Construction Techniques
Survey in Palestinian Territories

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Contents

1. INTRODUCTION 4

  1.1 General
  1.2 The Purpose of the Survey
  1.3 Methodology
  1.4 Scope of Work

2. TRADITIONAL BUILDINGS 6

  2.1 Introduction
  2.2 Walls
    2.2.1 Stone Walls
    2.2.2 Mud Walls (Unfired Brick)
  2.3 Roofing
    2.3.1 Mud Roofing
    2.3.2 Flat Roofing
    2.3.3 Pitched roofing (Marseille tiles)
  2.4 Frame
    2.4.1 Domes
    2.4.2 Vaults
    2.4.3 Floor on arches
    2.4.4 Assembled Frames (Pitched wooden Structure)
    2.4.5 Flat Slab (I-Beams with concrete)
  2.5 Finishing Coating – Renderings
    2.5.1 Lime Wash
    2.5.2 Trowel Smoothed & Float Sponged Smoothed

3. CONTEMPORARY BUILDINGS 24

  General
  3.1 Contemporary Building Types
  3.2 Elements under Ground
    3.2.1 Foundation
    3.2.2 Columns under ground floor slab (Columns Necks)
    3.2.3 Beams under ground floor slab (Tie Beams)
3.2.4 Walls under ground floor slab
3.3 Ground Floor Slabs
3.4 Slabs and Roofs
3.5 Columns & Beams
3.6 Walls
  3.6.1 External Walls
  3.6.2 Internal Walls
3.7 Opening (doors, windows, and skylights)
3.8 Finishing
3.9 Joints

EVALUATION

CONCLUSION

REFERENCES
1. INTRODUCTION

1.1 General

In the last century, building construction has changed considerably. After the widespread use of modern techniques, reinforced concrete that structurally exhibits high stability and solidity, the traditional building techniques totally lost their value, as the concrete buildings are correlated with the prestige of modern life. Furthermore, and due to the fact that the structural stability in correct relies basically on the role played by the columns rather than walls; this made possibility to reduce the thickness of the building skins. This leads to low thermal comfort inside the buildings and to the need for heating, cooling, and ventilation systems which increase the energy consumption in the new buildings.

Planning in West Bank & Gaza Strip is in the earliest stage of evolution to the new Palestinian situation. Building design is inherently complex activity. Decisions made in this stage of planning will influence building operation and economy throughout the building life cycle.

After Oslo Agreements, the demand of housing in West Bank and Gaza Strip is increasing day by day. This is according to Palestinian people returning to the Palestinian Territories and due to the encouragement of developing the Palestinian situation to match with the Palestinian needs for housing and building development.

According to what mentioned, this study (Construction Techniques Survey) will cover the traditional building techniques and contemporary building techniques used in the West Bank & Gaza strip to use the information as a base for alternative solutions regarding rules and guidelines for new building techniques which will achieve energy consumption in the building sector and to establish Energy Building Codes.

1.2 The Purpose of the Survey

This Survey aims to review the traditional and contemporary building techniques used in West Bank and Gaza Strip, and to introduce thermal specifications and energy efficiency of these techniques so as to be considered as a base for alternative solutions of developing the building construction with correlation to the architectural styles, building materials, and climatic zoning in West Bank and Gaza Strip, so as, to establish Energy Building Codes.

1.3 Methodology

The methodology of this study is based on:
1. Review of available literature.
2. Field visits to concerned parties to conduct interviews with officials to get the data concerning Construction Techniques. In this regard, officials from An-Najah University,
Engineering Association, Ministry of Public Works, Palestinian Standard Institution, Palestinian Energy Authority, and Energy Research Centers were interviewed.

3. Field visits to Engineering Offices to conduct interviews with specialists to get the data concerning Construction Techniques. In this regard, engineers from Madar, Beit Asia, Al-Andulos, and Somer Engineering Offices were interviewed.

4. Review information submitted from Engineering Association, Engineering Union-Gaza Strip, Bir Zeit University, and Riwaq Center.

1.4 **Scope of Work**

This study (Survey) will discuss the techniques according to building types which are mainly divided into two types:

1. **Traditional Buildings**: Stone, Mud, and Clay/Straw.
2. **Contemporary Buildings**: Stone, Concrete, Hollow Concrete Blocks, and Steel.

The study will consider the materials used, the location with climatic link, the compositions of building elements, the thermal behavior, and the advantages and disadvantages of them.
2. TRADITIONAL BUILDINGS

2.1 Introduction

Building Techniques in West Bank and Gaza Strip is influenced by the materials available domestically as well as techniques in neighboring countries. In general, there are four main kinds of building materials which are widely available in West Bank and Gaza Strip. These are mud or adobe; concrete, concrete block and cut stone. These kinds of building materials can be used individually or together with each other to form the structure of buildings.

At the beginning of this century and in many villages, mud or adobe were used to construct houses. In many cases, houses were constructed with dry stone and plastered roughly on the outside with mixture of mud and ashes. The roof was constructed some times from branches or brushwood covered with mud. It described the way in which the roof was constructed in many Palestinian cities as in city of Jericho. Where, most of the houses constructed with four arches to carry the roof.

Mud and adobe are widely used in many Palestinian areas to construct the houses. It is believed that these houses provide the inhabitants with more comfortable internal environment than the new concrete houses built in many areas. Some of the newly constructed concrete houses and others built of mud bricks in West Bank and Gaza Strip showed that the internal temperature in mud brick houses was 5-6 lower than the external temperature. While the internal temperature was only 0.5-1 deg C lower than the external temperature in concrete block houses (Khammash, 1990). Mud houses have high thermal capacity in comparison with that of concrete houses, and when dry grass is mixed with mud to strengthen the mud brick wall, the thermal properties of the wall are enhanced. Some architects these days believed that they can use mud bricks mixed with some other materials such as cement to build houses.

