
How are you?

Debre Markos University

Debre Markos Institute of Technology

School of Civil and Water Resource Engineering

Ac/Program of Construction Technology and Management

Cost Efficient Construction

COTM 5281

By: Abebe D.&Tesfahun A.

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CHAPTER 1: INTRODUCTION

Introduction

Problem Background

- The United Nations Statistical Division (UNSD; 2008) groups homeless persons into two broad categories:

(a) Primary homelessness (or roof lessens).

- This category includes persons living in streets or without a shelter or living quarters;

(b) Secondary homelessness

- This category may include persons with **no place of usual** residence who move frequently between various types of accommodation (including dwellings, shelters or other living quarters)
- This category also includes persons living in private dwellings but reporting ‘no usual address’ on their census form.

Introduction…

What is the difference between cost efficient construction and low cost construction?

1.1. CONCEPT/THEORY

- The United Nations estimates that at least **one hundred million** people in the world have no home. If those with poor quality housing are included, the number is more than **one billion**.
- The rural populations of Ethiopia live largely under difficult conditions dominated by poverty and lack of access to knowledge on alternative, appropriate construction technologies that can exploit local resources leading to a cost efficient construction.
- Construction costs in Ethiopia are increasing dramatically. Due to inflation rates, primarily due to cost of basic building materials such as steel, cement, bricks, timber and other inputs like cost of labor.

• As a result, the cost of construction using conventional building materials and construction tachinids is beyond the affordability of the economically weak and low income groups of population.

1.1. CONCEPT/THEORY...

- **Therefore**, there is a need to adopt cost-effective construction methods either by:-
  - up gradation of traditional technologies using local resources or
  - applying modern construction materials and techniques with efficient inputs leading to economic solutions.
- Low cost or affordable construction technologies and materials are often touted as a panacea in meeting the ever growing demand for rapid housing delivery in developing economies.

1.1. CONCEPT/THEORY…

- **Affordable housing** is a term used to describe dwelling units whose total housing cost are deemed "Affordable" to a group of people within a specified income range.
- It is desirable to have increased understanding of the various materials and technology options, its structural and functional characteristics and efficiencies and more importantly the methodologies for implementation.
- These would cover work related to regulatory measures, organizational development needs and also technology transfer mechanisms evolved.
- This would play a major role in ensuring the adoption of appropriate and cost-effective technologies in housing and building construction scene, which is one of the vital inputs to make affordable and acceptable housing a reality for the vast majority of low-income people.

1.2. Importance/Objectives

- The investigation of the production of local materials and alternative technologies of “low - cost” construction houses aims at:-
  - To take advantage in a sustainable and ecologically acceptable way the local resources for the production of alternative construction materials;
  - To promote the production of local construction materials and alternative constructive systems that are popularized and disseminated within Communities, Educational Institutions and in the Professional Training Centers;
  - To contribute to the creation of regulations of alternative constructive systems and uniformity of the method and quality of the local production materials.

1.3. APPLICATION AREAS

- The following are the possible application areas of low-cost construction:
  - ➢Land cost should be kept to a minimum.
  - ➢Compact design.
  - ➢Community buy-in to the housing process from the start.
  - ➢Location of project should be close to existing bulk services.
  - ➢Maximum utilization of space inside house.
  - ➢Implement measures to reduce your overheads cost (enough human resources on site).
  - ➢Buy material in bulk and Good house design (simplifies construction, saves time and resources).

1.3. APPLICATION AREAS…

- **The following should be taken in to account in cost effective housing:**
  - Where practical, affordable housing should reflect the architectural style of the area in which it is to be located. However, this should not restrict the adoption of variations and improvements to suit structural requirements and changing aspirations of the occupants.
  - Affordable housing should be designed and constructed in accordance with local building regulations and standards. Where these are not adequate, international standards should be used.
  - Particular attention should be paid to design for wind loading, earthquake loading and unstable foundations.

1.4. Theories of cost efficient construction process

Stages for Cost Minimization

Planning Stage

- Integrated Planning
- Detailed Planning
- Documentation

Construction Stage

- Material
- Labor
- Wastage Minimization
- Building Systems

Building Use Stage

- Low electricity
- Low water
- Maintenance

1.4. Theories of cost efficient construction at preliminary and design stage

DESIGN

- Cost effectiveness through material quantity modulation could be achieved during preliminary and final design stages:

✓ **Substructure**

- **Mat foundation:** Upper part of mat foundation can be used as a ground floor element. This could save the cost of ground floor slab construction.
- **Isolated Footing:** Volume concrete could be reduced by adopting an optimum shape of a footing.

1.4. Theories of cost efficient construction at preliminary and design stage

- **Combined Footing:** Trapezoidal type needs lesser volume of concrete and reinforcement steel if the geometrical conditions and loads allow

✓ **Super structure**

- Simplicity and Repetition
  - The use of simple structural elements repeated throughout a project can reduce the overall cost as design and set-out need only be done once.

Economies of Scale

- The larger the order, the lower becomes the cost. Generally medium to large construction projects are more economical, per sqm, than smaller ones.

1.4. Theories of cost efficient construction at preliminary and design stage…

- **Number of amenity areas**

- Kitchens, laundries and bathrooms are more expensive to fit-out than other rooms because of the intensive use of fixtures, fittings, wet area treatment, tilling and joinery items.
- A good way to reduce cost is to minimize the number of amenity areas.

Amalgamating services

- Locating bathrooms kitchens and laundry's etc adjacent or above each other, can reduce the cost of providing services (particularly plumbing)

Accuracy of Documents

- The completeness and proper coordination of contract documents, including consultant's documents, can be an important factor in the cost of construction because it can affect the accuracy of tendering and the likelihood of changes to the design or variations to the building contract.

1.5. Strategic plans for CEC

- Selection and evaluation of materials and processes.
- Up scaling and modernization of home-grown production technologies
- Selection, evaluation and establishing economics of emerging methods of construction
- Economy and efficiency in housing/building construction projects
- Strengthening technology dissemination and demonstration capabilities.
- Training and skill up gradation including entrepreneurship development.
- Field level applications of innovative building materials and construction technologies in mass housing projects.
- Vulnerability reduction, risk assessment and disaster resistant construction.
- Technology Transfer

1.6.Causes of high Construction Costs

- Expensive materials
- Lack of skills and knowledge in selection of appropriate Construction packages:
  - Designs
  - Materials
  - Methods
  - Equipments

1.7. Factors considered in Cost Efficient Construction

The following points are very important in the cost effective construction and reducing cost of construction:

- ✓ Strength
- ✓ Durability
- ✓ Functional
- ✓ Aesthetic
- ✓ Environment friendly
- ✓ Ecologically appropriate
- ✓ Energy efficient
- ✓ Affordable and adaptable
- ✓ Cost-effective materials
- ✓ Appropriate technologies in construction

1.8. Low cost = Low energy

- construction activities consume 50% of all resources globally, 70% of all global timber products and 40% of energy.
- The consumption of these resources adversely affects the environment through over-exploitation of both renewable and nonrenewable resources (materials and energy).
- The building materials industries as a whole rely to a large extent on high temperature processes and are among the most energy-intensive industries.
- For example, the cost of energy in the production of cement or clay bricks/tiles accounts for 50 to 70 percent of the direct cost of manufacturing.
- It is therefore, important that the use of energy in the production process is optimized so that overall cost of building construction is reduced and the polluting impact of the excessive use of fossil fuel is arrested.

1.8. Low cost = Low energy…

- Five phases of energy consumption in buildings:
  a) Embodied energy = manufacturing of building materials
  b) Grey energy = transport materials
  c) Induced energy = actual construction
  d) Operational phase and
  e) During demolition process

1.8. Low cost = Low energy…

Table 1 Energy Consumption of Some Construction Materials

	Classification of material	***Energy consumption in MJ/Kg of material***
I	Burnt-clay tiles	3
II	Burnt-clay bricks	1.43
	Hollow-concrete blocks	1.20
	Sand-lime blocks	1.03
III	Reinforced concrete	2.00 - 8.00
	Unreinforced concrete	1.20
	Aerated concrete	2.89
IV	Portland cement	6.70
	Hydrated lime	4.21
	Gypsum plaster	1.52
	Calcined-clay pozzolana	1.39
V	Steel	26.00
	Aluminum	144.00
VI	Wood products	3.00

