BUREAU OF INDIAN STANDARDS

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Learning Science via Standards



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CERAMIC TILES

Lesson 14

May 2023





STANDARDS CLUB
BUREAU OF INDIAN STANDARDS

Nurturing Young Minds as Ambassadors of Quality and Standards



Foreword

Everything around us, whether natural phenomena or manmade products can be explained through science. The product which are used in our daily life are outcome of conscious efforts by the mankind to fulfil and exceed the needs of the present and demands of the future. Students are taught science as part of their school curriculum, to enable them to understand the various scientific laws and principles and also to inculcate the habit of exploring the world through the lens of science. Quality characteristics of any product or service are decided based on the stated and implied needs and are generally described in a document called 'Standard'. Science and standards are inseparable and integral aspect of any product.

Bureau of Indian Standards (BIS), the national standards body of India, is mandated for establishment and promotion of standards and creating a quality ecosystem in the country. This is achieved through developing Indian Standards on products and services through the active involvement of relevant stakeholders and dissemination of information of such standards for their use and implementation across all sectors of economy. Academia, as an important stakeholder of BIS, has been contributing towards development of standards through research activities and providing inputs related to technological advancements in product development, their characteristics and use as well as methods of tests. BIS, on its part has also been promoting standards in academia through a variety of programmes. This has since been institutionalized in the form of "Standards Clubs" which are being established in educational institutions across India to nurture the young minds as ambassadors of quality and standards and prepare them for dealing with these aspects in future.

In this initiative of BIS, called "Learning Science via Standards", a series of Lesson Plans are made elaborating the various scientific concepts, laws and principles to help students understand their practical applications via standards. The series comprises of a variety of subjects for insights into the scientific laws and principles and relating them to the quality characteristics of products used in day-to-day life. First 10 Lesson Plans in the series are released on the occasion of World Consumer Rights Day on 15 Mar 2023.

The Lesson Plans are expected to serve as a useful tool for the teaching fraternity for imparting knowledge on scientific laws and principles through their practical applications in activities and products around us and facilitate an interactive learning experience for the students.

Ceramic Tiles

1. Introduction



Ceramic tiles are a type of building material made from clay, sand, and other natural minerals that are moulded and then fired at high temperatures to produce a hard, durable surface. They are commonly used for flooring and wall coverings in homes, commercial buildings, and outdoor spaces.

Ceramic tiles come in a variety of shapes, sizes, colours, and finishes, and are known for their durability, water resistance, and ease of maintenance. They are also resistant to wear and tear and can last for many years with proper care. Some ceramic tiles are designed for specific uses, such as floor tiles with a non-slip finish for use in bathrooms, or tiles with a glossy finish for use as decorative accents.

In addition to their aesthetic appeal, ceramic tiles also offer a number of practical benefits. For example, they are an environmentally friendly option, as they can be made from sustainable raw materials and can be recycled at the end of their useful life. They are also a cost-effective option compared to other flooring and wall covering materials and are widely available and easy to install.

2. Ceramics

Ceramics are a type of material that are made by heating natural clay and other raw materials to high temperatures, resulting in a solid and hard substance. Ceramics are commonly used in a wide range of applications due to their durability, resistance to heat, electrical insulation, and chemical resistance. Some examples of ceramic products include pottery, tiles, engine components, and dental crowns.

What are pressed Ceramic tiles?

Pressed ceramic tiles are a type of ceramic tile that are made using a process called dry pressing. In this process, a mixture of clay, sand, and other natural minerals are moulded and then compressed using a press to produce a dense, homogeneous tile. The tiles are then fired at high temperatures to produce a hard, durable surface.

Pressed ceramic tiles are commonly used in both residential and commercial settings due to their durability, water resistance, and ease of maintenance. They are available in a variety of shapes, sizes, colours, and finishes, and are known for their uniformity in terms of size, shape, and texture. This uniformity makes them well-suited for use in large-scale projects, such as flooring and wall coverings in hotels, shopping centres, and other public spaces.

In addition to their practical benefits, pressed ceramic tiles also offer a number of aesthetic options. For example, they can be glazed to produce a glossy finish, or they can be embossed to create a texture on the surface. The process of dry pressing also allows for the production of tiles with intricate

patterns and designs, making them a versatile and attractive choice for a variety of interior and exterior design projects.