Concrete and concrete blocks are widely used in towns and cities. In West Bank and in the particular Northern parts; most houses are built from concrete and concrete blocks. In other cities, most buildings are constructed with concrete columns to transfer the load of the roof to the ground while the concrete or the concrete blocks fill the area between these columns.

The following section of this report will give description of the elements used in the traditional types of buildings West Bank and Gaza Strip starting from (Walls, Roofing, Frame and Finishing)
2.2 Walls

2.2.1 Stone Walls

1. Two linked Facing

This type of wall is used for all types of buildings. These walls are constructed after digging and making foundation system, wherever these walls exist even for the internal division walls. In particular cases, the walls were built directly on the clear rock layer with no real earth works, also this type of walls is associated with continuous foundation system, which is usually made of thicker walls of bigger two linked rough stone faces with mortar, earth and gravel fill.

In particular cases, when the walls were built on the clear rock layer, no foundation system was needed.

Stone and lime stone were used as the construction materials. Stone hardness varies depending on the stone origin and the depth of stone strata, the thickness of wall depends on the height of the building as well as on the type floor used.

The thickness of the wall gets thinner as we get higher. Also, the texture of the stone might change from floor to other separating different types, by one stone course as a simple cornice. Usually when we get higher, the stone texture becomes smoother.

Walls of this type have good thermal performance, they serve as good insulation from the weather conditions, because of their thickness and they reflect the sun heat through their light colors.
This technique allows column construction. These columns can be of stone pieces put together with minimum mortar on top of each other, or they can be cavity walls, as in walls, filled by mortar and gravel. Also the use of stone columns in the classical way (one long piece) was the other possibility to construct the columns of arcades or verandas. This way of column construction existed in Palestine in Roman period; it was widely used in private and public buildings.

Regular pointed stone walls is the most used technique in traditional architecture in all types of buildings such as monuments, tombs, stables, stone mashrabiyyas, madras’s (schools) and even in stone walls in gardens.

The materials used in the construction (stone, mortar and gravel fill, the type of the stone used and its physical characteristics are important to stand against the weather conditions and deterioration problems.

Excessive cost of stone, the appearance of new materials and techniques in additions to the lack of the skilled trained masonry builders caused the disappearing of this technique and accelerating the use of new materials which are less expensive and easier to work with and plaster.

2. One Facing:

This type of wall exists in the mountain rural areas, it is associated with continuous foundation system, which is usually made of thicker walls of bigger two linked rough stone faces with mortar, earth and gravel fill.
The building materials used for this type are stone, mortar, gravel fill; limestone and stone rubble of different sizes were put either in the foundations or in the internal part of the wall. Thickness of stone range from 20 cm to 35 cm.

Walls of this type have good thermal performance, they serve as good insulation from the weather conditions, because of their light materials and they reflect the sun heat through their light colors. Also this type has good acoustic performance, they serve as good insulation from outside effects due to their thickness, and they absorb the echo inside due to the plasters high porosity.

The one facing wall is rarely found. It is used in rural areas to construct Saqeefeh (Peasant house), storage places, and cattle place.

The type of the stone used and its physical characteristics are important to stand against weather conditions and deterioration problems. For example, the soft lime stone of bad quality will
deteriorate quickly and lead to demolition of the wall. The quality of the mortar used as a linking material of the two faces of the wall is very important to keep these two faces together, if this mortar was loose or of bad quality with little binding materials, this probably leads to the demolition of the wall.

3. Stone Laid Dry (Rubble Masonry)

This type of wall exists in the mountain areas. This technique is of last two centuries and it is still used in barrier construction in rural areas. The building materials used for this type are stone, limestone and rubbles, the thickness of the walls depend on the size of the span of the structure or the height of the structure whether it is a farmhouse or a retaining wall in the landscape. Wall was not intended to be protected, while the roof was intended to be covered for farmhouse structures with slightly rough earth layer mixed with little lime mortar, with clear slope for rainwater drainage. This type of wall was used to build farmhouses, stables, retaining walls and barriers in landscape.

Maximum height for buildings using this technique is about 4m (i.e. 1 floor)

Usually farmhouses and barriers are smoothly constructed with no real angles. The farmhouse has the shape of cylinder, which has no angles in it, and in the barriers it is possible to construct angles with the same technique. At the same time, this technique doesn’t allow column construction, since this type of construction wasn’t used to construct spaces with columns and bearing walls.

Walls of this type weren’t meant to be high insulated from exterior environment. It was used to build either landscape barriers or farmhouses, which were only used in summer time and not as permanent housing.

This technique disappeared from use for several reasons:

- Leaving the agricultural work for industrial and commercial works (the use of the farmhouses is getting less and less)
- The development of transportation (no need to stay weeks in the farm)
This technique disappeared but in restoration of stone barriers and retaining walls in the landscape.

2.2.2 Mud Walls (Unfired Brick)

This type of wall is associated with simple stone continuous foundation system. This type of wall is used for all types of buildings such as housing, commercial, farmhouses, convents and monasteries. The building materials used for this type of wall was stones, unfired bricks, earth, wood and pebble. The material used in production is sun-dried clay, which is not hard. This technique is very old, this type of walls were built in Jericho and one of the most known refugee camps called Ein Al-Sultan camp in the Jordan valley was built with mud in 1950s. Walls of this type have good thermal performance, since they are of light material; they serve as good insulation from the weather conditions outside. On the expansion and the extraction level this type is suitable for the weather conditions. Mud walls are to be permanently maintained, since material used in construction is very light and not resistible for the outside natural changes such as sun, water and vegetation. Those usually cause cracks in the plaster allowing for water to penetrate, which causes weakness in structure by flushing out the mortar causing the falling after that. Also the frame, which associated with this type of walls, is usually made of assembled wood structure with mud roofing on the top of it. Once this mud is not protected and painted by plaster, rainwater penetrates to the wall form the upper side of the wall, using direct destruction of the joints and the mortar, which keep the blocks together. Then the wall collapses as it is not any more resisting the loads on it.