1.8. Low cost = Low energy…

Table 2 Cost of energy relative to production cost of selected materials

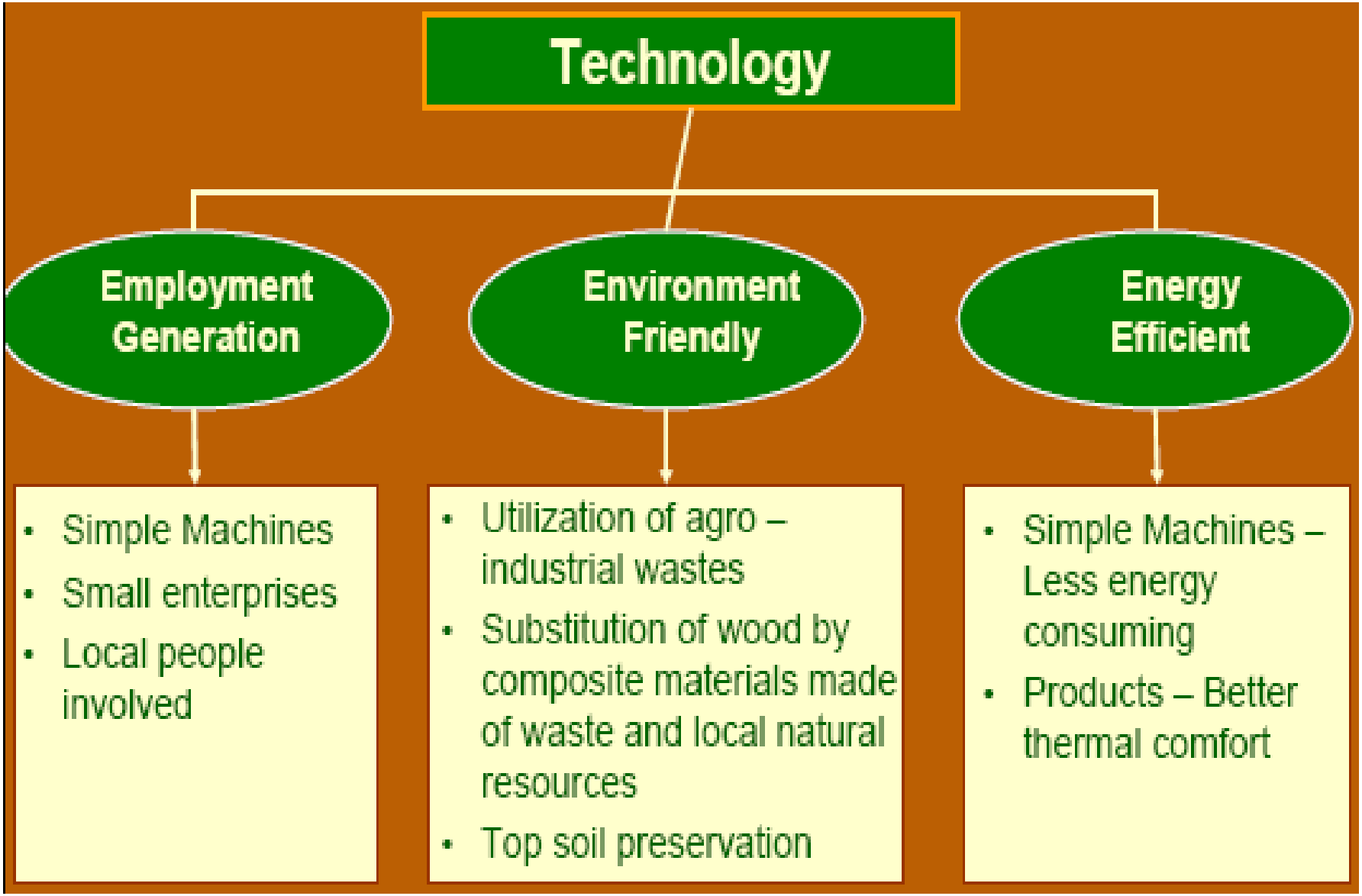
Material	Energy cost as percentage of total material cost
Cement	**43.0 – 53.0**
Lime	**47.9 – 59.5**
Gypsum products	**11.1 – 16.6**
Bricks and tile	**29.7 – 36.5**
Other structural	**23.7**
Clay products	**35.2**
Concrete blocks	**3.6 – 6.5**
Timber sawmills	**2.2 – 4.1**

1.9. Technology for Cost Efficient Construction

Technology Selection Criteria

- Lower initial cost and more productive
- Lower consumption of materials
- Time saving in construction.
- Utilization of waste materials
- Saving skilled labour
- Achieving better utilization of equipment
- Better utilization of space.

1.9. Technology for Cost Efficient Construction…



1.9. Technology for Cost Efficient Construction…

A. Energy Efficient

- ✓ Simple machines : saves energy in production
- ✓ Raw Materials : derived from agro-industrial wastes and natural fibers, requires less energy in production
- ✓ Products : provide better thermal comfort that results in conservation of operational energy.

1.9. Technology for Cost Efficient Construction…

B. Environment Friendly

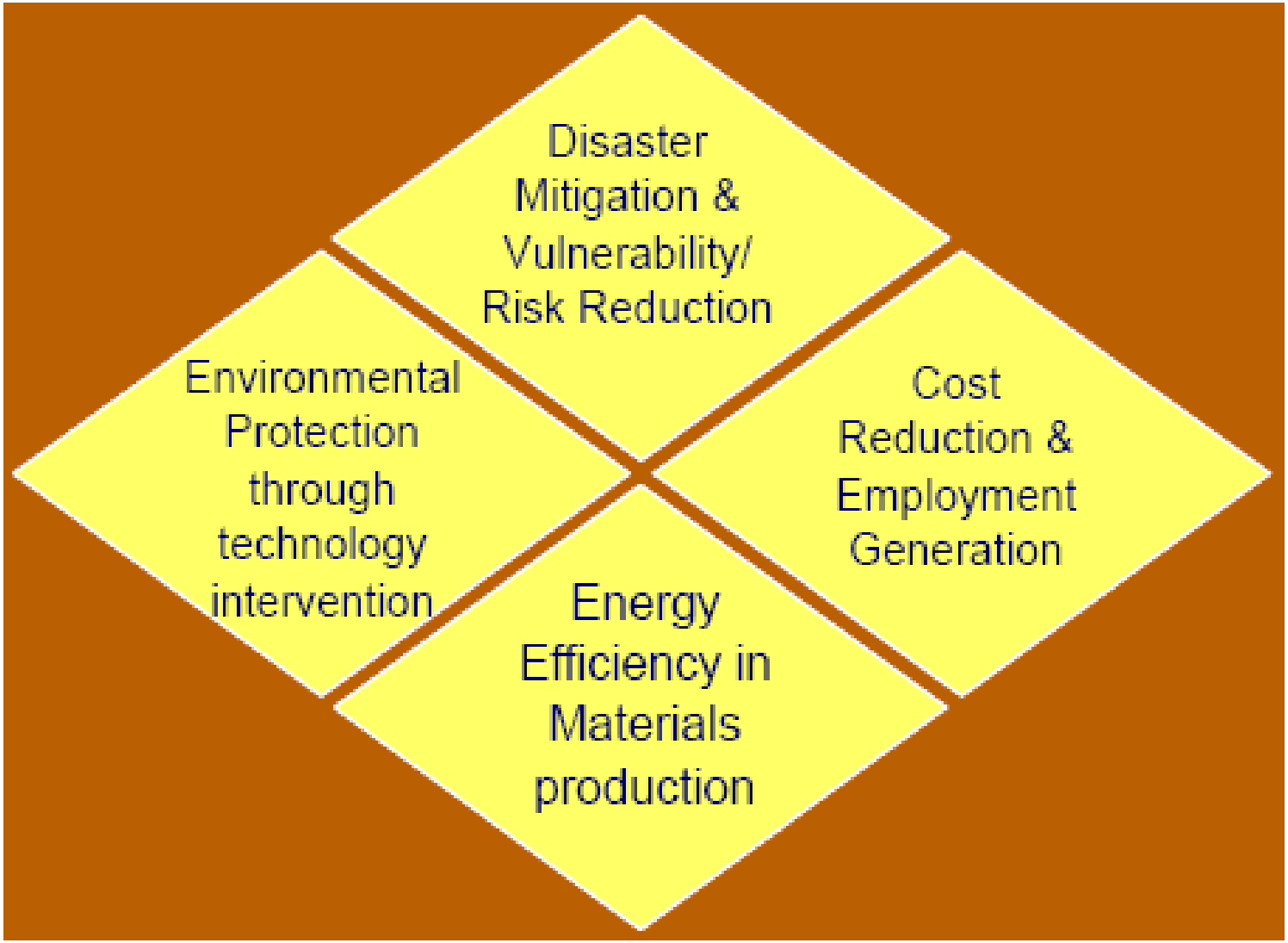
- ✓ Converts agro-industrial waste into alternative material for low cost construction , thus improving waste management & environmental protection
- ✓ Utilizes local resources
- ✓ Substitutes wood – preserving forest cover

1.9. Technology for Cost Efficient Construction…

C. Employment Generating

- ✓ Simple machines – with manual handling, increases employment for unskilled and semi-skilled workers
- ✓ Small enterprises – can be set up at decentralized locations
- ✓ Production of components – involves local people after short training

1.10.Focus Areas for low cost construction



Thank you

Chapter 2: Planning and low cost design

INTEGRATED PLANNING

- Building construction basically involves four stages including conceptual, preliminary design, final design and execution. Cost minimization could be achieved through close and serious consideration at all stages.

CONCEPTUAL STAGE

- At the conceptual stage coordination among professionals is very crucial. The following professionals could be involved in the design:
  - Architect
  - Structural Engineer
  - Sanitary Engineer
  - Electrical Engineer
  - Electro-mechanical engineer
  - Sociologist
  - Others (Environmentalist, …)

PRELIMINARY AND FINAL DESIGN STAGE

- Examples of design areas where cost effectiveness through material quantity modulation could be achieved during preliminary and final design stages:

SUBSTRUCTURE

- **Mat foundation:** Upper part of mat foundation can be used as a ground floor element. This could save the cost of ground floor slab construction.
- **Isolated Footing:** Volume concrete could be reduced by adopting an optimum shape of a footing. (b and c types need lesser volume of concrete in Fig 1)
- **Combined Footing:** Trapezoidal type needs lesser volume of concrete and reinforcement steel if the geometrical conditions and loads allow (Fig 2).

