ADVANCED MASTERS IN STRUCTURAL ANALYSIS
OF MONUMENTS AND HISTORICAL CONSTRUCTIONS

# Master's Thesis

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# Building Science of Indian Temple Architecture

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# Abstract

Every style of building construction reflects a clearly distinctive basic principle that represents a particular culture and era. In this context the Indian Hindu temple architecture are not only the abode of God and place of worship, but they are also the cradle of knowledge, art, architecture and culture.

The practices and traditions of temples exist not only in history but also in present time which greatly influence the socio-cultural life of its people and gives continuity to traditional Indian values. The evolution of Indian temple architecture is marked by a strict adherence to the original ancient models that were derived from religious consideration- and that continued over many centuries.

The Hindu religion and its philosophy greatly influenced Hindu temple architecture in its evolutionary process which continues till this date. Therefore this dissertation through archival research and other documentary, literary works and theoretical investigation on ancient treatise and modern research works on the temple architecture of India brings out the concepts that have been adopted since ancient times for the construction of the sacred Hindu temples, the science involved in the construction of the temple structure and the processes involved along with the skill it took to build such edifices.

Together these aspects bring out the art, science and philosophy behind the construction of the Hindu temple which is as relevant today as it used to be in the ancient times. A continuity of tradition and a science which has its root in the dawn of human conciousness.

# Resumo

Cada tipo de construção reflecte um princípio básico claramente distinto que representa uma cultura e época em particular. Neste contexto a arquitectura dos templos Hindus não figura apenas a casa de Deus e local de culto, mas também o berço do conhecimento, arte, arquitectura e cultura.

As práticas e tradições dos templos existem não apenas no passado histórico mas também no presente, o que evidentemente influencia a vida sociocultural da população e dá continuidade aos valores hindus. A evolução da arquitectura dos templos hindus é caracterizada por uma concordância rígida relativamente aos modelos antigos, que resultaram de contemplações religiosas – o que continuou por muitos séculos.

A religião Hindu e a sua filosofia influenciaram largamente a arquitectura dos templos Hindu e o seu processo de evolução contínua até aos dias de hoje. Por isso, esta dissertação que teve por base a pesquisa de arquivos e outros documentários, trabalhos literários e investigação teórica de dissertações antigas, assim como pesquisa de trabalhos recentes sobre a arquitectura dos templos na Índia, demonstra os conceitos que têm sido adoptados desde a antiguidade na construção dos tempos sagrados Hindus, a ciência utilizada na construção da estrutura dos templos e os processos envolvidos, assim como a perícia necessária para construir tais edifícios.

Em conjunto, estes aspectos revelam a arte, ciência e filosofia subjacente à construção dos templos Hindus, que é tão importante hoje, como o foi na antiguidade. Uma continuidade da tradição e uma ciência que tem a sua origem no despontar da consciência humana.

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# Chapter I

# 1 RESEARCH BACKGROUND

*"Architecture is that great living creative spirit which from generation to generation, from age to age, proceeds, persists, creates, according to the nature of man, and his circumstances as they change. That is really architecture."* …….Frank Lloyd Wright

*"Architecture is the matrix of civilization"…..*Lethaby

A study of history of architecture shows that the meaning of architecture and its relation to human experiences have been expressed in number of ways in the past. The intellectual and creative development of man manifested itself in the varied nature of architecture in different ages and across different civilizations. Thus, all over the world, various civilizations and cultures have contributed greatly to the art of building construction and which have been revealed in substantial form (Rowland,1953).

Every style of building construction reflects a clearly distinctive basic principle that represents a particular culture and era. For example, the strict and formulaic building design in Greek architecture exhibits a sophisticated aptness, whereas the Roman building design which are impressive even by modern standards, were based on their advanced technology (Brown, 1942). Similarly, a uniquely zealous French Gothic signifies a passionate culture and the Italian Renaissance reflects the artistic scholarship of its time. In the same way, the typical quality of early Indian architecture lies in the expression of spiritual contents through its temple architecture.

In India the temples are found everywhere varying from small villages to the metropolitan cities. The word '**temple'** is derived from the Latin word *templum* means a sacred precinct. According to the definition temple is a structure reserved for religious or spiritual activities, such as prayer and sacrifice, or analogous rites. Traditionally, the temple is a sacred structure and also an indicative of abode of god or gods. However the Indian temples are not only the abode of God and place of worship, but they are also the cradle of knowledge, art, architecture and culture. The practices and traditions of temples exist not only in history but also in present time which greatly influence the socio-cultural life of its people and gives continuity to traditional Indian values. However, unlike the western architecture, the evolution of Indian temple architecture is marked by a strict adherence to the original ancient models that were derived from religious consideration- and that continued over many centuries with the use of the basic proportion and rigid forms of the early temples.

One of the most significant highlights of Indian architecture has been the evolution of the Hindu temple architecture. The Hindu temple architecture is distinguishable from the Jain and Buddhist temple architecture. Jain temples are seldom simple, the most elaborate of them a result from

multiplication of the basic forms. The main difference between the Jain and Hindu temple is the lighter and more elegant character of the former. Buddhist shrines differed from those of the Hindus and Jains in two principal respects: they were designed for congregational as well as devotional use by the monks and in their design decorative detail was used to emphasise rather than conceal the structure. By comparison to Buddhist and Jain structures, Brahmanical and Hindu buildings conformed to a rigidly prescribed plan form leading to a single focal point in the temple group (Fletcher,1992).

## 1.1 Aim:

This dissertation focuses on the study of the Hindu temple. There has been a lot of research into Hindu temple architecture, still many aspects of this subject is still unexplored. This study attempts to collate all the existing research that has been undertaken in this field, and potentially contribute to the exisiting body of knowledge through a structural analysis of Hindu Temple architecture.

This dissertation presents the philosophical and practical aspects that govern the construction of a Hindu temple building with the aim to understand how it influenced the form of the Hindu temple in its evolutionary process. The various stages of temple construction and construction techniques that have been employed in temple construction since ancient times has been studied not only though archival research but also through a comparitive study of these important aspects and their relevance in modern day Hindu temple construction.

Finally the dissertation aims to present a dimensional study of temples taken from different time periods from the northern and the southern styles respectively for the safety assesment of the temples.

Therefore the objective of the dissertation is as follows-

## 1.2 Objectives

1. Understand the basic concept of Hinduism and its relevance on the design and construction of Hindu temple architecture.

2. Present a study of the concept of a Hindu temple, its evolution, development of its architectural styles along their materials of construction with the main focus on Nagara or ‘north indian style’ and Dravidian or the ‘south indian style’.

3. Identify and synthesize the geometry and structural systems of Hindu temple architecture with examples from the Nagara or ‘north indian style’ and Dravidian or the ‘south indian style’ Hindu temples.

4. Studying the material characteristic, construction techniques and process involved in the construction of a Hindu temple.

5. Dimensional study of the temples with respect to the simple indexes for the safety assesment of the stucture.

## 1.3 Methodology

This dissertation is based on archival research and other documentary, literary works and theoretical investigation on ancient treatise and modern research works on the temple architecture of India.

The archival research has helped to bring out the basic concept of Hinduism and how it influenced the design of Hindu temple architecture. The *Vastushastra* and *Shipshastra* along with other general manuals on Hindu architecture have been referred to highlight the concepts that have been adopted since ancient times for the construction of the sacred Hindu temples.

This dissertation brings out the differences in the form and scale of the Hindu temple with the help of examples from the 'north indian style' and the 'south indian style' temples, highlighting that though the elements of Indian temples may differ across regions they were all based on a single philosophy of design. The design philosophy of the Hindu temple is based on concepts of Hindu cosmology ie the divine '*Vastupurushamandala'*.The infuence of this basic divine concept on the layout of the temple plan and its external and interanl forms and features is further explained with the examples of temples of the 'north indian style ' and the south indian style' from different time periods.

A study of the plan of the Hindu temple and various other elements of the temple along with the form and sizes in which they evolved over centuries of temple development form the basis for understanding the structural basis for adopting certain traditional construction techniques for the construction of these temples.

This dissertation also presents the construction technology of the Hindu temple the processes involved during its construction, the human skills required and methods utilized by architects and their team. Together these aspects bring out the art, science and philosophy behind the construction of the Hindu temple.

The dimensional study with respect to the simple indexes analysed in the dissertation is an attempt to look into the safety assesment of the Hindu temple structure. Studies have been conducted from the drawings and information available in the books, journals and websites.

## 1.4 Limitations

The scope of this dissertation is mainly the *Nagara* 'north Indian style' and the *Dravidian* 'south Indian style' temple architecture, the two major forms of temple architecture styles that marked the high point of Hindu temple architecture in India. It looks into aspects of their origin and development, the philosophy which created them and the way in which this philosophy can be interpreted for better understanding of the structure itself and the time and society that created them. However in this study the root of the Hindu temples i.e. the Buddhists temples is not covered. Also, since the Jain temples

are not fundamentally different from the Hindu temple architecture in that they differ in the iconography rather than form and style, it has also not been included in the scope of the present study.

This study also does not take into account the details of different types, forms and architectural features developed amongst the '*Nagara'* and the *'Dravidian'* style. The study is primarily limited to temple construction in stone and not those built with other materials like wood and brick. The study does not include the temples constructed of wood from the regions of Kerala and the foot hills of Himalayas. The stone temples from the Kashmir region which have there own distinct style, the early rock cut architecture temples and temples built during the 14$^{th}$ century and later which developed new forms due to the fusion of two different cultures is also not included here. The dimensional study of the temples was restricted to few examples from the north and the south temples due to the limited availability of the required information and drawings.

Also since this study could not be supplemented with field work in India most of the information is gathered from the secondary sources.

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# Chapter 2

# 2 HINDUISM AND ITS RELEVANCE TO ARCHITECTURE

*"The temple is the most characteristic artistic expression of Hinduism, providing a focus for both the social and spiritual life of the community it serves."".....Goerge Michell*

The main purpose of the early building art in the Indian sub-continent was the representation of the existing religious perception of the people in a tangible form. Therefore early Indian architecture in the form of various sacred monuments is essentially a representation of its religious beliefs. The earliest significant known buildings relate to Buddhism and Jainism. Those related to Hinduism were to follow soon after the beginning of the Christian era when the Vedic Gods were superseded by the Trimurthy of modern Hinduism. The Hindu temples that came to be known for their ornamental value are also symbolism of Hindu philosophy.

Hinduism is the oldest and among one of the largest religious traditions practiced till date. It has flourished for over two thousand years in many parts of Asia covering Indian sub-continent, the peripheral sub-Himalayan valleys and major parts of south–east Asia. It spread as religious, social and political force during this period. Even though the remnant of Hindu culture are seen throughout the south-east Asia, India, Nepal and Bali are most predominantly Hindu.

**"Hinduism is not a sole religion, it is the collection of costumes of various religions which are native and predominant in India, does not believe in any one philosophic concept or any single God, thus may be broadly described as a way of life."**

This chapter discusses the basic concept of Hinduism and its relevance to the design of Hindu temple architecture.,

## 2.1 Origin of Hinduism

Hinduism is the religion and social institutions of the great majority of the people of India. Hinduism has no fixed scriptural canon but its doctrines are to be found in certain ancient works, notably the *Vedas*, the *Brahmanas*, the *Upanishads*, and the *Bhagavad gita* (Baker, 1969).

The oldest Vedic text '*Rig Veda'* expresses the land of the Indo-Aryans as *Sapta Sindhu* (the land of the seven rivers in northwestern South Asia, one of them being the Indus) (Wikipedia 2008). The word Hindu is the name of river Indus in Persian and this term was mostly used by the Persians and Greeks for the people who reside around the river Indus and without any religious connotation. Later, the term was extensively used by Mughal empires and towards the end of 18$^{th}$ century by the British for referring to religious, spiritual, and philosophical traditions of the Indian sub-continent thus creating clear distinctions between the religious cults of Hinduism, Sikhism, Buddhism, and Jainism.

The dark skinned Dravidians are said to have established a civilization in the Indus valley between 3250 and 2750 BC. They were polytheists who worshipped a number of nature gods; some elements of their beliefs persisted in Hinduism. They were subdued by a light skinned Aryan people who invaded the Indus valley around 1500 BC. The language of these Aryan people was *Vedic,* parent of Sanskrit in which their religious literature (the *Vedas*) came to be written after many centuries of oral transmission (Baker, 1969).

The *Veda* or Sacred Lore in the form of *mantras* or hymns of which there are four great collections, the best known being the *RigVeda*. These Vedic Aryans worshipped nature-deities, *Indra*(rain), *Agni* (fire) and *Surya* (the sun). Their religion contained no idolatry but later absorbed the beliefs of the conquered Dravidians. Sacrifice and ritual became predominant in a ceremonial religion.

As a reaction a more philosophic form arose (in 500 BC) with its scriptures in the *Upanishads*. At its highest level, known as *Brahmanism,* belief is in a subtle and sophisticated form of monotheism (*Brahma* is an impersonal, all embracing spirit), but there is a tolerant acceptance of the beliefs of Dravidians. Thus *Vishnu* (a conservative principle) and *Siva* ( a destructive principle) grew out of Vedic conceptions. The two great doctrines of Hinduism are *karma* and transmigration. The universal desire to be reunited with the absolute (the *atman or Brahma*) can be satisfied by following the path of knowledge. Life is a cycle of lives (*samsara*) in which man's destiny is determined by his deeds (*karma*) from which he may seek release (*moksa*) through ascetic practices or the discipline of Yoga. Failure to achieve release means reincarnation- migration to a higher or lower form of life after death- until the ultimate goal of absorption in the absolute is reached (Baker, 1969).

In the great Sanskrit epic poems *Ramayana* and *Mahabharata* the deity takes three forms, represented by the divine personalities of *Brahma, Vishnu,* and *Siva*. There are also other gods, demi-gods, supernatural beings, and members of the trinity may even incarnate, as *Vishnu* became identified with Krishna, one of the driving charaters of *Mahabharata* and the *Bhagavadgita*.

## 2.2 Gods and Cults

The ritual and legalistic side of Brahmanism is the caste system based on the elaborate codes of the Law of Manu, according to which God created distinct orders of men as he created distinct species of animals and plants. Men are born to be brahmins, soldiers, agriculturists, or servants (Baker, 1969).

Thus the early Hindu Aryan society was socially divided into four classes (*Varnas*) and their rituals involved worshiping of the abstract forms of natural forces such as fire, water and wind and they chanted the Vedic *mantras* (hymns) and performed fire sacrifices but did not build temples. Later, when the rituals became complicated they required priests to perform the rituals and thus a distinct priest class was developed among other classes. Rise of class system in Hinduism gave birth to various unorthodox groups that developed around 1$^{st}$ millennium BC. These groups opposed the caste system and the rituals performed by the priests, and gave birth to two new major religions:

Jainism and Buddhism. Both the religions, Jainism and Buddhism in their early stages of evolution did not encourage the use of religious images or shrines. During the rule of Emperor Asoka, masonry structures were erected, to offer service to the Buddha and to spread the message of Buddhism. It is in Buddhism that one owes the earliest monumental architecture still more or less intact in South Asia, consisting of mounded reliquaries or stupas, monasteries and rock cut sanctuaries (Brown, 1942).

The devotional worship through sculpted images increased during third and second centuries among various cults and grew and merged into the true form of Hinduism (Brown, 1942). Hinduism is today a religion of innumerable gods and goddesses; still throughout the religious history one finds two major cults in the religion those of male gods Shiva and Vishnu. The third cult, the mother or goddess who is essentially the consort of Shiva also holds great importance. Many of the Hindu temples are devoted to the worship of these cults.

## 2.3 Treatises

There are several ancient scriptures and books in Hinduism. These scriptures were mostly written in Sanskrit language and categorised as *Shruti* ("that which is heard") and Smriti ("that which is remembered"). This consists of the *Vedas*, the *Dharmas Shastras*, the *Purans*, the *Upanishads*, the *Shilp shastras*, etc. These scriptures guide Hindus in their daily life, help preserving the religious dimensions of family and society, gives knowledge of medicine, astrology, sociology, philosophy of religion, techniques and structural rules on architecture. The technical treatises in Sanskrit on the basic rules in the field of architecture and sculpture are called as the *Shilpa Shastras* and *Vastu Shastras*. The *Mayamata* and *Mansara* are the two well known treatises of South India on architecture and iconography respectively. The rules from these treatises were strictly followed for the construction of temples which are still present throughout the country in different forms and styles dating back from the 5$^{th}$ Century A.D. 'The typical plan of a Hindu temple is an illustration of sacred geometry where the temple is representation of the *mandala*. Here the sacred geometry means the science of the accurate laying out the ground floor of the temple in relation to the astronomical movements and positions and the cardinal directions. The *mandala* is the sacred form consisting of the intersection of the circle and the square.'(Exoticindiaart 2007)

## 2.4 The Temple: Divinity and Man

The ideology behind the designing of Hindu temples is to link man with the gods. Hindu temple is the place where one can feel being close to god. It is a depiction of the macrocosm (the universe) as well as the microcosm (the inner space) and has developed over two thousand years.

According to the Hindu religious philosophy, a man life is asummation of countless individual life-spans bound up in the cycle of rebirth. One can from achieve enlightenment thorough pure deeds, thoughts and dedication. Thus, in this world the temple is the symbol of enlightenment: it is the place

where god's presence can be felt and through rituals and ceremonies men can discover the divine knowledge.

The sacred and secular lives of a Hindu are unified and for the most part, the daily routines require numerous contacts with the divine, whether it takes place in miniature temple at home or a local temple. There is rarely any evidence of religious persecution among the cults of Hinduism, as Hindu believes that cults are all aspects of the divine in different forms i.e. Shiva, Vishnu and Goddess. This apparently results in a remarkable degree of tolerance and attempts of harmonization among the cults.

Hence, the temple is also the product of a desire to transcend the world of man-the principles of its construction, the forms of its architecture and decoration, as well as the rituals that take place within its walls, are all aimed at ultimate liberation (Michell, 1988).

## 2.5 Temple and Society

A large variety of Hindu temples was constructed throughout India with distinction in scale, techniques of building and particularly the deities that were worshipped, which were the result of the differences in political, cultural and prosperity between the towns and villages. The character of Hindu temples reflected local architecture styles and the material and skills to which they related. It is not easy to distinguish these temples otherwise due to limited information has survived about the Hindu temple and their builders which are mostly inscribed on the stone slabs and metal plates and on manuscripts written on the plant leaves. The information which survived explains that the temple building, especially in stone and brick was carried out as a result of royal patronage. Building of temple in stone was an expensive affair and expresses the physical power and economic resources of the ruler. Other than royal patrons, association of wealthy merchants and group of individuals played an important role in the construction of temples. However, apart from the royal patrons and the merchants, every individual donated something to the temple such as they might donate a field or water tank, or fund a perpetual lamp, or give two sheep to supply milk to make *ghee* to keep lamp burning.

In Hindu culture temple is not only a place of worship but they act as a centre for intellectual and artistic life (Michell,1988). The temple complex housed schools, hospitals and courts for the community. The spacious halls of the temple were the place for the recitation and listening of folk tales, *Vedas, Ramayana, Mahabharata* and debates. Music and dance were the part of daily rituals in the temple. The presence of these activities eventually gave the people more knowledge about the traditions and made them appreciate the older practices. The temple also owned cultivable land which was leased out and revenues were earned. By this method the temple was sustaining the maintenance of the temple and able to also support the needful during poverty and emergency. Temple provided means of livelihood for a large number of persons and greatly influenced the

economic life of the community. The written evidences of Brihadeshvara temple, Thanjauvr(1011 AD) shows that the temple had 600 employers (Brown, 1942). The temple is the centre of all aspects of the life of the community and every member of the community contributed in the up keeping and building of temple.Although the temple is the hub of different religious and cultural activities, the nucleus is the main shrine.


Figure 1

Figure 1-The the major temple sites in India (Source: Hardy, 2007).

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# Chapter 3

# 3 THE HINDU TEMPLE

The Hindu temples commonly known as *Mandir* in Hindi and derived from the Sanskrit word *Mandira*, are identified by several names in different parts of India as *koil* or *kovil in* Tamil*, devasthana* in Kanada and *devalaya*, in Telugu etc. In general Hindu temple structure can either be isolated structure or a part of complex.

