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A comparative study between the theoretical and practical implementation of a one-way hollow brick slab

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Abstract:

This paper included a comprehensive comparison between the theoretical part according to scientific references and according to the American ACI code, and specifically included mainly the strength of concrete considered during the design stage, how to lay hollow bricks , reinforcing steel and the rest of the instructions, as well as how to design a one-way hollow brick slab and compare the theoretical part with practical implementation through investigations of three sites in Tripoli, including the strength of concrete and various works in execution, in addition to the dimensions of ribs, the amount of reinforcing steel and the structural drawings for roofs were identified.

What is being worked in Libya, whether in the implementation of private or public sector projects, and what the first and second researchers noticed is that the concrete is poured for the roof slab in two stages, whether the pouring is used with manual mixers on site or those in which the pump and mobile concrete mixers are used, the first stage is poured up to the upper surface of hollow bricks, and the upper layer is the one above the first, where an extra water is added to the mixture to increase the workability, and all we know that the upper layers of concrete above the neutral axis is the most important for the design purposes .

Samples were taken from several sites in Tripoli and several differences were found between the design and implementation, including the high w/c ratio in the upper layer, which weakens the compressive strength of concrete, as well as some damaged materials that are not suitable for use in the slabs, and the failure to maintain design spaces such as the spaces between the stirrups.

Keywords: concrete resistance, w/c ratio, ceiling, theoretical and practical

Introduction : A comprehensive study on the unidirectional hollow block roof in terms of design, concrete compressive strength, materials used, and the method of execution was conducted, and then compared with the practical implementation in terms of the methods and ways of pouring concrete and the difference between the first and second layers of concrete, which is usually done during the pouring of concrete on site, where the lower layer up to the upper level of the brick and the upper layer of concrete up to the upper final level of the roof, in the latest which was observed that contractors increase the water for this layer without scientific justification, in addition to the defects of the pouring execution.

To achieve the goal of the research, samples were taken from the first and second layers for the three sites and the compressive strength test was conducted on them during 7 and 28 days and the difference between them was observed. The difference between the design and implementation such as the distance between the steel bars and the number of stirrups, as well as how the bricks are laid and how important it is to reduce the weight of the roof. The research structure was divided into two parts, the first part will be about the theoretical background, while the second will be about the implementation observed by the researchers in sites and lastly a comparison was made.

The first part: the theoretical background:

In this part many references were studied [1, 2]

Hollow block bricks:

It is the brick units that are laid between slab ribs, and can be used in the following:

A-construction of non-load-bearing walls in buildings structures

B-in reinforced concrete roof slabs, to fill the voids between ribs with the lowest possible weight, depending on the quality of the roof, in addition to improving the properties of those ceilings for thermal and sound insulation.

How to lay hollow bricks:

1. This brick is stacked in the same direction as the ribs and with a dimension equal to (length) 20 cm. So you will find the net Inter Digital distance between the ribs is 40 cm.

2. In the ideal case the roof should start with a row of bricks and end with a row of bricks taking into account the solid side.

3. The first and last bricks of the unloaded brick are placed upside down to avoid the entries of concrete into the brick, which causes a waste in the amount of concrete and an increase in the weight of the unloaded brick, which increases the self-weight of the roof.

4. All the bricks must be on a straight line.

5. In a hollow brick one of the two bases is different in measurement (that is, it takes the form of a trapezoid).

6. The bricks is laid so that its largest base is the lower one, in order to increase the cross-section of the upper compaction concrete zone (above the neutral axis).

7. There is a common mistake where brick units are installed and placed on the lower base thinking that this will prevent the bricks from falling.

The hollow block slab:

It is a roof consisting of a group of ribs (small beams with the thickness of the roof) in a certain direction, and it is the direction of loading and transferring weight to the group of drop or hidden beams, and from them to the columns, the foundations and then to the soil, and between these ribs, the bricks with a rib, then a row of parallel bricks, then a rib, and so on. It is possible that the ribs can be in both directions and this method allows covering a larger area, such as large halls that are more than 7 meters wide and long.

Reinforcement of the hollow block slab:

1. The roof of a hollow brick consists of a group of ribs, and most often their reinforcement is like beams, where each rib represents a small beam that has an upper and lower reinforcement with stirrups.

2. a steel mesh in two directions on the upper surface layer.

3. It is possible to add one or more transverse ribs (perpendicular to the main ones) to resist deflection in large spaces.

