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Utilization of waste glass as partial replacement of cement and sand in the production of concrete

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GENERAL INTRODUCTION

GENERAL INTRODUCTION

Concrete is one of the most widely used building materials in the world for construction because of its economical and technical advantages, and one of its most important constituents is cement which plays a role of a binder.

Although it represents only a small portion of the composition of concrete, cement production releases a large amount of CO2 emissions that has a negative impact on our habitat. In addition to deforestation and fossil fuel burning. Global warming is caused by the emission of green house gases, such as CO2, to the atmosphere and the global cement industry contributes about 7% of greenhouse gas emission [1].

In addition, Ordinary concrete typically contains about 80% aggregate content by mass. This means that concrete making requires the consumption of large quantities of sand and gravel at a high rate [2]. The importance of sand as a natural resource is due to the fact that is considered the second most consumed natural resource on Earth after fresh water. The United Nations Environment Program (UNEP) stipulates that Sand and gravel represent the largest volume of raw material used on earth after water but also sounded the alarm over the fact that “their use considerably exceeds their natural renewal rates [3]. In response to these problems, engineers and scientists around the world are proposing alternatives to these traditional building materials.

One of these alternatives is glass powder, which many studies have focused on using it as partial replacement of coarse or fine aggregates and cement in concrete. Recycling waste glass to be used in the field of construction has been of significant interest in last decade; it was found that as an aggregate is environmentally effective and has an economic advantage [4].

Waste glass is inert and not biodegradable which poses a major environmental problem, by reusing waste glass in the construction industry; this problem can be reduced or eliminated. The reuse of waste glass in construction can also reduce demand on primary raw material sources and natural resources like alluvial sand deposits. Using waste glass provides significant environmental and economic benefits. [5]

In this study consists of examining the possibility of using finely powdered Glass as a partial replacement of cement and using glass aggregates as a partial replacement of construction sand and to verify the efficiency and characteristics of this new type of concrete with varying percentages of glass powder compared to conventional concrete. Glass powder was partially replaced as 10%, 20%, and 30% in four different mixes and tested for its compressive, flexural strength and porosity up to 56 days of age and were compared with those of conventional concrete.

The work plan for this research is planned in the following order:

The first chapter is devoted to bibliographic research, about concrete and its components and their roles in concrete, the recycling of waste glass, its characteristics and its uses in the field of civil engineering

The second chapter presents the different experimental methods and test that was carried out for the characterization of the used materials, the mix design for the concrete specimens and evaluating and testing their physical and mechanical properties.

The third chapter presents the results obtained from the test and the characteristics of the materials, on the concrete samples, specifically the porosity, ultrasound, compressive strength and flexural strength. Followed by interpretation of the results and general discussion.

CHAPTER 1

Bibliographic Research

I.1.Introduction

Concrete is a very important element in the realization of constructions and it is considered the one of the most used building materials. The characteristics of concrete depend on its components. This chapter is intended to talk about and discuss the different ingredients of concrete, and give an overview of the recycling and recovery of waste glass and the purpose and benefits of the utilization of waste glass in construction (concrete production).

I.2. History and significance of the work

The utilization of waste glass as construction material has attracted a lot of interest due to the large quantity consumptions of resources and construction materials. Recently, many studies have focused on the uses of waste glasses as partial replacement of cement and natural aggregates in concrete **[5]**. Based on experimental testing concerning the compressive strength and flexural strength of concrete, found that The Compressive and Flexural Strength of Concrete increases when the replacement of Cement with Glass Powder was up to 20% **[6]**. Other research have found that even a 30% glass powder content could be incorporated as cement replacement in concrete without any long-term detrimental effects. concrete made with recycled glass aggregate have shown better long term strength and better thermal insulation due to its better thermal properties of the glass aggregates. When tested for the compressive strength values at the 10 %, 40%, and 60 % aggregate replacement by waste glass with 0 – 10mm particle size were 3%, 8% and 5% above the value of conventional concrete **[7]**. Moreover, Glass aggregates were shown to be a suitable alternative to fine sand for geopolymer concrete. Fine glass particles increase the alkalinity of the matrix, which helps with the higher extent of dissolution and reaction near the aggregates **[8]**.