The appearance of new materials and techniques, which considered on the level of the average as sign of the modernity and civilization, led for the absence of this technique in contemporary
buildings. At the same time, this kind of wall is still used in the construction but in very smaller scale, one can still see those technique used in oven (Taboon) construction in rural areas and in the restoration works of the exciting mud structures

2.3 Roofing

2.3.1 Mud Roofing

This type of roofing exists in the mountain rural areas. The mud roofing was associated with buildings of different types, mainly, the residential houses, stables, and agricultural storages. In most cases, the mud walls were associated with this type of roofing. The mud roofing was associated with frame superstructure mainly appeared in the Ottoman period especially the 17th century and continued to be used until the late 1940s.

The materials used for this type of roofing are as the followings:

1. Fired clay which can be divided to:
   - green clay such as earth mortar
   - Wood such as wood trunks, leaves and branches
   - Vegetation such as dried hay and vegetal roots
   - Stone such as pebbles and rubbles
2. Others (Ashes & Lime).

The mud roofing is about 10 to 15 cm, not including the frame thickness that depends on the span and the wood quality. The building method used in this type of roofing is with mixed with vegetal bond stacked with branches and leaves on a wood trunk frame.

This type of roofing is suitable to resist all the extremes of weather conditions (wind, rain, snow,...) in West Bank and Gaza Strip, especially in the Jordan valley area which is very dry, however, in rural areas in the middle of mountains, the mud roofing is maintained in regular bases and its quality is enhanced by adding the lime to its mortar.

This type of roofing shows positive thermal performance, it acts as good insulation from outside effects and it serves as good insulating material with light components. Also, on the level of expansion and extraction it is suitable for the weather conditions.
2.3.2 Flat Roofing

1. Stone Tiles

This type of roofing was used in all types of buildings. Lime Stone was used in this type of roofing, flag stone roofing was usually applied when the roof was used as terrace. Flagstone is laid with mortar, the slope of flag stone roofing is usually less than the slope of the screed mortar. The stone was of unequal rectangular shapes. I-beams with concrete slab as well as all types of vaults are associated with this type of roof.

This type of roofing is suitable to resist all the extremes of weather conditions in Palestine, also it is stable enough to resist from being torn off or penetrating water.

This type of roofing shows positive thermal performance. It acts as a good insulation from the outside effects and it reflects the sun heat by its light colors.

The deterioration of the stone, joint loses and gutter closure lead to vegetation problems as well as penetration problems which weaken the structure and cause failure roof.

The technique is still used but in regular shapes with concrete mortar for different types of buildings especially houses and done by the same trades. The technique is still alive in contemporary structures with little changes, the stone tiles are mechanically cut and of regular dimension, while the traditional ones are irregular with different dimensions, Also the mortar used is a cement mortar, while the traditional one is a lime mortar.
2. Lime Mortar

This type of roofing was used in all types of buildings.

The lime mortar made of lime mortar is 10 cm thick, this thickness is the one of the last layers and not the total thickness of the roof with the same superstructure. The lime mortar vault roofing is laid with mortar, I beams with concrete slab as well as all types of vaults are associated with type of roof. This type of roofing is suitable to resist all the extremes of weather conditions in Palestine, also it is stable enough to resist from being torn of or penetrating water.

This type of roofing shows positive thermal performance, it is acts as good insulation from the outside effects and it reflects the sun heat by its light colors. The lime mortar roofing is an old technique dates back to Roman and Byzantine periods and continuous to be used till recent decades.

In the lime mortar roofing, the lime mortar is not any more used and was replaced by light weight concrete made of cement mortar and gravels.

2.3.3 Pitched roofing (Marseille tiles)

This type of roofing exists in Jordan valley areas, the mountain areas (rural & urban) and the coastal areas. This type of roofing is suitable to resist all the extremes of weather conditions in West Bank and Gaza Strip, also it is stable enough to resist from being torn off or penetrating water.

This type of roofing shows negative thermal performance, this type was meant to be a good damp insulator and not heat insulator. Thus doesn't act as a good insulation from the outside effects, on the contrary, it absorbs the heat and radiates it to the inside.

The red tiles pitched roofs were used for all types of buildings, the red tiles pitched roofs date to 19th when the I -beam with concrete slab was introduced as a frame method. Hence, the red roof was one of protection methods for such a frame, and continued to be used now.
2.4 Frame

2.4.1 Domes

The domes were used in rich houses or in important public or religious building such as mosques, tombs, khans, caravanserais and madras’s (schools). This technique is very old one, dating back to Byzantine times in the 5th century. This technique disappeared because of the excessive costs and lack of materials and the skilled workers to do the work. The creation of the new building concepts using concrete made it easier and quicker to construct bigger and higher buildings or domes.

Stone and limestone, pebbles, lime and rubbles are the construction material used for domes, all the materials of making domes can be found in the market in the traditional form or industrial
Mortar was used as the building method in domes, as in the cross vault, the work needed a framework, usually the formwork was made of wooden structure or by earth fill with branches and leaves cover with the form of dome which is removed after the construction of dome from the doors. The frame is intended to be protected; it is plastered from the inside and covered by stone tiles or lime plaster from outside. The dome is mostly intended to be protected by lime plaster, in some cases the dome was left as is, but not for pointed only, especially when the stones were well cut and decorated such as in tombs and madras’s of Mamlouk architecture.

