

**Indian Knowledge System  
IIT Kharagpur**

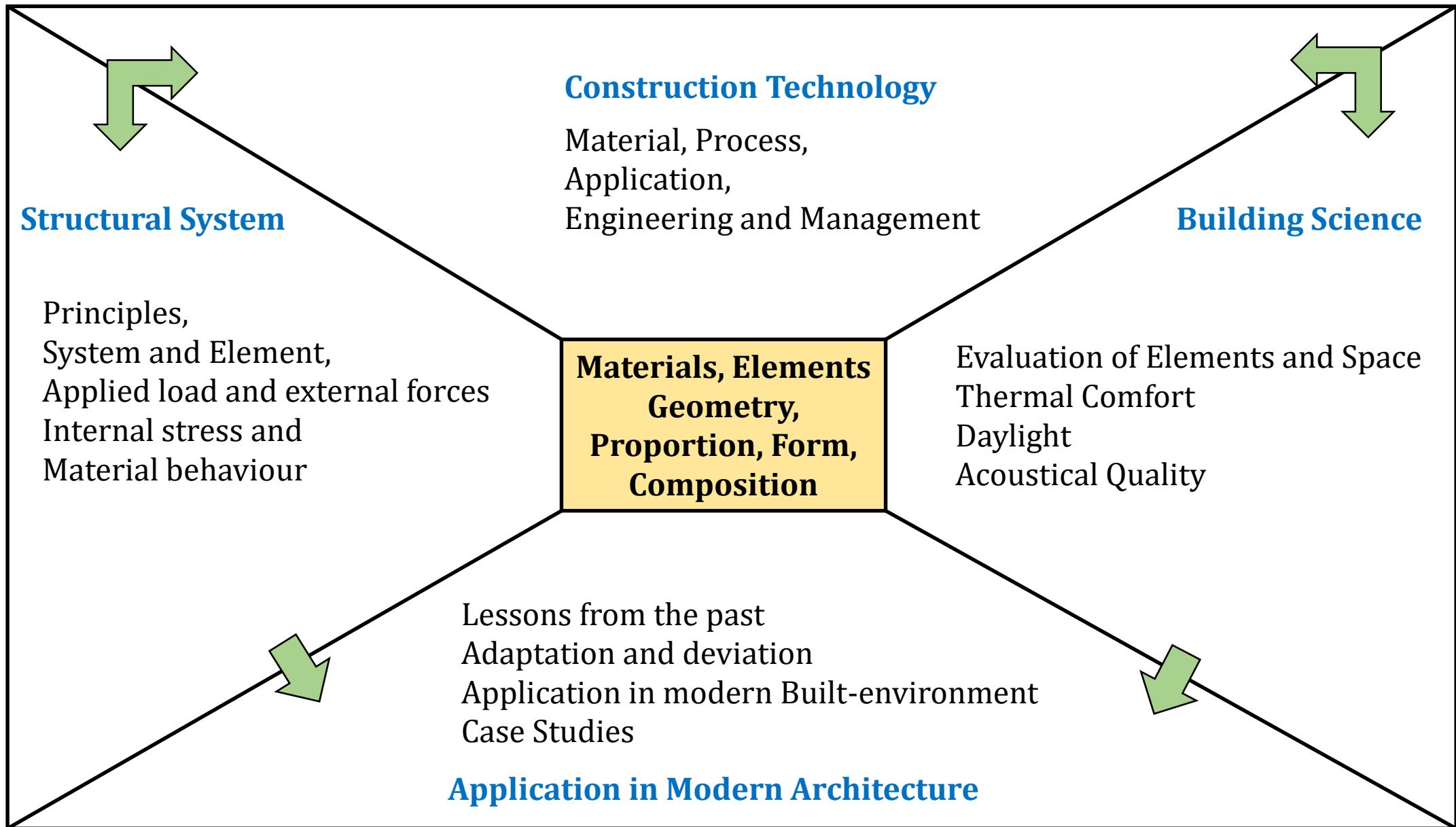


**INTRODUCTION TO STHAPATYA VASTU & NIRMAN  
VIDYA AND ARTHASHASTRA  
(KS60001 )**

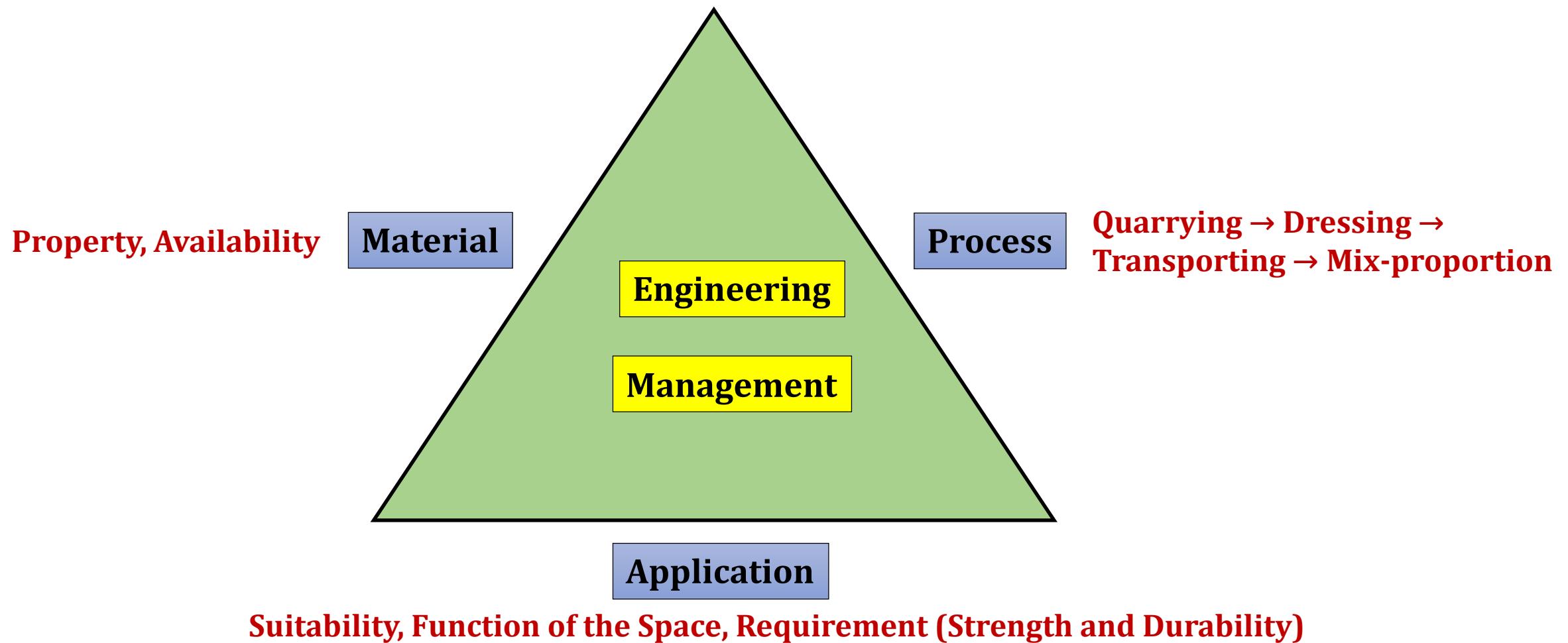
**Indian Traditional Construction System and Practices  
Lecture-1**

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Associate Professor  
Department of Architecture and Regional Planning  
IIT Kharagpur**

# **Introduction**



# Construction Technology



# **Indian Knowledge System in Construction Practices**

**Material Sensitive Construction**

**Structure Sensitive Construction**

**Climate Sensitive Construction**

**Activity Sensitive Construction**

## **Material Sensitive Construction**

## Material Properties

**Strength**

Structural Strength, Span, Load Transfer, Flexibility

**Ductility**

**Porosity**

**Water/Moisture Movement**

Durability, Life-cycle, Material Replacement, Maintenance

**Abrasion**

**Density**

Curving, Decorative features, Time of Construction,  
Manpower Requirement, Material Transportation

**Hardness**

**Thermal Expansion**

**Thermal Conductivity**

Climate Responsive Design, Thermal Comfort

**Thermal Diffusivity**

**Sound Absorption**

Indoor Acoustical Quality

**Sound Transmission**

# Construction Practices during Vedic Period

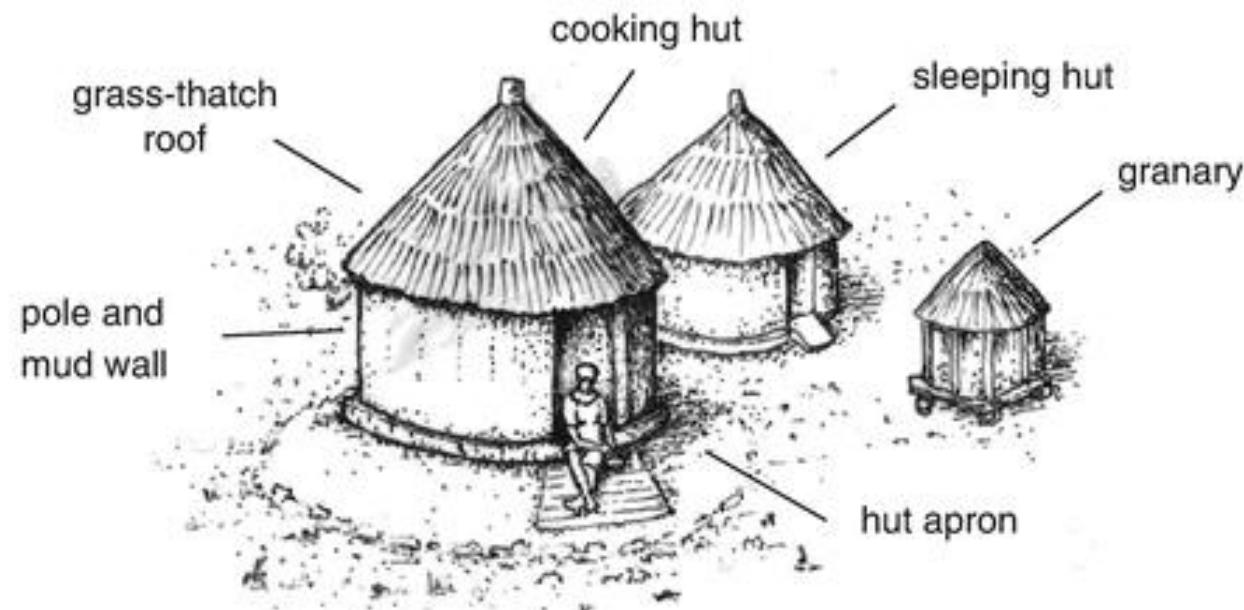
- **Quality of housing is a measure of development** of early civilizations.
- Sanskrit literature has several references to planning and construction of buildings - residential, royal, military and religious.
- The **Atharva-veda**, in the '**Shala-nimrana-sukta**' and the '**Shala-sukta**', contains several hymns on permanent constructions.
- The science of architecture and civil engineering is known as **Sthapatya Shastra**
- The word 'Sthapatya' was derived from the root word **Sthapana** (to establish)
- The techniques of construction and architecture follow both **science and art**
- Hence, it is known as '**Sthapatya Kala**'. The word 'Kala' means 'Art'

