CHAPTER - 3

CONSTRUCTION INDUSTRY AND THEORITICAL FRAMEWORK

3.0 Introduction

Civil Engineering is defined as the art of directing the Great Sources of Power in the Nature for the use and convenience of mankind. Construction and building is a global business of creating physical infrastructure such as dams, highways, bridges, factories, airports, and power plants. It also includes millions of smaller projects to protect human activity with walls, roofs, and floors. Also included is the provision for electricity, lighting, heating, and cooling for people who live and work in those buildings. Construction and building are heavily regulated at all levels of government and by codes and standards.

3.1 Profile of Construction Industry

The engineering efforts of humans are recorded by constructed systems such as works to bring water to the population of a city. The purpose of those built systems and structures is to support our civilization. Or in other words, civilizations are built upon construction efforts. Such systems and structures built in the past provide a historical record of how Engineering and Construction have developed.
3.2 Historical Perspective

History of construction activities can be traced back to 5000 BC when the sole means of construction were the human labour, without any sophisticated equipment. The world civilizations are built through the planned as well as unplanned construction efforts. Each and every civilization of the past had a construction industry that fostered its growth.

The construction works done by the people of prehistoric age includes not only buildings but bridges, dams, roads, canals etc... But it can very well be ascertained that the most preferred and prioritized structure the ancient men built were houses or shelters which were the ancient form of present buildings. Building materials which are in present use have a long history and some of the structures built more than thousands of years ago are regarded as remarkable. In ancient period, humans began to produce identifiable tools and use fire. Construction had its rudimentary beginning at that point in the non literate ages of human antiquity when humans built their first shelters.

The history of building is marked by a number of trends. One is the increasing durability of the materials used. Early, building materials were perishable such as leaves, branches, and animal hides. Later, more durable natural materials such as clay, stone, timber and later, synthetic materials, such as brick, concrete, metals, and plastics were used. Another is a quest for buildings of ever greater height and span; this was made possible by the development of stronger materials and by knowledge of
how materials behave and how to exploit them to greater advantage. A third major trend involves the degree of control exercised over the interior environment of buildings: increasingly precise regulation of air temperature, light and sound levels, humidity, odours, ventilation, and other factors that affect human comfort has been possible. Yet another trend is the change in energy available to the construction process, starting with human muscle power and developing toward the powerful machineries which are being used today.

3.3 Global Scenario and Chronological development

The history of construction is a wide aspect which encompasses the history of engineering, the history of building materials, the history of building techniques, economic and social history of builders and workmen, the history of construction machinery etc. Each of these has a complex literature devoted to it.

3.3.1 Neolithic Construction

Neolithic, also known as the New Stone Age, was a time period roughly from 9,000 BC to 2,000 BC. It is named so because it was the last period of the age before metal working began. The tools available were made from natural materials like bone, antler, hide, stone, wood, grasses etc... and they used fire also. Building materials included bones such as mammoth ribs, hide, stone, wood, bark, bamboo, mud, lime plaster, and the like.
The types of bridges made by humans of those periods were probably just wooden logs placed across a stream which later turned to timber trackways. In addition to living in caves and rock shelters, the first buildings were simple shelters, tents and huts meant to suit the basic needs of protection from the wild elements and sometimes as fortifications for safety. Built self sufficiently by their inhabitants rather than by specialist builders, using locally available materials, traditional designs and methods together are called vernacular architecture. The very simplest shelters and tents leave no traces to further generations.

The absence of metal tools placed limitations on the materials that could be worked, but it was still possible to build quite elaborate stone structures with ingenuity using dry stone walling techniques such as at Skara Brae in Scotland, Europe's most complete Neolithic village. The first mud bricks, formed with the hands rather than wooden moulds, belong to the late Neolithic period. One of the largest structures of this period was the Neolithic long House. In all cases of timber framed and log structures in these very early cultures, only the very lowest parts of the walls and post holes are unearthed in archaeological excavations, making reconstruction of the upper parts of these buildings largely conjectural.

The now ruinous remains are of post and lintel construction and include massive sandstone lintels which were located on supporting uprights by means of mortise and tenon joints; the lintels themselves being end-jointed by the use of tongue and groove joints. There is also evidence
of prefabrication of the stonework; the symmetrical geometric arrays of stone clearly indicate that the builders of Stonehenge had mastered sophisticated surveying methods.

**3.3.2 Copper and Bronze Age Constructions**

The Copper Age is the early part of the Bronze Age. Bronze is made when tin is added to copper. Copper came into use before 5,000 BC and bronze around 3,100 BC, although the times vary by region. Copper and bronze were used for the same types of tools as stone such as axes and chisels, but the new, less brittle, more durable material cut better. Bronze was cast into desired shapes and if damaged could be recast. A new tool developed in the copper age is the saw. Other uses of copper and bronze were to harden the cutting edge of tools such as the Egyptians using copper and bronze points for working soft stone including quarrying blocks and making rock-cut architecture.

For constructions, the concept of corbelled arch was introduced during the Bronze Age. The wheel came into use but it became common much later. Heavy loads were moved on boats, sledges or on rollers. The Egyptians began building stone temples with the post and lintel type construction method and the Greeks and Romans later followed this style.

**3.3.3 Iron Age Construction**

The Iron Age is a cultural period from roughly 1200 BC to 50 BC with the widespread use of iron for tools and weapons. Iron is not much
harder than bronze but by adding carbon iron becomes steel which was being produced after about 300 BC. Steel can be hardened and tempered producing a sharp, durable cutting edge. A new woodworking tool allowed by the use of steel is the hand-plane which later influenced much the carpentry works of buildings.

3.3.4 Construction in Ancient Mesopotamia

The earliest large-scale buildings for which evidence survives have been found in ancient Mesopotamia. The smaller dwellings only survive in traces of foundations, but the later civilisations built very sizeable structures in the forms of palaces, temples and ziggurats and took particular care to build them out of materials that last, which has ensured that very considerable parts have remained intact. Major technical achievement is evidenced by the construction of great cities. The Ziggurat of Ur is an outstanding building of the period, despite major reconstruction work. Another fine example is the ziggurat at Chogha Zanbil in modern Iran. Cities created demands for new technologies such as drains for animal and human sewage and paved streets.

The chief building material was the mud-brick formed in wooden moulds similar to those used to make adobe bricks. Bricks varied widely in size and format from small bricks that could be lifted in one hand to ones as big as large paving slabs. Rectangular and square bricks were both common. They were laid in virtually every bonding pattern imaginable and used with considerable sophistication. Drawings survive on clay tablets
from later periods showing that buildings were set out on brick modules. By 3500 BC, fired bricks came into use and surviving records show a very complex division of labour into separate tasks and trades. Fired bricks and stone were used for pavements. The later Mesopotamian civilizations, particularly Babylon and thence Susa developed glazed brickwork to a very high degree, decorating the interiors and exteriors of their buildings with glazed brick reliefs.

3.3.5 Construction in Ancient Egypt

Adobe (sun-baked mud brick) construction was used for ancillary buildings and normal houses in ancient times and is still commonly used in rural Egypt. The hot, dry climate was ideal for mud-brick, which tends to wash away in the rain. The Ramesseum in Thebes Egypt provides one of the finest examples of mud brick construction. Extensive storehouses with mud-brick vaults also survive, all constructed with sloping courses to avoid the need for formwork.

Although the Egyptians achieved extraordinary feats of engineering, they appear to have done so with relatively primitive technology. As far as is known they did not use wheels or pulleys. They transported massive stones over great distances using rollers, ropes and sledges hauled by large numbers of workers. The ancient Egyptians are credited with inventing the ramp, lever, lathe, paper, irrigation system, window, door, glass a form of plaster of Paris, a standardized measurement system, geometry, silo, a method of drilling stone, veneer, plywood, rope truss and
more. There are no surviving Egyptian manuals so there has been considerable speculation on how stones were lifted to great heights and obelisks erected. Most theories centre on the use of ramps.

The pyramids are chiefly impressive for their enormous size and the staggering manpower that must have been employed in their construction. One of the finest example is the Great Pyramid of Giza. Engineering problems involved were chiefly to do with the transport of blocks, sometimes over long distances, their movement into location and exact alignment. The skilled building workers were respected and well treated in those periods.

3.3.6 Construction in Ancient Greece

The ancient Greeks like the Egyptians and the Mesopotamians, tended to build most of their common buildings out of mud brick, leaving no record behind them. However very many structures do survive, some of which are in a very good state of repair, although some have been partly reconstructed or re-erected in the modern era. The most dramatic are the Greek Temples. The Greeks made many advances in technology including plumbing, the spiral staircase, central heating, urban planning, the water wheel, the crane, and more.

Fired clay was mainly restricted to roofing tiles and associated decorations, but these were quite elaborate. The roof tiles allow a low roof pitch characteristic of ancient Greek architecture. Fired bricks began to be employed with lime mortar. Very prominent buildings were roofed in stone
tiles, which mimicked the form of their terracotta counterparts. While later cultures tended to construct their stone buildings with thin skins of finished stones over rubble cores, the Greeks tended to build out of large cut blocks, joined with metal cramps. This was a slow, expensive and laborious process which limited the number of buildings that could be constructed. The metal cramps often failed through corrosion.

