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Foundation System for " Akshardham" to Control Deformations Related to Probable Liquefaction

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ABSTRACT

The paper presents a system of foundation for 38.0 m high monumental unique structure " Akhsardham" on bank of "Yamuna" river at Noida ,New Delhi(India). The design is outcome of interaction of ideological requirements of Architects, Seismologist, Geotechnical and Structural engineers, as well as those empirical rules of Vastu- Shastra for religious places. The structure is typical flexible stone monument. It is located on alluvium of "Yamuna" river in seismic Zone IV of Bureau of Indian standards. The preliminary exploration report indicated liquefaction potential and suggested deep foundations. The engineering priests decided against use of steel for the structure expected to exist for 2-3 countries. The authors reviewed soil report, got quick check tests to for analysis of probability of liquefaction. Based on this studies and deliberations with the above agencies evolved economical massive foundation to fulfill requirements without compromising safety. The construction over foundation is in full swing.

INTRODUCTION

A socio- religious sect of Akhshar Pursottam Pramukh Swami has planned massive complex with monumental structure Akhshardham near Noida-New Delhi (India). The 80.0 m x 95.0 m monument with 38.0 m height will be flexible stone construction using stone columns, stone beams and stone slabs. Based on ancient art, architect and construction practice it will surpass their famous temples of "Nesden" in U.K. and Gandhinager in Gujarat(India).

LOCATION

The location is on left bank of Yamuna river opposite to Nehru Power house. The site is between two bridges old Yamuna barrage-bridge and Noida bridge about 1.5 km from river bank. The plot originally in flood plane is now protected by a flood dyke. The river bank is deep alluvium.

STRUCTURE

The planning of monumental stone structure is based on proven time tested art. Such artisans with empirical knowhow are known as Sompura. The material, mass and stone cutting from mines to carving are an art. For practical purposes of foundation, it can be considered as flexible structure.

SITE CONDITIONS

The site is flood plane which has been reclaimed and raised 2 to 3 m by dredged river bed materials mostly silty fine sand. Now site is protected by flood dyke. It is located in seismic Zone IV as per Bureau of Indian Standards.

The river data shows : Bed levels RL 202 .00m , Flood level RL 203.00 m, Ground water table at site is RL 193 to 196 m (RL : Reduced Level).

SEISMIC DATA

Delhi has recorded tremors of intensity of 5 (MM scale) in 1960. "Tehri " dam site, 175 km away, recorded earth quake of intensity 6.5 on Richter scale on 20th Oct. 1991. No major damages were recorded at Delhi. For all practical purposes, for special structure, 0.12 g acceleration was adopted for study of Liquefaction Potential etc. After Bhuj(Gujarat,India) earthquake studies conducted by academic institutions have brought out following data for Delhi (PTI 2002) for disaster management.

The Seismic Zone for Delhi region is Zone IV (IS : 1893).Twentyforur epicenters have been identified in Delhi (PTI 2002). The seismicity is attributed to seven tectonic faults.

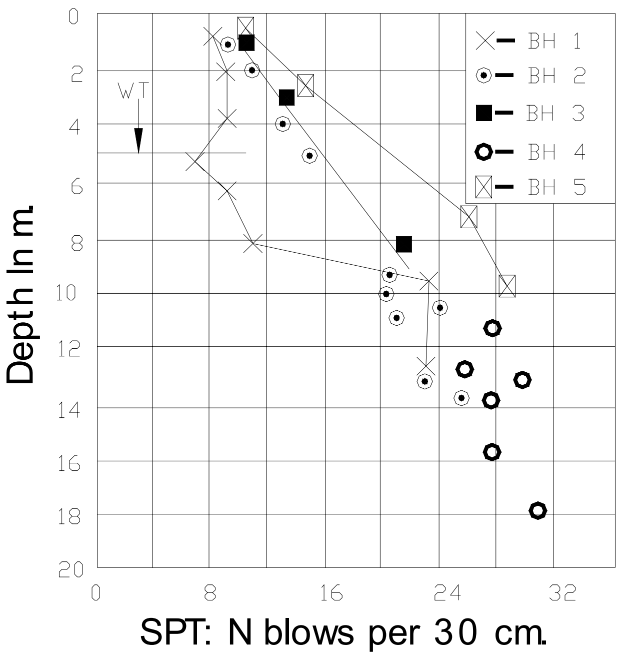


Fig.1. Variation Of SPT N Value with depth at site (GEOTECH 2OOO)