## Basic Character of Housing Units

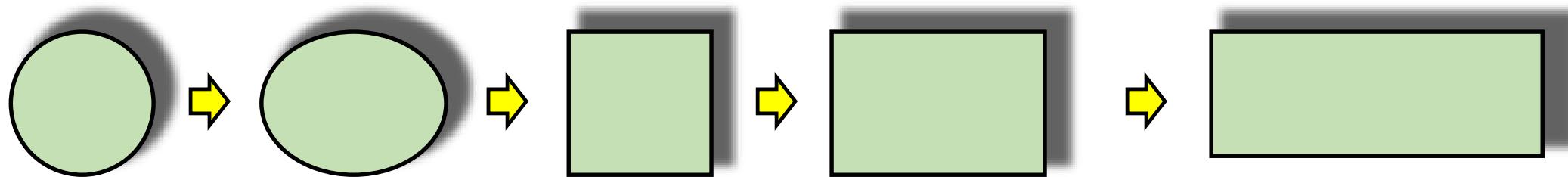
The basic housing was a **simple hut** made out of **Forest raw stock product, Bamboo, Grass, Thatch, Mud.**

The Aryan hut, in its most basic shape, was **circular in plan, with a thatched roof over a bamboo network of ribs.**

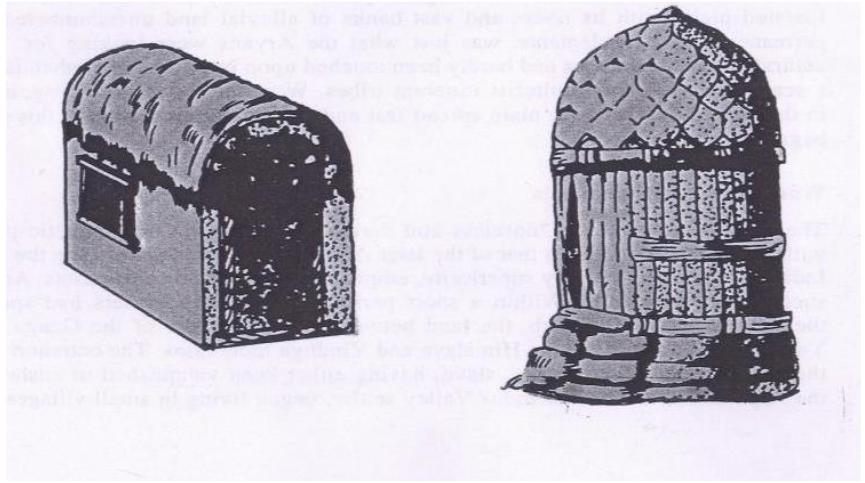
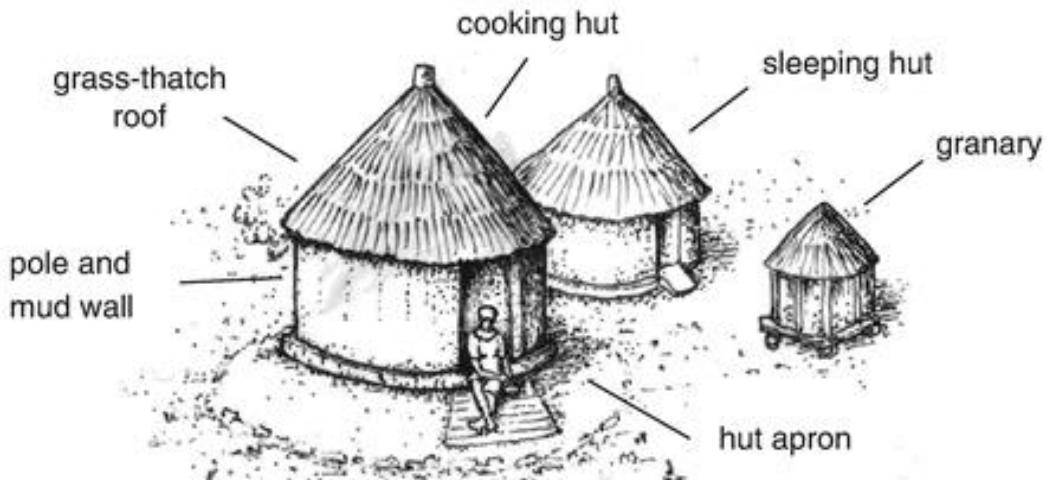
**Wattle and daub** type of Construction method was used, in which vertical wooden stakes, or wattles, are woven with horizontal twigs and branches, and then daubed with clay or mud. This method is one of the oldest known composite material a weatherproof structure.



## Shape Transformation with Structural Modification



Parameters	←TRANSFORMATION→			
Plan Shape	Circular	Square and Rectangular	Rectangular	
Wall Material	Mud and Bamboo	Mud, Bamboo Timber, Stone, Sun dried Block		
Roof Material	Bamboo & Thatch	Bamboo & Thatch, Stone Clay Layer & Clay tiles		
Roof Shape	Conical	Triangular Folded Plate	Vault, Barrel	



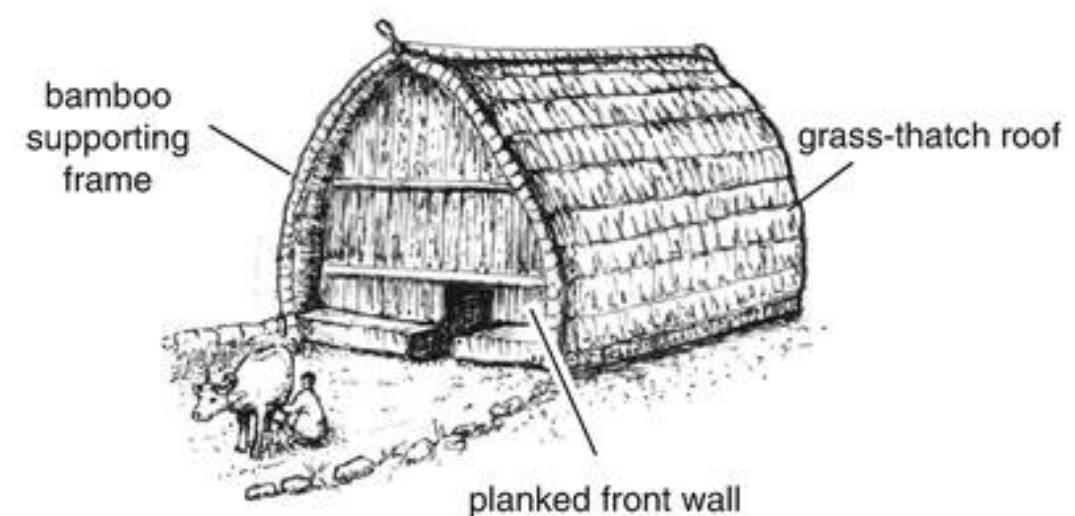
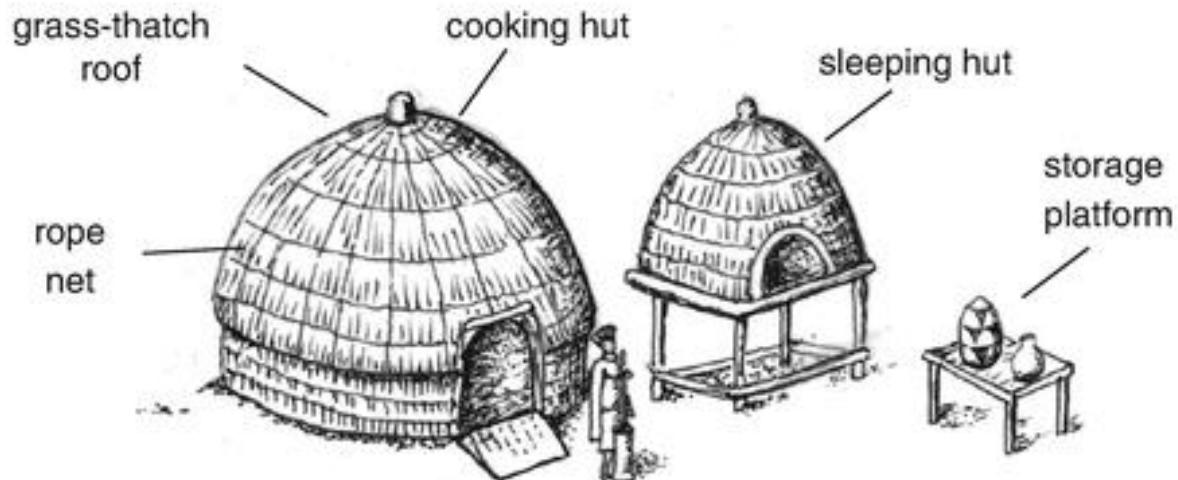
Over the times the circular huts transformed to elongated huts.

Finally it become a narrow rectangular.