Building structures mostly used a simple beam and column system without vaults or arches, which based strict limits on the spans that could achieved. However, the Greeks did construct some groin vaults, arch bridges and, with the Egyptians, the first "high rise", the Lighthouse of Alexandria, one of the Seven Wonders of the Ancient World.

Greek mathematics was technically advanced and we know for certain that they employed and understood the principles of pulleys, which would have enabled them to build jibs and cranes to lift heavy stonework to the upper parts of buildings. Their surveying skills were exceptional, enabling them to set out the incredibly exact optical corrections of buildings like the Parthenon,. The ancient Greeks never developed the strong mortars which became an important feature of Roman construction.

3.3.7 The Roman Construction

The great Roman development in building materials was the use of hydraulic lime mortar called Roman cement. Previous cultures had used lime mortars but by adding volcanic ash called a pozzolana the mortar would harden under water. This provided them with a strong material for
bulk walling. They used brick or stone to build the outer skins of the wall and then filled the cavity with massive amounts of concrete effectively using the brickwork as permanent shuttering. Later they used wooden shuttering which was removed for the concrete to cure. The concrete was made of nothing more than rubble and mortar; it was cheap and very easy to produce and required relatively unskilled labour to use, enabling the Romans to build on an unprecedented scale. They not only used it for walls but also to form arches, barrel vaults and domes which they built over huge spans. The Romans developed systems of hollow pots for making their domes and sophisticated heating and ventilation systems for their thermal baths.

The Romans also made bronze roof tiles. Lead was used for roof covering material and water supply and waste pipes. Romans also made use of glass in construction with colored glass in mosaics and clear glass for windows. Glass came to be fairly commonly used in windows of public buildings. Central heating in the form of a hypocaust a raised floor heated by the exhaust of a wood or coal fire.

The Romans had trade guilds. Most construction was done by slaves or freed men. The use of slave labour undoubtedly cut costs and was one of the reasons for the scale of some of the structures. The Romans placed a considerable emphasis in building their buildings extremely fast, usually within two years. For very large structures the only
way this could be achieved was by the application of vast numbers of workers to the task.

The invention of the waterwheel, sawmill and arch were by the Romans. Roman roads included paved roads, sometimes supported on raft or pile foundations and bridges. The Romans developed sophisticated timber cranes allowing them to lift considerable weights to great heights. Roman building ingenuity extended over bridges, aqueducts, and covered amphitheatres. Their sewerage and water-supply works were remarkable and some systems are still in operation today.

3.3.8 The Chinese Construction

China is a cultural hearth area of Eastern Asia, many Far East building methods and styles evolved from China. A famous example of Chinese construction is the Great Wall of China built between the 7th and 2nd centuries BC. The Great Wall was built with rammed earth, stones, and wood and later bricks and tiles with lime mortar. Wooden gates blocked passageways. The oldest archaeological examples of mortise and tenon type woodworking joints were found in China dating to about 5000 BC.

The Chinese followed the state rules for thousands of years; so many of the ancient, surviving buildings were built with the methods and materials used in the 11th century. Chinese temples are typically wooden timber frames on an earth and stone base. However, Chinese temple builders regularly rebuilt the wooden temples and hence some parts of these ancient buildings are of different ages. Traditional Chinese timber
frames do not use trusses but rely only on post and lintel construction. The Anji Bridge is the world's oldest "open-spandrel stone segmental arch bridge" built in 595-605 AD. The bridge is built with sandstone joined with dovetail, iron joints.

### 3.3.9 The Medieval construction

The Middle Ages of Europe span from the 5th to 15th centuries AD from the fall of the Western Roman Empire to the Renaissance and is divided into Pre Romanesque and Romanesque periods.

Fortifications, castles and cathedrals were the greatest construction projects. The Middle Ages began with the end of the Roman era. Most buildings in Northern Europe were constructed of timber. Brick continued to be manufactured in Italy throughout the period 600–1000 AD but elsewhere the craft of brick-making had largely disappeared and with it the methods for burning tiles. Roofs were largely thatched. Houses were small and gathered around a large communal hall. Medieval stone walls were constructed using cut blocks on the outside of the walls and rubble infill, with weak lime mortars. The poor hardening properties of these mortars were a continual problem, and the settlement of the rubble filling of Romanesque and Gothic walls and piers is still a major cause for concern.

Master craftsmen transferred their knowledge through apprenticeships and from father to son. Trade secrets were closely guarded, as they were the source of a craftsman's livelihood. Medieval buildings were built by paid workers. Unskilled work was done by labourers on daily wages. Skilled
craftsmen served apprenticeships or learned their trade from their parents. Towns were in general very small by modern standards and dominated by the dwellings of a small number of rich nobles or merchants, and by cathedrals and churches.

### 3.3.10 Construction during Renaissance

The Renaissance in Italy, and the Reformation changed the character of buildings. During the Middle Ages buildings were designed by the people that built them. The master mason and master carpenters learnt their trades by word of mouth and relied on experience, models and rules of thumb to determine the sizes of building elements.

The major breakthroughs in this period were to do with the technology of conversion. Water mills in most of Western Europe were used to saw timber and convert trees into planks. Bricks were used in ever increasing quantities. An increasing amount of ironwork was used in roof carpentry for straps and tension members. The iron was fixed using forelock bolts. Roofing was typically of terracotta roof tiles. In Italy they followed Roman precedents. In Northern Europe plain tiles were used. Stone, where available, remained the material of choice for prestige buildings.

The rebirth of the idea of an architect in the Renaissance radically changed the nature of building design. The Renaissance reintroduced the classical style of architecture. The concept of architecture was raised to a new level, defining architecture as something worthy of study by the
aristocracy. Previously it was viewed merely as a technical art, suited only to the artisan. The resulting change in status of architecture and more importantly the architect is key to understand the changes in the process of design. Occasionally the architect would get involved in particularly difficult technical problems but the technical side of architecture was mainly left up to the craftsmen. Where the Medieval craftsmen tended to approach a problem with a technical solution in mind, the Renaissance architects started with an idea of what the end product needed to look like and then searched around for a way of making it work. This led to extraordinary leaps forward in the field of Civil Engineering.

3.3.11 Construction in the Seventeenth Century

The seventeenth century saw the birth of modern science which would have profound effects on building construction in the centuries to come. The major breakthroughs were towards the end of the century when architect-engineers began to use experimental science to inform the form of their buildings. Seventeenth-century structures relied strongly on experience, rules of thumb and the use of scale models.

Iron began to be increasingly employed in structures. Iron hangers were used to suspend the floor beams and iron rods to repair and strengthen the parts of various churches and cathedrals. Most buildings had stone ashlar surfaces covering rubble cores held together with lime mortar. Experiments were made mixing lime with other materials to provide a hydraulic mortar. Many tools have been made obsolete by modern
technology, but the line gauge, plumb-line, the carpenter’s square, the spirit level and the drafting compass were in regular use. Despite the birth of experimental science, the methods of construction in this period remained largely medieval. The same types of crane that had been used in previous centuries were employed for construction purpose.

3.3.12 Construction in the Eighteenth Century

The eighteenth century saw the development of many ideas that had been born in the late seventeenth century. It was not until the eighteenth century that Engineering theory developed sufficiently to allow sizes of members to be calculated. The architects and engineers became more professionalised. Experimental science and mathematical methods became more and more sophisticated and employed in buildings.

In the second half of the eighteenth century the decreasing costs of iron production allowed the construction of major pieces of iron engineering. Cast iron became increasingly used for columns and beams to carry brick vaults for floors. Steel was used in the manufacture of tools but could not be made in sufficient quantities to be used for building. Brick production increased markedly during this period. Many buildings throughout the Europe were built of bricks, but they were often coated in lime render, sometimes patterned to look like stone.
3.3.13 Construction in the Nineteenth Century: Industrial Revolution

The industrial revolution was manifested in new kinds of transportation installations, such as railways, canals and macadam roads. These required large amounts of investment. New construction devices included steam engines, machine tools, explosives and optical surveying. The steam engine combined with two other technologies which blossomed in the nineteenth century, the circular saw and machine cut nails, lead to the use of balloon framing and the decline of traditional timber framing.

As steel was mass-produced from the mid-19th century, it was used, in the form of I-beams and for reinforced concrete. Glass panes also went into mass production, and changed from luxury to every man's property. Plumbing appeared, and gave common access to drinking water and sewage collection. Building codes have been applied since the 19th century, explaining the standards for construction works.

3.3.14 Construction in the Twentieth Century

With the Second Industrial Revolution in the early 20th century, elevators and cranes made high rise buildings and skyscrapers possible, while heavy equipment and power tools decreased the workforce needed. Other new technologies were prefabrication and computer aided design. Trade unions were formed to protect construction workers' interests. Personal protective and security equipments such as hard hats and earmuffs also came into use.
From the 20th century, governmental construction projects were used as a part of macroeconomic stimulation policies, especially during the Great depression. For economy of scale, whole suburbs, towns and cities, including infrastructure, are often planned and constructed within the same project. In the end of the 20th century, ecology, energy conservation and sustainable development have become more important issues of construction.

3.3.15 Construction Sector for the Current Century

Now, the construction activities have increased manifold and become progressively more complex. The progressive use of sophisticated technology has made the construction activities capital intensive. The changes in the political, economical, social and other conditions make different demand on the Construction Sector. Construction being critical to improve the standard of living of the people, there is a need for it to be more active, faster and quality conscious. The past recorded volume of construction together with the expected growth demands sophisticated managerial talent to properly manage these big projects.

