# ➢ Water Absorption in Dust-Pressed Ceramic Tiles: Measurement, Analysis, and Implications for Performance

- Comparison Between two methods in Water Absorption (Boiling and vacuum pressure method)

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# 1 Introduction

Ceramic tiles grace our homes and businesses, offering beauty, durability, and functional benefits. However, not all ceramic tiles are created equal. A crucial factor determining a tile's suitability for different environments is its water absorption. This introduction will explore the concept of water absorption in dust-pressed ceramic tiles, the methods used to measure it, and the crucial implications for tile performance and selection.

# 2 Brief Overview of dust press tile manufacturing.

- Raw Material Preparation

- ✓ Clay and Additives: The primary raw material is clay, often blended with other minerals like feldspar, quartz, and fluxes to achieve desired properties.
- ✓ Drying and Grinding: Clays and additives are dried and ground to a very fine powder with a controlled moisture content (around 5-8%).

2-2 Dust Pressing

- ✓ Mold Filling: The powdered clay is carefully loaded into a steel mold or die.
- ✓ Hydraulic Press: A powerful hydraulic press applies immense pressure (several tons per square inch) to compact the powder into the desired tile shape.
- ✓ Green Tile: This produces a "green" tile, which is solid but not fully hardened.

2-3 Drying

- ✓ Controlled Drying: Green tiles undergo a controlled drying process to remove residual moisture and prevent cracking or deformation.

2-4 Firing

- ✓ High-Temperature Kiln: Dried tiles are fired in a kiln at temperatures exceeding 1000°C. This fuses the clay particles, creating a strong and durable ceramic body.

2-5 Glazing (Optional)

- ✓ Decorative and Functional: Many dust press tiles receive a glaze coating for aesthetics and enhanced surface properties like stain resistance.
- ✓ Glaze Application: Glazes are applied as a liquid or powder.
- ✓ Second Firing: Glazed tiles typically undergo a second firing to bond the glaze to the tile body.

2-6 Finishing and Inspection

- ✓ Trimming and Sorting: Tiles may be trimmed or polished for specific edge details.
- ✓ Quality Control: Tiles are inspected for defects, dimensions, and overall quality.

# 3 The importance of water absorption in tile performance

3-1 Staining:

- ✓ High water absorption makes tiles more susceptible to staining. Liquids can penetrate into the pores of the tile, leaving behind discolorations that are difficult or impossible to remove.
- ✓ Tiles with low water absorption are more stain-resistant, as spills stay primarily
- ✓ on the surface and can be easily wiped away.

3-1 Freeze-Thaw Resistance:

- ✓ In areas with freezing temperatures, absorbed water can become a major issue. When water freezes, it expands, putting pressure on the tile structure.
- ✓ Tiles with high water absorption are more prone to cracking, spalling, or breakage due to freeze-thaw cycles.
- ✓ Low absorption tiles are better equipped to withstand these conditions, maintaining their structural integrity over time.

3-2 Efflorescence:
- ✓ This is the whitish, powdery substance that can sometimes appear on tile surfaces. Efflorescence occurs when soluble salts are carried by water through the tile and evaporate on the surface.
- ✓ Porous tiles with higher water absorption are more likely to experience efflorescence, affecting their aesthetics.

3-3 Strength and Durability:
- ✓ Over time, water absorption can weaken the tile's structure. This can lead to increased susceptibility to chipping, cracking, or other damage under load.
- ✓ Lower absorption tiles tend to exhibit higher strength and greater long-term durability.

3-4 Suitability for Wet Areas:
- ✓ Water absorption is directly linked to a tile's suitability for wet areas like bathrooms, showers, kitchens, or exterior applications.
- ✓ High absorption tiles are not ideal for these areas, as they are more prone to damage, staining, and hygiene concerns.
- ✓ Regulations often specify maximum water absorption limits for tiles intended for use in wet environments.