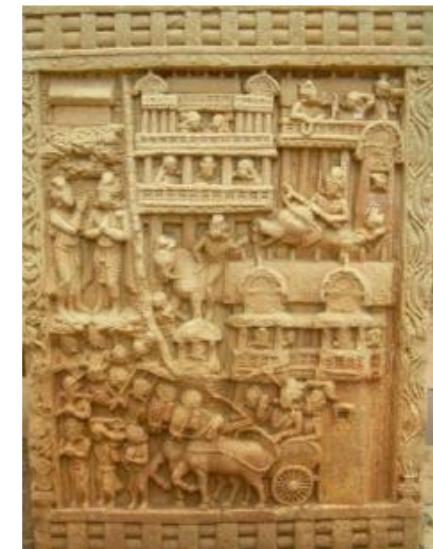
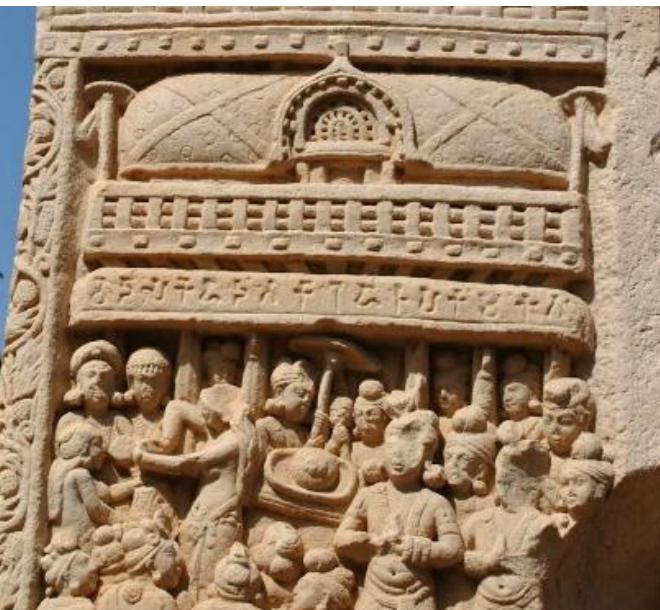
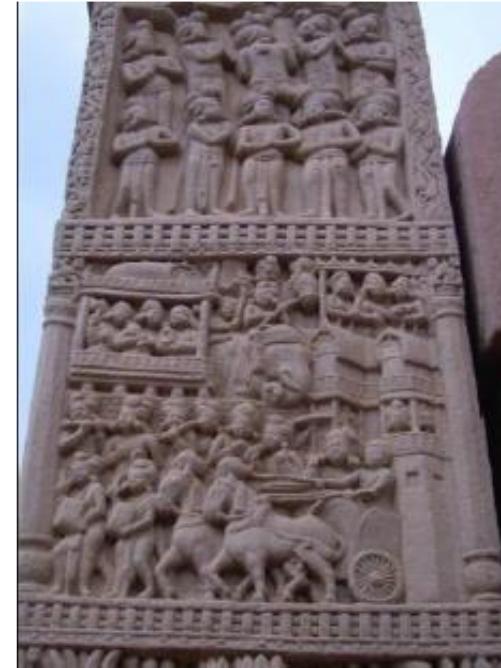
The shape of the Roof also changes accordingly

The shorter two ends of narrow rectangular unit become flatter with a semi-circular opening

Eventually become a Sun Window or Chaitya Style adopted in Buddhist period



## Record of Vedic Style of Construction of Houses

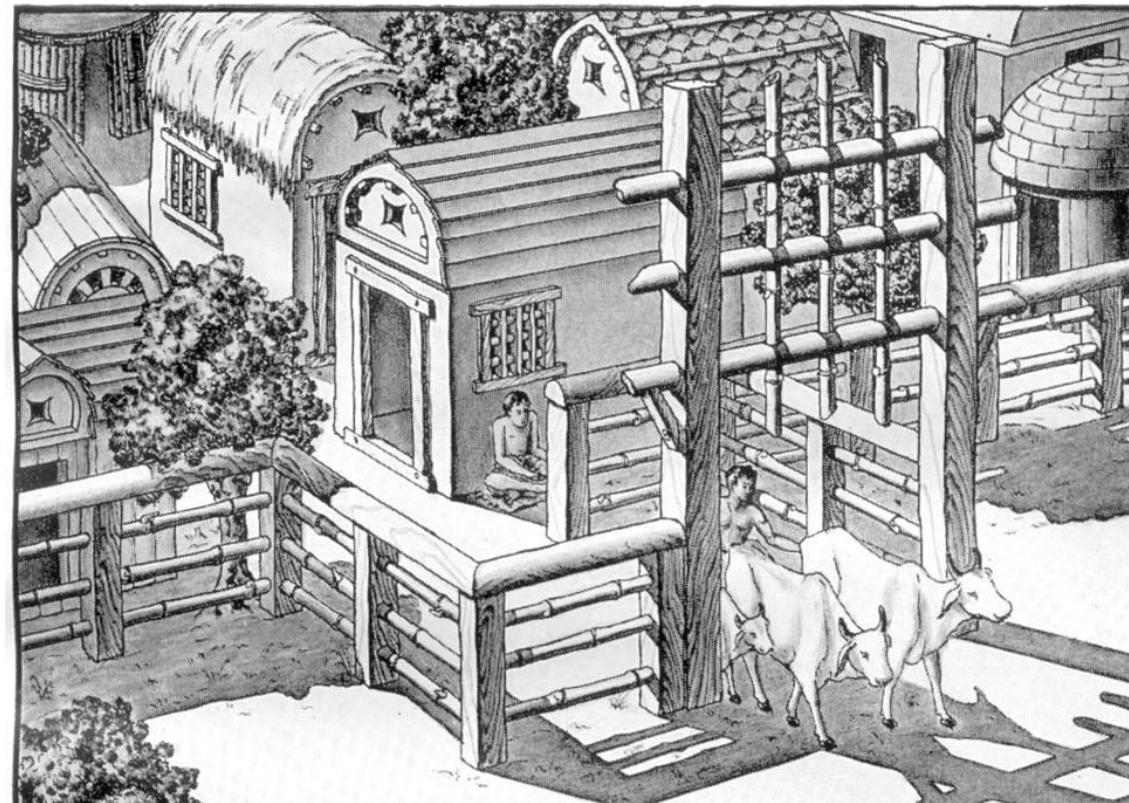


A **fence of wooden stakes** fixed in the ground, forming an enclosure to the whole settlement.

This fence was made of upright posts of bamboo with horizontal members threaded into holes in posts.

The fence was extended forward to form a sort of **gate**.

Construction of fence units probably the first kind of **Modular System** adopted in architecture



## **Building Materials**

Vedic materials consisted of mud, lime, stones, bamboo, thatch, dry leaf, tree sticks, wood, metal such as copper, and precious stones.

### **Stabilization of Mud**

Mud is stabilized with some additive of following combinations:

- Mud + Sand
- Mud + Lime
- Mud + Sand + Lime
- Mud + Straw / dry leaf
- Mud + Husk of paddy

Stabilized mud is used in wall and roof construction

## Building Materials

### Plastering

Two compositions of Vedic plaster compositions were implemented in building construction:

#### 1. Mud is mixed with cow dung and/or gypsum

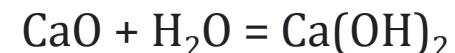
Note: Gypsum is the calcium sulfate mineral, and its chemical formula is,  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ .

Gypsum is a naturally forming non-metallic mineral, found as a rock or sand composed of 70.1% calcium sulphate and 20.9% water by weight

Plaster of Paris is de-hydrated gypsum.

#### 2. Mud is mixed with rice water with lime. Lime and rice water mix is also used to fill the cracks and joints

Calcium Oxide + Water = Calcium hydroxide



Quick Lime  $\rightarrow$  Slaked Lime

## Building Materials

### Earthen Block

Earthen blocks are also developed and used as early form of bricks.

Blocks are molded by hand molds, and wooden molds

Very light weight earthen blocks (2 to 10 times lighter than our modern bricks) are also developed

It was known as floating bricks contain partially interconnected micropores made using air entraining additives

### Use of Additives

lime powder, cow dung, gypsum, barks of milky trees, Trifala/Triphala, rice water, etc.

Here triphala and rice water were mixed with lime powder and gypsum paste today called lime mortar.

Note: *Trifala* is consist of three Ayurveda fruits Amla (*Emblica officinalis*), Bibhitaki/Baheda (*Terminalia bellirica*), Haritaki (*Terminalia chebula*)

## Transformation during Later Vedic Period

- Later Vedic period, elaborate buildings were built in **timber**.
- **Carpentry** took a front seat, as timber was the most used material.
- **Houses of different sizes** suggested a societal hierarchy.
- Many elements emerged and a **language of architecture** was developed.
- Houses consisted of typically **two to three levels** with **vaulted roofs and balconies**.
- The city was fortified with **bastions and gates**. There are **peepholes** in the city wall for the army to **shoot arrows**.
- There would be a **moat** to receive all the **sewage** and also to protect the city from the **enemy attacks**

## **Vernacular Architecture**

It is defined as the knowledge from ancient time sustain till date in architecture and construction domain. It is applied as traditional architectural knowledge, that developed in certain societies.

## **Notable Features of Vernacular Architecture**

- Capitalizing on local knowledge and traditions.
- Taking advantage of local materials and resources, meaning that they are relatively energy efficient and sustainable.
- Providing a vital connection between humans and the environment in which they live.
- They can be designed specifically with the local climatic conditions in mind, and often perform well.

## **Building Materials used in Vernacular Architecture**

- **Mud**
- **Stone**
- **Timber**
- **Bamboo**
- **Organic Fibers**
- **Metal**
- **Thatch**
- **Clay Tiles**
- **Rice Husk**

### **Features of Mud as Building Materials**

Locally Available Material

It can be re-use

Cut and construct method can be applied

High density and quite stable in compressive load, Perfect for wall construction

Low embodied energy material

Low initial cost and low maintenance cost

It has high degree of thermal insulation

Earth is non-toxic

It is fire resistant

Mud building techniques have been around for thousands of years.

Since before our recorded history, people have been using the earth to build with. Through history, earth architecture has traveled all around the world.

### **RAMMED EARTH WALLS**

Rammed earth buildings are environment friendly and water, fire, and termite resistant. It is naturally sound-and mold-resistant. Thick earthen walls create a sense of solidity and security.