The character of Hindu temples reflected local architecture styles and the material and skills to which they related. The main forms and styles of the Hindu temple were established during 600-800 AD. The cell or shrine, the *garbhagriha* (usually square in plan), housed the image and was approached through a columniated porch or *mandapa*. The shrine was roofed with a pyramidal spire or vertically attenuated dome like structure known as *sikhara*. The temple as a whole was raised on a massive plinth and was often surrounded by subsidiary shrines and by an enclosing wall pierced by one or more gigantic gateway towers or *gopurams*. It is the outline and detailing of the *sikhara* and other roof-forms which determine the character of monumental Hindu architecture and give a formal as opposed to historical basis for it classification.

The architecture of temples varies across India, however while the basic elements of the temple are the same, the form and scale varied. For example as in the case of the architectural elements like ***Sikhara*** (pyramidical roofs) and ***Gopurams*** (the gateways).

This following section describes the evolution of the temple and the development of their architectural styles along their materials of construction.

## 3.1 Elements of Hindu temple

It was the later half of the 7$^{th}$ century that the Hindu temple structures of India began to acquire a definite form (Fletcher,1952). Similar to terminology used to distinguish the basic components of a Gothic Church (for example nave, aisles, chancel, spire, etc), the common elements of a Hindu temple which are known in their original sanskrit words are as follows:

The sanctuary as whole is known as the ***Vimana*** that consists of two parts. The upper part of the *Vimana* is called as the ***Sikhara*** and the lower portion inside the *Vimana* is called as the ***Garbhagriha*** (cella or inner chamber).

1. '***Sikhara'*** meaning the tower or the spire**.** It is the pyramidal or tapering portion of the temple which represents the mythological '*Meru*' or the highest mountain peak. The shape and the size of the tower vary from region to region.
2. '***Garbhagriha'*** meaning the womb chamber. It is nucleus and the innermost chamber of the temple where the image or idol of the deity is placed. The chamber is mostly square in plan and is entered by a doorway on its eastern side. The visitors are not allowed inside the *garbhagriha* in most of the temples, only the priests perform the rituals and worship.

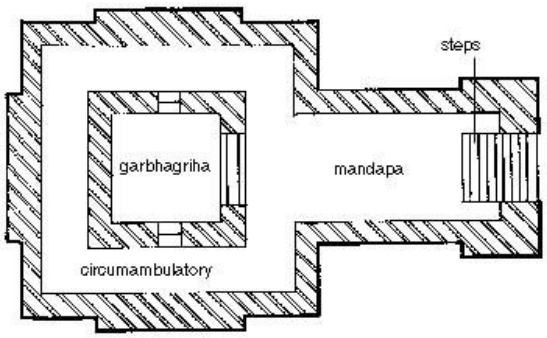



Figure 2a

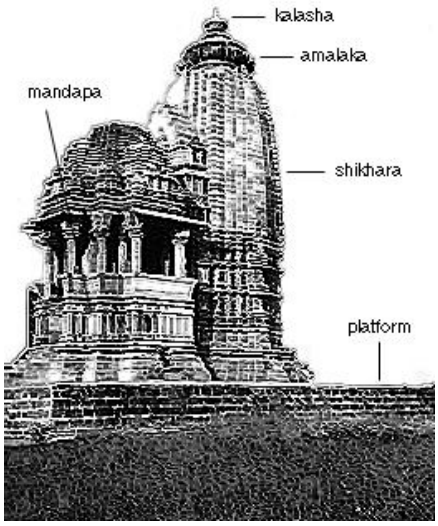



Figure 2b

Figure 2.1 &2.2 – The typical plan and the typical elevation of a Hindu temple illustrating various elements (Source: www.art-and-archaeology.com)

***3.*** '***Pradakshina patha'*** meaning the ambulatory passageway for circumambulation. It consists of enclosed corridor carried around the outside of *garbhagriha.* The devotees walk around the deity in clockwise direction as a worship ritual and symbol of respect to the temple god or goddess.

*4.* '***Mandapa'****,* is the pillared hall in front of the *garbhagriha****,*** for the assembly of the devotees. It is used by the devotees to sit, pray, chant, meditate and watch the priests performing the rituals. It is also known as '***Natamandira'*** meaning temple hall of dancing, where in olden days ritual of music and dance was performed. In some of the earlier temples the *mandapa* was an isolated and separate structure from the sanctuary.

5. '***Antarala'*** meaning the vestibule or the intermediate chamber. It unites the main sanctuary and the pillared hall of the temple.

6. '***Ardhamandapa'*** meaning the front porch or the main entrance of the temple leading to the *mandapa*.

Some other essential elements found in the Hindu temples are

7. ***'Gopurams'*** meaning the monumental and ornate tower at the entrance of the temple complex, specially found in south India.

8. ***'Pitha'*** , the plinth or the platform of the temple.

9. ***'Toranas',*** the typical gateway of the temple mostly found in north Indian temple and

10. The ***Amalaka*** the fluted disc like stone placed at the apex of the *sikhara*

## 3.2 Material of Construction

The Indian temples were built with all types of materials depending upon the availability from region to region. The range of material varied from timber to mud, plaster, brick and stone during all periods and throughout India. The materials play an important role in the overall appearance, construction techniques and monumental character of these temples.

As the earlier structures were fashioned from less durable materials such as timber, brick and plaster the early examples of Hindu architecture and art have mostly disappeared or are detectable only by the most fragmentary remains. However some of the relief carvings and paintings show that the earlier Hindu temples were constructed in timber and bamboo. Many of the later stone temples were modelled on wood and bamboo architecture is apparent from the carvings, roof forms and window shapes. This usage of timber and bamboo governs the form of temples mostly in the Himalayan valleys and regions of Kerala and Bengal. The remains of temples constructed in brick dates back to the centuries before the Christian era. The brick and mortar temples were constructed in the region were there was easy availability of brick and the availability of suitable stone were limited.

The construction of temple in stone is the most distinctive expression of Hindu architecture. The highly evolved techniques of excavating and cutting blocks of stone constitute one of the major technical achievements associated with the history of the Hindu temple (Michell, 1988). The construction in stone dates back to 2$^{nd}$ and 3$^{rd}$ centuries in the form of rock cut sanctuaries and later in the form of temples with use of stones like granite, marble, soap stone, sandstone and locally available stones. The stones were used with most intricate and ornate carvings and sculptors throughout India.

## 3.3 Evolution of Architectural Styles

The distinctive architectural styles of Hindu temples have so developed due to broad geographical, climatic, cultural, racial, historical and linguistic differences between the northern plains and the southern peninsula of India. Broadly based on geography, Hindu temples have been classified into three different orders; the ***Nagara*** or ‘northern’ style, the ***Dravidian*** or ‘southern ‘style, and the ***Vesara*** or hybrid style which is seen in the Deccan between the other two.

There are also other distinct styles in peripheral areas such as Bengal, Kerala and the Himalayan valleys. This dissertation focuses on The ***Nagara*** or ‘the northern style’ and the ***Dravidian*** or the southern style of Hindu temple architecture.

Figure3.1 Nagara Style

Figure3.2 Dravidian Style

Figure3.3 Combined Vesara style

Figure 3.1, 3.2 & 3.3-Different styles of Indian Temple (Source: www.asia.msu.edu)

The emergence of Hinduism under the *Gupta* dynasty (320-550 AD) responded in sacred forms of art and architecture built with permanent materials to protect the divine essence in monumental temples.

The history of northern style of temple begins from the *Guptas* and their successors ($5^{th}$ to $7^{th}$ century) and advanced to *Early chalukyas* ($7^{th}$ to $8^{th}$ century), the *Kalingas* and *Eastern Gangas*($8^{th}$ to $13^{th}$ century), the *Pratiharas* and *Chandellas*($8^{th}$ to $11^{th}$ century), the *Maitrakas* and the *Solankis*($8^{th}$ to $13^{th}$ century) and the *Rajputanas*($8^{th}$ to $12^{th}$ century).

The Hindu temple construction during the medieval period ($6^{th}$-$13^{th}$ centuries) took place on a magnificent scale comparable to the building of churches and cathedrals in the medieval Europe. Hindu temple architecture reached to its final form by combining influences from both the northern and southern India and probably also from the cultures of invaders who continued to enter India from the north- west during this period (Michell, 1988).

In the southern style of temples the history begins with the *Early Chalukyas*, and *Kalchuris* ($6^{th}$ to $8^{th}$ century) and advanced to the *Pallavas*($7^{th}$ to $8^{th}$ centuries), the *Rashtrakutas*($8^{th}$ to $10^{th}$ century), the *Cholas*($10^{th}$ to $11^{th}$ century), the *Hoyshalas* and *Later Chalukyas*($11^{th}$ to $14^{th}$ century) and the *Vijayanagas* and the *Nayakas*($15^{th}$ to $17^{th}$ century (Brown,1942).

In northern India the evolution of Hindu temple architecture was largely interrupted by the Muslim invaders whose presence was increasingly felt from the $11^{th}$ century AD onwards. Many of the finest temples were destroyed during this time (Brown, 1942). In contrast, the southern India did not experience Muslim rule until a late period and thus had a less disrupting effect upon Hindu tradition and architecture of south India. The temples architecture of south India is therefore relatively better preserved till present time.

## 3.4 Developments in Temple Architecture

### 3.4.1 *Nagara* or the 'Northern Style'

The characteristic temple plan of the northern India was developed in the 5th century under the rule of Hindu dynasty. These temple consisted of all the basic elements; the *garbhagriha* surrounded by an ambulatory path, an outer portico with columns in front and a flat roof of stone. The temples constructed during this period were simple and less impressive compared to the temple constructed during the 10th -13th century temples. Some of the examples from this period are temples at Sanchi, Tigawa and Deogarh. The development of *sikhara* started at the temple of Deogarh in Madhya Pradesh (Brown, 1942). The temples constructed in the 8th century had smaller shrines and the *sikhara* became the crowning feature of the temples. The addition of *mandapa* (the pillared hall) to the temple started during this period itself. The other distinct character of this period was the rectangular wall around the temple and addition of subsidiary shrines at each corner. The most common examples of this period are the temples at Osian Rajasthan and the cluster of Jain temples built between 8th -12th century in Gujarat and Rajasthan.

The temple of Teli-ka mandir, Gwalior and Vaital Deul, Bhubaneshwar were unique and inspired from the early Buddhist architecture with rectangular plan and the barrel vault roof of *chaitya* hall. These temples don't make the full composition of Hindu temple as they only consist of main sanctuary with neither the *mandapa* nor the portico. This form of architecture was abandoned by the architects in the north but was accepted in the architecture of south India. A distinct architectural style developed in the temples of Orissa (7th to 11th century). The elliptic curve of *sikhara* from the earlier periods were modified as a perpendicular prismatic tower and converged near the peak. For the first time in history special attention was given to the construction of *mandapa*; the roof of the *mandapa* was now pyramidical with tapering at the top and lower than the *sikhara*. The finest examples of this period are the Lingaraja temple, Bhubaneshwar, the Jaganath temple Puri and the Sun temple Konark with there *sikhara* height ranging from 43 m to 57 m high.

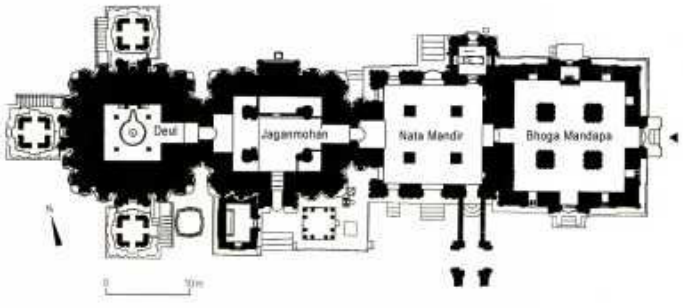
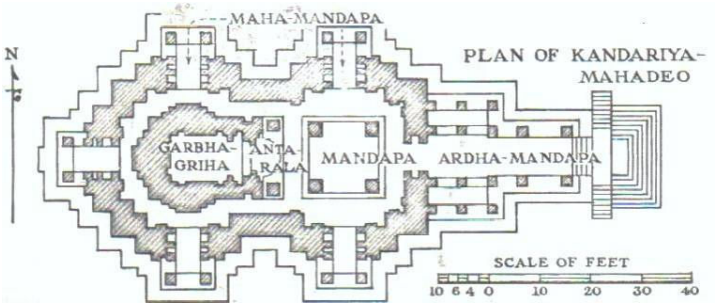



Figure 4.1.

Figure 4.2.

Figure 4.1 & 4.2. Plan and view of the Lingaraja Temple(Source:www.indoarch.org)

A parallel development to the Orissa temple, took place in the central India during the 9th to 11th century. The temples of Khajuraho are famous for their conical tower made of piles of stone with an arrangement of miniature towers called *sikhara* (Grover,1980). Each of these temples has portico, entrance hall and the sanctum. The roofs of various sections of the temple have distinct form. Each and every façade, wall, ceiling of these temples have carved figures from the mythology and history. The finest examples are the Khandriya Mahadev temple, and Lakshmana temple, Khajuraho.

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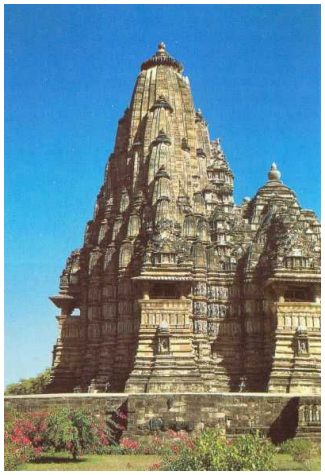

Figure 5.2

Figure 5.1 & 5.2. Plan and view of the Kandariya Mahadeo Temple(Source:www.indoarch.org)

### 3.4.2 *Dravidian* or 'Southern Style'

Temple development in southern India started during the *Chalukya* rule in the early 7th century. These temples were inspired from the Buddhist architecture. The temples evolved from simple rock cut shrines to large and complicated structures. The temples in this period were large square building with a projecting porch and decorative pillars. The roof of the temple had small structure which later emerged as the *sikhara*. The entire temple is simple with minimal decoration. Some of the examples from this period are Lad Khan temple and Durga temple , Aihole.

The rock cut structures developed during the 7th -9th century under the rule of *Pallavas*. The *Pallava* rulers lead the way of dravidian style of temple architecture and they built the temples at Mahabalipuram. During the *Pandyas* rule the south Indian temples were added with the lofty gateways *gopurams* at the entrance with the basic temple composition. The *gopurams* made the temple visually attractive and also provided the temples with an enclosure. The *gopurams* evolved from a rectangular base with a pyramid crowned with a barrel vaulted form. In the 11th century the Chola rulers built one of the tallest temples of that time the Brihadeshvara temple, Thanjavur with a height of 60 m (Hardy 2007). In the later period the temples extended and became more intricate.

More *mandaps* were included for various activities like dancing, assembly, eating, marriages, etc. The Dravidian style concluded in a series of extended temple cities or townships. The finest example of the temple township is the temple at Srirangam and Madurai with several concentric enclosures.

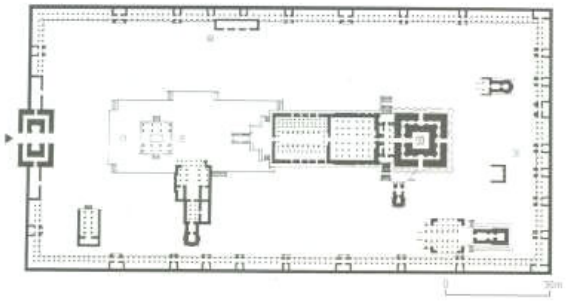

Figure 6.1.

Figure 6.2.

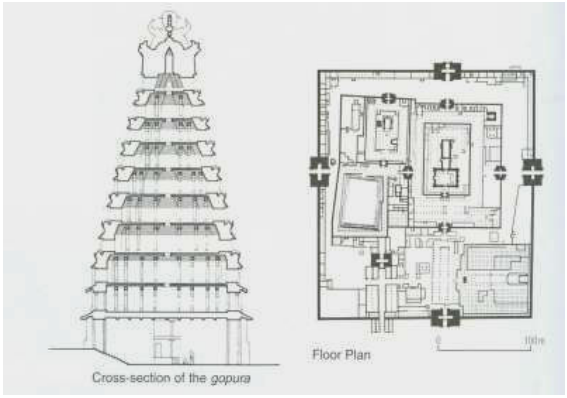


Figure 7.1.

Figure 7.2.

Figure 6.1 & 6.2. Plan and view of the Brihadeshvara Temple (Source:www.indoarch.org)

Figure 7.1 & 7.2. Plan, Gopuram-section and view of the Minakshi Sundaresvara Temple (Source:www.indoarch.org)

## 3.5 Distinct Features of 'Northern style' and 'Southern style' temples

The major and distinct features between the north Indian temple and the south Indian temple are their superstructures. In the north the beehive shaped tower is the most distinguished element called as the *sikhara*. The gateways are in the north and they are plain, simple and small. The plans of the north Indian temples are based on square but the walls are sometimes broken at so many places that it gives an impression of temple being circular in plan. The tower is made up of miniature *sikhara* creating an amazing visual effect resembling mountain.

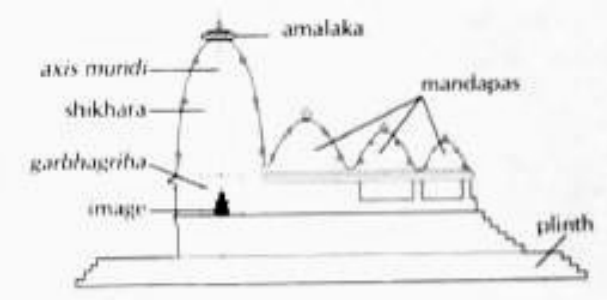


Figure 8.1.

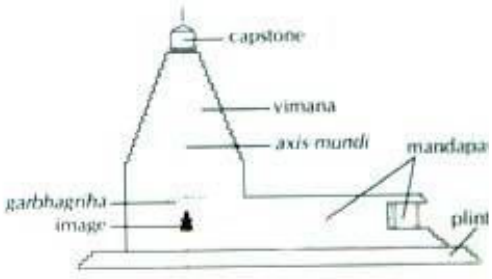


Figure 8.2.

Figure 8.1. Northern Style Temple (Source: www.india-forum.com)

Figure 8.2. Southern Style Temple (Source: www.india-forum.com)

In the south, the distinct features are the *vimana* and the *gopurams*. The *vimana* is a tall pyramidal tower consisting of several progressively smaller storeys, the peak of the *vimana* is called as *sikhara* in the south Indian temples. This stands on a square base. The temple complex consisting of the main shrine and other smaller shrines are enclosed by the outer wall called as the *prakara*. Along these outer walls are the intricate and marvelous gateways called as *gopurams*. These *gopurams* became taller and taller overpowering the main shrine and its superstructure and dominating the whole temple complex.

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# Chapter 4

# 4 THE GEOMETRY OF HINDU TEMPLE

The previous chapter covered the different styles and structural elements that prevailed in Hindu temples of India. It is evident that temple styles differed significantly from region to region. For example, a temple plan may be placed along a single linear axis or it may be placed in concentric rings. This chapter explains the geometry of Hindu temple with respect to the Hindu cosmology and philosophy based on the divine '*Vastupurushamandala'* and its application to the temple structure.

Although, the elements of Indian temples may differ across regions, the real motive was derived from a single philosophy of design. All small and large Hindu temples built since historic times have been following the same philosophy. This philosophy has apparently percolated to the remotest parts of India. The *Vastushastra* and *Shipshastra* along with other general manuals on Hindu architecture are still referred for the construction of the sacred Hindu temples.

## 4.1 Cosmology and Hindu Temple

According to the ancient Hindu scriptures, the temple is the microcosm of the cosmos and the cosmic order is perceived as integral to the human body, mind and spirit; with the human being a microcosm(Hardy, 2007). The Hindu temple structure presents the significant information about the science and cosmology of the period in which they were constructed. It is a symbolism of the outer and the inner cosmos where outer cosmos is expressed in terms of various astronomical connections between the temple structure and the motions of the sun, the moon, and the planets, whereas the inner cosmos is represented in terms of the consciousness at the womb of the temple and various levels of the superstructure correspond to the levels of consciousness (Kak, 2002).

The temple is a link between the physical world of man and divine world of God. And to connect them, the plan of cosmos were graphically copied in the foundation of the temples called as the *Vastupurashamandala*. The Hindu architecture, religious or vernacular, in the ancient times were based on the geometry of the *Vastupurashamandala*.

In the words of Stella Kramrisch, "The temple is the concrete shape (*mūrti*) of the Essence; as such it is the residence and vesture of God. The masonry is the sheath (*kośa*) and body. The temple is the monument of manifestation." The expansion may be seen either as proceeding from the central point of the *garbhagrha* in all the directions of space, reaching to the bindu above the finial of the temple and beyond, or as a manifestation held together by a tension between the *bindu* and the g*arbhagrha*, with the axis joining the two being the world axis (Kramrisch, 2002).

