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The subject

Study of the influence of the save modes on the mechanical behavior of the mortar to be improved by the porous stone

Discussed on 15/06/2024 before the committee composed of:

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2024/2025

In the name of God, Most Gracious, Most Merciful

We praise Allah and he is the one, who deserves praise and praise, and we use him in good times and bad, and we rely on him in all our matters. We pray and pray for the best of Creation, our Master Muhammad (peace and blessings of Allah be upon him

We extend our deepest thanks and appreciation to everyone who lit the torch of life for us and carried us on the lifeboat. To all those thanks to whom we have become writing and reading, to all those who have taught us to learn about it, we benefit and we rise in literature, starting from primary school teachers to our professors in higher education

A fragrant greeting and special thanks to **Dr. supervisor Mokhtari Abdessamad**, who gave us his advice and guidance, and to professors **Chaib Hachem** and do not forget to thank the **Civil Engineering Laboratory and his assistants** especially **Mr. Ali Keshirad**, who were of help to us

Greetings to the distinguished committee, each on his own behalf, which has kindly discussed this memorandum

In conclusion, we would like to thank everyone who helped us to accomplish this work, from near or far

Peace be upon you, the mercy and blessings of Allah

Dedication

I dedicate this fruit of my effort to those who recommended me to the blessings of Allah and the goodness of my generous parents, may Allah prolong their life, and dress them in the clothes of Health and wellness

To those with whom we gathered one house and they were the best support of my dear brothers, each in his name, and in particular

To the Companions of the path who left us, and their words remained in our ears

To those who taught me letters throughout my academic course and did not skimp on his giving, my best teachers each by his name and stature

To myself, who bet on success, my patience and patience, there is still a long way to go

And to all those to whom my heart has widened and this paper has narrowed from mentioning them, I dedicate to you my humble work

Thank you very much, and in appreciation of your efforts

Djihad bounaceur

Dedication

Who said I got it for her

The trip was not short, and it should not have been, the dream was not close, and the road was fraught with facilities, but I did it

Thank God for love, thanks and gratitude, thanks to which today I am looking at a long-awaited dream that has become a reality that I am proud of

to my immaculate angel, and my strength after God is my first and eternal support-Mom-I opened my eyes I dedicate to you this achievement, which if not for your sacrifices would not have existed, I am grateful that God has chosen you for me from the people, O good support and compensation

To those who supported me infinitely and gave me gratuitously my example in life, may God protect and take care of him

To my brothers and sisters, who are my support in life, may God keep you as a steady rib for me.

Debboune Amina

Abstract:

In recent years, the world is witnessing a severe economic crisis in the construction sector, which led to the use of alternative materials that contribute to reducing the cost and improving the mechanical properties of construction materials, while at the same time reducing the negative environmental impacts, especially the emission of carbon dioxide.

In this study, pumice stone was used as an additive to the cement mortar with the aim of improving its mechanical properties, in addition to reducing the carbon footprint resulting from the use of cement in different proportions of pumice powder (5%, 10%, 15%) with construction sand extracted from the area of El Mughaier State University and preparing an improved mortar mixture, and the resulting models were placed in different media and then subjected to a series of mechanical tests such as compression and bending resistance to see the effect of pumice stone added to the mortar.

After conducting mechanical experiments on the mortar and through the results obtained, it was found that the addition of pumice stone to the mortar improved its bending resistance while its compressive resistance was not positive.

Keywords: Pumice stone, construction sand, reinforced mortar, medium, simple compression, simple bending

الملخص

يشهد العالم في السنوات الأخيرة أزمة اقتصادية خانقة في قطاع البناء، مما أدى إلى استخدام مواد بديلة تساهم في تقليل التكلفة وتحسين الخصائص الميكانيكية للمواد الإنشائية ، وفي الوقت ذاته تحد من آثار البيئة السلبية، وعلى رأسها انبعاث ثاني أكسيد الكربون .

في هذه الدراسة تم استخدام الحجر الخفاف كمادة مضافة إلى الملاط الإسمنتي بهدف تحسين خواصه الميكانيكية ،بالإضافة إلى تقليل البصمة الكربونية الناتجة عن استخدام الاسمنت بنسب مختلفة من مسحوق الخفاف (5% ,10%,15%) مع رمل البناء المستخرج من منطقة جامعة ولاية المغير وتحضير خليط ملاط محسن ،وتم وضع النماذج الناتجة في وسائط مختلفة وبعدها إخضاعها إلى سلسلة من الاختبارات الميكانيكية مثل مقاومة الضغط والانحناء لمعرفة مدى تأثير الحجر الخفاف المضاف للملاط .

و بعد إجراء التجارب الميكانيكية على الملاط ومن خلال النتائج المتحصل عليها وجد أن إضافة الحجر الخفاف إلى الملاط قد حسنت مقاومة الانحناء بينما مقاومتها للضغط لم تكن إيجابية .

الكلمات المفتاحية : الحجر الخفاف ، رمل بناء ، ملاط مدعم ،وسط ،الضغط البسيط ، الانحناء البسيط

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General introduction

General introduction:

Mortar has become of great importance in daily life, as its use is not limited to human construction, but it has become necessary to develop it to keep pace with the development of the times, and the development of mortar has been an essential part of the development of building materials.

The importance of mortar in the field of construction is due to its reasonable cost, ease of pouring, and good resistance to compression forces, but its resistance to tensile forces is very weak, which made engineers seek solutions to enhance it, and after their intensive studies and research, they found that there are some additives that may contribute to its improvement, and among these additives as pumice stone.

Pumice stone is a lightweight natural material, characterized by its high porosity and its ability to improve the properties of the mortar in terms of thermal insulation and reduce the total weight, and from the environmental point of view, the introduction of pumice stone in the composition of the mortar contributes to large quantities of cement, which is one of the largest industrial sources of carbon dioxide emission. In this work, the use of pumice stone to reinforce the mortar with the aim of improving its properties was addressed by studying its mechanical properties by conducting some necessary experiments.

This work has been divided into three chapters:

Chapter I: This part deals with generalities about mortar, pumice stone and the media used.

Chapter two: The characteristics of the materials used in the composition of the mortar, including sand, cement, and pumice stone water

Chapter three: The composition of the reference mortar (witness) and the pumice stone reinforced mortar was studied, and the mechanical properties of the pumice stone reinforced mortar were studied using a volumetric mass, bending and compression experiment.

Finally, this work was concluded with a general conclusion and recommendations about the properties of the mortar and the effect of incorporating pumice stone in changing these properties through the results obtained

Generalities about mortar, pumice stone and aggressive medium

I-1- Introduction:

Pumice stone reinforced mortar is a type of construction material used in masonry to improve the properties of structures and provide lightweight and efficient solutions. It is an innovative construction solution that combines light weight, durability, and environmental efficiency, making it a preferred material in many modern construction applications.

In this chapter, generalizations about mortar, its components and types, as well as pumice stone and its advantages and disadvantages are discussed.

I-2-The mortar:

I- 2-1- Definition of mortar:

Mortar is a construction material composed of a binder, sand, water, and potentially additives, mixed in precise proportions to produce a paste with the desired plasticity for practical application. [1]

Figure I-1 : Example of a mortar batch [1]

I - 2-2 Mortar components:

- The method of composing classic mortar used is the one provided by standard EN-196 1.

- The different components of mortar (cement, sand, mixing water, additive)

- The mass composition of the classic mortar used is as follows:

3 parts sand

1 part cement

1/2 part water

I-2-2-1 cement:

I-2-2-1-1 - Definition:

Cement is the main hydraulic binder used in all mortars. This mineral powder, fine, almost volatile, is an essential material, the fruit of human imagination, used in all concrete and mortar-based constructions. The different dosages are designed to improve and adapt cement's resistance to the many construction applications.

The type of cement and its dosage depend both on the performance required (mechanical resistance, resistance to aggressive agents) and on the nature of the other components [2]

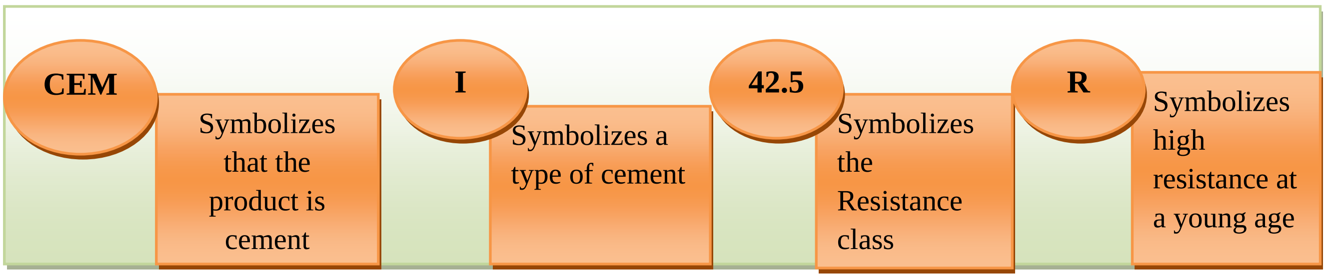
Cement consists of three basic raw materials

- Calcium carbonate found in limestone

- Silica found in clay and sand

- Aluminum oxide

- ❖ **cement naming:**



Shape I-1: Meaning of the acronym for cement [15]

I-2-2-1-2- Types of cement:

1-Ordinary Portland:

Ordinary Portland cement is (mars2025) the most widely used type of cement manufactured and used worldwide. “Portland” is a generic name derived from a type of building stone quarried on the Isle of Portland in Dorset, England. OPC is suitable for most general concrete jobs and mortar or stucco construction projects.

2. Portland pozzolana cement (PPC):

Manufacturers create Portland pozzolana cement by grinding pozzolanic clinker, sometimes with additives of gypsum or calcium sulfate, with ordinary Portland cement. Compared to OPC, it has a higher resistance to various chemical reactions within concrete. PPC is often used for projects like bridges, piers, dams, marine structures, sewage works or underwater concrete projects.

3. Rapid-hardening cement:

Contractors or construction teams may choose rapid-hardening cement for its high strength in the early stages of the hardening process. Its strength in three days is comparable to OPC strength at seven days with the same water-to-cement ratio. Rapid-hardening cement may have increased lime content, combined with a finer grinding process, or better strength development. It is often used for projects with early-stage formwork removal or when the focus is on increasing construction rates and decreasing costs.

4. Extra-rapid-hardening cement:

Extra-rapid-hardening cement may set and become durable even faster than OPC and rapid-hardening cement. Construction professionals achieve this by adding calcium chloride to rapid-hardening cement. This cement type may be useful for cold-weather concrete projects due to its fast setting rate.

5. Quick-setting cement:

Similar to extra-rapid-hardening cement, this concrete type may set and become stronger even quicker than OPC and rapid-hardening cement. Its grain and strength rate are similar to OPC, but it hardens faster. Quick-setting cement may be beneficial for time-sensitive projects or those located near stagnant or running water.

6. Low-heat cement:

Manufacturers produce low-heat cement by monitoring the percentage of tricalcium aluminate in the mixture to ensure it stays below 6% of the whole. This helps maintain low heat during the hydration process, making this cement type more resistant to sulfates and less reactive than other types of cement. It may be suitable for mass concrete construction or projects to help prevent cracking due to heat. However, low-heat cement may have a longer initial setting time than other types.

7. Sulfate-resisting cement:

Sulfate-resisting cement helps reduce the risk of sulfate side effects on concrete. Its most common use is for constructing foundations in soil with high sulfate content. This concrete type can also be beneficial for projects like canal linings, culverts and retaining walls.

8. Blast furnace slag cement:

Manufacturers make blast furnace slag cement by grinding clinker with up to 60% slag. This creates cement with many of the same properties as OPC. However, it may be less expensive to produce than other types, making it a good choice for financially conscious projects.

9. High-alumina cement:

High-alumina cement is a type of rapid-hardening cement created by melting bauxite and lime together and grinding it with clinker. It has high compressive strength and may be more flexible and workable than OPC. Construction teams can use high-alumina cement for projects where cement is subject to extreme weather like high temperatures or frost.

10. White cement:

White cement is a type of OPC that's white instead of gray. It's prepared from raw materials that don't include iron oxide and may be more expensive than other cement types. It's often useful in architectural projects and interior and exterior decorative projects like designing garden paths, floors, swimming pools and ornamental concrete products.

11. Colored cement:

Colored cement has properties similar to OPC and white cement. Manufacturers mix 5% to 10% mineral pigments with OPC to achieve the desired color. Like white cement, contractors often use this type for decorative purposes and projects to enhance their designs.

12. Air-entraining cement:

Air-entraining cement is more workable with a smaller water-cement ratio than OPC and other types of cement. Manufacturers add air-entraining agents like glues, sodium salts and resins to the clinker during the grinding process to create this cement. A common use for this type of cement is for frost resistance in concrete.

13. Expansive cement:

Expansive cement can grow slightly over time without shrinking during the hardening process. It may be beneficial for projects like grouting anchor bolts or concrete ducts. Teams can also use it in structure joints or to reinforce other concrete structures.

