COMPARISON BETWEEN WEIGHT AND VOLUME PERCENTAGES FOR CEMENT MORTAR

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Abstract:
The concrete in a simple case is a mixing of cement mortar and aggregates. Cement mortar consist of mixing cement and water which is cover the surface of aggregates. Through hydration of cement, the mortar becomes hardened and forming such like rock mass which is called concrete. The key of gaining hardened and strong concrete produced in a well mixing percentages and by mixing method which it is either weight or volume mixing. Concrete which has no equivalent cement mortar enough to fill spaces between aggregate particles lead to difficult molding process and produced concrete with weak strength. There are two ways of measuring materials in cement mortar: by weight and by volume percent, the first one is more accurate than the other specifically in determination compressive strength of cement mortar cubes, because it is having more cement content as compared with the second one. In this research, three percent (1:1, 1:2, 1:3) is taking with constant water to cement ratio of (0.35), the dimensions of cube are (7*7*7) cm to calculate compressive strength for (3, 7, 14, 28) days. The weight percentages have compressive strength more than volume percentages by changing factor of (1.2).

Keywords: cement mortar, weight measurer, volume measurer

1. Introduction:
Cement mortar is a homogenous mixture of cement sometimes lime is used along with sand and water.

The effect of using cement is to unify and tie sand grains to each other, when there happens a process of cement hydration and then sand grains will adhere to each other and fill the gaps between such grains [¹].

1.1 Cement:
Cement is a fine material that turns into viscous mortar if water is added, then changed to solid one after a period of time when exposed to both water and air. Thus, cement has hydraulic properties that enable it to be solid under water because of some chemical interactions and having water current resistance product.
So cement has an important role as adhesive material that helps to adhere different elements and materials. This role appears in structure and architectural works where cement is widely used [2].

1.2 Sand:
   It is a grain material found in nature. It is composed of fine metal grain that is only 0.0625 to 2 mm. the smallest one could be named as clay, and the biggest size grain is called gravel [3].

1.3 Water:
   Any kind of drinkable or undrinkable water could be used for mixing as some undrinkable water used in some kinds of concrete [4].

The effects of using water in cement mortar [1]:
   1- Hydration of cement and making a cement cover that mixes un related sand particles.
   2- Filling gaps between sand and cement grains and mixing together.
   3- Making mortar more cohesive with no segregation (gaps free).
   4- Facilitating workability of mixing and finishing.

1.4 Cement mortar properties [5]:
   1- Much widely used in Iraq.
   2- Used in building and walls finishing and it has humidity resistance.
   3- Affected by sulfuric salts, thus it is recommended to use anti-sulfuric cement especially in areas exposed to sulfuric salts.
   4- Walls and building units must be sparked with water before using mortar in order to have mixing water for a long period to have a great resistance.
   5- Cement mortar is affected by humidity, temperature change.

Figure1: cement mortar
1.5 Weight measurer:

This is measured when using different factories of multiple abilities then concrete is moved to the work site by special carts mixing or not mixing concrete, or it may be transported totally by tankers [6].

1.6 Volume measurer:

This could be measured by using a special volume containers measurable or non-measurable. These materials could be mixed by hand or by using different size of mechanic mixers [6].

2. Aim of the research:

The aim of this research is to study and compare weight and volume percentages of cement mortar as related to compressive strength and finding factors for changing from weight to volume choosing to set which is better and more accurate to have in future researches and projects.

This research also contain lab testing for cement mortar by using three common weight and volume percentages, they are as follows, (1:1), (1:2) and (1:3) also, compressive strength is tested aged (3,7,14,28) days.

3. Practical tests:

3.1 Material used:

A normal Portland cement (Mass) is used with graduated grains (Zone2) according to Iraqi Standard Specification No. 5 and No. 45 for year 1984 for cement and sand respectively.

Table 1 and figure 2 below show the gradation of sand grains used in this paper.

Table 1 gradation of sand used

| Sieve No. | % of Passing |
|-----------|-------------|
| 9.5       | 100         |
| 4.75      | 97.85       |
| 2.36      | 91.56       |
| 1.18      | 82.13       |
| 0.6       | 63.19       |
| 0.3       | 29.99       |
| 0.15      | 10.68       |
| 0.075     | 3.96        |
| Pan       | 2.72        |
3.2 Mixture design:

This common mixtures (1:1), (1:2), and (1:3) of cement mortar is used to make weight and volume mixes of 24 cube with dimensions (7*7*7) cm as shown in figure 3. Twelve of 24 cubes for weight mixes is tested by age (3,7,14 and 28) days, so to have three cubes for each age to test compressive strength. Then, get the average to determine the compressive strength per age.

Constant water to cement ratio is used. It is 0.35 cement and sand are mixed together in to two ways to get homogeneous mixture.

