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METHODS OF FOUNDATION CONSTRUCTION ON DIFFERENT KINDS OF SOILS FOR RESTORATION AND CONSERVATION OF HISTORICAL BUILDINGS. CONTENT VERIFICATION OF AN ARABIC HISTORICAL MANUSCRIPT.

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ABSTRACT

This paper discusses a criticism of a historical Arabic manuscript from 13th century A.H, different types of foundation construction in various kinds of soil and how foundations had been constructed on basis of the case of each kind of soil. There are two copies of this manuscript; one of them is in the Bibliotheca Alexandrina, the other is in King Saud University. I depend on both copies for my research (codicology) of the manuscript to extract, criticize, draw and analyze all the mentioned methods. The manuscript has no drawings, the terms it uses are highly technical and some of them have become irrelevant these days. I returned to old dictionaries of Arabic to define their meanings accurately. Not only this, but I also put illustrative geometric graphics and some field work photos to make it easy to understand. The manuscript classifies the soil into different kinds on basis of their components and hardness and gives complete information about the methods for foundation construction in each soil. It also discusses the required treatment of each kind of soil and foundation construction on the sea bottom (water). From this study, we can get useful information of the methods and materials used in the restoration and conservation processes of historical foundations of the buildings. During any restoration project, it is very important to know and identify the techniques, materials and traditional methods to make use of in our treatments of historical buildings. This can also help to know some of the reasons and causes of the structural problems related to the soil and foundation construction techniques of the historical buildings. By knowing these techniques, the traditional methods can be improved by using new technologies in both soil and foundation tests and restoration.

KEYWORDS: Construction - foundations- manuscript - soil – Roman cement- stone.

INTRODUCTION

There is no doubt that there is a shortage in the knowledge of foundation construction techniques in historical buildings [1]. This is due to many reasons resulting from the risk of digging under the bearing walls of historical buildings without scaffoldings and the special precautions that should be taken. The foundation is the most important part of the building. Building activities starts with digging the ground for the foundation and then the building is erected on it. It is the lowermost part of the building [2] which transfers the load of the building to the ground. Its main functions and requirements are to:

(a) distribute the load from the structure to the soil evenly and safely.
(b) anchor the building to the ground so that the under lateral loads of the building will not move.
(c) prevent the building from overturning due to the lateral forces.
(d) give a level surface for the construction of a super structure.

New excavations adjacent to historical foundations are avoided so as not to undermine the structural stability of a historical building or that adjacent to it [2]. Studies should be done to ascertain any potential damage to the archeological resources. Through the criticism of this manuscript which has not published or mentioned before in any study. It gives information about constructing foundations techniques in all soils, with different techniques like using wooden sheds foundation, constructing foundation on water, rocky soils, solid soils and

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soils with multiple properties (loose and solid) by using wooden piles in the foundations [3]. We can make advantage of this manuscript to get ideas about foundations constructing techniques and the treatments for different kinds of soils to be ready for foundation construction [4]. It also provides us with information about the foundation construction in vaults and in water [5], and methods of water prevention during construction operations. Moreover, it presents to us some constructing procedures and different methods of dealing with the same case. We can improve those traditional methods which are mentioned in this manuscript --with the new technologies in both soils and foundations tests and treatment. Before any restoration process we should identify and diagnose any structural problem related to the foundations and the soils after technical studies of their current states and conditions. This manuscript provides us with information about the traditional materials, like Khafki (Roman cement), slaked lime and rubble stones etc. The process of restoration and conservation of historical buildings' foundations needs a lot of information to identify the reasons of any deterioration which may badly affect the multiple bearing walls and other structural elements of the buildings [6]). t will be difficult to diagnose the structural problems, without technical information about the foundations constructing techniques and its connection to the soil. In addition to this, we should use all available tests with new technologies to help us in our analysis. Through complete studies we can put proposal for the restoration and strengthening of the historical foundations [7] and for the treatment of soils [8]. As for the materials , we should improve them through experimental studies of the methods and traditional materials like Roman cement, (Khafki) [9] and the stones and brick to decide which will be used in the process of conservation and restoration with traditional materials, The design of walls and foundations is influenced by the types of materials used, the location, the proportions and scale of openings , doors and windows, the massing and rhythm of features such as bays and porches, and the details and ornamentation[10]. The manuscript covers the foundation construction in approximately all kinds of soils. However, the manuscript cites the components of the materials without mentioning any ratios.

