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ARCHITECTURAL HERITAGE AND SEISMIC DESIGN WITH REFERENCE TO INDIAN TEMPLE ARCHITECTURE

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SUMMARY

India is a country of temples. Indian temples, which are standing with an unmatched beauty and grandeur in the wake of time against the forces of nature, are the living evidences of structural efficiency and technological skill of Indian craftsman and master builders. The Indian doctrine of proportion is designed not only to correlate the various parts of the structure in an aesthetically pleasing manner but also to bring the entire building into a magical harmony with time and space. In the present paper an attempt has been made to analyze the intrinsic qualities, constructional and technological aspects of Indian Temples from earthquake point of view. Based on an analytical study of Indian temples it highlights the aspects with reference to architectural form and proportion, which largely proved favorable for good seismic performance. It also presents the structural aspects and unique building techniques devised by Indian craftsman and builders in temple construction in order to render them adequate structural strength as far as earthquake occurrence is concerned.

INTRODUCTION

The science of architecture (Vastu Vidya) was a branch of occult knowledge from Vedic times. In the literature the earliest references to the vestiges of Indian architecture can be seen in books like Sthapath Brahman, Aitreya Brahman and Bramha samhita. Several expressions in the great book Rigveda refer to

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very advanced knowledge of building technology. According to Hindu mythology a Purna Vastu or a perfect building is that which is properly oriented and constructed with carefully laid out norms to protect it from the evil forces of the nature, which include floods, storms, hurricanes and earthquakes. The 22nd chapter of Bramha Samhita, which contains 107 chapters on science and technology, describes earthquakes (Bhukamp) and various aspects with reference to earthquakes resistance of the buildings (1). Indian temples, which were invariably built in accordance with these norms, are the living evidences of structural efficiency and technological aspects of the Indian craftsman and master builders (Sthapati).

The concepts underlying Indian architecture can be traced back to the worldview articulated in the Vedas and the metaphysics of the Upanishads (2). The earth on which the temple is built must be consecrated, the water tested, and the consistency of soil examined (6). The chief factor that gives these temples a considerable degree of earthquake resistance is usually their configuration, because they bring a great deal of material down to the ground by regular and direct routes, for example the simple and structurally logical configuration of a Dravida Temple particularly of the main structure (Vimana).

The square building termed as Rekha Deul consists of cubic base bada and the tower proper the Chapra. The assembly hall (Jagmohan) has a square ground plan, the base (Bada) and the terraced roof above in the form of a false vaulting (Pida). The tower terminates in a circular plate upon which rests the, a fruit like finial (Amalaka). All together compose a pyramidal shape, which has an intrinsic advantage that its mass reduces continuously with height (3).

Symmetry and Proportion

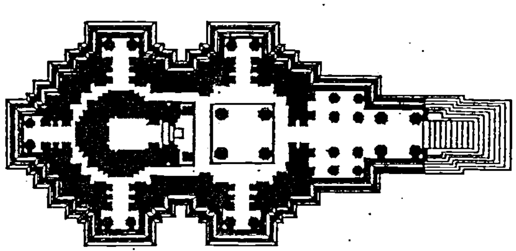
The term symmetry denotes a geometrical property of building configuration. Symmetrical forms are always preferred to those configurations with non-symmetrical profile, because asymmetry tends to produce eccentricity between the center of mass and center of rigidity, which result in torsion. On the other hand asymmetry tends to stress the concentrations. The selection of symmetrical plan shapes and layouts is of great importance in seismic design, because symmetry about the elevational axis is of less dynamic significance than plan symmetry (3).

The square was adopted as the final and equivocal form in Indian architecture. As a perfect form it is used by Indians to indicate the absolute (7). If one consider the earth merely from its physical external, it is depicted as a circle, if however it regarded as the manifestation of the supreme principal Brahma it is rendered as a square fixed by the cardinal points. In Indian architecture the use of square as the basic unit and of triangle as the principle governing the layout resulted in strictly symmetrical plans and layouts along one or two principle axis, which in turn resulted in simple structural systems and an increased structural strength against seismic forces.

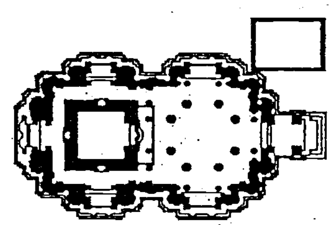
In seismic design the proportions of a building may be more important than its absolute size (2). The Indian doctrine of proportions is designed not only to correlate the various parts of building in an aesthetically pleasing manner but also to bring the entire building into a magical harmony with the space. (8). In all manuscripts the proportion between the length breadth and height of the various parts is the subject of detailed hardly comprehensive rules. These rules which are strictly followed in Indian temples resulted in the proportions seemed to be favorable for better performance against seismic forces.