3. Manufacturing Process

The manufacturing process of ceramic tiles typically involves the following steps:

a) **Raw material preparation:** The raw materials used in the production of ceramic tiles include clay, feldspar, quartz, and various other minerals and additives. These materials are crushed and finely ground to form a powder.

b) **Mixing:** The powdered raw materials are mixed together in a large mixer to ensure a uniform blend of all the ingredients.

c) **Forming:** The blended powder is then fed into a hydraulic press or extruder, which compresses the powder into a mold. The mold may be a traditional square or rectangular tile shape, or it can be a custom shape or size.

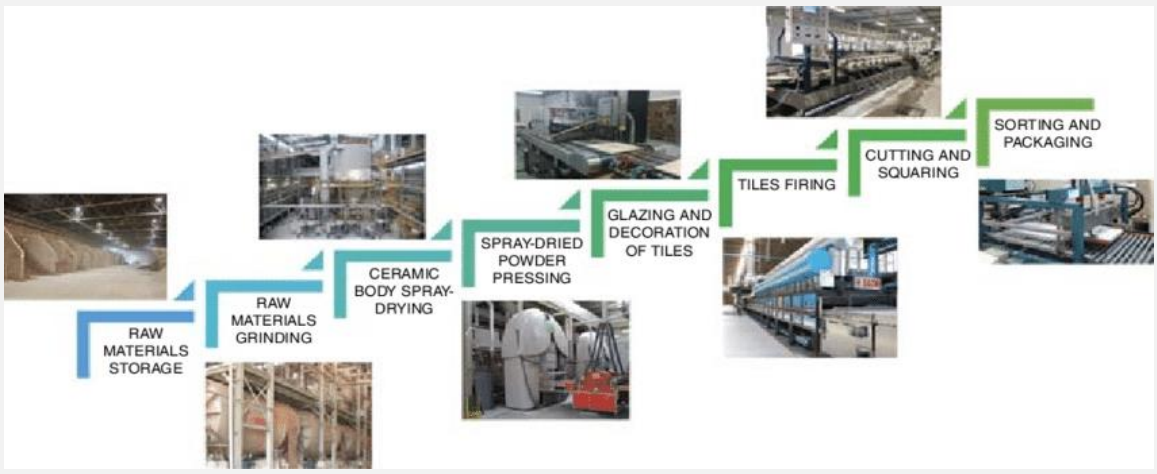
d) **Drying:** The newly formed tiles are then dried in a kiln or air-dried, depending on the manufacturer's process.

e) **Glazing:** If the tiles are to be glazed, a liquid glaze is applied to the surface of the tile. The glaze may be sprayed, brushed, or poured on, depending on the manufacturer's process.

f) **Firing:** The glazed or unglazed tiles are then fired in a kiln at high temperatures to harden and strengthen the tile. The firing process may take several hours or days, depending on the size and thickness of the tiles.

g) **Sorting and packaging:** Once the firing process is complete, the tiles are inspected for quality and sorted by size and color. They are then packaged and shipped to distributors or retailers.

The specific details of the manufacturing process can vary depending on the type of ceramic tile being produced and the manufacturer's process. However, these general steps are common to most ceramic tile production processes.



4. Properties of pressed Ceramics Tiles:

a) **Durability** — Pressed ceramic tiles are known for their durability and resistance to wear and tear, making them a long-lasting choice for flooring and wall coverings.
b) **Water Resistance** — Ceramic tiles, including pressed ceramic tiles, are generally water-resistant, making them suitable for use in areas where water is present, such as bathrooms and kitchens.

c) **Ease of Maintenance** — Ceramic tiles are easy to clean and maintain, requiring only regular wiping or mopping to keep their surface looking new.

d) **Uniformity** — Pressed ceramic tiles are known for their uniformity in terms of size, shape, and texture, making them well-suited for use in large-scale projects.

e) **Versatility** — Pressed ceramic tiles are available in a variety of shapes, sizes, colours, and finishes, making them a versatile option for a range of interior and exterior design projects.

f) **Aesthetic Appeal** — The process of dry pressing allows for the production of tiles with intricate patterns and designs, and the tiles can also be glazed or embossed to create a glossy finish or texture.

g) **Cost-Effective** — Compared to other flooring and wall covering materials, ceramic tiles, including pressed ceramic tiles, are a cost-effective option.

h) **Environmentally Friendly** — Ceramic tiles can be made from sustainable raw materials and can be recycled at the end of their useful life, making them an environmentally friendly choice.