## 4 Test specimens

### 4.1 Boiling method according to (EN ISO 10545-3:1997)

4.1.1 A sample of each type of tile under test shall consist of 10 whole tiles.

4.1.2 If the proper surface area of each individual tile is greater than 0,04 $m^2$, only five whole tiles shall be used for the test.

4.1.3 When the mass of each individual tile is below 50 g; a sufficient number of tiles shall be taken so that each test specimen reaches a mass of 50 g to 100 g.

4.1.4 Tiles with sides longer than 200 mm may be cut into smaller pieces, but all such pieces shall be included in the measurement. With polygonal and other non-rectangular tiles, the lengths and widths shall be those of the enclosing rectangles.

### 4.2 vacuum pressure method according to (ISO 10545-3:2018)

4.2.1 Sampling

Sampling shall be carried out according to the dimension of tiles as reported in Table 1. The number of the specimens to be tested for each tile as well the number of tiles are function of the tile dimension. Tiles and relevant specimens shall not contain visible damage or cracks prior to testing and shall not have been previously tested. Any loose or contaminating material shall be removed. This includes any mesh, paper and adhesive that has been applied to mosaics. When the mass of each individual tile is below 50 g, a sufficient number of tiles shall

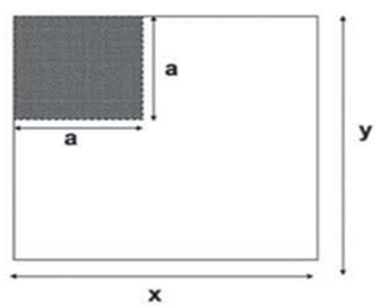
**Table 1 — Sampling**

| Maximum area A cm$^2$ | Reference paragraph forsample cutting | n°of specimens per tile to be tested | Totaln°of tiles | Totaln° ofspecimens |
|---|---|---|---|---|
| A ≤ 400 | 6.2.2 | 1 | 5 | 5 |
| 400 < A ≤ 3 600 (with x and y > 20 cm) | 6.2.3 | 1 | 5 | 5 |
| 400 < A ≤ 3 600 (with minor edge y ≤ 20 cm, and major edge x < 100 cm) | 6.2.4 | 1 | 5 | 5 |
| 400 < A ≤ 3 600 (with minor edge y ≤ 20 cm, and major edge x ≥ 100 cm) | 6.2.4 | 2 | 5 | 10 |
| A > 3 600 (with minor edge y ≤ 20 cm, and major edge x ≥ 100 cm) | 6.2.5 | 2 | 3 | 6 |
| A > 3 600 (with minor edge y > 20 cm) | 6.2.5 | 4 | 3 | 12 |
| NOTE For non-rectangular tile, consider the area of the minimum rectangle in which the tile can be fit. | | | | |

4.2.2 Sample cutting

Each tile shall be cut into smaller pieces as described in 6.2.3 where some common examples are reported. Cutting of specimens shall consist of scoring and snapping, or sawing when impossible to score and snap with conventional tile-scoring equipment (as can be the case with highly textured and structured porcelain tiles). Cutting may be performed at the factory following the sampling criteria described where the sample being cut is at least 10 cm bigger on each cut side. At the testing facility, cutting shall be done no more than four hours before the specimens are placed in the dryer. Specimens shall be kept clean with no contaminating material after cutting.

6.2.3 Tiles greater than 400 cm$^2$ and less than or equal to 3 600 cm $^2$, where x and y >20 cm A 20 x 20 cm portion, within 1 cm, shall be cut from one corner of each specimen for testing (see Figure below).




**x > 20 cm, y > 20 cm, a = 20 cm (within 1 cm)**

*Figure 2 - Scheme of cuts for tiles greater than 400 cm$^2$ and less than or equal to 3 600 cm$^2$ where x and y > 20*

## 5 Principles of water absorption measurement.

- ✓ Porosity: Ceramic tiles, even when seemingly solid, have a network of tiny pores or voids within their structure. These pores are a result of the manufacturing process and the composition of materials.