5 meters is a possible spanning structure with this type of frame. In this case, the frame is of 30-50 cm. There are no specific methods to increase the span, but the thickness of the walls and the frame make it possible to increase the span (the thicker the walls and the frame the longer span one gets).

As in the case of the vaults, the frame of these types shows positive thermal performances, it serves as a good insulation from outside effects.

On the level of expansion and extraction the frame is suitable for the weather conditions.

The shape of the stones applied in the dome should be segments of 3d sphere to achieve maximum surface of loading. This implies the hard work of the stone carver, especially when the stones of the dome are meant to be seen from beneath, then every piece, should be cut in proper and accurate way giving it a number and a direction.

The stone deterioration of the dome frame, the stone tiles and joints deterioration, the cracks in the frame plaster and the vegetation growth lead to major cracks and failure of the frame.

2.4.2 Vaults

1. Barrel Vaults

Earth, stone, limestone, pebbles and lime, and rubbles were the construction materials that used for this type, the work needed a frame work, usually the frame work was made of stacked wood or by earth fill with branches and leaves cover with form of the vault which is removed after the construction of the vault from the doors. The shapes of the barrel vault could be pointed or (Roman) semi circular.

As in the case of stone walls, the frame of these types shows positive thermal performances, it serves as a good insulation from outside effects. Also, the frame of these types shows positive acoustic performances, it...
serves as good insulation form outside effects and through its shape it absorbs the echo inside.

Photograph of a detail from inside Acre, Palestine

(Riwaq, 2000)

This technique is very old one and is not any more used; the reinforced concrete slabs and other structural solutions replaced the whole techniques.

The evolved technique is satisfying since it is economical comfortable structure with no damping and insulation problems.

2. Cross and keyed Vaults

Cross and keyed vaults were used for all type of buildings: public, commercial, or residential. Mortar was used in the building method, the construction materials was used for this type of frame earth, stone, limestone and lime and rubbles.
As in the case of stone walls, the frame of these types shows positive thermal performance, it serves as a good insulation from outside effects.

The frames of these types served in many cases as roofing where a lime screed slope or stone tiles protected the roof from damping. In other cases, the shape of the vault reflected itself on the shape of the roof, which was eventually easier for rainwater drainage.

This technique is very old one and it is not used any more, the reinforced concrete slabs and other structural solutions replaced the whole techniques. As in the case of stone walls, this technique disappeared because of the excessive costs and lack of materials and the skilled workers to do the work. The creation of the new building concepts using concrete made it easier and quicker to construct bigger and higher buildings.

2.4.3 Floor on Arches

The floor on arches frame was used in residential buildings as well as in the (Saqeefeh) the agricultural storages or animal stables structures.

Earth, wood, stone, limestone, pebbles, lime and rubbles were used as construction materials, the building method used was mortar. The floor on arches intended to be protected by plastering the roof with light mortar that consists of lime, plants, ashes and earth with clear inclination to drain the rainwater.

This type of frame shows positive thermal performance, it serves as good insulation from outside effects. There were no openings in the floor on arches frame. The cracking of plaster in the floor will allow water penetration and as a result the rooting of the wood and vegetation growth, which makes the floor weaker and weaker to resist the loads from the earth slab which will lead to floor failure.
The frame of this type served in many cases as roofing since it is a one floor structure, where the roof intended to plastered by light mortar (lime, vegetal hay, ashes and earth) with a clear inclination to drain the rainwater.

This technique disappeared because of the creation of the new building concepts using reinforced concrete, which made it easier and quicker to construct bigger and bigger buildings. Although this type of structures are still constructed in the same areas especially for the woven places.

2.4.4 Assembled Frames (Pitched Wooden Structure)

The pitched wooden structure was used mostly for residential buildings and palaces. The construction materials used for this type of Frame are wood and red tiles for covering. The pitched wooden structure was used assembled with mortar, it is intended to be painted from inside with rich decorations and covered by Marseille tiles protecting the structure from outside. In the pitched wooden structure as for the I-beams with slab structure, the span might be increased through applying thick or combined –inverted wooden beams hanging the roof up. These superstructures show positive thermal performances, they act as good insulation from the outside weather conditions since they are covered with red tiles roofs, which make them in shadow always or protected from direct snow.
The Marseille tiles lose or broken tiles allow for water penetration to the roof wood structure, which will rotten the wood and weaken the structure. The last might fall when the wood is not any more able to resist the loads of the roof structure. Also the less protection material applied to the wood will allow insects of different types to attack the internal structure of the wood, thus wreaking it and causing failure of the whole structure. The creation of the new concepts of construction made it easier to construct other types of structures. Since the pitched wooden structure was used as false ceiling but with rich details and decoration, these structures disappeared because the new false ceiling took place in contemporary buildings. The technique is alive for contemporary buildings on reinforced concrete; it doesn't work as structural solution.

2.4.5 Flat Slab (I-Beams with concrete)

I-slab with concrete slab frame was used in all types of buildings. I-beams and light concrete (lime, sand and gravel) used as the construction materials, the slab intended to be protected by plaster from the inside and the beams intended to be oil painted. The upper part the slab was covered by stone tiles or red tiles pitched roof.

This type of frame has negative thermal performances; it doesn't serve as good insulation from outside effects. Stone tiles deterioration, joints degradation and roof problems will allow for water penetration to the superstructure causing rust in the I-beams and weakness of the structure, which might be fall at the moment it cannot resist the loads of the floor or the roof.
This technique disappeared in housing and commercials buildings in the traditional way, because of the excessive costs and the creation of the new concepts of construction, which made it easier and quicker to build bigger and higher buildings.

In the contemporary buildings, especially for the industrials use, the I–beams are still used but with different joints and way of applications.