14. Hydrographic cement:

Manufacturers create hydrographic cement by mixing in water-repelling chemicals. This cement type has high workability and strength and also repels water to prevent weather damage. Teams can use hydrographic cement for projects such as dams, water tanks, spillways and water retaining structures.

15. Portland-limestone cement (PLC):

Portland-limestone cement is a blend of Portland cement and 5% to 15% fine limestone. Its properties are similar to Portland cement for general use. However, it also has about 10% lower greenhouse gas emissions, which can help increase sustainability. [3]

I-2-2-2 Sand:

I-2-2-2-1 Definition:

It is a natural granular material consisting of fragmented particles resulting from the fragmentation of rocks, minerals and some dry organic matter as a result of natural factors such as wind, rain, sea waves and valley torrents over the years, and due to the long time it takes to form sand, it can be said that it is a non-renewable natural resource. We see that the composition of sand varies according to the different sources of local rocks and their composition, and the most widespread component in continental and coastal areas is silica, which is silicon dioxide and is formed in the form of the mineral quartz, and the second type of sand is calcium carbonate It is one of the most widespread types of sand, and this type of sand is included in the manufacture of concrete and most types of sand are usually formed from quartz and silica, which make its composition chemically unreactive and very hard and more resistant to climatic and natural conditions, and its color varies depending on depending on the nature of the rocks, minerals or organic matter from which it comes [4]

I-2-2-2-2 Type of Sand:

Some of the most commonly used sands for strengthening construction and public works materials include the following:

1- Sea sand: Sea sand is extracted from the seabed by hydraulic projectiles and sea waves, sea sand is abundant on the shores of the seas and, like river sand, generally settles to the bottom of rivers, where it also settles in large quantities at the mouth of rivers and even beyond when sea currents take over the rivers to carry the sand grains. Due to its high salt content, marine sand is less important and less utilized than river sand it may cause damage to the durability of the concrete itself, and in order to preserve the marine environment of the beaches and due to the restrictive laws on the exploitation of this type of sand, it is recommended not to indiscriminately exploit this type of sand in construction.

2- Sand from natural valleys and rivers: This sand is one of the most pure types, and one of the advantages of this type is that its structure is homogeneous and small in relation to the size of the particles, and river sand is one of the most important types of materials for construction, and is used in the manufacture of many types of concrete, natural sand can come from rivers also known as “river sand” and is characterized by its round shape and hardness, and it comes from the movement of water on the rocks.

Because of its small mass, these grains of material move with rainfall, runoff, and rivers. When high-flow streams weaken as they reach the plains, the transported grains of sand, no longer carried by the energy of the water, are slowly deposited in streams and rivers. For environmental reasons, just like beach sand, very few of these sands are exploited directly in the bed of active rivers for fear of running out because they are considered non-renewable.

3 - Quarry sand: This sand is the result of the crushing of large rocks, in fact it is the whole process of extracting large rocks by blasting and then by grinding smaller and smaller rock blocks and fragments, we get a certain amount of sand according to the required diameter (usually less than 5 mm in diameter).

4- Dune sand: Dune sand is one of the most common types, especially in our desert region known as the eastern race and includes a large part of Algeria and Libya, and it is a pure white sandy rock that contains a high percentage of silica and is characterized by being symmetrical and homogeneous in shape and its grain size ranges from 08 microns to 168 microns, where this feature is considered undesirable for this type in the concrete mixture and this is due to its granular field very limited.

5- Synthetic sand: It is sand resulting from the grinding and crushing of molten slag blocks in steelmaking furnaces, as well as granulated slag subjected to rapid cooling in the steel industry. Many recent studies and experiments have been conducted on sand composite concrete from this type of sand and have shown that the latter has similar mechanical properties to sand composite concrete with natural sand. **[4]**

I-2-2-3 Mixing Water:

Mixing water is an essential component in the production of mortar. It is added during the mixing process to hydrate the cement and enable the binding of the concrete’s constituents.

Water also improves the workability of the mixture, making the application of the mortar easier. As an indispensable element for producing mortar, the water used must be clean and free of impurities, and it must not be added excessively. Failure to meet these two conditions can result in weak mortar and compromised performance. The final strength of a mortar depends on the water-to-cement (W/C) ratio in the mixture, which typically ranges between 0.4 and 0.6. The characteristics of mixing water are standardized by the NF EN 1008 regulation. [5]

I- 2 - 3 Mortar functions:

I-2-3-1 Masonry Bonding:

Construction with masonry elements (concrete blocks, cut stone, bricks) requires assembly with mortar that must have sufficient mechanical properties to ensure load transmission and enough compactness to be watertight.

Figure I- 2: Forming walls [6]

I-2-3-2 Plastering:

This is one of the largest application areas for mortars. In addition to traditional three-layer plasters, thick single-layer plasters and insulating plasters are now widely used.

Figure I- 3: Coatings [6]

I-2-3-3 Floor Screeds:

The primary function of floor screeds is to level the flooring and ensure the surface is smooth. Screeds can serve as a final finish or act as a base for flooring materials.

Figure I- 4: Floor Screeds [6]

I-2-3-4 Sealing and Packing:

The variety of sealing and packing needs has led industrial mortar manufacturers to develop specific products tailored to the tasks at hand: sealing roofing elements, secondary

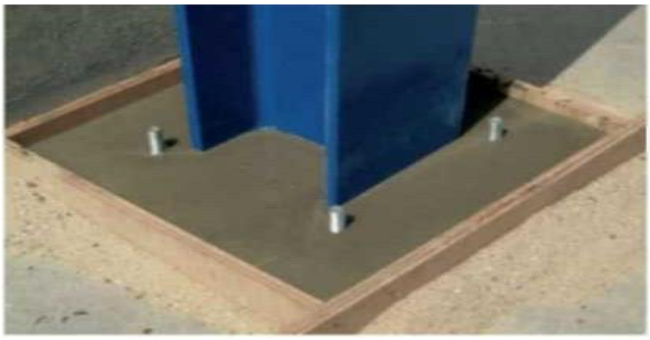


Figure I-5: Sealing and wedging [6]

construction components, urban furniture, and inspection covers. [6]

I-2-4 Types of mortar:

I- 2-4-1 Different mortars depending on binder type:

The types of mortars are chosen according to the application. There are multiple types of mortars with different properties and applications, more or less suited depending on the use. The most commonly used mortars on construction sites are:

I-2-4-1-1 Cement Mortars:

Cement mortar is the most basic product, essential for building walls and bonding stones or bricks together. It is a classic mix of cement, sand, and water. Cement mortar is very strong and waterproof but prone to cracking; it is suitable for assembling concrete blocks. For joints and seals, one might consider omitting the sand.

I-2-4-1-2 Lime Mortars:

This is a type of mortar where lime (fat lime or hydraulic lime) is used as the binder and sand is used as the fine aggregate. This mix is commonly used for plastering interior and exterior walls. Lime mortars are rich and creamy. They set more slowly than cement mortars, especially when the lime is calcareous. It is flexible but less waterproof than cement.

I-2-4-1-3 Composite Mortars:

The mix of cement and lime allows for the combined qualities of both binders. Cement gives it strength, while lime adds flexibility. The use of these two binders results in a mortar that is strong, sets faster thanks to the cement, and is sufficiently rich and creamy thanks to the lime. This combination makes it easier to work with. Typically, lime and cement are used in equal parts; however, the amount of one or the other can be adjusted depending on the intended use and the desired quality. [6]

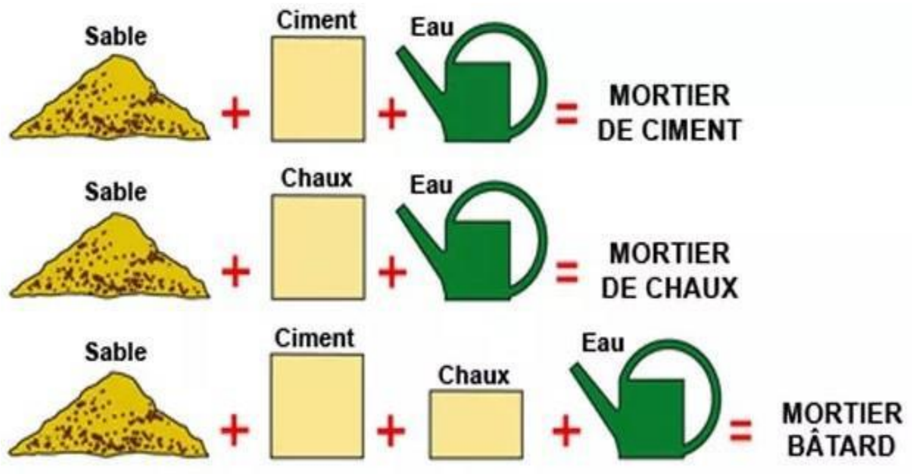


Figure I- 6: Different types of mortar [1]

I-2-4-2- Different mortars for different uses:

I-2-4-2-1- Cement- mortar:

This material is useful for all conventional constructions (walls, screeds, etc.) that do not require the use of a specific mortar. The advantage of cement is its excellent compressive strength. It also hardens faster than most other solutions. Common dosages are in the order of: 300 to 400 kg of cement for 1 m3 of sand. Insufficient cement content makes them practically waterproof.

I-2-4-2-2- Waterproof mortar:

As its name suggests, waterproof mortar is a water-resistant mortar that helps prevent moisture problems on a surface. It can be used to:

- ✓ Fill cracks,
- ✓ coat walls,
- ✓ Screeding.
- ✓ It is mainly used in damp areas (bathrooms, outdoors, etc.) or to create watertight structures such as swimming pools.

I-2-4-2-3- Refractory mortar:

Refractory mortar is a high-temperature-resistant mortar. Depending on the preparation, it can generally withstand temperatures of 900° or less.

Logically, it is only used for constructions that are exposed to this type of temperature, i.e. for the assembly and jointing of:

- ✓ Fireplaces
- ✓ Masonry barbecues.

This material protects the joints and structure of constructions exposed to flames and heat. However, it is never used on constructions that don't need it?

I-2-4-2-4- Lime mortar:

Lime is one of the most widely used binders in ancient construction. So much so that lime mortar is still frequently used. This type of mortar allows the wall to breathe better and is also water-repellent (ideal for damp rooms). The use of lime in mortar generally makes for easier application, thanks to a slightly longer drying time. However, these mortars are more complex to dose than cement.

I-2-4-2-5- Bastard mortar:

Bastard” mortar is a mortar that uses two different types of binder (cement + lime or two different cements), generally in equal proportions. A bastard mortar (lime-based) takes advantage of the benefits of both binders. More adherent and plastic than pure cement, it is more resistant to cracking: the right compromise for terracotta brick and semi-tender stone.

I-2-4-2-6- Adhesive mortar or cement-glue:

As the name suggests, this is an adhesive mortar used to bond a covering to a wall or floor.

This material is used to bond cladding, wall or floor tiles, or flagstones. Depending on the adhesive mortar chosen, it can be used indoors and/or outdoors. [6]

I-3- Additives:

They are substances added to concrete or mortar during or before the mixing process that are often similar to cement in their physical and chemical properties and in the presence of water we get almost the same results as cement mixes.[7]

I-4- Stone additions:

There are many types of stones that can be added to mortar as additives, and each type has a specific benefit depending on the nature of the intended use. Here are some common types and their benefits:

1- Lime stone: Reduces mortar shrinkage, increases workability, and helps reduce the amount of cement used without significantly affecting strength.

2-Basalt: Gives the mortar high mechanical strength and excellent abrasion and heat resistance, making it suitable for harsh environments.

3-Granite: Adds great durability and friction resistance, and is used in mortars for floors and areas subject to high pressure.

4-Marble: Gives the mortar an aesthetic appearance and increases its resistance to abrasion, so it is used in decorative applications.

5-Quartz: Enhances the hardness of the mortar and makes it more resistant to chemical corrosion, making it suitable for industrial settings.

6-Shale clay: Improves the thermal and acoustic insulation of the mortar, making it a good choice in buildings that require thermal control.

7- Silica Fume: Increases the density of the mortar and improves its resistance to compression and shrinkage, typically used in high-performance concrete.

8-Pozzolana: Improves mortar durability and reduces water permeability, making it ideal for marine work and sulfate-resistant concrete structures.

9-Fly Ash: Reduces cement consumption, improves workability, and increases long-term crack resistance.

10-Crushed glass: Enhances aesthetic appearance, increases wear resistance, and is used indecorative mortar or colored flooring. [**7**]

I- 5 -Porous stone:

I-5-1- definition:

Pumice stones are generally a highly porous form of vitrified (glassy) volcanic rock. In volcanic eruptions, the molten inner rock is first exposed to a high gas density. It is then ejected from the volcano as light, spongy particles. These light stones, which begin to take their final shape by cooling, accumulate in time and take their place in nature as ideal building materials **.[8**]

Figure I-7: porous stone

I-5-2- History of pumice:

The earliest known reference to pumice stone is based on an architectural summary by Vitruvio in the first century BC. Vitruvio defines piles as lighter than water. It also states that it does not absorb water and is clean. During the ancient Roman era, pumice stone was mostly used in the construction of baths and temples. These works still exist today. Notable examples of these periods are the Roman Pantheon and the Hagia Sophia Church in Istanbul. Subsequently, pumice stone reappeared in the Coblens region of Germany in the 19th century. The use of pumice stone as a building material began in California in 1851. Since then it has spread to 15 states and 103 fields of study. [9]

I-5-3- Pumice stone locations:

Pumice stone is found in areas with volcanic activity, and one of its most famous habitats:

-Italy (especially in Sicily and Vesuvius)

- Indonesia

- Japan

- United States (such as Oregon and California)

- Greece

- Turkey

- Iceland

* These areas are rich in volcanoes, making them ideal environments for the formation of pumice stone.