### **EARTHBAG STRUCTURES**

Earth-bag building uses polypropylene rice bags or feed bags filled with soil or insulation that are stacked like masonry and tamped flat. Barbed wire between courses keeps bags from slipping.

## COMPRESSED EARTH BLOCKS

If the blocks are stabilized with a chemical binder such as Portland cement they are called compressed stabilized earth blocks (CSEB) or stabilized earth blocks.



## STRAWBALE

Straw-bale construction is a building method that uses bales of straw, commonly wheat, rice, rye & oats straw as structural elements, building insulation, or both.

## COB

Also known as cob, is a easy to build technique with local building material that comprises subsoil, straw (or another fibrous organic material), water, and occasionally lime.



## ADOBE BRICKS

These are unfired, sun-dried building blocks, made of earth with a fairly high clay content and straw. If produced manually the earth mix is cast in open moulds onto the ground and then left to dry out.

## Recent Mud House Projects in India

### Urbun hut Vernaculars Projects



[\*\*Aravali Resorts\*\*](#) Alwar, Rajasthan



[\*\*Village Life Farms\*\*](#) Sikkim



Eco-friendly house, Palakkad, Kerala  
Architects: Manasi and Guruprasad



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*"To me as an architect, we have to synchronize energies of poverty and environment to create beautiful expressions in architecture."*

G Shankar  
People's Architect

< >

# DR. G SHANKAR

Dr. G Shankar is dedicated at evolving the most cost effective and eco friendly designs that can guarantee sustainability.

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A portrait of Dr. G. Shankar, a man with glasses and a mustache, standing in front of a background of a dense urban slum.

## **Features of Bamboo as Building Materials**

Locally Available Material

It can be cultivate

Through cultivation it absorb much higher quantity of GHGs

Bamboo is having very good tensile strength

It can be embedded with mud to improvise the composite strength

Low embodied energy material

Low initial cost and low maintenance cost

It is non-toxic

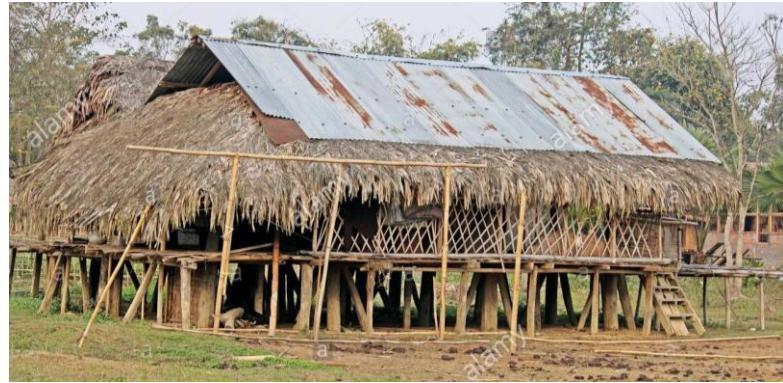
## Bamboo Architecture in India

**North Eastern States:** Bamboo used as local building material. Riang houses, Mizo houses and Adi Gallong houses use bamboo as the primary material for construction. These are typical houses constructed on bamboo stilts and have woven bamboo mats for walls. Flooring is made of splits or flattened bamboo. The houses in Assam and some other states are built sometimes with a plinth base with Wattle and daub walling in combination with wooden poles.

**The River Planes:** In Bihar, Bengal and Orissa house built with bamboo only are found in rural and tribal areas. Walls are made of mats of splits or flattened bamboo, with mud flooring on a plinth. In these, bamboo was also used as reinforcement in lime *surki* flat slabs.

**Central India:** Traditional dwelling of bamboo worker has a walls are made of thick bamboo matt covered with mud plaster, thick bamboos are used for vertical support. The attic floor is made of bamboo mating, covered with mud plaster. The roof consists of wooden trusses, rafters and purlins of bamboo and covering of country tile or thatch. The mud is used for plastering; flooring is done by rammed earth, covered with cow dung. The timber doors and window frames with bamboo shutters, bamboo jail are used for lighting and ventilation.

**South India:** bamboo was used for walls in a wattle and daub system with composite mud plastering and roof structure in sloped roofs in rural areas. In urban areas, bamboo was used majorly in roofing structure for both sloped and flat lime *surki* roofs.



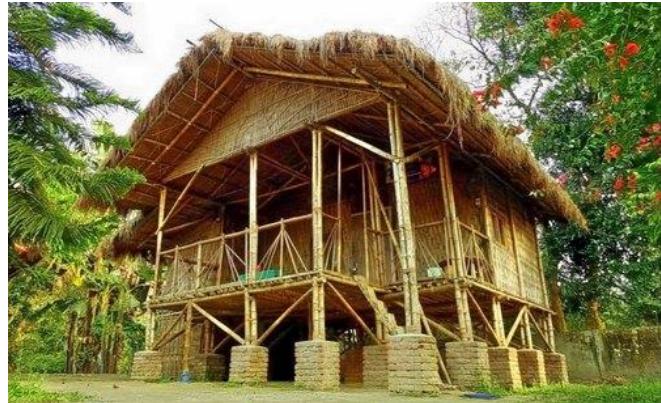
Adi Gallong House



Riang houses



Mizo houses



Assam / North Bengal



Tamilnadu



MP



Andhra Pradesh



Bihar/ Jharkhand

# **Structure Sensitive Construction**

## Mouryan Period

The Mauryan rulers were great patrons of art and architecture and the buildings and pillars of this period can be considered as some of the finest specimens of Indian art.

**Megasthenes**, the great Greek ethnographer and author of the work '**Indika**', was considerably impressed by the Mauryan art.

He gave a topographical account of **Pataliputra**, the capital of the Mauryan Empire, and described it as "**the greatest city in India**", having the **shape of a parallelogram** and surrounded with a wooden wall.

Megasthenes described that most of the **houses in the cities were made of wood** and the royal palace at Pataliputra itself was made of timber.

## Mouryan Period

### New Construction type:

Mauryas made a remarkable contribution to art and architecture, and introduced **stone masonry** on a wide scale.

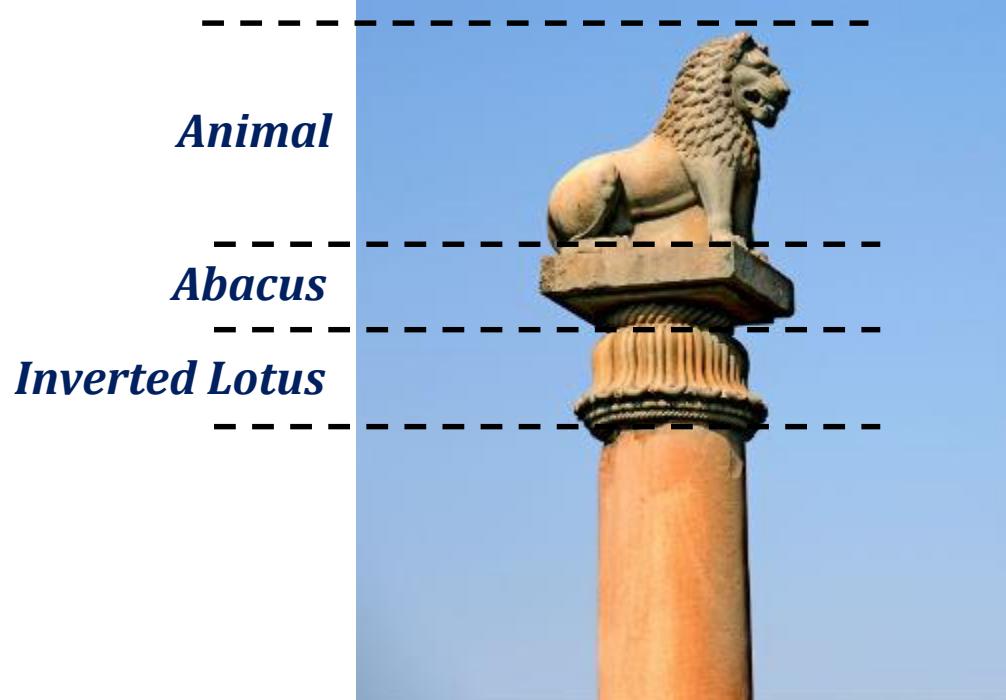
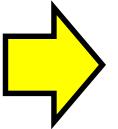
### Development of Pillars and Sculptor:

The **developed the pillars** as a structural and piece of art work as well. The **capital, shaft and base** was distinguished separately as three prime part of the pillar

High technical skill was achieved by Maurya artisans in **polishing the stone** pillars, which are as shining as the Northern Black Polished Ware.

Each pillar is made of a single piece of sandstone. Only their capitals, which are beautiful pieces of sculpture in the form of lions or bulls, are joined to the pillars on the top.

The erection of the polished pillars throughout India shows the spread of the technical knowledge involved in the art of polishing them



### **Cave Architecture:**

The Maurya artisans also started the **practice of carving out caves from rocks** for monks to live in. Later, this form of cave architecture spread to western and southern India.

### **Development of Terracotta Art:**

In the central Gangetic plains became the center of **terracotta art**.

### **Development of Wooden Construction:**

High standard of workmanship **wooden construction** found in the palaces.

In the foundation a number of massive **teak-wood platforms** (each thirty feet in length) found **buried** deep in the silt and clay.

It apparently introduced as a kind of **raft** to support the foundations of the palace.

The carpentry joints were **simple but effective**. The **bamboo pegs** were inserted as **pin joint** connector.

