



## **THE ROLL OF SOIL IN ARCHITECTURE**

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### **Abstract**

In this article, soil and its developing stages in the framework of traditional and modern buildings are investigated. The tradition of building construction is a dynamic outcome where structure builders consciously yet gradually and progressively put their efforts into action for the development and improvement of their methods and shapes. If the new structures be built with modern stuff and materials they will be of more favorable and accepted, but there should be no reason to hesitate in finding innovative solutions in using traditional building materials such as soil, rocks and pottery clay suitable in certain cases. The use of soil in housing projects was not only a prevalent fashion in all over the world but also in Iran since ancient times. Masons and architects knew the significance role that this substance plays in building construction. However, people are today more habituated to other types of environments involving concrete and metal buildings and thus demands materials according to time requirements that are also abundantly available and easily acquirable. Experts as well as lay people have become rather ignorant and estranged from a true, beautiful humanistic lifestyle based on human interests and values. But if they can be exposed to such lifestyle, they will surely become attracted. The answer to the question that why soil is used as an element of value in buildings, should be sought in the facts and premises determining its manifold applications. The main focus of this article is to present these qualities as well as the innovative methods with which many problems in construction can be solved.

**Keyword:** *Architecture, Soil, Structure building, Traditional, Modern, Methods*

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### **Introduction**

The scholars around the world have carried out great researches on the nature of soil and found characteristics in this substance which make it useful in building construction. The global statistic has revealed that 1/3<sup>rd</sup> of the world population live in houses made of soil. One can find a treasure of soil-made buildings in Iran, England, Scotland, Yemen, etc.

### **2. Literature review**

#### **2.1. Why “Soil” is regarded a valuable element in masonry?**

1-Natural elements including earth, air, fire and water are considered the four essential elements of the universe. The natural forms produced by these four elements can be analogous to the primary nature and attributes of Man, his innate characteristics such as Divine homesickness, the need to love and to be loved the yearning for the reciprocity of compassion and so forth. For example, the arches and domes which were made of soil thousands years ago in the rural areas of Iran were based upon the discovery Man had made in the area of forces. Examining the opposition of the force of pressure against gravity and focusing on the issue of softening or reducing the massive weight in relation to

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the arched levels, masons realized that they could produce mud-bricks with soil to be later brought into a geometric shape to bridge the gap between the two walls and shaping it into the form of a roof.

2-The environmentally friendly application of soil is a feature that prevents the detrimental spread of the carbon dioxide and pollution in the environment. Construction is an industry considered to be one of the major sources of producing carbon and other hazardous waste.

3-The relatively low mechanical ability of soil gives the user the favorable advantages of availability and along with low cost. The process of digging and collecting soil in the close vicinity of the project is also another advantage to be taken into consideration.

4- As a major component of a building, soil enjoys the properties of durability and sustenance.

5-Another advantageous attribution of soil is its insulating capability against heat and cold. It doesn't mix with any harmful substance. Soil preserves the cool air in the summer and the warm air in the winter by balancing the layers of humid atmosphere inside the building.

6-None of the traditional materials whether it be soil, lime, Sarooj, or pottery clay and so forth were worthless since each and every one of them is an essential component for Man's physical, and spiritual health.

7-Soil can function as a resisting force against the forces.

8-Soil can play the role of an insulating agent in a building as it adjusts the humidity and resist to fire.

9-Soil can save energy in a building. For example, a mud wall with a thickness of 40 cm can create all the necessary conditions for heating insulation with the advantage of preserving the homogeneous in the structure. In comparing a structure made of soil with those made of concrete or brick, there is a possibility that the energy spent 20 times higher only for production, transportation and unloading the materials in the later.

10-Soil can become acoustic and insulating. It has the capability of adjusting humidity as well as the interior air along with preserving its quality. If soil be used in a proper manner it is perdurable and aesthetically pleasant.

11-At the end of the structure's life time, the materials will easily crumble and fall back onto the ground without polluting the environment.

12-Soil has various applications in construction such as building walls, floors, roofs, and other parts of a structure. (Figure 1, 2)

## 2.2. The provision of soil for construction purposes

In many cases, a structure can be built with the soil that has been excavated from the substrates of the building and from the same location. The excavated soil has to be examined, evaluated and measured in terms of quality and quantity, since its material and quality vary depending on from what strata it is excavated. When there is not enough amount of soil available at the location, it can be supplied and provided from other land developing areas. (Figure No. 3)

A source of providing soil from the same location is more preferable, profitable and convenient since it eliminates the costly expenses of transportation, reduces the amount of pollution and saves energy.