I-5-4- Advantages of using pumice stone in construction:

Being a very light stone, pumice does not sink in water. The pores that are abundant on it are round in shape and are usually 65 mm in diameter. If it is used as a cement aggregate, the content is accompanied by gravel, sand and water. Thus, a high-quality building mortar is obtained. Meanwhile, the sizes of pumice stone that should be used to obtain a good building material are between 1 and 16 mm. Regardless, if we were to list the characteristics of pumice stone in a short article, it would be as follows:

- ✓ It is very light.
- ✓ It is strong.
- ✓ It is resistant to adverse weather conditions.
- ✓ It is an easy stone to work with in construction.
- ✓ It provides sound insulation.
- ✓ Provides thermal insulation
- ✓ Balances the temperature between indoor and outdoor spaces.[**8**]

I-5-5 - Disadvantages of using porous stone in construction:

- ✓ The compressive strength of pumice concrete is lower compared to concrete containing other aggregates.
- ✓ Edges and corners tend to break more easily than pure concrete.
- ✓ Low frost resistance when exposed to water. [**8**]

I-6-The conservation media used in this study:

I-6-1 Water Curing:

It is a medium in which water is used as an environment for storing slurry samples, often pure water or saturated lime water, and the aim of its use is to study the resistance of samples when maintaining sample moisture and preventing dehydration, in order to ensure the completion of chemical reactions, especially the rehydration reaction (Hydration) in cement.

I-6-2- Laboratory Curing:

It is a medium represented by controlled laboratory conditions (specific temperature and relative humidity), the aim of its use is to provide constant and controlled conditions to simulate the ideal conditions for solidification of the slurry and monitor its performance. (Pressure and bending resistance)

I-6-3- Plastic Curing:

It is a medium in which samples are kept inside closed plastic bags or containers or wrapped with a plastic layer. Its goal is to prevent the evaporation of water from the sample and thereby preserve the internal humidity.

I-6-4-Acidic Curing:

It is a medium with a low pH, usually containing dilute acids such as sulfuric acid the objective of which is to study the resistance of the slurry to corrosion or degradation in aggressive environments, such as treatment plants or industrial environments.

- ❖ **General Information aggressive media:**

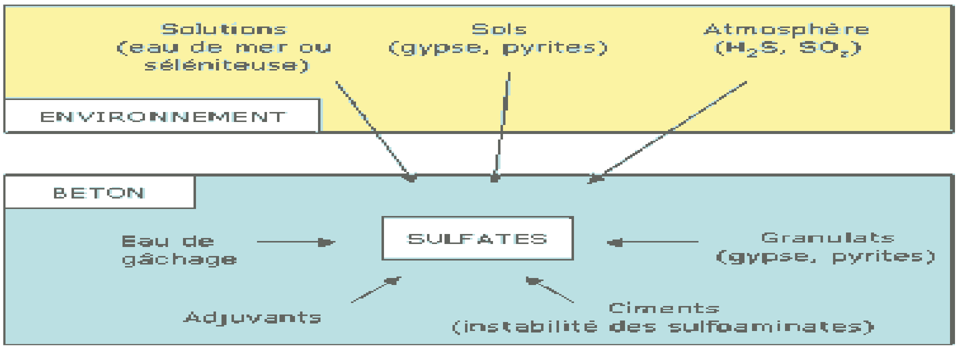
Chemical attack is a crucial aspect of mortar durability, as important of mortar, just as important as its mechanical properties. Durability is just as important as mechanical properties for mortar materials, and is defined (in a very general sense) by the material's ability to maintain its physical characteristics and mechanical performance in safe conditions over the expected service life of the structure, taking into account existing service conditions and the environment. This property is defined (in very general terms) by the material's ability to maintain its physical characteristics and mechanical performance in satisfactory safety conditions over the expected service life of the structure, taking into account existing service conditions and the environment in which it evolves. The parameter governing durability is, of course, permeability. The lower, the permeability, the greater the durability.

Cementitious matrix materials are subject to a wide variety of chemical aggressions. Are highly varied. Because of their porosity and the chemical composition of the interstitial solution, matter exchanges of matter can take place, resulting in changes in the composition of the cementitious matrix. [10]

- ❖ **Different types of chemical attack on mortar:**

  1-Sulfate attacks: Concrete's resistance to sulfate attack is one of the most important factors in its durability. The problem is as old as concrete itself, and was first studied almost 100 years ago. these attacks are accompanied by the formation of “secondary” sulfate products after cement hydration, leading to significant expansion and various chemical-mechanical deteriorations such as changes in transport properties, cracking, and loss of strength and cohesion

- **Sulfate sources :**



Shape I-2: Origin of sulfates [11]

2-Degradation due to marine attack: Marine environments are among the most aggressive natural environments for cementitious matrix materials. In terms of chemical composition, for example, the presence of ions foreign to the interstitial solution, such as chloride or magnesium ions, can lead to the formation of precipitates, dissolution or structural modification of certain phases within the cementitious matrix. In the case of reinforced concrete structures, there is a risk of reinforcement corrosion following the penetration of chlorine ions or a lowering of the pH of the interstitial solution.

3-Attack by chloride ions: Chloride ion attack is one of the main causes of deterioration in reinforced concrete structures. These ions, originating mainly from the external environment, may also be present in the concrete during the mixing process, or diffuse into the concrete from the environment. Reinforcement corrosion is initiated by the dissolution of metal and the formation of ferrous ions, followed by the hydrolysis of the latter, resulting in acidification and the formation of ferrous hydroxide, leading to rust. The diffusion of chloride ions in concrete depends on the nature of the cement and the porosity of the cement paste, as well as the concentration of salts in the surrounding solution. This diffusion promotes corrosion by reducing the resistivity of the electrolyte and depassivating the surface layer of the steel, leading to local and accelerated corrosion in the anodic zones. Chlorides exist in either free or bound form in concrete, with only the former able to diffuse and play an active role in the corrosion process of reinforcement.

4-Carbonation: Carbonation, a natural aging phenomenon in concrete, results from the reaction between cement compounds, mainly portlandite, and atmospheric carbon dioxide. This reaction forms calcium carbonates, releasing water and reducing the pH of the concrete, which initiates corrosion of the reinforcement. At a certain depth inside the concrete, generally from 25 to 30 mm upwards, carbonation ceases due to limestone deposits in the cement paste, stabilizing the pH and preventing corrosion. Immersed concrete generally does not carbonate, but manifestations may occur on interior faces when the air is humidified. Concrete composition, moisture content, electrical resistivity, the presence of oxygen and other aggressive agents such as sulfates and perchlorates all influence reinforcement corrosion. The electrical resistivity of concrete, which depends on its composition, microstructure, humidity and temperature, plays a crucial role in this process.

5-Alkali-reaction: Alkali-reaction, also known as alkali-aggregate reaction, is a chemical reaction between the amorphous or poorly-crystallized silica in reactive aggregates and certain ions in the interstitial solution. This reaction causes concrete structures to swell, leading to cracks and a reduction in mechanical properties, thus jeopardizing the safety and durability of structures. There are three main types of reaction: alkali-silica, alkali-silicate and alkali-carbonate. Reactive aggregates, consisting of amorphous or poorly-crystallized silica, react with the interstitial solution, forming silico-alkali or calco-silico-alkali gels. The alkalis required for this reaction come from the cement and other concrete components, dissolving during hydration. Predicting the evolution of swelling and degradation is crucial, as there is currently no way of stopping this reaction.

6-Freshwater leaching: Freshwater leaching refers to the gradual dissolution of hydrates from hardened cement paste when concrete comes into contact with soft, low-pH, low-ion water. This causes decalcification, an increase in porosity, and a reduction in mechanical properties such as compressive strength, modulus of elasticity and flexural strength. Degradation kinetics vary according to material and environment. For example, studies have shown significant differences in the thickness of degraded concrete layers depending on the type of cement and the presence of dissolved ions, with faster degradation in salt water than in freshwater. [**10**]

I- 7- Reasons for choosing pumice stone as a partial substitute for cement:

I-7-1- Economic aspect:

- Pumice stone is produced from volcanic stone, meaning that it is naturally available in some volcanic areas, and often does not need complex manufacturing processes like cement, which makes it cheaper than the production of Portland cement.

- Using pumice stone as an additive or partial replacement reduces the amount of cement required per cubic meter of concrete, thus reducing overall costs.

-Concrete made with pumice stone is lighter, which means less dead load on the structures, thus reducing the need for bulky reinforcement or large bases, which leads to financial savings in structural design and transportation.

Note: Although this pumice stone is imported because Algeria is not a volcanic region, it is not expensive (the total price of the pumice stone used in this study is 800DZ).

I-7-2- Environmental aspect:

- Cement production is responsible for about 8% of global carbon dioxide emissions and the use of pumice stone reduces the amount of cement used, thus reducing the carbon footprint of concrete, which is the main objective of this study.

- Pumice stone has very fine pores (it is a porous volcanic rock), which gives it the ability to absorb moisture and some gaseous compounds, such as: Carbon dioxide (CO_2) in limited quantities.

- Pumice stone does not need high temperatures for curing or manufacturing like cement, which reduces fuel and energy consumption.

- Pumice stone lightweight concrete provides good thermal insulation, which reduces energy consumption for cooling or heating in buildings.

I-8- Previous studies on pumice stone reinforced mortar:

I-8-1 -First study:

- Pumice stone is a natural sponge-like lightweight aggregate formed during the rapid cooling and solidification of molten lava. After suitable preparation, it can be used as an aggregate to produce lightweight concrete or as a cementitious material to produce blended cement or geopolymer. This article focused on the influence of pumice powder (PP) on fresh properties and hardened properties of conventional cementitious materials and geopolymers. Additionally, different modification methods carried out to modify some properties of conventional cementitious materials containing PP have been included. This review showed that the incorporation of PP in the traditional cement matrix has some benefits such as increasing thermal and acoustic insulation, increasing fire resistance, increasing abrasion resistance, decreasing unit weight, decreasing hydration heat, decreasing drying shrinkage, decreasing autoclave expansion, increasing sulfate resistance, increasing seawater resistance, increasing acid resistance, increasing electrical resistivity, decreasing alkali silica reaction (ASR) expansion, decreasing porosity, water absorption and permeability. On the other hand, it has a negative effect on workability, mechanical strength and increasing carbonation rate. This review also confirmed that PP has a promising future in the field of alkali-activated and geopolymer materials.[12]

I-8-2 - Second study:

- This experimental considered involves on the performance properties of pumice powder as a supplementary cementitious material for ordinary Portland cement materials. The results showed that the pumice powder can be categorized as pozzolanic constituents according to the ASTM C 618 standard, its main chemical composition $SiO_2 + Al_2O_3 + Fe_2O_3$ must be higher than 70% and it was confirmed as suitable for its potential use as supplemental cementitious resources in the production of concrete materials. As the amount of replacement of cement by the pumice powder increases its workability and density become decreases, it’s delayed in setting time observed, and it requires more water to achieve standard consistency. At 25%, it was a weight reduction of up to 3.83% was observed, as a weight of cement substituted with powdered pumice, and the compressive strength of the powdered pumice specimens was replaced with a cement at different levels of 5wt%, 10wt%, 15wt%, 20wt%, and 25wt% cement resulted in a decrease after 7, 28, 56 and 90 days. In addition, it was observed in this study that its strength decreased with increasing curing age; however; replacing ordinary Portland cement with 5wt% to 10wt% pumice powder achieved the specified minimum compressive strength after a curing time of 28 days. But, a concrete sample prepared with 15% partial replacement achieved the specified minimum compressive strength after 56 days. From 15% replacement, there is then a gradual drop in its compressive strength, and the specified minimum strength was not achieved even after a curing time of 56 days it was found that the maximum strain of the concrete was replaced with a powder pumice stone is lower than conventional concrete. Based on the above property, it indicates the suitable pumice powder as a cementitious supplementary material in various concrete constructions. [13]

I-9- Conclusion:

Over recent decades, the potential of traditional building materials has evolved and knowledge of their properties and structural potential has increased.

In this chapter, we touched on:

- A bibliographic study on the properties of pumice stone reinforced mortar, as its properties vary according to the material of manufacture.

- Choosing the proportions of mortar components very carefully as dictated by preliminary experiments.

- Pumice is a porous pumice stone formed from volcanic rocks produced by volcanic eruptions

- The disadvantage of using pumice stone is a decrease in pressure resistance.

