

Building Science of Ancient Indian Temples

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Abstract

Each culture and era has a distinctive construction practice which is unique and represents the ideology, development, art and architecture of that particular era or culture. In this context, the Hindu Temples are epitome of knowledge, art, architecture, culture and represents the advancement of building science of the ancient Indian subcontinent. The ideology and tradition of Indian Temple exists not only in history but also in the present era which gives a sense of flow to traditional Indian values and also creates a profound impact on the socio-economic life of the people. This paper deals with the styles, design and geometry, structural system and construction technology of the Indian temples. The distinctive architectural styles and elements of Hindu Temple are also presented in this paper. The structured systems which were prevalent in the Indian temple construction are explained in this paper. The construction technology starting from the selection of the team to planning, carving and assembling of individual pieces are also detailed in this paper. The relationship between structure stability and symmetry and proportion of Indian Temples is also presented here which explains the resistance of Indian Temples against Seismic forces and other environmental effects.

Keywords: Ancient Indian Temple, Geometry.

1. Introduction

The Hindu temples known as *Mandir* in Hindi. The word *Mandir* was derived from Sanskrit word *Mandira*. Although the architecture of the Indian temple varies across the India, its basic element

remains the same. The temple in India as an architectural entity, emerged with certain concepts about God and gods (human beings). They started to develop somewhere around 4500 years ago during the mature phase of Indus-Saraswati or Harappan Civilization (2600-2000 BCE) [1]. The temples in these periods were open air shrines kept under sacred trees or near water bodies which changed with the onset of Mahajanapada period (700 BCE). In this period, the concept of temple as closed structure gained prominence with the ordinary thatched huts of the villages of Northern India in the period between 700 to 500 BCE providing an early model for the temple builders. The multi-storeyed temples began to be constructed in the Sunga- Kusana period (200 BCE-200 CE) [1]. In 320 CE, the Gupta empire was established and the concept of Duality in Bhakti- the god and the devotee, the former being the most sacred entity, gained prominence. And due to this concept, two spaces were provided in the temple, one for the God (*garbha-grha*) and one for the devotees (*Mandapa*). An early example of such an arrangement is Sanchi Buddhist temple [1]. The limitation to vertical monumentality and height was broken in late fifth and early sixth century in Gupta period with a second storey as well as *shikhara* or *vimana* becoming a common feature in Indian temples. Also, one of the most interesting features of these temples is that they were raised without the use of mortars. The development of temple architecture or iconography took place prominently in this period as mythologies and deities were translated in stone and became ornamenting the entities of the temple structure. Upto the fifth century, there was a unilinear development in the temple architecture but with the onset of seventh century, the temple construction

took a turn for regionalization. The North Indian or the Nagara style adopted a curvilinear *sikhara* ending with a pointed finial at the top whereas the south Indian or Dravida style developed stepped *vimana* ending in a round *stupi*. In modern times, the temple construction in North India became more confused whereas the temples of South, Gujrat and Orisaa continued following the traditional temple construction practices.

Several treatises on architecture and construction such as the *Vedas*, the *Brahamanas*, the *Upanishads* and the *Bhagvad Gita* gives surprisingly accurate details on *pramana* (measurement) techniques, materials and other structural specification of the Indian temples [2-3]. The technical treatises in the field of the architecture and sculpture which gives the basic layout for the construction of temples are *Shilpa Shastras* and *Vastu Shastras*. The Mayamata and Mansara are the two most referred treatises of Southern India on architecture and iconography and the rules laid by these treatises are rigidly followed for the temple construction. It contained details about the science of the accurately laying out the ground temple, keeping in mind the astronomical and other cosmic movements and position which is also known as *mandala* [4-5]. The *mandala* is basically a sacred form consisting of the intersection of the circle and the square [6].

The Indian temple is a depiction of macrocosm (universe) as well as the microcosm (the inner space). The idea behind the development of Hindu temple is to link man with the god. Hence, the temple with all its architecture and decoration and rituals, is a place to get ultimate liberation which is the guiding philosophy of Hinduism [7]. The Indian temples also act as a place for more intellectual and artistic development. The temple complex housed schools, hospitals and courts for general citizen and its spacious halls were used for the recitation of Mahabharat and Ramayana. The temple maintained its sustenance through the income generated from the cultivable land which was assigned to it by the king [8]. It also provided livelihood for large number of persons and greatly influenced the economic life of the community.

