# The Collapse of Staircase at Gapernath Temple Site, Kota, Rajasthan: A geotechnical assessment

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**Abstract**

*Post disaster study of the collapse of staircase at Gapernath temple site was carried out in which two persons died and 165 were left stranded and later rescued as reported. The study area lies on the left bank of a NW flowing tributary of a Chambal River, flanked by steep rocky cliffs. The rock exposed is medium grained sandstone of Bhander group, beset with three prominent set of joints.*

*Geotechnical assessment of the site reveals that it was not a landslide but a failure of staircase due to the continuous seepage and erosion, at the interface. Measures have been suggested for a safe design of the structure.*

## Introduction

The recent staircase collapse at Gapernath Mahadev temple in south east Rajasthan has been a tragic event which created widespread panic and anxiety. As per the report, the mishap occurred on 10th August, 2008, in the afternoon when hundreds of devotees and tourists had gone to Shiva temple, taking the stair route. As the part of the approach stair case, with about 40 steps, suddenly collapsed (Photo 1), two persons were killed and 165 people got stranded. As the steps collapsed, few people were trapped in debris. Rescue operations were launched by the evening. The mishap was variously ascribed to as due to -a landslide, or fall of huge mass of soil on the staircase or due to heavy rush of devotees. The authors visited the site on 13th and 14th August 2008 to record the ground truth and to undertake geotechnical assessment, especially the causal factors that initiated the failure (Sanwal and Sharma, 2008).

The study area lies on the foothills of Chambal ravines, 22 km from Kota (Fig. 1). The temple is situated in the Darra wildlife sanctuary on the road leading to Rawatbhata Nuclear Power Plant.

Photo 1. Staircase leading to Lord Shiva temple.

## Geomorphological and Geological set up

The area features a vast rocky flatland deeply incised by a NW flowing tributary of river Chambal. The temple site is located on the mouth of the deeply entrenched valley, flanked by steep rocky cliffs (Fig. 2 and photo 2). An abrupt and deep rock cut at the temple site has given rise to a 40 m high water fall. The drainage pattern, in and around the area is more or less rectangular, vividly controlled by NE-SW and NW-SE trending joints.

Geologically, the area is represented by Bhander Group of rocks, of Vindhyan

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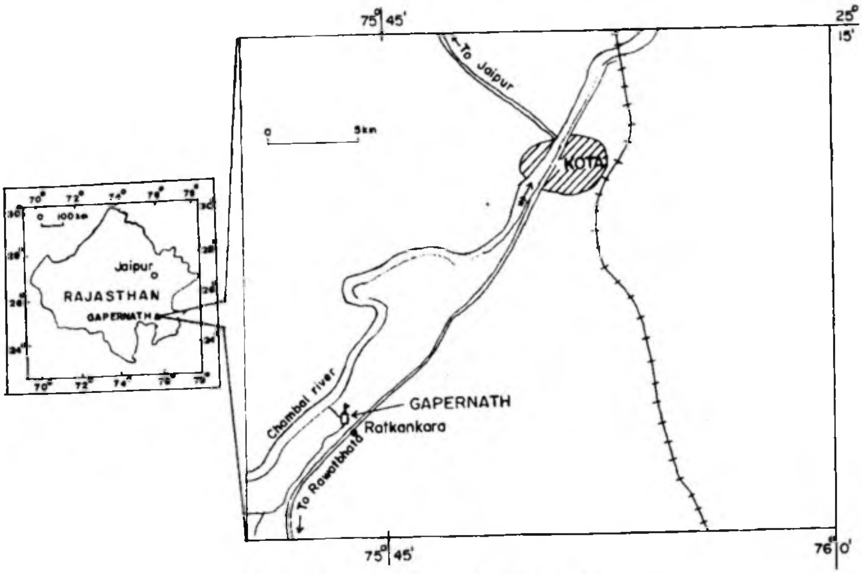