- It is said that the mortar is not good until it hardens, and this is by placing the materials in the correct proportions.

-There are many types of cement and each has its own characteristics and advantages.

-According to previous studies, the inclusion of pumice stone improves the resistance of the mortar.

Chapter two: Characteristics of the material used

II-1- Introduction:

As mentioned earlier, mortar is one of the most used building materials, as it is a heterogeneous mixture consisting of sand, water, cement and some enhancers, and may be supported by a range of additives such as fibers, for example.

It is necessary to know the characteristics of the various components (to determine the level of acceptance or rejection before mixing the mixture) as well as the ratio of the components specified for the formulation of the mixture of the Malta because each of these properties and quantities have an important impact on the results of the study.

This chapter will be devoted to the study and testing of the properties of various materials used according to the appropriate reference standards, how to formulate the mortar.

II-2 - Characteristics of material used :

We used in this study:

- Normal construction sand from the Djamaa area south east of Algeria Elmoghaier governorate.

Figure II-1: sample of construction sand for Djamaa area

- In order to improve the properties of mortar we used pumice stone .
- Durable cement f performance concrete of type CEM II.42.5 R.

II-2-1 Used sand:

For the object of characterization of our sand used in our study we used many experiences:

II-2-1-1 Apparent volumetric mass experiment (γapp) (NFP94-064):

- The apparent volumetric mass is the value of the solid mass of the sample to the total volume of the sample including voids.
- To calculate the apparent volumetric mass of the aggregate, the following steps can be followed:

❖ **Tools:**

- Vessel of known volume (VT)
- scale 1g
- Ruler

❖ **How to experiment :**

- Weigh the empty jar Mr.
- Fill the jar with sand using your hands in a funnel shape or use high funnel a 2 cm at medium speed.
- Remove excess sand with a ruler
- Wholesale weight MT

Figure II-2: Apparent volumetric mass experment

❖ **Result:**

➢ The apparent volumetric mass is calculated with the following relationship:

$$\Upsilon app = \frac{MT - Mr}{VT}$$

❖ **So that:**

➢ Empty pot weight (Mr)

➢ Weight of the vase with dirt(MT)

➢ Vase Volume (VT)

$VT = 3.14 \times (4)^2 \times 14.9 = 748.576 cm^3$

$= 1644.85 Kg/m^3 \Upsilon app = \frac{(2731.3-1500)\times 10^3}{748.576\times 10\text{^}3}$

Note: The apparent volumetric mass is between (1400-1700 kg/m3)[14]

II-2-1-2 -Absolute Volumetric Mass Experiment (NFP18-558):

Absolute volumetric mass is the amount of solid mass of the sample divided by the solid volume of the material without voids.

❖ **Tools used and how to experiment:**

➢ graduated tube

➢ Weigh a quantity of sand, say 100 g of dry sand (MS)

➢ Fill the tube with water up to (V1=100)

➢ Slowly empty the amount of sand or gravel into the tube and read V2

Figure II-3:Absolue volumetric mass experment

❖ **Result :**

- The absolute volumetric mass is calculated by the following relationship:

$$\gamma abs = \frac{Ms}{V2 - V1}$$

❖ **So that :**

✓ Dry mass (Ms)

✓ Volume of water (V1)

✓ Volume (water + sand) V2

$$\gamma abs = \frac{100}{140 - 100} = 2500kg\ /m3$$

❖ **Note:** The apparent volumetric mass is between (2400-2700 kg/m^3).

[16]

II-2-1-3- Granular gradient experiment (NFP18-560):

❖ **Definition:**

Granular gradation means separating the different sizes of the aggregates from each other, determining the size distribution of the aggregate grains. This is done by using sieve analysis using a set of sieves arranged according to the size of their openings and placed on top of each other so that the largest sizes are at the top this experiment enables us to calculate the different proportions of the sizes of the grains that make up the studied sample [17]

❖ **Objective of the experiment:**

Granulometric analysis allows the determination of the amount and proportion of the different diameters of the granules constituting the sample and allows the determination of the diameters of the granules and the radial distribution of the aggregate granules

❖ **The principle of the experiment:**

The process of granular classification is based on mechanical sieving, and these processes is done by taking a sample of sand and pass it through several standard sieves placed on top of each other, the sieves should be placed on top of each other from the largest to the smallest and the sample is placed on the highest sieve, The sieves are placed on top of each other from the largest to the smallest and the sample is placed in the highest sieve where the sieving process is done by a sieving machine for ten minutes or more to sort the granules.

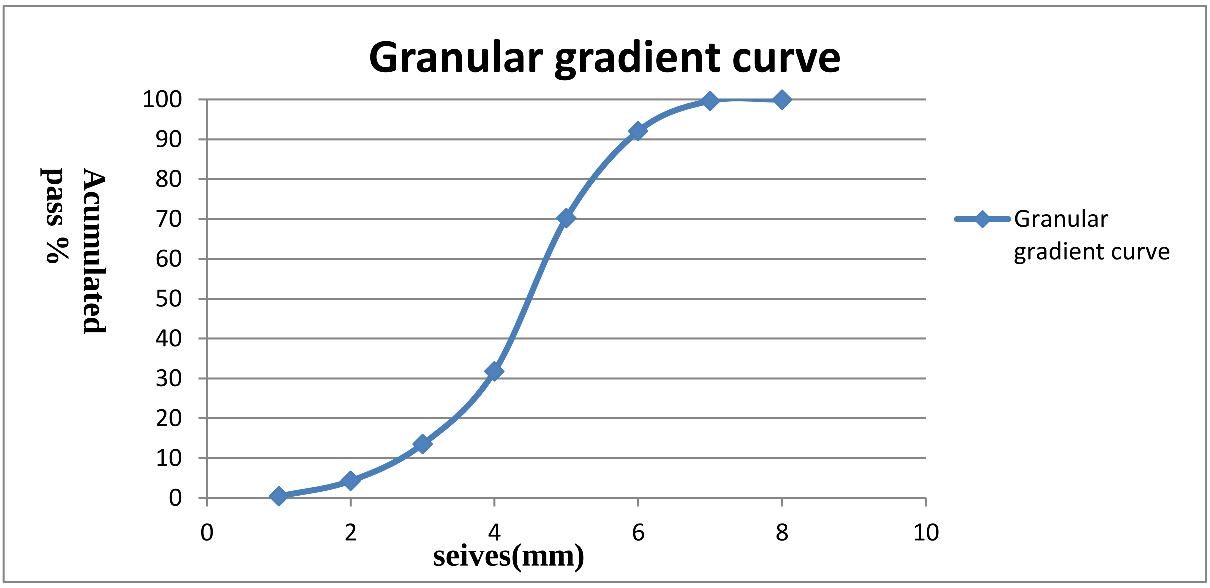
❖ **Tools used and how to experiment:**

- ✓ Sieves with square metal holes with standard diameters (5, 2.5, 1.25, 0.63, 0.315, 0.16, 0.08) mm
- ✓ Automated sieving device that creates vibrations in the sieves
- ✓ Prepare a series of sieves on top of each other with the smaller diameter sieve at the bottom and the larger diameter sieve at the top.
- ✓ Place a bowl at the bottom to catch items smaller than 0.08mm.
- ✓ Empty the weighed sample of 2 kg into the top sieve (5 mm).
- ✓ Close the sieves and run the machine for 10 minutes.
- ✓ - Weigh the residue in each sieve from top to bottom.
- ✓ We draw a graphical curve of the granular analysis of the soil sample, where the axis of the stratification represents the percentage of the combined passage (%) and the axis of the separators represents the diameters of the sieves (mm)

Figure II- 4 : Screening machine

Table II-1: Results of the granular analysis experiment

sieves en mm	Weight (g)	Cumulative refusals en (g)	Cumulative refusals en (%)	Cumulative passing en (٪)
5	8.7	8.7	0.43	99.57
2.5	77.7	86.4	4.3	95.7
1.25	185	271.4	13.5	86.5
0.63	366.6	638	31.79	68.21
0.315	772	1410	70.25	29.75
0.16	451.7	1861.7	92.93	7.24
0.08	125.8	1987.5	99.03	0.97
Find	18.8	2006.3	99.97	0.03



Shape II-3: The granular gradient curve of the used sand

II-2-1- 4 Fineness modules (Module de finesse NF P18-540):

It can be used to determine the quality of the sand and can be calculated by the following relationship:

(Mf = ΣRC%/100 Total Residual Collected % excluding sieve 0.08mm.)

Table II-2: Results of fineness module

The sieve	0.16	0.315	0.63	1.25	2.5	5	Total	Mf
Percentage of the remaining compound (%)	0.43	4.3	13.5	31.79	70.25	92.93	213.03	2.13

Table II- 3: Represent the permissible values of the fineness coefficient and the classification of sand by coefficient

Smoothness Unit MF		
1.8-2.2	The sand is mostly fine-grained	Allowable Sand
2.2-2.8	medium Sand	
2.8-3.3	Slightly coarse Sand	

- Since the value of the smoothness parameter Mf for the sand of Djamaa area which is equal to 2.13 , belongs to domain B, this indicates that this sand is mostly fine-grained acceptable granular gradient

II-2-1-5- Sand Equivalent Experiment:

Defined by the rule (NFEN933-8) .The goal is to determine the percentage of sediment and suspended matter present in the sand [18]

❖ **Tools:**

- ✓ Tube
- ✓ Scale
- ✓ Rule
- ✓ Shaking machine
- ✓ chronometer (for measuring time)

❖ **Experiment steps:**

- ✓ Weigh 120g of dried sand
- ✓ Fill the tube with lye solution up to 10 cm.
- ✓ Empty the amount of sand into the tube.
- ✓ Leave the tube for 10 minutes (resting state).
- ✓ Close the tube with a plastic stopper and then shake the sentence horizontally for 30 seconds (90 times) or using a shaker.
- ✓ Complete filling the tube with water up to the second milestone of 38 cm.
- ✓ Allow the sentence to rest for 20 minutes.
- ✓ Beginning of the measurement with the naked eye and then with the plunger

Figure II-5: Sand equivalente experment

- **Result:**

Table II- 4: Shows the classification of sand depending on the result of the sand equivalent

The nature and quality of the sand	**ES**	**ESV**
Clay sand not suitable for use in concrete	60>Es	65>Esv
Clay sand is allowed to be used in concrete	70>Es≥60	75>Esv≥65
Pure sand with low clay content (used for good quality concrete)	80>Esv≥70	80>Esv≥75
Very fine sand	Es≥80	ES≥85

Sand equivalent	ESV			ES		
Samples	78.57	80	78	70	72	77
Average	79			73		

Table II-5: Results of sand equivalent experiment

- **Result:**

The value of sand equivalents for Djamaa area equal to (ESV=79%, ES=73%) so it is clean, has some clay in it, and is usable.

II-2-1-6- The chemical analysis of the sand:

Table II-6: the chemical analysis of the sand

Chemical analysis	Value
CaCo3 (%)	1.44
Insoluble (%)	90.66
So3-(%)	3.06
CaSO42H2O (%)	6.6
Cl^-(mg/l)	0.019
So4-(mg/kg)	3675.14

II-2-2 water:

Water is of great importance in the mixture, and it is an essential part in construction, like the rest of the elements, as it is necessary for every construction activity, whether during or after mixing.

Note: the water used in the mix is the tap water of the Civil Engineering Laboratory

II-2-2- 1-The chemical composition of the water used:

Table II- 7: Chemical composition of used water [19]

PH	*HCO_3^-*	*SO_4^-*	*NH_3*	*Cl^-*	*Na^{++}*	*K^+*	*Mg^{++}*	*Ca^{++}*
6.66	159.24	1156	/	585.59	200	30	26.4	292.58

.

II-2-3-Cement:

-The cement used is CEMII/B-L42.5 M, which is available in the local market

Figure II-6: Used cement

II-2-3-1-Surface area of cement :

It is a physical property that determines the smoothness of cement, the more the cement is ground, the larger the specific surface area and smoothness is one of the most important properties that affect the following elements:

- The ratio of the chemical reaction.

- The development of resistance.