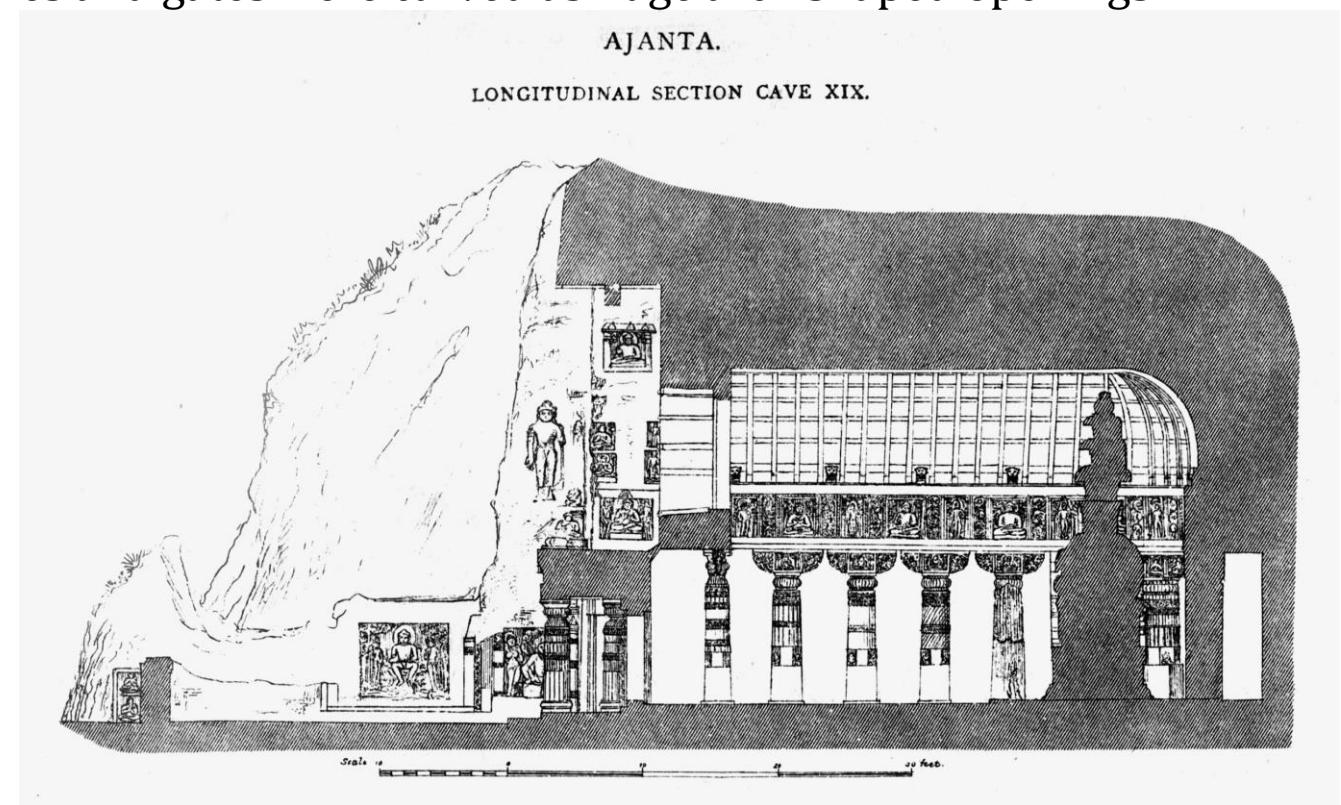
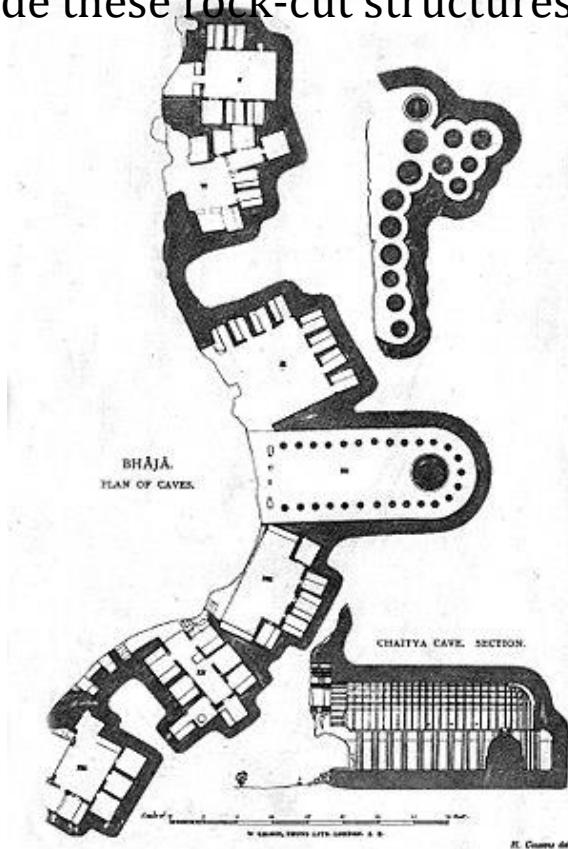
## Rock-Cut Cave Architecture

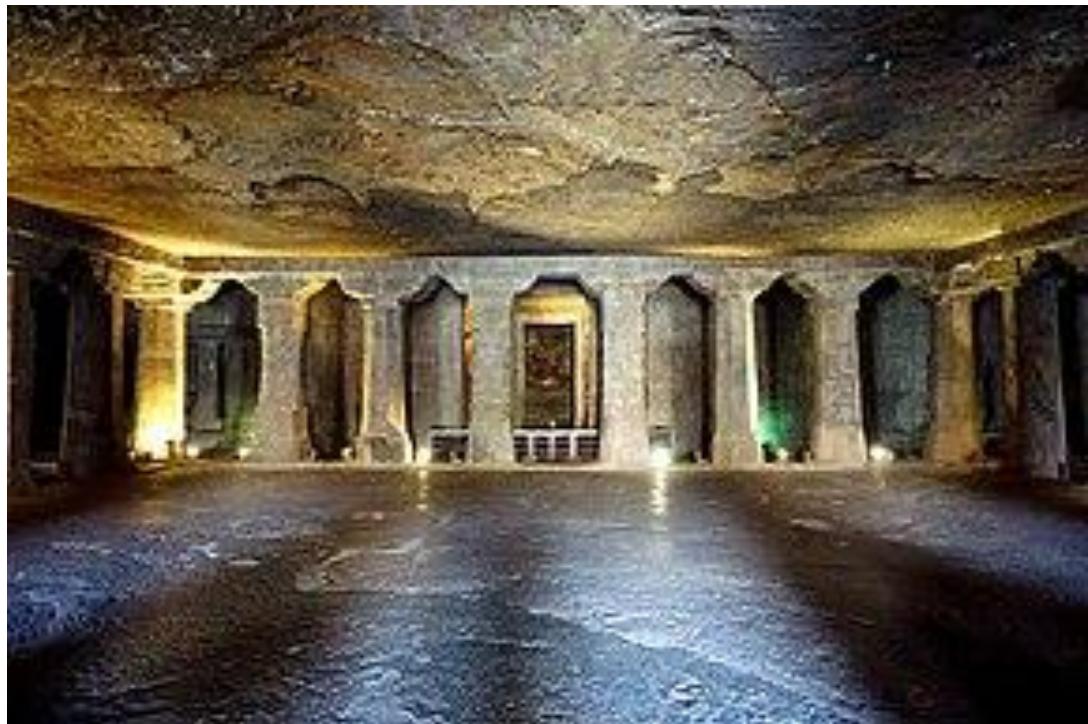
The rock-cut architecture is a type of Rock Art in which a structure is created by **carving it out of solid natural rock.**

Cave temples are found in many parts of India, Buddhist and Jain rock-cut structures were built in areas such as **Bihar in the east and Maharashtra in the west.**

The best example of this is **Chaityas** (prayer halls) and **Viharas** (monasteries).

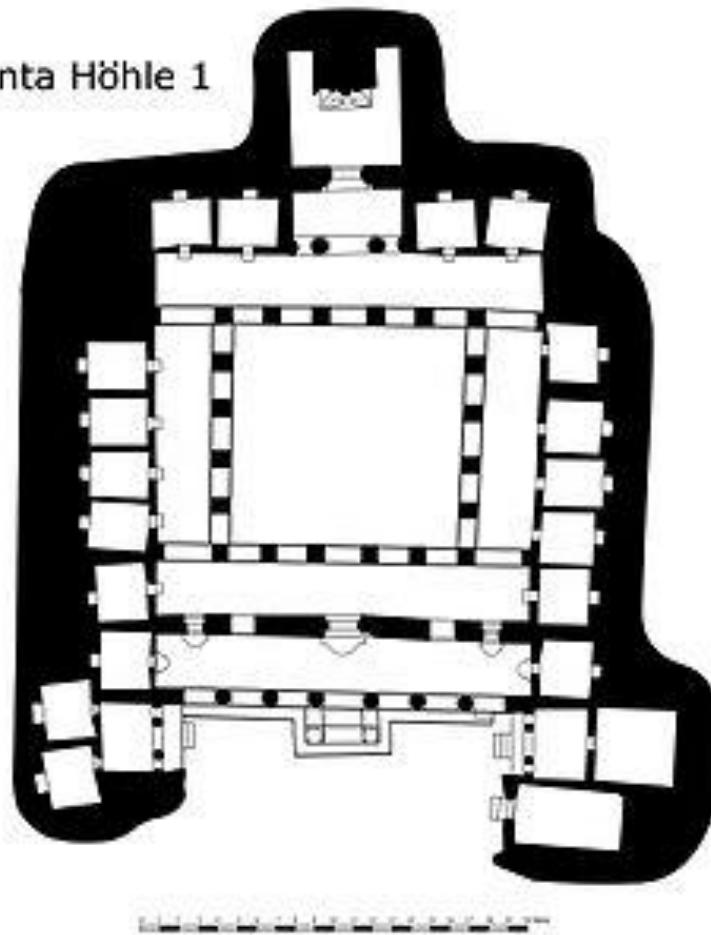
Inside these rock-cut structures, windows and balconies and gates were carved as huge arch shaped openings

