

Comparative Study of Terrazzo Tiles Produced in Koya and Erbil, and its Suitability for Construction Purposes

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Abstract—Tiles are durable and have a long lifespan. They may be used as a floor finish for both interior and exterior applications. Experimental and field studies were conducted to investigate the parameters and properties of terrazzo tiles from different regions, namely Erbil and Koya being represented by factories (A) and (B) respectively. These parameters and properties are dimensions, water absorption, modulus of rupture and impact resistance. Test results indicate that the dimensions and modulus of rupture for the tiles from both factories (A) and (B) are conformable with Iraqi specifications, but water absorption of terrazzo tiles from factory (B) does not conform with the Iraqi specification and having surface and total absorption values which are 55.1% and 23.8% higher than that for factory (A) tiles, respectively. The results show that terrazzo tiles of factory (A) have an impact resistance value which is 50% higher than that of tiles from factory (B). The field study which includes questionnaire procedure indicates that 63% of the residents agreed that the terrazzo tiles are beautiful as a floor finishing material and at the same time 94% agreed that this material is expensive. This study shows also that only 20% of Koya residents are satisfied with the quality of the production of factory (B), whereas, 90% of Erbil residents are satisfied with the production of factory (A).

Index Terms—Impact resistance, modulus of rupture, terrazzo tiles, water absorption.

I. INTRODUCTION

There are many different types of flooring which make it difficult to know just what type we can select for floor finishing and how to maintain and care for each type of floor. Tiles provide one of the most cost-effective and

environmentally friendly flooring choices. Its manufacturing does not necessitate the use of heavy chemicals or other harmful substances used to make other flooring types in forms of ceramic, porcelain, quarry, agglomerate and terrazzo tiles. They are durable and have a long lifespan, may be used as a wall or floor finish for both interior and exterior applications (National Terrazzo and Mosaic Association, 1994).

Tile is rated and placed in one of five grades or groups based on its relative hardness, ability to stand up to wear and percentage of water it will absorb. Group I is for area of light traffic such as a residential bathroom floor. Group II is for most areas inside the home except the kitchen and entry ways. Group III is for anywhere within a home. Group IV is for homes and light to medium commercial areas. Group V is for extra heavy traffic areas and can be used anywhere.

Terrazzo tiles get their name from the Italian word for “terraces” and were created several hundred years ago in Europe when Venetian workers discovered a new use for discarded marble remnants (National Terrazzo and Mosaic Association, 2014). Since that time it has become a logical, practical solution for contemporary design and construction. The beauty and versatility of terrazzo offers today's architects and designers a contemporary flooring and wall material for interior and exterior design use. Fifteenth century Venetian marble workers began to use odd-size marble pieces, remaining from the custom made marble slabs, to surface the terraces around their living quarters. The uneven, rough surfaces created when the spells were set in clay to anchor them, convinced the workers that flattening the surface would produce a smoother surface which is more comfortable for walking. And so they began to rub the surfaces with hand stones achieving a smoother, flat surface (National Terrazzo and Mosaic Association, 2014). The workers soon advanced their technique for rubbing the surfaces by designing a long handle with a weighted end to which they could fasten their rubbing stones. Now they were able to rub the terraces in a more comfortable stand-up position, using their body weight to provide the pressure to abrade the surface faster. With this crude equipment and back-breaking labor they achieved a smoother, flat surface but still lacking the true marble color that only resulted when the surface was wet. Ceramic Institute

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of America mentioned that the first president, George Washington, selected terrazzo floors for many of his important rooms. Soon American terrazzo was created from the wealth of marble in the United States, and American ingenuity advanced installation techniques. This made terrazzo materials available for all concepts of construction. Terrazzo has proven itself throughout history as the sensible choice for floor surfaces that require resistance to heavy abuse, while still retaining beauty and low maintenance costs. (Karam and Tabbara, 2009) specify that the material is a composite of natural marble chippings set in a matrix of cement with a color pigment added to it. The range of aggregates in size and color is vast and they can be set into practically any color cement to create an endless number of finishes. Once laid, the terrazzo is ground down and polished to expose the aggregate. A minor disadvantage of using terrazzo tiles is that after the initial heavy polishing at the time the tiles are laid it is essential to polish the tiles from time to time. This is necessary to maintain the shine and appearance of the floors.