GENERAL INFORMATION ABOUT ALL KINDS OF SOILS

This section discusses the methods of foundation construction in all kinds of soils in all places, especially those of bad conditions. Before constructing any foundation, some tests should be done to know and study the case and the kinds of soil which can be identified by digging and excavation. The various kinds of soil are classified into three main ones.

2-2-The three main kinds of soil:

2-2-1 First kind: This kind contains two types of soil, one called Tufa's soil and the other is the rocky soil. The identification of any soil depends on its being difficult or easy to dig. Both can be treated when constructing foundations without problem.

2-2-2 Second kind: This is the sandy soil which contains two types of sand as follows:

2-2-2-1-Rigid, solid and stable sand: This type of sand can be dealt with in foundations without any problem or danger.

2-2-2-2-Non-stable and Non-solid sand: This type cannot be used in reconstructing any foundation without taking certain precautions.

2-2-3- Third kind: This kind of soil is of different sorts and is divided into three main kinds:

2-2-3-1-The ordinary soil: It is widespread in locations of solid and soaring places.

2-2-3-2-The fatty soil: It contains medium clay which is non-hydrated or non-crusty. It is found in the lower places and this kind should not be used to construct any foundation without taking accurate precautions.

2-2-3-3-Alluvial deposits soil: It is locating in both lower and upper places and there are no problems when constructing foundations over it as long as it is thick and as its parts are flat and solid. However, whether it is non-flat or non-solid accurate precautions should be taken before constructing foundations

2-2-3-4-Carbonic (coaly soil): This kind always exists in aqueous and bog lands. It is a kind of black soil and a lot of things should be known about it before constructing foundation on this soil.

HOW TO TEST THE KINDS OF SANDY SOIL?

As mentioned in the transcript, they use an iron tool called (Abbasah) whose end is like a drill and is shoved into the soil to identify its nature (stratum) [11]. If the machine shoves the tool into the soil with difficulty, that means the sand in that soil is stable and solid (Figure. 1). On the contrary, if the tool is shoved into the soil easily they determine that the soil is non-stable and non-solid (Figure. 2).

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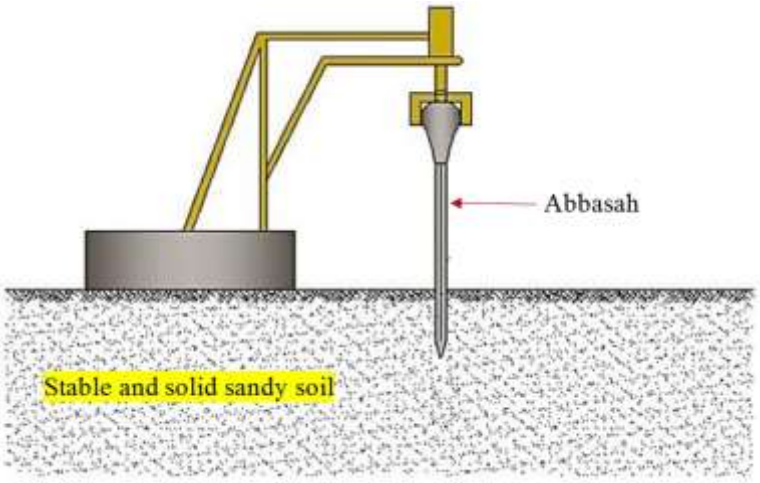

Figure. 1: Iron tool (Abbasah) tests for the stable and solid sandy soil.

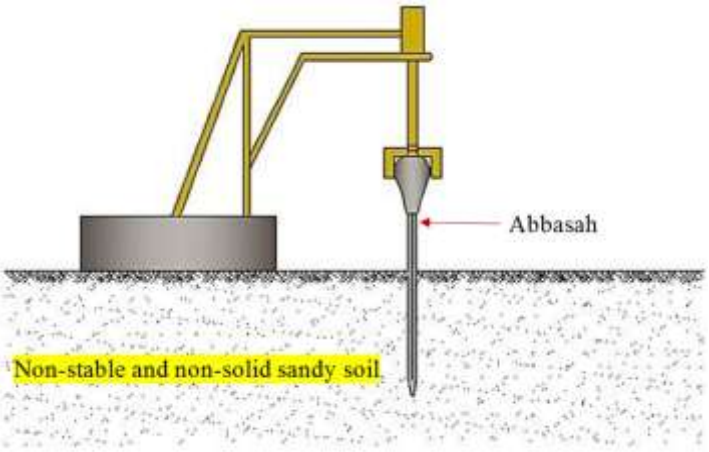

Figure. 2: Iron tool (Abbasah) tests for non- stable and non- solid sandy soil.