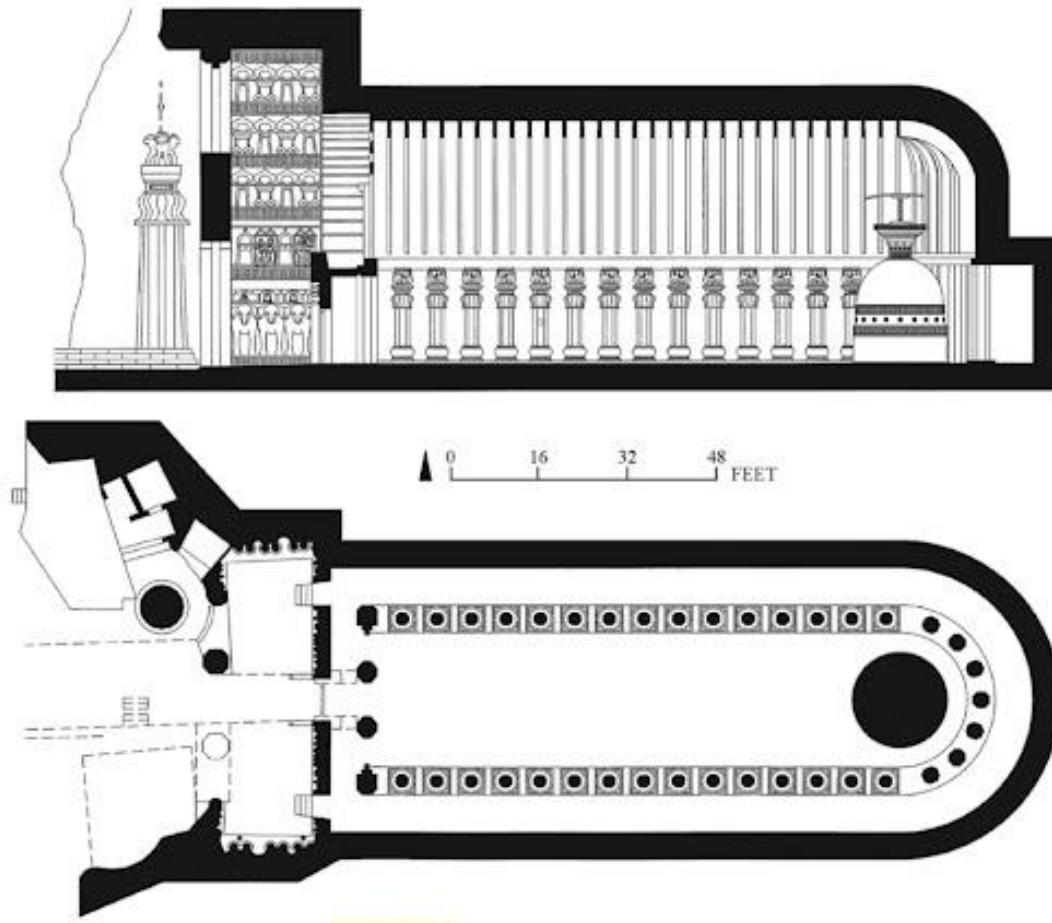
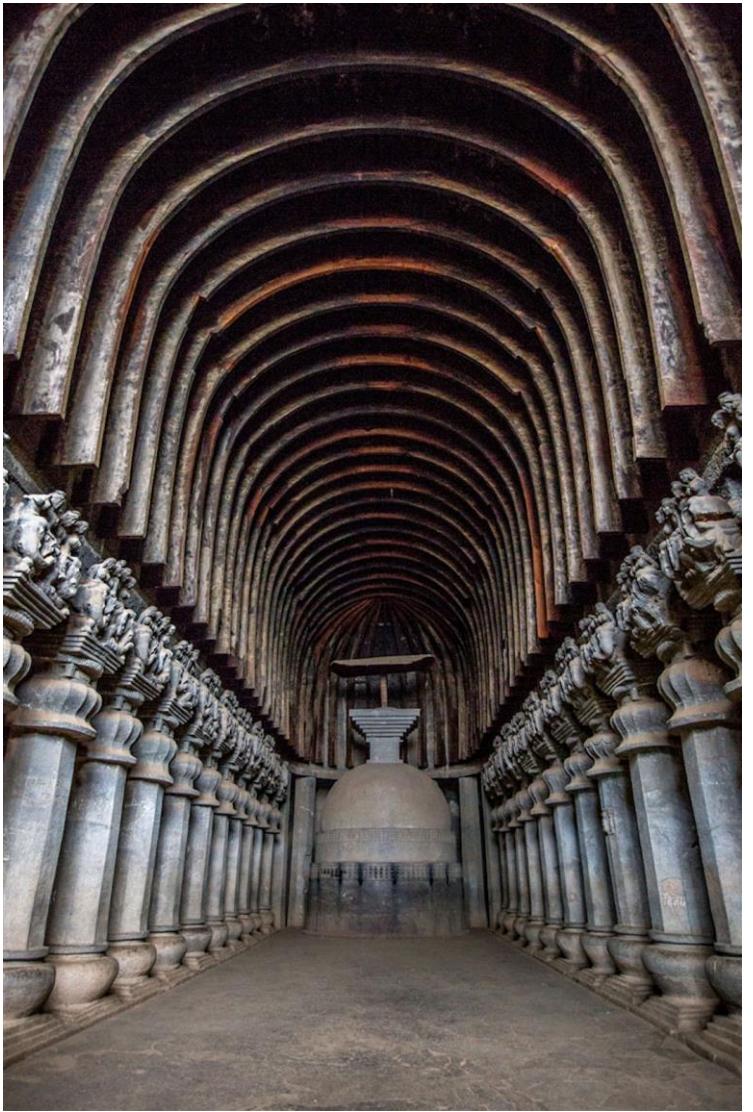




Viharas (monasteries)

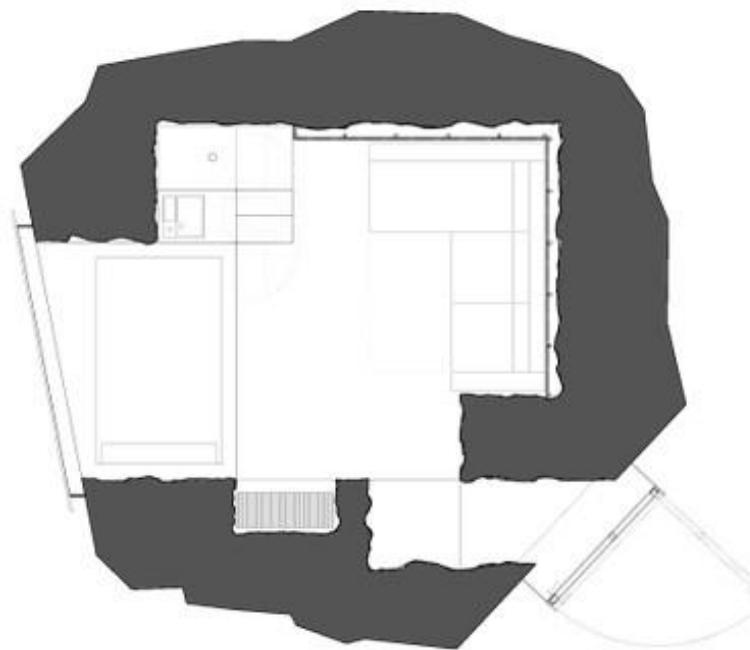
Ajanta Höhle 1



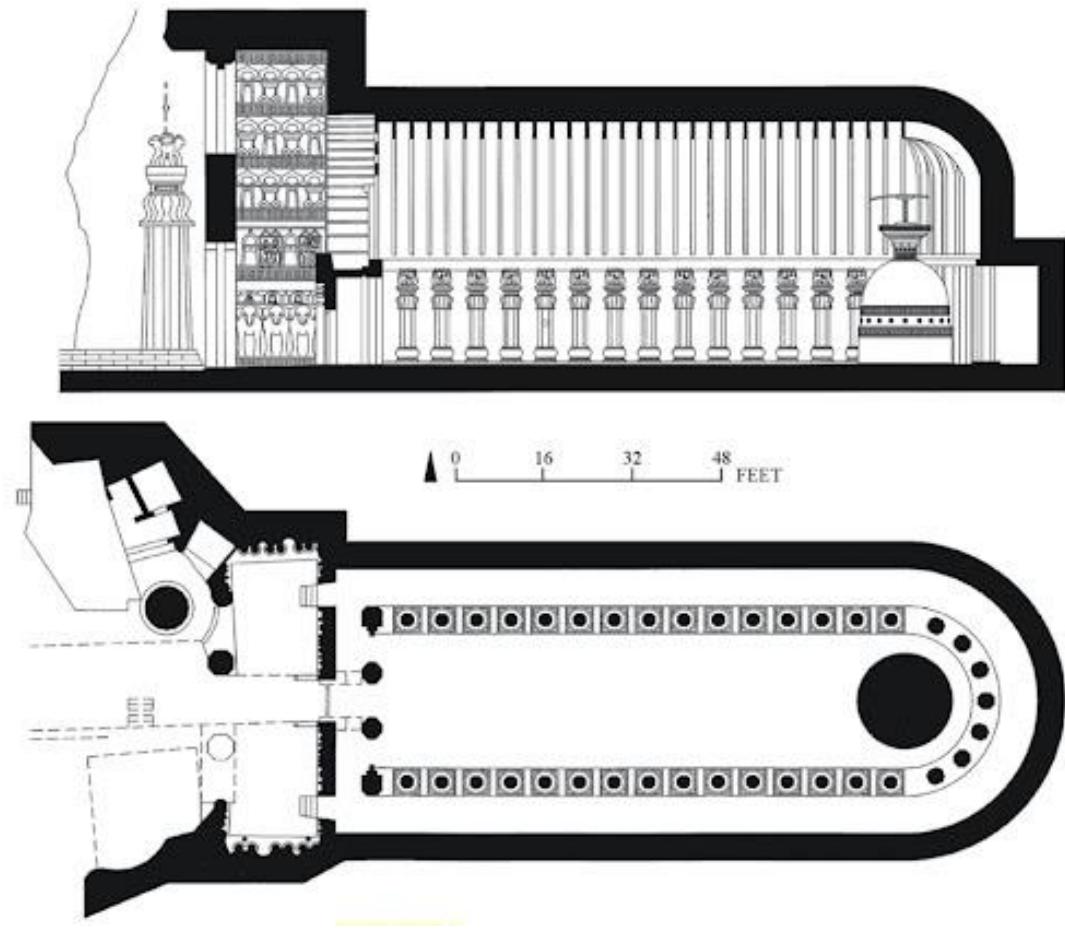
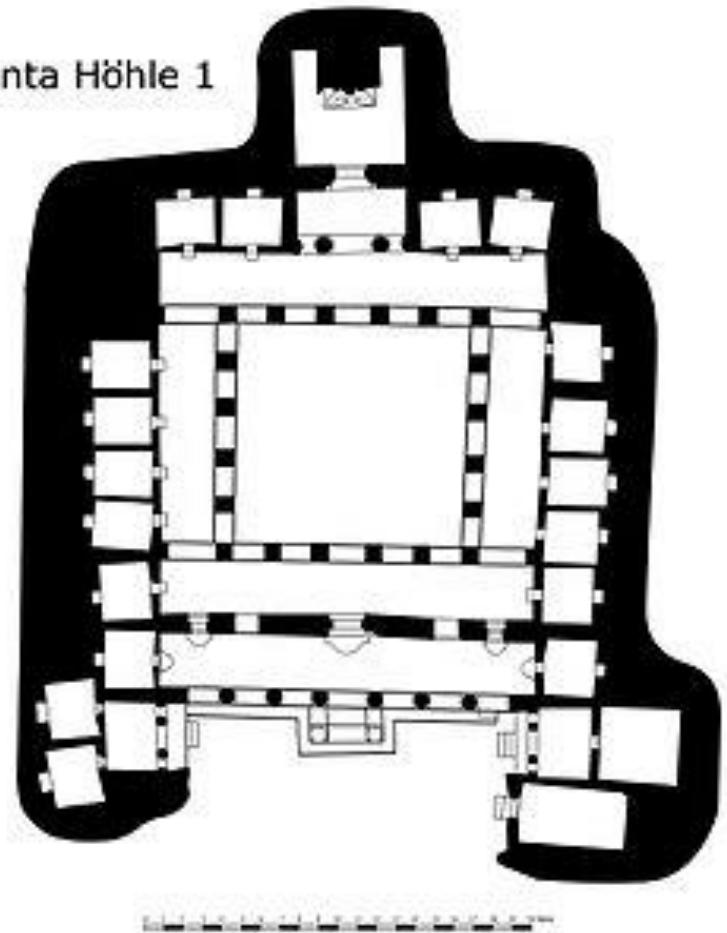