4. The solid part is that part that interferes with the embedded beams, preferably the solid part is surrounded by all sides of the roof of the hollow brick.

Transverse rib or cross rib:

It is used in large areas (the smaller dimension of the roof is greater than 5 meter) and is perpendicular to the main ribs and with the same reinforcement and cross section Strip and mounted on them. Its stirrups are always closed, and it reduces the values of deflection and is better when it is located closer to the middle.

Compressive strength of concrete

The authors (H Jebali and Z. Hatush) [3] and others [4,5] clarifies that the concrete strength describe the structural efficiency of concrete, the compressive is the most important property which gives an idea of the quality of concrete and obtaining the required strength by conducting this test for the age of 7 days and 28 days from the date of casting and because the compressive strength expresses most of the physical and mechanical properties of concrete in its hardened state and determining the degree of its quality, for this reason, most of the other properties of concrete is related to its compressive strength. Bear in mind that the compressive strength is important in the ribs and beams that are subjected to flexural and bending, and therefore the upper part above the neutral axis is subjected to a compression that is resisted by Concrete.

Compressive strength test-importance and guidelines

The compressive strength test is the most common test in the field of hardened concrete tests, for several reasons, including that it is an easy test to do, but the main reason for this lies in the fundamental importance of the compressive strength of concrete in structures and buildings. compressive tests can be broadly classified into mechanical tests and even to destructive tests and non-destructive tests, allowing re-testing of the same sample, and thus being able to study the changes in different properties over time.

Method of preparation for concrete compressive test:

Twenty four hours after placing the samples in the moulds the moulds are removed and the test samples are placed in water for processing, the upper surface of this sample should be even and smooth, this is done by applying cement paste and spreading it smoothly over the entire area of the sample. Samples of concrete cubes are prepared in the required proportion and the materials for making these test samples are from the same concrete used in the concrete mixture, the sample consists of 6 cubes with a size of 15 cm.

How to prepare cubes and test them:

1. Clean the empty cube moulds and grease them with oil.

2. Fill the concrete into moulds with layers of about 5 cm.

3. Tamp each layer at least 35 strokes per layer using a tamping Rod.

4. Level the upper surface and smooth it using a levelling tool.

5. Treatment of cubes.

6. The test samples are stored in humid air for 24 hours and after this period the samples are marked, removed from the moulds and kept immerged in clear fresh water until taken out before the test and the treated water should be tested every 7 days and the water temperature should be at 27^{o} (±2) degrees Celsius

Testing procedure for concrete cubes:

1. Take the sample out of the water after the specified processing time and wipe the excess water from the surface.

2. The dimension of the sample was taken to the nearest 0.2 m.

3. Clean the bearing surface of the test machine.

4. Place the sample in the machine so that the load is applied to the opposite sides of the cube casting.

5. Align the sample centrally on the base plate of the device.

6.Gently rotate the movable part by hand so that it touches the upper surface of the sample.

7. The load is applied gradually without shock and continues at a rate of 140 kg per square centimetre per minute until the sample fails.

8. Record the maximum load and Note Any unusual features in the type of failure.

Notes that must be taken into account when testing:

At least three samples should be tested at each specified age, if the strength of any sample differs by more than 15 percent of the average strength the results of these samples should be rejected, the average of three samples gives the crushing strength of concrete the strength requirements for concrete.

How to work on the site:

In this paragraph, we will explain how to process samples on-site. This will be clarified through the samples that were conducted for three sites and the work was carried out as follows:

First, the cubes were cleaned, greased with oil and numbered, the concrete was placed in the cube in stages and compacted each stage 25 times the surface was levelled, 6 samples of the first layer and 6 samples of the second layer were taken and after 24 hours the samples were extracted from the mould and placed in a water container for 7 and 28 days, after that the samples were extracted, dried and weighed, they were placed in a testing machine to measure the compressive strength of concrete for 6 samples at 7 days, of which 3 samples for the first layer and 3 samples for the second layer and 6 samples at 28 days, of which 3 samples for the first layer and 3 samples for the second, the average strength of the samples were taken, and included in the results item. Figures 1, 2 and 3 shows the plans for preparing samples for testing.