5. Scientific Concepts and Laws

a) **Pascal's Law:** This law states that pressure applied to a confined fluid is transmitted uniformly in all directions. In the manufacture of ceramic tiles, Pascal's Law is used in the hydraulic press or extruder, which compresses the powdered raw materials into a mould.

b) **Boyle's Law:** This law states that the volume of a gas at a constant temperature is inversely proportional to the pressure exerted on it. In the firing process of ceramic tiles, Boyle's Law is used to control the atmosphere inside the kiln to achieve the desired results.

c) **Charles's Law:** This law states that the volume of a gas is directly proportional to its temperature at a constant pressure. In the drying process of ceramic tiles, Charles's Law is used to control the temperature and humidity inside the kiln or drying room.

d) **Archimedes' Principle:** This law states that an object immersed in a fluid experiences a buoyant force equal to the weight of the displaced fluid. In the testing of ceramic tiles, Archimedes' Principle is used to determine the density of the tiles.

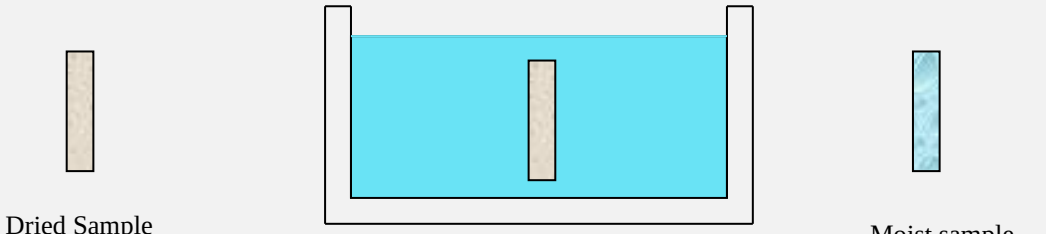
e) **Hooke's Law:** This law states that the force required to deform an elastic material is proportional to the deformation. In the testing of ceramic tiles, Hooke's Law is used to measure the elasticity and strength of the tiles.

6. Performance requirements in Ceramic Tiles

Physical Properties

a) **Water absorption, percent by weight :** The water absorption refers to the amount of water that is absorbed when exposed to water. This measurement is expressed as a percentage of the total weight of the tile. The water absorption is determined as follows:

- A sample is dried in the oven, so the entire water is evaporated. The mass of the dried sample (M_1) is determined.
- Then the sample is put into the water for predetermined duration and temperature of water.
- After the predetermined time has been elapsed the mass of the moist sample (M_2) is determined.



Dried Sample with Mass = M_1

Sample submerged in water.

Moist sample with Mass = M_2

Therefore, water absorbed by the sample (M_w) = ($M_2 - M_1$)

Water absorption as the percentage of dried mass of sample = W_a

$$W_a = \frac{M_w}{M_1} \times 100$$

b) **Modulus of rupture/ Breaking strength :** The determination of modulus of rupture (MOR) and breaking strength are important tests for assessing the mechanical properties and quality of ceramic tiles.

- **Modulus of Rupture (MOR):** The MOR test measures the maximum amount of stress that a tile can withstand before breaking or cracking under a three-point bending load. This test provides an indication of the tile's resistance to bending, flexing, and impact.

  A high MOR indicates that the tile is strong and durable, and can withstand heavy foot traffic or weight. A low MOR means that the tile is weak and more prone to cracking or breaking, which can lead to safety hazards and costly repairs.

- **Breaking Strength:** The breaking strength test measures the force required to break a tile under a uniformly distributed load. This test provides an indication of the tile's ability to resist crushing and deformation.
  A high breaking strength indicates that the tile is strong and can withstand heavy loads, while a low breaking strength means that the tile is weak and can be easily damaged by heavy objects or foot traffic.

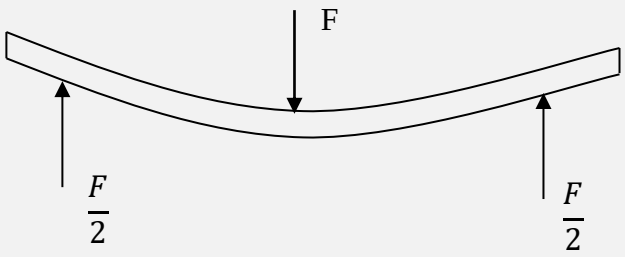
What is Moment?

In physics, a moment is a measure of the tendency of a force to cause rotation around an axis. It is also known as *torque* and is calculated as the product of the force and the distance from the axis to the point where the force is applied. The unit of moment in the International System of Units (SI) is Newton-meters (Nm).