If they want to make a boring test of the soil, they extend the previous machine (drill) with an iron piece and connect it with Auger (miser), (Figure. 3). Sometimes, in aqueous places, they find the soil contains ground water and that water comes out of the sand when it is compressed. In such case, they decide that this is section of soil is more suitable than the previous one for constructing the foundations without any problem when it becomes solid.

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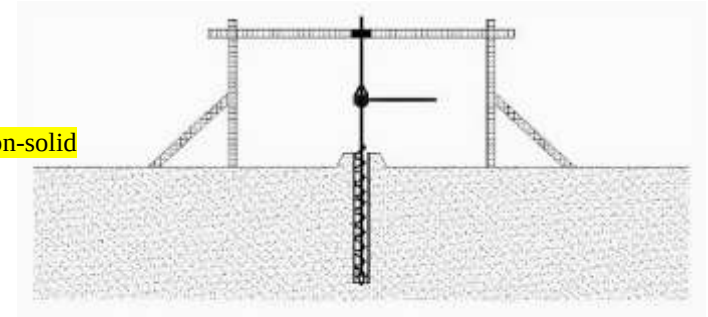

Figure. 3: A drill connected with Auger to do boring test for the soil.

METHODS OF FOUNDATION CONSTRUCTION ON THE ROCKY SOIL

If the rocky soil is high and will be ascended and descended and there is necessity to construct a foundation, they the rock is carved like a staircase and after that they can start their procedures to build the foundation and the building should be sloped from two directions approximately proportion of four or five fingers; in another copy length will be of one finger and a half. The slope of the building will be stable and keep it sturdy (Figure. 4-5).

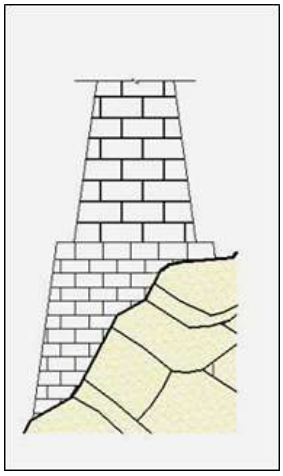

Figure .4: A sloped foundation on the stepped high rocky soil.

Figure.5: An image shows Historical building constructed on the rocky soil, south of Saudi Arabia.

4-1. Methods of foundation construction on flat rock.

If the rock is flat and there is danger of non-cohesion between the rock soil and the foundation, a small excavation is dug and filled with rubble stone and Roman cement, then they demolish it in order to intervene the rock, after that they can construct their foundation if they want to support their building. They excavate some parts of the rock and fill it with Roman cement and rubble stone to have a great interlocking and good cohesion between the structural elements of the building. (Figure 6).

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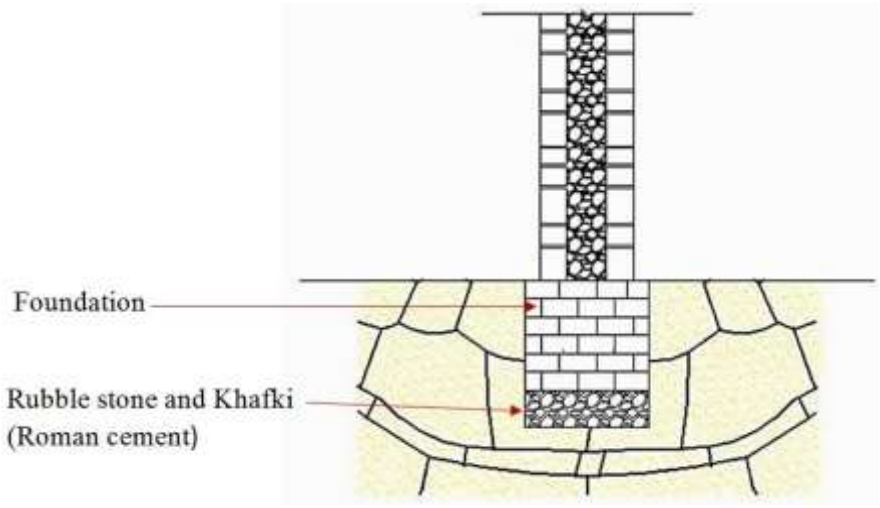

Figure. 6: The wooden box and iron tool during fixing the stone, Roman cement, and fractures of marble with rocky soil

4.2. Methods of foundation construction on uneven rock:

For constructing a foundation on uneven and very solid rock after flattening and leveling they row stones and follow the stone foundation method.