3.2.1 Weight measurer:

It is used to mix weighed materials as they were calculated manually earlier, then put in cube molds of dimensions (7*7*7) cm. They are compacted to removes air bubbles and left 24 hrs in the molds. After that they are taken out for curing then to be tested to determine compressive strength per age. This kind considers more accurate in determining material amount as mistakes are avoided especially mistakes of sand and cement compaction and the effects of humidity in sand that leads to buckling ( an increase in sand volume), where density decreased 40% according to fines of sand and humidity in it.

3.2.2 Volume measurer:

Materials mixed by using it can be measured by standard cylinder with (16 cm diameter by 17 cm height) dimensions. Then, mixed and put in 12 cubes (3 cubes per age) and compacted. It could be left for one day. Then put in curing tanks and to be tested finally determine compressive strength per age. This way is considered less accurate due to the inability of determining accurate amount of sand and cement as
well as changing of amount taken by every different mold by the changing of compaction. Figure 3 shows the molds used.

Figure 3 mold used in the work

4. Calculation and results:
   4.1 Amounts of materials used in mortar production:

Table 2 shows amounts of materials of weight and volume mixing percentages used in this paper.

As figures 4 and 5 show amounts of cement and sand for each percentage and for every square meter. Also, amounts of cement and sand for weight measurer are higher than those of volume measurer i.e weight percentage of mixtures are richer in cement content from that mixture of volume percentages.

Table 2 the amounts of materials for weight and volume percentages

| Mix percentage | Cement kg/m³ | Sand kg/m³ | Water l/m³ | Cement in mix kg | Sand in mix kg | Water in mix l |
|----------------|--------------|------------|------------|------------------|----------------|----------------|
| 1:1 by weight  | 938          | 938        | 328.5      | 4                | 4              | 1.4            |
| 1:1 by volume  | 778.5        | 941.5      | 272.5      | 3.5              | 4              | 1.2            |
| 1:2 by weight  | 616          | 1232       | 216        | 3                | 6              | 1.1            |
| 1:2 by volume  | 517          | 1913       | 181        | 2.5              | 9.5            | 0.88           |
| 1:3 by weight  | 462          | 1368       | 162        | 1.2              | 3.5            | 0.4            |
| 1:3 by volume  | 427          | 2624       | 150        | 1                | 12             | 0.35           |
Figure 4 cement amounts

Figure 5 sand amounts

4.2 Calculating density of cement and sand:

Through table 3 and figures 6 and 7 below, it is shown that there is a difference in density of materials used in this paper according to laboratory working method and modeling process.

Standard containers are used to determine the density of the used cement and sand. Results are shown below for every mixing percentage whether it is weight or volume. It is noticed that cement density is ranged between (995-1395) kg/m$^3$.

The dissimilarity of cement density may be due to different compaction degrees for the specimens during density measuring but [7] attributes this to way of transporting cement and pressure impact during lifting and discharge on density, properties and amount of pressure used in pumping.

As for sand density, it was between (1327-1395) kg/m$^3$. The difference in sand density may be due to its gradation and compaction rate plus humidity in it [8].
Shows that aggregates density used to change percentages of weight measurer to volume measurer or vice-versa may depend on many factors:

1- Gradation, as gradation continues aggregate gaps would be reduced and increased density.
2- Shapes of grains, as their interference increases aggregate gaps are reduced thus increasing density.
3- Compaction degree.
4- Aggregate humidity.

As these factors are all changing constantly, thus, density remains changing.

| Mixture ratio | Cement weight | Cement volume | Cement density | Sand weight | Sand volume | Sand density |
|---------------|---------------|---------------|----------------|-------------|-------------|--------------|
| 1:1 weight    | 4 kg          | 4.02*10^{-3} m³ | 995 kg/m³     | 4 kg        | 3*10^{-3} m³ | 1333 kg/m³   |
| 1:1 volume    | 3.32 kg       | 3.2*10^{-3} m³ | 1037.5 kg/m³  | 4.01 kg     | 3*10^{-3} m³ | 1337 kg/m³   |
| 1:2 weight    | 3 kg          | 3*10^{-3} m³   | 1000 kg/m³    | 6 kg        | 4.4*10^{-3} m³ | 1364 kg/m³   |
| 1:2 volume    | 2.52 kg       | 2.4*10^{-3} m³ | 1050 kg/m³    | 9.32 kg     | 6.8*10^{-3} m³ | 1370.5 kg/m³ |
| 1:3 weight    | 1.15 kg       | 1.2*10^{-3} m³ | 958.3 kg/m³   | 3.45 kg     | 2.6*10^{-3} m³ | 1327 kg/m³   |
| 1:3 volume    | 1.06 kg       | 1*10^{-3} m³   | 1395 kg/m³    | 12 kg       | 8.6*10^{-3} m³ | 1395 kg/m³   |

Figure (6) densities of cement
4.3 Calculating compressive strength of cement mortar cubes:

Difference in weight and volume measuring lead to different values of compaction strength where highest values are in weight mixtures in 1.2% increasing percentage as shown in table 4 and figure 8.