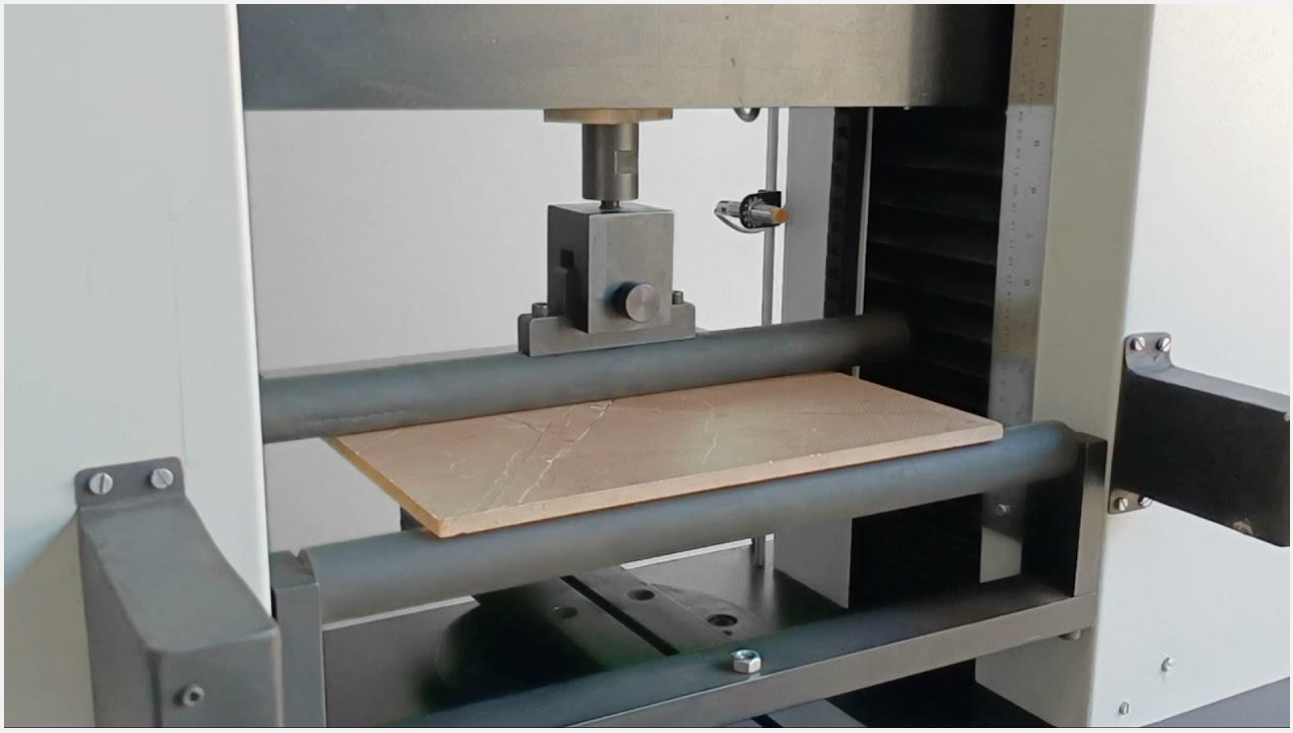
For example, when you try to close a door, you apply a force that creates a moment about the axis of the door hinge. The greater the force you apply and the longer the lever arm (the distance from the hinge to the point where you apply the force), the greater the moment and the easier it is to close the door.

What is the use of Moment in Modulus of Rupture?

When the force (F) is applied on the specimen, the specimen try to rotate about the supporting axis but due the reaction force the specimen is not able to rotate about the supporting axis. It creates internal stress in the specimen due to which it bends. It is called *bending moment*. The specimen bends in the following shape due to bending moment:



Area Moment of Inertia — Area moment of inertia, also known as second moment of area, is a property of a shape that describes its resistance to bending and deflection. In other words, the area moment of inertia is a measure of how the shape of an object affects its ability to resist bending and deformations when forces are applied to it. The higher the area moment of inertia, the more the object will resist bending and deformations.

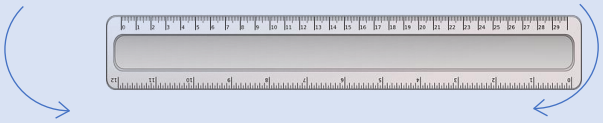


Activity:

1. Try to bend a ruler as shown below:



2. Try to bend a ruler as shown below:



In which case it was easier to bend the scale? Second case? Why? 