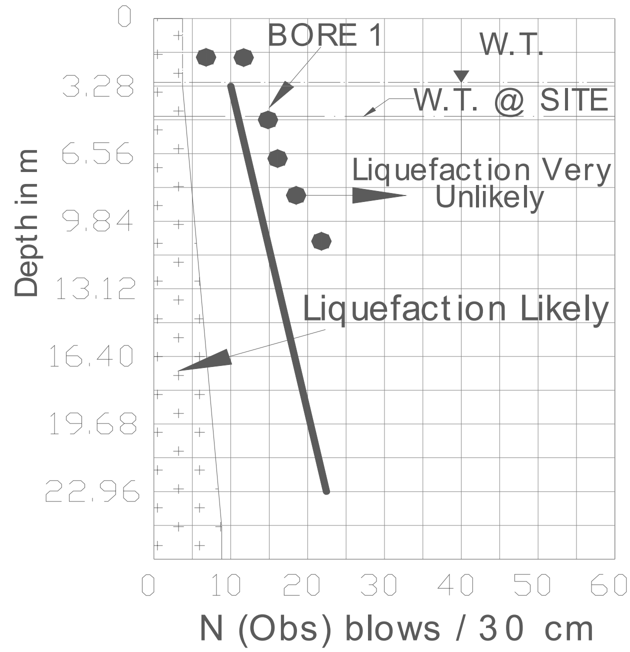


Fig. 2. Probability of liquefaction for the site using Seed & Idriss approach (1971) for 0.15g acceleration.

The epicenter close to seven ligaments are confined to Motiakhan, Indrapuri, Chankya puri, Sangamvihar, Maidan Garhi, rajkori, Ghatomi, Rangashala, Pusha institute, IGI airport, Shahbad, Sagarpur, Bharathal and Renikhera areas, Micro zoning is in progress. In absence of specific details the design studies adopted conservative approach. The temple location do not fall in these regions.

SOIL PROFILE

The overall plot was explored by Geotech Consultants. The generalized soil profile was :

0-2 m	Low cohesive, Non Plastic siltyfine sand (SM group) with average S.P.T. resistance of 10 blows/30 centimeters.
2-18 m	SM-SP group, siltyfine sand, medium to dense with SPT resistance, N increasing from 10 to 30 blows / 30 centimeters. Sand below 10 m is very dense, Ground water was at 6.0 m below Ground level.
18-25 m	Fine grained soils (CL/CI group)

The report considered as per IS 1893-84 during earth quake, the subsoil is likely to liquefy upto about 10.00 m depth below ground surface. Therefore deep foundations are suggested".

The overall data showed SPT values as 15, 20, 24, blows/30 centimeters [excl. Bore Hole (BH) 1] at 5,8, 10 meter depths (Fig. 1). Sand (SP) from 11.0 m to 18.0 m depth is very dense. The soil below 18.0 m is cohesive (CL).

The data was corrected for surcharge and relative density by above data was estimated as 65% or more(Desai M.D. 1970). Using work of seed, acceleration of 0.15g and water table at 3.28 m the data compiled as shown in Fig.2, shows liquefaction very unlikely at site. The SPT in Delhi soils with Shell boring technique of drilling have been found to be conservative (Desai M.D. 1970). The typical grading of top 5.0 m strata for Delhi and temple Site are shown in - Fig. 3.