## 4.2 The Concept: - *Vastupurashamandala*

The Hindu philosophy was among the first to relate the human figure as the basis of a system of proportion, which was years later demonstrated by Leonardo da Vinci and by Le Corbusier in Modular system of measurement. In Hindu philosophy the form of the *purasha* (human) body was made to suit the abstract idea of the square, as the supreme geometric form (Groover,1980).

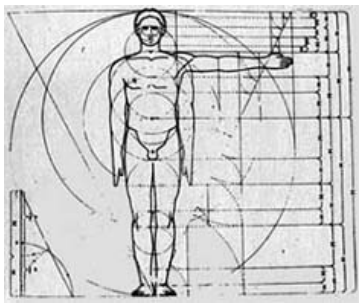
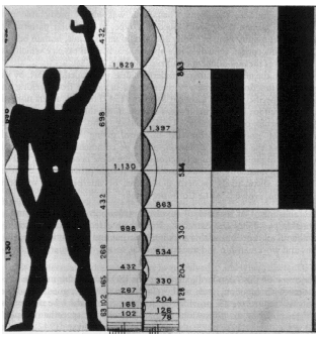


Figure 9.1



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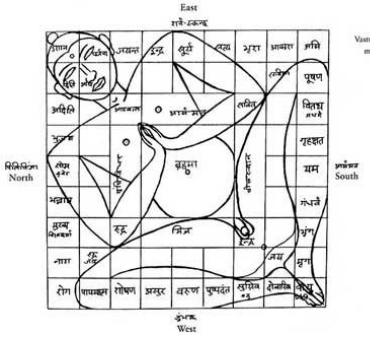



Figure 9.3

Figure 9.1 –The Vitruviun Man,(Source:www.boloji.com),

Figure 9.2- The Modulur,(Source: www. mypages.surrey.ac.uk),

Figure 9.3 –The Vastupurashamandala (Source: www.exoticindia.com)

The *Vastupurashamandala* is derived from three separate words each having a specific meaning where *vastu* refers to physical environment, *purusha* refers to energy, power or cosmic being, and *mandala* is the diagram or chart (Rian,et al. 2007).

The basic form of the *Vastupurashamandala* is the square and square is the important and ideal geometric form in Hindu philosophy, which represents the earth. All the necessary forms like the triangle, hexagon, octogan and circle, etc can be derived from the square. The four sides of the square represent the four cardinal directions. The square also symbolizes the order, the completeness of endless life and the perfectness of life and death (Michell, 1988). According to Hindu beliefs, man's everyday life is also governed by the number four as in four classes(varnas), four phase of life, four great eras, four head of Brahma(the creator God), the four Vedas, etc. (Exoticindiaart, 2003). Similarly, the circle represents the universe and is considered as the perfect shape, without any beginning and end, suggesting timelessness and infinity, a typically heavenly feature.

The *mandala* is actually a square subdivided into smaller squares in the form of a grid with each square unit clearly marking the areas of respective gods. The most commonly used *mandala* is the square divided into 64 and 81 squares. Mostly the square of the *mandala* on its outer periphery are divided into 32 smaller squares, in accordance to the astrological calculation called *nakshatra,* representing the constellations or the position of planets through which moon passes in its monthly

path. The closed polygon of thirty-two squares is symbolical to the recurrent cycles of time as calculated by the movements of the moon (Gosai 2002-2008). The four directions lie outside the *mandala* which represents the meeting of the earth and the universe as well as the movement of the sun from east to west and its rotation to the northern and southern hemispheres. The central portion of the *mandala* is the place for the Brahma, the creator, and the rest squares are the position of other Gods as per their relevance.

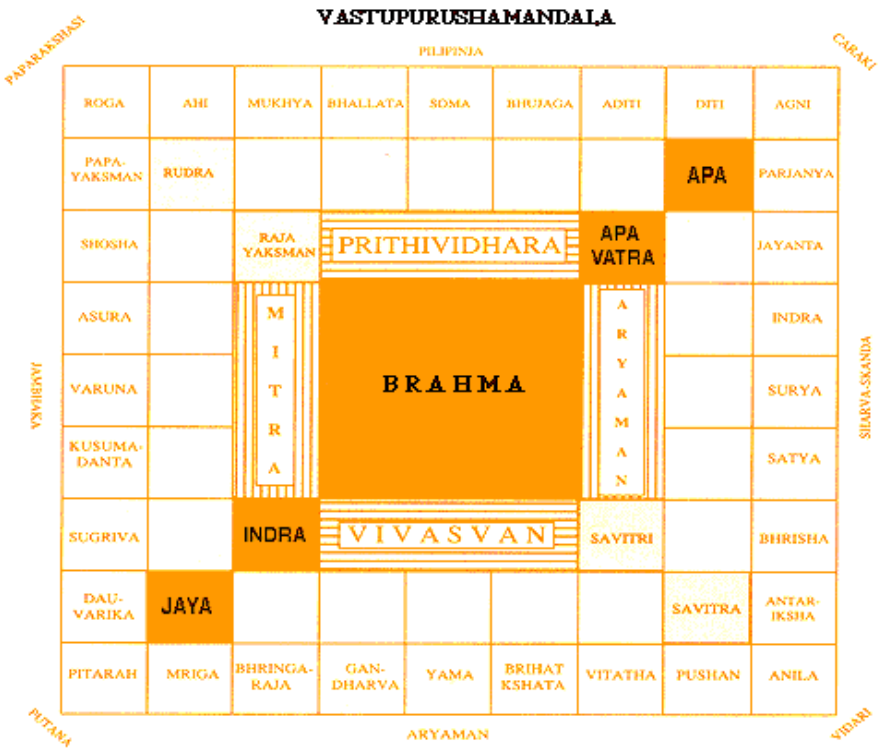



Figure 10

Figure 10 –The diagram of Vastupurashamandala,(Source: www.gosai.com)

The *vastupurashamandala* are the square grids and are of various types formed from the fundamental shape, the square. The smaller squares in the grid are called as the one *pada* and they may vary from 1, 4, 9, 16, 25, and so on 1024 and follows a geometric progression series of 1, 2, 3, 4, 5,…, 32 with the common factor 2. There can be even numbers of *pada* and odd numbers of *pada* in a *mandala* and are called as *yugma mandala* and *ayugma mandala* respectively.

*Vastupurushamandala* has different names according to the numbers of *pada* within the grid. The *mandala* having 1,4,9,16,25 and 36 numbers of *pada* within the grid are known as *sakala mandala, pechaka mandala, pitah mandala, mahapitah mandala, manduka chandita mandala and paramasayika mandala*, respectively(Rian,et al. 2007).

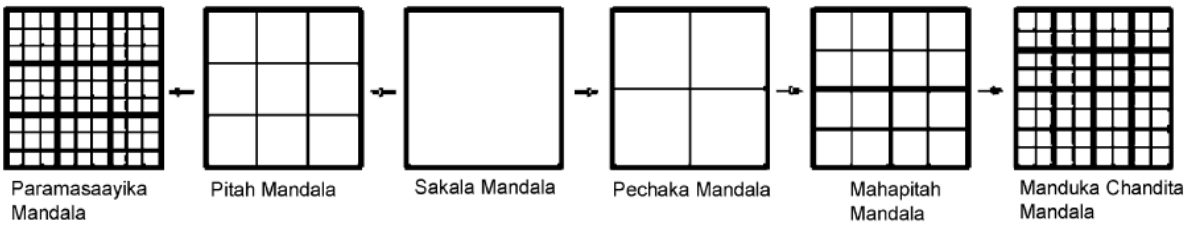



Figure 11

Figure 11 – The various types of *Vastupurashamandala*(1, 4, 9, 16,64 and 81) (Source: Rian, et al 2007)

The *Vastupurashamandala*, having all the geometrical, astronomical and human properties was the basis of the ground floor plan for all Hindu temples. The basic shape acquired by the temple plan is the outer most ring of square of the *mandala* forms the thickness of walls of main shrine. The central 4 squares acquire the place of the main deity and the inner ring of 12 squares form the walls of the *garbhagriha* and the next 16 to 28 forms the *pradkshina path*a. These simple divisions of square with many permutations and combinations became the base for the complex structures of the temple; in the form of orthogonal and stellate plans of the temple Therefore the large squares of *mandala* were divided into thousand squares thus virtually forming a graph paper for the architect to facilitate him to add a unit at one side and setting back on the other.

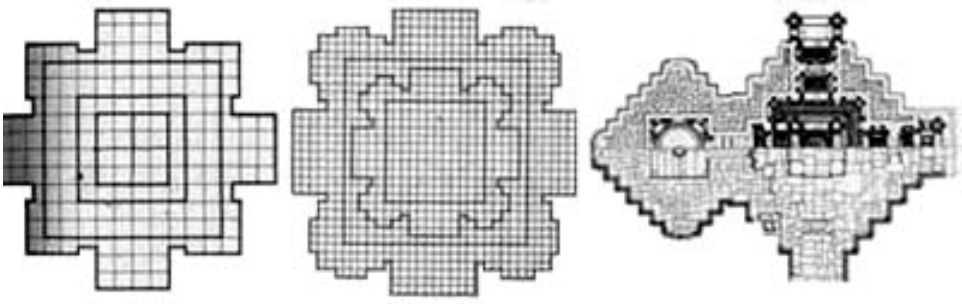


Figure 12

Figure 12- The *Vastupurashamandala* transformed into architectural plans (Source: Grover, 1980.)

## 4.3 The Layout of Hindu Temple

The *Vastupurashamandala* is first sketched on the planning sheets and afterwards outlined on the earth on the place of the actual temple building site. This divine diagram is the symbolic of the universe with its fractal behavior. As mentioned in the previous section each unit of square represents the birth of new universe and the central square is the creation of the each unit. The *mandala* is a square grid and the repetition of even number of square grid develops into 4 square grids and further to 16 square grids and so on. Similarly the repetition of odd number of square grid develops into 9 square grids and further to 81 and so on.

The mandala is now placed on the foundation plan of the temple to seize all the cosmic energies underneath the temple. The centre of the mandala generates the energies and emits to the physical world. The square shape of mandala significantly implies to maintain the energy equilibrium. Each side of the squares applies the force towards the centre and in return the centre applies the force towards the sides, thus maintaining the equilibrium (Rian,et al. 2007).Thus increasing the number of squares in the divine diagram helps to hold more energies and emit it out to the physical world through the centre. Therefore, the centre of the mandala is the place for the main deity in the temple.

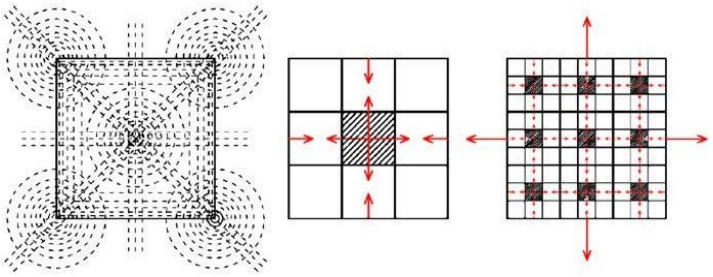
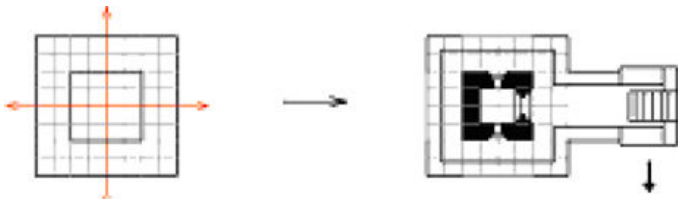


Figure 13

Figure 13 – Fields of forces in the square, radiation of forces from 9 grids square and radiation of forces from 81 grids square (Source: Rian, et al. 2007).

### 4.3.1 The Plan

The plan of the temples are the replica of the *Vastupurashamandala*, the grids of the square of 8X8 where the cella is twice the width of the walls of the cella. The Nagara style of temples in the west and the central India followed the orthogonal grids of the *mandala*. In examples from 7$^{th}$ century at the Vishnu Temple Deogarh in Madhya Pradesh, the square grid was modified by extending one time on each side outwards. Further, during the 10$^{th}$ century at the Surya temple, Modhera the square grid was modified by extending twice on each side outwards. Later on in the 11$^{th}$ century the Hindu temple plan became complex and reached their final form. This time the square grid was modified by extending thrice on each side outwards, The Khandriya Mahadev Temple at Khajuraho in Madhya Pradesh is the best example for this.



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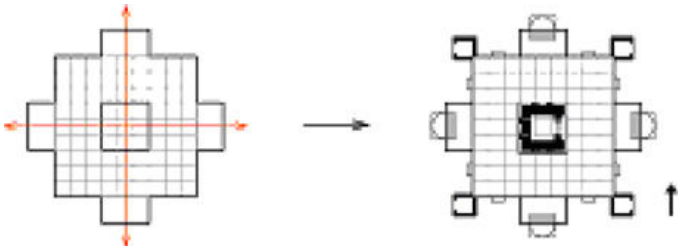

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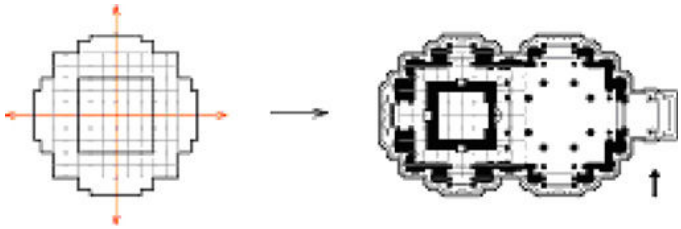

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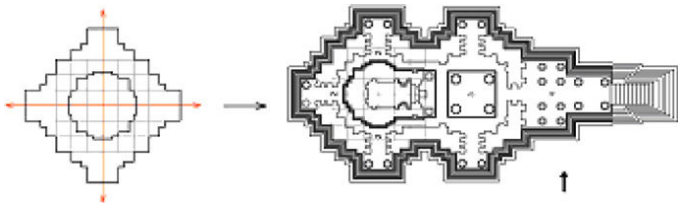

Figure 14.4

Figure 14

Figure 14 –Evolution of plans of temple through *vastupurashamandala* during different centuries.

Figure 14.1- Plan of Parvati Temple, 6th century (Source: Rian, et al. 2007)

Figure 14.2 – Plan of Vishnu Temple, Deogarh, M.P, 7th century (Source: Rian, et al. 2007)

Figure 14.3 – Plan of Sun temple Modhera, 10th century (Source: Rian, et al. 2007)

Figure 14.4 –Plan of Kandariya Mahadeo Temple, Khujaraho 11th century (Source: Rian, et al. 2007)

The temples in the South India in the early 7th to 8th century and later in the 13th century developed the stellate plans meaning the plan of the *garbhagriha* was in the elaborate star shaped. These complex plans were derived from the basic square . This was achieved by rotating the square around

its fixed centre, and turning it diagonal through a series of equal angles. Thus the corners formed by overlaping so many squares resulted in a star. The number of points and their proportions could be varied merely by changing the angle through which the diagonal was turned up at every step (Grover 1980). Normally the plan of the temple consisted of 8, 16, 24 and 32 points. The 16 and 32 pointed star plan was achieved by bisecting the angles of an 8 point star. And also 24 pointed star plan is achieved by the 6 point star plan. The Chenna Kesava temple, Belur is one of the finest example of the stellate plan.

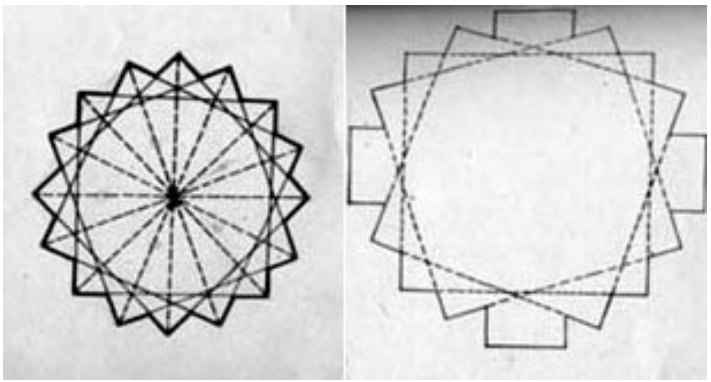

Figure 15

Figure 15 – The rotation of square around its centre gave rise to star shaped plans ‘stellate plans’ (Source: Grover, 1980)

## 4.4 The Structural System of the Hindu temples

The basic construction technique used in the Hindu temple was the trabeated system or the post and the beam method and which was extended by the use of corbelling techniques. This method was originally used for wooden construction in India and was later adopted for the stone structures as well.

### 4.4.1 Trabeated System

In the trabeated system only the horizontal and the vertical members are used and the stability is achieved by the massive arrangements of vertical elements such as pillars and pilasters together and heavy cross beams and lintels. The use of the spanning system to enclose the interior spaces was the most typical feature of this system. The openings in the Hindu temple have lintel made of stone or timber. The roofing system consists of horizontally laid slabs of stone spanning from one supporting beam or wall to the other.

The arrangement of the internal ceilings in the Hindu temple were deliberately confined to the overlapping of the one stone course with the another or, alternatively, to the laying of the diagonal and square stone course to produce designs with rotating and diminishing squares (Michell, 1988).

Later in the 10th and 11th centuries the internal ceilings were spanned circular stone courses, seated one above the other in receding diameters, to produce complex designs.

Figure 16.1

Figure 16.2

Figure 16.3

Figure 16.4

Figure 16.5

Figure 16.6

Figure 16

Figure 16 The Trabeated System and the internal ceilings of the Hindu temple

Figure 16a, 16b & 16c – The pillars and the beams of the temples

Figure 16d, 16e, 16f – The internal ceilings with the rotating and diminishing squares and circles.

(Source: Kuili's Suganya Collection & author's collection & Www.indoarch.org 2006)

### 4.4.2 Corbelling System

In the corbelling system the stones or the bricks in each horizontal courses are projected out to bridge the gap between the two walls to diminish until it can be closed with a single piece of stone or brick. The corbelling system was used to create the interiors of the temple and the stone shells of the super structure that rise above the sanctuary. Later in the the 13th century the use of iron clamps and wedges to hold the stone slabs together, allowed the special feature of corbelling in which horizontal stone layers were projected out over large spans and cut into unusual shapes to produce highly decorative ceiling schemes (Michell,1988).

Figure 17.1

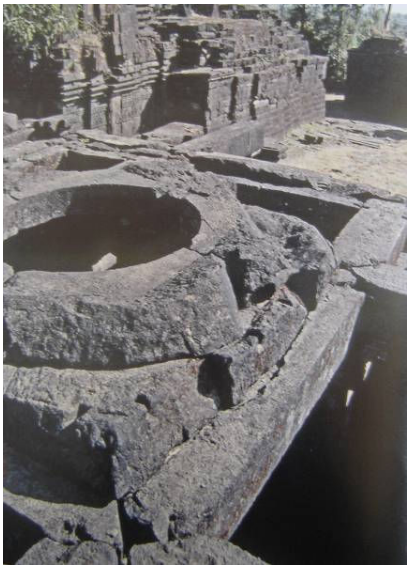

Figure 17.2

Figure 17.1 & 17.2 The Corbelling System (Source: www. personal.carthage.edu & Hardy 2007)

The column-beam-corbel method of construction was the main structural principle governing the construction of every Hindu temples. The principles of equilibrium of forces in action by means of arch, vaults and other forms of functional engineering rules never really played a part in the evolution of Hindu temple. Its doesn't mean that architects of Hindu temples were ignorant about these techniques, rather it is their conformance to tradition and strict adherence to precedents, reflecting a certain firmness in their cultural attitude (Brown, 1942). There was no instance of use of vaults or domes in the Hindu temple architecture, but arched niches were created on the surface of the walls and they rarely carry loads from above.

The Hindu architects remained attached to his own traditional techniques and accomplished his task of construction by carefully study of the laws of gravity, obtaining the strength by the mass supporting mass and stability by the solid resistance of the weights acting vertically, all pressure being tranismitted directly downwards. As a result the use of mortar was pointless because there being almost no inclined pressure to distribute between the courses of masonary. Therefore, the Hindu temple architecture masonary developed as dry masonary system (Brown, 1942).