3.4 Indian Scenario

India has a glorious past in the field of construction work. The earliest known organized construction of dwellings at Mohan-Jo-doro dates back to 3000 B.C. The monuments of cave temples at Ellora and Ajanta are the testimony of the skill and craftsmanship in construction of the early days.
In those prehistoric periods, the sole means of construction were the human labour, without any sophisticated equipment. With the advancement in all spheres of technology, the civil engineering has also developed tremendously, utilizing all the modern techniques and management concepts. Construction industry is one of the oldest and largest industries (perhaps the second largest economic activity next only to agriculture) in India and the construction activity provides employment on a large scale.

3.4.1 Construction Industry in India

From the very beginning of the existence of the human being on this planet, man has been constantly devising means of safeguarding himself against the onslaught of nature and wild animals. In the ancient times man used to live on trees, machans and in caves. With the advancement of knowledge and civilization man started constructing huts and then houses and started living in groups. With the passage of time, new techniques of construction developed and construction activity turned into an Industry. Thus construction industry is the single largest important undertaking in the economy of a country. Thus the basic needs of human beings from the very beginning are as

- Food
- Clothing
- Shelter
After independence, the Government of India adopted a policy of planned investment in the form of five year plans for the quick development of the country. In all the five year plans more than 50% expenditure incurred is related to construction work in one form or the other such as dams, power and irrigation projects, roads, establishment of heavy industries, communication, housing and urban development etc. Thus the construction is the second largest economic activity in India next to agriculture. The volume and scope of construction industry can be directly linked with the population and size of the country and plays a critical role in allround development of the country. With the increase in population, the need for housing and industry also increases. Thus the national development is directly linked with the development of construction activities.

3.4.2 Construction and National Development

The national development of a country is inseparably linked to development in the construction activities. The status of a person or society can be determined by the type and nature of building he lives in, which is an outcome of civil construction technology. Or in other words, buildings, tools & plants, machineries etc. are the physical forms of technology.

Construction activity is an integral part of a country’s infra structure and industrial development. It includes hospitals, schools, townships,
offices, houses and other buildings; urban infrastructure including water supply, sewerage, drainage, highways, roads, ports, railways, airports, power systems, irrigation and agriculture systems, telecommunications etc... Since these activities cover such a wide spectrum, construction becomes the basic input for socio economic development. Moreover, the construction industry generates substantial employment and provides growth impetus to other sectors through backward and forward linkages. Hence it is very essential that this vital activity should not be neglected as far as healthy growth of the economy is concerned.

Construction plays a critical role in all development sectors like agriculture, irrigation, energy transportation, communication, manufacturing, housing, civil infrastructure etc. The size and population of a country directly influences the scope and volume of construction industry which means with an ever-lasting population, the need for housing and industry also increases.

The construction industry is highly linked with the national development and thereby to the economic progress of a country. For a developing country like India, construction work accounts for a large share of government development plan outlay. Construction industry plays a multiple role to the national economy. It is estimated that every rupee invested in construction would generate about 0.80 incremental earning to GNP. The corresponding figures for agriculture and manufacturing are about 0.20 and 0.14 respectively. Construction creates large scale
employment which by itself is a significant contribution to the Indian economy.

The Construction industry of India is an important indicator of the development as it creates investment opportunities across various related sectors. The construction industry has contributed an estimated ₹670,778 crores to the national GDP in 2011-12 (a share of around 8%). The industry is fragmented, with a handful of major companies involved in the construction activities across all segments; medium sized companies specializing in niche activities; and small and medium contractors who work on the subcontractor basis and carry out the work in the field.

3.5 Construction Sector – Employment Generator

The population of our country is increasing at a fast pace and with the ever increasing population, the need for housing and industry also increases. The construction industry is the second largest industry of the country after agriculture. It makes a significant contribution to the national economy and provides employment to large number of people. The use of various new technologies and deployment of project management strategies has made it possible to undertake projects of mega scale.
Table 3.1 Component of Construction investment in Other Sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>Percentage of cost going into Civil Construction</th>
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<tbody>
<tr>
<td>Power</td>
<td>37</td>
</tr>
<tr>
<td>Space and Scientific Research</td>
<td>20</td>
</tr>
<tr>
<td>Education and Culture</td>
<td>37</td>
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<tr>
<td>Health</td>
<td>40</td>
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<td>Railways</td>
<td>50</td>
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<td>Roads</td>
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<td>Ports, Inland water transport</td>
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<td>Civil Aviation</td>
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<td>Tourism</td>
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<td>Water supply</td>
<td>40</td>
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<td>Sanitation</td>
<td>25</td>
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<tr>
<td>Housing and Building</td>
<td>80</td>
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</tbody>
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In India, the construction industry employs a very large workforce probably next only to agriculture. Even in the absence of reliable data, approximate estimates place this figure around 5% of the total labour force in the country. Adding another 5-10% for those who work in construction related fields like construction materials, construction equipment and associated industries, this totals up to a whopping of 10-15% of the whole...
working population. Construction is a sector with immense potential to kick start the economy with its substantial contribution towards national income, GDP and employment generation. On account of the inherent forward and backward linkages, investment in the construction industry has been estimated to promote over 250 industries in other sectors. The National Buildings Organization has estimated that for every one million rupees invested in construction, generates 3000 man days of skilled and semi skilled labour and 1300 man days of managerial and technological employment.

3.5.1 Role of the Government

Most of the construction works in India is Government controlled and are financed by the Government. Even Industrial and housing sectors get financial support from institutions and banks regulated by the Government. The Government also regulates the construction by controlling the finance allotted to different infrastructure execution agencies. Many a time, delay taken place in giving timely decisions and bureaucratic red tapism cause great difficulties in the execution of a project and many a time cost exceeds many fold of the original estimated cost. Whenever there is a depression, it is the construction budget that is affected first. The Builders Association of India (BAI) is the main organization of contractors. It has 10000 direct and 15000 affiliated members and more than 70 centres throughout India. There are many public sector under takings in the construction sector. Most of the states also have their own organizations.
3.6 Kerala Context

Kerala occupies a unique position not only among the States in India but among the developing countries as well in social sector development. The State’s human development is comparable with those of the middle-income countries of the world. In addition, Kerala has achieved a high degree of equality in the distribution of human development achievements across gender, space, and social groups. Performance of Kerala in the sphere of social development is often projected as a model to be emulated. The State’s accomplishments show that well-being of the people could be augmented and social, political, and cultural conditions improved, even at low levels of income, provided there is appropriate public action.

Despite the general improvement, pockets of deprivation are visible in all the rural villages of the State. Slum-like human settlements or colonies in rural areas constitute one such example. There has been a housing boom in Kerala in recent years. House construction being a labour intensive and capital-light activity, investment in housing has significant multiplier and accelerator effects, which might benefit the weaker sections of society.

All the architectural wonders of kerala stand out to be ultimate testimonials for the ancient vishwakarma sthapathis of Kerala. Kerala’s style of construction is unique in India, in its striking contrast to Dravidian architecture which was normally practiced in other parts of South India. The architectural style has evolved from Kerala’s peculiar climate and long
history of influences of its major maritime trading partners like Chinese, Arabs and Europeans.

Geographically Kerala is a narrow strip of land lying in between western seaboard of peninsular India and confined between the towering Western Ghats on its east and the vast Arabian Sea on its west. Favoured by plentiful rains due to Monsoon and bright sunshines, this land is lush green with vegetation and rich in animal life. Heavy rains have brought in presence of large water bodies in form of lakes, rivers, backwaters and lagoons. The climatic factors thus made its significant contributions in developing the special Kerala style, to counter wettest climatic conditions coupled with heavy humidity and harsh tropical summers.

3.6.1 History

The locational feature of Kerala has influenced the social development and indirectly the Style of construction. In the ancient times the Arabian sea and the Ghats formed impenetrable barriers helping the evolution of an isolated culture of Proto-Dravidians, contemporary to the Harappan civilization. The earliest vestiges of constructions in Kerala belong to this period from 3000 B.C. to 300 B.C.

The natural building materials available for construction in Kerala were stones, timber, clay and palm leaves. Granite is a strong and durable building stone; however its availability was restricted mostly to the highlands and only marginally to other zones. Owing to this, the skill in
quarrying, dressing and sculpturing of stone was scarce in Kerala. Laterite on the other hand is the most abundant stone found as outcrops in most zones. Soft laterite available at shallow depth could be easily cut, dressed and used as building blocks. It is a rare local stone which gets stronger and durable with exposure at atmospheric air. Laterite blocks may be bonded in mortars of shell lime, which have been the classic binding material used in traditional buildings. Lime mortar can be improved in strength and performance by admixtures of vegetable juices. Such enriched mortars were used for plastering or for serving as the base for mural painting and low relief work. Timber is the prime structural material abundantly available in many varieties in Kerala – from bamboo to teak. Perhaps the skilful choice of timber, accurate joinery, artful assembly and delicate carving of wood work for columns, walls and roofs frames are the unique characteristics of Kerala architecture. Clay was used in many forms – for walling, in filling the timber floors and making bricks and tiles after pugging and tempering with admixtures. Palm leaves were used effectively for thatching the roofs and for making partition walls.