II. EXPERIMENTAL PROGRAM

Experimental studies and field works are made to study the method of manufacturing and properties of terrazzo tiles from different regions “Erbil (factory A) and Koya (factory B)”. The properties and parameters of the tiles were measured and recorded for each factory according to Iraqi specification (No.1042, 1984) including dimensions, surface water absorption, total water absorption and rupture strength. In addition to these properties the impact property for tiles was studied. The field work including questionnaire procedure for 50 houses in both regions made to study the usage of terrazzo tiles as finishing materials for floors, this study contains different opinions about the terrazzo tiles including peeling off, erosion, beauty, cost and others.

A. Manufacturing and Curing of Terrazzo Tiles

Square terrazzo tiles, of sizes $400 \times 400 \times 30 \text{ mm}^3$ and $300 \times 300 \times 30 \text{ mm}^3$ (length \times width \times thickness), were manufactured at local factories (A) in Erbil and (B) in Koya. The manufacturing process in factory (A) was accomplished with a good quality control according to the general of Iraqi Specification (No.1042,1984) casted in tempered steel moulds consisting of two layers: a 15 mm thick white hydraulic cement layer enclosing marble chips which were brought from Permam and Sulaimani then vibration was applied to the extent that it allows the trapped air to get out from the surface then a 15 mm thick regular gray hydraulic Portland cement mortar backing then maintaining a standard pressure of 150 bar to get sufficient merging of the two layers as shown in Fig. 1. Grain size distribution of the marble chips, marble powder filler, and aggregates for the mortar backing were all selected according to Iraqi specification recommendations. Finally a careful polishing process eliminates a 3 mm upper layer and reveals the beauty of the marble chips mixed in colored cement. On the other hand, the manufacturing process at factory (B) was accomplished without any quality control

casted in steel moulds consisting of two layers: a 15 mm thick white hydraulic cement layer enclosing marble chips brought from Gorashin then vibration was applied to allow the trapped air to get out from the surface then a 15 mm thick regular gray hydraulic Portland cement mortar backing followed by maintaining a standard pressure of 100-200 bar to get sufficient merging of the two layers as shown in Fig. 2. Finally a careful polishing process eliminates a 3 mm upper layer and reveals the beauty of the marble chips mixed in colored cement.

B. Curing

Factory (A) followed two methods for curing of terrazzo tiles:

- 1) Putting the tiles in a vapor room for six hours then taking them out into sunlight for 2 hours.
 - 2) Putting the tiles in clean water for 1-2 weeks (which is close to the method recommended by Iraqi specifications).
- But tiles in factory (B) were cured by putting them in water containing impurities for 4-days only.

C. Test Technique

Dimensions and Shape

The dimension and shape were determined according to Iraqi specification (No.1042, 1984) using $400 \times 400 \times 30 \text{ mm}$ terrazzo tiles at the age of 28 days. The dimensions determined by using simple measuring devices like steel ruler, angles and T-square in order to check the sides, edges of the tile and the accuracy of the angles in addition to the thickness of surface layer and thickness of terrazzo tile. The average values of three samples were recorded.



Fig. 1. Manufacturing machine for terrazzo tile in factory (A).



Fig. 2. Manufacturing machine for terrazzo tiles in factory (B).

Water Absorption

Water absorption includes:

1) Face Absorption

The face absorption test was determined according to Iraqi specification (No.1042, 1984) using 300×300×30 mm terrazzo tiles at the age of 28-days. In this test the samples were dried for 8 hours by placing them in oven at temperature of (100±5)°C then cooled for 24 hours at laboratory temperature then recording the weight which will be the dry weight. After that, tile is immersed on its face in water for 24 hours with attention that the height of water is 5 mm from the thickness of the sample and the tile should not be totally immersed in water. Then the sample is taken out from water and the surface is dried with a dry cloth and the weight is recorded which will be the wet weight. The face absorption is calculated by:

$$Face\ Absorption = \frac{B - A}{Surface\ area} \quad (1)$$

Where:-

A = Dry weight of the sample (gm).