## 2.3. The application of the soil excavated from local substrates and its characteristics

There are many points to be considered in building construction using soil with respect to certain aspects such as the quality of the existing soil, the methods with which it is going to be used, and the way it functions in any condition, with a few exceptions, soil with good quality for building purposes is found in the substrates of earth. The soil of the upper strata is not suitable for construction since it contains perishable organic substances. Soil can be examined and stratified with respect to the composite and the proportion of pottery clay, sand and pebbles it contains. The existing soil is the determining factor of the most suitable and feasible method of building construction. Nevertheless, the soil

compounds can be altered depending upon its suitability for specific conditions. It is important to create a balance between the quantity of pottery clay and the amount of other types of soil in building construction. For example, the "crushed method" used for the types of soil containing less than 10% of pottery clay is the best method since these types of soil have higher proportions of sands and pebbles but a mud walls with heavier soil, and higher proportion of humidity (between 15 and 70%) can be more effective depending upon the nature a particular application.

## 3. Materials and Methods

### 3.1. Methods used in the mud-brick walls

The historical method of building walls made of mud-with a smooth consistency is done with a mixture of soil and pug. Mud wall is made of a type of dampened pottery clay which is prepared by kneading and free from filling materials such as sand, pebbles, and pug. This substance is the main element in the structure which shapes the building. When it is still in a paste form it can be shaped into a ball, clod, cylindrical or a flattened surface which will dry in place without the need to be moved into a particular area. The lined up pieces have to go through the process of drying and setting before the next row is placed above them. This will prevent the row below from falling apart. Although the process of putting the mud-brick pieces together facilitates the placement of the new ones, it still takes a long time to get completed. Therefore, as the work progresses, a checkered-like pattern will be produced. Different from the mud-brick techniques applied in the European countries up to the beginning of the last century, the process in Middle East was done without the wooden mold; molding would highly increase the possibility of adhesion through compaction which is produced by crushing, reducing the amount of water for the process of kneading and diminishing its effect. Dampness is one of the major elements in the consolidation of the mud bricks in construction. The word "chineh" (stratum) is often confused with the word "Kah-gel" (cob, or combination of mud and hay). But mud is only used to cover and preserve a mud-built structure (chineh, adobe). The soil which is used for the purpose of preparing cob is actually no different than that of used in stratum, but the soil used in cob is mixed with a large amount of hay remnants or plants and even animal hairs such as goat. In addition to having a filling role, hay prevents the excess of Cob. (The excessiveness of cob is due to the sufficient amount of water needed for the mixture to become workable with trowel.) Hay is a real amateur and gives Cob a fiber texture. In order to make the adhesion possible especially when it is not as thick, hay is essential. It should be noted that the purpose of troweling is to smooth and spread out the hay on the surface in opposition to the vertical, bending forces against which hay is very resistant. Hay has also a significant resistance against the mechanical action of

abrading elements. We can refer to Southern Yemen as an example (in the south of Arabian Peninsula) where construction is done using mud and adobe. (Figure No. 4)