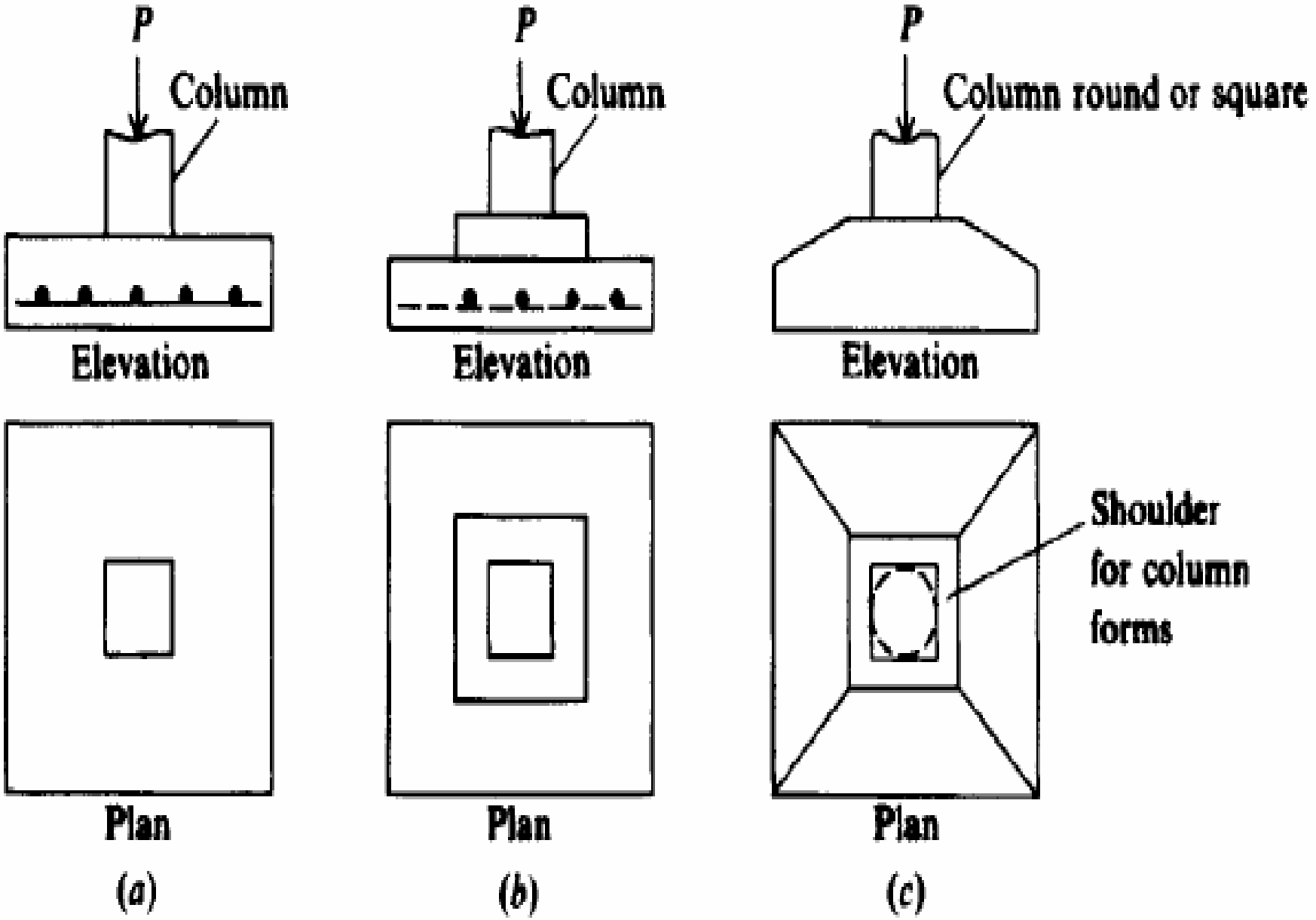


Fig 1 Possible isolated footing types

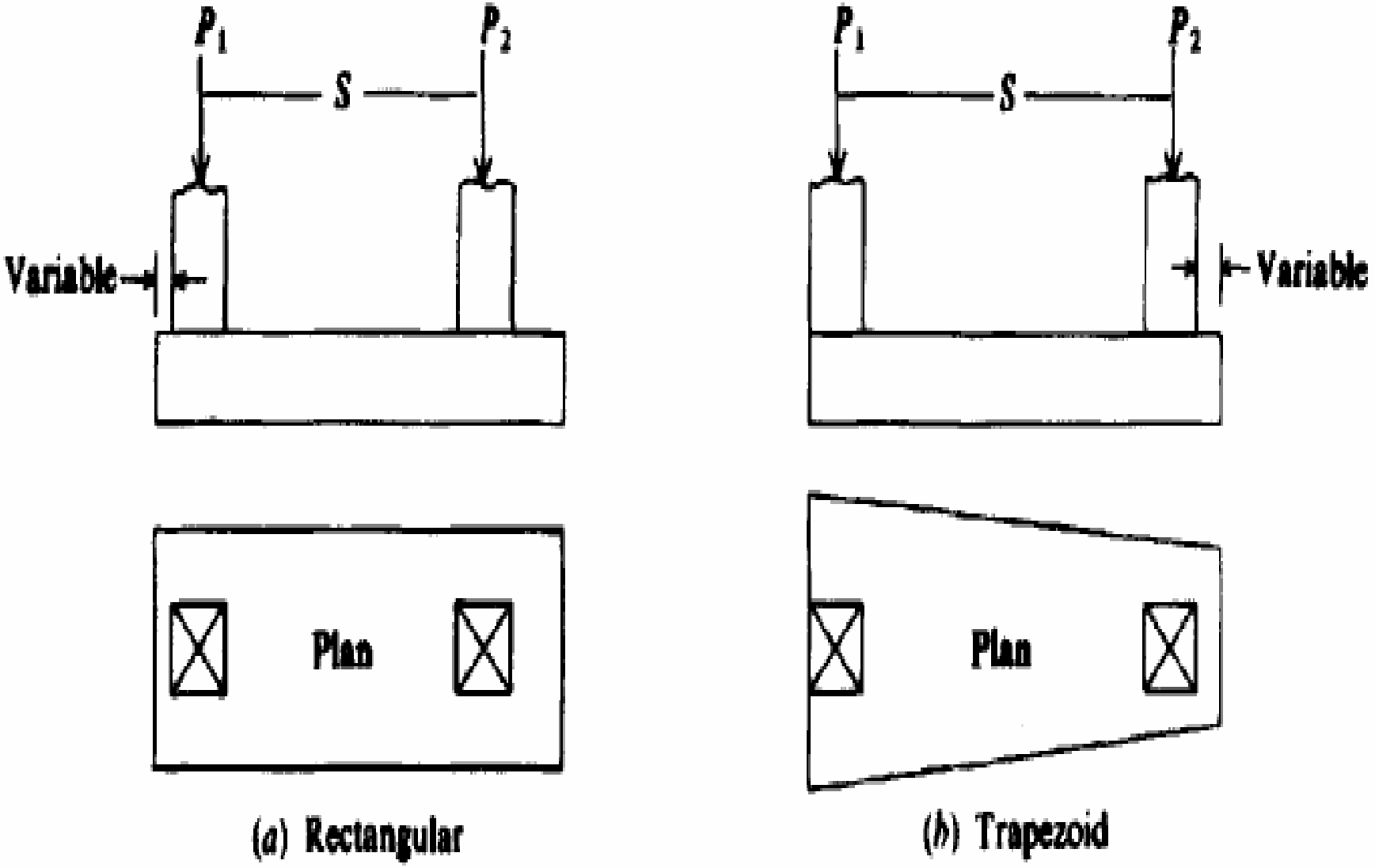


Fig 2 Possible combined footing types

PRELIMINARY AND DETAILED DESIGN:

- Preliminary and detailed design involves:

1. **Geometry and planning**

✓Simple geometry with minimal re-entrant angles minimizes external wall length while maximizing area. Similarly simple roof geometry minimizes junctions and materials. Planning to reduce circulation space can maximize the usable area of a home and minimize wasted space.

2. **Single or multi-storey**

✓Single storey construction is always cheaper than two storey because of the cost of scaffolding and transporting materials. Floors above ground are always more expensive than floors on ground because of the extra beams and support required. Above ground slabs require considerably more reinforcement and form working than slabs on ground.

3. Simplicity and Repetition

✓The use of simple structural elements repeated throughout a project can reduce the overall cost as design and set-out need only be done once. Duplicating elements can reduce costs because fabrication can be done in bulk.

4. Economies of Scale

- ✓ The larger the order, the lower becomes the cost. Generally medium to large construction projects are more economical, per sqm, than smaller ones.

5. New or existing work

- ✓Building new is always cheaper than alterations and additions because of the rectification work involved and because of the unknown complications in retaining existing work.

6. Number of amenity areas

- Kitchens, laundries and bathrooms are more expensive to fit-out than other rooms because of the intensive use of plumbing, electrical and gas services as well as intensive use of fixtures, fittings, wet area treatment, tilling and joinery items. A good way to reduce cost is to minimize the number of amenity areas.

7. Amalgamating services

- Locating bathrooms kitchens and laundry's etc adjacent or above each other, can reduce the cost of providing services (particularly plumbing) as the length of concealed pipe work and conduit is reduced. Similarly amalgamating several services in the same trench or duct can reduce costs.

8. Low cost building systems

- Generally the cheapest building system is the traditional method because the skills and materials are readily available; however, building systems that reduce the use of materials and or save in construction time can provide a significant savings. The only risk is that the longevity of new systems cannot always be verified.

9. Standard dimensions

- Many building products come in standard dimensions. Designing with this in mind can reduce cutting and wastage. Fabricated components such as aluminum windows and doors come in standard sizes. Standard sizes are always cheaper than custom made sizes.

10. Prefabrication

- Fabricating items in a factory is always faster and cheaper than on site. This is because there is not always a good supply of shelter, materials, specialized machinery and labor on site. The extent of prefabrication can range from individual components, right up to a totally prefabricated home.