B = Wet weight of the sample (gm).

2) Total Absorption

The total absorption was determined according to Iraqi specification (No.1042, 1984) using (300×300×30) mm terrazzo tiles at the age of 28-days. In this test the samples were dried for 8 hours by placing them in oven at a temperature of (100±5)°C then cooled for 24 hours at laboratory temperature after which the weight is recorded which will be the dry weight (A). After immersing the tile in water for 24 hours with attention that the tile should be totally immersed in water, the sample was taken out from water and dried with a dry cloth, then the weight was recorded which will be the wet weight (B). The total absorption is calculated, by:

$$Total\ Absorption = \frac{B - A}{A} \times 100 \quad (2)$$

Modulus of Rupture (M.O.R)

Modulus of rupture value was determined according to Iraqi specification (No.1042, 1984) and carried out using (300×300×30) mm terrazzo tiles simply supported with clear span of 200 mm at the age of 28 days. This test was carried out by placing the tile on the two supports of testing apparatus in symmetrical way, applying a continuous load until a homogeneous fracture happened, then recording the load that causes total failure of the tile. The Modulus of Rupture is calculated by:

$$M.O.R = \frac{3PL}{2bd^2} \quad (3)$$

Where;

M.O.R = Modulus of rupture (MPa).

P = Load at failure (N).

L = Clear loaded span (mm).

b = Width of the tile (mm).

d = Thickness of the tile (mm).

Impact Resistance Test

The impact resistance value can be measured by a test method that is simple and easy to carry out and has been developed by ACI committee 54, (1986) which recommends the use of repeated impact drop weight test to estimate this important property since there is no recognized standard test to assess the impact resistance of tiles. In this research a simple repeated drop-weight of 1.25 Kg used to fall down from 1 meter height on (400×400×30) mm terrazzo tiles through a tube of circular section with diameter of 3 inches which acts as a drop weight guide and held vertically above the center of the tile as shown in Fig. 3.

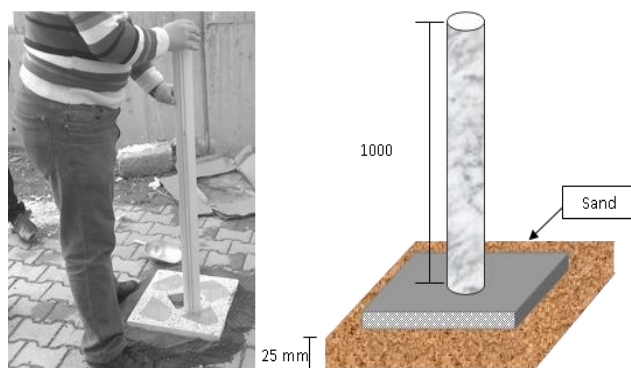


Fig. 3. The impact resistance test.

Questionnaires Procedure

Questionnaire procedure is another field study which was made for different 50 houses in both regions to study the usage of terrazzo tiles as finishing materials for floors. This study contains different opinions about the terrazzo tiles which were derived from the residents occupying these houses, including peeling off, erosion of face layer, beauty, cost and others.

III. RESULTS AND DISCUSSION

A. Manufacturing and Curing of Terrazzo tile

From the field vision in both factories the following results can be obtained:-

- 1) Marble chips used to make a terrazzo tiles in factory (A) were washed and stored into four silos classified according to the size as shown in Fig. 4-a, while the chips used to make the tiles in factory (B) were stored in an open area and used without washing or cleaning as shown in Fig. 4-b.
- 2) Mix proportion of base layer in both factories was 1:4 (cement: sand) which is not adequate to the standard Iraqi specification (No.1042, 1984) which recommended that the mix proportion should be 1:3 or 1:3.5.
- 3) Pressing pressure in factory (B) was estimated by workers between (100-200) bars while in factory (A) it was

controlled at 150 bars.

