined with specific reference to villages situated near riverbanks, where soil erosion is more severe during monsoon floods. By extending the apron around building foundations and critical infrastructure, the erosive forces of water are dissipated, preventing scouring and safeguarding the structural base. This technique not only improves the overall stability of foundations but also enhances disaster resilience in flood-prone regions. Therefore, apron protection provides a reliable, economical, and sustainable engineering solution for protecting villages and structures near rivers, ensuring safety and long-term performance against underlying soil erosion.*

**Keywords:** Soil erosion, apron protection, scour depth, Riverbank stability, foundation safety, flood-prone areas, hydraulic structures, reinforced concrete apron, uplift pressure

### INTRODUCTION

Erosion of underlying soil is one of the most critical challenges in geotechnical and hydraulic engineering. Structures such as dams, barrages, bridges, and even residential buildings near rivers are highly vulnerable to scouring and soil loss at their foundation base. When high floods occur, the velocity and thrust of water increase significantly, exerting uplift pressure and causing removal of soil particles below the foundation. This process weakens the soil's bearing capacity, which may result in excessive settlement, tilting, or even collapse of the structure [1–4].

#### \*Author for Correspondence

Birendra Kumar Singh  
E-mail: birendrasingh.civil@yahoo.co.in

Professor, Department of Civil Engineering, Birla Institute of Technology, Mesra, Ranchi, Jharkhand, India

Received Date: September 22, 2025  
Accepted Date: September 28, 2025  
Published Date: September 30, 2025

**Citation:** Birendra Kumar Singh. Erosion of Underlying Soil. International Journal of Geological and Geotechnical Engineering. 2025; 11 (2): 20–25p.

To counter this problem, aprons made of reinforced concrete or other protective materials are commonly provided at the foundation base. These aprons act as an extension of the foundation, absorbing hydraulic forces and distributing loads to prevent direct erosion of soil. The design of aprons must account for flood depth, velocity of flow, uplift pressure, and the geotechnical properties of the foundation soil. In addition, protective measures such as boulder pitching, sandbags, and filters are often combined with aprons to reduce scouring at riverbeds and banks [5, 6].

The present study focuses on the design and application of aprons in protecting villages located close to riverbanks, where the risk of soil erosion is severe during monsoon floods. By analyzing thrust conditions, uplift pressure, and scour depth, the study aims to determine the required thickness and depth of aprons that ensure structural safety. This approach provides an economical and sustainable solution for minimizing soil erosion and safeguarding infrastructure in flood-prone regions [7, 8].

Depth of water in case of high flood = 35 m

Thrust of water due to this standing water 35 t/m<sup>2</sup>

Velocity of flow = 1.2 x 35 = 42 m/sec

Thrust of water due to velocity of flow =  $\frac{1000 \times (42)^2}{19.62} = 90t / m^2$

Due to seeping of water below bed level of river uplift pressure = 35 t/m<sup>2</sup> depending upon depth of water in river.

Hence total thrust of water = 35 + 90 + 35 = 160 t/m<sup>2</sup>.

For this, much load intensity aprons will be provided at depth of foundation in case of saturated soil condition.

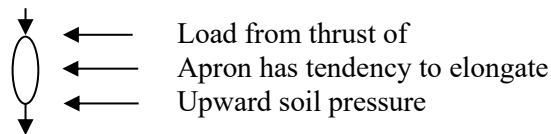
$$D_f = \frac{160}{1.6} \times \left[ \frac{1 - \sin 15^\circ}{1 + \sin 15^\circ} \right]^2$$

$$= \frac{160}{1.6} \times 0.347 = 35 \text{ meter}$$

where unit wt of saturated soil = 1.6 t/m<sup>3</sup> &  $\phi = 15^\circ$  taken.

Hence below bed level of river at depth 35 m aprons will be provided. Suppose from bank of river at distance 25 m taken & it is provided along village (length) which is situated near bank of river to prevent underlying soil erosion because due to scouring of underlying soil scouring of soil takes place & building falls [9, 10].

Now thickness of apron: Since thrust of water is acting on projected part of R.C.C slab from bank of river 25 m & per meter length along bank of river taken. Hence, load = 160 x 25 x 1 = 4000 t



$$= \frac{4000 \times 1000 \times 10}{25000 \times t} \times \frac{10}{100} \times 40 = 4$$

b [M40 grade concrete tensile strength = 4 N/mm<sup>2</sup>)

$$100000 t = 40000000$$

$$t = \frac{40000000}{100000} = 400 \text{ mm}$$

thickness of aprons at depth of foundation 35 m below bed level of river & 25 m projection R.C.C slab from bank of river of thickness 400 mm is to be provided so that underlying soil erosion will not take place & village near bank of river will be safe. Also, at bed level of river boulder, sandbags, etc. are provided so that it can resist the thrust of water & scouring of soil will be prevented.