- ✓ Absorption and Saturation: When a tile is immersed in water, these pores allow water to penetrate. The tile will continue to absorb water until it reaches a point of saturation, where all accessible pores are filled.

### 5.1 Principles of Measurement

Water absorption measurement methods, regardless of whether it's the boiling method or vacuum pressure, rely on the following key principles:

5.1.1 Dry Weight Determination: The tile is thoroughly dried to a constant weight. This establishes a baseline weight of the tile in its completely dry state.

5.1.2 Saturation: The goal is to force as much water into the tile as possible. This is where the boiling and vacuum pressure methods differ:

5.1.3 Boiling: Tiles are submerged in boiling water for a set time. The heat helps increase water penetration.

5.1.4 Vacuum Pressure: Air is removed from the tile's pores using a vacuum, and then the tile is immersed in water under pressure, forcing water into the airless pores.

5.1.5 Wet Weight Determination: After saturation, excess surface water is carefully removed, and the tile is weighed again. This wet weight indicates how much water the tile has absorbed.

5.1.6 Calculation: The fundamental calculation is:
Water Absorption (%) = [(Wet Weight - Dry Weight) / Dry Weight] * 100

### 5.2 Factors Affecting Measurement Accuracy

- ✓ Complete Saturation: The methods need to ensure that the tile reaches as close to full saturation as possible to provide a true representation of the maximum amount of water it can hold.
- ✓ Surface Water Removal: Before weighing the wet tile, it's crucial to remove all excess water from the surface without drawing any water out of the pores. This requires standardized procedures.
- ✓ Tile Variability: Natural variations within tiles can slightly affect the absorption results between samples.

## 6 Procedure

### 6.1 Sample preparation

- ✓ Dry the test specimens to constant mass (see NOTE) in the oven adjusted to a minimum of 110 °C, not to exceed 160 °C for a minimum of 24 h (or such other time as has been established for the oven in use and the mass of tiles being dried). The drying of the specimens and the determination of their masses may be done either before or after the specimens have been impregnated with water. Usually, the dry mass is determined before impregnation. However, if the specimens are friable or evidence indicates that particles have broken loose during the impregnation, the specimens shall be dried and weighed after the suspended mass and the saturated mass have been determined. In this case, the second dry mass shall be used in all appropriate calculations.

*NOTE: - Constant mass is reached when after two subsequent weightings, the final weight does not change more than 0.1 %. Specimens being tested directly following their manufacture can be considered fully dried so long as they have not been subjected to any process that wets the specimen post firing (such as can occur in cutting and polishing operations), and they are placed in a desiccator sufficiently quickly (usually within no more than 30 min of exiting the kiln) that no moisture has been absorbed from ambient air, as can be confirmed by weighing to constant mass a after impregnation.*

- ✓ *Cool the tiles in the desiccator over silica gel or another suitable desiccant but not an acid.*
- ✓ *Weigh each tile and determine with an accuracy of 0,01 % of the mass, the mass, m1, of each specimen.*

## 6.2 Boiling Method

Place the tiles vertically, with no contact between them, in the heating apparatus so that there is a depth of 5 cm of water above and below the tiles. Maintain the water level at 5 cm above the tiles throughout the test. Heat the water until it boils and continue to boil for 2 h. Then remove the source of heat and allow the tiles to cool to room temperature, still completely immersed, in 4h ± 15 min. Water at ambient temperature or refrigerating coils may be used to cool the test specimens to room temperature. Prepare the chamois leather by wetting and wringing out by hand. Place it on a flat surface and lightly dry each side of each tile in turn. Dab any relief surfaces with the chamois leather.