4.2.1. Stone foundation method:

After digging an excavation in the rock for constructing a foundation according to the height of the building, they start fixing wooden boxes whose upper ends are horizontally set and the lower ends in the form of the excavation which is dug for foundations, the required materials for a stone foundation method are stone + roman cement+ fractures of marble the size of a hand grip. These materials are put into the wooden boxes and pound with machine an iron head and with a weight of approximately 14kg to fix and mix the materials. (Figure. 7) After making sure of pounding and fixing the materials, the wooden boxes are removed and re-used in another location. In this process the rock soil and the materials are interpenetrated in all directions of the foundations. The pounding the materials should be very strongly made to render all the elements homogeneous.

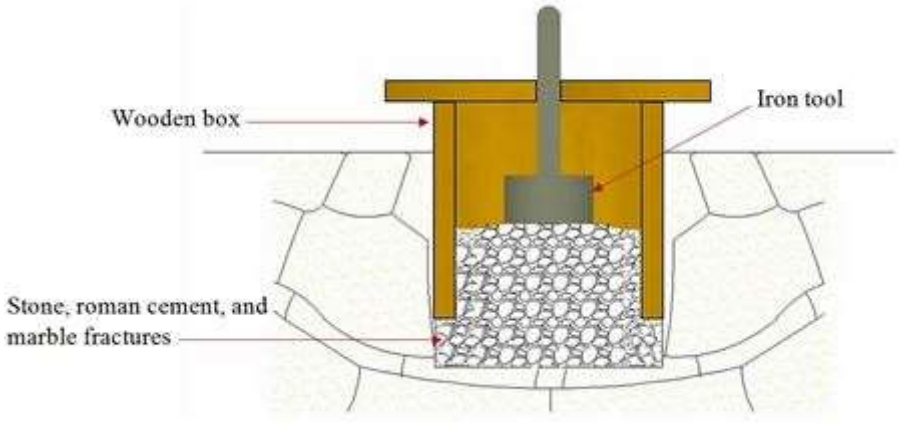

Figure 7: The wooden box and the iron tool during fixing the stone, Roman cement, and fractures of marble with the rocky soil.

In some cases, if the building is high in the center and there is need to extend all parts of the building to be at one level, they should take account of conforming of straightness of the extensions with the building height. In this case the old foundation must intertwined with the new one. This will be achieved by making the edges of the old foundation like stairs (a gradation process) to render them intertwined, then they spray water and start

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equalization of the edges while putting the materials. If they want to add other extensions of the foundation, the same process should be adopted with the same materials.

Through the previous treatment of the extension of a foundation, the results will be good because the buildings will act as one unit. It is difficult to that cracks should happen in the buildings and no compression will happen even if some parts have not the same hardness.

When an excavation for a foundation starts, it is found that soil is solid in some cases while in other cases it is loose. That is the main cause of non–equal compression, so the previous procedures should be done to prevent any other structural problems in the buildings like curvature, by using the method of stone foundation, which will prevent the appearance of cracks owing to the stability of the foundation that will not happen in case of using big stone blocks because the Roman cement will not give good cohesion with the big blocks. This the reason why the compression in some parts of the buildings is more than in others. It is said that an ancient building founded with small stone pieces with Roman cement is very hard and solid. This applies to both the foundations and the buildings. This can be observed in their ancient buildings which are harder than marble (Figure. 8.a, b).

Figure.8:(a) An image showing foundation construction with rubble stone, Ahmed Katkhuda EL-Razaz, (ARCE conservation project. Historical Cairo.

Figure.8:(a) An image showing foundation construction with rubble stone, Ahmed Katkhuda EL-Razaz (ARCE conservation project. Historical Cairo

CONSTRUCTING METHODS IN CASE OF DIFFICULTY OF GETTING SOLID AND BIG STONES

In some locations, it is difficult to find solid stones for stone foundation so it is advisable to use them for foundations even if they are costly owing to the high cost of the required lime to make the foundation hard and solid. There is another problem that results from using small stone pieces which causes a bad quality of the foundation. That can be solved by making false joints using two kinds of Roman cement; one mixed with small stone pieces and the other made with the sand (medium size of sand), starting the work with the second kind (Roman cement with sand) in the center of the bottom of the boxes and in the sides, then, putting the first kind (Roman cement mixed with small stone pieces) in the center, because the second kind is more attached than the first. By pounding the stones with the previously mentioned iron tool they cohere and dry and become like stone, then they draw joints to be like dressed stone building and make it well appear as if built from dressed stones (Figure. 9a, b).