I.3.Concrete

The most widely used building material in the construction industry is Concrete a composite manufactured material. It consists of a mixture of binding material, fine aggregate, coarse aggregate and water that is rationally chosen. This can be easily molded to desired shape and size before losing plasticity and becoming hard like stone due to chemical action between water and binding material. Concrete is strong in compression but very weak in tension. The Major ingredients of concrete are: binding material (cement), fine aggregate (sand), coarse aggregates (gravel) and water **[9]**.

It is also possible to add a small quantity of admixtures for waterproofing, workability to give the concrete mixture special properties. The strength of concrete varies depending on the ingredient ratio. By mixing design procedure, it is possible to determine the proportion of ingredients for a specific strength **[9]**.

I.3.1.Components of concrete

I.3.1.1.Cement

Cement is the material that binds. It hydrates and binds aggregates and surrounding surfaces such as stone and bricks after adding water. Richer mixing (with more cement) generally gives more strength. After 30 minutes, the setting time begins and ends after 6 hours. Therefore, concrete should be placed in its mold before 30 minutes of water mixing and should not be subjected to any external forces until the final setting occurs **[9]**.

A. Classification of industrial cements

Cements are classified by their composition into five main types according to NF P 15-301:

- CPA-CEM I: artificial Portland cement
- CPJ-CEM II: Composite Portland cement (CPJ)
- CHF-CEM III: blast furnace cement
- CPZ-CEM IV: pozzolanic cement
- CLC-CEM V: slag and ash cement (composite cement)

b. Portland Cement Production

The production of Portland cement starts with two basic ingredients: calcium oxide, which is a calcareous material. In addition, an argillaceous material that is a combination of silica and alumina from clay, shale, and blast furnace slag. These materials are crushed and then stored in silos as shown in the figure below. The raw materials are passed through a grinding mill in the desired proportions, using either a wet process or a dry process. Then they are melted at temperatures between 1400 ° C and 1650 ° C to transform the raw materials into cement clinkers. The clinker is cooled down and stored. The final process involves grinding the clinker into a fine powder. A small amount of gypsum is added during grinding to regulate the cement's setting time in the concrete. A standard cement sack in Algeria is 50 kg. The cement, provided it is kept dry, can be stored for a long period of time **[10]**.