- ➢ Advantages
  - ✓ Simple and Cost-Effective: Requires basic equipment (hot plate, container, balances).
  - ✓ Relatively Straightforward: The procedure is easy to follow and less prone to operator error than complex methods.
  - ✓ Suitable for Basic Assessment: Provides a reasonably good indication of a tile's water absorption level.
- ➢ Disadvantages
  - ✓ Potential for Tile Alteration: The boiling process can cause some structural changes in the tile, potentially leading to slightly inflated absorption values.
  - ✓ Less Accurate for Low Absorption: For tiles with very low water absorption, the small differences in weight might not be as accurately detected compared to more sensitive method


Boiling container Instrument with Digital heat indicator according to the (ISO 10545-3)

(Placing the Sample in the Container with non-Contact Between the samples)

### 6.3 Vacuum Pressure Method

Place the tiles vertically with one of the cut side facing the bottom, with no contact between the specimens and the chamber. Evacuate to a pressure of 10 ± 5 kPa (91 ± 5 kPa below standard atmospheric pressure of 101 kPa) and maintain it for 30 ± 2 min. Then, while maintaining the vacuum, slowly admit sufficient water, taking no longer than 10 min to cover the tiles by at least 5 cm. Release the vacuum and allow the tiles to remain submerged for 15 ± 2 min. Determine the suspended mass according to 7.3. After the determination of the suspended mass, or directly after the 15 ± 2 min soak, if the suspended mass is not determined, blot each specimen lightly with a damp microfibre cloth to remove all visible water droplets from the surface, and determine the saturated mass m2, of each specimen, with an accuracy of 0,01 % of the mass. A dry microfibre cloth shall be saturated with water equal to two times its dry weight (for example, a 50 g cloth is saturated with 100 g of water).

This may be achieved by placing the cloth in a bowl, adding the required amount of water, and squeezing the cloth to ensure all of the water is absorbed and that the cloth is evenly saturated without any dry areas. The facial area of the microfibre cloth shall be at least 65 % of the total facial area of specimens tested (for example, five 20 × 20 cm specimens require a microfibre cloth surface area of 1 300 cm2 or greater). Multiple microfibre cloths may be used to meet the required minimum cloth facial area. The blotting process shall involve patting the specimen lightly on all edges and surfaces with the damp microfibre cloth. Take care not to blot excessively as this could introduce error by withdrawing water from the pores of the specimen. Weight determination shall be performed immediately after the blotting process to avoid errors due to evaporation of water from the test specimen.

- Advantages
  - ✓ Higher Accuracy: A more reliable representation of a tile's true water absorption capacity, especially for low absorption tiles.
  - ✓ Simulates Real-World Conditions: Better mimics the forced water penetration that can occur under high water pressure or wet environments.

- Disadvantages
  - ✓ Specialized Equipment: Requires a vacuum chamber and pressure apparatus, increasing cost.
  - ✓ Slightly More Complex: The procedure can be more involved, requiring careful handling and potentially more sources of error for inexperienced technicians.


Vacuum Pressure Instrument full automated according to the (ISO 10545-3)

(Placing the Sample in the Container with non-Contact Between the samples)

## 7 Classification of Dry Pressed Ceramic Tiles: -

| Shaping | Group I $E_v \leq 3\%$ | Group $II_a$ $3\% < E_v \leq 6\%$ | Group $II_b$ $6\% < E_v \leq 10\%$ | Group III $E_v > 10\%$ |
|---|---|---|---|---|
| B Dry pressed | Group $BI_a$ $E_v \leq 0,5\%$ | Group $BII_a$ | Group $BII_b$ | Group $BIII_b$ |
| | Group $BI_b$ $0,5\% < E_v \leq 3\%$ | | | |
| Dry pressed Ceramic Tile | | | | |

## 8 Water absorption Calculation

In the following calculations, the assumption is made that 1 $cm^3$ of water weighs 1 g, where

m1: is the mass of the dry tile.

m2: is the mass of the tile impregnated by immersion under vacuum.

For each tile, the water absorption, $E_v$, expressed as a percentage of the dry mass, is calculated using Formula.

$$E_v = 100 \times \frac{(m_2 - m_1)}{m_1}$$

The calculation is between two methods, shows the deferent type of average water absorption groups in dust pressed tiles, tested 5 samples according to the (Table 1) with dimension (20 cm x 20 cm) taken from the Iranian deferent product companies.