### 3.2. Crushed soil method

In this method, we consider the crushed-soil wall as a large concentrated block because it is much larger than a large-pressed block of soil directly built on a retaining wall. The construction of such walls in an appropriate manner is difficult. But if constructed properly, it will prevent from the waste of labor and efforts, as it doesn't require to collect and carry multitudes of smaller blocks to install them in the wall. It is possible to build a wall made of crushed soil as well as a wall with pressed blocks. In order to provide a suitable crushed soil, the most significant issue after finding a soil with good quality is to find a mold for crushing and then with the help of different hammers with different thicknesses to crush the soil. (Figure 5&6) In construction with crushed soil method, the first portions which should be crushed are the corners of the building situated on the retaining wall. We have to pay special attention and make sure that the corners of the wall are in vertical alignment, otherwise there will be no remedial solution to a wall which is built crookedly. We need to watch over or guard all the parts of the newly constructed wall until the time that it becomes fully resistant and stable especially during the night when it is raining. We need to cover the whole wall with matting, a thick fabric, or a water-proof paper. These protective shields are so vital especially around the top because the damages happen in that area. Some types of soil, particularly the kind which contains sand might have a tendency to crumble when the latter portion of the wall which was previously raised high gets crushed. In case of such situation, we wait till the lower part becomes resistant enough to prevent such incident. Hence, we can proceed with the action of crushing when we feel assured that the top of each portion of the wall is stable without any sign of crack or the possibility of crumbling. Before crushing a new area, we have to carve out the finished part of the lower section for about 1 centimeter with either a sharp pointed wood or metal. If the finished portion is dry, we need to dampen it a little to speed up the process of adhesion. The barbed-wires, woven wires or small armatures might be used to arm the walls which are constructed from crushed soil. If the building is located in an area which is earthquake or storm-prone and it is made of stabilized soil, this method is so useful. The technique used to arm the walls which are made of unstable soil does not have the same effect as it has on the stabilized soil. The presence of armatures around the opening of the doors and windows will always give stability to a wall. To arm them is usually beneficial in the prevention of detrimental cracks in these areas. Crushed soil is similar to a geological outcome which produces sedimentary rocks. The walls which are built in this method can also have the hard and durable

qualities of the sand as well as being the carrier of heavy weights which are often not smeared. In comparison with the mud walls, the crushed-soil walls have more construction capacity and potentiality, and are exposed

to less contraction. Crushed soil is more suitable to construct the floor.

### 3.3. The method of soil-brick or Adobe

This method of construction contains the use of several methods, ranging from the hand-made adobe to factory-mass produced clay bricks. The size of each unit differs depending on the location and the condition. The substrata clay soil containing water or fibers is similar in thickness to the mixed mud before it is poured into a mold to get shaped. The bricks prior to use are exposed to air to dry and then are placed on a bed. Their surface can be protected with a lime or soil cover. Drying the bricks without fire can take a slow process without the presence of any source of heat. The bricks, while still wet should be protected against freezing when it is very cold. The density of bricks, depending on its role varies. The fiber bricks as well as the soil bricks are heat resistant. (Figure 7 & 8) The handmade bricks are easily made. Therefore, even non-skilled people can make them. They can be mass-produced depending on the factors of time and place. The required equipment varies and can range from a simple wooden mold usable in a non-advanced method to a more sophisticated one including fully mechanized bricks for the commercial purposes.

### 3.4. The method of compressed-soil block

This type of block is an outcome of a manually-compressed procedure through which the soil inside the mold undergoes an intense pressure by hands. The blocks are produced in a standard size. The type of soil needed in this method is like crushed soil. The production of manually-compressed blocks takes a slower pace, (The average number of blocks that each person can produce is between 150-200 blocks) and the time of drying is longer compared with the damp molded-bricks. The blocks can be immediately stacked which is an advantage in itself because it eliminates the need for a space to dry or to store them.

### 3.5. The crushed soil

This method is performed by crushing and dampening the connected walls (with an optimum damp) inside a sturdy wooden mold. When the lower section of the wall is compacted, the molds are moved upward or to the sides, a process which is repeated till the completion of the wall. The act of crushing is done either by hands or hammer which in either case the soil should be crushed to the state that is fully compacted and sturdy. The compacted soil is more durable than the other types of processed soil. This is revealed in the buildings which have lived for many centuries. On the other hand, this

method will eliminate the need for the skilled workers, as anybody can do it.

### 3.5.1. The defects of the crushed soil

- 1- It is not easy to provide and appropriately mix.
- 2- The procedure of making and producing the sturdy wooden molds proves costly requiring significant attention and precision.
- 3- If the mixture is not properly prepared, the soil contraction causes it to crack.
- 4- The amount of water to dampen the soil should be measured and controlled with considerable attention.
- 5- The cases in which the uniform grading is eliminated in the wall and the proper compaction is lacking the surface will not look pleasant but using paint or the like will make it look pleasing.