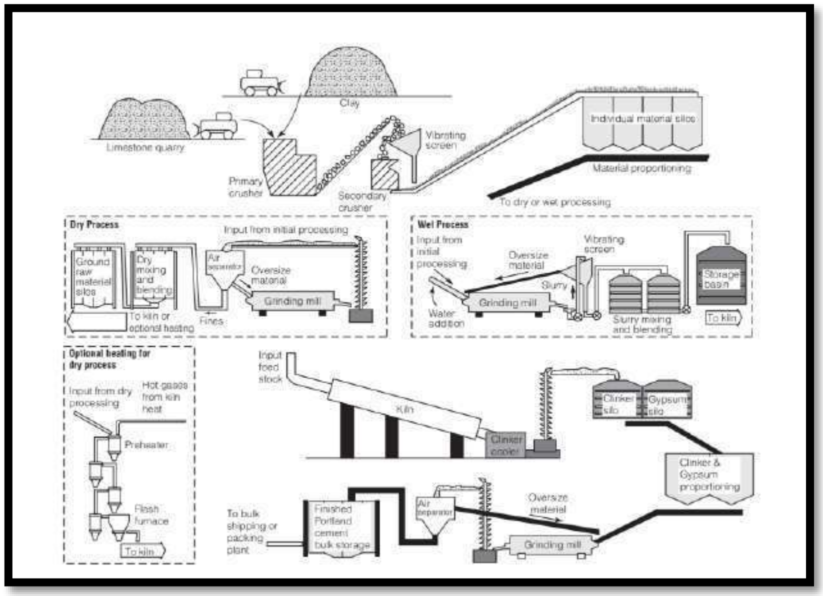

Figure I.1 Steps of the manufacturing of Portland cement **[10]**

c. Chemical composition

The three constituents of hydraulic cements are lime, silica and alumina. In addition, most cements contain small amounts of iron oxide, magnesia, sulfur trioxide and alkalis. **[10]** The approximate percentages for each chemical component are provided in Table I.1.

Table I.1 chemical composition of Portland cement [10]

Compound	Chemical Formula	Common Formula*	Usual Range by Weight (%)
Tricalcium Silicate	$3\ CaO \cdot SiO_2$	C_3S	45–60
Dicalcium Silicate	$2\ CaO \cdot SiO_2$	C_2S	15–30
Tricalcium Aluminate	$3\ CaO \cdot Al_2O_3$	C_3A	6–12
Tetracalcium Aluminoferrite	$4\ CaO \cdot Al_2O_3 \cdot Fe_2O_3$	C_4AF	6–8

*The cement industry commonly uses shorthand notation for chemical formulas: C = Calcium oxide, S = silicon dioxide, A = Aluminum oxide, and F = Iron oxide.

d. Hydration of cement

Cement hydration is the chemical reaction between cement and water. The reaction occurs between cement's active components (C4AF, C3A, C3S and C2S) and water. The hydration products start to deposit on the outer periphery of the hydrated cement nucleus when the cement comes into contact with water. This reaction lasts 2-5 hours slowly and is called an induction or dormant period. As the hydration proceeds, the deposition of hydration products on the original cement grain makes it increasingly difficult to diffuse water into an unhydrated nucleus, thus reducing the hydration rate over time. The crystals of the different resulting compounds gradually fill the space that was originally occupied by water, resulting in the mass stiffening and subsequent strength development **[8]**. The compounds and their products have the following reactions:

Table I.2 Primary chemical reactions during cement hydration **[10]**

$2(3\ CaO \cdot SiO_2)$ Tricalcium silicate	+	$6\ H_2O$ Water			=	$3\ CaO \cdot 2\ SiO_2 \cdot 3\ H_2O$ Calcium silicate hydrates	+	$3\ Ca(OH)_2$ Calcium hydroxide
$2(2\ CaO \cdot SiO_2)$ Dicalcium silicate	+	$4\ H_2O$ Water			=	$3\ CaO \cdot 2\ SiO_2 \cdot 3\ H_2O$ Calcium silicate hydrates	+	$Ca(OH)_2$ Calcium hydroxide
$3\ CaO \cdot Al_2O_3$ Tricalcium aluminate	+	$12\ H_2O$ Water	+	$Ca(OH)_2$ Calcium hydroxide	=	$3\ CaO \cdot Al_2O_3 \cdot Ca(OH)_2 \cdot 12\ H_2O$ Calcium aluminate hydrate		
$4\ CaO \cdot Al_2O_3 \cdot Fe_2O_3$ Tetracalcium aluminoferrite	+	$10\ H_2O$ Water	+	$2\ Ca(OH)_2$ Calcium Hydroxide	=	$6\ CaO \cdot Al_2O_3 \cdot Fe_2O_3 \cdot 12\ H_2O$ Calcium aluminoferrite hydrate		
$3\ CaO \cdot Al_2O_3$ Tricalcium aluminate	+	$10\ H_2O$ Water	+	$CaSO_4 \cdot 2\ H_2O$ Gypsum	=	$3\ CaO \cdot Al_2O_3 \cdot CaSO_4 \cdot 12\ H_2O$ Calcium monosulfoaluminate hydrate		