- The Water Absorption Group ($BI_a$): -

**WATER ABSORPTION OF TILES**

**Test Method :- ISO 10545 - 3 (BIa)**

**Vacuume Method**

| Code No | Wet Weight (g) | Dry Weight (g) | water absorption(%) |
|---|---|---|---|
| 1 | 978.81 | 970.73 | 0.832363 |
| 2 | 933.90 | 930.42 | 0.374025 |
| 3 | 939.19 | 935.72 | 0.370837 |
| 4 | 962.39 | 954.48 | 0.828723 |
| 5 | 936.84 | 932.90 | 0.422339 |
| Average of Water Absorption (%) | | | 0.565658 |

**Boiling Method**

| Code No | Wet Weight (g) | Dry Weight (g) | water absorption(%) |
|---|---|---|---|
| 1 | 909.65 | 908.67 | 0.107850 |
| 2 | 921.82 | 920.63 | 0.129259 |
| 3 | 920.03 | 918.83 | 0.130601 |
| 4 | 918.43 | 917.18 | 0.136287 |
| 5 | 907.83 | 906.58 | 0.137881 |
| Average of Water Absorption (%) | | | 0.128376 |

The group ($BI_a$) is depending on the label of the manufacture company

- Understanding the Data
  - $BI_a$ Classification: $BI_a$ refers to a tile classification with very low water absorption (< 0.5%). Tiles in this category include porcelain.
  - Vacuum Pressure of 0.565658%: This is likely the water absorption result specifically from a vacuum method test.
  - Boiling Method of 0.128376%: This is likely the water absorption result specifically from a boiling method test.

- Calculating the Ratio
  To determine the ratio of water absorption between the two methods, divide the vacuum method result by the boiling method result:
  Ratio = (Vacuum Absorption / Boiling Absorption)
  Ratio = (0.565658% / 0.128376%)
  Ratio ≈ 4.406

- The Water Absorption Group ($BI_b$): -

**WATER ABSORPTION OF TILES**

**Test Method :- ISO 10545 - 3 (BIb)**

**Vacuume Method**

| Code No | Wet Weight (g) | Dry Weight (g) | water absorption(%) |
|---|---|---|---|
| 1 | 953.58 | 936.68 | 1.804245 |
| 2 | 929.54 | 924.95 | 0.496243 |
| 3 | 961.41 | 953.93 | 0.784125 |
| 4 | 943.53 | 941.09 | 0.259274 |
| 5 | 950.58 | 944.83 | 0.608575 |
| Average of Water Absorption (%) | | | 0.790492 |

**Boiling Method**

| Code No | Wet Weight (g) | Dry Weight (g) | water absorption(%) |
|---|---|---|---|
| 1 | 539.19 | 538.72 | 0.087244 |
| 2 | 521.45 | 521.08 | 0.071006 |
| 3 | 540.20 | 539.51 | 0.127894 |
| 4 | 522.70 | 522.15 | 0.105334 |
| 5 | 526.83 | 526.53 | 0.056977 |
| Average of Water Absorption (%) | | | 0.089691 |

**Equation :** $E_v = [ m2 - m1 / (m1) ] \times 100$

$E_v$ : water absorption , expressed as a percentage ( % ) .

m1 : is the mass of the dry tile , expressed in gram ( g ) .

m2 : is the mass of the wet tile , expressed in gram ( g ) .

The group ($BI_b$) is depending on the label of the manufacture company

- Understanding the Data
  - $BI_b$ Classification: $BI_b$ refers to a tile classification with low water absorption (0.5% - 3%). This category includes a wider range of tiles than BIa, such as some stoneware tiles.

- Vacuum Pressure of 0.790492%: Represents the water absorption result using the vacuum method.
- Boiling Method of 0.089691%: Represents the water absorption result using the boiling method.