The technique is not any more used. The reinforced concrete slabs were the new slabs with reinforcement, but this time with steel net and not steel individual sections. In industrials contemporary buildings, the technique is different; Heat and sharp additional tools are not any more used to cut or drill the a I-beams, the new mechanical cutting or drilling tools replace them. Also, the bolts were replaced by the welding system.

### 2.5 Finishing Coating - Rendering

#### 2.5.1 Lime Wash

Lime wash applied to either the external stone facades or the inside plastered surfaces in all types of buildings, in rural areas, the peasants used to apply to lime wash on the main façade to the height the worker could reach.

The materials used consist of binding materials (rich lime, vegetal oil and coloring additives. The binding materials other than oil, which themselves serve as a lime wash, are found in powder
The traditional colors used can be white and sky blue mostly, reddish and light green we used too, especially for the inside.

Photograph of the inside Ras-Karkar, Palestine  
(Riwaq, 2000)

The lime wash is not a strong material, so it is meant to be repeated every one or two years. The direct rain, the surface water drainage and the rising damp with salts cause the lime wash to separate from stone or plaster. Also, the lime falls down when many layers are applied year after year, and then it becomes too thick and heavy to be attached to the wall.

2.5.2 Trowel Smoothed & Float Sponged Smoothed

Trowel smooth plaster was used on all exterior facades for all types of buildings, in rural and urban areas; this type of rendering was used in cases of rough stone walls which were meant to be plastered for all types of buildings.
Coating composition were Binding material such as Rich lime, ashes, roots of plants, and aggregate such as gravel, broken and animal hair. The binding materials were found either in powder form (lime) or raw (roots and hair), aggregates were in raw form resulted from stone carving.

Preparing the mortar by adding 1 volume of wet lime powder to 3-4 volumes of aggregates and some ashes, roots and animal hair, these components are mixed to form fine mortar.

The plaster is then applied to a clean wet surface in three layers:
- The grainy layer, which is obtained by throwing the mortar on the surface by trowel to obtain homogeneous surface with no holes in it, then it is left to dry.
- The slightly grainy layer, which is obtained by throwing mortar on the first layer, is smoothed by smoothing tools.
- The last layer is made by fine lime paste using a float to obtain a smooth surface.

The humidity problems especially raise damp with salts cause the plaster to crack and split from the stone or the plastered surface, trowel smooth plaster is maintained by replacing the damaged parts using the same recipe, and protecting the surface by applying the lime wash, which sacrifices itself and protects the outer layer of the plaster from salts.

This technique is contemporary in the conservation operations, the same technique is still used but in modern materials (cement with sand mortar) and is applied on inside walls as well as outside walls, when it is concrete blocks or reinforced concrete structure.
3. CONTEMPORARY BUILDINGS

General

The contemporary buildings are divided mainly according to the external walls and materials used into four types which are:

2. Concrete Buildings.
3. Hollow Concrete Block Buildings.

The elements of the building are:

- Foundations.
- Columns under ground floor slab.
- Walls under ground floor slab.
- Beams under ground floor slab.
- Ground floor slab.
- Columns.
- Beams.
- External walls.
- Internal walls.
- Slabs and Roofs.
- Openings - doors, windows, and skylights.

Regarding the thermal effect of building elements compositions on the building envelope; the Foundations, Columns under ground floor slab, Walls under ground floor slab, and Beams under ground floor slab will be discussed briefly as they do not mainly affect the building envelope thermal comfort.

Also, the Columns which are considered as apart of the external walls and the Beams which are considered as apart of the slabs will be discussed briefly

3.1 Contemporary Building Types

1. Stone Buildings

This type of buildings is widely spread in West Bank cities and some villages and while it is rarely found in Gaza strip cities. It is commonly used in the construction of residential and public buildings. Stone is used for cladding the external facades of the buildings. This type of construction usually apply for the external walls covered with 12 rows of stone each height is 25 cm with 7cm thickness. It is mainly consists of (12 X 25cm) stone plates 7 cm thick and 22 cm thick layer of concrete backing is caste behind the stone plates.
The materials mainly used in stone buildings are:
Stone, Concrete, and Hollow concrete blocks for the walls and slabs. There are different compositions for them which discussed in the part of building elements in which there was some other materials used in the compositions.

The thermal behavior of stone buildings is not efficient as it was in the traditional buildings because of:

- The small thickness of walls and slabs in comparison to that in the traditional.
- The high thermal transmittance of stone and concrete.

In order to develop the thermal behavior of stone buildings, there are some techniques of adding some insulation materials to the building elements composition which were discussed and the thermal transmittance of each element composition was calculated and recorded.

2. Concrete Buildings

This type of buildings is widely spread in West Bank villages and Gaza Strip cities and to a small scale in West Bank cities.
The external walls are constructed from concrete of 20-25 cm thick layer and rendered with cement plaster on both faces.
Concrete is mainly the material used for external walls, reinforced concrete and hollow blocks are used for slabs and roofs. The thermal behavior of concrete buildings is not efficient as it was in the traditional buildings because of:

- The small thickness of walls and slabs in comparison to that in the traditional.
- The high thermal transmittance of concrete.

In order to develop the thermal behavior of concrete buildings, there was adding of some insulation materials and techniques to the building elements composition.

### 3. Hollow Concrete Block Buildings

This type of buildings is widely spread in West Bank villages and Gaza Strip territories and to a small scale in West Bank cities. It is commonly used in the construction of residential and public buildings. Reinforced concrete columns are constructed and then building of 20 cm thick hollow concrete blocks between the columns to establish the external walls.

Hollow Concrete Blocks are mainly the materials used for external walls, reinforced concrete used for columns and beams, and reinforced concrete and hollow concrete blocks used for slabs and roofs. There are different compositions which were discussed in the part of building elements.