11. Speed of Construction

- A building construction method that is faster not only utilizes labor more efficiently but also reduces the daily on-site costs such as building foreman, fencing, scaffolding, site services, insurances etc.

12. Variations

- Whilst it may be undesirable to avoid all variations, they should be minimized if you want to reduce the cost. Variations to a building contract not only amount to the cost of altering the work, but attract an additional percentage cost to cover builder's site attendance and coordination. Variations may also extend the construction time.

13. Accuracy of Documents

- The completeness and proper coordination of contract documents, including consultant's documents, can be an important factor in the cost of construction because it can affect the accuracy of tendering and the likelihood of changes to the design or variations to the building contract.

DETAILED PLANNING

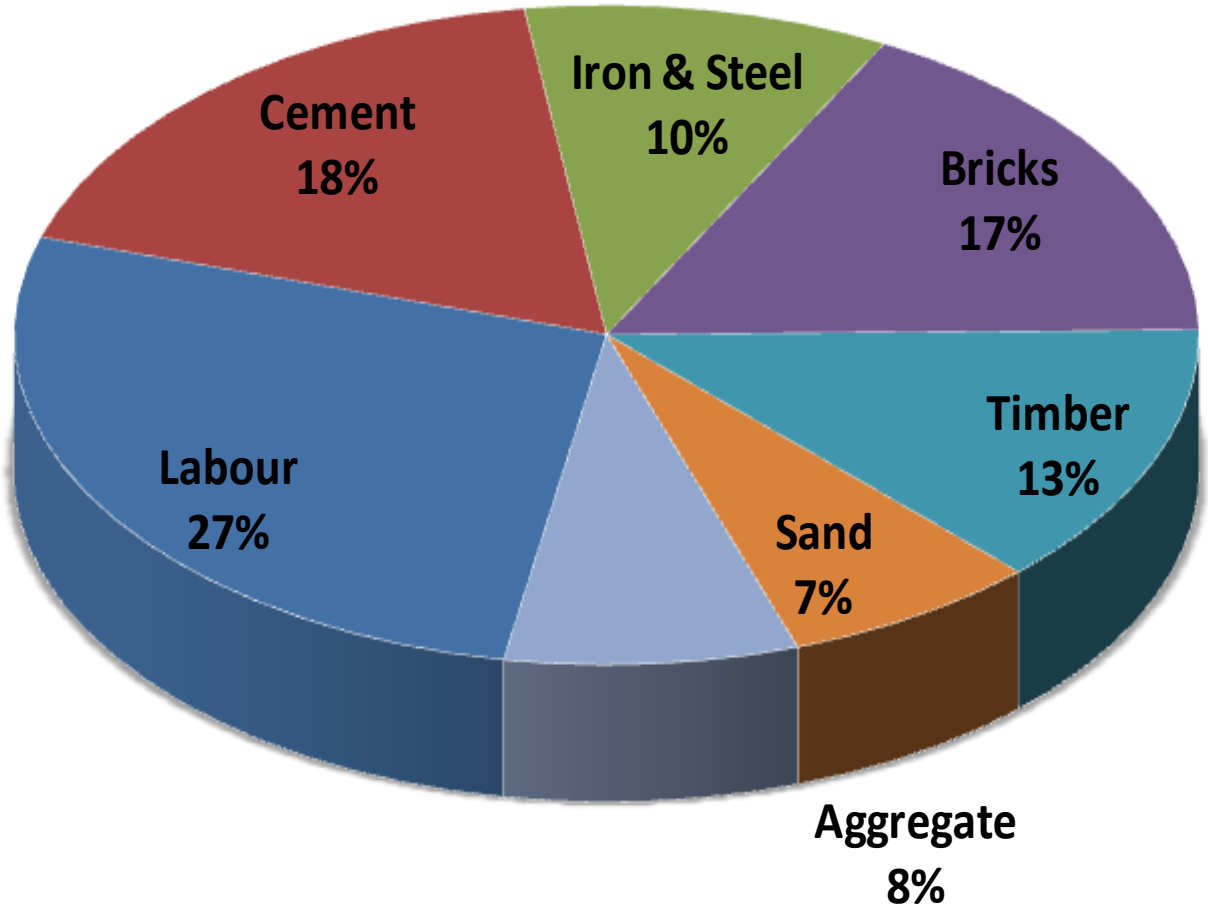
- *Adequate time and information should be available to perform detail planning and design*
- Examples of details design aspects which result in low-cost construction:
  - Increasing the quality of concrete/steel – needs benefit/cost analysis
  - Reinforcement cuts : in beams and slabs (proper reinforcement cutting schedule)
  - In high rise buildings lower story columns have higher load carrying capacity they might not need much increased section (concrete, steel)
  - Steel truss systems: all members need not be of the same cross section, proper orientation of members

DOCUMENTATION

- It is always important for the designers to make sure that their design ideas are properly conveyed to the ones who would be executing project. Therefore, documents prepared during design should be clear enough so that ambiguities are avoided during the actual construction phase.
- The following is list of some of the documents produced by the designers:
    - Drawings including details
    - Models
    - Statical Calculation Reports
    - Technical Specifications
    - Bill of quantities and work schedules
    - (Contract Documents)
    - (Guide Lines and manuals)

Chapter 2: Material

Approximate Break-up of Total Construction Cost in Materials and Labour



- The five leading modern construction materials are cement, concrete, steel, bricks and wood.
- This has contributed to changing living patterns of the middle class, but not for the poor. Steel and cement are symbols of wealth and power - but many people cannot afford them.
- Low cost building materials do not mean sub-standard materials, but the materials available/developed locally, cutting the transportation charges and manufactured applying civil engineering know-how for better service and economy.

- The various building materials available can be divided into two types and they are:

1. Traditional materials

- These materials serve the basic needs of the majority of the population. These have very useful properties; however, there is a scope to modify these through appropriate changes in the process of production as well as in the techniques of application, so that these are made structurally and functionally acceptable.

2. Conventional materials

- The conventional materials are those, which have been obtained by using the modern technologies and can be mentioned as fruit of research and adopted to indigenous requirements.

ALTERNATIVE CONSTRUCTION MATERIALS

1. MUD

- During post earthquake reconstruction, mud houses are most effective and environmental friendly, cool in summer and warm in winter.
- Mud is only a material available everywhere in abundance free of cost and is being used as building material from centuries. But such types of houses are temporary in nature, prone to erosion by heavy rains.
- The disadvantages of mud can be overcome by suitable improvement in design and construction techniques.
- The strength of mud is improved by adding cement, lime, bitumen or fibers and it also becomes resistant to water.
- Cement stabilized mud blocks, using 3 to 10% cement by weight molded in mechanical machines are better than adobe mud bricks.

2. CEMENT AND CONCRETE SUBSTITUTES

- With 1 m3 produced per year per capita, concrete is the most widely used material in the world and accounts for 5-8% of manmade CO2 emissions.
- It is possible to reduce its environmental impact by substituting cement with supplementary cementiteous materials (SCM) like fly ash, slag, silica fume and natural pozzolana.
- Calcined Cuban clayey soils are an interesting SCM for low-cost housing projects which promote the use of locally produced and affordable "eco-friendly" materials in developing countries.
- Investigations have shown that fly ash produced as an industrial waste from thermal power stations can safely replace up to 20 per cent by weight of normal Portland cement.

3. WOOD/TIMBER SUBSTITUTES

- Continuing dependence on conventional building materials like burnt clay bricks, cement, steel and primary timbers from natural forests is neither possible nor desirable without detriment to environment. Though their application in field has yet to achieve the desired level, however, it is amply demonstrated that by their increasing application it is possible to conserve non-renewable materials, reduce pollution and achieve substantial savings in energy consumption.

Materials	Energy for production MJ/Kg	Weight per volume Kg/m3	Energy for production Kg/m3	Stress when in use	Energy for unit stress
Concrete	0.8	2400	1920	8	240
Steel	30	7800	234000	160	1500
Wood	1	600	600	7.5	80
Bamboo	0.5	600	300	10	30

ALTERNATIVE WALLING MATERIALS

- The materials used for walling for instance can consist of:
  - Mud
  - Sun-dried bricks
  - Rammed earth
  - Stabilized soil blocks
  - Kiln-burnt bricks
  - Stone block masonry
  - Timber/bamboo
  - Precast/factory-made walling units using light weight cellular concrete
  - Ferro-cement
  - Concrete hollow blocks

ALTERNATIVE WALLING MATERIALS

- Mud, sun-dried bricks and rammed earth can be used extensively depending on the availability and quality of existing soils.
- Stabilization of soil is done by stabilizers like cement, lime, asphalt, and molasses. With the strength of kiln-burnt bricks being of the order of 40 to 200 kg/sq.cm it is possible to use single brick load bearing walls of up to five storeys.
- Stone-block masonry is using stone blocks and lime/cement mortar, In places which area seismically active, the conventional system of timber, bamboo, mat-based wall system can be employed.

ALTERNATIVE WALLING MATERIALS

- Factory made cellular concrete wall panels have been used in some places. In situations where it is not possible to have access to masonry building blocks made of local materials, recourse has to be taken to manufacture masonry blocks. This could cover aerated light weight concrete blocks and hollow concrete masonry blocks.
- The hollow concrete block masonry can be used both as structural/non-structural elements. Large prefabricated panel units have been used in mass construction schemes. However, its application in the country might be limited mainly due to the limitations in lifting/erecting equipments as well as weaknesses in joints of wall to wall and roof to wall interaction locations.