### 3.6. The advantages of using the soil

- 1- Soil is humble with no pomposity and arrogance.
  - 2- It changes into forms and shapes under the ground and evolves into places of residence over the ground.
  - 3- The outcome of a crushed soil is open and adaptable to any delicate work.
  - 4- The construction of plane structural soil without any cosmetic addition on the façade is possible.
  - 5- The walls constructed by making consecutive (woven) layers will automatically incorporate an ornamental aspect.
  - 6- It is possible to benefit from all the characteristics of soil as an element in construction.
  - 7- The function of high temperature in soil allows the walls to breath.
  - 8- The reinforcement and reformation of the traditional techniques are possible through the reinforcement of its structural ability and potentiality.
  - 9- Soil adapts with the inevitable laws of ecology and environment.
  - 10- Crushed soil as a constructional material is much better responsive to the hardest environmental condition in a favorable environment.
  - 11- Soil is a cost effective material abundantly found in nature.
  - 12- Soil is a great sound insulator.
  - 13- Soil has the advantages of a homogeneous structure.
  - 14- The recognition of the old constructional materials is evaluated and measured through experience, and attention on the principles of creativity.
  - 15- Considering the technology of production and performance as well as creativity and innovation will create a ground for the abilities and opportunities to discover new materials.
- The architects and designers who already have pioneered their styles and ideas are to evaluate and foresee the needs of the future of their society to be able to invent new methods of material application in various projects through experimentation and suggestion in an innovative manner.

### 3.7. Cutting soil into stone-looking blocks from suitable mines

We have always believed that the natural and virgin soil existing in the substrates of the earth which have gone through the natural process of compaction is much better and more resistant than the crushed soil. The question posed now is that despite the presence of the advanced technology, and the feasibility of cutting and carving the soil of the deeper substrates of the earth into cubical and then pulling them out just like the pre-fabricated walls to be heated or injected with adhesive substances to stick to one another, and while we know that the soil has a good capacity for adhesion due to the due to its high Silica content, why it is not adopted it in construction. (Figure No.10) Even though the silicate melts and flows freely in a high degree temperature of 1200°, it manifests its quality of adhesion in much lower degrees. One of the characteristics of the clay soil is that when it is exposed to water it becomes sticky but as the amount of water increases it becomes flowing which can be poured into the molds of the walls, then with proper molding and the injection of soil in a compacted form, it is heated and dried until the desired compacted soil is obtained. This procedure can be followed by shooting the particles of soil onto the walls to reinforce the condition. This whole process will create a quality of humidity isolation at the deep layer while causing cohesion and smoothness on the surface,

## 4. Results

### 4.1. The methods of application:

A: The method similar to that of Gabion's in the temporary and permanent walls:

The main hypothesis:

The main hypothesis applied in this section is the creation of a kind of metal or plastic wire mesh. The size of the inside enmeshed portion is smaller than a certain amount, so that the soil cannot easily pass through. I have used the adhesive to serve another purpose. First the wire mesh was smeared with the sticky substance, and then the soil was poured over it. The sticky substance should be absorbable and stick to the soil till it becomes satisfactorily stabilized.

Explanations:

As in Gabion's style that the natural rocks are fixed, the goal was to fix the soil by using cells or compartments of different shapes. The soil will take the shape of those cells therefore, we come across bulks placed next to each other like the light bricks with defined dimensions to shape the main desired form. Since the form of the soil can be changed easily, it is only necessary to build the wire mesh and its compartments in different shapes and dimensions to be filled then with soil and be stacked in the model which can be used in any structural work.

Some of the attractive features of this style are the speed of administration and the low cost of the construction materials but the disadvantage comes along with tall buildings which need an especial reinforcement and cannot be done without this especial treatment. These compartments are not connected in a special manner. Two methods of connection are suggested:

1-Using metal roots as an anchorage in between the vertical and horizontal pieces to create the maximum strength and evenness.

2- Using the welded wires. The main advantage in this case is that the welded wires in armature, despite lacking strength individually, can become very strong and distribute the force when they are in large numbers.

Easy installation, supplying construction materials from the same location where the project is located, and time effectiveness are the other advantages of this method to be mentioned here. Surely, all these advantages depend upon the skill which can minimize the time spent and maximize the quality.

In Iran, there is always access to soil with a good quality, therefore this material can be used in the areas where the projects deal with light and short structures.

Another point to be mentioned here is that the structure might relatively have a larger skeleton than other construction materials, a feature in this method that is related to gravity. In order to better protect the project against climatic erosion and natural disasters, it is always wiser to use a thin layer of insulation to reinforce the durability of the construction.

