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Foundation for an 85-m High Bungy Jumping Tower at Rishikesh

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Abstract. An 85-m high bungy jumping tower, set to be the highest in India is under construction in Rishikesh. Located on right bank of River Hule at Shivpuri between the North Almoda Thrust and the Saknindhar Thrust, rocks in the area are sheared and disturbed. The paper presents the geotechnical conditions at site and the foundation system for the tower. Appropriate slope stabilization measures were implemented for long-term stability.

Keywords: bungy-jumping tower, foundation for tower, stabilizing hill-slopes.

1 Introduction

The hilly terrains, an intrinsic part of the Rishikesh experience in Uttarakhand offer a fun-filled adrenalin rush matched by no other. An 85-m high bungy jumping tower coming up in Shivpuri, Rishikesh is planned to be the highest bungy jumping tower in India. This tower is set to offer an exciting dose of thrill to those ready for a courageous and sensational experience. A schematic sketch of the tower is illustrated on Fig. 1.

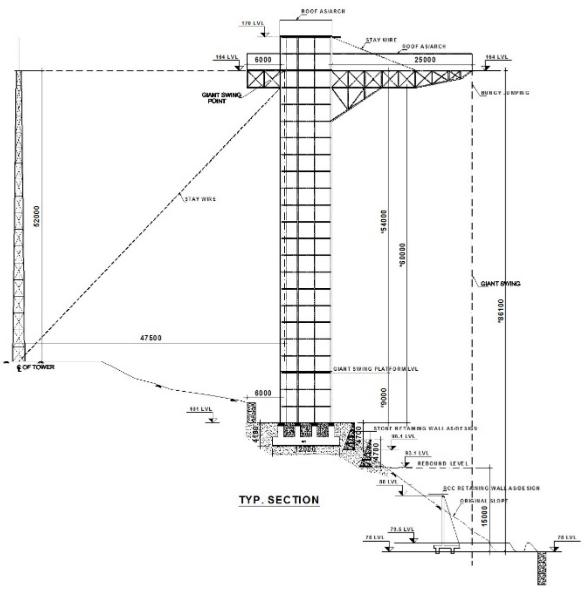

Fig. 1. Schematic sketch of the tower

2 Project Details

2.1 General

The tower itself shall be 76-m high. The proposed jump height is just over 86 m which will be highest in India once completed. The site location opens up to a panoramic view of the Ganga and the Himalayan ranges and imbibes the thrill and adventurous aura of the activity.

2.2 Location

The site is in the mountainous terrain of lesser Himalaya on right bank of Hule River, near its confluence with the River Ganga at Shivpuri. It is accessible from NH-7 and lies at Latitude 30°8'3.85"N and Longitude 78°23'3.90"E and is about 15-20 km east of Rishikesh city. A satellite image showing the site location is illustrated on Fig. 2.

Fig. 2. Satellite image showing the site location

2.3 Project Features

The imposing steel tower will have a plan area of 9 m x 9 m and a total weight of about 175MT. It shall be located in an artificially terraced soil, covered rectangular area (about 21 m x 12 m) bound by concrete masonry walls, in moderate to steep, largely debris covered slopes. The terrace is about 22m high with relatively steep (35-40°) debris-covered and forested slope with a gentler slope below. Key details are as follows:

- The tower shall be in square shape, 9 m x 9 m in plan with a grid of 3 m x 3 m. Total height of tower is 76 m.
- There shall be total 16 columns, connected by cross beams at every 3 m height.
- The RCC raft foundation is proposed at about 4 m below the ground.

- The bungy jump shall be performed from a cantilever boom of 25 m projection at 63 m above the ground level. The drop point shall be about 22 m below the base level of the tower.
- A boom for giant swing shall be attached on the other side of the tower of 6 m projection at 53 m above ground level and.
- A viewing deck is proposed at the top of the tower at 69 m height above the base of the tower.

2.4 Structural and Architectural Details

The tower is designed and constructed as RCC-steel hybrid structure. The substructure up to the plinth level shall be in RCC and the superstructure shall be constructed using braced HR steel frame of steel frame with stay wires. Steel columns have been analyzed as fixed at top of RC pedestal. Cross bracings in vertical and horizontal planes are provided at suitable locations to resist the lateral force and torsional effects due to earthquake and wind. The foundation was checked for overturning moments due to wind forces. A conceptual visualization of the tower as developed by the architect is presented on Fig. 3.