- 4) Terrazzo tiles in factory (A) were made by automatically operating machine with a good quality control and they used binders for surface (face) layer while that for factory (B) the mixture was made on the floor then poured into the mould manually by hand, as shown in Fig. 2, without binders used in face layer.
- 5) Production of factory (A) is (3000) tiles/day which is 233.33% higher than that of factory (B) (900) tiles/day due to using of multi moulds machine for making tiles as shown in Fig. 1.
- 6) Curing tiles in factory (B) is not confirmable with the Iraqi specification (No. 1042, 1984) which recommended curing the tiles in a humid condition for 9 days; 2 days in clean water then sprinkling the tiles with water for 7 days.



Fig. 4. Marble chips storing; (a) In factory (A) and (b) In factory (B).

B. Dimensions and Shape

The average dimensions of six terrazzo tiles from factories (A) and (B) are shown in the Table I. These dimensions confirm to the Iraqi specification article (No.6, 1984) which allow tolerance (± 1 mm) in length and (± 3 mm) in thickness after polishing and grounding. The tiles from factory (A) were polished and grounded better than tiles from factory (B) with surface clean from cracks and flaws and homogeneity distribution of marble chips, both group of tiles (factories A and B) are square in shape with vertical edges these properties confirming with the Iraqi specification article (No.7 , 1984).

TABLE I
DIMENSIONS OF THE TERRAZZO TILES

| Source of Terrazzo tiles | Erbil (Factory A) | | | Koya (factory B) | | |
|--|-------------------|----------|----------|------------------|----------|----------|
| Dimensions (mm) | <i>l</i> | <i>w</i> | <i>t</i> | <i>l</i> | <i>w</i> | <i>t</i> |
| | 399 | 399 | 29.1 | 399 | 399 | 29.8 |
| Iraqi specification (400×400×300 mm ³) | ± 1 | ± 1 | ± 3 | ± 1 | ± 1 | ± 3 |
| | Conformable | | | Conformable | | |

l is the length, *w* is the width and *t* is the thickness

C. Water absorption

Surface Absorption

The surface absorption results of six samples which were taken from factory (A) and other six samples from factory (B)

are presented in Table II and Fig. 5. From these results, it is indicated that the surface absorption of factory (B) terrazzo tiles is 55.1% higher than surface absorption of factory (A) terrazzo tiles: This can be attributed to high absorption of the marble chips used in face layer of terrazzo tiles and insufficient compaction of the face layer. It is noticed that the surface absorption of factory (B) terrazzo tiles is not conformable with the Iraqi specification (No.1042 article No.9-1-1, 1984) which recommends that the surface absorption should not exceed 0.4 gm/cm².

TABLE II
SURFACE ABSORPTION OF THE TERRAZZO TILES

| Source of Terrazzo tiles | Erbil (Factory A) | Koya (Factory B) |
|--|-------------------|------------------|
| Surface Absorption (gm/cm ²) | 0.22 | 0.49 |
| Iraqi specification (Not exceed 0.4 gm/cm ²) | Conformable | Not Conformable |

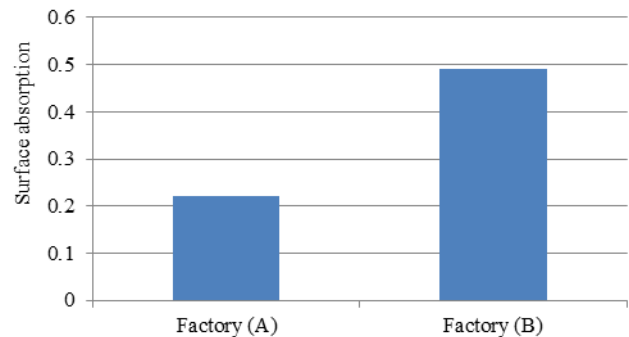


Fig. 5. Surface absorption (gm/cm²) of the terrazzo tiles in factories (A) and (B).