- The amount of cement necessary to coat the aggregate grains of aggregate (sand, gravel) to support the bonding between all the grains [20]

II-2-3-2- The technical properties of cement are listed in the following tables:

The chemical analysis of cement is given in the following tables:

Table II- 8: Technical Card Used Cement [21]

Chemical analysis	**Value**
Loss of fire	8.0 – 2
Sulfate content(SO_3)	2.5 - 0.5
Magnesium oxide content(MgO)	1.7 - 0.5
Potential clinker composition (%)	**Value**
S_3C	60 -3
C_3A	7.5 -1

Physical properties	**Value**
Natural consistency %	26.5 - 2.0
(mm) Heat expansion	≤3.0

(20°) Uncertainty time	**Value**
Start of uncertainty time(min)	150 – 30
End of uncertainty time(min)	230 -50

Pressure resistance	**Value**
Day2(Mpa)	≤10.0
Day28(Mpa)	≤42.5

II-2-4- Used stone (white pumice stone):

We ground the pumice stone and then sifted it

Figure II-7: Preparation of pumice powder

II-2-4-1-Pumice stone analysis:

Table II- 9: Pumice stone analysis [9]

Typical(٪)	Chemical Name	composition
70.37 -71.76	Silica	SiO_2
10.27 -14.13	Alumina	AlO_3
4.19 -4.29	Potassuim oxide	K_2O
3.58 -4.10	Sodium oxide	Na_2O
0.82 -1.3	Iron oxide	Fe_2O_3
0.64 -0.75	Lime	CaO
0.09 -0.18	Magnesium	MgO
0.05 -0.11	Titanium oxide	TiO_2
4.33 -5.87		Loss at ignition

Absolute volumetric mass (kg/m^3)	1666.6

II-3 -Conclusion:

In this chapter, all the properties of the materials used in this experimental study and the various stages of experimental processes have been addressed, and we also draw in this axis some of the most important points:

- ✓ The construction sand of the Djamaa area south east of Algeria Elmoghaier governorate is suitable for constron, based on the results of the sand equivalent experiment (ESV=79).
- ✓ The cement we have used is durable cement for high-performance concrete of type CEM II 42.5 R.
- ✓ The used water is drinkable from the tap of the Civil Engineering Laboratory of the University.
- ✓ The stone used is white pumice stone, which is rich in silica (SiO_2)

Chapter Three: the composition of ordinary mortar and reinforced with pumice stone, analysis and discussion of the results

III-1- Introduction:

- The selection of the materials involved in the composition of the mortar and knowledge of all its properties is an important stage, which we touched on in the previous chapter, and then we look in this chapter at the concentration ratio of each of the compounds used in the mixture in order to determine the optimal composition of the mortar with acceptable operation and high resistance. [22] ***EMILE O***

- The pumice stone optimization process for mortar is an important and necessary stage in the science of materials engineering and the process is not limited to adding a percentage of pumice stone only, but other factors must be taken into account, the most important of which is operational, as adding this material to the mortar causes a change in the amount of cement and thus affects the operational. [22]

- Mechanical properties are one of the most important characteristics that distinguish a lot of materials from others and after knowing the composition of mortar reinforced with pumice stone. In this chapter, the study of the mechanical properties of mortar reinforced with fabric strips was discussed on days 14, 21 and 28.

III-2 -Composition of the reference slurry (witness):

As mentioned above, the mortar is a compound consisting of water, cement, and sand, and in order to obtain the composition of the mortar which in turn will be used as a witness, one part of cement and three parts of sand were taken, as for the water part, it was determined according to the operational experiment, which is conducted through the Maniabilimètre B device for this experiment, which is responsible for adjusting the appropriate proportion of water in the mixture, in order to obtain a flexible mortar as recommended. The appropriate proportion of water in the mix, in order to obtain a flexible mortar as recommended.

III-3- Operational experience:

The workability of the mortar is an important characteristic because it facilitates the process of laying in molds. Therefore, it should be easy in order to save time on the one hand and to avoid deformations resulting from molding that are difficult to treat later. We say that a mortar is more functional if it is easier to pour it into molds [23] ***DUPAIN R، LANCHON R***

Therefore, this experiment aims to measure the time required for a quantity of mortar to flow and then judge the quality of the mortar and then judge the operationality and then determine the appropriate water ratio for acceptable operationality, as fresh mortar is categorized according to operationality into four classes:

Dry slurry, flexible slurry, very flexible slurry, fluid slurry [24] ***GORISSE F***

These are defined as [NF P18 -452 and NF P15 -437]

Operational experience is shown in the picture III-1

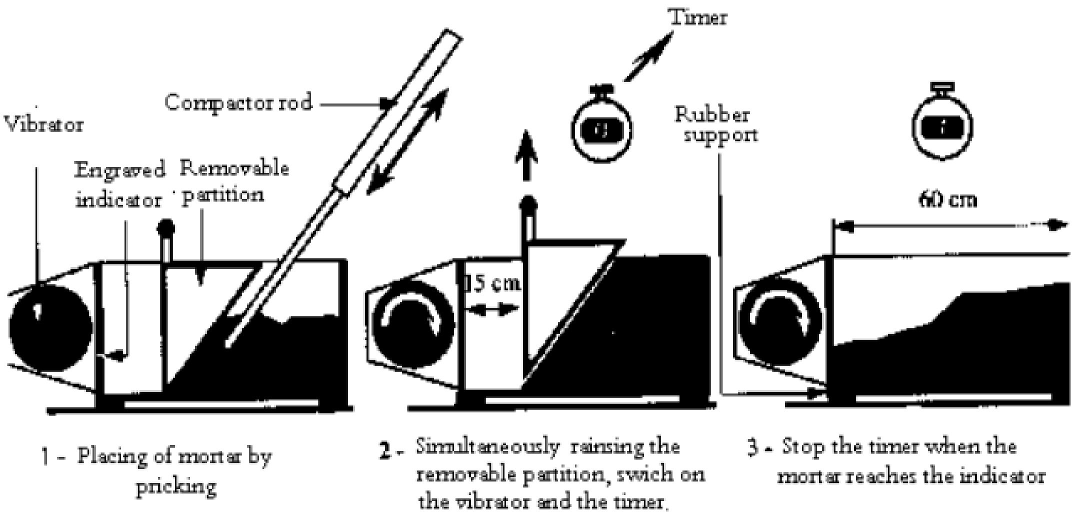
Figure III-1:Operational experience

The following Table III-1 shows mortar varieties by operation.

Table II-1-10:Slurry class in operational terms [25]

Class of slurry by operation	Duration in seconds
t≥40	dry mortar
20 < t ≤30	Flexible mortar
10 < t ≤20	Very flexible mortar
t≤10	fluid mortar

III-3-1 The device used in the experiment: The device is called **Maniabilimètre B** as mentioned earlier and is shown in the picture III-2, it consists of a parallelogram box with dimensions of 30 * 15 * 15 cm placed on rubber stands and are equipped with a vibrator and a sliding part that gives the signal to start the shaking when pulled [25]. The figure shows the operational experience.



Shape III-1 -1: Operational experience [26]

Figure III-2: Maniabilimètre device

III-3-2 - Stages of the experiment:

- ✓ Prepare the slurry mix according to the formula suggested above.
- ✓ Fill the basin with mortar in four layers and hammer between each layer.
- ✓ Pull the iron piece with the timer running at the same moment of pulling to start the vibration process, allowing the mortar.
- ✓ Measure the time of arrival of the mortar to the reference line in the device.
- ✓ The following table shows the results obtained after conducting an operational experiment on the reference slurry (witness).

Table III-2: Composition of the reference slurry (witness)

Water (ml)	Sand (g)	Cement (g)	Time (s)	W/C
202.5	1350	450	31s	0.45
211.5	1350	450	25s	0.47
225	1350	450	13s	0.5

- So, after conducting a trial run, the water-cement ratio was determined to be W/C = 0.47, one part cement and three parts sand for the witness's mortar composition.

III-4- Determine the composition of the pumice stone reinforced mortar:

We used pumice stone in a proportion of the mix, where we take away a block of cement and replace it with different proportions of pumice stone

Table III-3 : Pumice stone reinforced mortar composition

Type of mortar	Sand (g)	Cement (g)	Water (ml)	Pumice stone (g)	W/C
Reference mortar	1350	450	211.5	0	0.47
Pumice stone reinforced mortar 5%	1350	427.5	225	22.5	0.5
Pumice stone reinforced mortar 10%	1350	405	247.5	45	0.55
Pumice stone reinforced mortar15%	1350	382.2	256.5	67.5	0.57

III-5-Sample preparation:

To prepare the studied samples, molds with dimensions (16*4*4*4 cm) were used after obtaining the optimal composition of the reference mortar and reinforced with cloth strips, where we prepared the mortar mixture manually and then poured the samples, where the method of preparing the mixture was as follows:

➢ **For the reference mortar:**

- ✓ Prepare the weights of the materials used in the mixture
- ✓ Mixing construction sand for a minute.
- ✓ Add cement and mix well for two minutes.
- ✓ Add water gradually while mixing until the desired consistency is obtained.
- ✓ Fill the molds in two layers, shaking each layer as it is filled with 30 shakes with a shock table.
- ✓ Samples are left in the open air and removed after 24 hours. The number of samples was 12 for each time point of the mortar age where The ages in this study were taken as (14, 21 and 28 days)

➢ **For pumice stone reinforced mortar:**

- Laying sand and mixing it well

- Mixing cement with pumice stone powder according to the studied ratio (5%, 10%, 15%) for a certain period of time

- Add the mixture of cement and pumice stone powder to the sand

- Gradually add water and mix the mixture for 5 minutes

- Finally, fill the molds in two layers, shaking each layer as it is filled as we did before.

Note: We used the following symbols in this study

MC: It is the reference cement mortar that does not contain pumice stone

M5%: It is the cement mortar that contains 5% pumice stone

M10%: It is the cement mortar that contains 10% pumice stone.

M15%: It is the cement mortar that contains 15% pumice stone

Figure III-3: Preparation of samples

III-6 Chemical attack with sulfuric acid:

After the creation of the pre-cracking in the mortar specimens, sulfuric acid attack tests were carried out in order to study the durability of the mortar under similar chemical conditions. The mortar specimens were immersed in a bath of sulfuric acid solution (H_2SO_4) at 5%

concentration. The choice of the latter is based on the work of (L. Wu, 2021). In which the degradation process was accelerated in order to get as close as possible to real conditions where degradation can take several years to occur. The samples were immersed in sulfuric acid solution in order to accurately study the effect of sulfuric acid. [**10]**

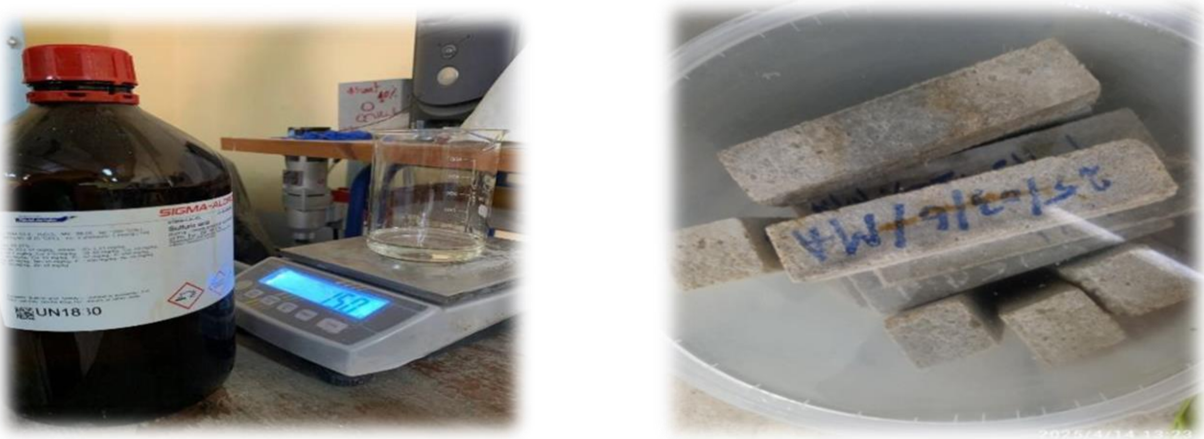


Figure III-4: Sulfuric acid (H2SO4)

- The following table III-4 contains all the compositions used in the preparation of the mortar for 1m^3 of mortar, and the volumetric mass of the mortar is estimated at 2200 kg/m^3

Table III-4: Slurry composition for one cubic meter

Type of mortar	Cement(kg)	Sand(kg)	Pumice stone(g)	Water(L)
MC	492	1476	0	2431.4
M5%	464.5	1467	24.5	244.5
M10%	435.15	1450.5	48.35	266
M15%	408.74	1444.2	72.66	274.4

III-7-Experiments performed on samples

- There are two types of experimentation methods that are conducted on mortar, one of which is destructive and destroying the structure, as in this type of experimentation, the results cannot be obtained until the samples are destroyed in this type of experiments, results can only be obtained after destroying the samples, usually on systematic samples prepared in advance for this, and they are called Some of them are non-destructive, that is, they do not damage the body but expose part of it, or leave no trace at all, and are called non-destructive experiments. They are called non- destructive or non-destructive experiments [27]. In this work, destructive experiments were carried out on the bending, compressions experiments and volumetric mass then discuss their results.