I.3.1.2.Aggregates

Aggregates are the materials that are used in the production of mortar and concrete as a filler with binding material. They come from igneous, sedimentary and metamorphic rocks. Aggregates form the concrete body, reduce the economy of shrinking and effect, occupy 70-80% of the volume and have a significant influence on the concrete's properties. Therefore, obtaining the right type and quality of aggregates is important. To ensure the quality of the concrete the aggregates should be clean, hard, strong, durable, and graded in size. There are two major types of aggregates, the larger ones are called coarse aggregate (gravel) and the smaller ones fine aggregate (sand). The coarse aggregate form the main matrix of concrete and the fine aggregate from the filler matrix between the coarse aggregate **[11]**.

a. Coarse aggregate

They consists of crushed stones. They should be well graded and the stones should be of igneous origin. They are supposed to be clean, sharp, angular and hard. They give the concrete mass and prevent cement shrinking **[9]**. Gravel generally comes from pits and deposits on the river, while crushed stones are the result of quarry rock processing. Usually, gravel deposits also need to be crushed to get the necessary size distribution, shape, and texture, so the size, shape, hardness, texture, and many other properties can vary greatly depending on the location. Even materials from the same quarry or pit and stone type may vary considerably. Gravel can be either smooth or rounded (like river gravel) or angular (like crushed stone). Several key features often used to describe coarse aggregate including specific gravity, bulk density, and absorption **[10]**.

Figure I.2 coarse aggregate (gravel)

b. Fine aggregate

Sand is a granular material consisting of finely divided rock particles and minerals, it is a natural product obtained from the alluvial sand from rivers. It enters the voids in coarse aggregates, and fills them, which gives the concrete its density. It subdivides the binding material allowing it to adhere and spread, it prevents cementing material from shrinking and the sand silica contributes to formation of silicates resulting into the hardened mass. Good sand should be chemically inert, free from organic or vegetable matter, salt-free and it should be well-graded **[9]**.

Figure I.3 fine aggregate (sand)

I.3.1.3.Water

Water triggers cement hydration and forms a plastic mass, then it becomes a hard mass as it sets completely. It gives concrete workability, which allows the concrete to be easily mixed and placed in the final position. However, excess water reduces the strength of concrete **[9]**.

The purpose of adding water to cement is to cause cement hydration. Water above the hydration requirement acts as a lubricant between coarse and fine aggregates and produces a workable and cost-effective concrete. For concrete mixing, any natural drinking water that has no pronounced taste or odor is acceptable. It is also possible to use some water sources that are unsuitable for drinking. Excessive impurities can affect setting time, strength, durability, and can cause steel efflorescence, decoloration of the surface, and corrosion **[11]**.

I.3.2. Environmental impact

Portland cement production is responsible for large emissions of carbon dioxide (CO2), the most important greenhouse gas. It is the product of an energy-intensive industry and is one of the main ingredients of concrete. Based on data from the World Resources Institute, it was reported that 3.8% of energy used and 5% of carbon dioxide emissions produced worldwide are due to Portland cement production. Each tonne of cement requires approximately 1.5 t of raw materials and 1700 kWh in terms of energy. Carbon dioxide emissions are roughly 800–1000 kg/t, with global cement production reckoned to have reached 3 300 000 tonnes per year **[12]**.

Achieving sustainable development through the consumption of industrial by-products and waste materials has become an important strategy since recycling is an environmentally friendly method to prevent air, water and land pollution **[12]**.

I.4.WASTE GLASS

Glass is a transparent material formed by melting at high temperatures a mixture of materials such as silica, soda ash and CaCO3 followed by cooling, during which solidification occurs without crystallization. It exhibits properties of an aggregate material when waste glass is crushed to sand-like particle sizes, similar to that of natural sand **[4]**.

Many forms of glass are produced and the use of glass products has greatly increased, resulting in large quantities of waste glass. The volume of annual solid waste disposed of by the United Nations is estimated at 200 million tons, 7% of which is made up of glass worldwide **[4]**.