The thermal behavior of hollow concrete block is better than concrete and stone because of higher % of voids in them, but still the small thickness affect negatively the thermal behavior.
4. Steel Buildings

This type of buildings is not familiar in West Bank and Gaza, so it will be discussed briefly. It is used for industrial buildings to a very small scale; there are few buildings in which it is used. The materials used in steel buildings are; steel for columns and beams; stone, concrete, and blocks for external walls; concrete and steel for slabs.

The construction of foundation in this type of building is the same as in the previous types of buildings, also the construction of the ground floor slabs. This type of buildings is constructed by using steel I-beam columns instead of concrete columns, then the steel I-beams or steel trusses are fixed to the columns, and finally the slabs are constructed from concrete on the steel beams.

Regarding walls, the external walls are constructed between the columns and all the alternatives of adding layers for insulation which are discussed in the previous types of buildings can be used in this type of building for the external walls and slabs; also all types of internal walls used in other types of buildings can be used in steel buildings.
3.2 Elements Under Ground

3.2.1 Foundations

There are different types of foundations used in West Bank and Gaza strip according to soil type and bearing capacity and to loads of the building. The foundations usually consist of reinforced concrete with different thickness, lengths, and widths. The main types used are:

1. Spread footings.
2. Continuous footings.
3. Mat foundations.
4. Pile foundations.

3.2.2 Columns under ground floor slab (Columns Necks)

The columns under ground floor slab consist of reinforced concrete with different cross sections according to the design loads of the building.

3.2.3 Beams under ground floor slab (Tie Beams)

The beams under ground floor slab consist of reinforced concrete with different cross sections according to the design loads of the building.

3.2.4 Walls under ground floor slab

The walls under ground floor slab consist of reinforced concrete if they are shear walls (bearing walls) or from plain concrete if they are not loaded (non-bearing walls).

Regarding the parts from 3.2.1 to 3.2.4; there are some techniques of construction used in West Bank and Gaza strip for water insulation by adding different types of layers to them. The familiar techniques are:

- Adding Bitumen (Asphalt) insulation layer of 0.5 cm thick.
- Adding Bitumen (Asphalt) insulation layer of 0.5 cm and Polystyrene (Kalkal) layer of (2-3) cm thick.
- Adding Bitumen (Asphalt) insulation layer of 0.5 cm and then hollow concrete block layer of (7) cm thick.
- The composition of all layers in past 3 techniques; Bitumen, Polystyrene, and then Hollow Concrete Blocks.
3.3 Ground Floor Slabs

Ground floor slabs are constructed from 10cm thick layer of reinforced concrete which is installed on a 15-20 cm thick compacted base coarse layer; as explained in (Figure 1)

There are some techniques used in West Bank and Gaza Strip by adding other layers to the ground floor slabs for water insulation which are:

- Adding plastic sheets (polythene) over the compacted base coarse before installing the concrete; as explained in (Figure 2)
- Adding bitumen (asphalt) layer 0.5cm thick over concrete slab, as explained in (Figure 3)

![Figure 3](image)

- The combination of the past two methods, by adding plastic sheets (polythene) over the compacted base coarse before installing the concrete and adding bitumen (asphalt) layer 0.5cm thick over concrete slab; as explained in (Figure 4)

![Figure 4](image)
3.4 Slabs and Roofs

In West Bank and Gaza Strip there are main types of slabs and roofs, which are:

- 15-20cm thick solid reinforced concrete slabs; as explained in Figure 5

![Figure 5](image)

- 25-30cm thick hollow concrete block slabs (Ribbed Slabs) with 17-24cm thick hollow concrete blocks covered by 6-8cm thick reinforced concrete layer; as explained in Figure 6

![Figure 6](image)
• Same as in (Figure 6) using Eton blocks instead of hollow concrete blocks.

For insulation of the roof slabs, there are different techniques used in West Bank, which are:

• Adding a layer of plain concrete (falling screed) 8cm average thickness, for both types of solid slabs and ribbed slabs; as explained in (Figure 7 & 8)

![Figure 7](image1)

**Figure 7**

![Figure 8](image2)

**Figure 8**
• Adding a layer of plain concrete (falling screed) and then a layer of bitumen (asphalt) 0.5cm thick, for both types of solid and ribbed slabs; as explained in (Figure 9 & 10)

Figure 9

Figure 10
Pitched roofing (Marseille tiles)

This type of roofing exists in West Bank and Gaza Strip, the mountain areas (rural urban) and the coastal areas. This type of roofing is suitable to resist all the extremes of weather conditions in West Bank and Gaza Strip, also it is stable enough to resist from being torn off or penetrating water. This type of roofing shows negative thermal performance, this type was meant to be a good damp insulator and not heat insulator. Thus doesn’t act as a good insulation from the outside effects, on the contrary, it absorbs the heat and radiates it to the inside. Broken tiles, bad joints, gutter lose and rotting or missing tiles allow for water penetration to the roof structure and then rotting the wood causing the structure to fall. The red tiles pitched roofs were used for all types of buildings, the red tiles pitched roofs date to 19th when the I-beam with concrete slab was introduced as a frame method. Hence, the red roof was one of protection methods for such a frame, and continued to be used now. The red tiles pitched roofs are contemporary technique done in the same traditional way with same trades. The tiles are mostly imported from Italy and they have the possibility to be nailed and not tied as before to prevent it from being blown by the wind. Also, these roofs are associated with different kinds of frames such as reinforced concrete slab and steel trusses for different types of buildings.
3.5 Columns & Beams

The columns of the building are mainly consist from reinforced concrete with different cross sections according to loads of the building. They are mainly transfers the loads to the foundations.
They are considered as apart of the external walls regarding the insulation aspect.
The beams are mainly consist from reinforced concrete with different cross sections according to loads calculated for the building design and to the spans between the columns. They are considered as apart of the slabs regarding the insulation aspect.
In Steel Buildings the columns and beams are from steel I-beams and trusses with different cross sections according to loads of the building.