This table shows that percentage of weight mixtures give more compressive strength than percentage of volume mixture, this shows that the latter has less cement than weight mixtures as well as containing more sand due to volume measuring which allows more material that weight measuring process.

| Mix percentages | 3 days MPa | 7 days MPa | 14 days MPa | 28 days MPa |
|-----------------|------------|------------|-------------|-------------|
| 1:1 weight      | 6.95       | 12.88      | 17.15       | 20.57       |
| 1:1 volume      | 4.73       | 8.03       | 12.67       | 17.10       |
| 1:2 weight      | 3.11       | 6.26       | 11.61       | 15.52       |
| 1:2 volume      | 1.89       | 4.00       | 9.03        | 12.35       |
| 1:3 weight      | 1.41       | 3.12       | 4.60        | 10.30       |
| 1:3 volume      | 1.30       | 2.39       | 4.15        | 9.50        |

Figure 8 compressive strength for specimens

4.4 Changing from weight measuring to volume measuring and vice-versa:

Table 5 and equations (1and 2) are used to change amounts of cement and sand from weight measuring to volume measuring and vice-versa by using a special changing factor for each material in the practical part of the paper as shown below:

| Mix | Changing factor for cement | Changing factor for sand | Changing type |
|-----|----------------------------|--------------------------|---------------|

Figure (7) densities of sand
By using equations, weight measuring would be changed into volume measuring and vice-versa as below:

\[
\text{Cement amount in weight measurer} = \text{Changing factor} \times \text{Cement amount in volume measurer}
\]

\[
\text{Cement amount in weight measurer} = 1.2 \times \text{Cement amount in volume measurer} \quad \cdots \quad (1)
\]

\[
\text{Sand amount in weight measurer} = \text{Changing factor} \times \text{Sand amount in volume measurer}
\]

\[
\text{Sand amount in weight measurer} = 0.72 \times \text{Sand amount in volume measurer} \quad \cdots \quad (2)
\]

Same thing concerning densities, it would be changed from weight measurer to volume measurer and vice-versa by using changing factors shown in table 6 and equations (3 and 4) below:

### Table 6 changing factors for cement and sand densities

| Mix percentage | Changing factor for cement | Changing factor for sand | Changing type          |
|----------------|---------------------------|--------------------------|------------------------|
| 1:1            | 0.96                      | 1                        | Weight to volume       |
| 1:2            | 0.95                      | 1                        | Weight to volume       |
| 1:3            | 0.70                      | 0.95                     | Weight to volume       |
| average        | 0.87                      | 0.98                     | Weight to volume       |

By using equations: Densities are changed from weight measurer to volume measurer and vice-versa as below:

\[
\text{Cement density in weight measurer} = \text{Changing factor} \times \text{Cement density in volume measurer}
\]

\[
\text{Cement density in weight measurer} = 0.87 \times \text{Cement density in volume measurer} \quad \cdots \quad (3)
\]

\[
\text{Sand density in weight measurer} = \text{Changing factor} \times \text{Sand density in volume measurer}
\]
Sand density in weight measurer = 0.98 * Sand density in volume measurer .................. (4)

Concerning compressive strength, changing factors is shown in table 7 and equation (5) below:

Table 7 changing factors for compressive strength at 28 days

| Mix percentage | Changing factor for compressive strength | Changing type       |
|----------------|-----------------------------------------|---------------------|
| 1:1            | 1.2                                     | Weight to volume    |
| 1:2            | 1.26                                    | Weight to volume    |
| 1:3            | 1.1                                     | Weight to volume    |
| average        | 1.2                                     | Weight to volume    |

As equation, it could be changed as follows:

Compressive strength in weight measurer = 1.2 * compressive strength in volume measurer .. (5)

5. Conclusions:

In the light of the present study and the quality of materials used, it could be concluded that:

1. Mixtures of volume measurer gave less cement amount than other mixtures of weight measurer with changing factors 0.83 due to possibility of expansion in cement volume when volume measuring (increase in volume), this increase reaches 1.25% so, these mixtures are poorer in cement.
2. When sand used, its humidity must be good (saturated surface dry) when it could not affect the water of mixture.
3. Densities of both cement and sand in volume measurer are higher than weight measurer with changing factors 1.15 and 1.02 respectively, due to the small size of the sample in volume measurer in contrast to weight measurer sample.
4. When sand amount double and triple increased over cement amount in mixture percentage, water would be decreased by 0.41%.
5. Compressive strength of weight measurer mixtures are higher than volume measurer mixtures, because of the good amount of cement in weight measuring and it is according to Iraqi Standard Specifications.
6. Recommendations and suggestions:

1. Necessity of mentioning ways of measuring materials in a table of amounts of contracts whether weight or volume in order to determine compressive strength of mortar to avoid problems due to absence of such information.
2. Necessity of interference between mixture design, materials and chemical composition of cement along with ways of saving materials, mixing speed, efficiency and quality of equipment plus situations of the site (temperature and humidity). All these should be taken into consideration by the engineer and try to find solutions.
3. This paper could be seen as the core to many projects in this field that determines the amount of materials, densities and changes along with the incompatibilities of materials when they are measuring.

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