ALTERNATIVE ROOFING MATERIALS

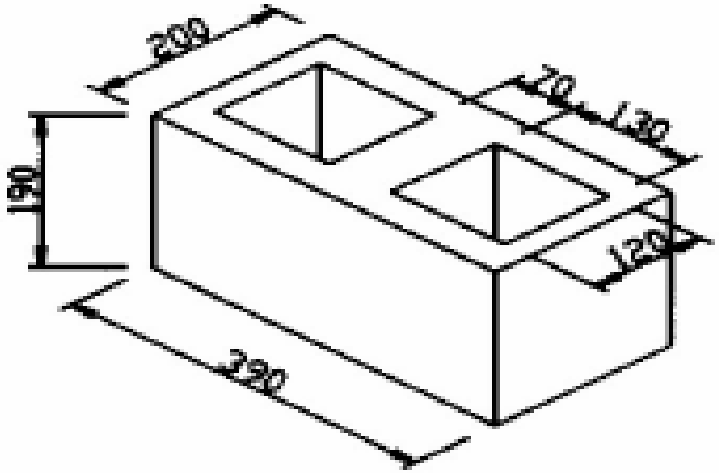
- Reinforced cement concrete (RCC) rooting slabs are predominantly used in many housing projects more so in the urban context. But the use of the many economic alternatives can play a major role in large housing projects.
- The various alternative systems that can be used are:
  - Clay/micro-concrete tiled roofing with insulation over timber/ferro-cement rafters
  - Stone roofing with distributors
  - Corrugated sheet: asbestos, galvanized iron (GI)
  - Prefabricated brick panel
  - 'L'panel roofing
  - Filler slab roofing with various filler material
  - Clay tile - RCC batten roof
  - Pre-cast cellular concrete roofing unit
  - RCC channel units

- Pre-cast joist and hollow block construction
- Pre-cast RCC solid planks/joists
- Funicular shells over edge beams
- Pre-cast plate floors
- Ferro-cement roofing elements
- Filler slab roofing with various filler material

- Timber is used for door and window frames and shutters and also for structural and non-structural walling and roofing units. With a view to effect the economic use of timber and also conserve the primary species of timber, use of secondary species of timber has been resorted to by giving appropriate seasoning and chemical treatment before use.
- Pre-cast concrete door/window frames are competitive in cost and function and do not need repetitive maintenance. The latest contribution is the use of ferro-cement. Use of pre-cast hollow decorative blocks has also become very popular mainly through the work of building centers as well as private sector entrepreneurs. With regard to door shutters, the use of alternatives like cement bonded particle boards and bamboo boards are becoming popular in many regions.

INTER-LOCKING BLOCKS

- The construction industry is acknowledging the strong need to accelerate the masonry construction process, as the conventional method is labor intensive, hence, slower due to the presence of a large number of mortar joints. There is need for further acceleration of the rate of construction leading to the elimination of bedding mortar and thereby to the development non-conventional methods of masonry construction techniques, one that adopted special interlocking blocks as well as conventional blocks.
- With the use of conventional blocks, adoption of partial grouting and surface bonding becomes essential. Interlocking blocks further differ from conventional blocks in that the units are assembled together using geometrical features incorporated in the units without the aid of mortar. Attempts have been made to increase productivity through the development of varied types of interlocking blocks.



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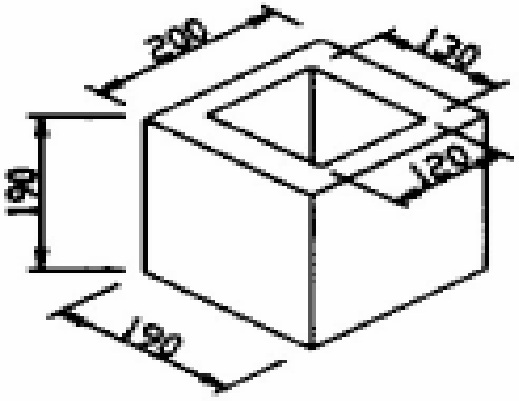
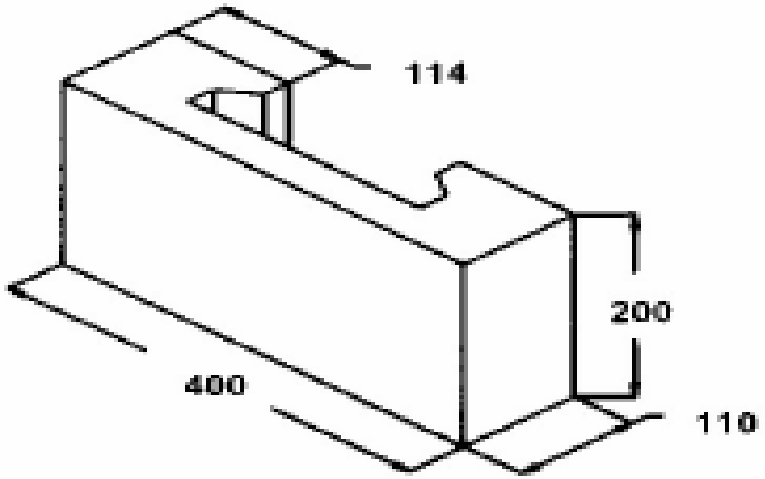
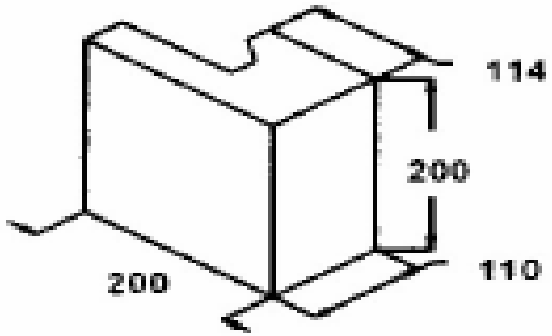




Stretcher unit



Jamb unit

- Advantages of Interlocking Blocks/Bricks
  - ➢Interlocking blocks masonry has much higher output per productive hour compared to conventional – brick/hollow – block masonry
  - ➢Due to easier alignment facilitated by the interlocking features and the elimination of vertical joints, a production enhancement of 80 - 120% and 60 – 90% more than conventional masonry was observed for dry-stacked masonry and thin-jointed, mortar bedded interlocking-block masonry respectively.

Compared to conventional masonry, the interlocking-block has less indirect contributory work- the reduction ranging from 30 -50%.

CONCRETE BLOCK

- The three methods of concrete block making considered are summarized below.

Option 1 - Automated mass production

- This is a capital intensive manufacture, low labor option, based on modern high speed concrete block manufacturing equipment. Being one of the smallest commercially available automated plants, it represents the option requiring the least capital input of the truly automated plants. It requires a reliable electricity supply, access to gas or oil supplies.

Option 2 - Mechanically assisted manual production

- This is labor intensive multiple-unit manufacture assisted by "low technology-low capital investment" equipment which has been designed to reduce the manufacturing costs. This option requires minimum capital input. It does not require an electricity supply or access to gas or oil supplies.

CONCRETE BLOCK

Option 3 - Manual single concrete block mould

- This is labor intensive manufacture, based on manually mixing bagged cement and locally quarried sand and aggregate. Typically the mix will be prepared in a tub and poured into a steel or aluminium mould, perhaps several at a time, and allowed to cure overnight before being stripped from the mould.

BAMBOO(VEGETABLE STEEL)

- For housing radical new ideas are needed. For example, one of the best structural materials available in abundance is bamboo.
- There are many advantages to using bamboo in construction. It is a highly functional, beautiful, earthquake-indifferent material. Bamboo occurs in many sizes, many degrees of hardness, and many grades of color and occupies a wide range of habitats.
- It is possible to build multiple-storey buildings with bamboo. Whereas trees must be replanted when they are harvested, bamboo roots sprout up again quickly
- Main characteristic features, which make bamboo as a potential building material, are its high tensile strength and very good weight to strength ratio. It can withstand up to 3656 Kg/cm2 of pressure.

BAMBOO(VEGETABLE STEEL)

- It can be easily worked upon by simple tools and machines. The strength-weight ratio of bamboo also supports its use as a highly resilient material against forces created by high velocity winds and earthquakes.
- Components made by bamboo can have a reasonable life of 30 to 40 years.
- Bamboo as a versatile material and its various composites along with other building materials offer a very appropriate option to partially replace materials like steel, aluminium and hard forest wood for housing applications.
- Uses of bamboo in buildings:
    - Door shutters
    - Flooring
    - Shuttering and Scaffolding
    - Roofing sheets

OTHER ELEMENTS

- The scope for the use of pre-cast elements is coming into sharp focus for areas of application such as:
  - Thin pre-cast lintels
  - Thin ferro-cement pre-cast shelves
  - Pre-cast sanitation unit rings
  - Pre-cast septic tanks
  - Ferro-cement bio-gas units
  - Pre-cast jalousies
  - Pre-cast poles for street lighting
  - Pre-cast posts for boundary walls
  - Ferro-cement based sanitation units/cladding
  - Ferro-cement water tanks
  - Pre-cast well rings for water wells