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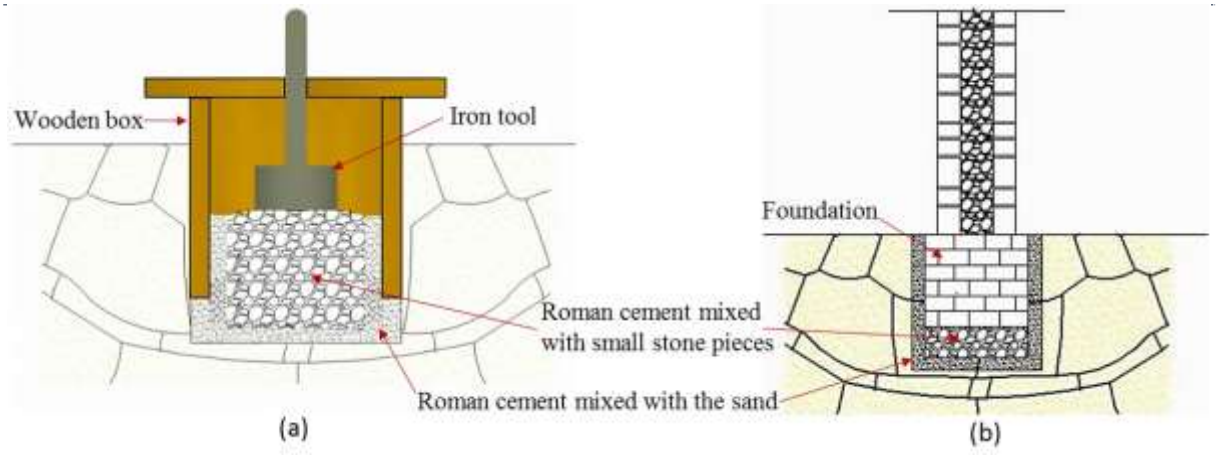

Figure. 9: (a) The wooden box and the iron tool during fixing two kinds of Roman cement, the first one mixed with the sand awhile the second with small stone pieces with rocky soil, (b) the foundation.

CONSTRUCTING FOUNDATIONS ON SOLID SOIL.

Building foundation in solid soil was a non-complex process as it needs digging an excavation in two directions (length and width). In this in kind of soil the slopping is into one direction (Figure. 10)whose magnitude is six fingers (13-15) cm. In another copy of the manuscript (King Saud copy) if the foundation thickness is 12 foot (365.76) i.e., approximately one part for each twenty-four part, flat and big stones should be put in the first row of the foundation, while in the next row, the stones should be put on a different position in both length &width. In the middle of the double face of foundation, like multiple bearing walls, they put rubble stone with Khafki (Roman cement) and they should also make sure that all rows are identical and in horizontal (image.11, a,b).

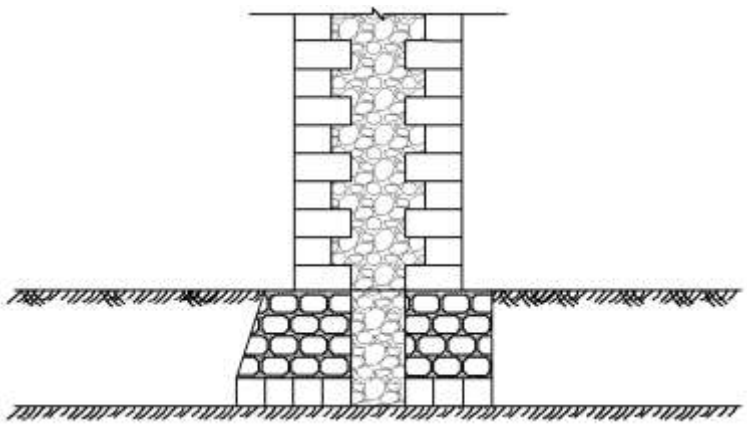

Figure.10: double face foundation sloped from one side on solid soil.

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CONSTRUCTING FOUNDATIONS FOR ARCADE

If it is required to construct a foundation for an aqueduct (arcade) and the soil is non-solid in all foundation extensions and there is fear of having non-equal legs of the aqueduct, which may in time render the arcade dangerous, such problem is solved by building a reversed vault and putting its ends over the arcade and through this process there will be got a non–compressive soil and stable foundation (Figure. 12).