From the limitations of the materials, a mixed mode of construction was evolved in Kerala style of construction. The stone work was restricted to the plinth even in important buildings such as temples. Laterite was used for walls. The roof structure in timber was covered with palm leaf thatching for most buildings and rarely with tiles for palaces or temples. The exterior of the laterite walls were either left as such or plastered with
lime mortar to serve as the base for mural painting. The sculpturing of the stone was mainly moulding in horizontal bands in the plinth portion whereas the carving of timber covered all elements like pillars, beams, ceiling, rafters and the supporting brackets. The indigenous adoption of the available raw materials and their transformation as enduring media for architectural expression thus became the dominant feature of the Kerala style of construction.

The primitive construction models in ancient Kerala were huts made of bamboo frame thatched with leaves in circular, square or rectangular plain shapes. The rectangular shape with a hipped roof appears to have been finally evolved from functional consideration. Structurally the roof frame was supported on the pillars on walls erected on a plinth raised from the ground for protection against dampness and insects in the tropical climate. Often the walls were also of timbers abundantly available in the land. The roof frame consisted of the bressumer or wall plate which supported lower ends of the rafters, the upper ends being connected to the ridge. The weight of the rafters and the roof covering created a sage in the ridge when the ridge piece was made of flexible materials like bamboo. This sage however remained as the hall-mark of roof construction even when strong timber was used for the roof frame. Further gable windows were evolved at the two ends to provide attic ventilation when ceiling was incorporated for the room spaces. This ensured air circulation and thermal control for the roof. The lower ends of the rafters projected much beyond
the walls to shade the walls from the sun and driving rain. The closed form of the Kerala houses was thus gradually evolved from technical considerations.

The pillars and walls are again of simple shape with no projection or recesses. The main door faces only in one cardinal direction and the windows are small and are made like pierced screens of wood. The rectangular plan is usually divided into two or three activity rooms with access from a front passage. By tenth century, the theory and practice of domestic architecture were codified in books such as Manushyalaya Chandrika and Vaastu vidya. This attempt standardized the house construction suited to different socio-economic groups and strengthens the construction tradition among the craftsmen. The traditional craftsman like carpenters preserved the knowledge by rigidly following the canonical rules of proportions of different elements as well as the construction details.

3.6.2 Traditional Building Process

Traditional Kerala style construction was based on the principles of Vaastu Sasthra. It considers the astrological placement of the Sun, Earth, and other Planets during the actual construction along with the location of the site, its shape, the proposed building's shape, perimeter, the facing direction of the building, the location of gates, height of compound walls, entry doors, doors to each room, windows, and the general design of the building. The basic theories of Vastu Sasthra are closely connected with astrological principles.
Therefore, deviation from the accepted rules was believed to cause detrimental effects to those who use the building or the artisans who had constructed it. Thus the technology demanded highly skilled craftsman and precision in the entire work. The whole process was under the control of a head craftsman. Also the building process was based on caste-related social customs and traditions. It had a great influence on the overall building process, such as the type of buildings, materials used for construction, technologies employed, labour involved etc. Absence of wage, labour relations and the supremacy of the caste system was a distinguishing characteristic. Houses belonging to each caste had a common name of identification revealing their appearance and technology used. The quality and size of houses diminish as we go down to the caste scale. The caste system provided the framework for occupational division of labour. Only the upper class enjoyed the privilege of employing the services of artisans, and the poor people used to build their houses with self-help or mutual help using locally available materials. This situation continued till the early 1970s.

3.6.3 Modernisation of the Building Process

The social reform movements and the larger process of modernisation of Kerala since independence and later the formation of Kerala state had effectively overcome many social and caste-based restrictions in all sectors of life including the building process. Following the 1973 hike in oil prices, the majority of youth from Kerala migrated to the
Gulf countries in search of better employment opportunities and there was a significant inflow of remittances to the state from the Middle East. Income windfalls and exposure to the outside world brought out greater changes in their aspirations, desires and preferences. A major part of the investment at that time was in the housing sector. Average prices of indigenous building materials (sand, clay) increased by about fifteen to twenty times during this period. Free access to the natural materials was denied and traditional practice of community co-operation in house building became non-practicable. At the same period, the factory-produced materials like cement and steel showed an increase of less than ten fold.

The number of new residential buildings has also showed a steady increase. This housing boom was the combined effect of economic, social, institutional and cultural changes occurring during those days. Land reforms conferred ownership on land to those who had earlier been landless labourers. Also the popularity of One lakh housing scheme generated the importance of having own houses, even among the economically weaker sections. These social changes and subsequent investments in housing favoured the excessive use of energy-intensive building materials like cement, steel and bricks, replacing the traditional materials.
Table 3.2
Changes in material use pattern in Kerala

<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Traditional materials (Lime, Mud, Grass, thatch, Bamboo, wood) (In percentages)</th>
<th>Modern materials (Burnt bricks, stone, tiles, concrete, GI and other metal sheets) (In percentages)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>74.1</td>
<td>25.2</td>
</tr>
<tr>
<td>Wall</td>
<td>63.7</td>
<td>35.4</td>
</tr>
</tbody>
</table>


The modernisation of the building process during those periods opened up a new era of technology in the housing sector of Kerala. It resulted in the vanishing of environment friendly Kerala architecture. The most adverse effect of this process was the excessive dependence on energy-intensive building materials. Only 0.10 per cent of houses had concrete as roofing material in year 1961, but the latest census reports shows figure of 26.50 per cent in 2001. These changes in the technology consequently generated changes in the employment sector and the wage structures, especially in the rural areas, and intermediaries or agents emerged for all sectors of the building process, including supply of materials and labour. As a result, even for small constructions except kutcha houses, the households are forced to depend on these intermediaries, and this further increased the cost of construction. Wages of skilled labourers increased many fold. Also this modern technology with
its undue stress on costly and energy-intensive materials like steel and cement is not affordable to the majority of the population. In addition to this, these materials consume large amounts of non-renewable natural resources like energy, minerals, and top soil affecting the environment. In order to overcome these problems and to solve the urgent housing demand, the government of Kerala promoted cost effective construction techniques and innovative materials.

3.7 Theoretical Framework

Construction is nothing but creation. The output of a construction work is a fine structure. In construction, the various resources are used in an effective and efficient manner for the convenient use of the man kind. The resources used for the construction works are classified as 1-Man, 2-Materials, 3-Money, and 4-Machines. Apart from these four resources there is one more aspect which is also considered to be an important resource these days which is nothing but Management. Without proper management, the construction activity will not be fruitful.

3.7.1 Classification of Construction Works

The classification of construction works may be made depending upon the following factors.

1. Based on the cost of construction – Based on the money value or cost of construction, the construction works may be classified as minor works, medium works and major works.
2. Based on the life of work – In this category, construction works are classified as follows:

a) Temporary work. If the work is made of cheaper materials, and is of temporary nature and can be dismantled easily at a later time, then such a construction is called as temporary work.

b) Semi permanent work. If the life span of the work is short and can be dismantled, and replaced then it is called as semi permanent work.

c) Permanent work. If the structure is wanted to remain for a long time and made durable, then it is called a permanent work.

3. Based on the nature of the work – In this category, construction works may be classified as follows:

a) Original work. All new construction works are classified as original works.

b) Repair works. Any repair of an old work is called a repair work.

Now a day the rehabilitation of old buildings in big cities, monuments and important structures affected by environmental factors is gaining importance. The repair of monumental works needs special attention, technique and materials. For such works, some specialists have given the name as Forensic Engineering.

4. Based on the type of structural members and equipment used –
Under this category, construction works are classified as follows:
a) Light construction. The construction works which have light structural members and consequently light foundations and do not need heavy machinery and equipment for their construction are called light construction. Residential and commercial buildings, warehouses, schools, village and city roads, light industrial buildings, small water supply and sewage works etc. are classified as light construction works.

b) Heavy Construction. Structures having heavy structural members and heavy foundations which require heavy machinery and equipment and large quantities of material, labour and heavy investment for their construction are called as heavy construction. Construction of dams, bridges, irrigation works, railways, highways, oil pipe lines, thermal and hydro power generation works, docks and harbour, tunneling etc. are classified under this category.

c) Industrial construction. The works which need specialized equipment and machinery and special technology and know how for their construction are known as industrial construction. The construction work for atomic power plants, steel and fertilizer plants, oil refineries, chemical plants, are classified under this category.
3.7.2 Stages in the Construction of a Project

The various stages in the construction of a project may be classified under the following heads:

1. Conceptual or Initial stage
2. Study and Evaluation stage
3. Design stage
4. Awarding of contract for construction stage
5. Construction stage
6. Utilization and maintenance stage

1. Conceptual Stage: It is the stage which a project is conceived to be undertaken to achieve certain aims. Thus, either due to the efforts of individuals or to satisfy the social and public needs many construction projects was undertaken. Whatever may be the source, of originating idea for starting a welfare project, needs to promote with the user agencies to generate sufficient interest for its further consideration and development to reach the completion stage.