PREFABRICATION

INTRODUCTION

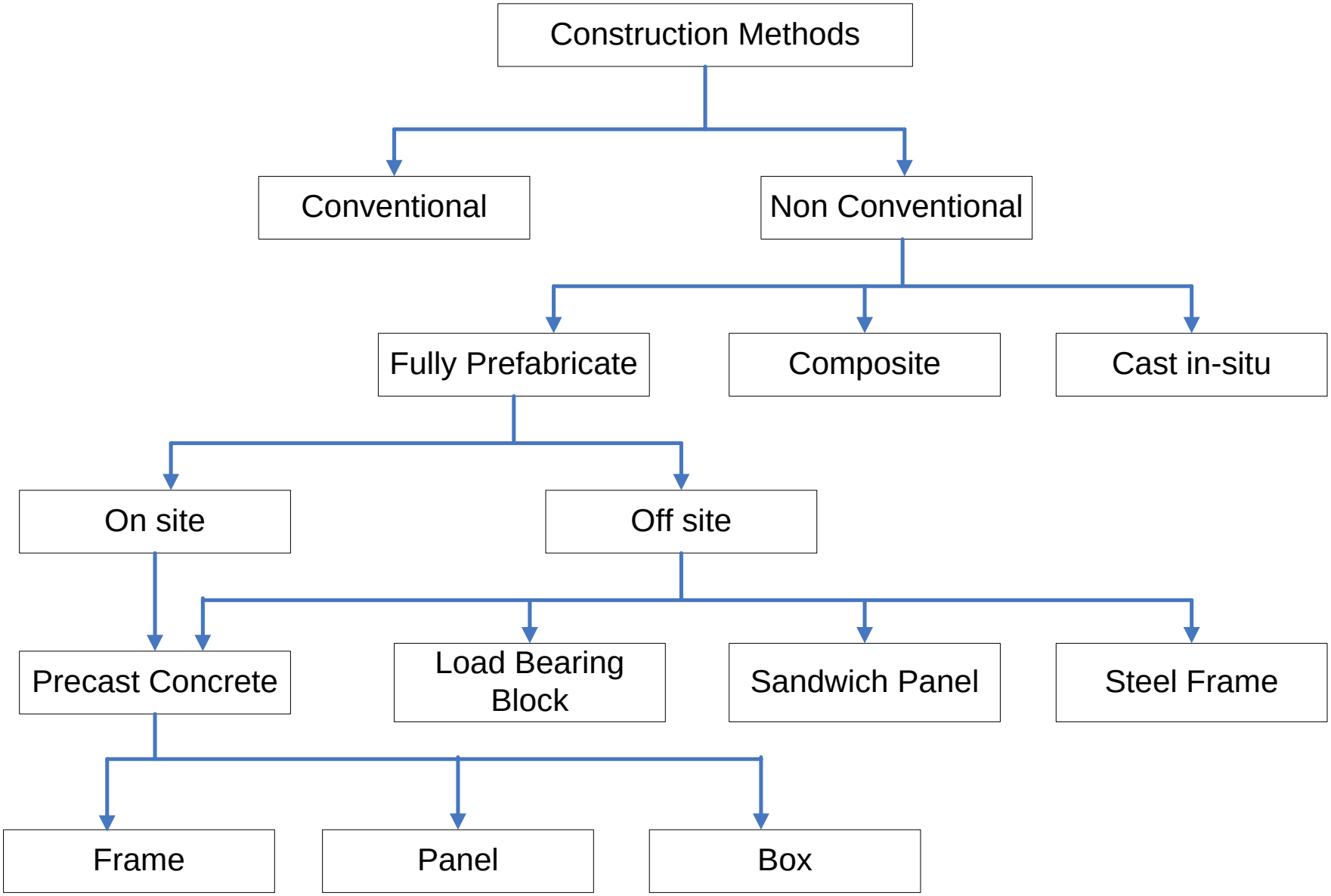
- ✓**Prefabrication is a continuity of production of implying a steady flow of demands, standardization, a high degree of organization of work, and experimentation integrated with production process.**
- ✓**The term prefab may apply to any construction method where a significant part of the construction takes place off-site in a factory where large, complex pieces are produced and then are assembled at the site into the finished structure.**

✓**It is part of industrialization of the building sector to solve demands for house, offices, industrial buildings, etc. the prefabricating system has gained the attention of housing experts as an option for low cost housing.**

✓Prefab/precast construction is the most widely-used form of prefabrication in building and civil engineering is the use of prefabricated steel and concrete sections in structures where a particular part or form is repeated many times.

•The types of construction in which prefab involved includes Building, Heavy and Industrial Construction, Road Construction, Bridge Construction and the likes.

The various types of construction Methods are classified as:


Construction Methods
Conventional
Non Conventional
Fully Prefabricate
Composite
Cast in-situ
On site
Off site
Precast Concrete
Load Bearing Block
Sandwich Panel
Steel Frame
Frame
Panel
Box

Benefits of Prefabrication Techniques

- Higher productivity
- Cost savings (labour and materials costs)
- Faster return on investment for the client;
- Reduced project durations for fixing and erection operations;
- Lower manpower requirement on-site
- Savings in space allocated to materials storage
- Better quality control
- Less materials wastage
- Enhanced teamwork spirit
- Less influence of site tasks by inclement weather conditions
- Application to public and private sector housing, commercial building and road construction

Prefabrication in Ethiopia

- The former Yugoslavian technical assistance, introduced the first modern prefabricated building parts production industry in Ethiopia in 1984
- The factory started production of structural elements in 1986 for office buildings, apartments, hotels and residential building since then
- types and sizes of structural elements are columns, slabs, footing, shear walls, stairs, flights and landings.
- The product of the enterprise designed to build three categories of building: residential building up to 5 stories, commercial building up to 10 stories and public buildings up to 10 stories.

Production place of PBPPE

Production place of PBPPE

PRECAST CONCRETE

✓**Precast Concrete is obtained by mixing, cement, sand aggregate such as gravel or crushed stone and water in desired proportions**

✓**Precast concrete provides architects with an exciting medium when designing a wide range of buildings, commercial office buildings to sports stadiums.**

Precast concrete provides:

- **Complete thermal protection**
- **Effective rain screens**
- **Superior lifespan**
- **Reduced construction schedule and on-site labour**
- **High quality control standards**
- **Numerous finish options and colours**

ADVANTAGES OF PRECAST CONCRETE CONSTRUCTION

- ✓ **Enables faster construction - not affected by weather or labour shortages**
- ✓ **Very rapid speed of erection**
- ✓ **Good quality control**
- ✓ **Produces a high standard of workmanship in factory conditions**
- ✓ **reduces potential for accidents,**
- ✓ **addresses on-site skill shortage**
- ✓ **Installs quickly and easily - most can be done in one day.**
- ✓ **Maintenance free - No need to paint or periodically**

DISADVANTAGES OF PRECAST CONCRETE CONSTRUCTION

- Very heavy members
- Camber in beams and slabs
- Very small margin for error
- Connections may be difficult
- Somewhat limited building design flexibility
- Economics of scale demand regularly shaped buildings.
- Need for repetition of forms will affect building design.
- Cranes are required to lift panels.

TENDENCIES IN PRECAST CONCRETE

- Structural efficiency
- Flexibility in use
- Optimum use of materials
- Speed of construction
- Quality consciousness
- Adaptability
- Protection of the environment

PRECAST BUILDING SYSTEM

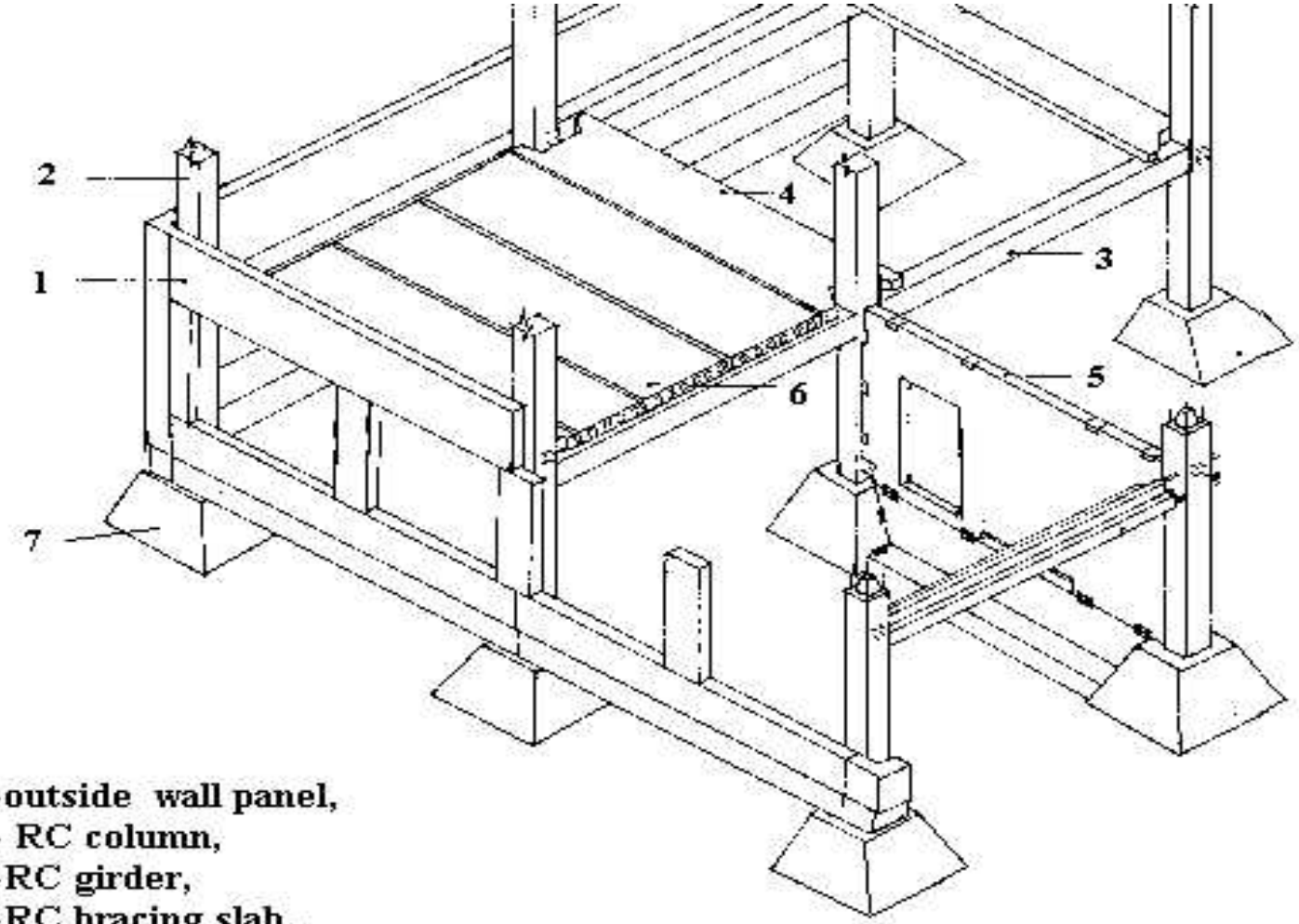
- Precast concrete frame
- Precast concrete wall
- Precast concrete floor

Precast concrete frame

✓Precast concrete frames involve an entire structure being fabricated off-site. Such as Column, Beam, footing and etc.