Figure I.4 waste glass

I.4.1. Properties of Waste Glass

I.4.1.1. Physical Properties

Crushed glass particles are generally angular in shape and may contain some elongated and flat particles. Glass generally has a specific gravity of approximately 2.5. Crushed glass exhibits coefficients of permeability ranging from 10−1 to 10−2 cm/sec, is a highly permeable material, similar to coarse sand. The coefficient of permeability depends on the gradation of the glass **[4]**.

I.4.1.2. Chemical Composition

Glass-formers are those elements that can be converted into glass when combined with oxygen. Silicon dioxide (SiO2), used in the form of sand, is the most common glass-former. Common glass contains about 70% SiO2. Soda ash (anhydrous sodium carbonate, Na2CO3) acts as a fluxing agent in the melt. It lowers the melting point and the viscosity of the formed glass, releases carbon dioxide, and helps stir the melt **[4]**.

Table I.3 Chemical Composition of glass **[4]**

Sr No.	Particulars	Proportion
1.	Silicon Dioxide (SiO_2)	66.56 %
2.	Aluminum oxide (Al_2O_3)	01.02 %
3.	Potassium Oxide (K_2O)	01.06%
4.	Calcium Oxide (CaO)	11.50 %
5.	Magnesium Oxide (MgO)	03.02 %
6.	Sodium Oxide (Na_2O)	12.32 %
7.	Boron Trioxide (B_2O_3)	02.45 %

I.4.1.3. Thermal conductivity

Compared to natural aggregates mix, crushed glass can be expected to exhibit higher heat retention than natural aggregate materials. The low thermal conductivity of glass can help to reduce frost penetration depth **[4]**.

I.4.2 Management Options

I.4.2.1. Disposal

Most of the waste glass is dumped into landfill sites. However, glass is not biodegradable; landfills do not provide an environmentally friendly solution. There have been extensive efforts over the past decade to recover post-consumer glass. In general, attempts were made to recover and recycle glass by collecting waste glass at recycling centers **[4]**.

I.4.2.2. Recycling

Glass recycling involves the collection and sorting of colored glass to be used in the production of new glass products. Due to environmental concerns, recycling waste glass is a major problem worldwide. The recycling of glass from solid waste for use as raw material in new glass products is limited due to high collection and processing costs and specifications limiting impurities in the process of glass production **[5]**. In addition, high percentages of glass breakage (30–60 %) limit the amount of glass that can actually be recovered using hand-sorting practices during collection and handling of glass, therefore recycling rates were relatively low in view of these limitations [4].

Recycling waste glass to be used in the field of construction has been of significant interest in last decade; it was found that as an aggregate is environmentally effective and has an economic advantage **[4]**.

I.4.3. Waste glass as construction material

Because of large quantities of consumption and widespread construction sites, the use of waste glass in construction has attracted a lot of interest worldwide. Many studies have recently focused on the use of waste glasses as a partial replacement of natural concrete aggregates. Using waste glasses as concrete aggregates did not significantly affect workability and strength, but reduced concrete slump, air content, and fresh weight **[5]**.

Waste glass can be recycled into various materials in concrete production. Waste glass of 10 mm particle size is normally used as a natural aggregate replacement, while waste glass of 5 mm particle size is used in mortar as a replacement for sand. Lastly, the small particle size is ground to produce glass powder with natural strength, minimal water absorption, and the ability to meet excessive temperature without deterioration. Ground glass powder of 75-150μm particle size can be used in concrete as a pozzolan for cement replacement. Recycled waste glass can also be used as decorative because of its esthetic properties and the esthetic value **[13]**.