Figure. 11: (a) An image showing stones in a horizontal position. Ahmed Katkhoda EL-Razaz's house Foundations, Ottoman Era (ARCE conservation project)

Figure. 11(b) An image showing stones in a horizontal position, Qait-by Wekalah, Mameluke Era, (historical Cairo projects)

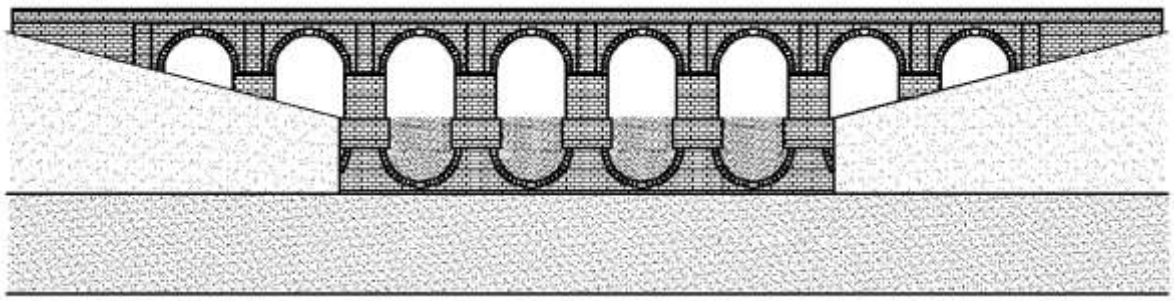

Figure12: Foundation for arcade on reversed vaults

METHOD OF PREVENTING WATER RISE

In some places if there is a spring which could cripple the building of a foundation, this problem is solved by bailing it up by a primary machine or by excavating a canal covered with stones to take the water away from the working zone [13], or a sluice is made nearby the excavation to move the water into a neighboring well or pit (Figure. 13), or cutting a canal that should take the water away from the working site.

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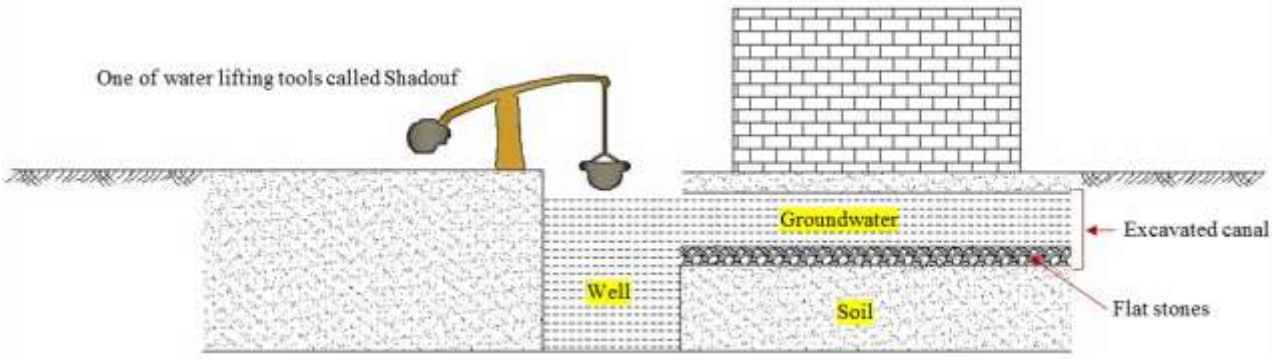

Figure. 13: Excavated canal covered with flat stones for taking the water out of working zone and moving it to nearby well.

CONSTRUCTING FOUNDATION BY THE WOODEN SHEDS METHOD.

Sometimes the soil is found non-solid and need to be dug in order to get solid soil. In case they reach the lower layer soil under the soil surface, they should not continue the depression, but put wooden sheds in all foundation extensions, which should be interlocked in both length & width. The thickness of the wooden sheds should be between 9 and 10 fingers approximately (25cm). After that the spaces between the wooden sheds are filled with brick, rubble stones and Khafki (Roman cement). Sometimes the wooden sheds are covered with thick wooden panels by fixing them with nails; then, the foundation constructing can start. (Figure. 14a, b).

Figure.14:(a) 3D-view of wooden sheds interlocked in length & width and the spaces between the wooden sheds filled with brick and rubble stones.

Figure.14, (b) 3D-view of wooden sheds covered with a thick wooden panel fixed with nails

CONSTRUCTING FOUNDATION METHODS ON WOODEN PILES

That method does not match all positions of all kinds of soils, so it is used in a few kinds of soils and there are different levels of solidness and hardness of the soil, especially in aqueous places where it is very useful there are two methods:

10-1-The first method:

Flat wooden shed is put on the soil then start planting or penetration or pier the wooden piles in all spaces of the wooden sheds and two wooden piles are planted in each space facing each other on two chords, then all the spaces on the wooden sheds are filled with big stones. After horizontally lifting the wooden piles are flattened the foundations start as usual.