Fig. 3. Architect's visualization of the tower and its surroundings

3 Site Conditions

3.1 Regional Geology

The area represents a highly rugged topography characterized by moderate to steep slopes that are intervened by narrow valleys. The topography of the region appears to be controlled by structural and lithological factors [1]. The area thus exhibits high relative relief. Presence of overburden on steep slopes and high precipitation make this area prone to landslides.

The area from Rishikesh to Rudraprayag via Devprayag has a very complex geology, which varies from outer Lesser Himalayas to inner Lesser Himalayas. The entire stretch shows variations in rock type of Proterozoic to Cambrian meta-sediments.

These meta-sediments are intersected by faults and thrusts at many places. The bed rock has also suffered multi-phase of folding at places [2].

The corridor from Rishikesh to Rudraprayag lies within older folded sequence over printed by Himalayan fold-thrust movement. The geological formations have suffered extensive tectonic movement and the rock formations were subjected to displacement from their original place of deposition. This transportation occurred due to large scale thrusting of various geological formations and intensive operative compression tectonic activity in geological past resulting in numerous nappe structures.

3.2 Site Geology

North Almoda Thrust and Saknindhar Thrust are present close vicinity of the site which are separated by distance of 1.5-2 km from each other. Site is located at nearly the centre of these two thrusts. There is high possibility that area could be part of a shear zone. Photographs in Fig. 4 illustrate the shearing and disturbance to the rocks at site.

Fig. 4. Exposed rocks at site.
Note the shearing and disturbance to the formation

In general, the Garhwal Himalayas is known for its fragile landscape and frequent geological hazards. Landslides are the regular threats over this region. It is a highly rugged terrain in the vicinity of the Upper Ganga River valley up to Devprayag and Lower Alakhnanda river valley up to Rudraprayag.

The area is known to experience frequent landslides especially during every monsoon season. A map [3] showing these major thrusts (fault-lines) relative to the proposed site is presented on Fig. 5.

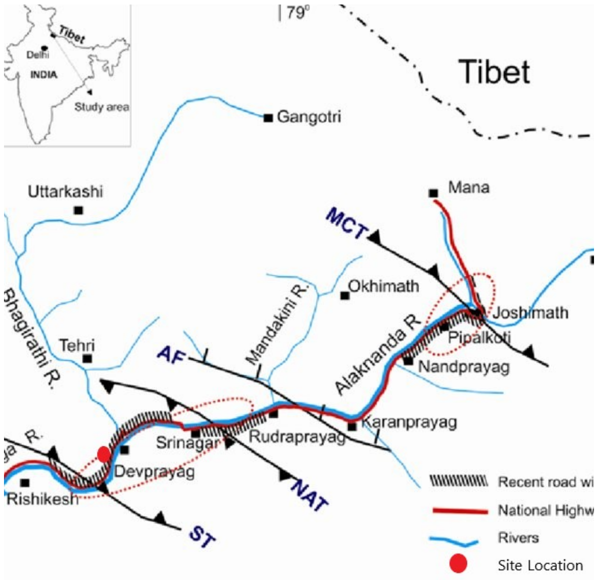

Fig. 5. Map of the Upper Ganaga and Alakhnanda valley showing prominent Fault / Thrust

These are MCT: Main Central Thrust, AF: Alaknanda Fault, NAT: North Almoda Thrust, ST: Saknindhar Thrust (Sati et al, 2011)

3.3 Site Description

The tower site is in the mountainous terrain of lesser Himalaya on right bank of Hule river, near its confluence with the River Ganga at Shivpuri. The tower shall be located in an artificially terraced soil, covered rectangular area (about 21m x 13m) bound by concrete masonry walls, in moderate to steep, largely debris covered slopes. The terrace is about 22m high with relatively steep (35-40°) debris-covered-and-forested slope with a gentler slope below. Fig. 6 presents photographs illustrating an overview of the site.

Fig. 6. Site Overview

Debris contains small angular fragments of shales in a silty-clayey matrix. Large dolomite boulders of up to about 3m size lie sparsely in the debris on northern side and on the slope below the terrace. Occasional smaller trees on the slopes are tilted downslope, however, many large, fairly old trees of normal appearance exist on the debris slopes, suggesting fairly stable-slope conditions. A sketch of the site identified for the tower is shown on Fig. 7.