## 4.5 The Structural Components

In the north Indian temples the sanctum or the *garbhgriha* is situated on a raised base, or a plinth (*pitha*). over which is the socle (*vedibandha*), these have different decorative mouldings, above the *vedibandha* is the walls of the sanctum (*jangha*), having prominent offsets and niches, which are further crowned by the cornice or a series of cornices(*varandika*) and above this is the superstructure (*sikhara*). On the top of the *sikhara* is a single piece of stone having grooves called as the *amalaka*

which in turn is crowned with a pot and finial. The whole temple complex including the mandapas and other shrines are usually raised on a terrace (*jagati*) which is at times having significant heights and size. The sanctum has a flat ceiling inside and the superstructure is usually hollow from inside to lessen the weight.

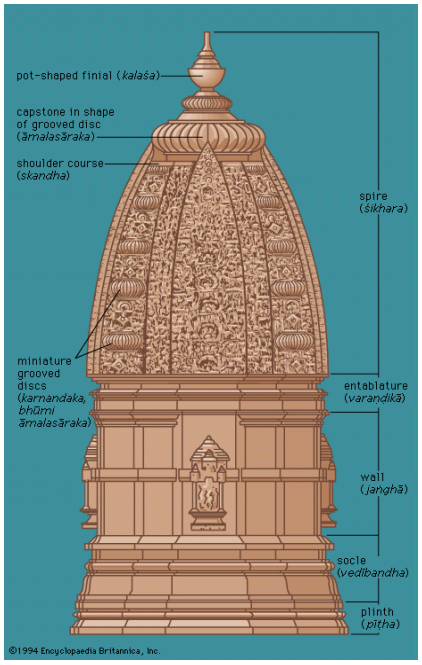


Figure 18.1

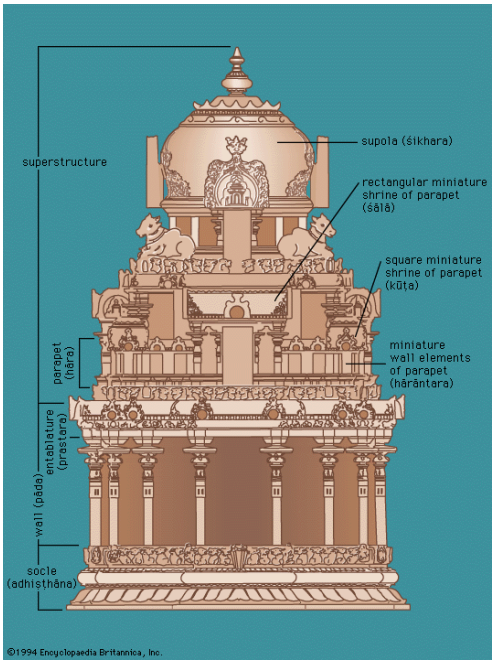


Figure 18.2

Figure 18.1 The sanctum showing the different elements of the north Indian temple (Source: www.britannica.com)

Figure 18.2 The sanctum showing the different elements of the south Indian temple (Source: www.britannica.com)

In the South Indian Temples the sanctum or the garbhagriha rises above the socle (*adhisthana*), consisting of series of mouldings which differ from the North Indian temples, they don't have the plinth (pitha), above the socle rises the walls (pada) of the sanctum, the walls are divided in to series of pilasters, above the walls rises the pyramidal shaped superstructure consisting of stepped stories and each of them are enclosed by there own parapet. The top of the stepped structure supports the solid cupola called as *sikhara* in the south which in turn is crowed by a pot and finial.

### 4.5.1 The Base or the *Pitha*

The base of the Hindu temple consists of series of mouldings. These mouldings are horizontal bands corresponding to the courses of masonry supporting the walls and super structure of the Hindu temple. In Hindu temple architecture mouldings exists not as edgings or modulations to other

elements, but as elements with larger elements. These are more similar to the architrave, frieze and cornice in a classical pediment than to mouldings within these (Hardy, 2007).

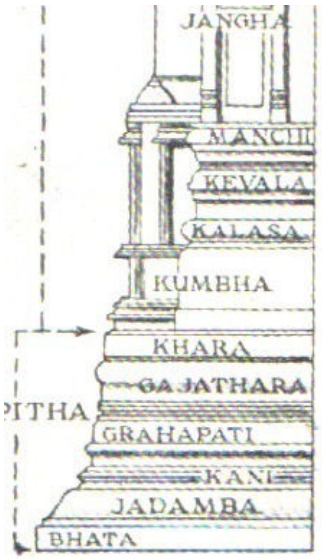


Figure 19.1

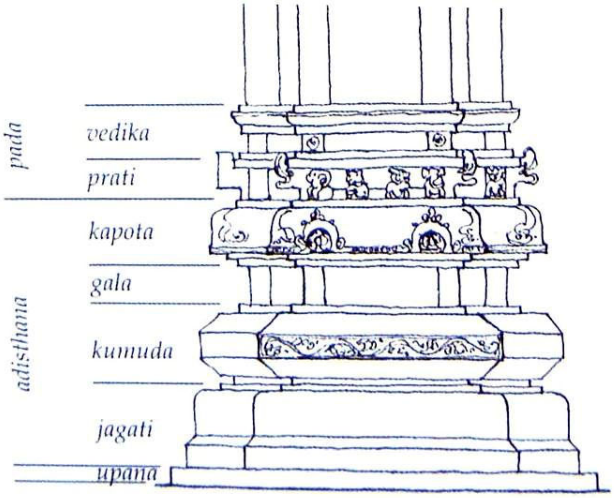


Figure 19.2

Figure 19.1 The base with mouldings in the north Indian temple (Source: Hardy, 2007)

Figure 19.2 The base with mouldings in the south Indian temple (Source: Hardy, 2007)

In the plinth or the parapet or in the superstructure each course of masonry can be defined as a single moulding. Sometimes these single moulding are subdivided and treated as two separate courses are carved out from one course. The moulded base is called as *vedibandha* in the North and *adisthana* in the South. The floor level is at the foot of this element in the North and above the element in the South. These have elaborate carvings and have sub-bases and pedestals.

### 4.5.2 The Walls:

The zone between the superstructure and the base of the Hindu temple architecture consists of walls, pillars and pilasters.

The walls in the Hindu temple architecture are constructed as composite stone masonary with an infill of stone and brick with lime and mud. The thickness of the stones varies from 300 to 4500 mm. The average thickness of the masonry wall varies from 800mm–1200mm. Through stones are provided at regular intervals to strengthen the walls.

Figure 20.1

Figure 20.2

Figure 20a Walls with courses of masonry in the north Indian temple (Source: www. personal.carthage.edu)

Figure 20b Walls with courses of masonry in the south Indian temple (Source: Hardy, 2007)

### 4.5.3 The Supporting Elements

The Hindu temple consists of tall, slender, free-standing, beam supporting columns, pillars and pillasters. The columns are not the defining elements of the Hindu temple architecture as that of the Western Classical architecture. It is not easy to categorise the Indian columns as there are no particular design type of the column.

The design of columns in each period and style have numerous interrelated yet different types, which were carried from one period to another or were transformed into new types. The Indian texts classify columns in terms of their cross section. The cross section ranges from square circular and polygonal (faceted), through scalloped (fluted), lobed, staggered and stellate (Hardy, 2007). The evolution and interaction broadly divide the Indian columns in five main types namely; the bell type columns, the block and roundel type columns, the cushion type columns, the *Ghata-pallava* columns and the *Bharana* columns.

Figure 21.1

Figure 21.2

F

Figure 21.3

Figure 21

Figure 21 – The different types of columns.

Figure 21.1 – The Bell types of column: Figure 21.2 – The cushion type of column: Figure 21.3 – The Ghata-pallava type of column (Source: Hardy, 2007).

Although, Indian columns consists of distinct parts arranged in vertical series, like the mouldings of the temple base and is seen usually in all the period and styles. The basic parts of the columns are:

The beam (*uttara*) the topmost section of the column is the beam and these are the structural beams of the temple. The section below is the bracket (*potikas)* supporting the beams. The brackets provides the bearing for the beam and shortens the span between the columns. There after is the flat plate (*phalaka*)and underneath is the *mandi*, something like a dish, fluted or petalled. These bears the bracket rather than the beam directly and act as a cushion to recieve the imposed loads. The head or the the capital of the column is called as the *ghata,* a rounded or swollen member which is held by the neck(*tali*) and the shoulder(*lasuna*)of the column. This *ghata* acts as cushion to the load of the structure. Below the *tali* and the *lasuna* is the horizontal band, a griddle*,* the *malasthana* and further down is the *mala* another horizontal band. These two element are inseperable are carved out of a single stone block. Below the mala comes the shaft which stands on the base block often cuboid in shape.

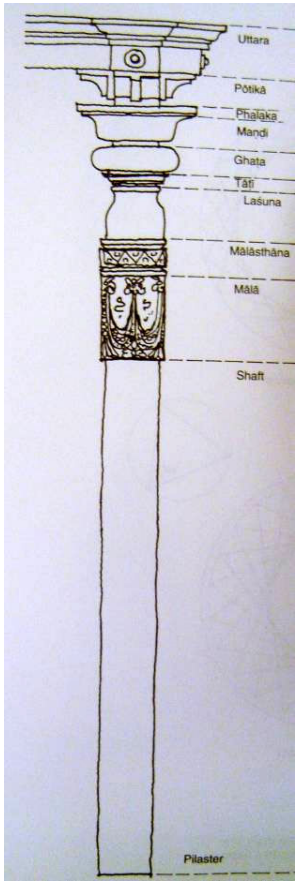


Figure 22

Figure 22 – The different parts of the columns (Source: Hardy, 2007)

### 4.5.4 The Superstructure or the Sikhara

The superstructure of the Hindu temple relates to the spire or the *sikhara* of the temple. The *sikhara* is the most distinctive part of the Hindu temple and provides the basis for the most useful and instructive classification.

In the North Indian temple there are three basic types of *sikhara* called as the *phamsana*, *latina* and the *sekhari*.

The *latina sikhara* is curvilinear in outline and is composed of series of one above the other horizontal roof slabs. The surface of the entire *śikhara* is covered with a creeper-like interlaced work, composed of tiny ornamental *candraśālā.* The *sikhara* diminishes at the top and is capped by a horizontal course (*skandha*), above which is a circular necking (*grīvā*), carrying a large grooved disc called the *āmalasāraka*. The *sikhara* is finally crowned with the *kalasa* (pot) and the finial (South Asian Arts, 2008).

The *phāmsanā śikhara* have rectilinear outline and is lower in height compared to the *Latina*. It also consists of horizontal slabs and is capped by a bell-shaped member called the *ghaṇṭā*. The surfaces of this type of śikhara also have projections, and are decorated with a variety of architectural ornament.

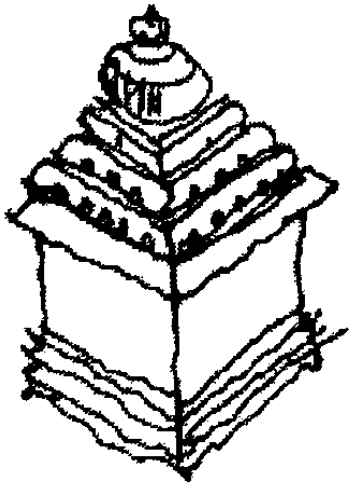

Figure 23.1

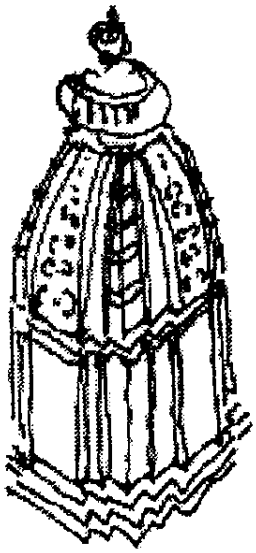

Figure 23.2

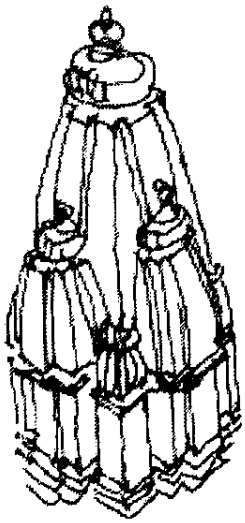

Figure 23.3

Figure 23

Figure 23 – The different types of *sikhara* of the north Indian temple.

Figure 23.1 – The *phamsana* type of *sikhara*: Figure 23.2 – The *latina* type of *sikhara*: Figure 23.3 – The *sekhari* type of *sikhara* (Source: Hardy, 2007).

During the 10$^{th}$ century another type of *sikhara* or spire developed called as *sekhari*. In its developed form it consisted of a central *latina* spire with one or more rows of half spires added on the sides and the base strung with miniature spires. The corners, too, are sometimes filled with quarter spires, the whole mass of carved masonry recalling a mountain with a cluster of subsidiary peaks (South Asian Arts, 2008).

In the North Indian Temple the *latina* and *sekhari* are generally found on the sanctum and the *phamsana* are usually found on the *Mandapa* or the pillared halls.

In the South Indian temple the super structure is that of the *kutina* and *shala* type. The super structure is pyramidical in form and consists of stepped stories. Each story replicates the main story and is conceived having its own “wall” enclosed by a parapet. In the ancient temples, these stepped stories of the superstructure with their parapets became more and more ornamental, so that in the course of time they evolved into more or less decorative bands around the pyramidal superstructure (South Asian Arts, 2008). The stepped structure is capped with a solid dome or cupola or with a barrel-vault

roof. The former is the *kutina* type and the later is the *shala* type. The structure is crowned with a pot and finial.

Figure 24.1

Figure 24.2

Figure 24.1 & 24.2 – The different types of *sikhara* of the south Indian temples (Source: Hardy, 2007)

### 4.5.5 The Pillared Hall or the Mandapa

The basic Hindu temple will have a porch in front of the sanctum. The larger temples have one or more *mandapa*, the audience hall in front of the main sanctum. The *mandapa* may be closed or open with one two or three entrances.

During the 7$^{th}$ and the 8$^{th}$ centuries the *mandapa* have flat roofs usually covered with massive stone slabs. The spacing between the columns was determined on the basis bearing capacity, practicality of the quarrying and transportation (Hardy, 2007). The slabs of stones for the roofing were carved underneath into beautiful patterns continuing the rock cut tradition.

In the north Indian temple during the 9$^{th}$ century onwards the *mandapas* were built on the *vastupurashamandala* theory and geometry. The *mandapa* reflects the plan of the main shrine, the central bay of the *mandapa* dominates the plan and have the same width as that of the *garbhagriha.* Different forms of ceiling patterns developed among which lantern ceiling was the most common. In the lantern ceiling the triangular slabs piled up to construct diminishing squares and rectangles. Later on the roof of the *mandapa* were constructed in the corbelled system. The square bays were reduced to circle via triangular corner slabs and diagonal beams and the space was covered with the stepped horizontal courses and diminishing until it can be closed with a single stone or brick. The *mandapa* have *phamasana* type of structure externally.

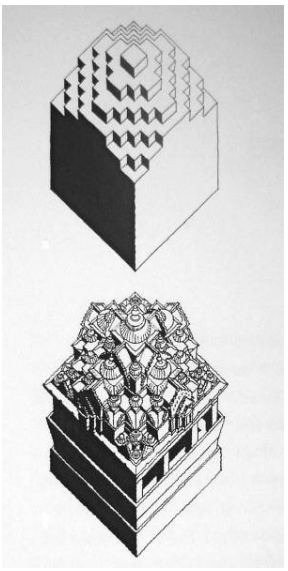

Figure 25.1

Figure 25.2

Figure 25.1 – The basic structure of the mandapa of the north Indian temples (Source: Hardy, 2007)

Figure 25.2 – View of the mandapa of the north Indian temples (Source: www.personal.carthage.edu)

While in the south the *mandapa* are provided with flatter pyramidal covering with waterproofing and surrounded by a parapet. The Madapa in the south Indian temple are often large in size. (hundred-pillar mandapa, thousand-pillar mandapa - in fact, there are less in number); pillars are most times well ornamented and display carvings of gods and goddesses, various characters and mythical animals.

Figure 26.1

Figure 26.2

Figure 26.1 – View of the mandapa of the north Indian temples (Source: Www.indoarch.org, 2006)

Figure 26.2 – View of the interior of the mandapa of the south Indian temples (Source:-Www.indoarch.org, 2006)

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# Chapter 5

# 5 THE CONSTRUCTION TECHNOLOGY OF HINDU TEMPLE

The construction of temple is an art, a science and a complicated creative study with a blend of mathematics, logic, geography, geology, science, ecology, art, sculpting, music, light and sound, religion, social sciences and astrology.

The historical information about construction of temples which is available today is mostly inscribed on the stones slabs, metal plates, palm leaves and manuscripts. The knowledge and skills of the construction techniques were passed on verbally from generation to generation among the temple architects. One of the most important surviving records about the construction of temple is in the palm leaf manuscript which explains the details of the building operation of 13$^{th}$ century Surya Temple at Konark, Orissa. This record shows the list of workmen, their salaries, and rules of conduct, and provides an account over several years of various building operations (Michell, 1988).

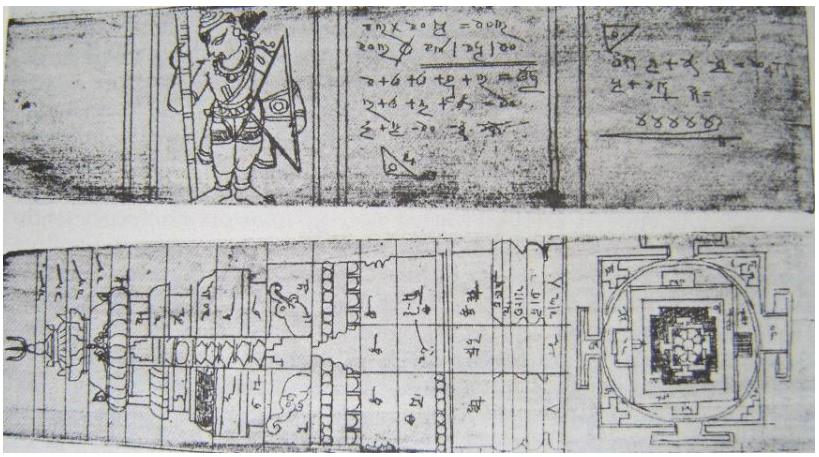

Figure 27

Figure 27-The palm leaf inscription from a manuscript showing architect, calculations on proportional's, section with heights and *mandala* plan.(Source: Michell, 1988)

This chapter deals with the understanding the processes involved during the construction of a Hindu temple and also about the skills required and methods utilized by the master architect and his team. This section will also present step by step, the process of how a site is selected, examination of a site, determining the orientation of the temple, taking measurements and laying out the temple plan on the site, selection of material, carving of the stones, tool and equipments used, joinery details and the final assembly of the temple.

The south and the north Indian temple construction follow the same procedures leading upto the construction of the temple. Only slight differences occur due to variability of materials used for construction, the climate and availability of human resources or the social structure of a particular

period. Therefore, the construction technology discussed here is applicable for both the 'northern style' and 'southern style' of temples.

## 5.1 Builder and Craftsmen

According to the past records and the existence of families and groups who still continue the tradition of temple construction we can say that there were various organized groups of architects, artisans and workmen who were employed in the various aspects of temple construction. These groups functioned as guild or society. The techniques and skills of these associations were passed on verbally and practically from generation to generations to those in the same family or household.

Figure 28

Figure 28-The work, rituals and the activities at the temple construction site camps (Source: author's collection & www.himalayanacademy.com).

These groups were like corporate body combining both the families and the individual workers. The associations had fixed rules of work and salaries, completion time of the work and prices and were as

good as laws. Among the association too they followed own judicial privileges, control the social life of the members and also could expel a disobedient member. The members of the association travelled one region to another region to work on different projects and spread the artistic and architectural traditions throughout the history of temple construction.

The workmen from these associations settled in camps around the building site and had their meals in the common mess. The construction of temple lasted for years and during the rainy season when work was halted they had their leave from work. Proper law and order was maintained and internal disputes were sorted out. Fines were charged as punishment for the delay in work, delivery of materials and work completion. The people who quarried and transported the stone to the site, the blacksmiths who extracted and casted tools, the carpenters, the sculptors, and various other service providers were associated with the erection of the temple. The women were also engaged for lighter auxiliary work such as cleaning, polishing stones, etc. and also there was provision to replace the artist or worker with another in case of death, illness and accidents (Hardy, 2007).

The association also provided training to the young generation and students, not in a separate school but right on the field where the projects were being execute under the supervision of experienced heads. They were taught all the theoretical instructions in the ancient manuals. They were given the knowledge of geometry, history, measurements and drawings. They were also given knowledge of music, dance and yoga. The training time lasted for almost 10 years and when they had acquired the knowledge they were send to work on the bigger or prestigious projects.