Because, in second case the *Area Moment of Resistance (I)* of the scale is more. So, the resistance to bend due to moment is more in second case and it's harder to bend the scale.

c) Moisture expansion : Moisture expansion refers to the increase in the volume of a material due to the absorption of moisture. This phenomenon can occur in a variety of materials, including wood, concrete, and other building materials. When a material absorbs moisture, the water molecules can occupy the spaces between the solid particles of the material, increasing its overall volume. This can lead to structural damage or deformation in some

materials, especially if they are already under stress. For example, swelling of wooden doors due to moisture absorption (especially in rainy season) can cause buckling or warping, while excessive moisture absorption in tiles can cause cracking or spalling (fragments of a material that are broken off a larger solid body).

d) **Scratch hardness of surface :** This is an important test for assessing the surface quality and durability of ceramic tiles. The test provides an indication of the tile's resistance to wear and tear, as well as its ability to maintain its appearance over time.

A high scratch hardness rating indicates that the tile has a hard and durable surface that can resist scratching and wear. This is important for tiles used in high-traffic areas, such as entryways, kitchens, and bathrooms, where heavy foot traffic and daily use can cause damage and wear over time.

Tiles with a low scratch hardness rating are more prone to scratches and wear, which can lead to a loss of visual appeal and functionality over time. Scratches can also allow dirt and bacteria, which can be difficult to clean and maintain.

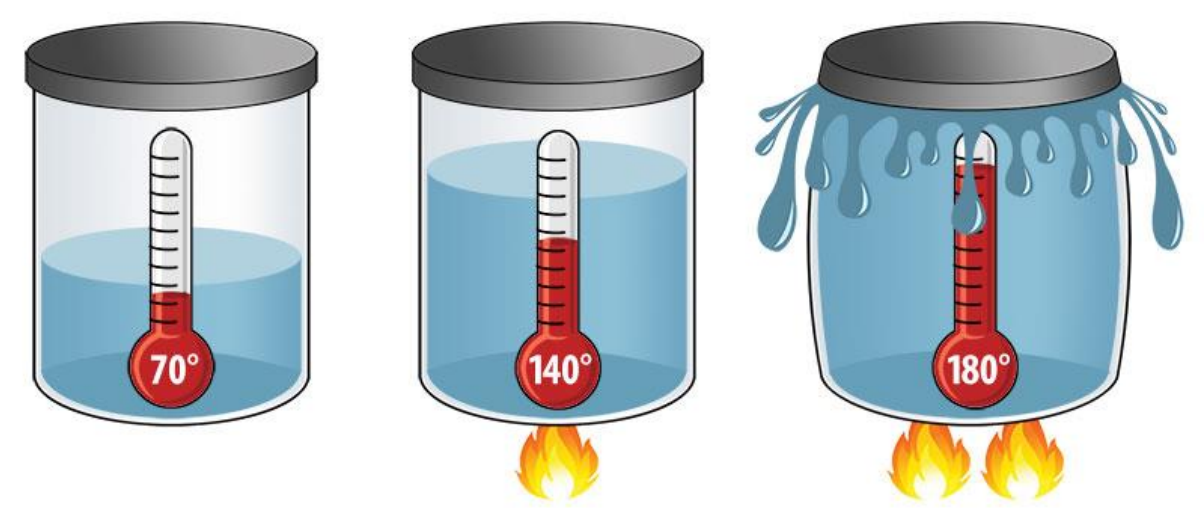


e) **Co-efficient of linear thermal expansion (CLTE):** The coefficient of linear thermal expansion (CLTE) is an important property to consider when selecting ceramic tiles for installation.
CLTE is a measure of how much a material will expand or contract in response to changes in temperature. It is expressed in units of length per unit of temperature change (e.g., inches per degree Fahrenheit or millimeters per degree Celsius).

In ceramic tiles, changes in temperature can cause expansion or contraction, which can lead to cracking or other types of damage. A high CLTE can increase the risk of tile damage due to thermal stress, while a low CLTE can reduce this risk.

Thermal Expansion:

In physics, Thermal expansion can be defined as the change in the length, width, height, or volume of any material on changing the temperature. Thermal expansion is very evident in solids as atoms are densely packed.



f) **Thermal shock resistance:** It is an important property to consider when selecting ceramic tiles, particularly for applications where the tiles will be exposed to sudden changes in temperature.

Thermal shock resistance is the ability of a material to withstand sudden and rapid temperature changes without cracking or breaking. In ceramic tiles, thermal shock resistance is important because changes in temperature can cause expansion or contraction, which can lead to cracking or other types of damage.For example, tiles in a kitchen may be exposed to sudden changes in temperature when hot pans are placed on them, while tiles in a bathroom may be exposed to sudden changes in temperature when hot water is poured on them during cleaning.