2. Study and Evaluation Stage: After the initial construction of any project, it is further studied and analysed regarding the cost of the project and benefits that will accrue from it. Before finally accepting the proposal, preliminary surveys are carried out and rough estimates are prepared to study the feasibility and economic viability of the project. If it is social welfare project, then the social utility of the project will be of main
consideration. After the acceptance of the project, sources of funding are found out. In case of a Government project, an administrative approval is accorded and a budget provision is made at this stage. In a private Organization a decision is taken to undertake the project and arrangements are maid to raise funds for its completion. Thus, after taking decision of the construction of a project, the following points are studied:

- a) Availability of land where the project is to be constructed
- b) Finances required for its completion
- c) Necessity for its construction at present
- d) Future utility of the project
- e) Type of construction to be adopted
- f) Returns from the project

3. Design Stage: This is a very important stage for the implementation of the project. At this stage, necessary field surveys and investigations are carried out. At this stage, generally the following investigations are made:

- a) Topography of the area
- b) Bearing capacity of soil
- c) Position of ground water table
- d) Access to the site
- e) Availability of construction material and required labour near the site of work
- f) Local weather conditions
Thus after the field investigations and surveys carried out, site and alignment finalised, the process of land acquisition and obtaining approval of local authorities goes on simultaneously. Any economy that can be effected in the cost of the project depends mainly on the decisions taken at the design stage on the basis of site investigations and other related data. Any change that needs after the approval of the design will prove more expensive.

4. Awarding of Contract for Construction: At this stage necessary tender documents are prepared and tenders called and evaluated. Finally, the work is awarded to the contractor, whose terms of execution are more favourable. Preference is given to a contractor, who has executed similar work successfully in the past. In case the work is to be executed departmentally, the internal orders are issued authorizing expenditure and preparations are made for its execution.

5. Construction stage: At this stage, maximum coordination is required between the various agencies connected with the implementation of the project. This stage needs the maximum skill from the project manager so that the project may be completed well in time as per approved design. Proper safety measures should be adopted during the construction. The work should be cost effective. Problems encountered during the construction due to the variations in site conditions should be refereed to the designer for suitable changes in the design.
6. Utilization and Maintenance stage: Some projects can be put to use even after completing some of its parts. After putting the full project, to use, the factors regarding its maintenance should be considered carefully. The performance, the nature and extent of maintenance and repair are good indicator of the quality of construction and provide a valuable feedback for the use in the construction of other similar new projects. Many projects completed with great efforts at huge cost failed to give fullest benefits due to non provision of continuous maintenance facilities to them. The line diagram of various stages of construction is shown in the following figure.
3.7.3 Construction Team

It is a well known fact that for the construction of any project, a group of persons or team with specific duties to be performed by each group is needed. Thus the construction team includes the following:

1. Owner
2. Engineer/Architect/Consultant
3. Contractor or Builder
The functions of each team or constituent of the construction depend upon the type and size of the work and method of execution of the work. Each constituent has to discharge his responsibilities and cooperate with other constituent to complete the construction work without delay and escalation in construction cost. Usually delay and accidents take place due to the un-coordinated efforts by the different constituent.

**Fig. 3.2 The construction Team and Interaction**

### 3.7.3.1 Functions of Constituents of Construction Team

Following are the functions of each constituent:

1. **Owner**: The owner may be an individual, group, private or public body who promotes the work and provides finances for the execution of the work. After completion of the work, the owner arranges for its proper utilization and maintenance.
2. **Engineer/Consultant/Architect:** May be an individual person or group of persons or a company who give the technical advice about the project to the owner. Engineer is a professional man and is responsible for the safe and economical design and construction of the work under his supervision. His field activities are as follows:

a) Filed investigations for the proposed project
b) To prepare the plans and design of the work
c) To prepare estimates and specifications
d) To work out the quantities of construction materials and the cost of the project
e) To obtain approval of the construction plans from the local authorities
f) To float tender, their evaluation and approval of the lowest tender
g) Supervision, control and inspection of the quality and progress of the work done by the contractor.
h) Measurements of works done and their payment.

In case the work is executed departmentally, then he is responsible to arrange construction materials, equipment and labour etc. If necessary for the proper design, the Engineer may be assisted by architect and other specialists.

The cost of construction is affected significantly by the specifications and design requirements. Thus an Engineer has a very important responsibility to ensure the minimum cost of construction of the
project. He may examine a number of proposals and designs and select the most economical and viable project.

**Consultant:** A consultant is a specialist in his field. A consultant may be appointed for a highly specialized project to help the owners and contractors in the execution of that highly specialized job. His appointment is optional.

**Architect:** An architect is a technical person. Usually he is involved in the building construction projects. He designs the buildings to give aesthetic look to the building and proper and economical use of the available space.

3. **Builder/Contractor:** A contractor for Civil Engineering works may be a single individual or a group of persons or a company who undertakes the construction of the work. He offers to undertake the construction of the work for a given amount of money. In case the tender is accepted in his favour, he signs a contract with the owner or promoter to execute the construction work. He must have the skill and competence to execute the work properly as per design and specifications. A small contractor usually relies on his own experience and judgement or on the advice of his experienced mistries in tendering and execution of work. A contractor may take the advice of qualified Engineers.

The contractor is responsible for procuring of materials not supplied by the owner. He may organize, plan and execute the work as per drawings and specifications laid down in the contract and as per construction schedule agreed upon. Big construction companies employ
Engineers who deal with office work involved in large contracts such as designing, tendering and scheduling. The site engineers are concerned with the execution of the work such as surveying, leveling and giving layouts for the construction.

The smooth and efficient progress of any construction project, whether large or small depends upon the coordination of different constituents involved in the project. Each constituent should know his job well and play his role effectively. In the construction work, there is always a degree of uncertainty due to unexpected site conditions, difficulties in the procurement of construction materials and labour. Local weather conditions also affect the progress of work. For eg. The progress of earth dam construction work is very less in the zones of heavy rains. Financial constraints are a major hurdle in the speedy progress of the project. Hence for a speedy and economic completion of a work, a constant liaison and interaction among the construction team i.e. Owner, Engineer and Contractor is essential.

3.7.4 Resources of Construction Industry

As any other industry, construction industry also needs some resources which are listed below.

a. Money 
b. Man 
c. Material 
d. Machines & Equipments 
e. Management
1. **Money.** It is the first and foremost item required for any project. Normally, it should be arranged before starting the work. Money should be supplied regularly as and when required for the proper progress of the work. Insufficiency of funds for the project will cause delay in the completion of the work, resulting in escalation in the cost of the project and also depriving the people from the benefits expected from the project. Thus irregular and insufficient supply of money will cause delay in the completion of the project and wastage of time and energy.

2. **Man.** For the successful completion of any project, man power, both skilled and unskilled is very important. It is economical and dependable both being the oldest resource. According to Planning, from labour to skilled supervisory staff is required for the successful completion of any project.

3. **Materials.** It has been estimated that for any work or project usually the cost of material is about 50% of the total cost of the project. Thus construction materials should be available within 5km radius of the site of work for economical completion of the work as the cost of cartage of materials affects the total cost of the project to a great extent. The supply of materials should be regular in sufficient quantity as per need. While stacking and storing the materials, proper care should be taken to avoid their deterioration.

4. **Machines and Equipments.** For major works, different kinds of machines are needed for different activities. On major projects it is economical in
terms of money and time both. The Engineer in charge of machines should have sufficient knowledge about the machines and equipments needed for a particular activity and most economical machine/equipment should be chosen. The machine/equipment chosen should be available as and when needed for the work.

5. **Management.** It is a sort of administration, whose functions are to plan, organize, control and coordinate the use of different resources to achieve the desired goal. In fact, Management is an art of arranging various activities and group of people to achieve the common goal. Thus an executive must have managerial skill.

### 3.7.5 Construction Economy

The construction economy can be achieved at design and supervision level. It can be classified into two categories as follows:

A. At the level of Designer/Engineer

B. At the level of Contractor

**A. At the level of Designer/Engineer**

A Designer or Engineer can effect economy on the following aspects:

- **Repeated use of formwork.** The design of the structure should be such that the same form work can be used repeatedly

- **Simple design.** The design of the structure should be as simple as possible.
• **Minimum requirement of machines and equipment.** The design of the structure should be such that for its execution minimum machinery and equipment is required.

• **Minimum labour requirement.** The design of the structure should be such that no special equipment is required for its execution and the requirement of labour also should be minimum.

• **Use of Local Materials.** As far as possible local materials should be used in the construction which will reduce the cost of the structure.

• **Language of specifications.** Specifications to be given to the contractor should be written in simple language and should be complete, specifying the results expected from the contractor.

• **Simple specifications.** Specifications should be in such a way that they can easily be understood by the contractor and also, the contractors should be familiar with them.

• **Skilled supervision.** The supervision of the work should be carried by experienced supervisors who understand the problem of the project and can take decisions on the spot.

**B. At the level of Contractor**

Contractor can control the cost of a project on the following aspects. These are the factors which influence the cost of a project to a great extent and hence, the contractors should study these aspects well before bidding for a tender.
• Topography of the site
• Climatic conditions of the site
• Sources of constructions materials and their availability
• Access to the site
• Availability of Labour
• Storage facilities for the materials and equipments at site
• Employing trained and experienced staff

3.8 Management and Cost Reduction Concepts in Construction

3.8.1 Relevance

Management is considered as a universal process. In every aspects of life, we can see the application of management in one form or other; whether it is an individual, a family, a club, a government, or an organisation. The approach and style of management may differ from one to another. The success and survival of an organisation largely depends upon the persons serving in the key levels. According to Terry, management can be defined as ‘a distinct process consisting of planning, organising, actuating, and controlling performed to determine and accomplish the objectives by the use of people and resources.’