Mistakes of the implementation process:

In this paragraph, common mistakes will be addressed during the implementation processes that cause significant waste work during the execution of the building, and it is assumed that all stages are carried out in accordance with the specifications and technical requirements of each element of the building, but the fact of the matter is that the implementation usually has several errors, which may be errors during the reinforcement or concrete mixing or during the casting of concrete. To avoid such errors the supervision must be good on monitoring the labours , reading of drawings, implementation of recommendations and warnings if it is included. The reference (Z hatush & Martin skitmore) [6] ascertained the importance of coshing the good contractor, in addition (NA karima & z hatush) [7] referred to the importance of good supervision

Figure1 on-site samples

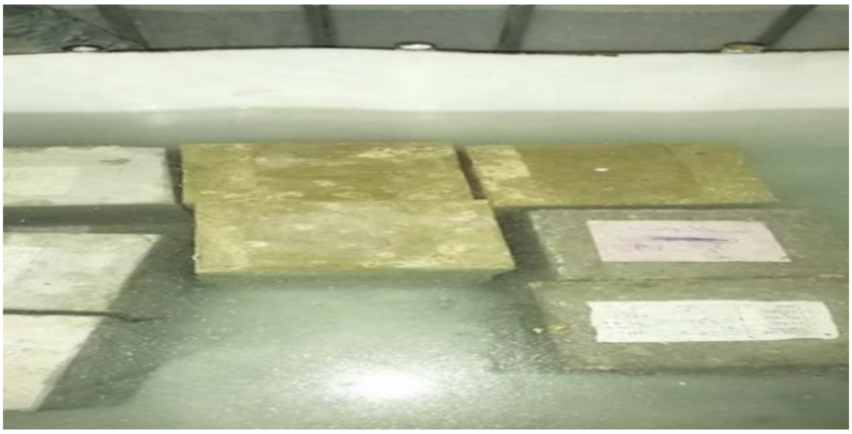

Figure 2 samples during treatment period in water

Figure 3 samples during testing in the compression machine

Reinforcement Arrangements errors:

There are many errors in arranging reinforcement during execution, which leads to problems such as:

1-surface thermal cracks as a result of insufficient concrete covering (due to the closeness of the reinforcing steel to the concrete surface).

2 - cracks and damages resulting in the area of positive moments in the beams and roofs (the middle of the spans) as a result of the lack of sufficient bottom reinforcement.

3 - cracks and damages resulting in areas of negative moments on the top of the beams and slabs at the columns and beams as a result of the lack of reinforcing steel that serves those areas.

4- bunching shear between columns and slabs as a result of not considering sufficient reinforcing steel to resist these forces.

5-cracks resulting from the separation of concrete from the rebar due to rust.

Errors in the concrete mixing:

1. Failure to comply with the mixing ratios according to the proportions specified in the concrete mix design.

2. Using the wrong methods of casting and compaction.

3. Using manual compaction methods.

4. Increase the proportions of mixing water. Increasing the Mixing Water leads to a decrease in compression strength, an increase in plastic deflection and an increase in the overall shrinkage of the concrete after the concrete dries.

5. The use of defective materials due to poor storage (rust in rebar – suspicion of cement).

6. Failure to properly perform casting or construction joints.

Mistakes of pouring of concrete.:

1. Pouring from high places (leads to granular separation with concrete).

2. Lack of good compaction (occurrence of aggregate segregation in structural elements).

3. Excessive levelling of the surface (the appearance of surface cracks and increased blood phenomenon).

4. The formwork is not properly anchored and there is a drop in formwork.

5. not using cold concrete during pouring concrete (by replacing some or all of the amount of water in the mix with pieces of ice).

Poor storage of materials:

1. Cement: it is stored in a protective way, effectively protecting from rain and from air and ground moisture.

2. Aggregates: large and small aggregates are stored separately and how to avoid contamination.

Preparation for pouring concrete:

1. All mixing and conveying equipment must be clean and must be calibrated before starting work and repeated at intervals determined by the supervising engineer.

2. The reinforcing steel is fixed by plastic biscuits, concrete blocks or the like to save spaces during casting, allowing the reinforcing steel of the slabs to be broken during casting.

3. It is strictly forbidden to walk on steel reinforcement after machined.

4. The reinforcing steel must be clean of harmful substances stuck or sticking to it and free of any scales as a result of rust.

5. Before pouring a new concrete, it is necessary to remove the remnants of the old concrete and the stuck materials, and then treat the concrete surface to ensure the cohesion between the two concretes.

Concrete pouring:

1. It is necessary to pour concrete immediately after complete mixing, provided that the time between adding mixing water and pouring concrete does not exceed 30 minutes in normal weather and 20 minutes in hot weather and it is compacted before 40 minutes in normal weather and 30 minutes in hot weather. If it is necessary to increase the previous periods, it is necessary to add additives for delaying cement setting time when mixing and should be approved by the consulting engineer of the project and in the proportions agreed upon, provided that this is confirmed by the laboratory before the start of pouring.