The main objective of this paper is to give a comprehensive view on the style, design and geometry, structural system and construction

technology of the Indian temples. The relationship between structure stability and symmetry and proportion of Indian Temples is also given here which explains the resistance of Indian Temples against Seismic forces.

ELEMENTS OF HINDU TEMPLE

The Hindu temples adopted a definite structure in the later half of the 7th century [9]. The common elements of the Hindu temples in their original Sanskrit terms are as followed [2,8]:

The main compound of the temple is known as *Vimana* which comprises of two parts. The top portion of the *Vimana* is known as *Sikhara* and the lower portion which lies inside the *Vimana* is called *Garbhagriha* (cella or inner chamber), see also (Fig. 1 and Fig. 2)

1. „*Sikhara*“ refers to the spire or the tower. It is shaped as pyramidal and tapering representing the mythological „*Meru*“ or the highest mountain peak.
2. „*Garbhagriha*“ refers to the womb chamber which is the innermost chamber of any temple where the deity resides. It is mainly square in layout and is entered through eastern side.
3. „*Pradakshina Patha*“ refers to the ambulatory passageway for circumambulation and comprises of enclosed corridor outside the *garbhagriha*. The devotees walk around the deity in clockwise direction, paying their respect to the deity.
4. „*Mandapa*“ is the pillared hall in front of the *garbhagriha*, used as assembling point by devotees for chant; rituals meditate or observe the priests perform the rituals. Sometimes, „*Natamandira*“ is also provided in some temples which mean the hall for dancing. In some early temple structures, the *mandapa* was isolated and separate structure from the sanctuary.
5. „*Antarala*“ refers to the intermediate chamber which joins the main sanctuary and the pillared hall of the temple premises.
6. „*Ardhamandapa*“ refers to the front porch in the main entrance of the temple which leads to the main temple. Some other essential structural elements found in the Hindu temples are:
7. Mainly found in the south Indian temples,

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- „Gopurams“ are the monumental and ornate entrance to the temple premises.
- 8. „Pitha“ or the plinths of the main temple.
- 9. The gateways typical to north Indian temples are „Toranas“.
- 10. The „Amalaka“ is the fluted disc like stone placed at the pinnacle of sikhara

THE GEOMETRY OF HINDU TEMPLE

The Hindu architecture was among the first ones that established a relationship between human figure and the system of proportion which was later studied by Leonardo da Vinci and Le Corbusier in modular system of measurement. It is based on the geometry of *Vastupurashamandala* in which the form of *Purasha* was made to fit the abstract idea of square as the highest geometric form [10]. The basic form of *Vastupurashamandala* is the square which represents the earth and the circle represents the universe suggesting timelessness and infinity (see Fig. 3). The *mandala* is actually a square divided into smaller squares arranged in the form of a grid. Each smaller square depicts the area of the respective Gods. The most commonly used *mandala* is the square subdivided into 64 and 81 squares. Thus, the *Vastupurashamandala* was the basis of the ground floor plan for all Hindu temples. The basic shape of the temple plan was : the outermost ring of square of the *mandala* from thickness of walls of main shrine, the central 4 squares was reserved for the main deity, the inner ring of 12 square form the walls of the *garbhagriha* and the next 16 to 28 forms the *pradkshina patha*. These simple divisions of square with permutation and combination became the base for the development of more complex temple compound.

Fig. 1: The typical Hindu Temple plan depicting various elements [8].

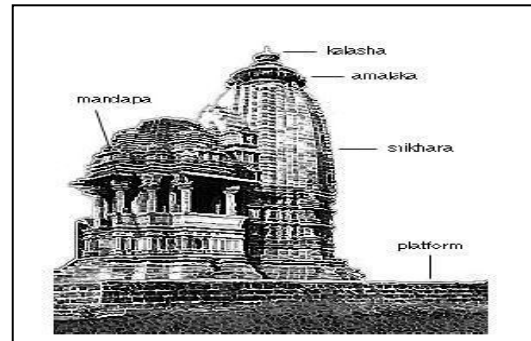
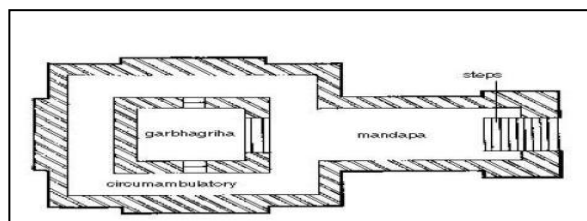