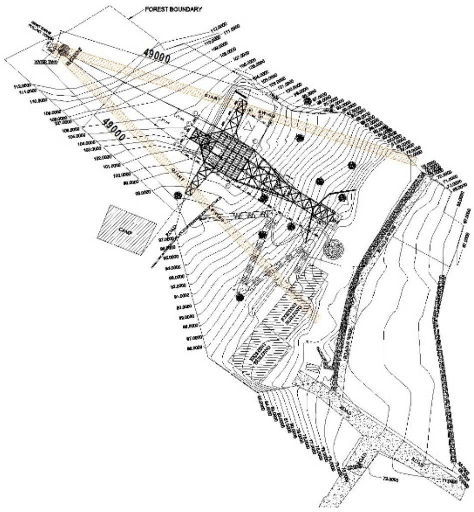

Fig. 7. Layout plan showing tower location

3.4 Stratigraphy

The scope of the geotechnical investigation included a borehole and a plate load test. A photograph of the drilling in progress is illustrated on Fig. 8.

Fig. 8. Borehole Drilling in Progress

An overburden of coarse to fine sand intermixed with rock fragments is met at site to 7.5 m depth. It is likely that part of this may be debris material from an old landslide; however, the overburden appears to be fairly compact and stable.

Below this, completely to moderately weathered and very weak to weak purple, shale (rock) was met at site to 20.0 m with core recovery 0-43% and RQD 0%. The underlying rock classifies as completely to moderately weathered and very weak to weak grey, sandstone (rock) was met to final explored depth of 25 m. Groundwater was met at 12.00 m depth during the period of the field investigation.

Field SPT-N values range from 35 to 45 to about 3 m depth values indicating the dense condition of strata. Below this, SPT values ranges from 55 to 67 to about 7.5 m, below this, SPT values exceed 100 to the final explored depth of 25.0 m. Groundwater was met at 12 m depth. Fig. 9 presents the pictorial representation of the borelog.

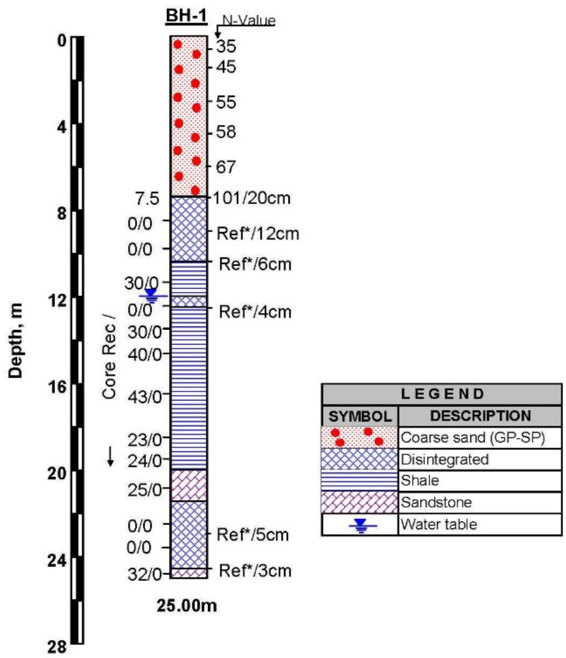

Fig. 9. Borehole Profile

Bed rock is exposed on the hill-side are thinly bedded to laminated weak shale and minor arenaceous shale / shaley arenite. Arenaceous content seems to increase southwards. Rocks are often highly weathered to considerable depths. The rock formation is closely jointed and has bedding / foliation dipping westwards (WNW to SSW) at low angles.

Gentler dips of the disturbed rocks near the tower area, seem the result of old slope creep. The area could be part of a shear zone as suggested by the dips of the rocks and the overturned and highly fragmented and crushed rock-mass.

A plate load test was conducted on a 60 x 60 cm size test plate at 3 m depth. Fig. 10 presents a photograph of the test in progress. The load-settlement curve is presented on Fig. 11.

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Fig. 10. Plate Load Test in progress

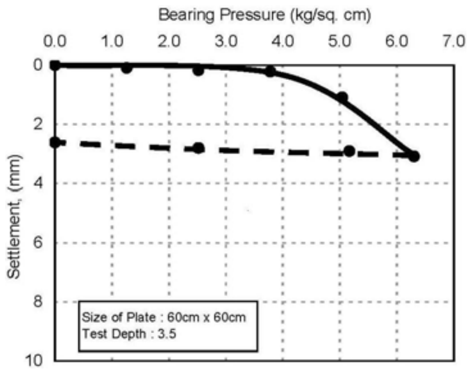

Fig. 11. Load-Settlement Curve - Plate Load Test

4 Foundation Design

4.1 Net Bearing Pressure for Design

Raft foundation of size 14 m x 15 m was planned at 4 m depth to support the steel structure weighing 175 tonnes. Analyzing the borehole data and plate load tests, the foundation is safe for a net bearing pressure of 35 T/m^2 for a permissible total settlement of 25 mm. The net bearing pressure due to the structural loads was about 10 T/m^2, hence the structure is safe from bearing capacity and settlement standpoint.