Today also these groups or associations exist and functions in the same manner as can be seen in the Indian states of Rajasthan, Gujarat, Karnataka and Orissa and have a major role in the construction of the temples within and outside the country. The manuals, treatises and books referred till date for the temple architecture are *Shilpratankar, Diparnav, Vastu Vidya, Vastu Shastrakarika, Vastusa, Prasad Mandan* etc

Among all the member of the association the most foremost person involved in the construction of temple was the chief architect. Every region in the country had there own chief architect and association which are called as *sompuras* in the west, *mahapataras* in the east and *sthapatis* in the south. The north of India too had there own, but they don't exist anymore.

The architect's work was a team work which was also bounded by the rituals performed before, during and after the construction. The construction team consisted of the four classes, ***sthapati, sutragrahin, taksaka*** and ***vardhakin***. The team followed the instructions of the ***sthapaka,*** the Brahmin architect priest. Several workmen worked under these four heads in the erection of the temple (Dagens, 1985).

## 5.2 Selection of the Team

The initial and foremost step before starting the construction of the temple is the selection of the team and their heads. Firstly the main architect 'the ***sthapati*** is selected. The *sthapati* should have complete knowledge of the Shilpshastras, the traditional sciences, mathematics and *Purans,* paintings, music and yoga. He should be fit to direct the construction to all the other members engaged in the construction work. As a person he should be kind, joyous, and free from hatred and jealousy, truthful, with control over the senses, focused in mind, and also free from greed, carelessness and disease (Kramrisch, 2007). Similarly the ***sthapaka*** is also selected by the patron and he should also be well versed with the *Shipshastras* and perform the architectural rites correctly. Both the *sthapati* and *sthapaka* have to work together and the construction started by the two should be continued by them only. In special cases the when they are not available the work should be done by an equivalent disciple.

Figure 29

Figure 29-The present day stapati, sutragrahin, takshaka and the vardhakin with their respective work (Source: author's collection & www.himalayanacademy.com).

The ***sutragrahin*** is the disciple or the son of the *sthapati* and whose role is to perform all the work assigned by the *sthapati* and also he should have knowledge of layout and proportionate measurements (vertical and horizontal) by chord and rod.

The ***takshaka*** is the cutter of the stone and other materials, who cuts and carves the large pieces and do the subtle detail and should be able to do work on own initiative and also follow the *sthapati*.

The fourth is the ***vardhakin***, the mason or carpenter who fits and places together what the *takshaka* has carved and by adding to the finished work and he also follows the *sutragrahin* (Kramrisch, 2007).

The team of all the four heads work together with other workmen in the construction of the temple and any one missing cause the disruption in the process of construction.

## 5.3 Stages of Construction

The construction of temple was a long process and used to last for decades. The building of the temple was divided into three stages. The first stage is the planning of the temple that includes the selection and examination of the site, layouts and measurements, selection of materials, quarry of the stones, orientation of the temple, list of parts of the temple and allocation of the work to the prescribed persons. The *sthapati* with the *sthapaka* and other team members do the planning and determining the overall architectural conception of the temple. The *sutragrahin* follows the instruction of the *sthapati* and controls the overall work and did the layout of the temple on the site.

The second stage is the carving of the different parts of the temple which includes carving and cutting of the stone, construction with brick, stone and timber, and the *takshaka* instructed the sculptors and *shilpis* to carve the parts according to the drawings, specifications and guidelines.

The third and the final stage is the assembling the parts of the temple i.e. the actual construction of the temple. Even today this same process is followed with slight variations done due to the availability of modern construction technology. The architect still visualizes the minutest detail of the temple.

Presently, the second stage involving carving and cutting works offers much possibility for correction and extra-supervision, though this stage slows down the process but leads to removal of the probable faults and accuracy in the final moment (Sompura 1996).

## 5.4 Construction Stages of a Hindu Temple

This section covers the different stages of temple construction.

### 5.4.1 STAGE I: Site Selection and Preparation for Construction

#### *5.4.1.1 Selection of the site*

The initial step for the construction of the temple is the selection of the land/site. According to the treatises the “The gods always play where groves, rivers, mountains and springs are near, and in towns with pleasure gardens.” Thus, most of the ancient surviving temples were built on the mountain peaks, lush valleys, grooves, near the water body, etc where the environment was considered to be suitable for the adobe of the gods (Kramicsh, 2007). Any land may be considered suitable for the construction after performing rituals for its sanctification; however the essential necessity is the existence of water, which can be present naturally or at least as a symbolic representation. The practical preparations for the building of a temple are invested with great ritual

significance and magical fertility symbolism (Exoticindiaart 2003). The probable site for the construction is first examined for the type of soil, colour, odour, form, flavour and sound. After knowing these criteria the religious cult to which the temple is favorable is decided. In this manner the auspicious sites were chosen.

### *5.4.1.2 Inspection, Insemination and Levelling of the site*

After the inspection of the site for its consistency it is important to check the condition of the soil. This can be determined by performing some simple test on the site. These tests are described in the ancient manuals i.e. firstly, a pit is dug on the site and the soil which has been taken out is put back again and checked whether the level of the packed soil is higher, same or lower. The land with the higher and the same level of packed soil are selected for the construction. Secondly, the pit is filled with the water and left overnight; the quality of the soil is evaluated according to the quantity of water remaining in the pit.

Finally, the fertility of the soil must be tested. This is tested by sowing a seed at the chosen site on a auspicious day and the germination is observed. If the growth of the plant is satisfactory the land is considered suitable for the construction of temple.

The germination of the seed is a metaphor for the fulfillment of the inherent potentialities which lie hidden in Mother Earth, and which by extension are now transferred to the sacred structure destined to come over it (Exoticindiaart 2003).

After all these preliminary investigations, the selected site needs to be leveled: the ground where the temple is to be constructed should be throughout equal plane. When the inspections, leveling and tilling is done, the site is ready for the laying out the divine diagram or the *vastupurashamandala*.

### *5.4.1.3 Orientation, Measurements and Layout*

The process of establishing the orientation of a temple binds it to the earth, the sun and their relationship at the moment of origination. The method by which orientation was undertaken was based on the 'Indian circle method' and was based on the use of an instrument known as '*shanku-yantra*' or the 'gnomon', which is an ancient device for determining the east-west direction as well as for knowing time (Hardy, 2007).

This method deeply influenced the geometry of the temple plan and its development. The process involved is making a perfect starting point for the constructing the geometry of the temple on the ground.

The gnomon is erected on a level surface, and a small circle is drawn around it using a chord. In the morning the shadow of the gnomon will shrink as the sun rises until its tip touches the edge of the circumference of the circle; in the afternoon, as the shadow lengthens its tip will again touch the circumference. The line between the two points run from runs from east to west. However variations

occurred in the declination of sun at different latitude. So slight differences have been found to occur in the orientation of temples in different regions which suggests that the place, the time of foundation and the process itself counted more than observance of strict orientation (Kramicsh, 2007).

The temple plan was generated from the original circle drawn on the ground, then a parallel line was drawn through the centre of the original circle. This was done easily by striking arcs with the chord. Striking arcs also set up the north-south axis. The next step was to draw four circles of the same size as the original one, centered on the points where the axes meet the circumference, resulting a figure which may be called the 'extended gnomon diagram' (Hardy, 2007).

This simple shape gives a square fitting perfectly around the original circle. This shape further leads to extended shapes in a beautiful sequence of nested circles and squares

If a second circle is drawn around this first square, and the same process repeated, as with the first circle a second square is generated, a third circle, a third square and so on. The side of the third square will measure twice those of the first square, its area therefore being four times the area of the first square, and so on (Hardy, 2007).

In this geometry are inherent diagonal squares, giving the sequence of nested octagons and 8 pointed stars. The 'extended gnomom diagram' contains a hexagon with an inscribed 6 pointed star (hexagram) made of equilateral triangles and an octagon with inscribed 12 pointed star, which can be made of equilateral triangle or of square. All this had implication for the plans of the temple, both octagonal and stellate.

The nature of the main deity greatly influences the orientation of the temple. According to the orientation of the plan the placement of the idol is decided. The specific directions of the deity are as such: East facing-any and all gods and goddess, because it's the best orientation. West facing-is considered to be the next best, and is used for the Jain *thirthankaras*. North facing-is the third best and is meant for the *Shiva* family of the Hindu pantheon such as *Shiva*, *Ganesh*, *Linga*, etc. This is because Lord *Shiva's* abode is Kailash in North, South facing-is for the monkey god *Hanuman*, and other aggressive gods and goddess, *Yama* or the god of death etc.

#### *5.4.1.4 Selection of material*

According to the ancient manuals on architecture the material used in the construction of the temple directly relate to a class of Hindu society. However, most of the *treatises* allow the use of stone for all kind of temples irrespective of the class of the Hindu society. The stone is considered as the most sacred building material- it is considered that the temple made in brick is hundred times more worthy than wood and the temple constructed in stone is ten thousand times more worthy than in brick. The materials of the temple in the manuals are identified with gender. The temples of male deity are generally made of stone and brick, the female deity temples are usually made of brick and wood, and temple with all the materials are considered neutral (Dagens, 1985).The manuals insist on the use of

newly prepared building material for the temple construction rather than the re-use of building materials from older construction though it has been observed that older materials were in fact re-used.

The stones are used in temple construction according to the availability and climate of the region such as granite in the south, marble in the west, sandstone in the central and limestone in the costal areas, sandstone is never used in costal areas and generally locally available stone is preferred. The stone selected for the construction should be of even colour, hard and perfect, pleasing to touch. The quality and type of stone is very important according the place where they are applied in the construction. The hard and even stones are used for the plinth, columns, beams and slabs. The supple stones are used for the construction of sculptures, idols, carvings etc. The preferred stones for the construction were then quarried. These quarries were mostly located in the nearby areas only in some cases the specific stones were transported from far of distances.

### *5.4.1.5 Quarrying of the stone*

In the past the stones were quarried using wooden wedges that are driven into the rocks and then wetted to cause expansion. This in turn causes the rocks to crack and are thus cut by subsequent application of pressure and dressed.

Figure 30

Figure 30-The present day quarry site and the process of quarry of stone (Source: author's collection & www.himalayanacademy.com).

#### *5.4.1.6 Transportation of Materials*

In the past the transportation of the stones from the quarries to the building site was done on the wooden rollers drawn by the elephants or floated on the wooden barge along the rivers and the canals.


Figure 31

Figure 31-Transportation of the materials by the elephants and on the wooden rollers. (Source: Kuili's Suganya & author's collection).

### 5.4.2 STAGE II- Carvings on the Temple

The stones are transported from the quarry to the work yard near the temple site. This is the second stage for the building of the temple According to the requirement a team of *takshaka* carve different parts of the temple such as pillars, beams, brackets, etc. as per the drawings and specifications.

Each stone to be included in the temple construction is carved separately and later assembled together by intricate interlocking system.

#### *5.4.2.1 Cutting and Carving the stone*

The carving of each stone piece is slow, tedious and work of patience. A single wrong strike of the hammer could spoil thousands of hours of work. A smallest piece like railing of staircases may take approximately a month of work. The carvings of stones are carried out in approximately four different phases corresponded to the task of different craftsmen.

Firstly, the team of stone mason will cut the stone block to the appropriate size, another team of carvers will give the stone a basic shape and finally the sculptors give them the final form. The joining system of each stones is pre-decided and the rough joinery details are prepared simultaneously. Later, during the time of assembly according to the requirement these details are made fine and corrected to make a proper joint.

Figure 32

Figure 32-Different stages of cutting and carving the stone from the rough to the final stage (Source: www.himalayanacademy.com).

### *5.4.2.2 Drawings in stone*

The intricate ornate carvings on the stones depend on the precise drawings. In the earlier days the drawings on the stones were made by sharpened coal piece and sharpened bamboo shoot (bamboo pencil). Stencils were made for the repetitive designs. The bamboo pencils are dipped in the any coloring agent such as lime, ink, red oxide for the markings and sketches on the stones. The long straight lines are marked by soaking the thread in the coloring agent and then stretching from one end to the other and snapped. After every phase of carving more lines are made for the carvers to detail the stones.

Figure 33

Figure 33-Making of drawings for carving on the surface of the stone with coal and bamboo pencils and the stencils (Source: www.himalayanacademy.com).

### *5.4.2.3 Polishing the stone:*

The final phase of work is polishing of the final form of the stones. The polising is done using stone bars. This is also a slow and work of patience. On an average it takes 12-20 days for polishing the stone depending upon its shape and size. The fine chiseled surface is leveled using different categories of stone bars; the stones are then washed and cleaned to remove any stains and dirt to give the final shiny finish to the stone surface. Once the carving and polishing is completed the pieces are stored for the final assembly of the temple.

Figure 34

Figure 34-Polishing of the stone (Source: www.himalayanacademy.com).

Figure 35

Figure 35-Stacking of the final carved pieces (Source: www.himalayanacademy.com & author's collection).

### *5.4.2.4 Tools and equipments.*

The basic tools, hammer and different types of chisels are used for cutting and carving of the stones. The tools are made locally and sharpened regularly in the work yard by the blacksmiths.

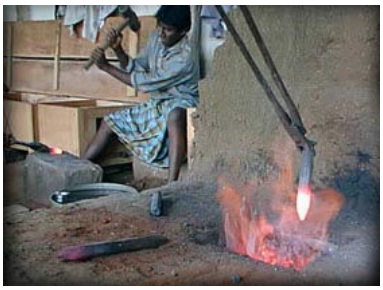

Figure 36

Figure 36-The process of making of equipments and the different tools used in carving of stone (Source: www.himalayanacademy.com & author's collection).

### 5.4.3 Stage III Process of Temple Building

#### *5.4.3.1 Laying the Foundation.*

The foundation of the temple is approximately 2 meter deep pit. The pit is dug throughout the base and is wider than the base of the temple. The stones are laid one above the other with out mortar towards the structure boundary. The foundation below the sanctuary is generally fully packed with stones placed one above the other. At the base of the foundation on the exact centre of the garbha griha a hollow duct is placed running from the foundation base to the base of the main idol of the temple, for performing the ritual called as *garbhadhana.*

Figure 37a

Figure 37b

Figure 37a-View of foundation of an ancient temple (Source: Kuili Suganya collection)

Figure 37b-Layout and markings for foundation of a new temple construction (Source: www.himalayanacademy.com).

#### *5.4.3.2 Assembly of Elements*

The final and the most important stage for the construction of the temple is the assembly of all the parts together.

After carving of the individual pieces is completed, the different levels of the temple with its different parts are pre assembled to check the accuracy of the joints and to avoid any mismatch and misfit during the time of placing the part at its actual position in the temple. After the corrections the parts are transported to the main site of the temple construction from the work yard. This phenomenon can very well be seen even today specially in temple construction being carried out in other parts of the world other than Indian subcontinent. The different parts of the temple are carved in India and transported to other far off lands.

Figure 38

Figure 38-The pre-assembly of the different levels of the temple and corrections done for the perfect fit (Source: www.himalayanacademy.com)

At the site the carved parts of the temple are erect into their exact position by rope and pulley on the scaffoldings. Ramps were also constructed of timber and sand to ease the placing of heavy members. The earlier remains of ramp are found near the Temple of Brihadeshvera, Thanjuvar, which was constructed to carry the 80 ton finial stone to the height of 60m. In the present day construction the temple builders use chain pulley derrick pole and cranes to place the parts together in the exact position.

### *5.4.3.3 Joinery system*

In the ancient times the traditional Hindu temples were derived from the timber and bamboo architecture. During the period of stone construction the architectural elements and the decorative details of the temple continued to follow the timber construction details for centuries in one form or another even though the original purpose and the context was lost. The timber joinery system was followed to assemble all the parts of the temple together.

The observations from the old temples clearly show that various types of assemblies were used for joining the vertical and horizontal parts of the temple together. Today, also the joints are made with and accuracy of 1/16th of an inch. The ancient manuals explain different types of assemblies, proportion and usage of the joints.

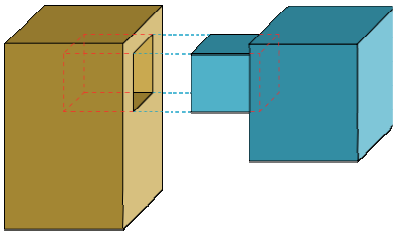

Figure 39.1

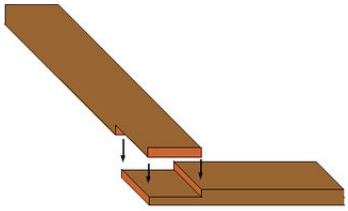

Figure 39.2

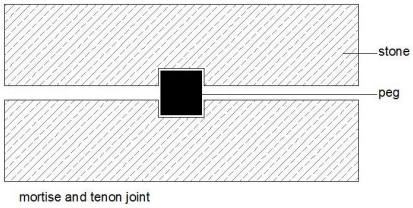


Figure 39.3

Figure 39.4

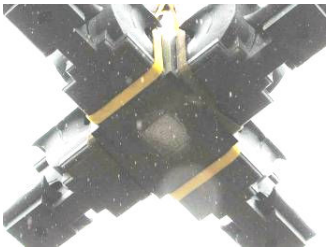

Figure 39.5

Figure 39.6

Figure 39.1-The mortise and tenon joint (Source: www.himalayanacademy.com)

Figure 39.2-The lap joint (Source: www.himalayanacademy.com)

Figure 39.3-The mortise and tenon joint with a peg

Figure 39.4 & 39.5-The mortise and tenon joint in the carved piece of stone(Source: www.himalayanacademy.com)

Figure 39.6-View of mortise and tenon joint in an ancient temple (Source: Kuili Suganya collection)

The major joining systems used were different types of mortise and tenon joint and the lap joint. The mortise and tenon joints were mostly used for the horizontal assembly and the lap joints were used in the vertical assembly. Another kind of joint is a kind of mortise and tenon joint i.e. a peg is fixed between the two mortise cut out in two different stones, this joint is usually used between the two courses of masonry to avoid the movement of the stones due to lateral forces. In the past natural binders were used to unite the joints together. In the present days cement acts as the binding agent between the joints.

In the past the use of steel was strictly prohibited as steel gets rusted and reduces the age of the temple. But temples constructed during the 13$^{th}$ and 14$^{th}$ century shows the use of iron clamps and wedges, with ends sealed in molten lead, to join the stone slabs firmly together

### *5.4.3.4 Plinth:*

The plinth stones placed above the foundation stones act as the retaining wall for the rubble compacted earth with in the plinth area of the structure. Above this compacted rubble are laid stone slabs for the flooring of approximately 200 mm to 300 mm.

The stones of the plinth are place one above the other and they are made stable with the self weight. The number of courses of stones at the plinth varies according to the size of the temple from 3 to 10 numbers.

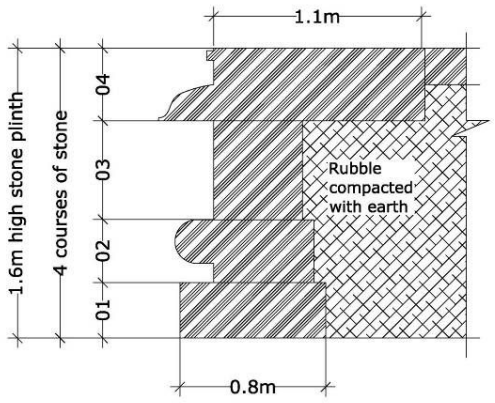


Figure 40

Figure 40-The typical plinth structure of a temple (Source: Kuili Suganya collection)

The top most courses on plan i.e. the stone floor of the temple, where exactly the vertical components were raised, was marked with chisel marks (mason marks) and grooves for the pillar bases with out lines for raising walls and entrances.

These chisel marks gave an indication of the plan of the temple and where the various components are to be raised.

### *5.4.3.5 Wall*

The main structural masonry walls are constructed as a stone composite masonry with stone, brick with lime or mud as the masonry core. The thickness of the stones varies from 300 to 4500 mm. The average thickness of the masonry wall varies from 800mm–1200mm. Through stones are provided at regular intervals to act as ties and thus strengthen the walls. The stone slabs are cut, dressed and carved and used for facing the earth filling or rock surface for the plinth. The joints are very fine either without any mortar or with fine lime mortar. Over the wall are the stone beams.

Figure 41

Figure 41-The walls of the temple showing the courses of masonry (Source: Kuili Suganya collection)

### *5.4.3.6 Column and beams*

The columns are monolithic structure. They are made up of 5 parts and all are interlocked by the mortise and tenon joints. The five parts consists of two parts of the base one part as the shaft and two as the capital of the column.