➢ Calculating the Ratio

To determine the ratio of water absorption between the two methods, divide the vacuum method result by the boiling method result:

Ratio = (Vacuum Absorption / Boiling Absorption)

Ratio = (0.790492% / 0.089691%)

Ratio ≈ 8.81

➢ The Water Absorption Group ($BII_a$): -

**WATER ABSORPTION OF TILES**

**Test Method :- ISO 10545 - 3 (BIIa)**

**Vacuume Method**

| Code No | Wet Weight (g) | Dry Weight (g) | water absorption(%) |
|---|---|---|---|
| 1 | 850.70 | 799.18 | 6.446608 |
| 2 | 859.77 | 809.62 | 6.194264 |
| 3 | 869.06 | 817.81 | 6.266737 |
| 4 | 859.93 | 812.02 | 5.900101 |
| 5 | 852.43 | 803.21 | 6.127912 |
| Average of Water Absorption (%) | | | 6.187124 |

**Boiling Method**

| Code No | Wet Weight (g) | Dry Weight (g) | water absorption(%) |
|---|---|---|---|
| 1 | 477.51 | 450.96 | 5.887440 |
| 2 | 470.84 | 445.03 | 5.799609 |
| 3 | 474.85 | 450.01 | 5.519877 |
| 4 | 485.53 | 459.87 | 5.579838 |
| 5 | 485.62 | 461.44 | 5.240118 |
| Average of Water Absorption (%) | | | 5.605376 |

Equation : $E_v = [ m2 - m1 / ( m1 ) ] \times 100$

$E_v$ : water absorption , expressed as a percentage ( % ) .

m1 : is the mass of the dry tile , expressed in gram ( g ) .

m2 : is the mass of the wet tile , expressed in gram ( g ) .

The group ($BII_a$) is depending on the label of the manufacture company

➢ Understanding the Data

- $BII_a$ Classification: $BII_a$ signifies a tile with moderate water absorption (3% - 6%). This includes various stoneware and semi-vitreous tiles.
- Vacuum Pressure of 6.187124%: Water absorption result from the vacuum method.
- Boiling Method of 5.605376%: Water absorption result from the boiling method.

➢ Ratio Calculation

Ratio = (Vacuum Absorption / Boiling Absorption)

Ratio = (6.187124% / 5.605376%)

Ratio ≈ 1.1038

➢ The Water Absorption Group (BIII):

**WATER ABSORPTION OF TILES**

**Test Method :- ISO 10545 - 3 (BIII)**

**Vacuume Method**

| Code No | Wet Weight (g) | Dry Weight (g) | water absorption(%) |
|---|---|---|---|
| 1 | 897.00 | 770.20 | 16.463256 |
| 2 | 911.78 | 782.66 | 16.497585 |
| 3 | 896.18 | 768.66 | 16.589910 |
| 4 | 912.89 | 783.15 | 16.566430 |
| 5 | 912.19 | 782.67 | 16.548481 |
| Average of Water Absorption (%) | | | 16.533133 |

**Boiling Method**

| Code No | Wet Weight (g) | Dry Weight (g) | water absorption(%) |
|---|---|---|---|
| 1 | 678.68 | 587.74 | 15.472828 |
| 2 | 684.11 | 593.26 | 15.313690 |
| 3 | 683.11 | 592.14 | 15.362921 |
| 4 | 680.98 | 589.82 | 15.455563 |
| 5 | 677.17 | 587.64 | 15.235518 |
| Average of Water Absorption (%) | | | 15.368104 |

**Equation :$E_v$ =[ m2 - m1 / ( m1 ) ] × 100**

$E_v$ : water absorption , expressed as a percentage ( % ) .

m1 : is the mass of the dry tile , expressed in gram ( g ) .

m2 : is the mass of the wet tile , expressed in gram ( g ) .

The group (BIII) is depending on the label of the manufacture company

➢ Understanding the Data

- BIII Classification: This classification indicates a tile with high water absorption (>10%). It includes many earthenware and terracotta tiles.
- Vacuum Pressure of 16.533133%: This is the water absorption value obtained using the vacuum method.
- Boiling Method of 15.368104%: This is the water absorption value using the boiling method.