4.2 Slope Stability

Assessment of Slopes: In general, the hill slopes at the project site are fairly stable. Based on the overall contour map of the area, the angle of the slopes in the surrounding area have been assessed, particularly where slope angle exceeds 20 degrees. Stabilization measures such as rock bolts in critical areas, proper horticulture planning, paving, etc. are being taken up.

Drainage Planning: The hill slopes are an important watershed in the area. It aids run off of rain water from the higher reaches into the nallahs below. During monsoons, some soil erosion or denuding of vegetation could occur. This can result in a situation where the hill slope could get disturbed, causing a localized landmass to move down the slope.

Drainage of the rainwater has been carefully planned so as to divert it away from the proposed construction. Diversion of water, which may flow from the higher reaches, should be done by drains. The rainwater from the slopes shall be intercepted and drained away from the proposed construction.

All water from higher reaches have been drained off into a drainage system capable of carrying the discharge expected during the peak monsoons. The drainage is being planned such that run off does not encroach into the effective rock mass which is considered to extend 8 m beyond the outer limit of the proposed construction on all sides.

4.3 Slope Protection Measures

Slope protection measures being undertaken at site for long-term stability of the slopes around the site are as follows:

1. Proper drainage is provided for the site roads. It is ensured that there is no localized ponding or stagnation of water which could seep underneath the road, cause undermining of the road.
2. Shoulder drains are provided on either side of the roads and the water is drained away into carefully selected drainage ditches for disposal.
3. In areas where rock slopes are to be excavated, adequate precautions have been taken to ensure that the slope is stable. The slope is inspected for any possible wedges that could slide. Such wedges are removed for stability purpose.
4. A bituminous or concrete paving is provided all around the outer perimeter of the tower. This pavement extends 1.5 m beyond the outer edge of the foundations. The paving will help in limiting water ingress into the soils beneath the foundations.
5. On the uphill side, 3-5 m high retaining wall or a gabion wall is being constructed at 2-3 levels to protect the tower from rockfall from higher elevations.

4.4 Foundation Construction

The foundation construction is nearly over and the steel structure erection is in progress. Fig. 12 presents site photographs of the foundation construction and the 16 columns.

Fig. 12. Foundation construction in progress

5 Concluding Remarks

An 85-m high bungy jumping tower coming up in Shivpuri, Rishikesh will be the highest such tower in India. It is located in the mountainous terrain of lesser Himalaya on right bank of Hule River, near its confluence with the River Ganga at Shivpuri. It offers a panoramic view of the gorgeous Himalayan hill-slopes to the adventurous few ready for an exciting thrill.

The RCC-steel hybrid tower, located in an artificially terraced soil, will have a plan area of 9 m x 9 m and a total weight of about 175MT. With a raft foundation at 4 m depth the steel structure shall have 16 columns with cross beams at every 3 m height. The jump shall be performed from a cantilever boom of 25 m projection.

An overburden of sand intermixed with rock fragments is met at site to 7.5 m depth. Below this, completely to moderately weathered and very weak to weak purple, shale (rock) was met at site to 20.0. This is underlain by completely to moderately weathered and very weak to weak grey, sandstone (rock) was met to 25 m depth. Groundwater was met at 12 m depth.

The geotechnical investigation justified a safe net bearing pressure of 35 T/m^2, however, the actual loading intensity from structural considerations was only 10 T/m^2. In such topography, drainage planning and slope protection measures are very important; these are being meticulously implemented.

Acknowledgements

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References

1. Public Work Department Rudraprayag Uttarakhand: Preparation of Detailed Project Report, Rehabilitation and Up-gradation to 2 lane with paved shoulder configuration and strengthening of Rishikesh-Rudraprayag from km 228.0 to km 368.0 section of NH-58 in state of Uttarakhand. <0_0_12113012712111Prarup-33-GeologicalReports.pdf (forestsclearance.nic.in)>, (2013).
2. Geological Survey of India, <Geological Survey of India - Home (gsi.gov.in)>, (2000)
3. Sati, S. P., Sundriyal, Y. P., Rana, N., Dangwal, S., Recent landslides in Uttarakhand: nature’s fury or human folly, Current Science, Commentary, Vo. 100, No. 11, pp. 1617-1620, (2011).