Figure42.1

Figure42.2

Figure42.3

Figure42.4

Figure42.5

Figure42.6

Figure42.7

Figure42.8

Figure42.9

Figure 42.1, 42.2 & 42.3-Process of fixing of the column shaft (Source: www.himalayanacademy.com)

Figure 42.4 -The capital of the column(upside down) (Source: www.himalayanacademy.com)

Figure 42.5-The columns shaft fixed with the capital (Source: www.himalayanacademy.com)

Figure 42.6, 42.7, 42.8 & 42.9-The fixing of beams over the columns (Source: www.himalayanacademy.com)

The top of the column have the brackets which provide a good bearing for the beams and reduce the spans. The beams were placed over the column structure which further supports the roofing system of the temple.

### *5.4.3.7 Mandapa*

The *mandapa* of the temple may be flat roofed in the south and have pyramidical superstructure in the north. The *mandapa* ceiling is build with basic beam and slab construction method. Later diminishing patterns of nested squares were constructed by placing the triangular slabs across the corners of the square plan. The square bay of the *mandapas* were reduced to stepped pyramidical roof via triangular corner slabs or diagonal beams.

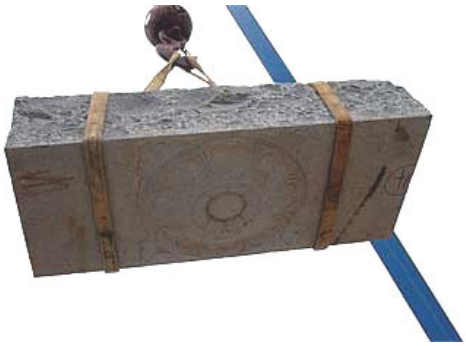

Figure43.1

Figure43.2

Figure 43.1 & 43.2 -Process of fixing of the roof slabs (Source: www.himalayanacademy.com)

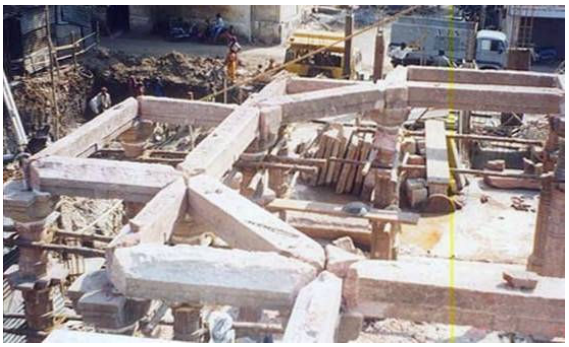

Figure44

Figure 44-Arrangement of the beams and roof slabs for the mandapa ceiling.(Source: www.sompura.com & author's collection)

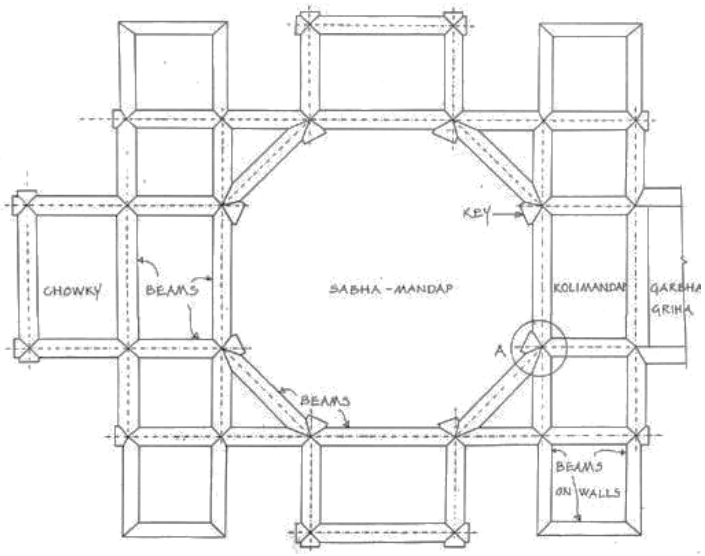


Figure45.1

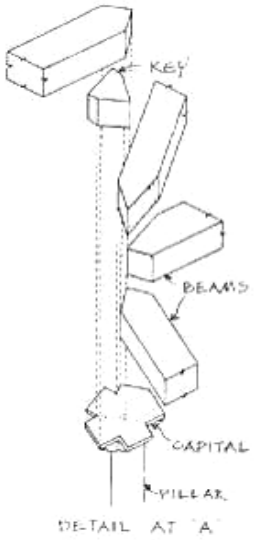


Figure45.2

Figure 45.1-Plan of the arrangement of the beams (Source: www.sompura.com)

Figure 45.2-The joining detail of the beams (Source: www.sompura.com)

### *5.4.3.8 Sikhara*

The *sikhara* is the pyramidical structure built on the *garbhagriha* of the temple. Corbelling construction system is used for the construction of the s*ikhara*. The horizontal courses one above the other are stepped inwards and progressive forward to cover the space. The *sikhara* is usually hollow from inside or in some cases filled with rubble. The apex of the superstructure is mounted by a single piece of stone called as *amlaka* in the north and *sikhara* in the south.

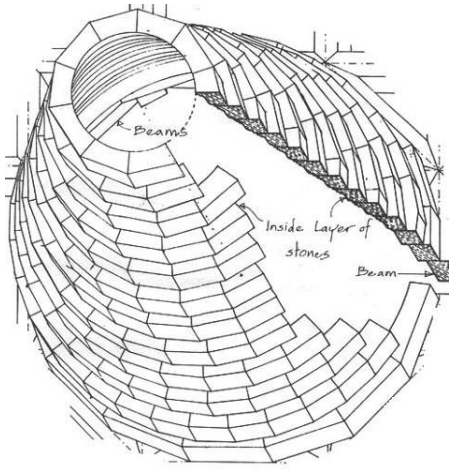


Figure46.1

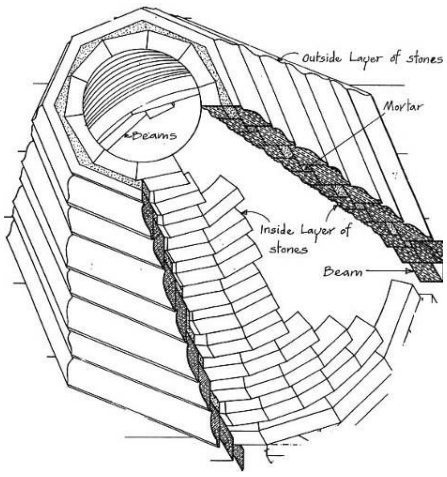


Figure46.2

Figure 46.1-the inner layer of masonry of the *sikhara* (Source: www.sompura.com)

Figure 46.2-the outer layer of masonry of the *sikhara* (Source: www.sompura.com)

Figure47.1

Figure47.2

Figure 47.1 & 47.2 –The process of construction of *sikhara* (Source: author's collection)

Figure48

Figure 48 –The process of placing the cap stone or *sikhara* (Source: www.himalayanacademy.com)

## 5.5 Ceremony and Rituals

The scared altar in the *brahmasthana* or the central shrine is located directly above the gold box, placed in the earth during the *garbhadhana* ceremony. Here on the sacred altar representing the heart of the Cosmic Being, the deity of Godhead called the *archa-vigraha,* the manifest form of total divinity is installed. The *mandala*, the *mantra*, and above all the sincerity and faith of the participants combine together to invoke the appearance of Godhead. The universe is the manifestation of the divine form of Godhead in the world of mundane existence. The body of the temple is the representation of that cosmic form, whereas the *archa-vigraha* is the manifestation of the transcendental form of Godhead descending from beyond the mundane. The ceremony for installing the deity is performed with great pomp and upon its completion the temple is complete (Gosai 2002-2008)

Figure49

Figure 49 –The rituals performed after placing of the cap stone or *sikhara* (Source: www.himalayanacademy.com)

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# Chapter 6

# 6 DIMENSIONAL ANALYSIS

This chapter discusses and analysis the results of the dimensional study of the Hindu temple.

Here the following simplified methods of analysis and corresponding indexes are considered:

1. In plan area ratio of the temple
2. Relation and comparison between the height and the time of construction of the north and south Indian temple
3. Relation and comparison between the area of the main shrine(*garbhagriha*) and the time of construction of the north and south Indian temple
4. Relation and comparison between the area and height of the main shrine (*garbhagriha*) of the north and south Indian temple.
5. Relation and comparison between the slenderness and time of construction of the main shrine (*garbhagriha*) of the north and south Indian temple.

The Hindu temple architecture has been classified into two major styles, the *Nagara*, the northern style and the *Dravidian*, the southern style. The examples of temple for the analysis have been selected from the northern style as well as the southern style. The date of construction of these temples ranges from the $5^{th}$ century till the $13^{th}$ century. A sample of 15 temples from the each style was selected. The selection was limited to 15 in number due to the limited availability of the basic drawings and information required for the analysis. The detailed table for both the styles has been shown in the appendix. The following two tables show the few examples among the selected ones.

**Temples of the North India**

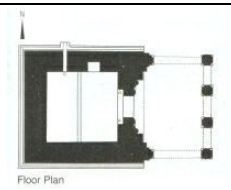
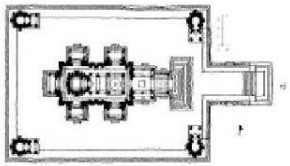
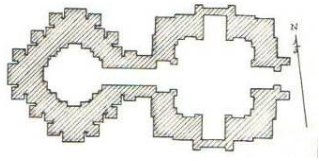
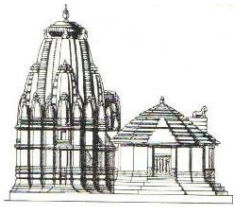
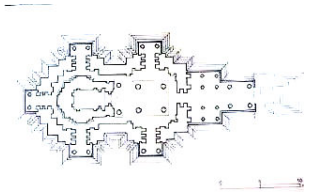
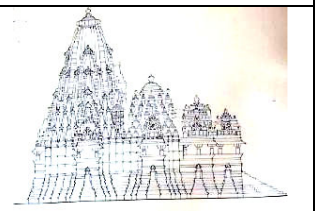
| Sr. No | Temples of North India | Period | Area of main shrine( sq m.) | Length of the main shrine( L)(m) | Height of Sikhara or spire(m ) | H/L | Slenderness ratio (1/H/L) | Plans | Elevation/Section |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Tigawa temple, Jabalpur M.P. | 5th cent. | 16.82 | 4.38 | 3.8 | 0.8676 | 1/.9 |  |  |
| 2 | Lakshmana temple, Khajuraho, M.P | 10th cent. | 34.18 | 9.75 | 24.5 | 2.5128 | 1/2.5 |  |  |
| 3 | Rajarani temple, Bhubaneswar, Orrisa | 10th cent. | 63.17 | 8.94 | 18.89 | 2.113 | 1/2.1 |  |  |
| 4 | Kandariya Mahadeo, Khajuraho,M.P | 11th cent. | 36.82 | 10.8 | 35 | 3.2407 | 1/3.2 |  |  |

Table 1- North Indian temple indexes

**Temples of the South India**

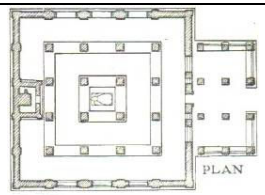
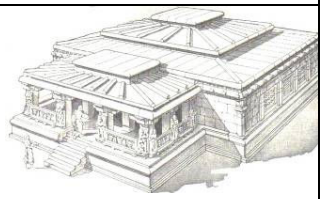
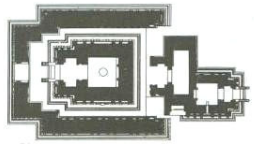
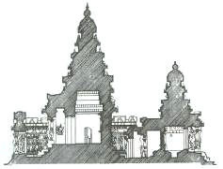
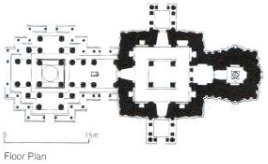
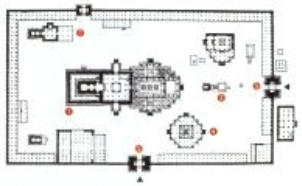
| Sr. No | Templesof North India | Period | Area of main shrine( sq m.) | Length of the main shrine( L)(m) | Height of Sikhara or spire(m ) | H/L | Slend ernes s ratio (1/H/L) | Plans | Elevation/Section |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Ladh khan temple, Aihole, Karnataka | 5th cent. | 9.2 | 2.74 | 6.82 | 2.4891 | 1/2.5 |   |  |
| 5 | Shore temple, Mahabalipuram, Tamil Nadu | 8th cent. | 23.35 | 4.45 | 13.46 | 3.0247 | 1/3. |   |   |
| 9 | Main Shrine , Itagi, Koppal district, Karnataka | 12th cent. | 54.13 | 7.11 | 14.2 | 1.9972 | 1/2. |   |  |
| 16 | Vitthal temple, Hampi, Karnataka | 15th cent. | 133.69 | 13.78 | 19.6 | 1.4224 | 1/1.4 |  |  |

Table 2- South Indian Temple indexes

## 6.1 In plan area ratio of the temple

The safety of the ancient construction, namely with respect to earthquake actions, can be tentatively evaluated by calculating the in plan ratio of the building (Lourenco, et al 2005). In plan area ratio is the ratio between the areas of the load bearing walls and the total in plan area of the temple. The ratio calculated for the samples of both the styles are shown in the tables:

| Sr.No | Temples of North India | Period | In Plan Area Ratio | | |
|---|---|---|---|---|---|
| | | | Total Area of the Temple (sq.m) | Total Wall Area of the Temple (sq.m) | Total Wall Area/Total Area of the temple (%) |
| 1 | Tigawa temple, Jabalpur M.P. | 5th cent. | 24.68 | 9.48 | 38.41% |
| 2 | Brick temple Bhitargoan, UP | 6th cent. | 25.82 | 17.65 | 68.51% |
| 3 | Dashavatara temple Deogarh, MP | 6th cent. | 26.29 | 15.63 | 57.45% |
| 4 | Parasurameswar temple, Bhubaneswar, Orrisa | 7th cent. | 97.19 | 41.23 | 36.82% |
| 5 | Teli ka mandir, Gwalior,M.P | 8th cent. | 258.2 | 175.47 | 67.96% |
| 6 | Surya temple, Osia, Rajasthan | 9th cent. | 53.82 | 15.94 | 29.61% |
| 7 | Mukteswar temple, Bhubaneswar, Orissa | 9th cent. | 69.8 | 37.31 | 53.45% |
| 8 | Vaital deul temple, Bhubaneshwar, Orissa | 9th cent. | 134.13 | 68.73 | 39.43% |
| 9 | Lingaraja temple, Bhubaneswar, Orissa | 10th cent. | 1049.66 | 499.91 | 47.62% |
| 10 | Lakshmana temple, khajuraho,M.P | 10th cent. | 167.43 | 64.82 | 38.71% |
| 11 | Rajarani temple, Bhubaneswar, Orrisa | 10th cent. | 152.56 | 87.34 | 57.24% |
| 12 | Jagadambi temple , Khajuraho, MP | 10th cent. | 154.67 | 70.23 | 45.40% |
| 13 | Brahmesvara temple, Bhubaneswar, Orissa | 11th cent. | 140.01 | 76.94 | 54.95% |
| 14 | Kandariya mahadeo, Khajuraho, M.P | 11th cent. | 182.89 | 85.31 | 46.64% |
| 15 | Gondeshvara temple, Sinnar, Maharastra | 11th cent. | 147.37 | 80.26 | 54.49% |
| 16 | Jaganath temple, Puri Orissa | 12th cent. | 1089.03 | 598.77 | 54.98% |
| 17 | Ananta vasudev temple, Bhubaneswar, Orissa | 12th cent. | 226.08 | 106.24 | 46.99% |

Table 3- North Indian temple for In plan area ratio

| Sr.No | Temples of South India | Period | In Plan Area Ratio | | |
|---|---|---|---|---|---|
| | | | Total Area of the Temple (sq.m) | Total Wall Area of the Temple (sq.m) | Total Wall Area/Total Area of the temple(%) |
| 1 | Ladh khan temple, Aihole, Karnataka | 5th cent. | 291.24 | 43.35 | 14.88% |
| 2 | Durga temple, Aihole, Karnataka | 6th cent. | 258.35 | 45.42 | 17.58% |
| 3 | Temple of papanatha, Pattadakal, Karnataka | 7th cent. | 199.42 | 58.07 | 29.11% |
| 4 | Temple of virupaksha, Pattadakal, Karnataka | 8th cent. | 162.8 | 55.12 | 33.85% |
| 5 | Shore temple, Mahabalipuram, Tamil Nadu | 8th cent. | 32.91 | 20.59 | 62.56% |
| 6 | Jaina temple, Pattadakal, Karnataka | 9th cent. | 148.81 | 49.82 | 33.47% |
| 7 | Brihadeshvara temple, Thanjavur, Tamil Nadu | 11th cent. | 2179.29 | 737.15 | 33.82% |
| 8 | Mallikarjuna temple, Sudi, Karnataka | 11th cent. | 176.19 | 78.57 | 44.59% |
| 9 | Gangaiacondacholapuran temple, Karnataka | 11th cent. | 2084.9 | 729.49 | 34.98% |
| 10 | Jain temple, Lakkundi, Karnataka | 11th cent. | 198.11 | 73.23 | 36.96% |
| 11 | Main Shrine , Itagi, Koppal district, Karnataka | 12th cent. | 378.19 | 131.98 | 34.89% |
| 12 | Temple of kallesvara, Kukkanur,Karnataka | 12th cent. | 459.92 | 232.63 | 50.58% |
| 13 | Virupaksha temple complex, Hampi, Karnataka | 12th cent. | 336.034 | 125.64 | 37.38% |
| 14 | Kesava temple, Aralguppe, Karnataka | 13th cent. | 472.31 | 214.6 | 45.43% |
| 15 | Isvara temple, Arisikerai, Karnataka | 13th cent. | 486.78 | 148.39 | 30.48% |
| 16 | Chandrasekara temple, Hampi, Karnataka | 14th cent. | 335.56 | 110.8 | 33.01% |
| 17 | Chandikeshawa temple, Hampi, Karnataka | 14th cent. | 106.21 | 36.62 | 34.47% |
| 18 | Vitthal temple, Hampi, Karnataka | 15th cent. | 769.04 | 397.54 | 49.92% |

Table 3- South Indian temple for In plan area ratio

The calculations show the trend of construction of the Hindu temple was massive, heavy and piled up masonry, beams and corbelling. The strength and stability is obtained by the mass supporting mass method. The ratios obtained in the tables are two to three times higher than typically required for masonry buildings (5 to 10% in modern masonry, Eurocode 8, and 10 to 20% in old churches (Lourenco, et al 2005). The average value of the in plan area ratio for the north Indian temple is 49.33% (with a range from 30 to 70%), while the average value for the south Indian temple is 36.55% (with a range from 15 to 65%). Thus, the Hindu temples seem relatively safe and stable structures for vertical and seismic actions.