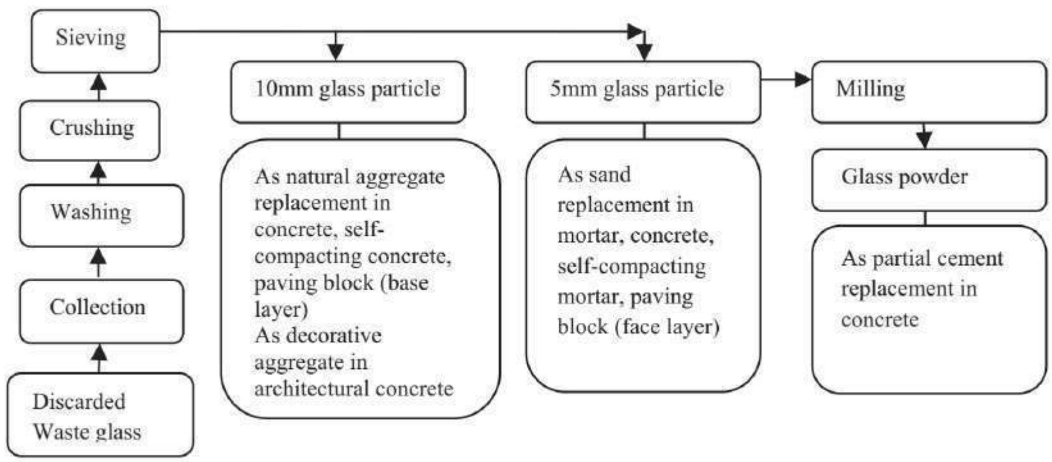

Figure I.5 Steps of converting waste glass to valuable materials **[13]**

I.4.3.1 Pozzolanic Activity of Glass Powder

A pozzolan is a siliceous and aluminous material, which in itself has little or no cementing properties, but which will chemically react with calcium hydroxide at ordinary temperatures in a finely divided form-and in the time, but its ultimate strength is about the same as that of ordinary Portland cement. The pozzolan percentage should be between 15 to 50 of cement weight **[13]**.

The pozzolanic reaction of waste glass consumes Ca(OH)2 cement hydrates and fills the previously formed pore structure with Calcium Silicate Hydrate (CS-H), thus producing a more compact pore structure and an increased strength of concrete **[13]**.

Glass was found develops its pozzolanic activity more quickly compared to other pozzolans including fly ash, which react only after one to several weeks. In fact, studies have shown that in 3 days of cure the resistance of mortars containing 20% of glass in replacement of cement is 70%

greater than that of mortars made with fly ash. It was also found that for optimum resistances, it is more interesting to substitute sand than cement with glass **[14]**. The pozzolanic activity depends on several factors such as the size of the grains of glass (the finer grains are better), glass content and color (brown glass has the weakest pozzolanic activity behind the green glass and then the white glass) **[14]**.

I.4.3.2 Alkali-Silica Reaction

Alkali-silica reaction (ASR) is a chemical reaction that occurs in concrete of the alkalis with the hydrous forms of the silica present in the mineral constituents. It happens during cement hardening where SiO2 reacts with Na2O and K2O, which produces hydro silicate crystals of alkali metals on the surface of reactive aggregates. The final by-product of this reaction is a viscous substance that leaks from cracks in concrete and can cause serious problems due to the expansion and cracking in concrete **[4]**.

Studies on the effects of using waste glass powder with multiple particle sizes as partial replacement of cement and up to 30% by volume, reported that the expansions were within the permissible limits. The expansion experiments showed that not only was the ground glass not expansive but it actually helped to stop the development of the alkali silica reaction compared to control sample **[4]**.

I.5 Conclusion

In this chapter, we have discussed the constituents of concrete used in this research and their role in concrete. We have also discussed the effects of production on the environment and indicated the recycling of waste glass and its reuse in the composition of concrete and their benefits economically and environmentally.

CHAPTER II

Materials and methods

II.1. Introduction

In this chapter, we will present the various tests and procedures required for the characterization of the materials used in making the concrete samples.