Tiles with high thermal shock resistance are able to withstand these sudden temperature changes without cracking or breaking, while tiles with low thermal shock resistance are more likely to suffer damage.

g) **Impact resistance - Coefficient of restitution:** This is an important property to consider when selecting ceramic tiles for high-traffic areas or areas where heavy objects may be dropped or moved.
The impact resistance or COR measures the ability of a tile to absorb and rebound from the impact of an object. In other words, it is a measure of the tile's ability to resist damage from impact and maintain its structural integrity.

Tiles with high impact resistance or COR are able to absorb the energy of an impact without cracking or breaking, while tiles with low impact resistance or COR are more likely to suffer damage.

Therefore, it is important to select ceramic tiles with appropriate impact resistance or COR for the specific application and environmental conditions. For example, tiles in a commercial kitchen or manufacturing plant may require higher impact resistance to withstand heavy equipment and objects, while tiles in a residential bathroom may require lower impact resistance.

h) **Co-efficient of friction –** The coefficient of friction measures the amount of friction or resistance between two surfaces when one surface is sliding or moving against the other.

In ceramic tiles, a higher coefficient of friction means that the surface is more slip-resistant, while a lower coefficient of friction means that the surface is more slippery.

Slip-resistant tiles are important for areas where there is a risk of slipping and falling, such as in bathrooms, kitchens, or entryways.

i) **Crazing resistance :** Crazing refers to the small cracks or lines that can appear on the surface of a ceramic tile over time. These cracks can be unsightly and can also compromise the structural integrity of the tile. Crazing can occur due to a variety of factors, including exposure to moisture or changes in temperature.

Crazing resistance is an important property to consider when selecting ceramic tiles for applications where the tiles will be exposed to moisture or temperature changes.
Tiles with high crazing resistance are less likely to develop these cracks, even when exposed to moisture or temperature changes. This can help to ensure the durability and longevity of the tiles, and can reduce the risk of costly repairs or replacements due to crazing.

Therefore, it is important to select ceramic tiles with appropriate crazing resistance for the specific application and environmental conditions. For example, tiles in a bathroom or outdoor area may require higher crazing resistance to withstand exposure to moisture and temperature changes.

j) **Resistance to surface abrasion :** Surface abrasion refers to the damage or wear that occurs on the surface of a material due to repeated contact with other surfaces, such as foot traffic or cleaning equipment. In ceramic tiles, surface abrasion can lead to a dull, worn appearance or even to the loss of the glaze, which can impact the durability and longevity of the tile. Tiles with high resistance to surface abrasion are able to withstand repeated contact with other surfaces without suffering significant wear and tear, while tiles with low resistance to surface abrasion may show signs of damage more quickly.

Chemical Properties

a) **Resistance to staining of glazed tiles :** Stains can cause permanent discoloration and damage to ceramic tiles, which can impact their appearance and longevity. Tiles with high resistance to staining are able to resist the absorption of these substances and maintain their appearance and durability over time, while tiles with low resistance to staining may show signs of discoloration and damage more quickly.

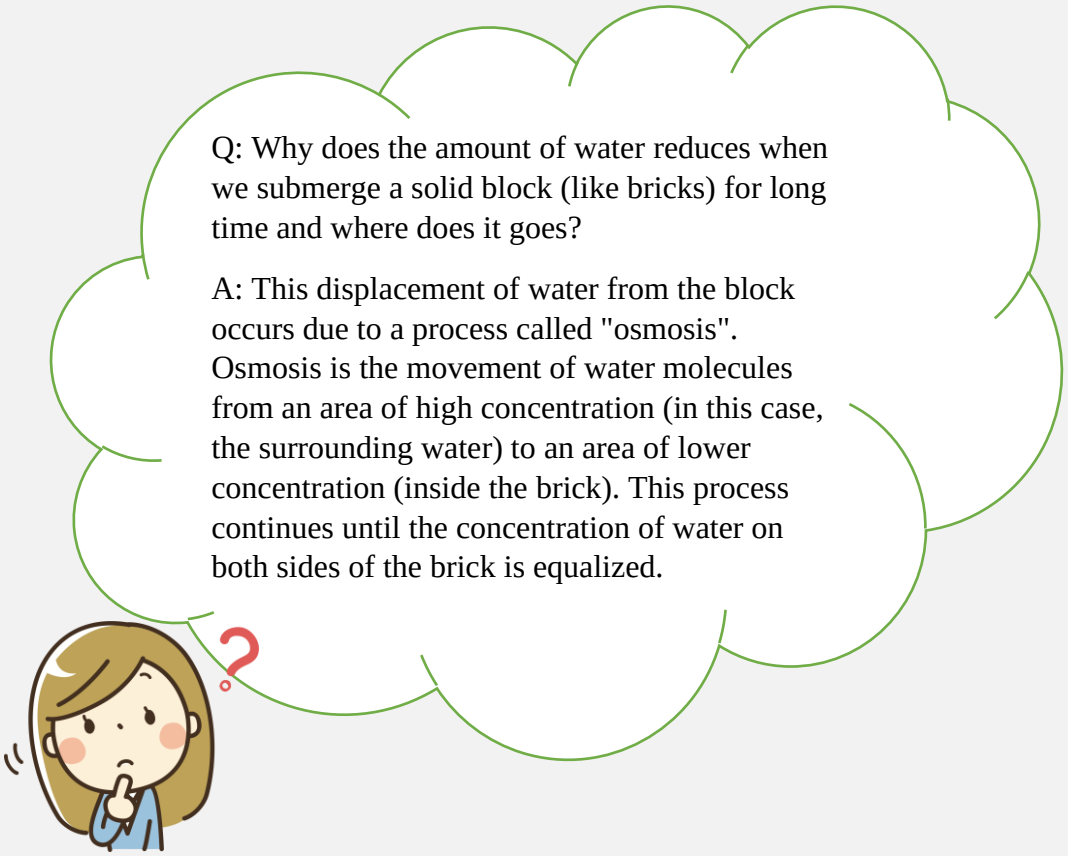
   Therefore, it is important to select ceramic tiles with appropriate resistance to staining for the specific application and environmental conditions. For example, tiles in a kitchen or dining area may require higher resistance to staining to withstand exposure to food and beverages, while tiles in a bathroom may require lower resistance to staining.