Fig. 2: The typical elevation of Indian Temple depicting various elements [8]

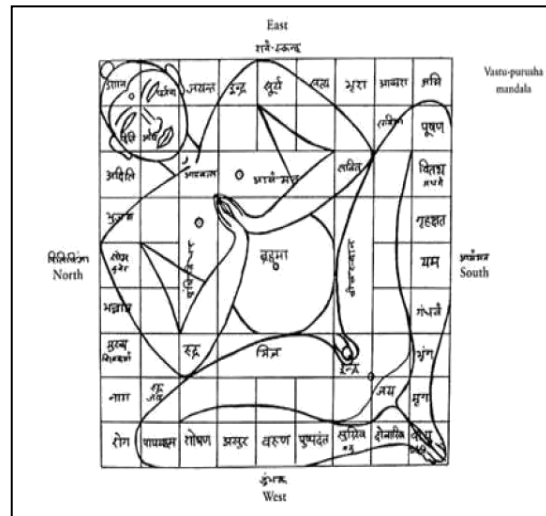


Fig. 3: Vastupurashamandala

CONSTRUCTION MATERIALS

The temples were constructed with all types of materials depending upon the availability from region to region. The materials varied from timber to mud, plaster, brick or stone incorporating the entire India. The material played a significant role in overall aesthetics, construction techniques and monumental character of the temple.

Earlier temple structures were constructed with less durable materials such as timber, brick or plaster and thus, have mostly disappeared or only fragment

remains. Sites excavated in Vaisali in Bihar shows examples of temples constructed with mud or mud brick. The usage of timber and bamboo was mainly in the temples of Himalayan valleys and the region of West Bengal and Kerala. The construction of the temples with bricks was prominent in pre Christian era but were limited to those area where suitable stone or bricks are available. The use of stone for temple construction was one of the prominent developments in Indian temple architecture [7]. The construction from stone evolved from rock cut sanctuaries (Stupa, Sanchi) to more complicated structure with ornate carvings and sculptings.

Fine grained dark marble and soapy chloritic schist was used by later western chalukyas who established themselves in the tenth century around the areas of Malkhed and kalyani. Jain temple of Lakkundi is a great example of this era. Earlier Pallava temples were constructed of hard igneous rocks such as granite (Olakkannesvara temple), leptinite (shore temple of Mamallapuram) and gnesis (Mukundanayanar temple). At later stages especially during Pandya era (around 6 century), the lower portion of the temples were being constructed using solid granite stone masonry whereas the lighter materials like brick, timber and plaster were used to construct the super structure [1]. The Hoyasala Empire (a prominent souther empire) which ruled over parts of Karnatka, parts of Tamil Nadu and Andhra Pradesh used greenish grey soapstone which were soft and sculptor friendly [1]. The temples of Kerala primarily used timber, tiles or copper sheet to build super structure whereas the vimana was constructed using granite or hard laterite blocks. The temples of Himachal Pradesh were generally built using the combination of wood and stones generally in dry stone machinery. The architects of Bengal used laterite, bricks, wood, terracotta or mud for erecting different types of temples with lime or mud mortar as binding materials.

THE STRUCTURAL SYSTEMS OF THE HINDU TEMPLES

The tarbeated system or the post and lintel method was the basic construction technique used in Hindu temples which was later developed into corbelling techniques. This method was primarily used for wooden construction but later evolved for stone

construction.

TRABEATED SYSTEM

In the trabeated system, the various arrangements between vertical elements (pillars and pilasters) and horizontal elements (cross beams and lintels) are used to provide the stability to the system. The most salient feature of the tarbeated system is that only horizontal and vertical members are used in this system and the spans were used to close the interior spaces. The roofing was done by laying horizontally the slabs of stone from one supporting beams or walls to another.