## 6.2 Relation between the height and the time of construction of the Hindu temple

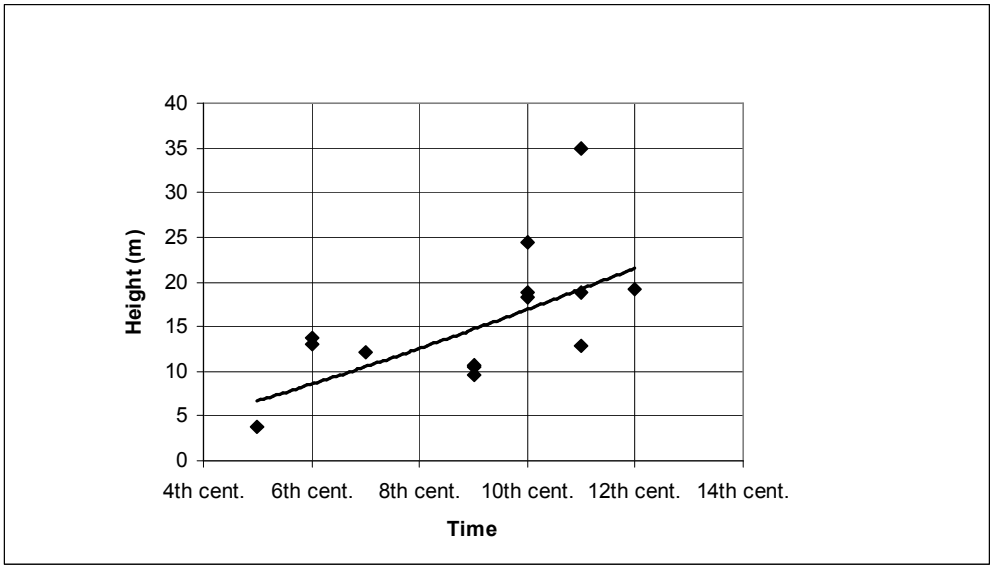



Figure 50 –Graph 1- Height and Time graph of north Indian Temple

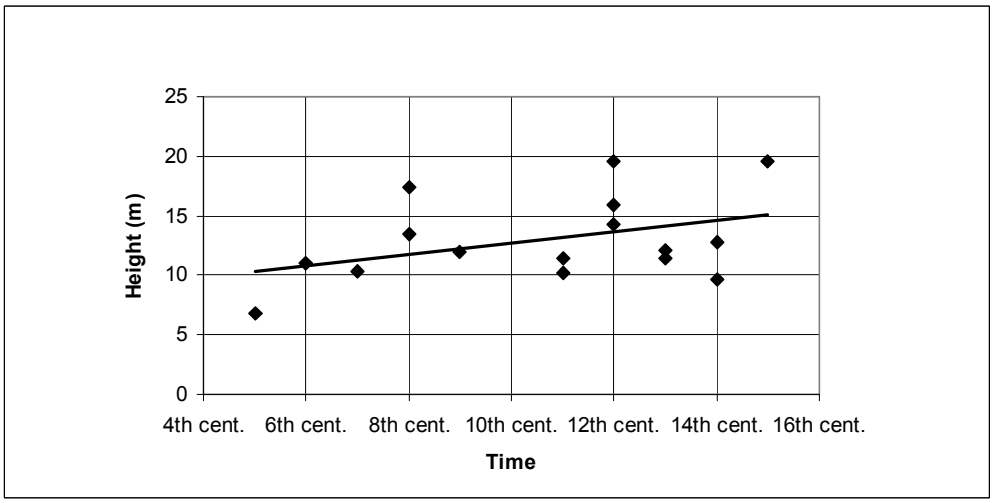



Figure 51 –Graph 2- Height and Time graph of south Indian Temple

The raised trend in the graph 1 shows that in the north Indian temples the height of the shrine increased with respect to the period of construction. In the early centuries the height of the temples was low and gradually in the later centuries the Hindu philosophy and better building technology inspired the Hindu architects to build higher temples. The average value of the height for the north Indian temple is 15.79m (with a range from 5 to 35m), while the average value for the south Indian temple is 12.99m (with a range from 5 to 20m). It is noted that the values found are relatively low, when compared with masonry towers in Europe (up to 100 m in the Cremona Torrazo (Binda, 2008)) and even with other buildings in India (e.g. Qutub Minar in New Delhi, which totals 76 m). Therefore the stresses in the masonry will also be relatively low.

In the south temple the trend in the graph 2 remains relatively constant which shows that the height of the temples does not increased with the time, probably due to religious reasons.

## 6.3 Relation between the area and the time of construction of the Hindu temple

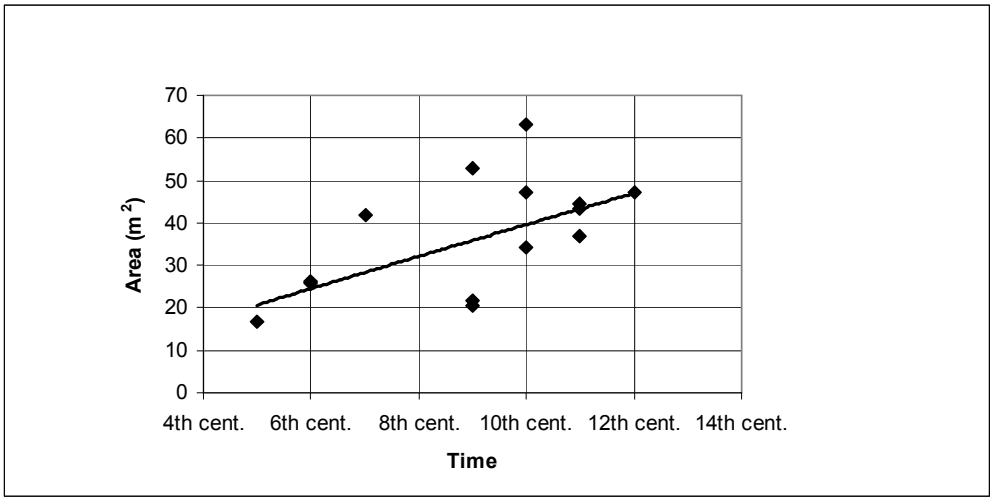



Figure 52 –Graph 3- Area and Time graph of north Indian Temple

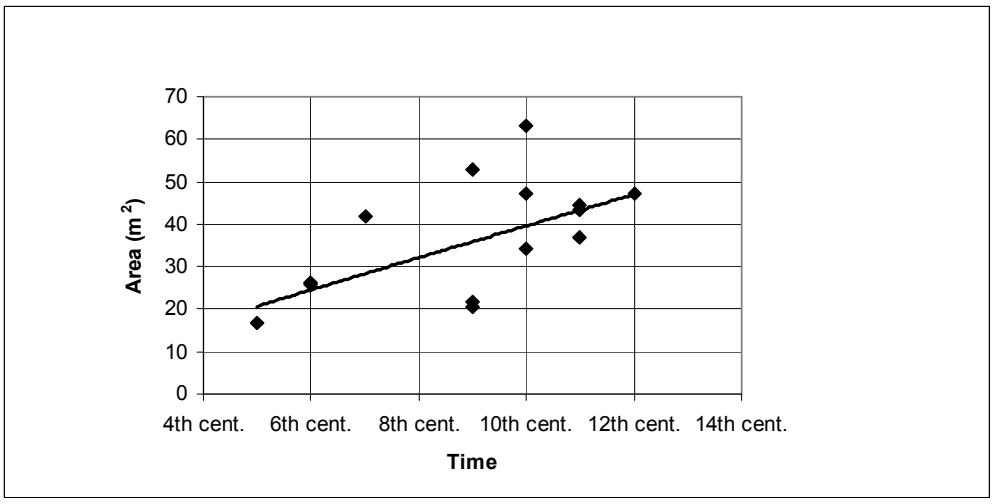



Figure 53 –Graph 4- Area and Time graph of south Indian Temple

The raised trend in the graphs 3 and 4 shows that the area of the shrine increased with respect to the period of construction. In the early centuries the area of the temples was low and gradually increased, possibly due to a combination of better building and material transportation techniques, wealth and size of the communities, and increasing workforce. In the north temple, an area increase of the shrine should be expected, in association of the higher heights of the temples, see also next section.

The average value of the area for the north Indian temple is 37.32m$^2$ (with a range from 15 to 65m$^2$), while the average value for the south Indian temple is 51.25m$^2$ (with a range from 15 to 65m$^2$).

## 6.4 Relation between the area and height of the main shrine of the Hindu temple

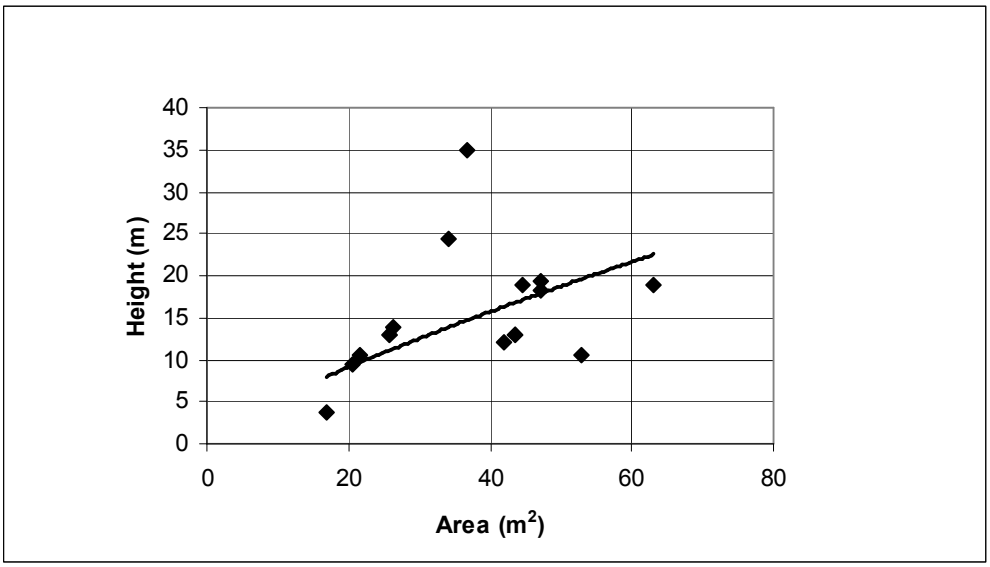



Figure 54 –Graph 5- Height and Area graph of north Indian Temple

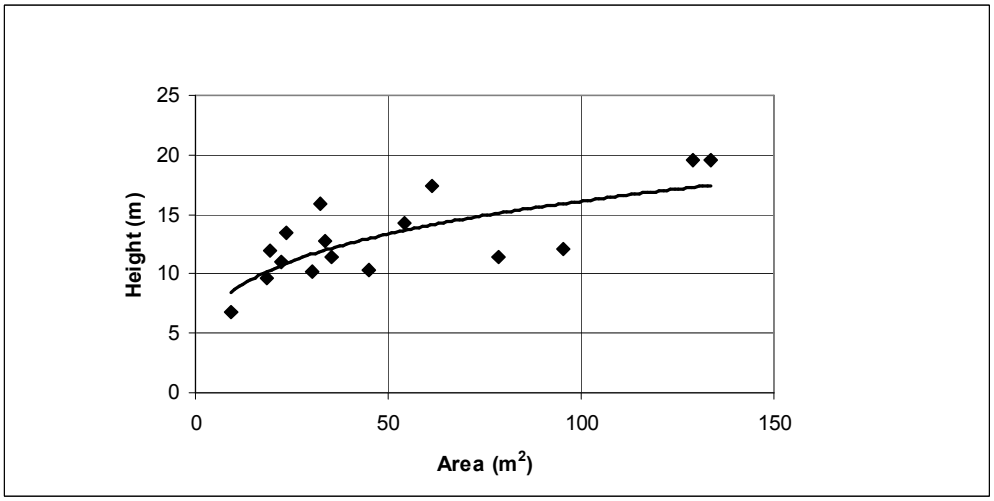



Figure 55 –Graph 6- Height and Area graph of south Indian Temple

The raised trend in the graph 5 shows that in the north Indian temples the area of the shrine increased with respect to the height of the temples. In the early centuries the area of the temples was low and gradually in the later centuries with the better building construction skills the area of the shrine was increased to sustain the higher heights of the temples.

While in the south the trend in the graph 6 increases which shows that the area of the shrine increased more relative to the heights of the shrine. In the south Indian temples the height of the shrine remained relatively constant but the area of the shrine increased because according to the practices and beliefs the heights of the main shrine were never altered. The historical development shows that the builders in the south increased the heights of the *gopurams* (the entrance gateways) instead of the heights of the main shrine. The study on *gopurams* is not included in this dissertation.

During the 10th and the 11th century due to the improvement in the construction technology, wealthy patrons and an impulse to extend upwards to create soaring heights, both in the north and south India few temples reached to height of 60 m. for example: Jaganath Temple, Puri, Orissa and Brihadeshvara temple, Thanjavur, Tamil Nadu

It seems thus that, due to the difference in thoughts and different purpose of usage the temples in the north grew vertically while in the south the temples expanded horizontally.

## 6.5 Relation between the slenderness and time of the main shrine of the Hindu temple

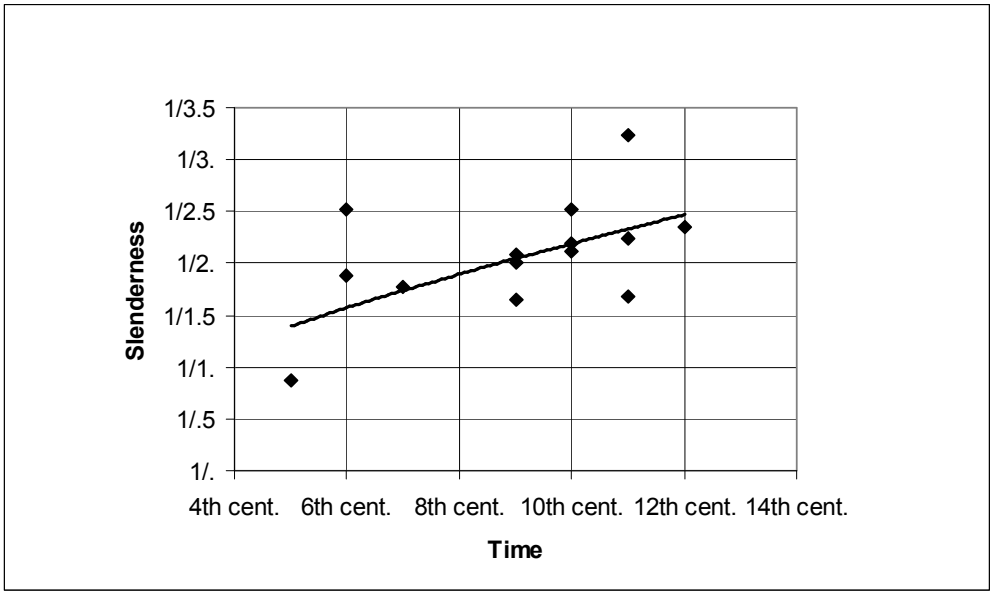



Figure 56 –Graph 7- Slenderness and Time graph of north Indian Temple

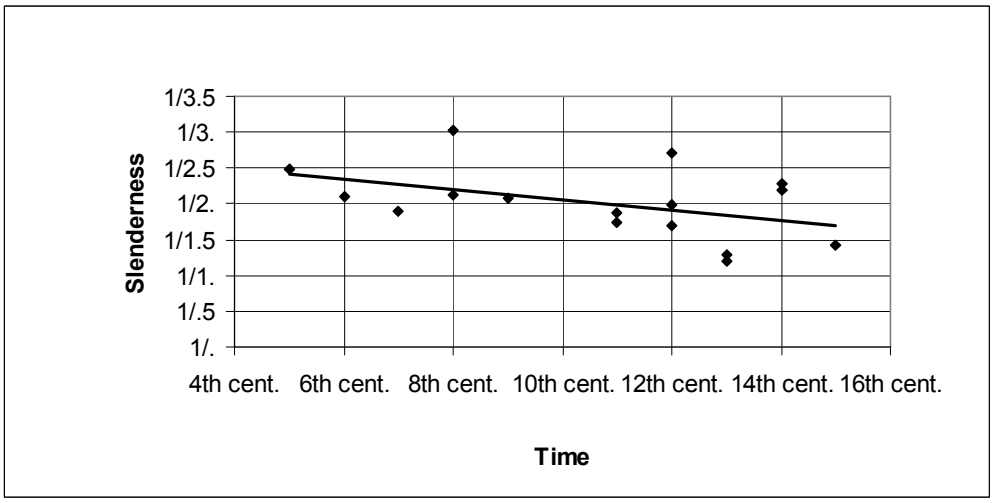



Figure 57 –Graph 8- Slenderness and Time graph of south Indian Temple

The raised trend in the graph 7 shows that in the north Indian temples the slenderness of the shrine seems to have increased moderately with respect to the time of construction. In the later centuries

with the better building construction skills and the empirical knowledge from the trial and error building process, and to achieve more heights of the temple, the builders started to build more slender temples.

In the south the trend in the graph 8 remains approximately constant between the values 1/1.5 to 1/3.

The average value of the slenderness for the north Indian temple is 1/2.09 while the average value for the south Indian temple is 1/2.

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**Books and Journals:**

1. Binda, L.; et al. - “Survey and Investigation for the Diagnosis of Damaged Masonry Structures: the“Torrazzo of Cremona”, 12th Int. Brick/Block Masonry Conf., Madrid, Spain, 2000, p.237-257.
2. Lourenco, P.B., Roque, J.A. “Simplified indexes for the seismic vulnerability of ancient masonry buildings.” Construction and Building Materials, 20, (2006), pp 200-208. http://www.sciencedirect.com/ (accessed May 20, 2008)

# Chapter 7

# 7 CONCLUSIONS

The Indian subcontinent in its long and varied history dating from 2500 BC to the colonial period has left behind in the form of its architectural legacy different types of buildings in a variety of architectural styles. The diversity of Indian culture is evident from the different forms of artistic expressions in its built heritage. Among them is the temple architecture of India which has given India a truly magnificent form of architecture. The temples in India are found everywhere varying from small villages to the metropolitan cities. The Indian Temples are not only the abode of God forming the link between God and man and a place of worship, but they are also the cradle of knowledge, art, architecture and culture. The practices and traditions of temples has its influence on the social, economic and traditional values system in India even today as it was in the ancient times. Today even as new temples continue to be built the character of Hindu temples follow age old traditions though its architectural style is influenced by the local architectural styles and locally available building material and skills.

This dissertation is a research into the foundation of the Hindu temples and the development of temple architecture in India. The distinctive architectural styles of Hindu temples have so developed due to its broad geographical, climatic, cultural, racial, historical and linguistic differences which are especially significant in the two major styles of Hindu temple architecture ie in the temples of the northern plains and in the southern peninsula of India. Hindu temples of these two regions have been classified as the ***Nagara*** or 'northern' style, the ***Dravidian*** or 'southern 'style. While both the regions share a common origin in thatched huts and modest timber forms, as reflected in early bas-relief depictions and their actual rock-cut representations, further evolution of the structural shrine in each region charters an independent course. But even though the appearance of the temple differed the basic philosophy that guided their planning and layout was the same guided by manuals on architecture.

There are several ancient scriptures and books or manuals in Hinduism. Among these are the scriptures that have guided Hindus on techniques and structural rules of architecture. The technical treatises written in Sanskrit, which is an ancient language of India (the language of the Vedas), gives the basic rules in the field of architecture and sculpture are called as the *Shilpa Shastras* and *Vastu Shastras*. The *Mayamata* and *Mansara* is the other two well known treatise of South India on architecture and iconography respectively. The rules from these treatises were strictly followed for the construction of temples dating back from the 5$^{th}$ Century A.D and followed even today throughout the country in different temple forms and styles. The temple is a link between the physical world of man and divine world of God. And to connect them, the plan of cosmos were graphically copied in the foundation of the temples. Thus the typical plan of a Hindu temple is an illustration of sacred geometry where the temple is representation of the *mandala*. Here the sacred geometry means the science the accurate laying out the ground floor of the temple in relation to the astronomical movements and positions and the cardinal directions. The *mandala* is the sacred form consisting of the intersection of the circle and the square. Thus the Hindu architecture, religious or

vernacular, according to the sects in the ancient times were based on the geometry of the *Vastupurashamandala*.

The basic construction technique used in early Hindu temple was the trabeated system or the post and the beam method and which was extended by the use of corbelling techniques. This method was originally used for wooden construction in India and was later adopted for the stone structures as well. The column-beam-corbel method of construction however became the main structural principle governing the construction of every Hindu temples. The principles of equilibrium of forces in action by means of arch, vaults and other forms of functional engineering rules never really played a major part in the evolution of Hindu temple. The Hindu architects thus remained attached to his own traditional techniques and accomplished his task of construction by carefully study of the laws of gravity, obtaining the strength by the mass supporting mass and stability by the solid resistance of the weights acting vertically, all pressure being transmitted directly downwards.

The construction technology used in the construction of the Hindu temple, the processes involved during its construction, the human skills required and methods utilized by architects and their team, all of this together bring out the art, science and philosophy behind the construction of the Hindu temple. This covers aspects relating to the site is selection, examination of a site, determining the orientation of the temple, taking measurements and laying out the temple plan on the site, selection of material, carving of the stones, tool and equipments used, joinery details and the final assembly of the temple. The ‘north’ and the ‘south’ Indian temple construction follow the same procedures leading up to the construction of the temple. The slight differences occur due to variability of materials used for construction, the climate and availaibility of human resources or the social structure of a particular period. The tradition of temple construction is carried out by various organized groups of architects, artisans and workmen who were employed in the various aspects of temple construction. Today even though there are few of these associations remaining that still maintain the tradition of the construction of the temples

On the basis of the above studies this dissertation concludes by undertaking a structural study of temples taking examples from primarily ‘north’ and ‘south’ Indian temples in an attempt to graphically analyse the structures with respect to its structural stability. The finding of this dissertation on the basis of the above studies undertaken has been that the massive nature the stability of the temple structure depends mainly on the geometrical compatibility of the elements with respect to the load applied rather than material failure. A dimensional analysis therefore constitutes an important step in safety assessment of this kind of structures. The data concerning the main geometrical property of temple from the ‘north’ and ‘south’ of India here have been collected and elaborated through some specific though limited number of examples. In spite of the limited number of samples it is possible to find some interesting trend even though the absence of a stastical validity constitute a starting point for future works concerning the stability analysis of the temples."