To check relative density, quick dynamic cone penetration test (IS 4968,Part I) were conducted by M/S ATES Delhi. The results of 5 tests including one near BH 1 showing peculiar trend are shown in Fig 4. ,the average resistance Nc is 20 at 2.0 m depth. It increases to 50 at 10.0 m depth. The strata of noncohesive silty fine sand below 4.5 m depth has relative density of 70% or more (Desai M.D.1974).

LIQUEFACTION POTENTIAL

The preliminary report showing probability of liquefaction, as reviewed in Fig.2 indicate that there is no liquefaction likely below 4.5 m depth for seismicity assumed. For sand D_{10} = 0.02 mm, Cu = 10, acceleration of 0.15 g , critical density is 55%. The soil below 4.5 m or ground water table was not likely to liquefy.

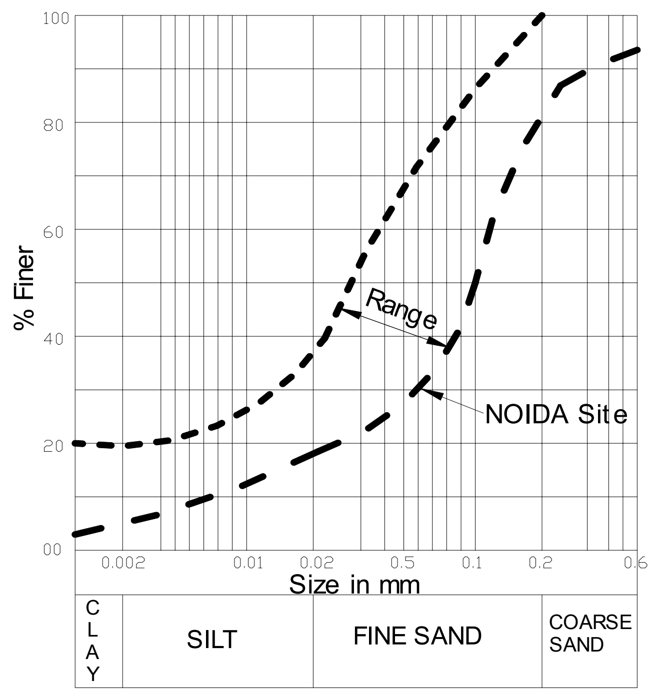


Fig.3. Grading range for top 5.0 m soils around Delhi and Noida Site. (Desai M.D., 1969)

FOUNDATION

As deep foundation was not acceptable to priests nor a necessity, shallow flexible foundation was planned. The depth of foundation was proposed as 4.5 m below original ground level.

The entire top 4.5 m, suspected to be problematic by some members of group, was excavated. The water table was 1.5 m below excavation.

The bottom was rolled by 10 tons vibratory roller. A woven type geotextile filter was used as separator and filter. The plot level and requirement of elevation for platform above ground required 2.0 m of filling, 2 m of mass concrete and over it designed 1500 mm cell walls filled with local sand as shown Fig. 5. These reduces probability of liquefaction of top soil. Also it has improved resistance against horizontal forces on foundation.

The system of flexible raft evolved is shown in Fig. 5 adopting geotextile filter and "Garware" rope mattress as reinforcement, Rope gabion 1m x 1m x 2m with 8 mm woven polypropylene rope in 100 mm mesh. The sequential filling of boulders 175 mm, 40 mm and sand with specified compaction is illustrated in Fig.5. Photo plates in Fig. 6 shows details as executed at site.

The total plinth area was covered by fiber reinforced cement concrete 1:2:4 grade. This platform carried hexagonal brick wall cells filled with local sand. This wall pattern will provide
base for stone beam and column grid for erection of stone structure.

The foundation is high friction reinforced, confined interlocked and sand sluiced stone pad with geofilter for filtration and drainage (pore pressure release). The specifications of geofilter and rope mattress are shown in Table 1 and 2. The overall functions of pervious stone raft was to provide (a) quick release of dynamic pore pressures & drainage of top 4.5 m layer (b) minimize compressibility by preloading, thus controlling post construction settlements (c) provide relatively stiff material to absorb energy with small deflection.