III-7-1- Volumetric mass experiment:

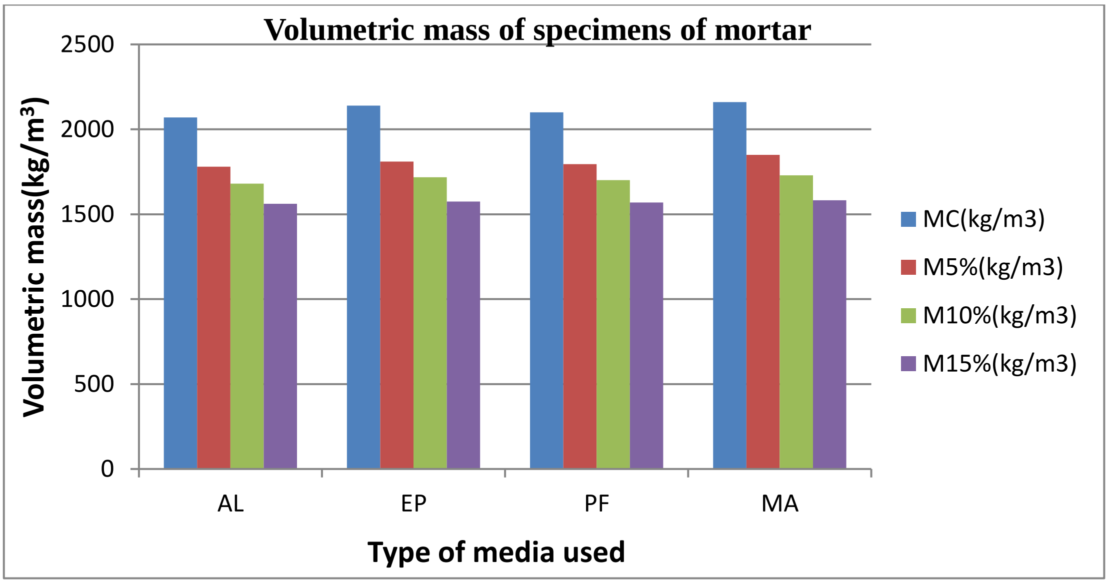
The volumetric mass is determined by weighing samples with dimensions (4*4*16) cm and is given by the following relationship: $\Upsilon = \frac{M}{V}$

Υ : Volumetric mass (kg/m^3)

M: Sample mass (kg)

V: Sample volume (m^3)

III-7-1-1-Results of the experiment:



Shape III-2- 2: Bar graphs representing the volumetric mass changes of the samples

III-7-1-2 Analyze and discuss the results of volumetric mass :

- The main objective of this work is to know the extent of the effect of pumice stone on the mortar in terms of volumetric mass, and after obtaining the results and comparing them with each other on the one hand and comparing them with the witnessed mortar on the other hand, it was found that the following:

- We note that the more the percentage of cement replacement with pumice stone increases by 5%, 10% and 15%, the less the volumetric mass in all media (laboratory medium AL, water medium EP, plastic medium PF, acidic medium MA) and this is expected because pumice stone is a lightweight material compared to cement and has a low density.

-We notice when comparing the media that the acidic medium is the highest in terms of volumetric mass, followed by the aqueous medium, then the plastic medium, and finally the laboratory medium, and we explain this by explaining that the pumice stone may be less reactive in acidic media, which makes its effect in reducing the volumetric mass less obvious, while in the aqueous medium, this can be explained by the fact that with the pumice stone the introduction of pumice stone reduces the density because it is not highly reactive with water, as for the plastic medium, this is due to the fact that the plastic medium hinders the bonding between the components of the mixture due to the lack of interaction compared to water, as for the laboratory medium, which is the lowest in terms of volumetric mass, this is explained by the fact that the pumice stone interacted better compared to other media

III-7-1-3- General note:

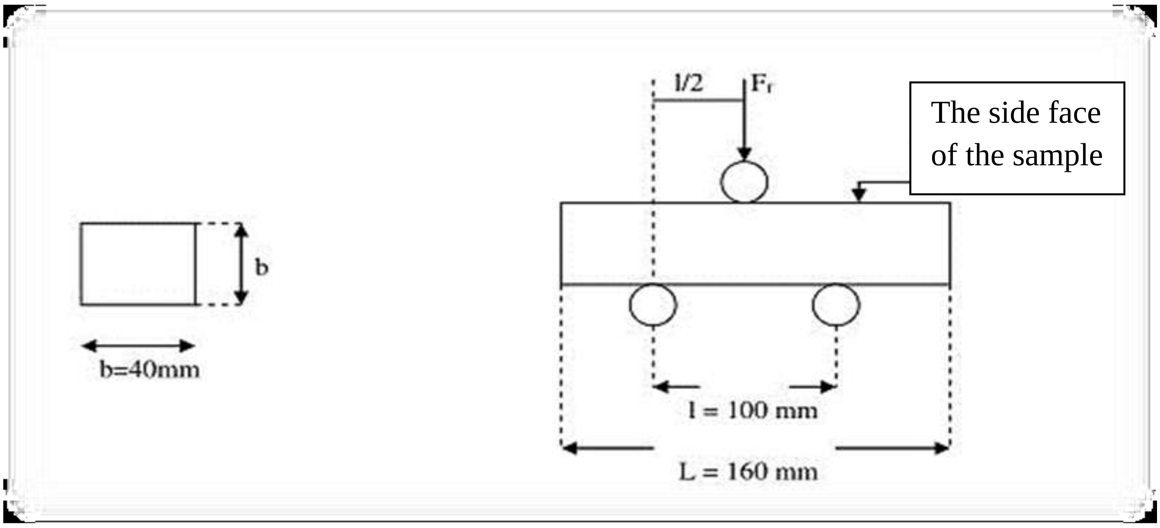
- Finally, we say as a general observation that the introduction of light stone as a partial replacement for cement reduces the volumetric mass of mortar or concrete, which may lead to the production of lightweight concrete.

III-7-2- The bending experiment:

The bending experiment is carried out on prismatic specimens with a square section of 4*4 cm2 and a length of 16 cm, the distance between the two supports is 12 cm. The process is also carried out by the bending machine, the machine is equipped with two cylindrical supports from the bottom that are fixed on which the specimen rests and a cylindrical upper support also applied in the center of them that is moved by the machine motor to apply the force on the specimen and the load is read directly from the machine

This experiment is provided by the rule [EN 196-1(P 15- 471)]**[28]** Shape III-3 is an illustration of the mechanism of shattering by bending.

EN 196-1(P 15-471)



Shape III-3: illustration of the bending crushing mechanism

The experiment is conducted by the crushing machine for the bending experiment for a mortar sample with dimensions (40*40*40*160) mm^3

The image of the device is shown in the image of (picture III-5)

Figure III-5: Demonstrates the bending smashing machine

The bending resistance is calculated with the following relationship:

$R_f = \frac{3}{2}\ \frac{l.Ff}{b3}$..1-III

R_f: bending resistance (MPA)

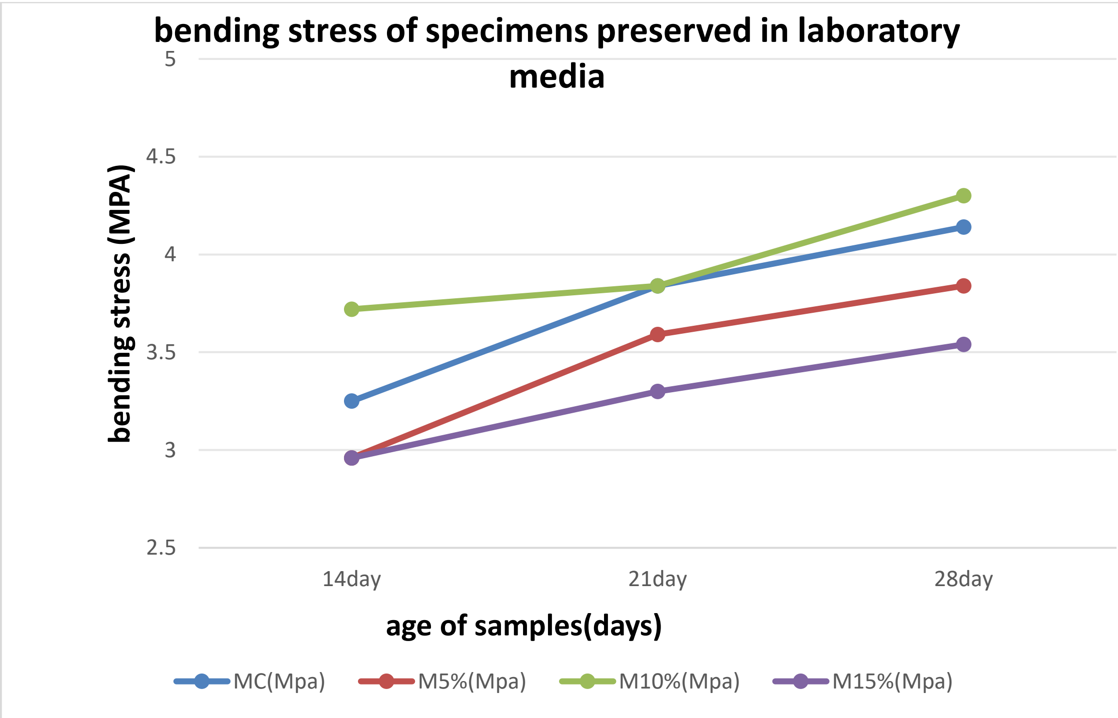
F: crushing force in bending (N)

l: The distance between the two datums (mm)

b: the dimension of the specimen section is equal to 40 mm**Source spécifiée non valide.**

III-7-2-1 In laboratory media:

III-7-2-1-1 Results of the bending experiment:



Shape III-4: The results of the experiment of bending samples preserved in laboratory media

III-7-2-1-2 Analyze and discuss the results of the bending experiment:

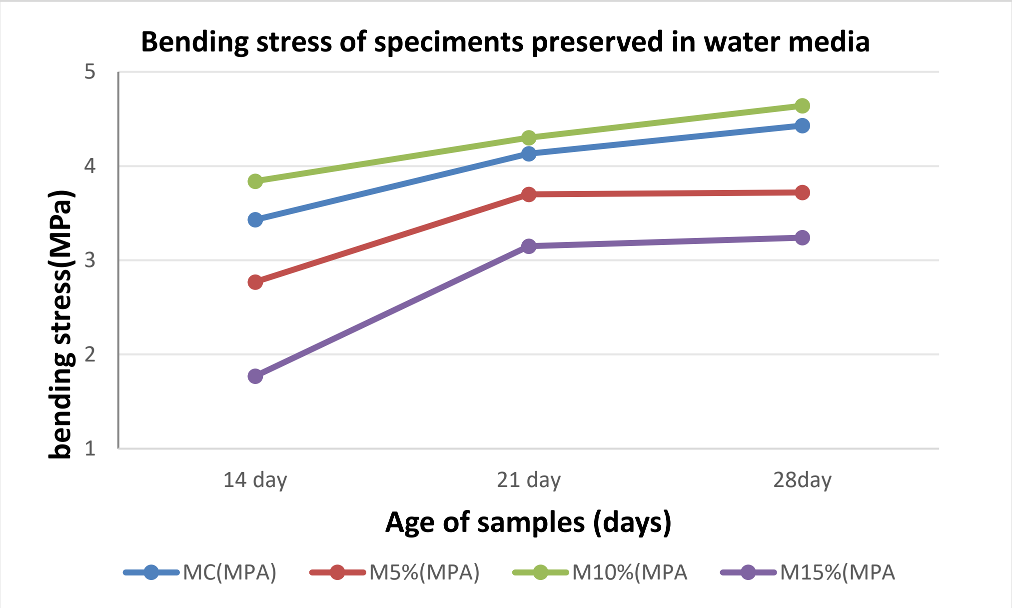
- The main objective of this work is to know the extent of the effect of pumice stone on mortar, and after obtaining the results and comparing them with each other on the one hand and comparing them with the witnessed mortar on the other hand, it was found that the following:

- From the curve, it was observed that the bending resistance increases with the passage of days for all compounds, and we explain this by the development and continuation of chemical reactions between the components within the mortar and the occurrence of hardening.

- It was observed that the slurry reinforced with 10% gave good and high results for the bending resistance compared to the reference slurry in the laboratory medium, where the percentage of increase was estimated (4%) and this can be explained by the improvement of the microstructure and the occurrence of sufficient chemical reaction, it was also observed that the compound M15% was less bending resistance compared to the witness slurry, where the percentage of decrease was estimated at 14% and this could be due to the decrease in bulk density, and the compound M5% also gave less results but considered better than the results of the slurry reinforced with 15%.