Structural Plan Density

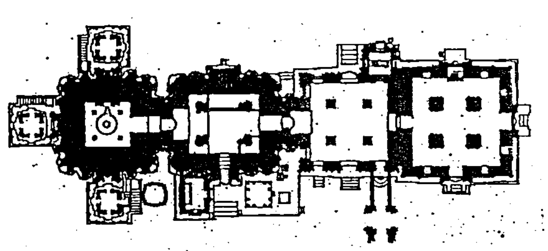
Earthquake forces are generally more at the ground level. The ground story is required to carry its own lateral loads as well as the shear force of the upper floors, which is analogous to the downward buildup of vertical gravity loads (3). This phenomenon is seemed to be well understood by the Indian master builders. Structural plan density defined as the total area of all vertical structural members divided by the gross floor area. The size and density of structural elements is very great in the Indian temples as compared to the today's buildings. For a R.C.C. framed building it is generally 3, but in Indian this can go as high as 47% as it is in the case of the Surya temple Konark (Fig-1 shows the structural plan densities of various Indian Temples).



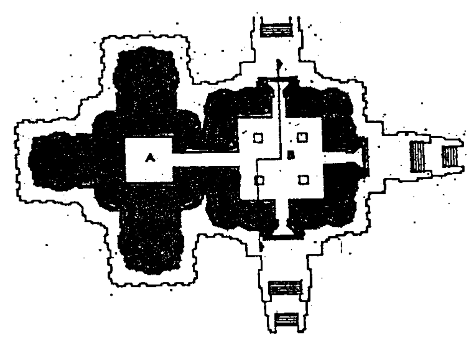
Khanderia Mahadeo Temple
Structural Plan Density-39%



Sun Modhera Temple, Gujrat
Structural Plan Density-28%



Lingraja Temple, Bhubaneshwar
Structural Plan Density-43%



Surya Temple, Konark
Structural Plan Density-47%

Fig.1
Structural Plan Density of Indian Temples

Lateral Resistance of Indian temples

As a building grows taller its period generally increases and a change in period means a change either upward or downward. The period of a building is not solely a function of height to depth ratio, story height, type of structural system and materials and the amount and distribution of mass (2). The structural system used in the construction of the tall pyramidal temple roofs (shikharas) is designed for greater structural strength. The north Indian temples consist of a Girbhagriha or cella, and a Mukhashala or hall for gathering both as a rule are square in plan and have corbel vaulting. In the shikhara the cavity above the cella narrows towards the top in a curve like manner, rather similar to the exterior outline of the tower. The cella is often as wide as two-wall thickness. Where this relation ship is less favorable, for example in the Mukhashala attempts were made to obtain the necessary equilibrium by widening the roof. The corners of a building have their own special seismic problem. South Indian Gopuram have stone only in the lower story while upper storeys are made of brick courses and wooden beams. In addition to this the tower above becomes progressively narrower towards the top corresponding to the tiered divisions of the façade (fig2 shows the typical roof profile of an Indian temple and fig.3 demonstrates the gradual decease in mass of a south Indian temple tower called Gopura).

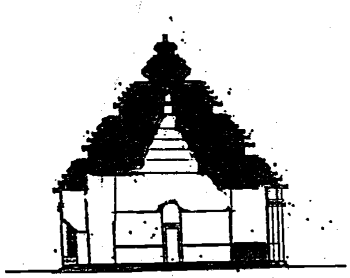


Fig.2
Pyramidal vaulted roof of an Indian Temple

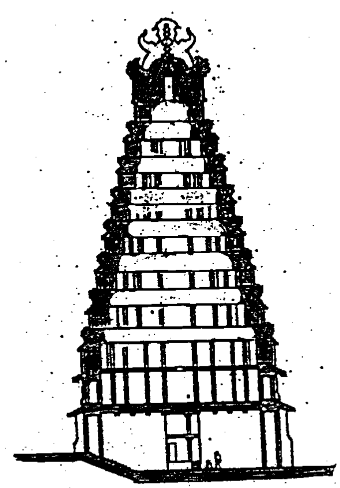


Fig.3
Tall light-weight roof of South Indian Temple

This phenomenon resulted in a lightweight structure, which apparently look massive. In Indian temples corners of the structure were provided with exceptionally large sections. The stones used at the corners are either interlocked (fig.4a) or provided with iron clamps (fig.4b).