CORBELLING SYSTEM

In corbelling system, each horizontal course is constructed in such a way that stone or bricks in each layer are projected out to bridge the gap between the two walls. It diminishes the space until it can be closed with a single piece of stone or brick. It was primarily used to create interiors of the temple and stone shells of super structure above the sanctuary.

The Construction Technology of Hindu Temples

The available information of temple construction was collected from stone slabs, metal plates, palm leaves and manuscripts. Primarily, both Dravidian and Nagara temple construction followed same procedures up to construction of the temple. The slight variation occurred due to the variability of materials used for construction, the climate or the availability of manual labors for construction.

It started with the selection of team headed by chief architect (sompuras in the west, mahapatras in the east and sthpatis in the south). The construction team consisted of four classes: 1) *Sthapati* (Main architect versed in traditional science, mathematics and Shilpashastras) 2.) *Sutragrahin* who did the work assigned by sthapati 3.) *Taksaka* who did the carving and cutting of stone 4.) *Vardhakin* is the mason or carpenter who assembled all the pieces.

The construction of temple was a long and **tremendous** process which sometimes used to last for years. The first stage was the planning of the temple where the *sthpati* with the team did the

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selection of site, inspection of site, orientation and layout of the site, selection of materials, quarrying and transportation of materials. The layout was done on the basis of Indian Circle Method and with the help of instrument known as „*shanku yantra*“. The nature of main deity played a major role in determining the orientation of temple. The stone which was to be used for construction must have some quality features such as even color, hard and perfect and pleasing to touch. The second stage was the carving of different parts of the temples in which the *takshaka* directed the sculptors and *shilpis* to carve parts according to the drawings and specification. The cutting and carving the stone was done according to pre defined shape. The joining was also pre decided and rough joinery was created while cutting. The tools required such as hammers, chisel were locally made and sharpened regularly. The sketching was done either by charcoal piece or sharpened bamboo pieces. The polishing was done using stone bars. The third and the final stage consisted of assembling of the parts of temple which consisted of the actual construction of the temple. Ramps were constructed for the easy placement of heavy materials. The major joinery system used during the assembling of temple were mortise and tenon joint (peg is fixed between the two mortise cut out in two different stones and was used primarily used between two courses of masonry to avoid movement due to lateral forces) and lap joint. The usual thickness of stone used for wall varied from 800 mm to 1200 mm. The column consisted of 5 parts as two parts of base, one part as shaft and two as the capital of column. Also, columns and beams were monolithic structure.

STRUCTURAL PLAN AND EARTHQUAKE RESISTANCE

The 22nd chapter of treatise Brahma Samhita contains 107 chapters of technology and science which presents various aspects related to earthquake resistance of the buildings [12]. One of the chief factors which provides these temples considerable degree of earthquake resistance is their configuration as they provide a regular and direct route for material to come down, such as the configuration of Dravida temple particularly of the main structure.

Symmetrical forms are always preferred from earthquake resistance as asymmetrical forms produces eccentricity between the centre of mass and centre of rigidity which results in the torsion and tends to stress the concentration. Thus selection of symmetrical plans and layouts is important in seismic design [13]. The square is selected as the basic unit and of triangle as the principle controlling the layout which concluded in strictly symmetrical plans.

Earthquake forces are felt more at the ground level. The ground story has dual purpose as apart from carrying its own lateral loads it also carries the shear force of the upper floors which is similar to the downward building of vertical gravity loads [14]. Structural Plan Density is defined as the total area of all vertical structural members divided by gross floor area. For a RCC framed building it is 3 but it is as high as 47 % for Surya Konark Temple giving it earthquake resistance. As building grows taller, its period increases with a change either upward or downward. The period of building is not a function of height to depth ratio, story height, type of structural system and amount of distribution of mass. The construction technique used in construction of tall pyramidal temple roofs (Shikharas).

CONCLUSIONS

The temple architecture portrays the advancement of ancient Indian building sciences. This paper discussed the styles, design and geometry, structural system and construction materials and technology of the Indian temples. The distinctive architectural styles of Hindu temples *Nagara* and *Dravidian* are also discussed in the paper along with the distinctive elements of Hindu Temple. The relationship between structural stability and symmetry and proportion of the Indian Temples is also given here which is used to explain the resistance of Indian Temples against seismic forces and other environmental effects

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