➢ Calculating the Ratio
Ratio = (Vacuum Absorption / Boiling Absorption)
Ratio = (16.533133% / 15.368104%)
Ratio ≈ 1.0758

# 9 Discussion

Water absorption is a fundamental property of ceramic tiles that significantly influences their performance and suitability for different applications. Two standard methods, boiling and vacuum pressure, are used to measure water absorption. Here's an analysis of the differences between these methods and their implications:

## 9.1 Tile Density and Its Impact

- Tile density describes how compact the material is within the tile. Manufacturing factors like raw materials, firing temperature, and the pressing process all influence density.

- Denser tiles, especially those in the BIa (very low absorption) category, present challenges for the boiling method. Air can become trapped in their small pores, hindering full water saturation and leading to an underestimation of water absorption.

## 9.2 Limitations of Boiling vs. Superiority of Vacuum

- While boiling increases water's ability to penetrate, it doesn't provide the same direct force as the vacuum method, which actively pulls water into the tile's structure.
- Consequently, the ratio between vacuum and boiling method results tends to be higher for dense BIa tiles, as the vacuum process achieves more complete saturation.

## 9.3 The Role of Porosity

- Inherently porous tiles (BIIa, BIII) have more pathways for water ingress. Both boiling and vacuum methods achieve closer to full saturation in these tile categories, leading to a smaller ratio.

➢ Practical Implications

- Classification: Water absorption classifications heavily rely on the vacuum method. Understanding typical ratios helps explain discrepancies between method results and why a tile might meet a classification using one method but not the other.
- Performance Prediction: The vacuum method provides a more accurate representation of a tile's potential vulnerability to moisture-related issues like staining, freeze-thaw damage, and strength reduction.
- Test Method Selection: While the vacuum method is ideal, the boiling method might suffice for basic classification in certain less-demanding applications, particularly for porous tiles.

# 10 Conclusions

10.1 mportance of Pore Saturation: Highlighting the superior ability of the vacuum method to saturate pores, especially in highly porous tiles. This makes the vacuum method indispensable for accurate classification and understanding a tile's true water absorption.

10.2 Porosity within Classifications: Emphasizing that even within a single classification, there can be a range of porosity levels. Tiles at the higher end of their classification's porosity range will likely exhibit larger discrepancies between the methods than those on the denser end.

10.3 Practical Application Choices: Helps us understand when the standard boiling method might provide a sufficiently close approximation for classification and when the extra precision of the vacuum method is necessary for tile performance evaluation.

- Important to Remember
  - Data Specificity: Without specific numerical ratios for each group, these conclusions remain somewhat general. Exact ratios will vary depending on the individual tiles tested.
  - Boiling Method Sufficiency: For some tiles within the $BII_a$ and BIII category, the boiling method might be close enough in outcome to the vacuum method, making the latter unnecessary for basic classification.
  - Laboratory Variation: Variations in laboratory technique can impact the ratio between methods, even for tiles within the same classification.

## 11 Resources

### 11.1 Global Resources

- ISO 10545: Ceramic Tiles
  - Specifically, ISO 10545-3: Determination of water absorption, apparent porosity, apparent relative density and bulk density
  - This is THE international standard. It outlines in detail the procedures for both boiling and vacuum methods and provides guidelines for result interpretation.

- ISO 13006:
  - Title: Ceramic tiles – Definitions, classification, characteristics and marking

- ASTM Standards
  - ASTM C373 - Standard Test Methods for Water Absorption, Bulk Density, Apparent Porosity, and Apparent Specific Gravity of Fired Whiteware Products (though aimed at whiteware, the methods are transferable)
  - ASTM standards are used widely throughout the Americas and have influence in other regions as well.

- European Norms (EN)
  - Various EN standards exist for ceramic tiles, and some touch on water absorption aspects. A search on the official EN website will bring up the most relevant ones. Key EN standards are often aligned with ISO standards.

### 11.2 Iran-Specific Resources

  - Institute of Standards and Industrial Research of Iran (ISIRI)