2. It is necessary not to use concrete that has set or partially hardened or contaminated with foreign substances.

3. It is necessary to take into account the determination of the places of the construction joints and the places of stopping the casting in advance before the start of the casting.

4. If the pouring is started, it needs to be continued completely regularly until the completion of the casting of the agreed part.

5. In the case of pouring concrete with a large height, it has to be taken into account that it should be poured on layers ranging from 30 – 50 cm with the use of mechanical vibrators so that the concrete can be compacted first, and it is taken into account that no more than 40 minutes should pass in normal weather or 30 minutes in hot weather between successive layers so that the bottom layer has not begun to harden when the next layer begins to be poured.

Neglecting of the concrete cover:

One of the main reasons of falling the concrete cover is that the concrete cover of the steel reinforcement was not sufficient in the required form, and in order to avoid this reason, it is necessary to protect all the reinforcing steel with a concrete cover for the roofs with a thickness of not less than 2.5 cm, and so we avoid this**:**

1. roofs that are exposed constantly to moisture and water vapours, the thickness of the concrete cover in them should be between (5 - 7.5) centimetres.

2. The biscuits should be directed (towards the centre of the span) so that they do not slip when the timber is pressed on them.

3. It is a mistake if the wooden moulds of the stirrups beams is touched from the sides.

Reinforced concrete design:

In this paragraph, a brief idea will be given about the design steps for the one-way rib slab, as no construction maps were obtained at the three sites visited, and therefore architectural maps were taken for each site and the necessary design was carried out using the Revit program (See Figure (4), (5)and(6)

Some laws used in the design:

a) W_D= Flooring (S+bw) + ɤb + ɤc .

b) W_L= Live Load (S+bw) .

c) W_u= $1.2W_D+1.6W_L$.

Where::

W_D= dead load. S = width of the brick.

bw = rib width.   ɤb = the weight of the unit of volumes of the brick.

ɤc = weight of the unit of volumes of concrete.

W_L = live pregnancy. Wu = maximum load.

We will calculate the thickness of the roof according to the case as shown in Table (1)

Table 1 calculation of roof thickness

(cantilever)	(both-end continuous)	(one-end continuous)	(simply supported)	Slab type
L/10	L/28	L/24	L/20	ribbed slabs
L/10	L/28	L/24	L/20	Solid slabs

The thickness of the ribs (hs) is depending on the condition in which the rib is located

Ln is the length of the rib and is also the length of the beam.

And in case the thickness of the beam is larger than the thickness of the ribs, we take the largest among them, and then the thickness is calculated (hs) **h=hs (0.4+fy/700)**