As far as construction industry is concerned, it can very well be seen that the management plays an important role in its success and
survival. In every day to day activities, whether it’s financial matter, or human resource matter, or inventory control matters, the concerned responsible persons must be very alert, keen, future oriented and opportunity capturing. In financial aspects, the money value gets fluctuated within short periods, and there are lots of price variations as far as construction materials are concerned.

For every construction project to be undertaken the rate of return is a key factor to decide whether the project should be undertaken and when to start the project. The cash flows should also be well managed. As far as human resource aspects are concerned, labourers will be somewhat unpolished and there may be both skilled as well unskilled ones among them. It needs different types of tactics to get the works done by them. Moreover, the managers must be well aware about the labour laws and must be capable of solving union problems.

3.8.2 Importance of Construction Management

- In construction industry, the work should be started and finished in a predetermined manner. For this to achieve, recruitment of right people at right time is very essential. Planning & scheduling help in such recruitment.
Labourers will be somewhat unpolished in construction industry and there may be both skilled as well unskilled ones among them. Hence wastage of labour is a common phenomenon in the construction industry. The leadership, decision making ability and proper directing the subordinates help to avoid the wastage of labour.

Communication and coordination skill helps to maintain the continuity of work and avoid delays.

In order to extract the maximum and increase the efficiency of labours, motivating the workers with various schemes and awards plays an important role in construction industry.
• Proper monetary control helps to optimize resource utilisation and to keep the construction cost minimum.

### 3.8.3 Duties and Responsibilities of Construction Managers

A construction manager has got so many tasks to perform. Prior to the beginning of a project, so many jobs are necessarily needed to be done like acquisition of land, planning process, obtaining permits, hiring of labours etc. The labours will be interviewed by the manager, hired and disciplined prior to the work and during the work, and even fired in case it is found necessary. Any problems created by the labours should be viewed seriously and dealt with tactically in order to keep the project going without any delay.

A construction manager should review the project in depth and should be very conversant with each and every stage of work so that he can thoroughly understand what will be needed along the way and can act accordingly.

Construction managers are responsible for forming a budget for the project. The two major factors which largely influence the budget are wages and materials. He must order the various supplies required for the project keeping in mind the budget of the project and without compromising the quality of materials.

A construction manager must manage the construction as per the schedule in an effective and efficient manner. This is very crucial as any
delay in any part of project may cause the construction cost to boost up. Hence he must be able to resolve any issues arising during the construction project in order to stay as per schedule.

The construction manager is the one who should supervise the project in a regular manner, to give proper directions, and to correct in case if there are any discrepancies. He must review the entire project as and when necessary and ensure that the work is being done as per schedule. If there appears to be any deviation from the planned construction project, it is up to the construction manager to get the project back on the right track.

### 3.9 Cost Reduction Concepts

#### 3.9.1 Need for cost reduction

The rising cost in civil construction industry has become a real menace these days. What contribute to this high cost are not only the high cost of materials and the high rates of wages prevailing in our state, but also the insane craze of the present generation for the new fashionable frills and designs. This high cost of operation not only affects the construction industry directly, but also the overall economy indirectly. Not only that, this high cost of infrastructure translates into higher user charges which again reduces the surplus that can be ploughed back into construction technology upgradation and labour welfare.

More over to that, with the construction work using with traditional building materials like cement, sand, steel etc., the environment is
becoming more and more polluted and sophisticated. Building materials like sand, timber etc. are becoming scarce and the cost of production of cement and steel is rising steeply. Trenching of river beds for sand collection, and mining of iron ores, lime stone and clay etc. for steel and cement manufacturing, and felling of trees for wood work in buildings have posed a serious threat to the environment and we will have to face serious set backs in the near future on account of disturbing the environment.

Within a short time, these conventional building materials will become scarce and it is high time to think of non conventional, cost effective and environment friendly approach in the construction process without any compromise on quality aspects. The concept of green architecture has already come into existence and we will be forced to practice the same in constructing our own buildings in the near future. Green architecture, also known as sustainable design, is a method of design that minimizes the impact of building on the environment. Green buildings are not only designed for present use, but consideration is also been given to future uses as well.
<table>
<thead>
<tr>
<th>Materials</th>
<th>Labour</th>
<th>Component wise</th>
</tr>
</thead>
<tbody>
<tr>
<td>(73%) Material</td>
<td>(27%) Labour</td>
<td>(100%) Component wise</td>
</tr>
<tr>
<td>Cement – 18%</td>
<td>Mason – 10%</td>
<td>Foundation – 10%</td>
</tr>
<tr>
<td>Iron &amp; Steel – 10%</td>
<td>Carpenter - 5%</td>
<td>Walls – 30%</td>
</tr>
<tr>
<td>Bricks – 17%</td>
<td>Unskilled labour - 12%</td>
<td>Roof – 25%</td>
</tr>
<tr>
<td>Timber – 13%</td>
<td></td>
<td>Doors &amp; windows – 15%</td>
</tr>
<tr>
<td>Sand – 7%</td>
<td></td>
<td>Flooring – 10%</td>
</tr>
<tr>
<td>Aggregate – 8%</td>
<td></td>
<td>Finishing – 10%</td>
</tr>
</tbody>
</table>

Source: “Construction Engineering & Management” by Prof. Dr. S. Seetharaman

Table 3.3 Component wise split up details of building construction cost

3.9.2 Cost Control

Cost control is the process of controlling the expenditure during all the stages of a construction project right from the planning and design, till the completion of execution and final payments are made. The funds available for construction projects may be limited and hence it becomes necessary for the engineer to ensure the maximum benefits from the expenditure of the limited funds available. For this, it is necessary to frame the estimates of the cost of the proposed projects and reasonably make sure that it can be carried out within the funds available. More over to that, the construction materials are becoming scarce day by day and it will sooner become imperative to use other alternatives for the construction materials like sand, rubble, wood etc. In construction management, if cost
control is neglected, it will not only result in heavy losses to the owner of
the project but will also reduce the profit margins to the contractor.

3.9.2.1 Objectives of Cost Control

1. To locate areas of inefficient functioning: - During the course of
construction, if there is inefficient functioning at any stage or the work
is carried out in an uneconomical manner, then the cost control data is
used to so that the remedial action can be taken well in time. Cost
control data gives the day-to-day costs incurred on the various items
of work and thus provides an immediate warning to the site engineers
whether the construction cost is going higher than the estimated one.
If the methods of cost control are not used, then any loss in the
construction of the project will be known only at the end and then it
would become too late to do anything except to accept the losses.

2. As a basis for preparing Estimates: - The estimates for any
construction project are prepared by taking the costs of the materials
as well as the performance of men and machines doing different
operations. Cost control acts as a basis of estimation and thus,
provides the feed back to the estimator for updating the knowledge of
the output data of men and machines. The unit rates of the cost for
various items of work cab be chalked out after the completion of a job
and these would help in preparing realistic estimates for similar works
for which the contractor may like to tender his bid.
3. Estimation of profit or loss: - In order to determine whether the estimated profit is being made or not, cost control techniques are adopted. The contractor can find his profit or loss by comparing the actual expenditure incurred on the work as indicated by the cost control data and measurements of the completed portion of the work.

3.9.3 Stages of Work at which Cost Control is Effecte
d
3.9.3.1 At the Design Stage

The cost of a project is partially dependent on its design and specifications. Various alternative designs should be considered at the pre-tender stage itself and only those which are most feasible and most economical as well as consistent with the requirements should be chosen. The specifications should also be decided upon in terms of the requirements. Local materials should be specified as far as possible so that the transportation cost can be effectively reduced.

3.9.3.2 At the Construction Stage

Construction cost mainly consists of expenditure on factors like Materials, Labour, Plants and Equipments & Overheads as detailed below.

1. Materials

Every construction job requires materials for the work. Whether it is a small building, a shopping mall, swimming pool or anything else, all those jobs require material inputs of some sort. The cost of construction includes
the cost of materials required for the work which are relatively fixed from contractor to contractor, site to site with only slight variances for purchasing costs if a different supplier or quality of materials is used.

2. Labour

Another factor in cost of construction is the labour cost. Whether the construction job requires one person or 100 people to complete, the contractor will expend some manual resources to complete the job. Some jobs will require a supervisor or specialist workers such as plumbers and electricians. The bid amount quoted by the contractor should document the man-hours or man-days required for each type of labor to complete the job, and the hour or day rate paid by labor type. Labor rates may vary from site to site, depending on the quality of workers they employ or the average wage rates in that area.

3. Equipment

For any construction work, it may have to use or rent specialized equipment to complete the construction work such as using a backhoe to dig a trench or a mixing machine for the proper mixing of concrete. Any special equipment required should be noted in the contract, along with an hourly or daily rate for its use. Normally, the equipment costs will be consistent from contractor to contractor, but some slight variations may occur with respect to the site conditions and other factors
4. Overhead

Overhead is the amount of money a contractor includes in his pricing to cover the cost of items not directly related to the construction project, such as office support, advertising and facilities maintenance etc.