II.2.Work chronology

The different steps followed from the beginning of this work to test the materials and make the concrete samples are shown in the figure bellow:

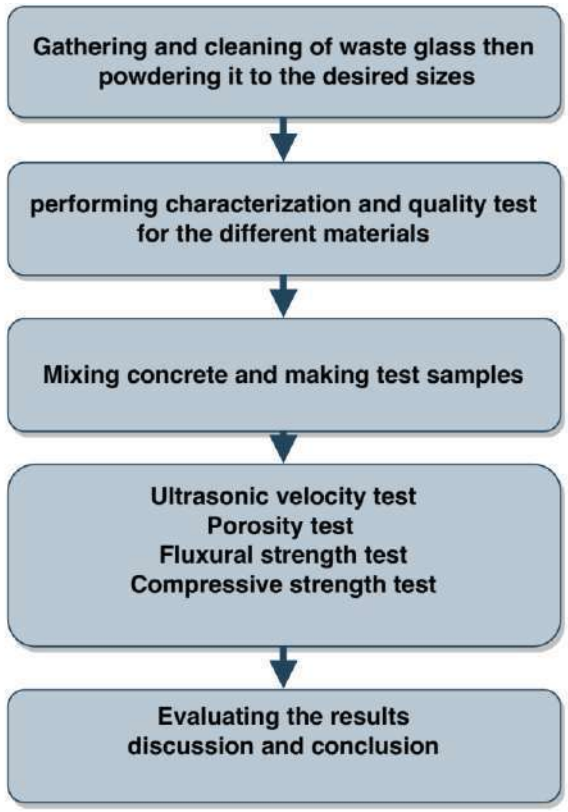

Figure II.1: Chronology of Work

II.3. Characteristics of used materials

II.3.1. Sand Characteristics

Two types of sand were use in this work:

a. construction sand: it was withdrawn from the MAAMRI quarry located in the road of Touggourt, it is an alluvial sand of granular class of (0/5).

b. dune sand: the sample used was withdrawn from the dunes of SIDI KHOUILED (Ouargla).

II.3.1.1. Particle size analysis "NFP18-554"

Sieve analysis is a set of operations resulting in the separation of the sample elements by size using sieves to determine the grain size, the proportions of grains of the same size and deduce the fineness module (Mf) of sand.

• Procedure

The test consists in classifying the various grains constituting the sample by using a series of sieves, nested one on the other, whose opening dimensions are decreasing from top to bottom. The studied material is placed in the upper part of the sieves and the rankings of the grains are obtained by vibration of the sieve column, and to weigh the refusal on each sieve. The Granulometric Curve is then plotted, a curve expressing the cumulative percentages by weight of grains passing through the successive screens.

Sieves whose square openings, of standardized size, are made from a metal mesh. For a test job with reproducible results, it is advisable to use an electric sieving machine that compresses a horizontal vibratory movement, as well as vertical shaking, to the sieve column. The nominal sieve size follows in a geometric progression of reason.

Figure II.2: particle size analysis sieves for sand.

II.3.1.2. finesse module "NF P18 -304"

It is a module that allows us to characterize the fineness of the different types of sand by the sum of the cumulative rejection percentages for the following series sieves (0.16, 0.315, 0.63, 1.25, 2.5, 5 mm).

The sands must have such a granulometry that the fine elements are neither in excess nor in too small a proportion. If there are too many fine grains, it will be necessary to increase the water dosage of the concrete whereas if the sand is too big, the plasticity of the mixture will be insufficient and will make the installation difficult. The more or less fine character of a sand can be quantified by the calculation of the fineness module (Mf).

$$Mf = \frac{\sum RC}{100}$$

RC: cumulated refusal in (%) under the sieves of module 5 to 0,16.

When Mf is between:

- 1.8 and 2.2: sand is predominantly fine grain
- 2.2 and 2.8: we are in the presence of a preferential sand
- 2.8 and 3.3: the sand is a bit coarse, I will give resistant, but less manageable.