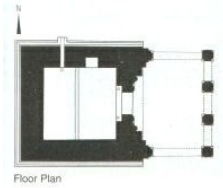
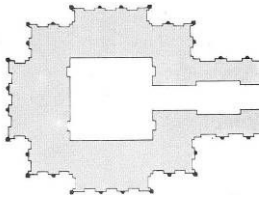
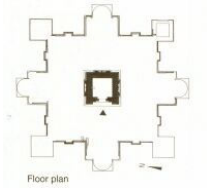
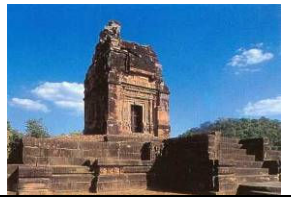
## 7.1 Scope for Future Studies

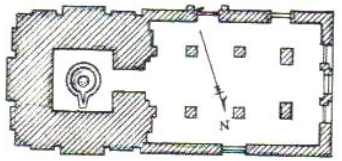
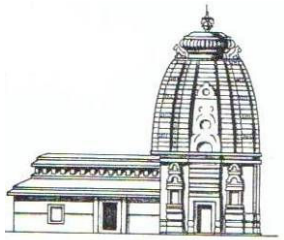
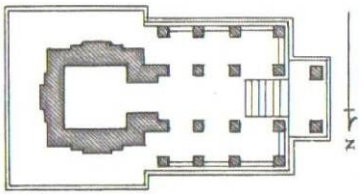
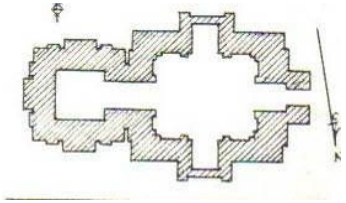
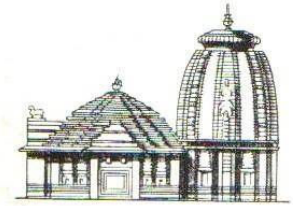
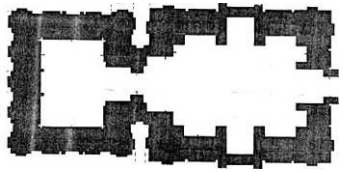
The Hindu temples of India has been a subject of study for numerous historians, religious scholars, art historians, photo-journalists, archaeologists, architects and other professionals. There is scope for much study on Hindu temples in different regions of India not just based on the iconography, form and transformation but more on their building technology and structural analysis..Some studies have been undertaken. For example it is known that numerous temples have fallen due to different calamities from time to time, yet there are even today examples of temple which haven't fallen either due to earthquake or cyclone or other natural calamity as because these temple were constructed in the form of an interlocking system as per laid out in the ancient manuals. Therefore these structure tend to vibrates along with the earth's vibrations, and will sway but not fall under any circumstances during earthquakes or cyclones. Therefore there is scope for further understanding of the structural aspects of Hindu temple and it can be a subject of more structural analysis like safety analysis and stability analysis of structures including calculation of the maximum average stress at the foundation and columns, the thrust analysis of the *sikhara*, and post & lintel etc.

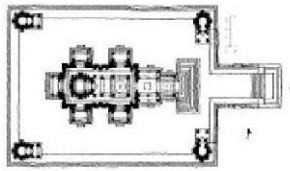
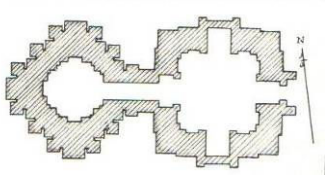
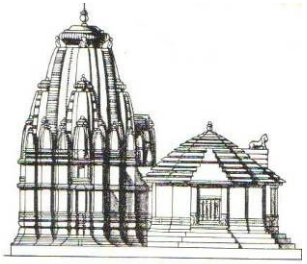
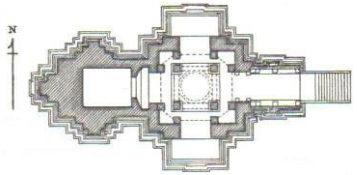
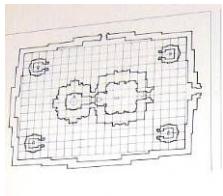
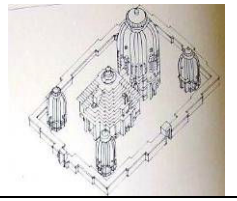
# Appendix

## THE DETAILED DATA FOR THE DIMENSIONAL STUDY OF THE HINDU TEMPLE

**The examples of the North Indian temple selected for the study**

| Sr. No | Temples of North India | Period | Area of main shrine(sq m.) | Length of the main shrine(L)(m) | Height of Sikhara or spire(m) | H/L | Slenderness ratio (1/H/L) | Plans | Elevation/Section |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Tigawa temple, Jabalpur M.P. | 5th cent. | 16.82 | 4.38 | 3.8 | 0.8676 | 1/.9 |   |  |
| 2 | Brick temple Bhitargoan, UP | 6th cent. | 25.82 | 6.89 | 13 | 1.8868 | 1/1.9 |  |  |
| 3 | Dashavatara temple Deogarh, MP | 6th cent. | 26.29 | 5.47 | 13.75 | 2.5137 | 1/2.5 |   |  |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4 | Parasurameswar temple, Bhubaneswar, Orrisa | 7th cent. | 42.03 | 6.89 | 12.19 | 1.7692 | 1/1.8 |  |  |
| 5 | Surya temple, Osia, Rajasthan | 9th cent. | 21.68 | 5.01 | 10.45 | 2.0858 | 1/2.1 |  |  |
| 6 | Mukteswar temple, Bhubaneswar, Orissa | 9th cent. | 20.54 | 4.77 | 9.54 | 2 | 1/2. |  |  |
| 7 | Vaital deul temple, Bhubaneshwar, Orissa | 9th cent. | 52.89 | 6.4 | 10.6 | 1.6563 | 1/1.7 |  |  |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 8 | Lakshmana temple, khajuraho, M.P | 10th cent. | 34.18 | 9.75 | 24.5 | 2.5128 | 1/2.5 |  |  |
| 9 | Rajarani temple, Bhubaneswar, Orrisa | 10th cent. | 63.17 | 8.94 | 18.89 | 2.113 | 1/2.1 |  |  |
| 10 | Jagadambi temple , Khajuraho, MP | 10th cent. | 47.23 | 8.35 | 18.35 | 2.1976 | 1/2.2 |  |  |
| 11 | Brahmesvara Temple, Bhubaneswar, Orissa | 11th cent. | 44.48 | 8.4 | 18.81 | 2.2393 | 1/2.2 |  |  |

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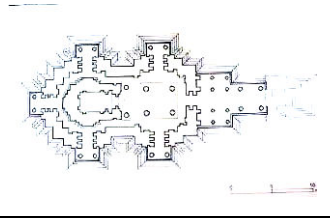
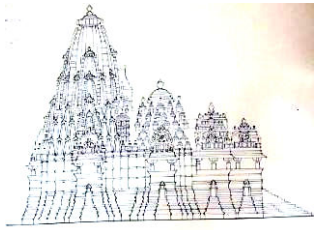
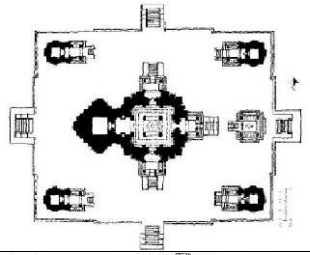
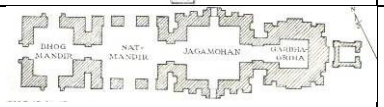
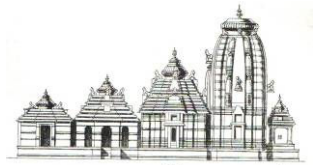
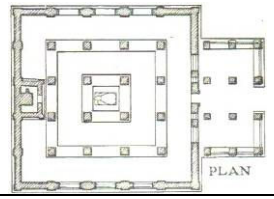
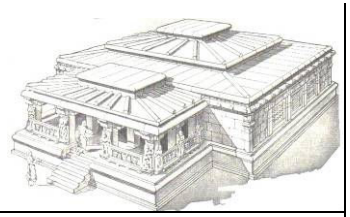
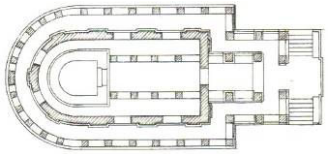
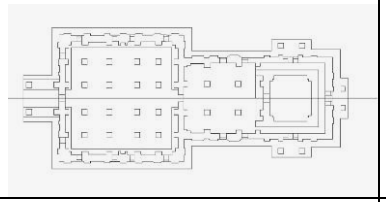
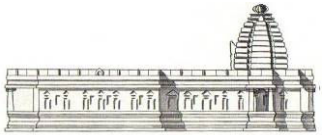
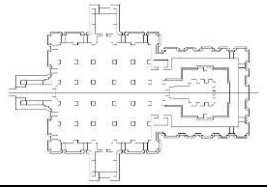
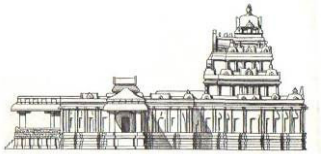
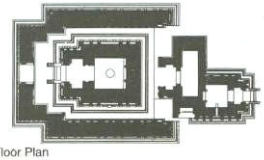
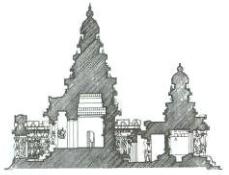
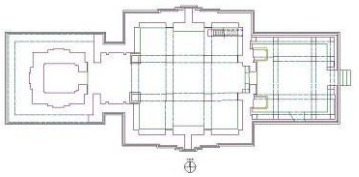
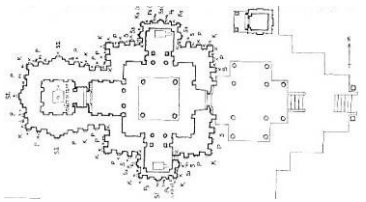
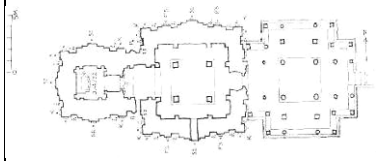
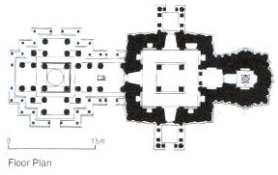
|---|---|---|---|---|---|---|---|---|---|
| 12 | Kandariya mahadeo, khajuraho,M.P | 11th cent. | 36.82 | 10.8 | 35 | 3.2407 | 1/3.2 |  |  |
| 13 | Gondeshvara temple, Sinnar, Maharastra | 11th cent. | 43.48 | 7.7 | 12.93 | 1.6792 | 1/1.7 |  |  |
| 14 | Ananta vasudev temple, Bhubaneswar, Orissa | 12th cent. | 47.05 | 8.2 | 19.27 | 2.35 | 1/2.4 |  |  |

**The examples of the South Indian temple selected for the study**

| Sr. No | Templesof North India | Period | Area of main shrine(sq m.) | Length of the main shrine(L)(m) | Height of Sikhara or spire(m) | H/L | Slenderness ratio (1/H/L) | Plans | Elevation/Section |
|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Ladh khan temple, Aihole, Karnataka | 5th cent. | 9.2 | 2.74 | 6.82 | 2.4891 | 1/2.5 |  |  |
| 2 | Durga temple, Aihole, Karnataka | 6th cent. | 22.1 | 5.27 | 11.06 | 2.0987 | 1/2.1 |  |  |
| 3 | Temple of papanatha, Pattadakal, Karnataka | 7th cent. | 44.89 | 5.48 | 10.36 | 1.8905 | 1/1.9 |  |  |
| 4 | Temple of virupaksha, Pattadakal, Karnataka | 8th cent. | 61.26 | 8.22 | 17.44 | 2.1217 | 1/2.1 |  |  |
| 5 | Shore temple, Mahabalipuram, Tamil Nadu | 8th cent. | 23.35 | 4.45 | 13.46 | 3.0247 | 1/3. |  |  |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6 | Jaina temple, Pattadakal, Karnataka | 9th cent. | 19.14 | 5.75 | 12 | 2.087 | 1/2.1 |  |  |
| 7 | Mallikarjuna temple, Sudi, Karnataka | 11th cent. | 35.14 | 6.07 | 11.36 | 1.8715 | 1/1.9 |  |  |
| 8 | Jain temple, Lakkundi, Karnataka | 11th cent. | 30.19 | 5.9 | 10.22 | 1.7322 | 1/1.7 |  |  |
| 9 | Main Shrine , Itagi, Koppal district, Karnataka | 12th cent. | 54.13 | 7.11 | 14.2 | 1.9972 | 1/2. |   |  |

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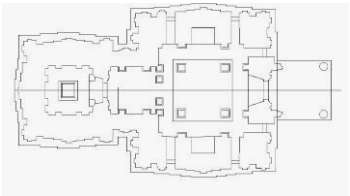
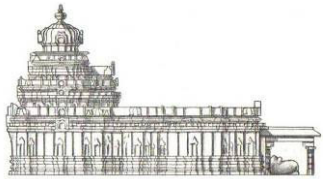
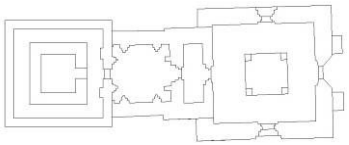
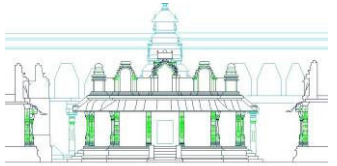
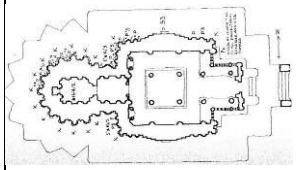
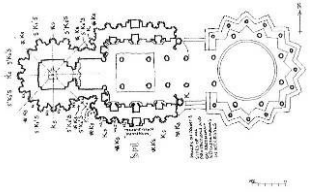
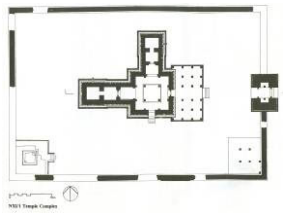
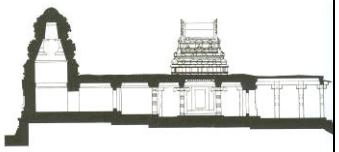
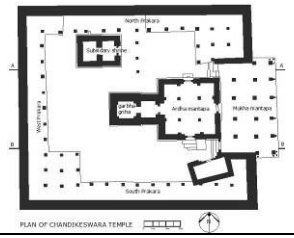
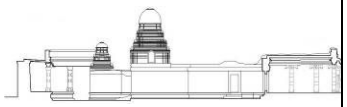
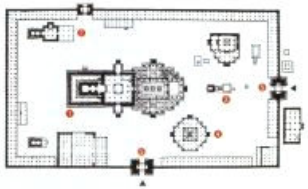
|---|---|---|---|---|---|---|---|---|---|
| 10 | Temple of kallesvara, Kukkanur,Karnataka | 12th cent. | 128.8 | 11.58 | 19.5 | 1.6839 | 1/1.7 |  |  |
| 11 | Virupaksha temple complex, Hampi, Karnataka | 12th cent. | 32.25 | 5.87 | 15.96 | 2.7189 | 1/2.7 |  |  |
| 12 | Kesava temple, Aralguppe, Karnataka | 13th cent. | 95.27 | 9.38 | 12.04 | 1.2836 | 1/1.3 |  |  |
| 13 | Isvara temple, Arisikerai, Karnataka | 13th cent. | 78.74 | 9.44 | 11.36 | 1.2034 | 1/1.2 |  |  |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 14 | Chandrasekara temple, Hampi, Karnataka | 14th cent. | 33.46 | 5.83 | 12.81 | 2.1973 | 1/2.2 |  |  |
| 15 | Chandikeshawa temple, Hampi, Karnataka | 14th cent. | 18.41 | 4.23 | 9.66 | 2.2837 | 1/2.3 |  |  |
| 16 | Vitthal temple, Hampi, Karnataka | 15th cent. | 133.69 | 13.78 | 19.6 | 1.4224 | 1/1.4 |  |  |

# Glossary

| | |
|---|---|
| *adhisthana* | moulded base or "plinth" of a Dravida temple. |
| *amalaka* | A flat fluted disc like stone representative of the holy fruit of "amala", usually at the summit of the Shikhara |
| *Antarala* | Vestibule, chamber in front of shrine or cella. |
| *Ardha Mandapa* | Chamber before the min "mandapa" or hall. |
| *atman* | the soul |
| *Bhagavad-gita* | The Hindu holy book |
| *bindu* | point |
| *Brahma* | The Hindu God Supreme. |
| *chaitya* | From "chita", a pyre but later a Buddhist sanctuary and ultimately the Buddhist hall of worship. |
| *garbhagriha* | Literally "the womb", the most sacred inner sanctum of the temple where the deity is enshrined. |
| *ghata* | Platform or steps at edge of lake or river water. |
| *ghee* | The butter used for burning the lamps in the temple |
| *gopurams* | Monumental South Indian temple gateway. |
| *grīvā* | "neck"; recess under kuta dome, sala roof or other roof-element |
| *jagati* | railed parapet. |
| *jangha* | applies to the broad band of sculpture towards the middle of the temple wall (exterior); sometimes called *panchakama*. |
| *kalasa* | literally vase, religious inverted ot installed over the amalaka as a finial for the Shikhara. |
| *Kutina* | peak: crowning pavilion especially domed Dravida type |
| *lasuna* | "chest-and-shoulders" element of pillars and pilasters |
| *latina* | mode of Nagara shrine with curved *Shikhara*. |
| *Mahabharata* | great Sanskrit Epic of India. |
| *malasthana* | in pillars or pilasters, a horizontal band, like a belt, above the mala or "bell". |
| *Mandapa* | Large hall generally the chambers preceding the inner sanctum of the Hindu temple. |
| *mantras* | The hymns |
| *Natamandira'* | dancing hall, usually the middle structure in an Orissan temple. |
| *phamsana* | shrine mode with pyramidal superstructure of tiered eaves-mouldings. |
| *Pitha* | base, pedestal. |
| *potikas* | brackets at top of pillars or pilasters. |
| *Pradakshina patha'* | Processional ambulatory passage particularly Buddhist, around the stupa. |
| prakara | enclosure wall. |
| *Ramayana* | Sanskrit Epic poem of great antiquity. |
| *sala-aedicule* | aedicule with a sala as the supersturcture. |
| *samsara* | |
| *shala* | representatin of a "barrel-roofed" ("barrel-vaulted", "wagon-roofed") pavilion; generally constituting the superstructure of a sala-aedicule. |
| *shilpis* | Sculptor |
| *sikhara* | Literally mountain peak but generally the spire or tower over north Indian Hindu temple. |
| *Siva* | The major Hindu deity: destroyer of the universe |

| | |
|---|---|
| *stapati* | Chief architect |
| *sthapaka* | Priest who have knowledge about the temple construction. |
| *sutragrahin* | disciple or the son of the *sthapati* and whose role is to perform all the work assigned by the *sthapati* |
| *takshaka* | cutter of the stone and other materials, who cuts and carves the large pieces and do the subtle detail |
| *tali* | a kind of necking in a Dravidian capital. |
| *Torana* | Gateway, particularly the ceremonial gates at the cardinal points of the stupa. |
| *Upanishad* | The Hindu texts |
| *uttara* | beam over column. |
| *varandika* | band of mouldings between wall and superstructure of a Nagara temple. |
| *vardhakin* | mason or carpenter who fits and places together what the *takshaka* has carved |
| *Varnas* | The four classes of society;Brahmin,Kshatriya,Vaishya and Shudra |
| *veda* | Ancient text(s) embodying the essence of the Aryan religious life in the form of mantras or chants to be recited at religious ceremonies. |
| *vedibandha* | moulded base or "plinth" of a Nagara temple. |
| *Vimana* | Pyramidical tower over the inner sanctum generally of South Indian temples. |
| *Vishnu* | the major Hindu deity: preserver of the universe |

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