✓Precast concrete frames are casted as they are designed as structural elements have heavier reinforcement than is required. Elegant connections are required between columns and beams to transfer considerable forces without adversely affecting the visual appearance of the frame.

Precast concrete frame



1-outside wall panel,
2- RC column,
3-RC girder,
4-RC bracing slab,
5- RC diaphragm,
6- RC ceiling slab,
7- RC foundation

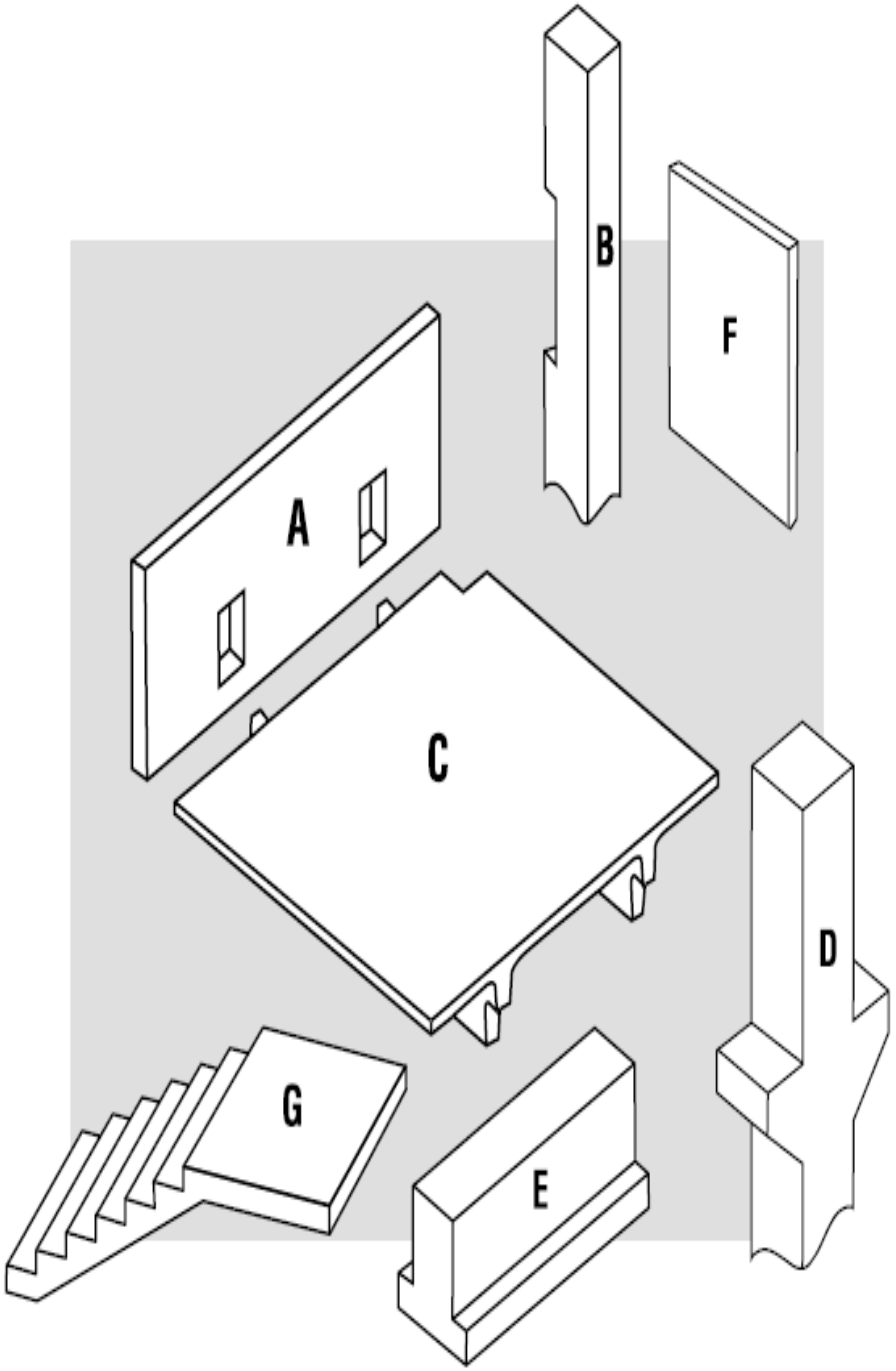
Precast concrete wall

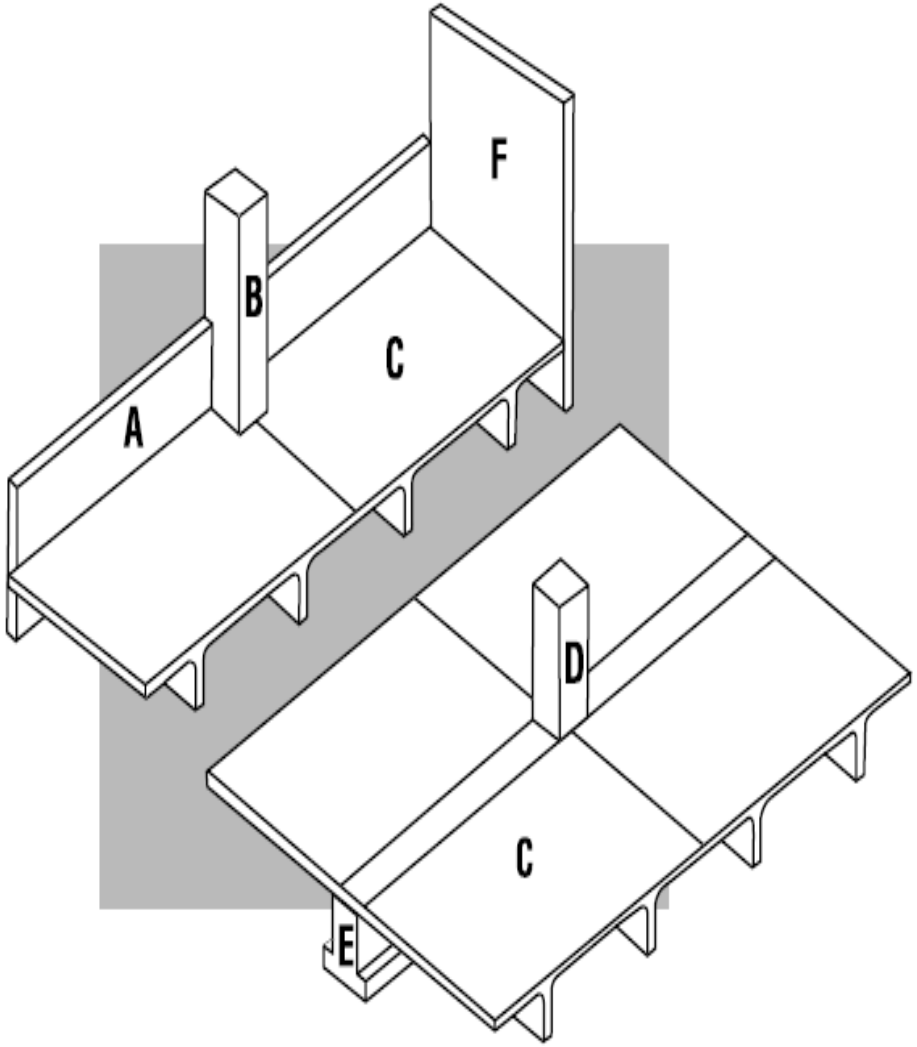
✓Precast wall are used for internal & external walls, lift shafts, central cores etc. Precast wall system are mostly used in domestic construction, both for individual housing & for apartments.

✓The Precast walls can be load bearing or only partition walls. The surface of the elements is smooth on both sides & ready for painting or wall papering.

Precast walls offer the advantage of speed of construction, smooth surface finishing, acoustic insulation & fire resistance.

A. Exterior Spandrel
B. Exterior Column
C. 15′ MEGA TEE™
D. Interior Column
E. Girder
F. Shear Wall
G. Stair System





PREFABRICATION

- Several low cost pre-cast roofing units such as doubly curved tiles, pre-cast cellular units, cored concrete, etc., have been developed and successfully used in buildings.
- In a building the foundation, walls, doors and windows, floors and roofs are the most important components, which can be analyzed individually based on the needs thus, improving the speed of construction and reducing the construction cost.
- The concept of pre-cast (also known as "prefabricated") construction includes those buildings where the majority of structural components are standardized and produced in plants in a location away from the building, and then transported to the site for assembly. These components are manufactured by industrial methods based on mass production in order to build a large number of buildings in a short time at low cost.