Total Absorption

The total absorption values of six samples which were taken from factory (A) and another six samples from factory (B) are presented in Table III and Fig. 6. These values indicate that total absorption of factory (B) terrazzo tiles is 23.8% higher than total absorption of factory (A) terrazzo tiles; this is due to high voids content in the mixture as a result of insufficient vibration applied during the production. It is noticed that the total absorption of factory (B) terrazzo tiles is not conformable with the Iraqi specification (No.1042 article No.9-1-2, 1984), which recommends that the total absorption should not exceed 8%.

TABLE III
TOTAL ABSORPTION OF THE TERRAZZO TILES

| Source of Terrazzo tiles | Erbil (Factory A) | Koya (factory B) |
|-------------------------------------|-------------------|------------------|
| Total Absorption% | 8 | 10.5 |
| Iraqi specification (Not exceed 8%) | Conformable | Not CONFORMABLE |

D. Modulus of Rupture (M.O.R.)

The modulus of rupture results of six samples which were taken from factory (A) and other six samples from factory (B)

are presented in Table IV and Fig. 7. From these results, it is indicated that the modulus of rupture for both factories (A) and (B) terrazzo tiles are conformable with the Iraqi specification (No.1042 article No.9-2, 1984) which recommends that the modulus of rupture of terrazzo tiles should not be less than 3 N/mm². It also indicates that the modulus of rupture for factory (A) tiles is 1.72% higher than that for factory (B). This is due to controlled pressing pressure applied during manufacture.

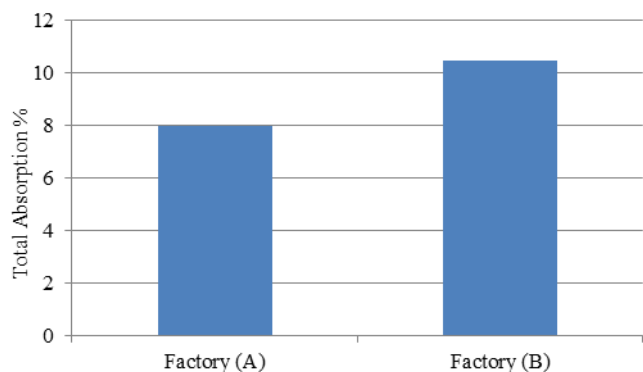


Fig. 6. Total absorption of the terrazzo tiles.

| Source of Terrazzo tiles | Erbil (Factory A) | Koya (factory B) |
|--|-------------------|------------------|
| Modulus of rupture (N/mm ²) | 5.23 | 5.14 |
| Iraqi specification (Not less than 3 N/mm ²) | Conformable | Conformable |

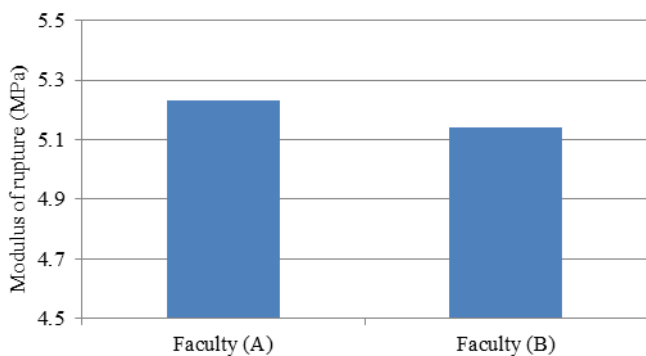


Fig. 7. Modulus of rupture of the terrazzo tiles.