B: Method similar to "Shot Crete" to create hard shell in a fast pace

Main hypothesis: There exist a non-synthetic, natural or organic substance containing cohesive ingredients that produces an acceptable degree of resistance and stability after getting dried and become consolidated. The main idea dawned on me through "Lui vegetation" which is said to be one of the principle components of "Sarooj" in the past. In addition to be an insulator, this substance reinforces the resistance of the soil to a desirable degree.

Explanations:

In order to introduce this method, first some points should be explained about shot Crete. There are two methods of shot Crete application including wet and dry known as wet mix and dry mix. In this article, the dry mix is our subject of discussion. Obviously, there is no need to explain about the wet mix which by the way is very similar to the dry mix method. In dry shot Crete method, the dry and non-dampened sand concrete with a determined design are blended and placed in a compressor or delivery equipment. The material is pumped to pass through a hose to reach nuzzle where it is mixed with a percentage of water to be shot onto the receiving surface. This material is consolidated rapidly and has a good degree of resistance which immediately replaces the side resistance of the soil lost in the process. Another point to be mentioned in here is that this

material has a potent adhesive quality to stick to the soil and function very well in the temporary reinforcement.

Considering the above mentioned explanations, it is concluded that using an appropriate uniform grading is better to replace concrete with natural adhesive material and replace sand with soil because this method has several advantages:

1- Easy access to materials.

2- Speed of administration.

3- The use of natural and organic materials towards the stabilization of improvement and so forth.

#### 4.1.1. A general description of the method:

The procedure includes first preparing a surface of soil. This surface then will be pre-determined into desirable dimensions by molds followed by an innovative method of shot Crete, (a method which is already explained) which covers the surface. The outcome will be used as a structural elements used in larger dimension. Since we have used molds, it is obvious that we can accommodate and put all the related details in it. In other words, while in use, the consumer is not limited to have a specific shape. More importantly, due to the fact that it is environmentally-friendly with no detriment to the ecology, it is a beneficial method towards conserving the environment and a good factor in durability and stabilization.

C: The use of soil adhesive and the temperature of the furnace:

This method enjoys a more coalescent characteristic focusing on creating a sturdy and resistant structure without using other skeletal and structural elements prevalent in construction.

The main hypothesis:

The existence of a material to be used as an adhesive, which is here named "soil adhesive", offering characteristic qualities in producing resistance when it is exposed to heat will give a premise to learn that it is only an additive element at the beginning of the process but as it gets exposed to heat and the process furthers along, this substance hardens up and gains a favorable degree of resistance.

Explanations:

In this method, we first mix soil, water and the soil adhesive. We pour the mixture into the pre-built large molds, and then we place them in the specific furnaces to bake. The outcome is a hard and heavy substance which can be used in all constructional projects. We know that this is not the only way to bake them. Baking the mixture is also possible with an ordinary furnace or specific torches to reach the same result. Some points should be noted in this method. The most important one is the amount of the added material and the degree of the heat. For example, does it gain more resistance if the temperature is increased or it still loses resistance when the temperature increases and exceeds in amount?

D: The method of reinforcing the soil with the power of pressure without any addition

As it is perceived by the title, the main goal of this method is to acquire a totally compacted earthy substance without any additive, which is firmly durable and with a resisting ability like that of a “natural conglomerate” with the minimal amount of erosion.

The main hypothesis:

The hypothesis in this method which is taken from conglomerate is being able to deliver pressuring force and gravity mass to the soil so it can acquire a rock-like state.

The reason behind selecting this method:

In traditional and experimental form, we have witnessed that all the manual, water and wind-mill rocks are from the same gender of conglomerate stone,

Explanations:

Soil is the prime material to be used so it has to have several uniform gradings with optimal wetness in order that the process of uniform grading can be performed by the heavy compactors. The soil is first compacted to produce the form of mosaics and reach an appropriate resistance. The compacted soil with various sections can bond with one another to create an organized and neat structure. Other methods of reinforcement have merely the capacity to reinforce the soil but they don't change the quality of it. Considering the temperature that exists on the substrates of earth originated from different layers and shells. It is concluded that the heat is required to reach a better sustenance; then the compactors need to be equipped with heat, the result of which is that the product will be better sustained and stabilized. Soil is flexible towards different forms and quality due to the sand and pottery clay content. So it is easy to be compacted and shaped. (Figure No. 11)

## 5. Discussion

### 5.1. Suggested techniques of construction with earthy masonry

Currently, most of the construction materials are originated from earth therefore we can produce many materials from earth.