There is scope of cost control in all the above items, but, the two areas in which cost control can be achieved are labour and materials. Some cost effective techniques can be adopted for achieving the cost reduction. There is also need for adequate supervision, so that any wasteful activity can be immediately located and corrective actions taken.

3.9.4 Cost Effectiveness – The concept

It is sometimes felt that what is really intended by Cost effective construction is mere the cost reduction in construction work. Others view it as a low cost housing. There is a huge misconception that low cost housing is suitable for only sub standard works and they are constructed by utilizing cheap building materials of low quality. The fact is that Low cost housing is done by proper management of the resources of construction like money, man, machines and materials.

Cost effectiveness in building construction means not merely reducing the cost of construction alone. It is a long term parameter considering the quality and strength aspects, comfort level of the inhabitants etc. Of course, the cost reduction concept is there in cost effectiveness. Cost effective construction means construction of structures by controlling the cost for all sections of the population in a better quality standard. Thus the
accent is on housing at effective cost as compared to the prevailing cost levels. However, Cost effective construction, is not meant for only the low income people, but it can even be projected to high income group also. The perspective should be clear to all. Cost effective construction should not mean low quality housing although the quality and cost go together. In a Cost effective construction, the total cost of housing, called life-cycle cost of housing taking in to consideration the initial capital cost of housing construction and also the recurring cost of maintenance and repair of housing, over a period of its economic service life, should be determined and the most cost-effective housing should be adopted.

The conceptual review with respect to cost saving mechanisms is addressed from two aspects, namely

- **Construction technology aspect**
- **Construction management aspect.**

Besides these two construction aspects are interrelated, a good management skill helps not only to retain the cost saving mechanisms considered during the design phase but also to attain additional cost saving and quality techniques. If the project is not well managed it may cost additional amount and may become more expensive than the conventional construction method. Thus, it is clear that greater attention should be given to the **construction management** that encompasses the inception till completion of the project.
For a better Cost effective construction work, it is essential to get a well organized construction management team works as well as quality control techniques at construction sites. It is obvious that construction quality management is necessary to ensure that the construction is always underway and operating smoothly by addressing problems caused by:

- Supply of insufficient skilled construction labors
- Inadequate supply of construction materials
- Lack of proper control of production process, etc.

Thus a good construction management team can reduce building cost with the help of optimum utilization of building materials that are scarce and costly. Speed in construction is also to be brought about so that construction is completed in as short time as possible because any delay occurs in the project completion time may cause a hike in the construction cost.

3.10 Emergence of Cost Effective and Environment Friendly Technology

Housing is one of the basic needs for living. Proper housing is an important need for every human being. However, the type of accommodation largely depends on the economic development of the country. The developing counters today have three major challenges to face:

- The alarming increase in population,
- Poverty
• Fast pace of urbanization.

As a result of these challenges a large number of people in Asia, Africa, and Latin America are either homeless or inadequately housed, which adversely affect their well-being and retards social and economic development.

The paradigm shift in the housing policy during the beginning of 1980s facilitated the introduction of cost-effective technology in the housing sector of Kerala. Several non-governmental organizations sprung up in early 1980s with affordable technological options. Mr. Laurie Baker, a well known architect, settled in Kerala, took the lead in this effort. Based on his principles, Alternative Technology (AT) initiatives and institutions like Centre of Science and Technology for Rural Development (COSTFORD), Nirmithi Kendra etc. came up in the eighties.

**Centre of Science and Technology for Rural Development (COSTFORD)**

COSTFORD is registered as a non-profit voluntary organization in 1984.

It has a taskforce of people from different disciplines such as architects, engineers, economists, geo-physicists, scientists, advocates, accountants, doctors, industrial consultants, educationalists and social workers. COSTFORD, in general, has two main foci of activities, namely, social activities and construction activities using appropriate building technologies. The focus is to empower and enable the weaker sections of
the society to improve their living conditions by the application of appropriate and people-friendly technologies. Promotion of non-commercial building practices, which discourage the role of intermediaries from the building process, is also among their priorities.

For their core activities, COSTFORD is supported by the Central Government departments like Department of Science and Technology and the department of Rural Development together with the department of local Self Government, Government of Kerala and Housing and Urban Development Corporation (HUDCO). For activities such as training they get funding from the State Department of Science and Technology.

**Nirmithi Kendra**

The devastating flood during the year 1985 and the consecutive rehabilitation works connected with it in the coastal areas of Kollam district opened up a new era of cost effective and environmentally-friendly (CEEF) building technology through Nirmithi Kendras. India’s first "Nirmithi Kendra" (Building Centre) was set up in Kollam for bringing out affordable solutions for housing. Arising from the success of the Nirmithi movement in Kerala, the ministry of urban development and HUDCO decided to start a national programme of setting up a net-work of building centres throughout the country. Later in 1989, the Kerala State Nirmithi Kendra (KESNIK) was established as an apex body to all the District Kendras.
3.10.1 Emergence of Cost effective Technologies

In line with the initiatives of COSTFORD and Nirmithi Kendra several appropriate technology organisations also came into active involvement in the building scenario of Kerala. Habitat Technology Group established in 1987 as a charitable agency, committed to the concept of green and humane architecture was a major organisation among them.

The appropriate technology initiatives in Kerala are based on the assumption of abundant supply of labour and availability of indigenous building materials. Their focus is to create maximum employment opportunities and to provide livelihood security to the poor by constructing their own houses. The government of Kerala supported the AT initiatives in the state through financial assistance and providing facilitative environments. Most of the public housing schemes are also formulated with a concept of utilizing the options of CEEF technology. The evaluation of the public housing schemes in Kerala showed that despite the continued efforts of CEEF technology institutions in the state, the dissemination of these technologies to those houseless people who are in need of affordable solutions has not been very successful. It clearly points towards the difficulties of the poor households in accessing affordable technological options. These aspects urge the need for modifying the present technology options to suit the needs of end users. Selection of materials and technologies for the building construction should satisfy the felt needs of
the user as well as the development needs of the society, without causing any adverse impact on environment

3.11 Popular building Alternatives in Kerala

A mixed mode of construction can be seen in the traditional buildings of Kerala. The stonework was restricted to the plinth and laterite was used for the walls. The roof structure in timber frame was covered with palm or coconut leaf thatching for most buildings and rarely with tiles, only for palaces or temples, till the mid of twentieth century. The exterior of the laterite walls were either left as such, or plastered with lime mortar. Mud construction was also one of the most common methods of making cost effective and sustainable habitat in the ancient days in Kerala. Since earth or soil is readily available everywhere, it could be utilized for constructing a very good monolithic, sustainable structure. The indigenous adoption of the available raw materials was the dominant feature of traditional constructions in Kerala.

The natural building materials available for construction in Kerala are stone, laterite, timber, clay and palm or coconut leaves. Granite is a strong and durable building stone; however its availability is restricted mostly to the highlands only. However, laterite is available in most parts of Kerala. The quarrying and extraction of these two are less energy intensive, and it does not require much skilled labour. So it can be used for foundations and superstructure, in places where it is locally available. Cement, steel, and bricks are the other popularly used building materials in Kerala for the last
three decades. The CEEF technology initiatives in the state since 1980 opened up the market for alternative materials such as ferro cement, hollow and solid concrete blocks, ruble filler blocks and most recently, for interlocking blocks. The recent interest in promoting traditional mud construction is a positive sign towards sustainable building process in Kerala.

3.11.1 Building Components Based on Embodied Energy

Building materials that we use are having some embodied energy. Sustainable housing development requires materials and technologies which have less impact on the environment. Human activity has increased the levels of certain greenhouse gases in the atmosphere resulting in global warming. Greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, troposphere ozone and chlorofluorocarbons (CFCs). Of these gases CO2 is the most important by-product of the building material industry. Several studies have been done to identify and solve the implications of building materials industry on the environment due to emission of carbon dioxide, dumping of waste materials and excessive energy utilization during the production, processing and transportation of building materials. Construction activity contributes 17% of the carbon dioxide emission in India. The major energy intensive building materials, namely steel and cement are readily available in all the corners of the state, even though they need to be transported over large distances from the place of their origin. Extensive use of these materials can deplete the non
renewable resources and adversely affect the environment. At the same time it is difficult to meet the alarming housing needs by adopting energy efficient traditional materials alone. Hence there is a need for optimum utilization of available resources and raw materials to produce environment friendly sustainable affordable alternatives. This necessitates the choice of building alternatives based on embodied energy.