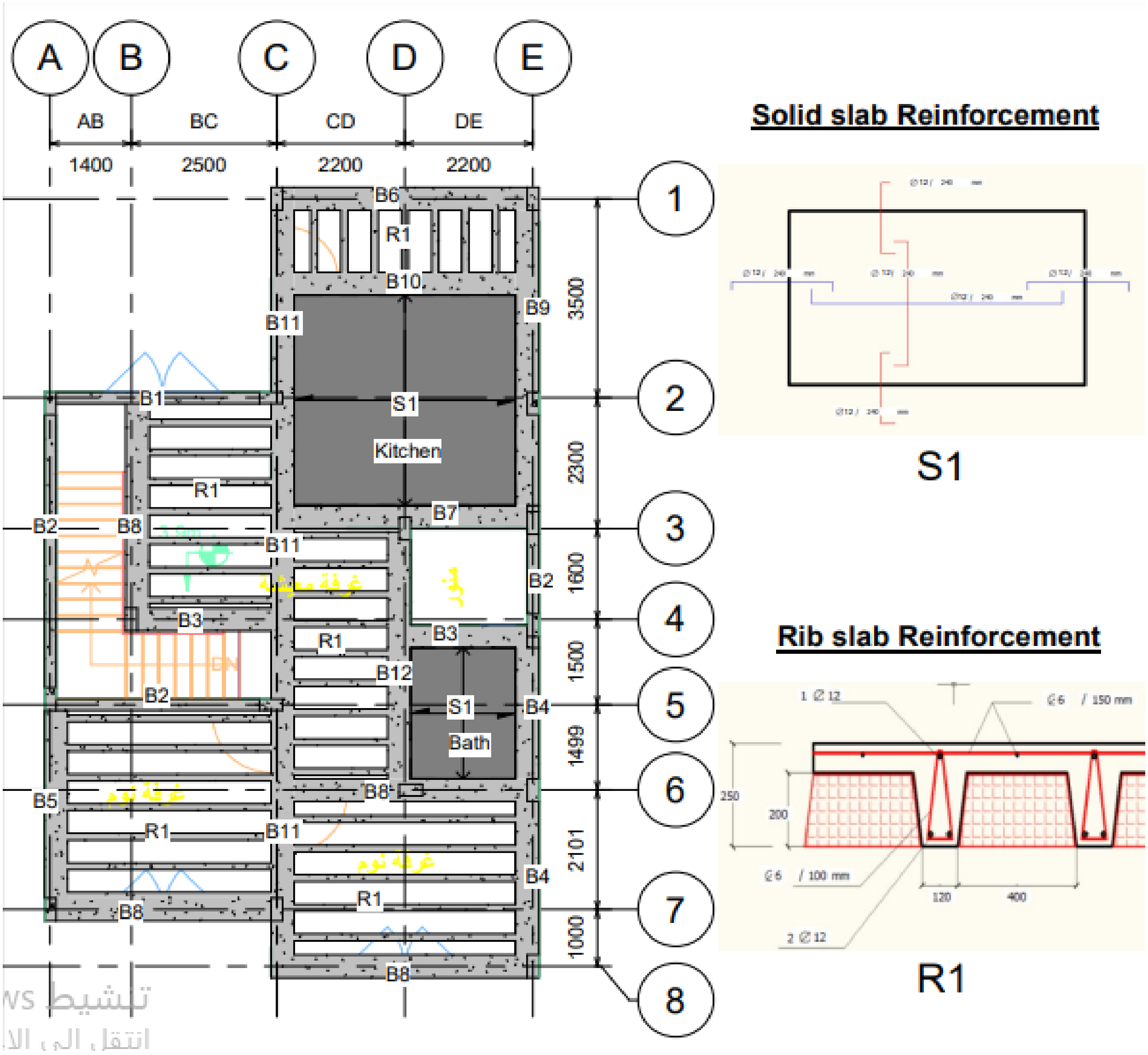

Figure 4 design drawing of Tajoura site

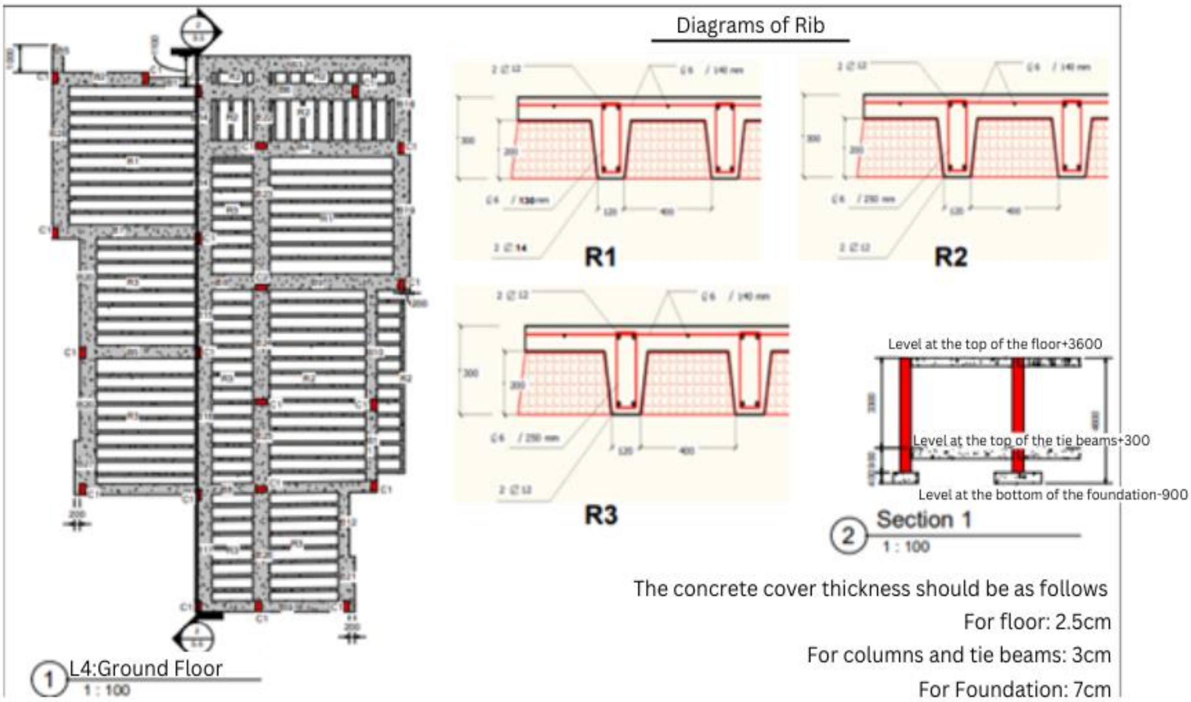

Figure 5 Design drawing of the Islamic neighbourhood site

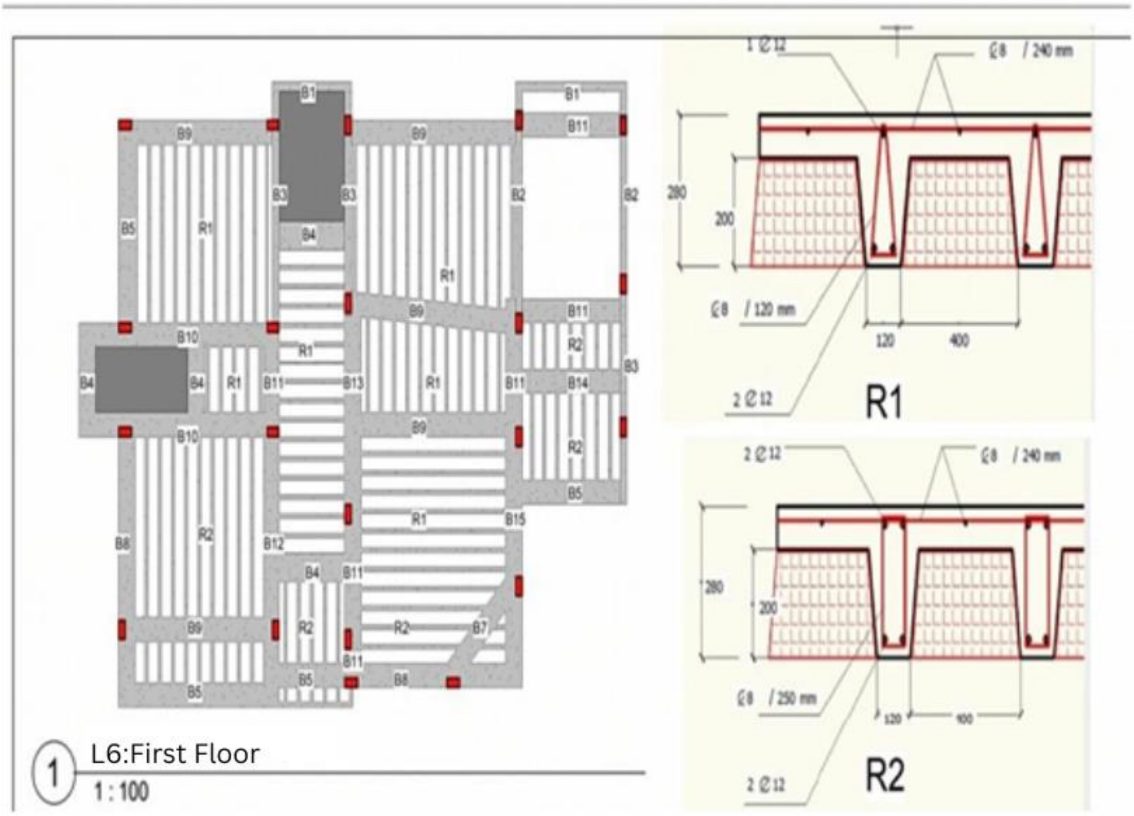

Figure 6 design drawing of al-Saraj site

Part two: practical implementation and comparison

1. steel reinforcement

It is difficult to compare in this case because there are no structural drawings, but the reinforcement and their numbers and dimeters were placed by the contractor according to his knowledge. Comparison cannot be fairly made with our full design of the slab as mentioned, other reasons are the design data such as the design or concrete grade strength and the steel yield stress, however the full details of our design could be found in reference [8], with a comparison with site reinforcement chosen by the contractor, a clear difference is noticed in bar dimeters, number of main reinforcements and in stirrups.