III-7-2 In water media:

III-7-2-2-1 Results of the bending experiment:



Shape III-5: The results of the experiment of bending samples preserved in water medium

III-7-2-2-2 Analyze and discuss the results of the bending experiment:

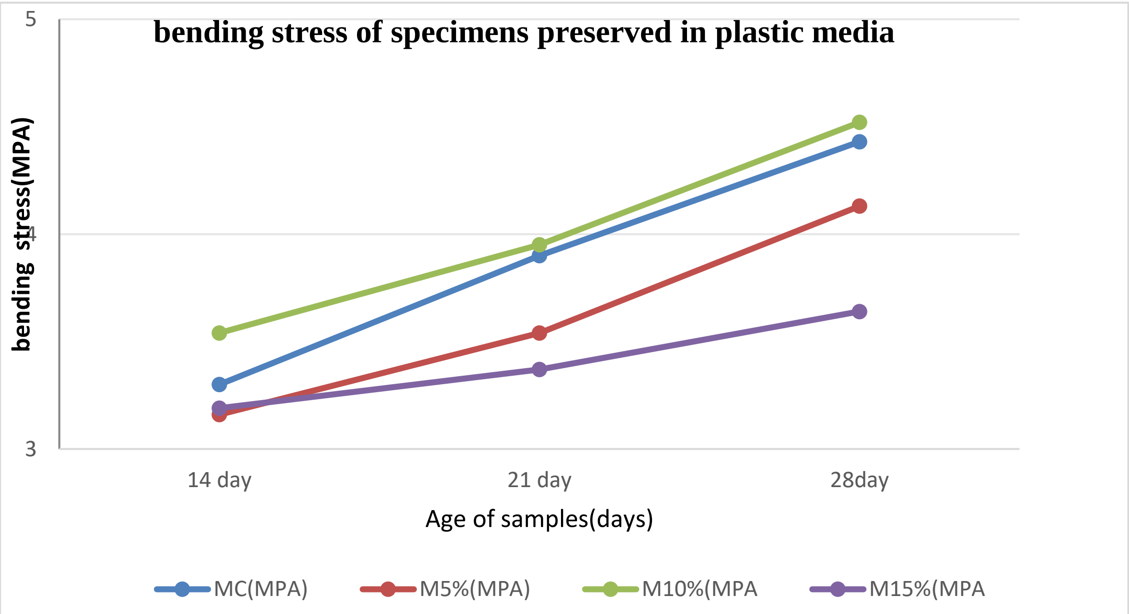
The main objective of this work is to know the effect of pumice stone on the mortar in the aqueous medium, and after obtaining the results of the bending experiment and comparing them with each other on the one hand and comparing them with the witness mortar on the other hand, it was found the following:

From the curve, it was observed that the bending resistance increases over time for all compounds and we explain this by the development of chemical reactions (adsorption reactions)

-It was observed that the mortar reinforced with 10% gave good and high results for bending resistance compared to the reference mortar in the laboratory medium, and this may be explained by the fact that the pumice stone reacted with rehydration products such as calcium hydroxide and produced compounds that enhanced the bending resistance (sufficient chemical reaction limit), as it was observed that the compound M15% was the weakest in terms of bending resistance compared to the witness mortar and other compounds, which could be due to the fact that the higher the replacement ratio, the less the amount of active clinker and thus the less the ability of the mixture to develop bending resistance, and the compound M5% also gave lower results but is considered better than the results of the mortar reinforced with 15% .

III-7-2-3 In plastic media:

III-7-2-3-1 Results of the bending experiment:



Shape III-6: The results of the experiment of bending samples preserved in the plastic medium

III-7-2-3 Analyze and discuss the results of the bending experiment:

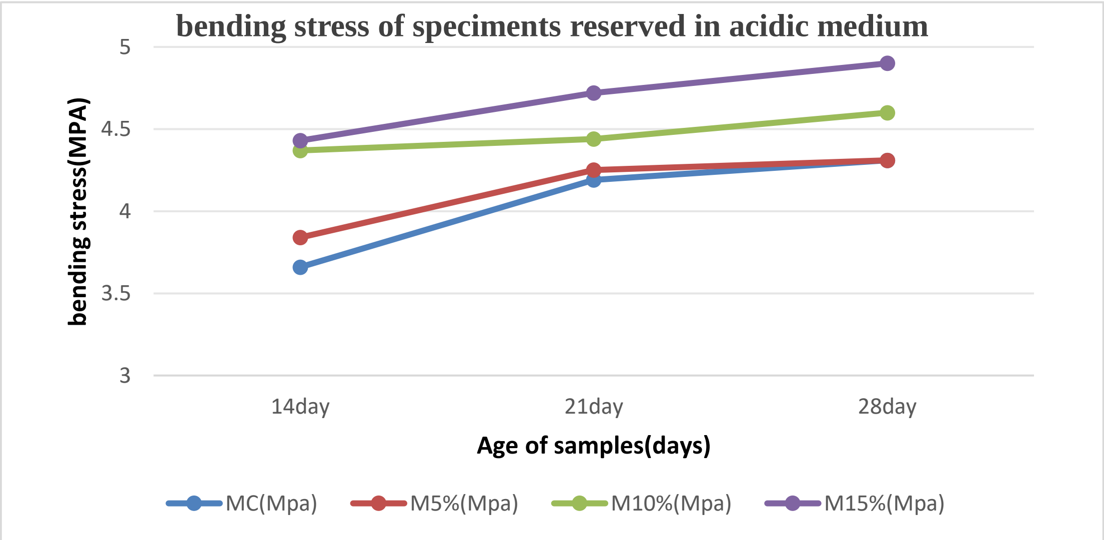
- The main objective of this work is to know the effect of pumice stone on the slurry in the plastic medium, and after obtaining the results of the bending experiment and comparing them with each other on the one hand and comparing them with the witness slurry on the other, the following was found.

- It was observed from the curve that the bending resistance increases with time for all compounds and we explain this by the development of chemical reactions and the occurrence of solidification.

- It was observed that the 10% reinforced mortar gave good and high results for bending resistance compared to the reference mortar in the plastic medium, i.e. it is the optimal ratio where it balances between reducing cement and stimulating pozzolanic reactions while maintaining a cohesive structure, while in compound M5% we observe a relative decrease in the beginning, but it approaches the resistance of the specimen. This indicates that there is a slow and gradual pozzolanic reaction, while the M15% compound was the weakest in terms of bending resistance compared to the witness mortar and other compounds, and this is explained by the fact that the pozzolanic reaction did not sufficiently compensate for the decrease in the amount of cement

III-7-2-4 In acidic media:

III-7-2-4-1 Results of the bending experiment:



Shape III-7: The results of the experiment of bending samples preserved in the acidic medium

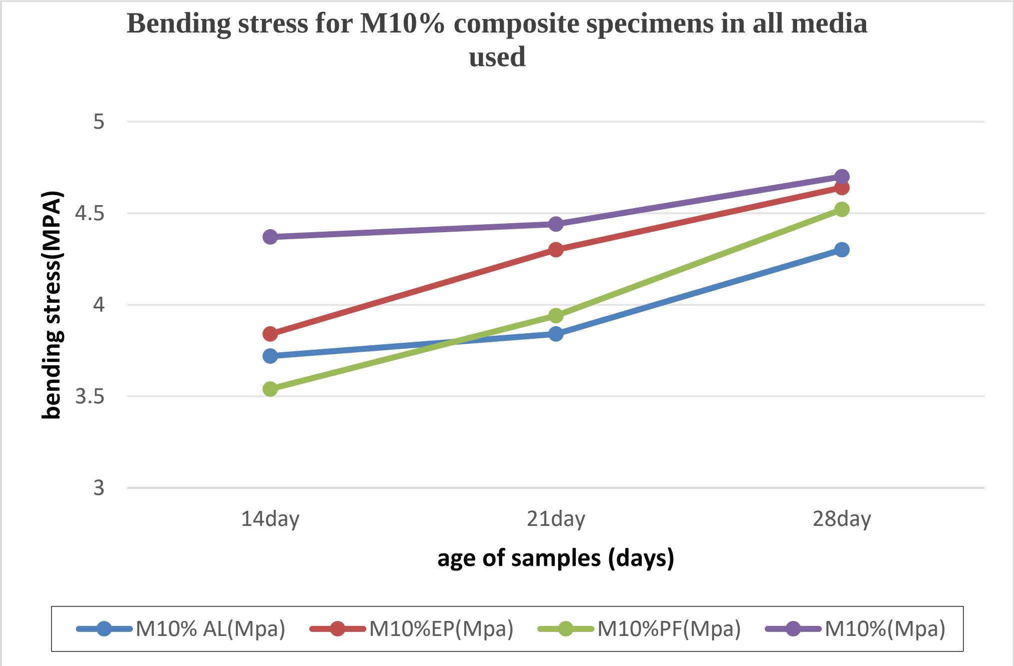
III-7-2-4-2 Analyze and discuss the results of the bending experiment:

-The main objective of this work is to know the effect of pumice stone on the acidic medium slurry, and after obtaining the results of the bending experiment and comparing them with each other on the one hand and comparing them with the witness slurry on the other hand, it was found the following:

-From the curve, we observe that the bending resistance increases with the passage of days for all compounds and this is explained by the evolution of chemical reactions with the passage of days .

-We observe in the acidic medium that the bending resistance increases as the percentage of pumice stone increases, where the best results were in the compound M15%, followed by M10% and then M5%, where all compounds can give better results compared to the reference mortar and this is explained by the fact that pumice stone consists mainly of silica that does not react well with weak or medium acids.

- **Bending experiment results for M10% compound in all media used**



Shape III-8: Bending stress results for M10% composite samples in all media used

- **Analyze and discuss the results of the bending experiment:**

-The curve represents the results of the bending resistance of the M10% composite for the different types of media used in this study where we observe:

- That the bending resistance increases with the passage of days in different media, as the highest results were in the acidic medium, followed by the water medium, then the plastic medium, and finally the laboratory medium gave the lowest results. This can be explained in the acidic medium that the pumice stone consists mainly of silica, which is a material that does not react with weak and medium acids, which led to reduced corrosion or reaction, while in the water medium, this may be due to the fact that water contributed to the rehydration reaction of the pumice stone, which increased the bending resistance over time, but the reaction in the acidic medium was The rehydration of the pumice stone, which increased the bending resistance over time, but the stress in the acidic medium was stronger, while the resistance in the plastic medium was less compared to the aqueous medium. This is explained by the abundance of water in the aqueous medium increases the strength of the reaction, while the plastic medium is limited water and therefore less reaction, as for the laboratory medium with weaker resistance, we interpret its results on the fact that samples may be exposed to gradual evaporation of water which may cause weakness in the internal structure

III-7-2-5 General note:

- In the end, it can be said that the mortar reinforced with 10% pumice stone gave the best results for bending resistance in aqueous, laboratory and plastic media and this is explained by the occurrence of sufficient interaction between cement and pumice stone and can be said to be the ideal ratio while increasing or decreasing it will give unsatisfactory results.

- As for the acidic medium, 15% was the best because it minimized the chemical reaction (reducing the reaction due to silica), and the higher the percentage of pumice stone, the higher the bending radius.

III-7-3 Compression experiment:

This experiment is performed using a solid compression apparatus and is applied to half of the specimen This half is taken from the experiment of cracking the specimen by bending with a section of mm40*40 This specimen is placed between two solid metal plates where the latter is placed 1cm away from the side edges

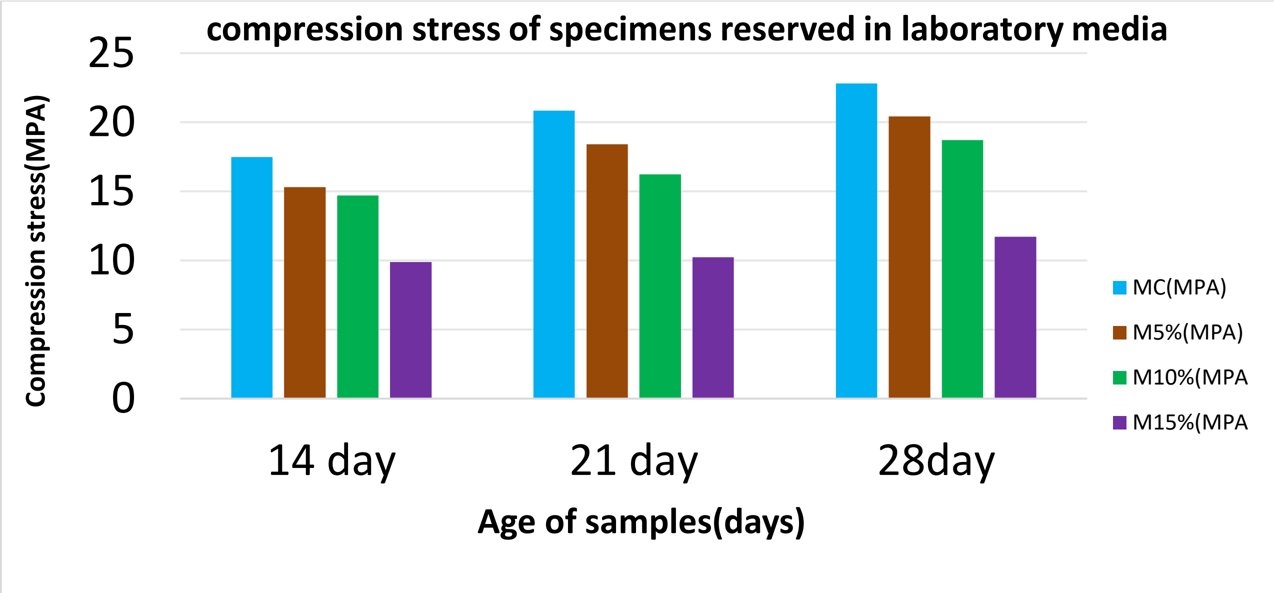
- This experiment is provided by the rule. [28]EN 196-1(P 15- 471)]

Shape III-9: Illustration of the pressure crushing mechanism

Figure III-6-: Pressure crushing machine illustrated

III-7-3-In 1aboratory media:

III-7-3-1-1 Results of the bending experiment:



Shape III-10: The results of the experiment of compression samples preserved in the laboratory medium

III-7-3-1-2 Analyze and discussion of compression stress results:

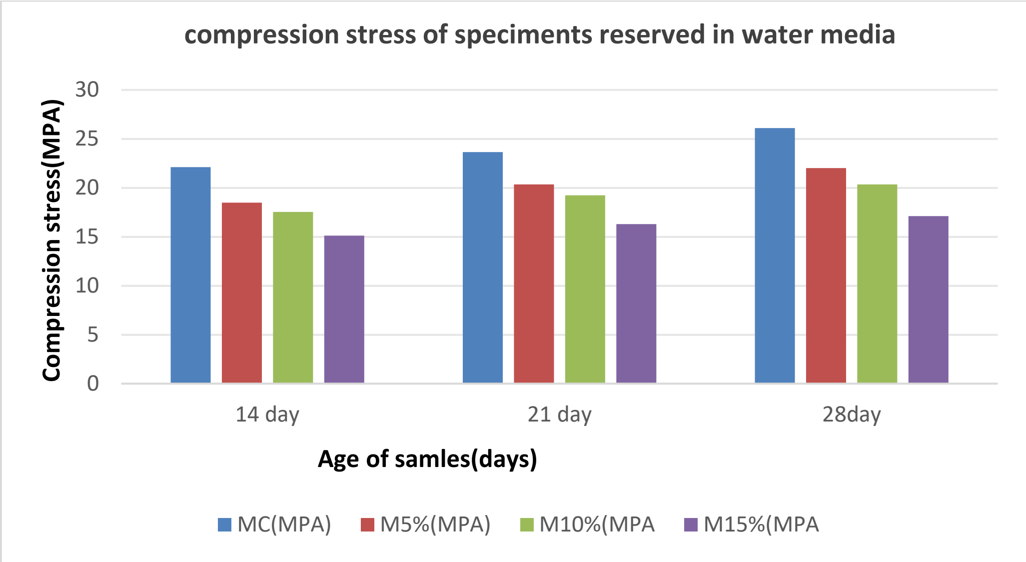
- The main objective of this work is to know the extent of the effect of pumice stone on the mortar in terms of compressive stress in the laboratory medium, and after obtaining the results and comparing them with each other on the one hand and comparing them with the witness mortar on the other hand, it was found that the following:

-Through the previous curve, we observe that the pressure resistance increases over the days for all compounds in the laboratory medium, and we explain this by an increase in chemical reactions over time.

-We note that the higher the percentage of pumice stone, the lower the pressure resistance, as the witness slurry gave the highest value, while the M15% compound had the weakest resistance, this is because the pumice stone absorbs a large amount of water that may reduce the percentage of water available for cement reaction, which negatively affects the compressive strength, as well as the greater the percentage of cement replacement with pumice stone, the weaker the internal structure, as a result, compression resistance decreases.

III-7-3-2-In water media:

III-7-3-2-1 Results of the bending experiment:



Shape III-11: The results of the experiment of compression samples preserved in the water medium

III-7-3-2-2 Analyzed and discussion of compression stress results:

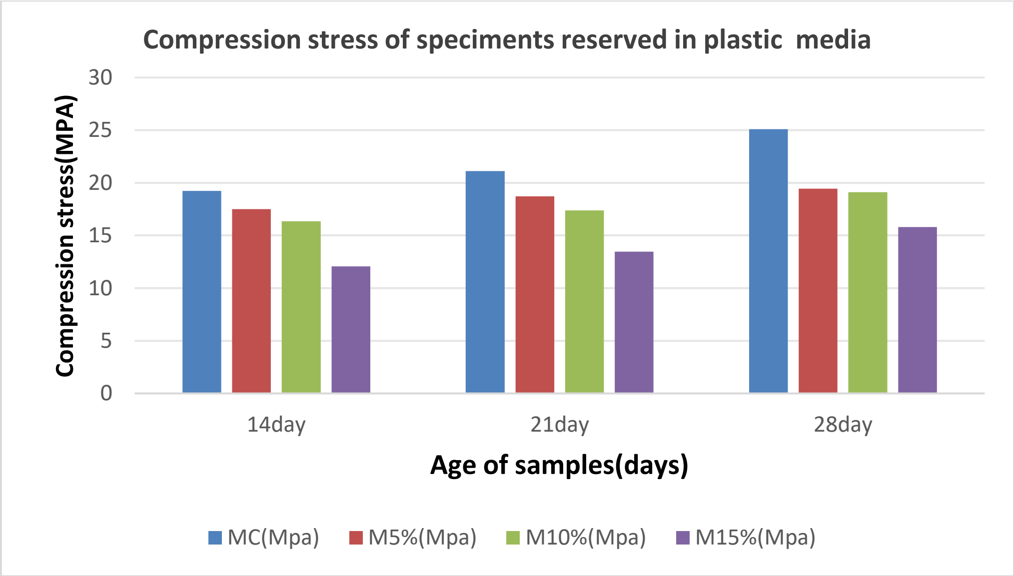
- The main objective of this work is to know the extent of the effect of pumice stone on the mortar in terms of pressure stress in the aqueous medium, and after obtaining the results and comparing them with each other on the one hand and comparing them with the witness mortar on the other hand, it was found the following:

- From the previous curve, we observe that the pressure resistance increases over the days for all compounds in the aqueous medium and we explain this by an increase in chemical reactions and rehydration reactions over time.

- We note that the higher the percentage of pumice stone, the lower the pressure resistance, as the witness mortar gave the highest value, while the M15% compound had the weakest resistance, and this can be explained by several reasons, including the high porosity of the pumice stone and thus the ability of the material to transfer loads between the grains, as well as the low cementing activity.

III-7-3-3-In plastic media:

III-7-3-3-1 Results of the compression experiment:



Shape III-12: The results of the experiment of compression samples preserved in the plastic medium

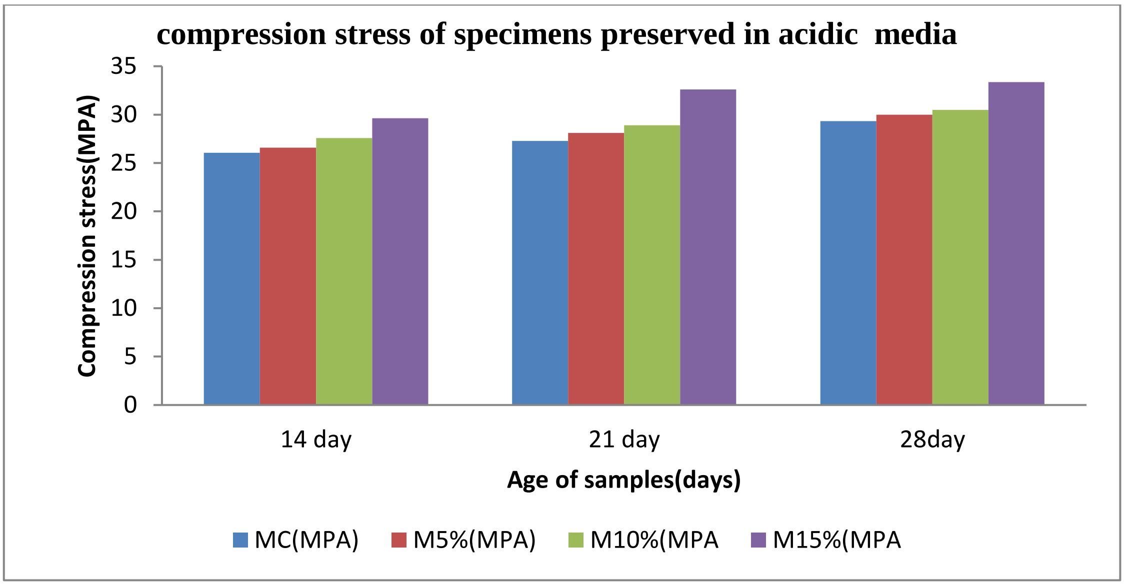
III-7-3-3-2 Analyzed and discussion of compression stress results:

-From the previous statement, we observe that the compressive strength increases with the passage of days for all compounds in the plastic medium as a result of increasing chemical reactions and thus increasing hardening.

- We note that the witness slurry is the one that gave the highest percentage compared to the other compounds and plastic media, as the higher the percentage of pumice stone, the lower the pressure resistance, as the compound M15% gave the largest value, while M10% and M5% had approximate values (M10% values are slightly different) This can be explained by several reasons, including that pumice stone does not help in rehydration reactions due to its large consumption of water.

III-7-3-4 In acidic media:

III-7-3-4-1 Results of the bending experiment:



Shape III-13: The experiment of compression samples preserved in the acidic medium

III-7-3-4-2 Analyze and discuss the results of stress experiment

- From the previous statement, we observe that the compressive strength increases with the passage of days for all composites and this is explained by the increasing occurrence of hardening over time.

-We observe in the acidic medium that the highest value of compressive strength was for compound M15% compared to the reference mortar, where we observe that the higher the percentage of pumice stone, the higher the compressive strength. This can be explained by the fact that pumice stone consists mainly of silica, a material that does not react with weak or medium acids, as well as the porous structure of pumice may help mitigate the effect of acids by distributing or absorbing part of them, which reduces the local concentration of acids that reach the cement paste, as well as the porous structure of the pumice may help in mitigating the effect of acids by distributing them or absorbing part of them.

III-7-3-5 General note:

Finally, it can be said that pumice stone negatively affects the pressure resistance so that the higher the percentage of pumice stone, the weaker the resistance, and this is in laboratory, water and plastic media, while in acidic media, the effect of pumice stone was positive so that the higher its percentage, the better the pressure resistance. This can be explained by the fact that pumice consists mainly of silica, a substance that reacts only with strong acids.

III-8 Conclusion:

From this study, we conclude that:

- The percentage of water on the cement plays a very important role, so it must be determined accurately because it affects the properties of the mortar.

- The composition of the pumice stone reinforced mortar and the mixing method are different from the witness mortar.

- The composition of the reference mortar, which was used as a witness, was by taking one volume of cement and three volumes of sand, while the water ratio was determined through an operational experiment with W/C=0.47

-The studied proportions of pumice stone powder are 5%, 10%, and 15%, where the mass of pumice is reduced from the mass of cement.

- The incorporation of pumice stone has a positive effect in improving the bending resistance of the mortar. However, it is limited to 10%, so if the percentage increases or decreases, it will reflect negatively on the mortar

- The addition of pumice stone leads to a decrease in the compressive strength of the mortar.

- Finally, we conclude that the compound that gave good results for bending resistance is M10%, which encourages the use of pumice stone in construction due to its low cost and environmental conservation.

- The compressive strength value of the reference mortar gave high results compared to the mortar reinforced with pumice stone except for the acidic medium

- The incorporation of pumice stone has a positive effect on the resistance to compression and bending in acidic media, so that the higher the proportions of pumice stone, the higher the resistance because it contains a large amount of silica, which is a material that does not react with mild acids.

General conclusions and recommendations

General Conclusions and recommendations:

1- Conclusion:

The use of pumice as a mortar improver is not a new concept, as it has been used since ancient times in many construction applications. However, it has recently regained interest due to its distinctive physical and chemical properties, such as light weight, thermal and acoustic insulation capacity, as well as its high porosity, which helps improve the mortar's compressive strength and insulation properties. Studies have shown that adding pumice to cement mixtures improves the mortar's resistance and increases its cohesion and ability to withstand environmental factors.

- With this in mind, some experiments were conducted to determine the quality and characteristics of the sand and its suitability for construction. The results suggest that it is good and produces mortar suitable for construction.

- The sand used in this study is ordinary construction sand taken from Djamaa of Almoghair area.

- The proportions of pumice used to reinforce the mortar were 5%, 10%, and 15%. These proportions were used to study the mechanical properties of pumice-reinforced mortar.

- Water is an essential component of the mixture, as an increase or decrease in the water content negatively affects the performance and workability of the mortar.

- By studying the bulk density of the pumice-reinforced mortar, it was observed that the latter reduces the weight.

- Through the results obtained in the mechanical tests (bending and compression) conducted on the mortar, it was observed that the process of mixing pumice powder with the mixture has a positive effect on the bending resistance of the mortar, while the compression resistance was negatively affected.

- The results of the mortar experiments showed that the optimal proportion of pumice is 10%, which gives good flexural strength, while compressive strength did not improve, but rather the opposite.

- Mortar reinforced with pumice stone is resistant in acidic environments and increases both compressive and flexural strength, with better results achieved as the amount of pumice stone is increased.

- In conclusion, we hope that this modest work will receive more attention, and we hope that research in this field will continue, following the recommendations below:

2- Recommendations:

- Conduct further studies with different types of mortar (use of local materials in mortar composition, such as sand from sand dunes)

- Conduct further experiments on durability to determine the resistance of mortar reinforced with pumice.

- Conduct experiments using additives to improve the properties of mortar.

- Conduct further experiments, such as acoustic scanning, to determine the degree of compaction.

- Conduct experiments to determine its usefulness in sound and heat insulation.

- Conduct more in-depth chemical studies to explain the chemical reactions.

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