Chaityas (prayer halls)

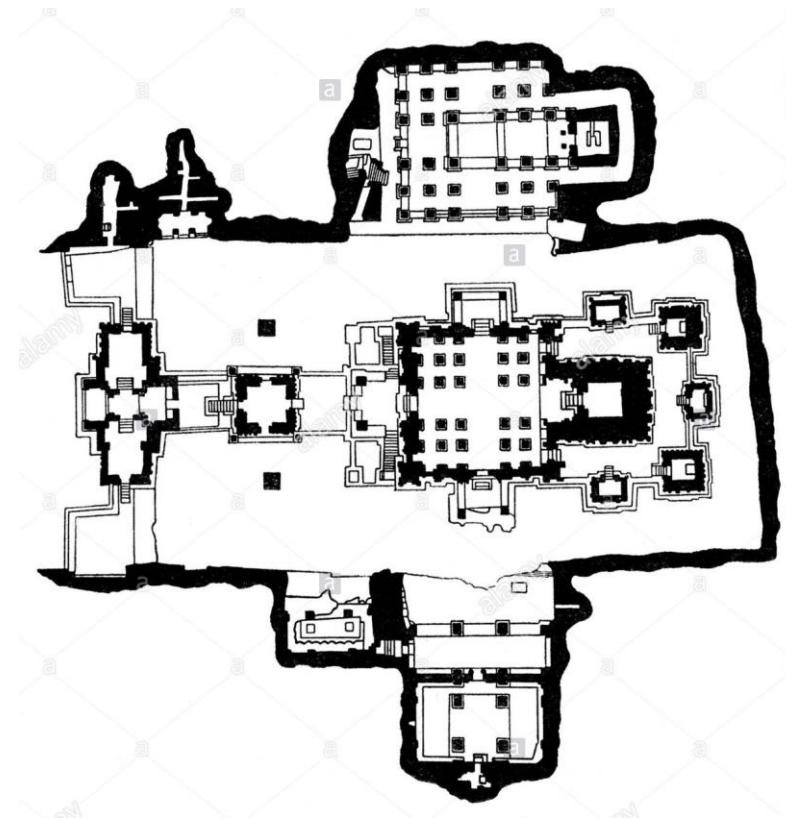
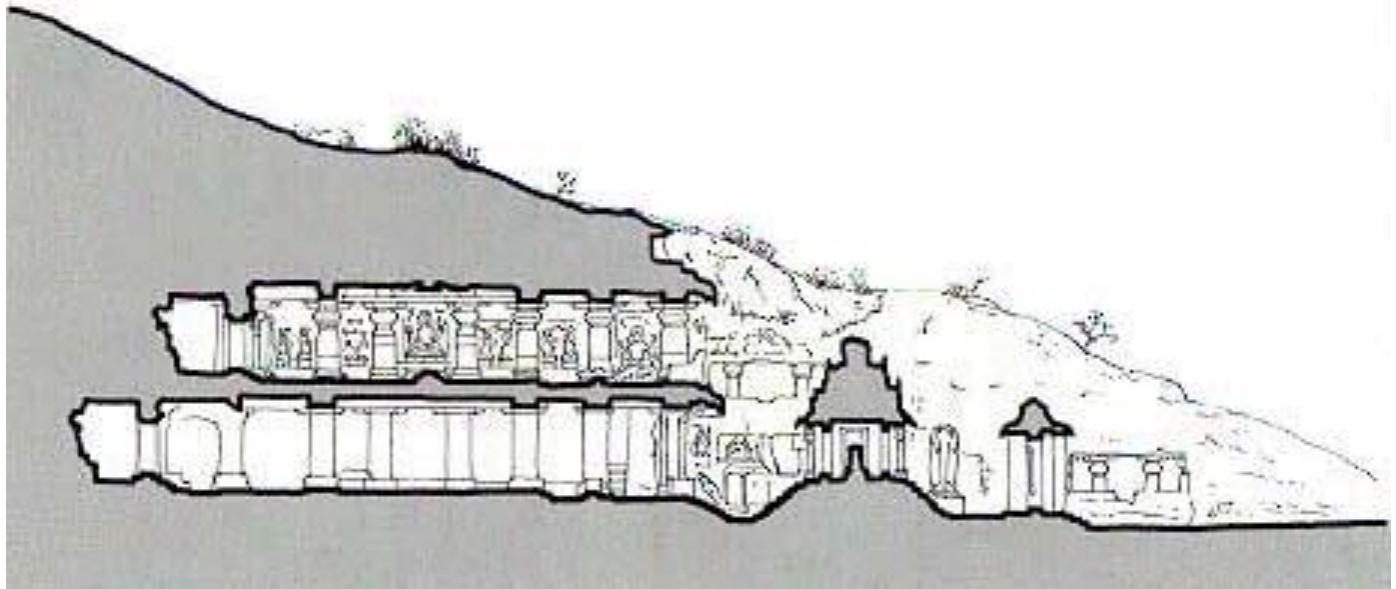
## Reverse Engineering



Ajanta Höhle 1



## Kailasa Temple, Ellora



The rock temple was cut in 'U' shape about 50 metres in the back, and about 2, 00,000 tonnes of rock was removed to give shape to it.

The archaeologists had calculated that it would have taken more than a hundred years to finish the temple construction. However, in reality it took only 18 years to complete it.

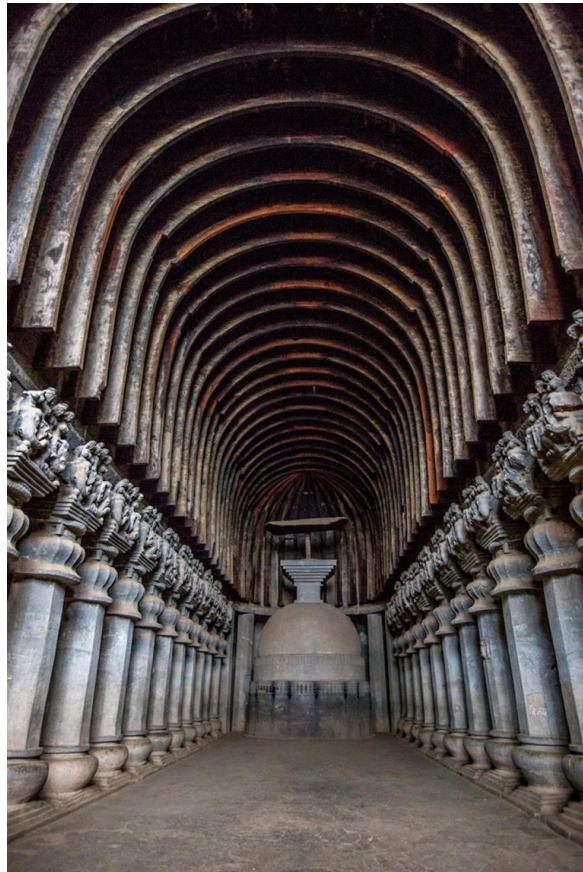


## **Curved Roof :**

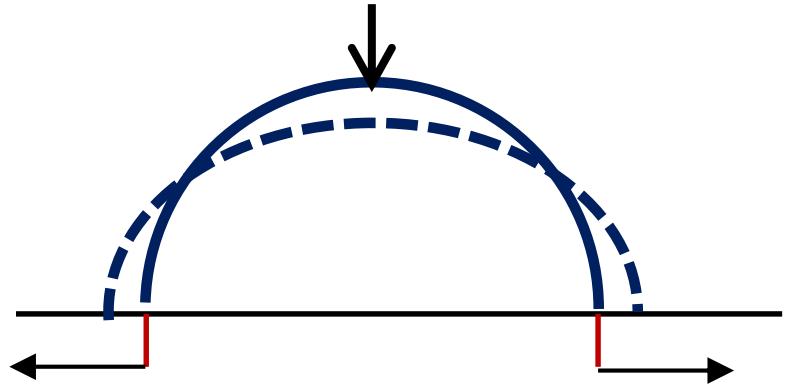
In the cave architecture, most interesting is the construction of the **vaulted roof**.

The structural member of the vault was supplemented by a series of **curved wooden ribs or groins** placed in close order.

The whole system is developed based on **arching a space** with **structural safety** and at the same time **artistic manner**.