The total weight of stone structure transferred to foundation Concrete pad is estimated as 72000 tons. The base shear stress for horizontal seismic coefficient was 0.075 for Zone IV was less than 1.5 T/m^2. The factor of safety in horizontal shear was estimated as 9.

Table 1. Specifications of Geofilter fabric (GWF 40-220 Polypropylene Multifilament woven fabric)

Property :	
Mechanical Breaking Strength (IS 1969)	
Warp (kN/m)	62
Weft (kN/m)	46
Elongation at break (%)	26-31
Grab strength (ASTM D5034) kN	1.845(min.)
Mullen Burst (ASTM D 3786) KPa	4632 (min.)
Hydraulic Pore (ASTM D4751)	<0.075 mm
Permiability (ASTM D 4491) Lit./m^2/sec.	6.35

Table 2. Specifications for Rope net

Size of body & border rope	8.0 mm
Weight	30 gms / m ± 10%
Material	Polypropylene with UV stabilization
Mesh opening	100 mm x 100 mm
Breaking strength of rope-net m/width	10,000 Kg. (min.)
Structure	3 Strand Houser laid, tucked joint at intersection

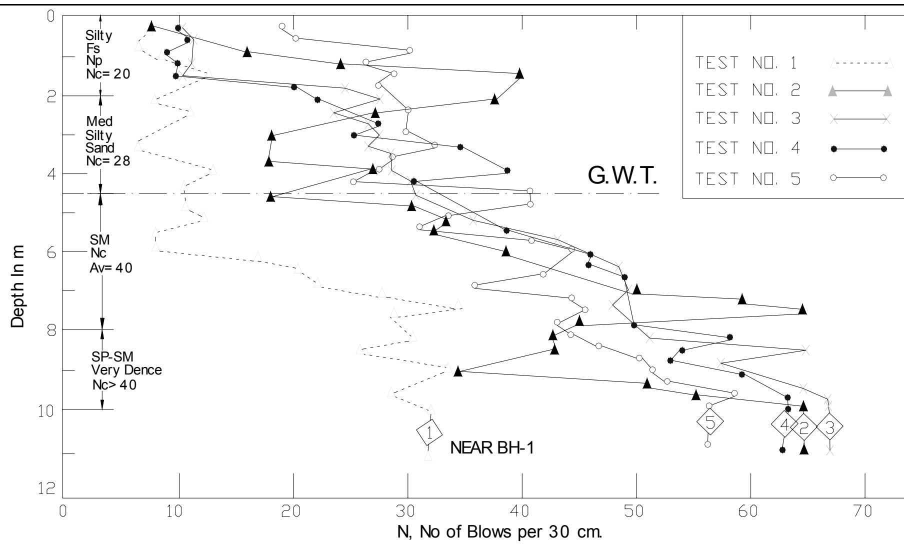
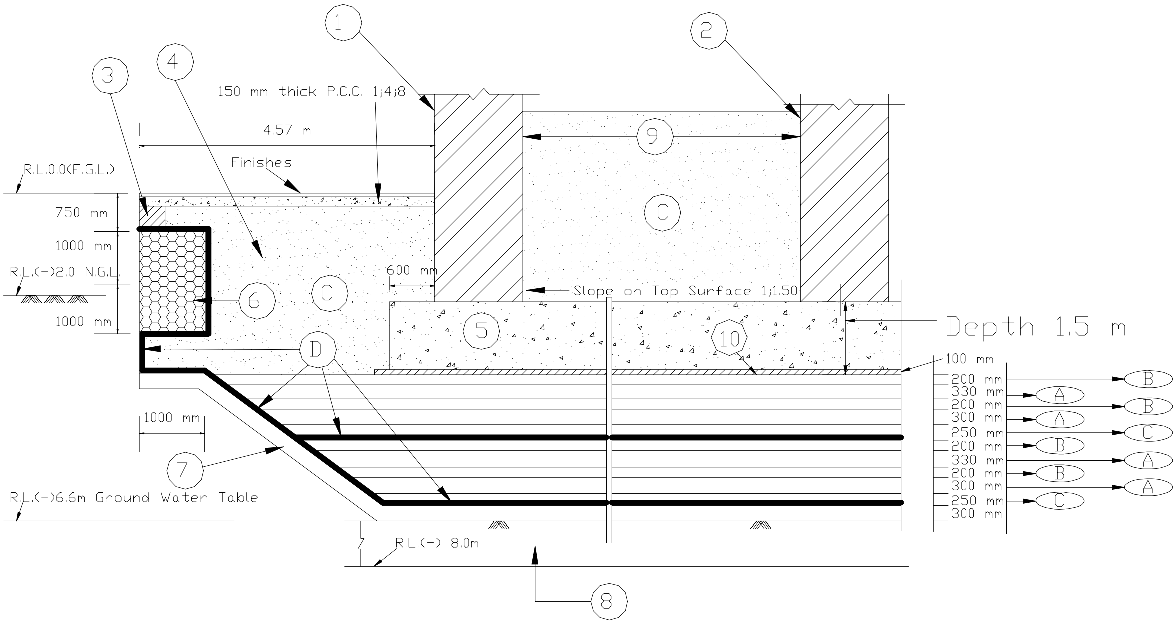