10-2-The second method:

No doubt that the previous technique is a good one, but this technique is still better owing to the hardness of the foundations got by this technique. The methodology starts with planting the wooden piles in rows in all the foundations directions. Also, spaces are kept between the wooden piles, and after that the spaces between wooden piles are filled with stones mixed with Khafki (Roman cement), then wooden sheds are put over the

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wooden piles in both the length &width. This technique is solid than the previous one. (Figure. 15a). Also, a pillow is put for the foundation and the wooden piles are planted for that pillows to lie on (Figure. 15b) between the pillow's angle and the foundation. If it is wanted to build wall, the rows of wooden piles are implant in the identified place, two of them on the middle and the others on the end. The required space is two-foot (60.96) cm and after that the spaces between the rows are filled with stone mixed with Khafki (Roman cement). Then the wooden sheds and pillows are put on it, two wooden piles are implanted under each pillow and the other two wooden piles are put between the pillows angle and the foundation.

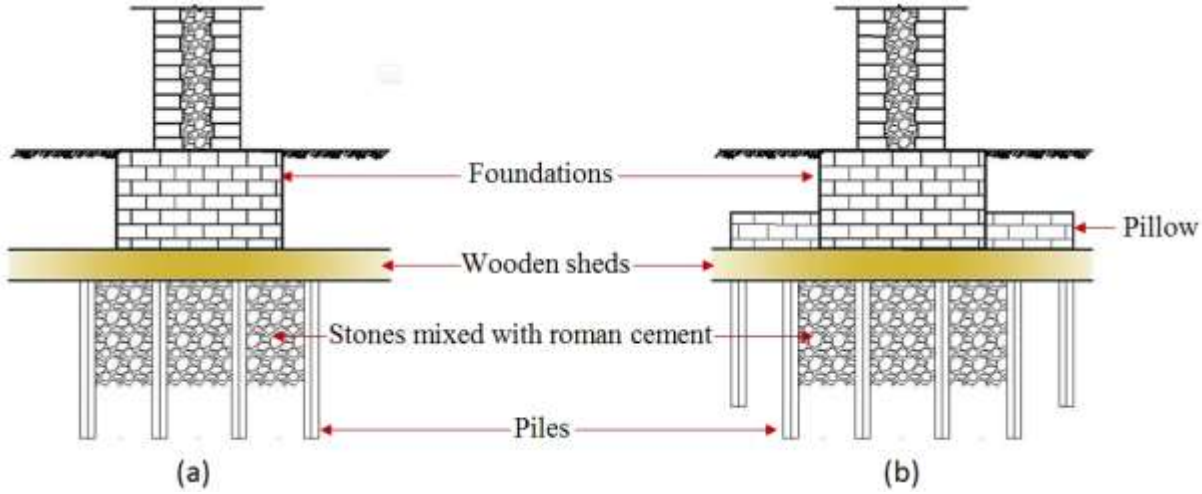

Figure. 15: (a) Foundations on wooden sheds over the wooden piles in both length &width, (b) A pillow is based on the wooden piles for strengthening the foundation

CONSTRUCTING FOUNDATIONS ON SEA WATER

If there is need to reconstruct in places full of water and it is difficulty to drain water like the case in the sea, this technique should follow for the foundation to be solid and hard, even if there is an opposite thought or view, boats are filled with stones, move into the identified place that would be the foundation where the stones are equally and carefully thrown to make sure that all stones are on the right position and on its sides in order to support the base of the buildings , after that it is covered with Roman cement (lime & pozzolan). Then two rows of rubble stones and gravel are put also and continually covered with the Roman cement until the required height is reached. (Figure. 16). In this method working should stop during the seas eruption and until it is calm. Also, the condition of the foundation should be tested over time to identify the stability of the foundation and this is compared with its relation with the water, after that they the building can start whether the stability could be identified or not, Wooden sheds are placed on a thick wooden panel and foundation constructing starts. For more safety, wooden piles are dug around the foundation to prevent any shaking which may happen from the water action. In this case, the foundation will be stable (Figure. 17).