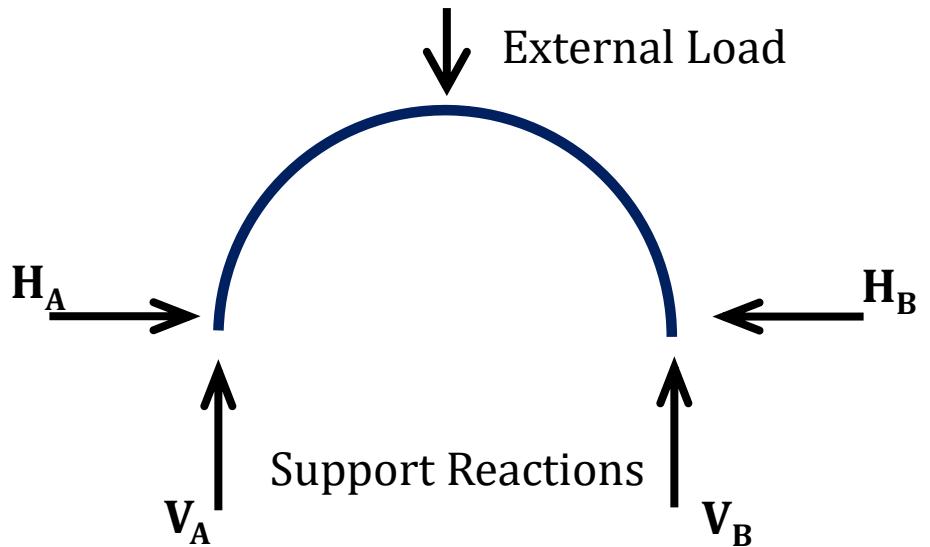


## Arch Action

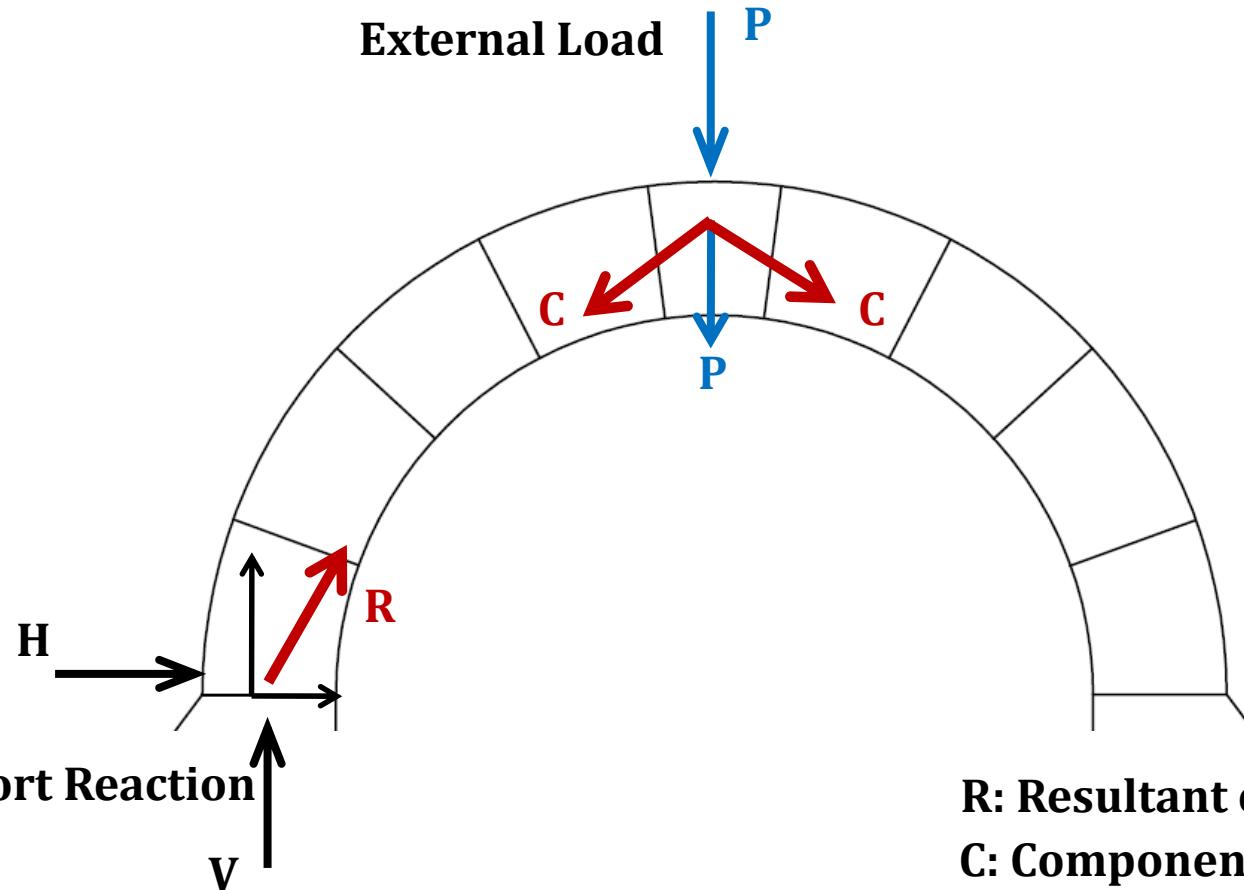


**Under the Downward External Loading  
the legs of arch spread outward**

**To establish a equilibrium along with the  
Vertical Reactions a Horizontal Reaction is also exist**



**This introduction of Horizontal reaction to achieve  
the stability is a unique for Arch**

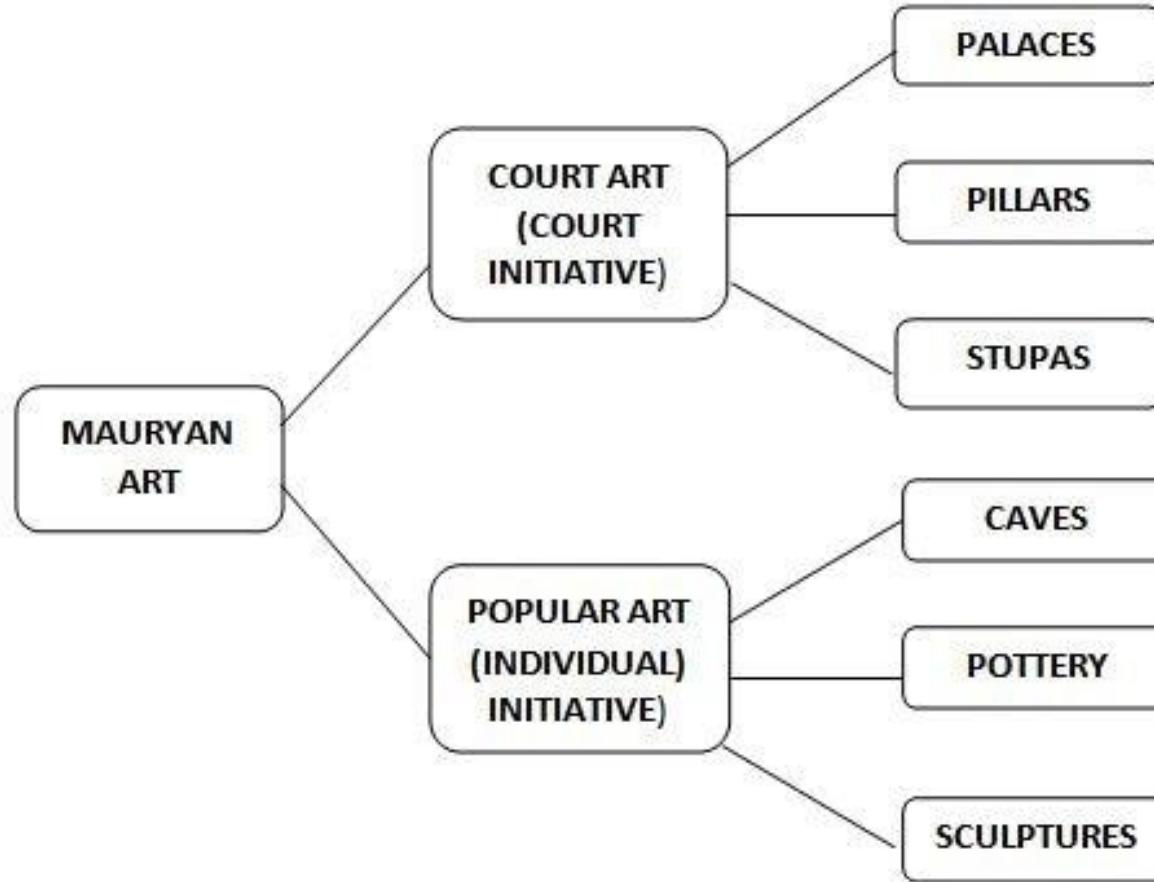


R: Resultant of Support Reaction  
 C: Component of External Load

Each component of a Arch are in **COMPRESSION** under the action of **GRAVITY** load  
 So, **BRITTLE** materials can be used in Arch construction.

## Modern Infrastructural Projects





## Gupta Period

In the Gupta period that building with lasting materials began, such as dressed stone and brick. The Gupta period marks the beginning of Indian temple architecture. Temple Architecture in the Gupta Age was a five stage development process.

### Stage-1

Square temple building with flat roof and shallow pillared approach to the front and temples on low platforms. The nucleus of a temple was the **sanctum or cella (garbagriha)** with a single entrance and a **porch (mandapa)** appears for the first time here.



Kankali Devi Temple at Tigawa

## Stage-2

Flat Roof and square temple continued and so did the pillar approach.

Temples were now on high platforms/upraised platforms. There were Covered **ambulatory (pradakshina)** around the sanctum around the sanctum (garbagriha).

Instances of **two storeyed** temples were also seen.



**Shiva Temple at Bhumara**

### Stage-3

Square temple with a low and squat tower (**shikhara**) above.

A high platform at the base and the tower add to the elevation of the composition.



**Dasavatara Temple, Deogarh**

## **Stage-4**

Rectangular temple with an apsidal back and barrel- vaulted roof above.



**Kapoteswara Temple at Cezarla**

## **Stage-5**

Circular temple with shallow rectangular projections at the four cardinal faces.



**Maniyar Matha shrine at Rajgir**