E. Impact resistance

The impact resistance results of six samples which were taken from factory (A) and other six samples from factory (B) are presented in Table V and plotted in Fig. 8. From these results, it can be recognized that the impact resistance for factory (A) tiles is twice higher than that for factory (B) terrazzo tiles. This can be attributed to sufficient pressing pressure being applied during manufacturing. The important

visual observation which can be drawn from Figs. 9 and 10 is the symmetrical failure of factory (A) tiles compared with a non-uniform failure of factory (B) tiles and the marble chips of the face layer in factory (B) tiles split from the surface at the line of failure compared with factory (A) tiles. This can be attributed to the bad bond between the materials (cement and marbles) due to insufficient pressing used in the manufacturing which was selected by workers.

| Source of Terrazzo tiles | Erbil (Factory A) | Koya (factory B) |
|----------------------------------|-------------------|------------------|
| Impact resistance (No. of blows) | 6 | 3 |

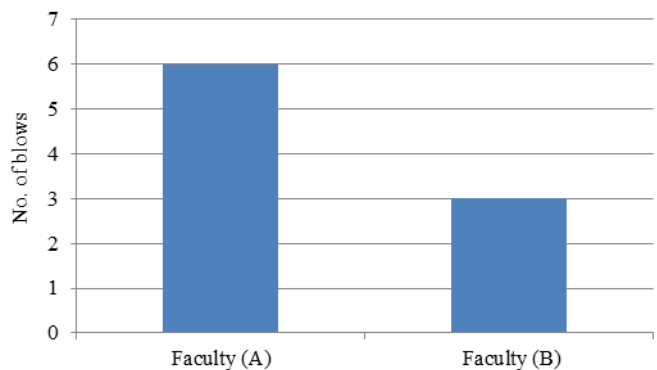


Fig. 8. Impact resistance (No. of blows) of the terrazzo tiles.



Fig. 9. Splitting failure of terrazzo tiles of factory (A).



Fig. 10. Splitting failure of terrazzo tiles of factory (B).

F. Questionnaire Procedure

The questionnaire procedure is another field study which was made for different 50 houses in both regions to study the usage of terrazzo tiles as finishing materials for floors. This

study includes different opinions about the types of flooring (ceramic, granite, porcelain and terrazzo tiles), and which one the residents preferred. The reasons behind using of terrazzo tiles in flooring were also discussed in this study which was derived from the opinion of the residents occupying these houses, including beauty, peeling off, erosion, cost and others.

Table VI and Fig. 11 show that the terrazzo tiles have a high usage percentage as a flooring finish material compared with other types. 63% of the participants in both regions, Erbil and Koya agreed that the terrazzo tiles are beautiful and 94% have agreed that this type of flooring is expensive, as shown in Table VII and Fig. 12.

TABLE VI
PERCENTAGE OF USAGE FOR THE DIFFERENT TYPES OF FLOORING

| Flooring types (%) preferring to use this type in both Erbil and Koya | Granite | Ceramic | Porcelain | Terrazzo Tiles |
|---|---------|---------|-----------|----------------|
| | 4.66 | 27.48 | 6.66 | 61.2 |

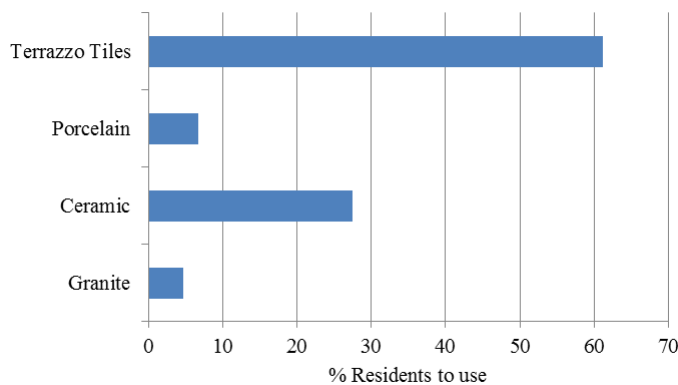


Fig. 11. Percentage of usage for the different types of flooring.