2. concrete strength

Samples were taken from the two layers and it was assumed that the strength of the concrete would be equal in both cases

These are the laboratory results of the test samples at both the al-Saraj and the Islamic neighbourhood sites only

Al-Sarraj site

Three samples of the first layer were tested with weights (7.725, 7.715, 7.861) kg and dimensions (150*150*150) mm the samples were 8 days old and the density was as follows (2289, 2286, 2329) kg/m3 these samples were loaded with fracture loads (360.50, 376.51, 357.42) KN and the result of fracture stress of these samples was (16.02, 16.73, 15.89) N/mm2, respectively .

With the same steps, three samples of the second layer were taken with weights (7.920, 7.800, 7.820 kg) and dimensions (150*150*150) mm the age of the samples was 8 days and the density was as follows (2347, 2311, 8317) kg/m3 these samples were loaded with fracture loads (298.08, 259.34, 303.44) KN and the result of fracture stress of these samples was (13.25, 13.13, 13.49) N/mm2, respectively .

The same steps were repeated 28 days after the samples and the weights assigned to the first class were (7.850, 7.990, 7.993) kg and with dimensions 150*150*150 the density was (2326, 2367, 2368) kg/m3 and loaded with fracture loads (615.01, 568.89, 612.06) KN and the result of fracture stress for these samples was (27.33, 25.28, 27.20) N/mm2, respectively.

As for the weights of the samples of the second layer, they were (7.671, 7.760, 7.665) kg with dimensions 150*150*150 the density was (2273, 2299, 2271) kg/m3 and loaded with fracture loads (451.56, 428.09, 391.42) KN and the result of fracture stress for these samples was (20.07, 19.03, 17.40) N/mm2, respectively.

The following table shows the comparison between the average compressive strength of the concrete of the first and second layer as well as for the assumed concrete strength grade required

concrete grade	the average realistic pressure resistance of concrete		Number of days
C30	16.21 (N / mm2)	the first layer	Within 7 days
	13.29 (N / mm2)	The second layer	
C30	26.61 (N / mm2)	the first layer	Within 28 days
	18.83 (N / mm2)	The second layer	

The results of concrete strength are observed here after 28 days in the upper layer, is less than the lower layer, although both did not achieve the desired grade.

The Islamic quarter site

Three samples of the first layer were tested with weights (7.997, 7.918, 7.879) kg and dimensions (150*150*150)mm the samples were 7 days old and the density was as follows (2369, 2346, 2335) kg/m3 .these samples were loaded with fracture loads (640.55, 591.72, 701.13) KN and the result of fracture stress of these samples was (28.47, 26.30, 31.16) N/mm2, respectively.

By the same steps, three samples of the second layer were taken with weights (7.573, 7.698, 7.664) kg and dimensions (150*150*150) mm, the samples were 7 days old and the density was as follows (2244, 2281, 2271) kg/mm3 .these samples were loaded with fracture loads (690.14, 687.24, 685.77) KN and the result of fracture stress of these samples was (30.67, 30.54, 30.48) N/mm2, respectively.

The same steps were repeated 28 days after the samples and the weights of the first layer samples were (7.946, 7.985, 7.877) kg and with dimensions (150*150*150) mm the density was (2354, 2366, 2334) kg/m3 and with the fracture loads (753.05, 722.20, 722.52) KN and the result of fracture stress of these samples was (33.47, 32.10, 32.11) N/mm2, respectively.

As for the weights of the samples of the second layer, they were (7.637, 7.623, 7.601) kg with dimensions (150*150*150) mm the density was (2263, 2259, 2252) kg/m3 and loaded with fracture loads (790.18, 810.53, 830.43) KN and the result of fracture stress for these samples was (35.12, 36.02, 36.91) N/mm2, respectively.
The following table shows the comparison of the average compressive strength of the concrete of the first and second layer as well as for the assumed concrete grade compressive strength:

grade concrete	the average realistic pressure resistance of concrete		Number of days
C30	28.64 (N / mm2)	the first layer	Within 7 days
	30.57 (N / mm2)	The second layer	
C30	32.56 (N / mm2)	the first layer	Within 28 days
	36.02 (N / mm2)	The second layer	

It is noted that the concrete at this site is identical to the specification after the age of 28 days in the second layer, but what raises the question is the difference in the strength of the concrete of the two layers, whether at 7 days or 28 days.