Fig.4. Nc blows per 30 cm by dynamic cone penetration test, soil profile at "Noida" site. (ATES 2000)



(A) Boulders (size not less than 175mm) with smaller in filling stones and quarry spoil/stone screening rolled with 10 T roller eight times. (B)Boulders (size 90mm – 40mm) with smaller in filling stones and quarry spoil/stone screening rolled with 10 T roller eight times,(C) Compacted sand,(D) Geocomposite comprising of rope mattress and geofilter

<u>Legends:</u>
(1) Face of outer plinth wall (2) Outer face of inner plinth wall (3) 345 mm thick brick wall (4) Compacted sand on either side of gabion wall (5) Fiber reinforced PCC 1:2:4 grade (6) Gabion wall 2m high (7) Compacted thick stone soiling (8) Insitu sand compacted by 10 T pneumatic tyred roller to density 1580 Kg/ Cu.m. (9) Hexagonal cell of brick masonry (Bricks of 120 Kg/Sq.cm. strength) (10) 100 mm thick P.C.C. 1:4:8

Fig .5. Foundation system for temple at "Noida"- A typical section.

Fig.6(a). *Sequential construction of the foundation system shown in fig 5 in a typical cross section*

Fig.6(b). Photo plate showing the geo fabric, overlaying rope mattress and stone

The mass of laterally confined stone pad below ground is 65000 tons. Surcharge of Concrete pad and hexagonal base platform would be 24000 tons. The temple stone work would weigh about 30000 tons.

The work of stone pad raft foundation was executed in 90 days at 50% cost of the alternative i.e. pile foundations.

CONCLUSIONS

(1) The design provides vertical mass concrete and hexagonal sand fill cells with massive stone pad replacing liquefiable sand to act as preloading to control settlements which are critical for flexible structure and carved sculptures.

(2) The pore pressure dissipation is provided by a woven geotextile filter cum separator of stone fill and silty fine sand.

(3) To restrict the lateral movements of the foundation under seismic forces, the stone pad is confined by woven rope mattress and Gabions of Polypropylene rope.

(4) The case study illustrates that foundation and ground improvement is still art based of years of experienced based judgment and observations. For monumental structure with number of deciding authorities, conflicting data of structural loads-site conditions-seismicity etc a safe, economical and time bound solution is evolved by interaction.

(5) This solution may or may not be best academically depending on assumptions academicians make in absence of data. Such solutions may not be acceptable as it may not satisfy any one of technologists, artisans, priests, financers etc.

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