Fig. 1 Location of Gapernath Temple

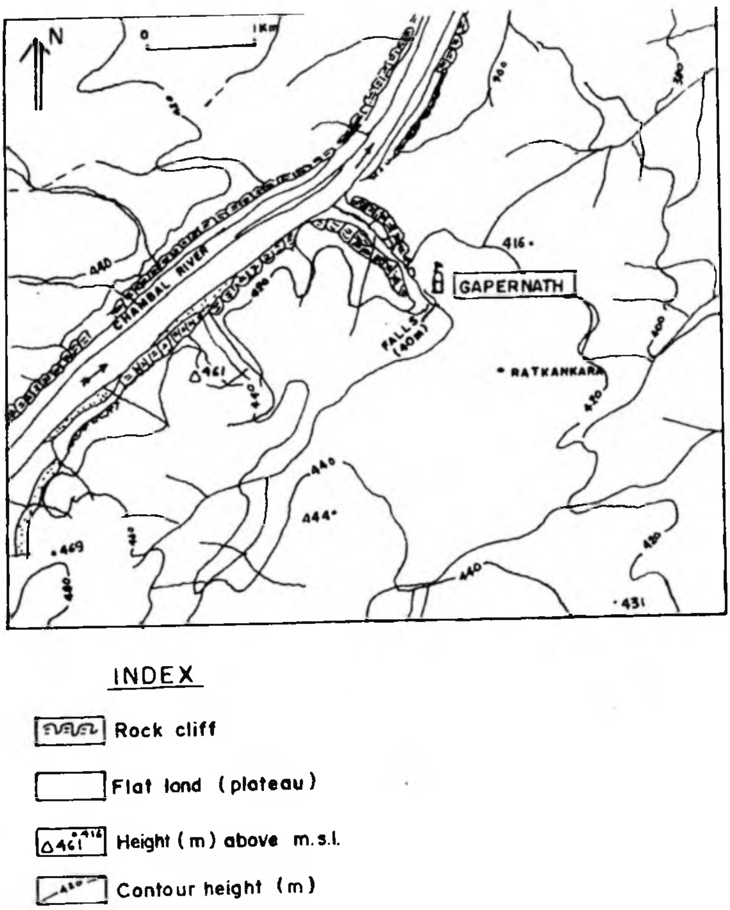


Fig. 2. Geomorphotlogical Map of Gapernath Area

Supergroup (Proterozoic age), comprising predominantly massive sandstone with thin bands of limestone. The sandstone is well bedded, fine to medium grained and quartzitic in nature (Sinha-Roy et. Al. 1998). Rocks in general, show very low dips 3-10º/ due NW. Two sets of subvertical joints, NW-SE and NE-SW have significantly dissected the rocks. The NW-SE joint has opening up to 1 m and essentially represent the relief structure that controls the steep abutment profile.

## Geotechnical Assessment

The approach to Gapernath Shiva temple and the picnic spot located on the left bank, through narrow (2-2.5 m) steep staircase, is founded on firm bedrock (sandstone). The steep rock face, along the approach, represents sub vertical valley wall sloping in N30°E direction (Fig. 3). The top of the rocky cliff at elevation 415 m, abruptly grades into an extensive, sub-horizontal flat rocky surface. The bottom portion of the valley marks a constricted section with river bed level at about elevation 345 m.

Bedrock, represented by sandstone, is quite compact and thickly bedded with distinct sub-horizontal bedding plane dipping due N75°W. Compressive strength of sandstone, as measured in the field, is 60-70 MPa (BIS, 1987). The valley slopes are almost devoid of soil/overburden cover, but for the isolated accumulations in the down slope areas close to the river, which support dense vegetal cover.

The rock mass structure is beset with 3 sets of open joints. The vertical open joints, parallel and perpendicular to the valley course, are spaced 1 to 3 m and provide passage for water infiltration. Sub-horizontally disposed bedding joints are undulating. The valley parallel, vertical joints (N70°W-S70°E) represent relief structure and show dislodgement at few places. Barring this, no potential slope failure mode is evident at the site resulting from an interplay of joints sets or their daylightment.

Both primary and secondary permeability is evident in the pervious and well jointed