   In addition, resistance to staining is also important for maintenance purposes. Tiles that are more resistant to staining will require less frequent cleaning and maintenance, which can save time and resources over the long term.

b) **Resistance to acids and alkalis :** Acids and alkalis are commonly used in cleaning products, and can also be present in certain industrial or manufacturing environments. Exposure to these substances can cause damage to ceramic tiles, including staining, etching, or surface degradation.

   Tiles with high resistance to acids and alkalis are able to withstand exposure to these substances without suffering significant damage, while tiles with low resistance to acids and alkalis may show signs of damage more quickly.

   In addition, resistance to acids and alkalis is also important for maintenance purposes. Tiles that are more resistant to these substances will require less frequent cleaning and maintenance, which can save time and resources over the long term.



7. Scientific Laws and Concepts in Ceramic Tiles

a) **Conservation of Energy:** This law states that energy cannot be created or destroyed, only converted from one form to another. In the manufacturing of ceramic tiles, energy is needed for processes such as drying, firing, and glazing. By understanding the principles of conservation of energy, manufacturers can optimize their processes to reduce energy waste and improve efficiency.

b) **Chemical Reactions:** Ceramic tiles are created through a series of chemical reactions that occur during the firing process. These reactions involve the transformation of raw materials into the final product. Understanding the principles of chemistry is essential for controlling the firing process and ensuring the tiles meet the desired specifications.

c) **Fracture Mechanics:** Fracture mechanics is the study of how materials break under stress. Ceramic tiles need to be able to withstand a certain amount of stress without breaking. By understanding fracture mechanics, manufacturers can design tiles that are strong and durable.

d) **Thermal Expansion:** Ceramic tiles expand and contract with changes in temperature. This can cause problems if the tiles are not designed properly. Understanding the principles of

thermal expansion is essential for creating tiles that can withstand changes in temperature without cracking or breaking.

e) **Abrasion Resistance:** Ceramic tiles are often used in areas where they are exposed to a lot of wear and tear. Understanding the principles of abrasion resistance is important for creating tiles that can withstand this kind of use without wearing down too quickly.

8. Interesting Facts about Ceramic Tiles

a) Ceramic tiles have been around for thousands of years, with evidence of their use dating back to ancient Egypt.

b) The first ceramic tiles were handcrafted and decorated with intricate designs using natural pigments.

c) Ceramic tiles are made from natural clay that is fired at high temperatures, which makes them incredibly strong and durable.

d) They are resistant to water, stains, and scratches, making them ideal for use in kitchens, bathrooms, and other high-traffic areas.

e) Ceramic tiles come in a wide range of colors, patterns, and textures, so they can be used to create a variety of looks, from sleek and modern to rustic and traditional.

f) They are eco-friendly, as they are made from natural materials and can be recycled at the end of their lifespan.

g) Ceramic tiles are easy to clean and maintain, as they can be swept, vacuumed, or mopped with a mild detergent.

h) They are often used in public spaces like hospitals and schools because they are hygienic and easy to clean.

i) Ceramic tiles are versatile and can be used for floors, walls, countertops, and backsplashes.