<table>
<thead>
<tr>
<th>Basic Building materials</th>
<th>Embodied Energy (MJ/Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>237</td>
</tr>
<tr>
<td>Structural Steel</td>
<td>42</td>
</tr>
<tr>
<td>Cement</td>
<td>5.85</td>
</tr>
<tr>
<td>Lime</td>
<td>5.63</td>
</tr>
<tr>
<td>Lime Pozzolana</td>
<td>2.33</td>
</tr>
<tr>
<td>Bricks</td>
<td>1.4</td>
</tr>
<tr>
<td>Laterite</td>
<td>0</td>
</tr>
<tr>
<td>Sand</td>
<td>0</td>
</tr>
<tr>
<td>Rubble</td>
<td>0</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>0</td>
</tr>
<tr>
<td>Rice husk Ash</td>
<td>0</td>
</tr>
<tr>
<td>Straw</td>
<td>0</td>
</tr>
<tr>
<td>Mud</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table 3.4 Embodied Energy of Basic Building Materials**

The total energy use during the life cycle of a building is an important concern and the embodied energy forms a considerable part (40%) of the
total energy use in low energy residential buildings. It is the energy that is used to extract, process, manufacture and transport building materials and components, and can be taken as an important index on measuring the sustainability of building alternatives. But the value of embodied energy for different materials varies from one country to another depending on the source of energy used for manufacturing. The indirect energy use in a residential building through the energy content of the materials of construction in India is about 3-5 GJ/m2 of floor area, whereas the same indicator for an office building in Japan is 8-10 GJ/m2. The higher value in Japan can also be attributed to the use of more energy intensive mechanised construction activity. Studies on this show that traditional bricks which are most widely used for walling in India prove to be the worst choice with respect to energy input.

Among the basic building materials, aluminium is the highest energy intensive material. Steel and cement, the most widely used building materials for house construction are also energy intensive in nature. Lime pozzolana can be a better alternative to replace cement in this respect. All the renewable materials and waste products which are being used as building alternatives are the most sustainable choices with respect to energy (zero energy).

The following points can be taken as guidelines for the selection of new alternatives:
• Alternative technological options should be capable of being produced locally using decentralised production methods and with utilisation of local resources (materials and manpower).

• The alternative technological options should be able to prove their advantages over prevailing options within a reasonable time period. (This could help in improving their acceptance and popularity).

• Technologies which demand minimum infrastructure, local resources and know how with unskilled and less labour intensive nature should be popularized.

• Locally produced environmentally friendly alternatives in the building process which utilize local waste materials, renewable or reusable materials and less energy intensive technology should be promoted.

3.12 Techniques for Cost Reduction

To keep pace with the fast growing population and the liberalization policy set by the Government, huge investment will be needed in the near future in construction component in various sectors like power, telecommunication, housing, education etc will have an influence in the country’s economy. Hence it is very essential to utilize some cost effective materials also along with the conventional materials. These cost effective materials assume significance with respect to the construction industry as well as to the need for protecting and preserving our environment.
Various research organizations in the country have undertaken research programmes in this field and are still conducting research and development programs in this area. Some of them are:

- Central Buildings Research Institute (CBRI), Roorkee
- Structural Engineering Research Centre (SERC), Chennai
- National Buildings Organisation (NBO), New Delhi
- National Environmental Engineering Research Institute (NEERI), Nagpur
- Regional Research Laboratories (RRL) etc… etc…

It has been proven that so many industrial and agricultural waste materials can be very effectively used as low cost and low energy consuming construction materials. Some of them are fly ash, phosphogypsum, water work silts, cinder, red mud, rice husk, cotton stick, coconut husk etc…

Other techniques are also being practiced and proven effective such as

- Use of indigenous, renewable materials with low embodied energy cost (energy needed to secure, process and transport materials) – e.g. Mud, burnt bricks, stabilized soil blocks, bamboo etc…
- Use of renewable energy – e.g. solar, biogas, fossil fuels
- Encouraging manual labour, especially in rural areas, by decreasing use of mechanization
• Filler slab roofs for weight reduction, cost savings and creative utilization of waste materials
• Cost reduction construction strategies saving labour and materials—e.g. jali works (brick spacing for ventilation, security and beauty)
• Rat trap bond techniques and arch construction in brick works
• Compressed earth blocks for wall construction
• Funicular shell roofing elements
• Filler slab roofs for weight reduction, cost savings and creative utilization of waste materials.
• Ferro cement concept in building construction

3.12.1 Cost Effective Technologies Adopted for Building Construction

1. Hollow concrete blocks

Hollow concrete blocks generally are made of size 40x20x20cm and will cover a volume of about 11 country burnt bricks. The cost savings are on three counts leading to about 23% saving in cost. It offers less value for equivalent volume as compared to brick masonry. Other advantages are less usage of mortar, less work for the mason and insulation against heat and cold.

2. Soil Cement Blocks

Soil blocks stabilized by cement or lime will have a higher compressive strength that that of ordinary soil blocks. The general specification given is that the crushing strength of blocks 65cm in diameter
shall not be less than 28Kg/cm². There will be a saving of 28% in cost as compared to country burnt brick masonry.

3. Cavity wall construction

Cavity walls are recommended for situations where good thermal insulation is needed. A 200 mm thick wall consists of two masonry leaves 75mm thick with a continuous air gap of 50mm between them. The leaves are tied together by means of either bricks or concrete blocks. Such walls can be used as curtain walls in multistoried buildings and as load bearing walls in one and two storeyed residential and other lightly loaded buildings provided the bricks have a compressive strength of at least 100Kg/cm².

Rat trap bond is a varied form of cavity wall and leave rectangular cavities in the masonry ensuring that there will be a break in the cavity in each course.

4. Concrete door and window frames

Timber, an important building material is becoming more and more scarce every day. There is an argument that timber is perhaps the only building material which nature can regenerate and as such the best solution for solving scarcity of timber is planting of more trees. Admitting the basic logic of this argument one must also be aware of the fact that the planting of trees extensively will require a lot of time and energy for the nation and there should be short cut solutions to solve the problem. An ideal replacement is concrete. They bring down the cost and prevent the problem of lack of quality control in the case timber not seasoned properly.
The concrete used shall be such as to produce a dense mix not weaker than grade M20 having compressive strength of 200kg/cm² or more. It is estimated that the cost reduction for concrete frames will be at least 31%.

5. Filler slab

Lightweight, inexpensive materials such as low-grade Mangalore tiles, bricks, coconut shells, glass bottles, etc. are used as filler materials in filler slabs to replace the redundant concrete in tension zones.

These materials are laid in the grids of steel reinforcement rods (6mm or 8mm dia.), and concreting is done over them. The concrete mix used is 1:2:4. The grid size depends upon the design, span, and the material used. For Mangalore tiles (size 23cm by 40cm), the grid size is 33cm by 50cm. The slab thickness is 10 centimeters.

This technique saves energy-consuming concrete. Roofs and intermediate floors account for 20-25% of the total cost of the house. This roofing costs 30-35% less than conventionally used concrete roofing. Thus a considerable amount is saved in terms of materials, energy, and cost.

This technique also reduces the unwanted dead load of roofing. Compared to other roofing systems, it is thermally comfortable and has no health hazards. Galvanized iron and asbestos cement sheet roofs dissipate too much heat and are difficult to live under. Also, asbestos cement sheets...
are long associated with diseases such as lung cancer, hence must be avoided.

6. Mud construction

The advantages and possibilities of mud construction are endless. Mud is environmentally the most sustainable material. Besides its obvious eco friendly nature, its easy availability makes it almost a no cost material, abundantly present, generally on the site itself. This cost-effective material is also energy efficient and can be used to produce aesthetically very appealing structures. Its unique plasticity that allows it to be molded, its texture and earthy feel lend its structures a certain timeless quality. Buildings made of mud are also extremely comfortable, both in warm and cool weather, due to its thermal characteristics.

7. Manifestations of mud

Depending on the characteristics of the mud available, availability of supporting materials and technology used, different manifestations of mud are used. These include Adobe or Sun-dried bricks, Cob, Rammed earth, Pressed bricks, Wattle and Daub etc.

i. Cob: - A large lump of clay is roughly molded into a ball. A row of these cobs of mud is placed side by side. The second layer is laid on the depressions of the first layer. The building should proceed only slowly, allowing sufficient time for hardening.
ii. Adobe / Sun-dried blocks: - This is one of the most widely used forms of mud. The stiff clay is squashed into a small box or mould of wood or metal and then turned out to cure and slowly dry.

iii. Rammed earth: - This is an improvement on the Cob since it regularizes the thickness and is more compressed. Here, two parallel planks form the formwork, into which the stiff mud is thrown. This is then rammed down using a ramrod.

iv. Wattle and Daub: - This system uses mud as a plaster to cover thin panels of cane/split bamboo which has been woven together and held in place by poles.

8. Bamboo Construction

The art of using Bamboos in day to day life has a history of more than 5000 years. Millions of villagers in India have developed skill to use bamboo for construction of their houses, to make furniture and household items, Cowsheds, Poultry sheds, Goat farms, protecting agriculture land by constructing fences and gates etc. Introduction of cement and steel during the last 50 years has virtually killed the Artisans working with Bamboo.

For most parts of the India, bamboo is a locally available material and has been used as building material for centuries. It can be easily grown and is one of the cheapest construction materials. A good bamboo cut into strips has the tensile strength almost equal to that of steel.

It is used for reinforcement, shuttering, scaffolding, roofing, piles, filler material and much more. Bamboo in lime concrete can be used for
foundations, especially in the sandy areas along the seacoast. It is resistant to seawater and remains intact whereas other foundations will crack with shifting sands. For places where stones and bricks are not available, foundation for mud walls can be of moist soil with layers of split bamboo reinforcement inserted. However it needs experience to know about the quality of the bamboo and it is difficult to calculate the exact strength of slabs with bamboo reinforcements.

After having a detailed discussion on the conceptual frame work of cost effective construction in the foregoing pages, it is imperative to examine the structure and activities of Costford as an organisation. The next chapter is devoted to explain the features and working of the Costford.