## RESULTS AND DISCUSSION

The analysis of erosion control using aprons was carried out considering different hydraulic and soil conditions. The case study assumes a high flood depth of 35 m, resulting in a thrust of approximately 35 t/m<sup>2</sup> due to standing water. When combined with the thrust induced by water velocity (42 m/s) and uplift pressure, the total intensity of loading on the foundation was calculated to be about 160 t/m<sup>2</sup>. To resist this magnitude of hydraulic load, an apron at a depth of 35 m below the riverbed was proposed. For villages situated near riverbanks, a reinforced concrete apron projected 25 m from the bank was considered. Under these conditions, the structural analysis indicated that an RCC slab with a thickness of 400 mm would be sufficient to counter the thrust and prevent soil scouring. In addition, the placement of boulders and sandbags at the riverbed was found to further reduce erosive forces, thus improving overall protection.

Scour depth was also evaluated based on river hydraulics. For a river width of 300 m with a discharge of 441,000 m<sup>3</sup>/s, the maximum scour depth was estimated at 43 m. Accordingly, a foundation depth of 88 m would be required to ensure long-term stability. However, for smaller discharges (1470 m<sup>3</sup>/s per meter run), the estimated scour depth was only 16 m, suggesting that the proposed 35 m depth of apron is more than adequate for protection.

Similar evaluations were extended to roads and bridges in flood-prone areas. For roads subjected to flash floods (depth 10 m, velocity 12 m/s), the combined water thrust and vehicular loads yielded an intensity of approximately 47.34 t/m<sup>2</sup>. Including additional loading due to waterlogging, the total load intensity reached about 50 t/m<sup>2</sup>, requiring a foundation depth of 11 m. Reinforced concrete aprons with 2–3 m projections were found effective in preventing scour at road and embankment foundations.

Overall, the results confirm that properly designed aprons, combined with supplementary protective measures, significantly reduce the risk of underlying soil erosion. This ensures structural safety of buildings, bridges, and roads located in flood-prone regions, thereby protecting both infrastructure and communities.

From scour depth point of view depth of foundation of apron:

Depth of water = 35 m.

Velocity of flow = 42 m/sec.

Width of river = 300 meters.

Discharge of flow:  $bdV = 300 \times 35 \times 42 = 441000 \text{ m}^3/\text{sec}$  scoured depth provided to prevent maximum erosion of underlying soil.

$$\begin{aligned} \text{Scoured depth:} &= 0.47 \left( \frac{441000}{0.556} \right)^{0.333} \\ &\quad \downarrow \\ &\quad \text{Silt factor} \\ &= 0.47 (793165)^{0.333} \\ &= 0.47 \times 92 = 43 \text{ meters} \end{aligned}$$

Hence depth of foundation for apron is required =  $2 \times 43 + 2 = 88$  meter to prevent underlying soil erosion.

Since width of river is much larger than depth of flow & velocity of flow hence per meter run we take  $Q = 1 \times 35 \times 42 = 1470 \text{ m}^3/\text{sec}$ .

$$\begin{aligned} \text{Scoured depth} &= 0.47 \left( \frac{1470}{0.556} \right)^{0.333} \\ &= 0.47 (2644)^{0.333} \\ &= 0.47 \times 14 = 7 \text{ meters} \end{aligned}$$

Hence scoured depth =  $2 \times 7 + 2 = 16 \text{ m}$  but  $35 \text{ m}$  is more than  $16 \text{ m}$  hence at depth of foundation 35-meter apron is to be provided.

This projected part of R.C.C slab is case of building at foundation base (raft foundation) is to be provided. Also, at foundation base of raft foundation for pier in bridge is to be provided to prevent underlying soil erosion. Also, for road  $\rightarrow$  from foundation level of road stabilized soil or rock particles to ground level at projection of  $2\text{m}$  to  $3\text{m}$  is to be provided so that scouring of underlying soil will not place & road will be not washed away.

In road from scoured depth point of view the depth of foundation is to be taken:

Depth of water =  $10 \text{ m}$  in case of flash flood velocity of flow =  $1.2 \times 10 = 12 \text{ m/sec}$ .

Length of road = Per meter taken.

$Q = 1 \times 10 \times 12 = 120 \text{ m}^3/\text{sec}$  which is very less.  
Thrust of water =  $10 \text{ t/m}^2$

$$\text{Thrust of water due to velocity of flow} = \frac{1000 \times (12)^2}{19.62} = 7.34 \text{ t/m}^2$$

Due to underground uplift pressure  $10 \text{ t/m}^2$ .

Hence, total thrust of water  $10 + 10 + 7.34 = 27.34 \text{ t/m}^2$

Due to vehicle load intensity  $3.5 \text{ m} \times 1.2 \text{ m} = 70 \text{ t}$

$1 \text{ m}^2 \rightarrow 17 \text{ t/m}^2$  take  $20 \text{ t/m}^2$ .