9. Questions

1. What is the primary raw material used in the production of ceramic tiles?
   a) Sand
   b) Clay
   c) Stone
   d) Cement
   Answer: b) Clay

2. What is the firing temperature range typically used in the production of ceramic tiles?
   a) 200-300°C
   b) 400-500°C
   c) 800-1000°C
   d) 1200-1400°C
   Answer: d) 1200-1400°C

3. Which of the following tests is used to determine the resistance of ceramic tiles to surface abrasion?
   a) Coefficient of linear thermal expansion test
   b) Crazing resistance test
   c) Scratch hardness of surface test
   d) Resistance to staining test
   Answer: c) Scratch hardness of surface test

4. Which of the following properties is important to consider when selecting ceramic tiles for areas that may be exposed to acidic substances?
   a) Resistance to thermal shock
   b) Resistance to impact
   c) Coefficient of friction
   d) Resistance to acids and alkalis
   Answer: d) Resistance to acids and alkalis

5. What is the purpose of the crazing resistance test for ceramic tiles?
   a) To determine the resistance of tiles to surface abrasion
   b) To determine the resistance of tiles to thermal shock
   c) To determine the ability of tiles to withstand bending and breaking
   d) To determine the resistance of tiles to cracking under load
   Answer: d) To determine the resistance of tiles to cracking under load

Lesson Plan Subjects

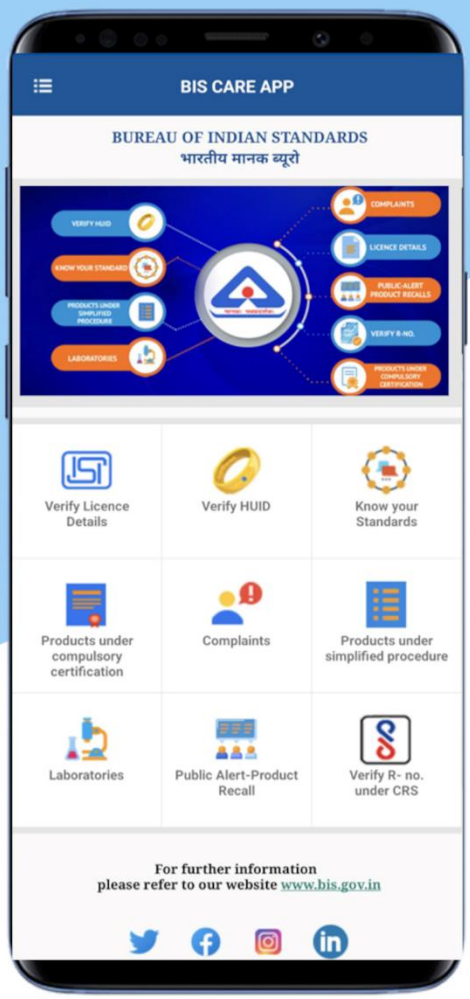
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1.	Caustic Soda	**11.**	Boric Acid
2.	Football	**12.**	Ceiling Fan
3.	Cement	**13.**	Cables
4.	Gas Stove	**14.**	Ceramics Tiles
5.	Geyser	**15.**	Rear View Mirrors
6.	Helmet	**16.**	Headphones
7.	LED Bulb	**17.**	Milk Powder
8.	LPG Cylinders	**18.**	Pressure Cooker
9.	Cement Ash Brick	**19.**	Plywood
10.	Paints	**20.**	Multipurpose dry batteries

Forthcoming…

21.	Drinking Water	**37.**	PVC Pipes
22.	Electric Iron	**38.**	Bicycle
23.	Electric Mixer	**39.**	Refrigerator
24.	Family Sized Biogas Plant	**40.**	Solar Flat Plate Collector
25.	Fire Extinguisher	**41.**	Solid and Hollow Block
26.	Ballpoint pen	**42.**	Stainless Steel
27.	Power Threshers	**43.**	Steel Bar
28.	Conduits	**44.**	Submersible Pump set
29.	CNG Cylinders	**45.**	Thermometer
30.	Precast Concrete	**46.**	Tyres for buses and trucks
31.	Pasteurized Milk	**47.**	Vacuum Flask
32.	Hearing Aids	**48.**	Water Meter
33.	Paving Block	**49.**	Water Storage Tank
34.	Microwave Oven	**50.**	Weighing balance
35.	Loudspeakers	**51.**	Wheel Rim
36.	Plugs and Socket	**52.**	Geosynthetics

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