Tajoura site

The same steps were repeated for 7 days and 28 days for the two layers for tajoura site , The following table shows the comparison of the average compressive strength of the concrete of the first and second layer as well as for the assumed concrete grade compressive strength:

concrete grade	the average realistic pressure resistance of concrete		Number of days
C30	15.45 (N / mm2)	the first layer	Within 7 days
	12.65 (N / mm2)	The second layer	
C30	27.67 (N / mm2)	the first layer	Within 28 days
	22.83 (N / mm2)	The second layer	

The results of concrete strength are observed here after 28 days in the upper layer, is less than the lower layer, although both did not achieve the desired grade, and these results were almost the same as al-aseraj site.

3. Implementation or execution errors:

In this paragraph, some implementation errors will be mentioned, supported by images

1.The spaces between the stirrups are not equal and may vary from one stirrup to another, while in the design the spaces should be equal and uniform as shown (7):

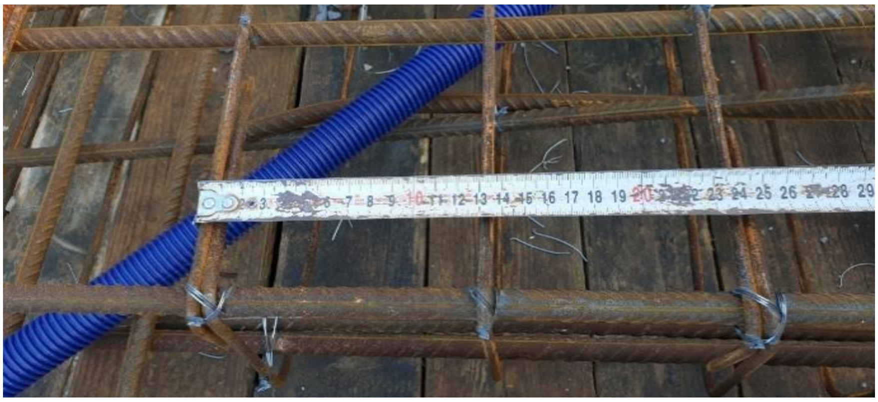

Figure 7 the spaces between the stirrups are uneven

2. The hollow brick is broken from the sides and not replaced, the brick is used to reduce the volume of concrete and hence reduces the weight of the structure and is included in the design as it reduces the weight of the structure as shown in figure (8):

Figure 8 The Shape of broken bricks

3. The presence of sewage pipes penetrating the roof and the beams and were not calculated in the design as shown in figure (9):


Figure 9 sewage pipes inside the beams

4. adding water when pouring the second layer to facilitate the levelling of the surface, but adding the water reduces the compressive strength of the concrete as shown in figure (10):

Figure 10 increasing water for concrete in the upper layer

5. pouring using a manual machine where the mixing ratio is inaccurate as shown in figure (11):

Figure 11 manual machine mixing and pouring

6. The delay in pouring the second layer, where the first layer began to harden, which causes a separation between the first layer and the second, as shown in figure (12):

Figure 12 delayed pouring of the second layer

7. The visibility of the deflection in the roof due to the lack of good supports of wooden formwork as shown in figure [13):

Figure 13 The deflection of the slab due to poor supports

Conclusion and recommendations

Conclusion:

Through this study, it was revealed that the people working on the technical specifications are not familiar with the technical specifications, and therefore the engineering principles of implementation are not adhered to, no structural drawings are being worked on, and this represents a great risk to the safety of citizens and the safety and age of the building, in addition to the lack of good supervision to follow up the implementation work on the project so that you can notice mistakes during implementation.

Through the study, it was found that the upper layer of concrete were poured with an addition of water and this result of water cement ration higher than the first layer, gives less strength than the required concrete grade, knowing that the upper layer it is the most important layer.

It was found many errors about the specifications, such as the number of steel numbers and stirrups and the spacing between the stirrups, which are neglected even if they are observed. The use of incompetent contractors has been observed.

Recommendations:

1. It is better that the concrete mix is prepared at the factory and not on site so that the mixing ratio of the materials is accurate and gives the required strength.

2. The need for good supervision and control of workers.

3. Do not add water to the concrete mix while it is in the truck, but the addition is in the factory while it is in the mixer.

4. It is advisable to replace the broken hollow bricks because the brick takes the place of concrete and reduces the amount of concrete and thus the weight of the roof decreases.

5. Water and sewage pipes must be included in the drawings during the design.

6. Make sure that the steel reinforcement does not come into contact with the wood to get a concrete cover that protects the steel.

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