3.6 Walls

3.6.1 External Walls

1. Stone - External Walls

Stones, concrete, and hollow concrete blocks are used as the construction materials. Stone hardness varies depending on the stone origin and the depth of stone strata, the thickness of wall is around 30 cm.

This type of walls is used for all types of buildings. In stone walls construction, which consist of stone and concrete or stone and hollow concrete blocks, there are two main techniques used in West Bank and Gaza strip which are:

- Stone Building: Building stone plates of 7 cm thick layer and then casting 22 cm thick concrete layer behind the stone, as shown in (Figure 11)
• Stone Cladding: Constructing reinforced concrete columns then casting 20 cm thick concrete layer or building 20 cm thick hollow concrete block layer between columns and finally cladding walls with stone plates of 7 cm thick with fine concrete of 5 cm thick in between.

There are different techniques used for constructing other layers from the inside face of the walls for insulation which are:

• Adding a layer of 7cm thick hollow concrete blocks; as shown in (Figure 12)
• Adding a layer of 7cm thick hollow concrete blocks with 5cm cavity in between; as shown in (Figure 13)

![Figure 13](image13.png)

• Adding a layer of 7cm thick hollow concrete blocks with 2-3cm thick polystyrene (kalkal) plats layer in between; as shown in (Figure 14)

![Figure 14](image14.png)
Concrete is produced in four basic forms, each with unique applications and properties.

1. Ready mixed concrete, by far the most common form, accounts for nearly three-fourths of all concrete. It's batched at local plants for delivery in the familiar trucks with revolving drums.

2. Precast concrete products are cast in a factory setting. These products benefit from tight quality control achievable at a production plant. Precast products range from concrete bricks and paving stones to bridge girders, structural components, and panels for cladding.

3. Concrete masonry, another type of manufactured concrete, may be best known for its conventional 8 x 8 x 16-inch block. Today's masonry units can be molded into a wealth of shapes, configurations, colors, and textures to serve an infinite spectrum of building applications and architectural needs.

4. Cement-based materials represent products that defy the label of "concrete," yet share many of its qualities. Conventional materials in this category include mortar, grout, and terrazzo. Soil-cement and roller-compacted concrete—"cousins" of concrete—are used for pavements and dams. Other products in this category include flowable fill and cement-treated bases. A new generation of advanced products incorporates fibers and special aggregate to create roofing tiles, shake shingles, lap siding, and countertops. And an emerging market is the use of cement to treat and stabilize waste.

In concrete walls construction, which consists of reinforced concrete columns and concrete walls, the construction is done by constructing columns and then casting concrete layer of 20-25cm thick between them; as shown in (Figure 16)
For insulation, there are different techniques used for constructing other layers from the inside face of the walls which are:

- Adding a layer of 7cm thick hollow concrete blocks; as shown in (Figure 17)

![Figure 17](image)

- Adding a layer of 7cm thick hollow concrete blocks with 5cm cavity in between; as shown in (Figure 18)

![Figure 18](image)
• Adding a layer of 7cm thick hollow concrete blocks with 2-3cm thick polystyrene (kalkal) plats layer in between; as shown in (Figure 19)

Figure 19

Pre cast concrete products can be use for external walls which is divided into two general categories

1. Facing for exterior or interior walls of buildings
   The pre cast concrete used for facing buildings usually has a textured or polished surface with granite, quartz, and vitreous ceramics materials of specific color selected for the job.

2. Miscellaneous items for masonry work such as stair treads and coping
   Pre cast concrete is widely used in hotels. The concrete provides superior fire resistance and sound control for the individual units.

There are two types of pre cast products. Standard products such as beams, decks, are shaped in one way and used over and over again. The other type of product is a specialty product, designed especially for the building, bridge, or structure where it will be used.

Most pre cast companies have their own carpentry shops where skilled workers create forms for the many specialty pre cast products available. Architectural concrete is often cast specially for each new project.

3. Hollow Concrete Block- External Walls

Concrete masonry has become a standard building material. Concrete block is a masonry unit, usually with single or multiple hollows available solid, made of following ingredient:
water, Portland cement, blended cements and various types of aggregate such as sand, gravel, crushed stone. Aggregates are generally designated as fine or coarse.

There are three types of concrete blocks
1. Hollow load bearing
2. Hollow non-load –bearing
3. Solid load bearing

In hollow concrete block walls construction, the reinforced concrete columns are constructed and then the 20cm thick hollow concrete block layer is build between the columns ; as shown in (Figure 21)

![Diagram of hollow concrete block wall](image1)

For insulation, there are different techniques used for constructing other layers from the inside face of the walls which are:
- Adding a layer of 7cm thick hollow concrete blocks with 5cm cavity in between; as shown in (Figure 22 )

![Diagram of insulation layers](image2)
• Adding a layer of 7cm thick hollow concrete blocks with 2-3cm thick polystyrene (kalkal) plats layer in between; as shown in (Figure 23)

![Figure 23]

**NOTE 1**

In all figures above:

1. Dimensions are in cm.
2. H.C.B = Hollow Concrete Block
3. R.C = Reinforced Concrete.
4. U = Thermal Transmittance (W/m²·C)
5. Insulation Material is Polystyrene, Randoban, Fiberglass.
6. Plaster layers are included in calculations of U-values.
7. U-value for the compositions calculated according to the equation:

\[ U = \frac{1}{R_a}, \quad R_a = R_{so} + R_{si} + \sum R_i \]

Ra= Total thermal resistance for the composition
Rso= The outside surface thermal resistance
Rsi= The inside surface thermal resistance
Ri= The thermal resistance of each layer of the composition
U= The thermal transmittance of the composition
R – Units (m²·C/w)
U – Units (w/m²·C)