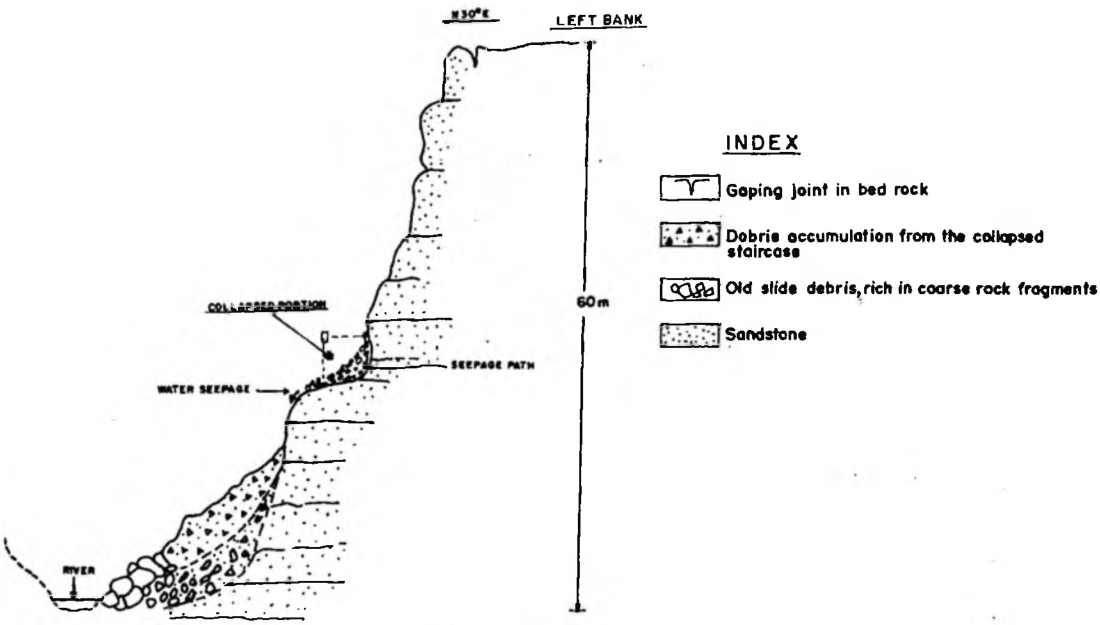


Fig. 3. Schematic section showing staircase collapse of Gopernath temple site

sandstone at the site. Easy percolation of water through joints especially the relief joints is an influential phenomenon in destabilizing the staircase through sub surface erosion after a heavy rainfall.

The entire stretch of staircase descending from Hanuman temple on the top of the slope, to the Shiva temple at the valley bottom, is aligned on the left bank, embracing the steep rocky surface. The staircase structure, entirely founded on firm bed rock surface, is quite narrow (2-2.5 m width) and seems disproportionate to behold the rush of pilgrims and tourists during peak hours. Perhaps, the lack of space precluded slope modification during the construction period.

The partial collapse of staircase structure (Photo 3), along a length of about 20 m, is restricted only where water seepage and saturation on the valley walls is most pronounced. The staircase, here, rests on a 3.5 m high wall, having a width of only 2.1 m. The structure has construction in dry stone masonry with lime cement mortar at few locales. In the upslope end of the collapsed structure, as seen in the overhang, the construction has been in stone masonry in clay mortar. Apparently, the structure lacked weep holes and effective drainage arrangement, to release the pore water pressure. Prima facie, the structure is poorly designed to withstand the load (including live load) and loss of shear resistance disregarding the ground conditions.

Photo 3. The collapsed staircase structure and its debris.

## The Causes

The process, which promoted the collapse and subsequent down slope movement, was primarily continuous water seepage along the open joints, causing progressive erosion along the interface between the bedrock and the staircase structure (Photo 4). The process of erosion resulted in formation of gap/cavity and overhangs which subsequently enlarged in due course of time.

Photo 4. A portion of the collapsed staircase with prominent gap along the interface.

The increased pore water pressure and the loss of contact of the structure with the bed rock resulted in decrease of the shearing resistance.

## Conclusions

Preliminary geological investigations carried out at Gapernath temple site, following the collapse of the staircase reveal that it was neither a landslide event nor a mishap due to any unfavorable geological site conditions. It was simply a failure of an underdesigned staircase structure which was not in harmony with the local ground conditions. Furthermore, the structure was neither reinforced nor tied to the bed rock. It also lacked appropriate drainage arrangement. It may, thus, be regarded as an engineering problem requiring appropriate engineering solution.

Continuous seepage through joints and attendant saturation at the interface, between the staircase and the bed rock caused erosion creating cavities beneath the structure. It, effectively and adversely changed the stability state culminating in collapse of the staircase structure, in a zone where saturation was more pronounced.

For a safe and effective design of the approach path/ staircase, it is advised to-

- Construct a concrete gravity wall with adequate reinforcement.
- Alternatively, the retaining piles may be installed in the bed rock through the boreholes.
- Tie up the structure to bedrock, on the steep wall section.
- Provide appropriate drainage arrangements so as to prevent water accumulation behind the wall at the interface and within the structure.

Additionally, an alternative passage like a' rope way'/ cable car system may also be considered as the topography and the rock conditions at the site seem to be favorable. Before planning such a venture, however, a proper techno economic feasibility needs to be worked out.

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