Hence, total load intensity  $20 + 27.34 = 47.34 \text{ t/m}^2$  for this load intensity we have to provide depth of foundation so that maximum erosion of soil will be prevented.

$$D_f = \frac{47.34}{1.6} \times 0.347 = 10 \text{ meter}$$

depth of foundation of road in case of flood zone will be taken.

Also, from foundation level projection  $3\text{m}$  taken & like apron up to ground level R.C.C base like apron is made to prevent underlying soil erosion & this concrete projected part will resist the thrust of water due to flood.

In case of floods or due to very heavy rainfall water logging on bridges, roads, railway tracks, etc. will be there. Hence in design for pier in bridge which is on river also deck slab (concrete) or in building (concrete) etc strength of concrete will be less by  $8 \text{ N/mm}^2$  suppose if we have designed for  $30 \text{ N/mm}^2$  but due to heavy rainfall its strength will be only  $22 \text{ N/mm}^2$ .

Hence design for building, pier of bridge, deck slab, etc. will be done taking strength of concrete 22 N/mm<sup>2</sup> only not 30 N/mm<sup>2</sup>. (In saturated state of concrete).

When water logging in road or railway embankment is there in case of high flood. Suppose on road or runway of airfield etc or railway embankment for runway there will be loss in asphalt hence this loss will be taken into consideration. Supposed for road → water logging is 2 m on road it produces additional thrust of 2 t/m<sup>2</sup> hence in depth of foundation load intensity 47.34 + 2 = 49.34 t/m<sup>2</sup> or load intensity 50 t/m<sup>2</sup> will be taken & depth of foundation for road or railway embankment (same process will be adopted):

$$D_f = \frac{50}{1.6} \times 0.346 = 11 \text{ meter}$$

Hence, instead of 10 m we must provide 11 m depth of foundation for road. If water logging on roof of building. In case of saturated state of concrete its strength is lost by 8 N/mm<sup>2</sup>. If M30 grade concrete then 30-8 = 22 N/mm<sup>2</sup> we must provide thickness of slab taking strength of concrete 22 N/mm<sup>2</sup>.

## CONCLUSION

- By providing projected part of R.C.C slab like apron in dam underlying soil erosion will be prevented.
- Also, due to heavy rainfall or water logging on structures the loss in strength of material is to be considered.

The study highlights the importance of apron protection in preventing erosion of underlying soil in flood-prone and riverbank areas. Analysis of hydraulic thrust, uplift pressure, and scour depth demonstrates that properly designed aprons provide an effective barrier against soil loss beneath structural foundations. By resisting water-induced forces and distributing loads, aprons safeguard the stability of dams, bridges, roads, and buildings situated near rivers. For the case analyzed, an RCC apron of 400 mm thickness, projected 25 m from the riverbank at a depth of 35 m, was found adequate to counter the combined hydraulic load of 160 t/m<sup>2</sup>. The design also accounts for maximum scour depths, with additional protection provided by boulder pitching and sandbags at the riverbed. Similar measures applied to road and bridge foundations showed that aprons significantly reduce erosion risks even under severe flood and waterlogging conditions. Furthermore, the study emphasizes that material properties must be reassessed in saturated conditions, as the effective strength of concrete may reduce by approximately 8 N/mm<sup>2</sup> due to water absorption. Designing with this reduction in mind ensures structural safety during prolonged flooding or heavy rainfall.

In conclusion, apron protection emerges as a simple, economical, and durable engineering solution for erosion control. Its application not only preserves the integrity of foundations but also enhances disaster resilience in rural and urban areas located near rivers. Adoption of such measures can play a vital role in protecting communities and infrastructure from the adverse impacts of soil erosion.

## REFERENCES

1. Chow VT. Open-channel hydraulics. New York: McGraw-Hill; 1959.
2. Terzaghi K, Peck RB, Mesri G. Soil mechanics in engineering practice. 3rd ed. New York: Wiley; 1996.
3. Breusers HNC, Raudkivi AJ. Scouring: Hydraulic structures design manual. Rotterdam: Balkema; 1991.
4. Richardson EV, Davis SR. Evaluating scour at bridges (HEC-18). 5th ed. Washington, DC: Federal Highway Administration; 2012.
5. Briaud JL, Ting FCK, Chen HC, Cao Y, Han S, Kwak KW. Erosion function apparatus for scour rate predictions. J Geotech Geoenviron Eng. 2001;127(2):105–13.
6. Melville BW, Coleman SE. Bridge scour. Highlands Ranch (CO): Water Resources Publications; 2000.

- 
7. Hoffmans GJCM, Verheij HJ. Scour manual. Rotterdam: Balkema; 1997.
  8. Annandale GW. Scour technology: Mechanics and engineering practice. New York: McGraw-Hill; 2006.
  9. Jain RK. Estimation of scour depth around bridge piers using hydrodynamic approaches. *Int J Civil Eng Technol*. 2018;9(8):1042–50.
  10. Shukla SK, editor. Geosynthetics and their applications in geotechnical engineering. London: Taylor & Francis; 2002.