TABLE VII
PERCENTAGE OF RESIDENT'S OPINIONS ABOUT PROPERTIES OF THE TERRAZZO TILES

| Property | Beauty | Peeling off | Erosion | Cost |
|---------------------------------------|--------|-------------|---------|----------------|
| Residents' opinion (%) (Erbil & Koya) | 63 | 52 | 50 | 94 (expensive) |

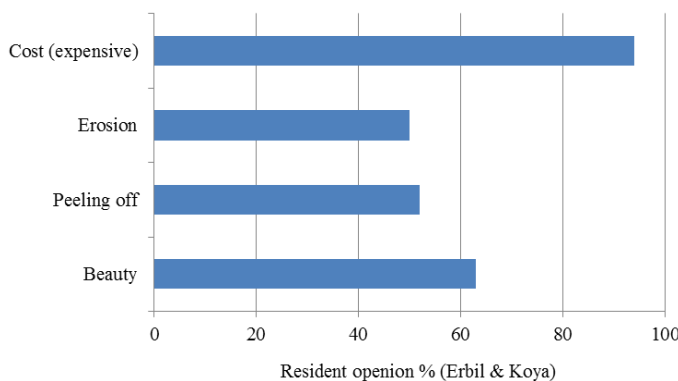


Fig. 12. Percentage of residents' opinion about the properties of the terrazzo tiles.

Table VIII and Fig. 13 show that 20% of the participants in Koya are satisfied with the type of terrazzo tiles used, while about 90% of those from Erbil show satisfaction with the same floor finishing material. This can be attributed to the manufacturing and properties of factory (B) terrazzo tiles.

TABLE VIII
PERCENTAGE OF RESIDENTS' SATISFACTION WITH THE TERRAZZO TILES

| Property | Erbil | Koya |
|------------------|-------|------|
| Satisfaction (%) | 89.33 | 20 |

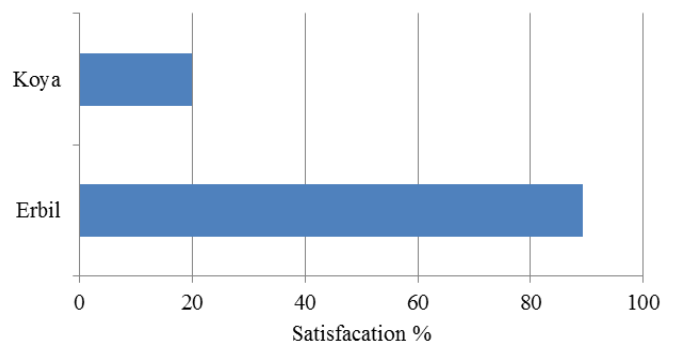


Fig. 13. Percentage of residents' satisfaction with the terrazzo tiles.

IV. CONCLUSION

The following conclusions can be drawn from this study:-

- 1) Factory A produced tiles according to Iraqi specification requirements and has better production than factory B.
- 2) Both factories did not achieve the Iraqi specification (No. 1042, 1984) related to the base layer.
- 3) Surface absorption of factory (B) terrazzo tiles is 55% higher than factory (A) terrazzo tiles and did not conform with the Iraqi specifications (No. 1042, 1984).
- 4) Total absorption of factory (B) tiles is 23.8% higher than factory (A) terrazzo tiles and did not conform with the Iraqi specifications.
- 5) Modulus of rupture of terrazzo tiles from both regions (Erbil and Koya) are confirm with Iraqi specifications (No. 1042, 1984).
- 6) Impact resistance of factory (A) terrazzo tiles is twice higher than factory (B) tiles with a symmetrical failure.
- 7) Terrazzo tiles have a higher percentage (61.2%) for being used as a floor finishing material compared with granite, ceramic and porcelain, based on questionnaire results in Koya and Erbil.
- 8) The residents' questionnaire procedure has indicated that only 20% of the participants in Koya show their satisfaction with the type of terrazzo tiles they used while about 90% of those from Erbil show satisfaction with the same floor finishing type.

V. RECOMMENDATIONS

According to the experimental work in this investigation, the following is recommended:

- 1) Marble chips used for making the face layer of terrazzo tiles should be tested for water absorption and washed by clean water before using them in the manufacturing of terrazzo tiles.
- 2) The manufacturing components of terrazzo tiles should be automatically mixed and poured with sufficient vibration for both surface and base layers.
- 3) Pressing pressure should be sufficient to obtain tiles with good properties and without splitting of marble chips from the face layer.
- 4) Erosion percentage and mechanical properties of the tiles should be tested.

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