PREFABRICATION

- The main features of prefabrication construction process are as follows:
  - The division and specialization of the human workforce
  - The use of tools, machinery, and other equipment, usually automated, in the production of standard, interchangeable parts and products.
- This type of construction requires a restructuring of the entire conventional construction process to enable interaction between the design phase and production planning in order to improve and speed up the construction.
- Many countries used various pre-cast building systems during the second half of the 20th century to provide low-income housing for the growing urban population. In general, pre-cast building systems are more economical when compared to conventional multifamily residential construction (apartment buildings) in many countries.

PREFABRICATION

- Depending on the load-bearing structure, pre-cast systems can be divided into the following categories:
    - Large-panel systems
    - Frame systems
    - Slab-column systems with walls
    - Mixed systems
- **Large-Panel Systems**

- The designation “large-panel system” refers to multistory structures composed of large wall and floor concrete panels connected in the vertical and horizontal directions so that the wall panels enclose appropriate spaces for the rooms within a building. These panels form a box-like structure (see Figure 3). Both vertical and horizontal panels resist gravity load. Wall panels are usually one story high. Horizontal floor and roof panels span either as one-way or two way slabs. When properly joined together, these horizontal elements act as diaphragms that transfer the lateral loads to the walls.

PREFABRICATION

1. LARGE-PANEL SYSTEMS

- The designation "large-panel system" refers to multistory structures composed of large wall and floor concrete panels connected in the vertical and horizontal directions so that the wall panels enclose appropriate spaces for the rooms within a building. These panels form a box-like structure (see Figure 3). Both vertical and horizontal panels resist gravity load. Wall panels are usually one story high. Horizontal floor and roof panels span either as one-way or two way slabs. When properly joined together, these horizontal elements act as diaphragms that transfer the lateral loads to the walls.

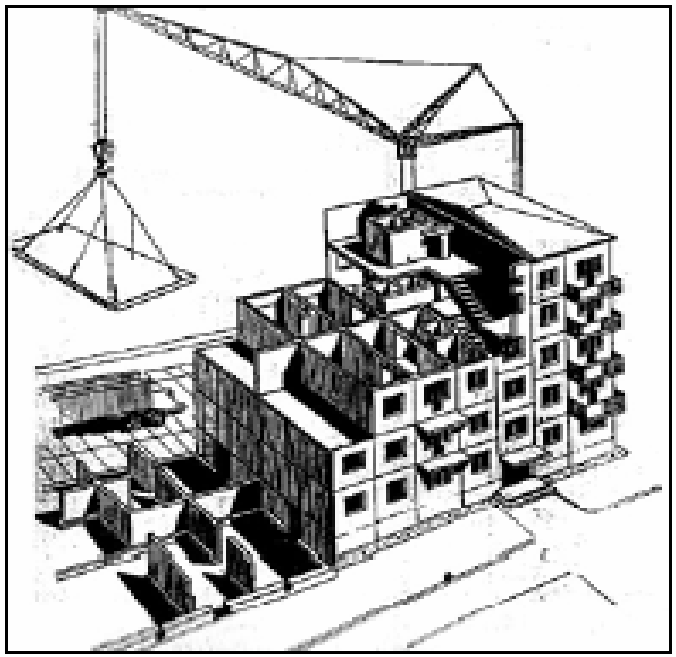


Figure 3: A large-panel concrete building under construction (WHE Report 55, Russian Federation)

PREFABRICATION

2. FRAME SYSTEMS

- Pre-cast frames can be constructed using either linear elements or spatial beam-column sub-assemblages. Precast beam-column sub-assemblages have the advantage that the connecting faces between the sub-assemblages can be placed away from the critical frame regions; however, linear elements are generally preferred because of the difficulties associated with forming, handling, and erecting spatial elements. The use of linear elements generally means placing the connecting faces at the beam-column junctions. The beams can be seated on corbels at the columns, for ease of construction. The beam-column joints accomplished in this way are hinged. However, rigid beam-column connections are used in some cases, when the continuity of longitudinal reinforcement through the beam-column joint needs to be ensured. The components of a pre-cast reinforced concrete frame are shown in Figure 7.

PREFABRICATION

2. FRAME SYSTEMS

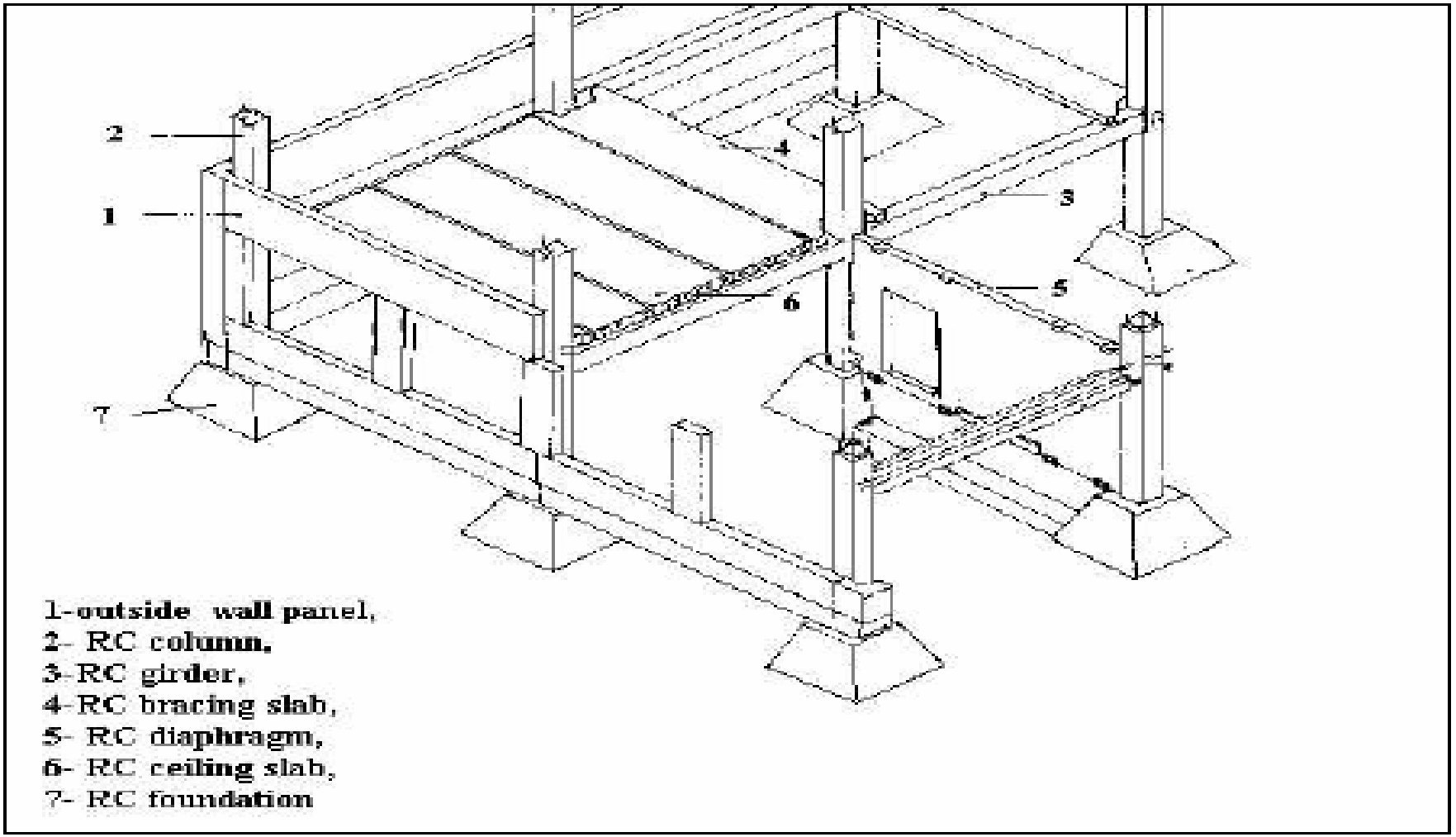


Figure 7: Components of a precast reinforced concrete frame system of Seria IIS-04 (WHE Report 66, Uzbekistan)

3. SLAB-COLUMN SYSTEMS WITH SHEAR WALLS

- These systems rely on shear walls to sustain lateral load effects, whereas the slab-column structure resists mainly gravity loads. There are two main systems in this category:
  - Lift-slab system with walls
  - Pre-stressed slab-column system
- The load-bearing structure consists of pre-cast reinforced concrete columns and slab. Pre-cast columns are usually two stories high. All pre-cast structural elements are assembled by means of special joints. Reinforced concrete slabs are poured on the ground in forms, one on top of the other. Pre-cast concrete floor slabs are lifted from the ground up to the final height by lifting cranes. The slab panels are lifted to the top of the column and then moved downwards to the final position. Temporary supports are used to keep the slabs in the position until the connection with the columns has been achieved.

STANDARDIZATION AND MECHANIZATION

- In high-income countries, building products manufactured locally by automated processes can be distributed cheaper than their manually manufactured competitors. In low-income and middle-income countries, building products manufactured locally by automated processes can be distributed cheaper than their manually manufactured competitors only if the market is predictable and sufficiently large enough to provide a reasonable return on the capital invested. Otherwise, manually produced products will hold a competitive edge.

- In low-income and middle-income countries, building products manufactured locally by mechanically assisted manual methods may provide a cheap building products, a reasonable level of local employment and a reasonable return on a relatively low level of investment. In the short term, manual production and mechanically assisted manual production provide more opportunities for local employment than automated production. There are two direct approaches towards cost reduction in brick production, viz. mechanization of the brick making process and improvement of the efficiency of brick kilns.