#### 5.1.1. The use of local or indigenous soil:

Providing a series of bulky thermometry blocks to be connected to or tied up with one another, just like the Children's toys called Lego blocks with the difference that by filling these pieces with earth we can create reinforcement to sustain the stability of the structure. Using these hard plastic blocks (P.V.C) is greatly suggested. Although light, they are so easy to transport, cost effective and right for the desired designs. Building a series of pre-fabricated pieces, just like the pre-fabricated concrete roofs, walls can be made with a membranes or tongue-like features to be either interlocked with one another or by passing a series of armatures through they become firmly connected. This interlocking technique with connecting armature can be used in roofs. (Figure No. 12).

#### 5.1.2. The use of plastic P.V.C tubes or natural reeds

In this method, a series of hollow tubes twisted tightly around one another and coated with mud or natural reeds can be used instead of wide mud-brick walls. These tubes or reeds are similar to the armatures that can sustain the stability of the structures and contribute to more lightness of the structure while acting as an insulating factor for the interior structure. (Figure No.13)

#### 5.1.3. The application of adhesive materials

The adhesive material which can stick the particles of soil with crystal color is an important factor. The mixture of soil and the adhesive are poured into large molds with particular sized to convert the soil into a hard substance. We can also take benefit from the crystal-clarity of this adhesive material which creates clear holes on the body of the building. In other words, this process creates not only a new structure material but also makes the inside of the building brighter.

#### 5.1.4. Machine made or compressed earth blocks:

Recently, several simple, inexpensive machineries have been designed and built to compress and produce molded earth blocks. These blocks have many great advantages. They almost have the same strength and durability of the crushed soil. In comparison with the baked pottery bricks or some other structure materials, some of the mud bricks which are added with fixing substances are preferred. The compressed mud bricks are dried and contracted in the sun before they are arranged and set to the extent that they can be used in building the walls without cracks or walls with a loam of less contraction. The walls made of compressed mud bricks have a pleasant look and if the soil used have a good quality with uniform grading, there would be no need to cover or coat the exterior of the building. (Figure No. 15)



Figure 1



Figure 1



Figure 3



Figure 4



Figure 5



Figure 6



Figure 7



Figure 8

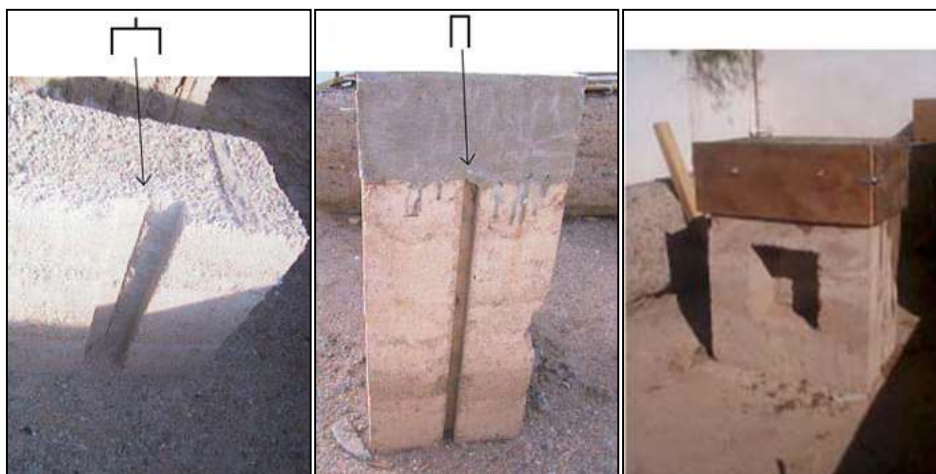


Figure 9





Figure 10



Figure 11

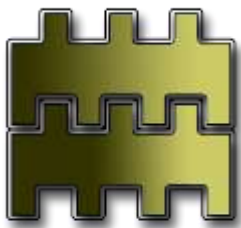


Figure 11



Figure 12



Figure 13



Figure 14

## 6. Conclusion

Concerning all the conditions and advantages of the soil, it is one of the best materials in building structures. The methods of application, administration and construction can benefit from the valuable experiences of our ancestors in Iran as well as the experiences treasured in other countries. The marriage of the old treasure and modern technology bestow upon us the amazing child of ancient while new architecture to evolve forever.

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