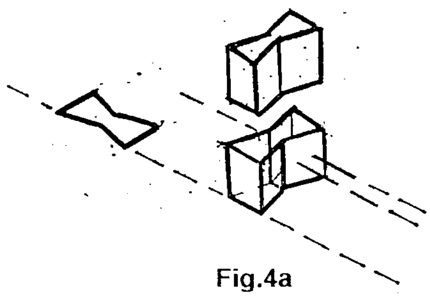


Fig.4a
Interlocking of stones

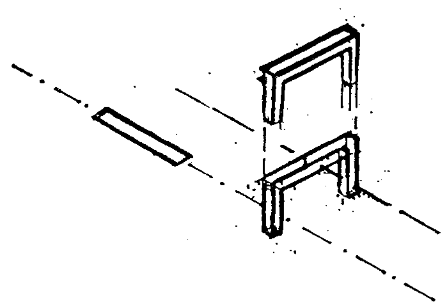
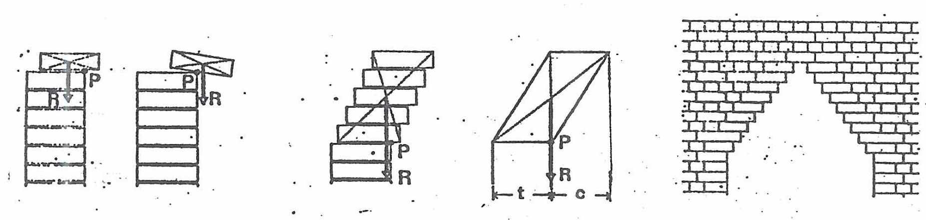


Fig.4b
The use of iron clamps

The Palavas used an excellent technique to provide additional stability to the stone masonry. They laid without mortar with carefully worked out joints. Thin layers of large granite panels were inserted at regular intervals which acted as binders. This phenomenon is resulted an increased structural strength against sideways movements (8).

The Jain temples at Mont Abu are one of the excellent examples of roof construction with a high degree of structural strength coupled with endeavoring aesthetical appeal. In the construction of the low domes of the dancing pavilions they have reached the limits of what was statically possible in the construction with corbelling courses. The vaulting with tiers of concentric rings supported only by columns rises above an octagon consisting of architraves. Here the joints through frictional resistance absorb a large part of the horizontal thrust. Spacious pilastered halls frequently surround the low-corbelled domes so that the eight columns below the octagonal architrave should not have to bear the thrust alone. (Fig-5 demonstrates the placing of stone in corbelled roof).



The stone will topple over from its own weight unless its center of gravity rests within the limits of wall. Therefore stones are placed above one another in a way that their center of gravity rests within the same limits i.e. to the left of the pivot (p).

Fig.5
Placement of stones in vaulted roof of Indian Temples

The Sthapati (Architects) devised many efficient ingenious solutions to provide adequate structural strength to various roof profiles for example the roof of Varahi Temple at Caurasi. The stone slabs jutting out into the chamber also project on the other side of the wall partly as an extensions of the roof to such an extent that remains between the arms the arms was bridged by thin light stone slabs. Because of this slight extra weight the resultant must have been shifted close to the pivot. Some of the roof slope inwards and only extensive supports in the interior will prevent the roof slab from collapsing. The roof like the ground plan is rectangular in every horizontal section but the vertical joints in the corbelling were not set at right angles to the ceiling of the chamber instead they were set radialy as though this were a circular building. If stone slab tips over it cannot fall since it cut in a conical shape and held in position by the neighboring slab (8).

The roof of the Mandapa at Konark, Puri and Khajuraho temples is supported on four massive pillars. In all three cases to encounter the possibility that horizontal thrust might force the building to break apart, the colonnade was made to carry some of the load of the roof. The corbel- vaulting which was added transferred the horizontal thrust to the thick enclosure walls (4). The line of force is similar to the system used in Gothic Cathedrals where a line of pillars carries the vertical loads and the horizontal thrust is diverted to the buttresses.

CONCLUSION

The characteristic configuration, simple geometric form of the Indian temple has increased structural strength against earthquake movements. Thoughtfully conceived design and constructional practices, which were executed with an extraordinary perfection (5), resulted in the creation of these everlasting, structurally sound structure, which have proved earthquake resistant to a considerable extent. The architectural heritage of India is full of possibilities which can provide the basis of inspiration for future requirements, if we can derive from them the fundamental aesthetical values constructional techniques in building design which may sometimes be valid in the very changed circumstances of today.

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