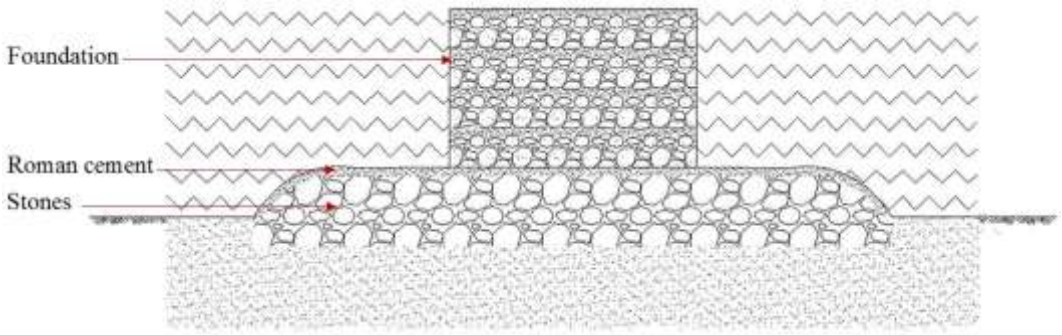

Figure. 16: A foundation (from rubble stones and gravel covered with the Roman cement) on stones paced on the sea bottom and covered with Roman cement.

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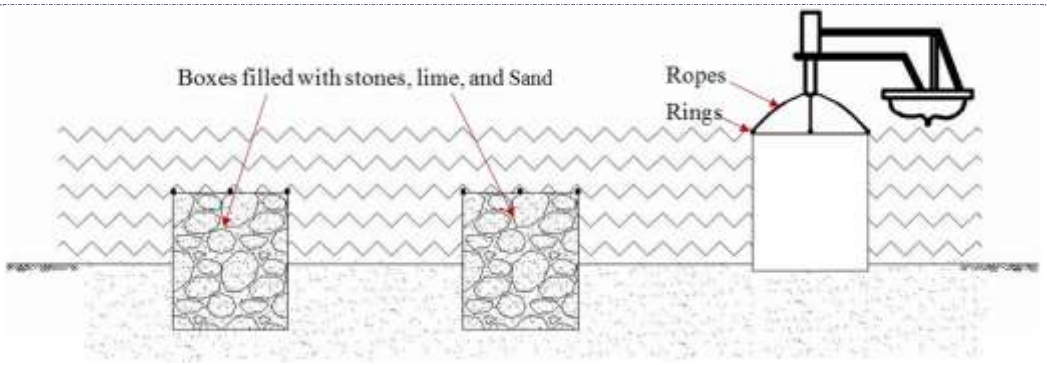

Figure. 17: A foundation on wooden sheds and wooden piles.

There is another technique for constructing foundation on the seas in which boxes are brought and fixed with rigs through which ropes pass, then then they are filled with stones, lime, sand and dropped on the site of work. In this case, the heavy weight of the boxes will make it easier to let them fall until they reach the sea bottom or bed. (Figure .18).

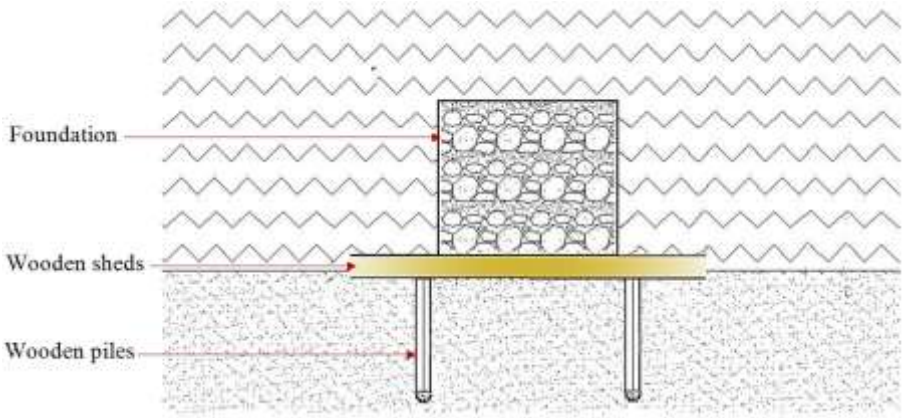

Figure. 18: A foundation (with boxes filled with stones, lime, and sand) set on the sea bottom.

CONCLUSION

This manuscript gives a lot of information about the techniques used in the past in foundation construction in most kinds of soil which and what treatments were adopted for constructing in any kind of soil even the very bad kinds. The data it presents shall help specialists in historical buildings with structural restoration. They are advised to use these traditional techniques in their structural restoration and conservation work to keep the flexibility of the traditional buildings by their structural elements and materials. The manuscript provides us with a lot of information about the old techniques and materials. This should be studied, tested and experimented with and be used in conservation and restoration operations of the historical buildings.

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