**NOTE 2**

The thermal conductivity values used in the calculations are as follows:

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thermal Conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Plaster</td>
<td>1.2</td>
</tr>
<tr>
<td>Concrete</td>
<td>1.75</td>
</tr>
<tr>
<td>Stone</td>
<td>2.2</td>
</tr>
<tr>
<td>Falling Screed</td>
<td>1.2</td>
</tr>
<tr>
<td>H.C.B-for walls</td>
<td>0.75</td>
</tr>
<tr>
<td>H.C.B-for slabs&amp;roofs</td>
<td>0.95</td>
</tr>
<tr>
<td>Bitumen (Asphalt)</td>
<td>0.18</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>0.04</td>
</tr>
</tbody>
</table>

**3.6.2 Internal Walls**

The internal walls are constructed by using different materials, the familiar types of them in West Bank and Gaza Strip are:

- Concrete walls 15-20cm thick.
- Hollow concrete block walls 10-15cm thick.
  - There are other types used to a small scale, which are:
    - Etong blocks walls 10-15cm thick.
    - Gypsum walls 5-15cm thick.

**3.7 Opening (doors, windows, and skylights)**

These parts are constructed according to the advice of the architect who decides the location, size, and orientation of them.
They must be fixed perfectly to prevent air leakage and water leakage to and from the envelope of the building. This is done by using silicone, rubber, rubber water stops … etc. Also by using double glaze windows and insulated sections.

**3.8 Finishing**

- For stone buildings, the external walls are finished by pointing from out side (stone face). From inside; the walls and the slabs are rendered by 2cm thick layer of ordinary cement plaster and then painted.
For concrete and block buildings, the external walls are rendered by 2cm thick layer of ordinary cement plaster from the two faces of the walls in West Bank. The same is used in Gaza Strip for the inside face of the walls and by rendering Shabriz plaster from the outside of the walls.

The internal walls are rendered by 2cm thick layer of ordinary cement plaster from the both sides and then painted.

The floors are finished by adding a layer of tiles.

### 3.9 Joints

Regarding the joints in the building; there is a need for high accuracy insulation construction and in cases of insulation, the insulation must be done to prevent thermal bridges; so as; to achieve the best thermal behavior. As a main example of the joints, when two elements of the building are connected to each other like the connection between the slabs and the walls.
EVALUATION

Referring to the information in this report, the types of buildings in West Bank and Gaza Strip are divided to Traditional and Contemporary buildings. The construction techniques used in traditional buildings depends on traditional materials which are with good thermal properties and the compositions of them in which the walls and the slabs are thick; these properties gives the result of low thermal transmittance which means thermal comfort inside the buildings. The construction techniques used in contemporary buildings depends on the new materials as stone and concrete and the compositions of them in which the walls and slabs thickness are small; these properties gives the result of high thermal transmittance which affects negatively the thermal comfort inside the buildings. So, the techniques need the development process according to thermal behavior and thermal calculations. As we observe in the neighboring countries like Jordan, there are some techniques used and reported in research papers about energy construction techniques. The following technique which is "Polystyrene Block Insulated construction Techniques" may be considered as an alternative solution to the used techniques in West Bank and Gaza Strip.

Alternative Example

"Polystyrene Blocks Insulated Construction Techniques"

There were many studies and research in many countries about developing construction techniques to achieve the aim of energy saving in the building sector, this technique is used at the beginning of eighties in Europe and Latin America, also it is used at the end of eighties in Jordan and some Arabian countries. The walls are consist of hollow blocks from polystyrene which acts as supports, then the concrete is installed inside of them to construct the bearing walls which transfers the vertical loads to the strip footings. Columns from reinforced concrete are constructed at the corners and where needed to support the walls. The slabs are consist from beams which are pre-stressed or pre-cast, between them hollow polystyrene blocks are laid, and then reinforced concrete (7cm thick) installed on them to complete the slab construction. (Ø8mm 20*20cm) steel mesh is added to the polystyrene wall by fixing the steel mesh and stone panels using steel clamps and steel fasteners every 50cm and then installing mortar in between. The walls can be only rendered with plaster by adding galvanized wire mesh to the polystyrene wall and then plastered with cement mix. For the internal walls, they can be rendered with plaster as in the case of the external walls or by gypsum plates fixing to the walls. There is an important note which is, in this technique there is a possibility to combine other techniques for some elements, as an example, reinforced concrete beams construction on site instead of using pre-cast or pre-stressed concrete beams.

Advantages of this Techniques
• Easy and fast in working.
• Less use of wood frame work.
• Reducing dead loads.
• High efficiency of thermal insulation.

CONCLUSION

According to this report, we can observe that the construction techniques used in West Bank and Gaza Strip does not differ too much from each other because they depend on the same materials as stone, blocks, and concrete and because there is no development to these techniques.

As mentioned in the report, some techniques of construction is used by adding layers of Bitumen (Asphalt) or polystyrene (kalkal); but this is done for water insulation and not for thermal because of low engineering experience about thermal behavior of building elements with adding thermal insulation materials to the compositions.

As a result, development of construction techniques must take place in West Bank and Gaza strip by using insulation materials depending on thermal calculations to achieve reducing energy consumption in the building sector. For that this report will be considered as initial information for creating alternative solutions to match with the guide lines and regulations of the Energy Building Codes.
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7. KHADER AKAWI (Thermal Insulation Guide Lines), Building Research Center, RSS, Jordan, 1995

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9. KAREEM KHAMMASH (Building Design For Climatic Control and Thermal Comfort In Low Cost Houses), Jordan, 1990
In addition, it is not only the designer's task to know all this but it is also important that people who are going to use these buildings are conscious from an energy and thermal comfort point of