II.3.1.3. Sand equivalent test "NF P 18 -598"

this test to aims to test the proportions of fine and clay materials in fine aggregate and cleanliness of a sand, and gives an overall account of the quantity and quality of the fine elements.

This test is commonly used to evaluate the cleanliness of sands used in the composition of concrete. The test consists in separating the fine particles contained in the balances coarser sand elements, a standardized procedure makes it possible to determine a coefficient of sand equivalent which quantifies the cleanliness of this one.

• Procedure

The test is carried out on the 0/5 mm fraction of the material to be studied. The sample is washed according to a standardized process and the whole thing is left to rest. After 20 minutes, the following elements were measured:

- Height h1: clean sand + fine elements,
- Height h2: clean sand only.

We deduce the equivalent of sand, which, by convention, is:

$$ES = \frac{h1}{h2} \times 100$$

II.3.1.4. volumetric mass "NF P18-554"

a. Absolut volumetric mass

It is defined as the mass per unit volume of the material that constitutes the aggregate, without taking into account the voids that may exist between the grains.

$$\rho s = \frac{Ms}{V2 - V1}$$

* ρs : Absolute density kg / m3
* Ms : Mass of solid grains
* V1: Volume of water
* V2: Total volume (grains + empty).

b. Apparent volumetric mass

It is defined as the mass of the unit of apparent volume of the body, that is to say that of the volume constituted by the material of the body and the voids that it contains.

$$\rho a = \frac{M}{V}$$

* ρa: Apparent density kg / m3
* M: Total mass of the sample
* V: Total volume of the sample

II.3.2. Gravel Characteristics

It occupies most of the volume of the concrete it is an important Constituent, Two sizes of aggregate were used in this research work. The first is from 3 to 8 mm particle size, and the second is from 8 to 15mm particle size.

The gravel used was acquired from SMCO quarry in hassi messoud.

II.3.2.1. Particle size analysis "NFP18-560"

Granulometric analysis of gravel makes it possible to classify a granulate in the different granular classes. It is achieved by automatically sieving a sample in a series of sieves and determining the percentage of loops and refusal on each sieve.

II.3.2.2. Volumetric mass "NFP18-554"

a. Absolute volumetric mass

It is the mass per unit of the volume of the material that constitutes the granulate, without taking into account the voids that can take place in or between the grains. It is determined by the following formula:

$$\delta s = \frac{M}{Vs}$$

* δs: The absolute density (t / m3, g / cm3 ...).
* M: The mass of the sample. (G).
* Vs: The absolute volume of the sample. (Cm3).

b. Apparent volumetric mass

It is the mass of the aggregate occupying the unit of volume including all voids. It is determined by the following relation:

$$\delta a = \frac{M}{Va}$$

* δa: apparent density (g / cm3).
* M: mass of the sample (g).
* Va: apparent volume of the sample (cm3).

II.3.2.3. Gravel cleanliness "NFP18-591"

This test consists of weighing a well-dehydrated sample, then washing it with water until it is perfectly clean, and then drying it and weighing again.

The following relation gives the percentage of impurities:

$$P = \frac{P1 - P2}{P2} \times 100$$

- P1: masses of dry gravel before washing.
- P2: masses of dry gravel after washing.

II.3.2.4. Absorption coefficient "NFP18-555"

The absorption coefficient is defined as the ratio of increase of the mass of a sample impregnated by water, to the dry mass of this sample. The absorption coefficient is obtained by:

$$Ab = \frac{Ma - Ms}{Ms} \times 100$$

- MS: mass of the dry sample after passing to the oven at 105 ° C.
- Ma: mass of the soaked sample.

II.3.2.5 Los Angeles abrasion test "NF P18-573"

The LOS ANGELES test measures the resistance of aggregates to fragmentation and test theirs hardness by subjecting them to a shock and abrasion test in a rotating steel drum containing steel spheres.

• Procedure

The test consists of measuring the amount of elements less than 1.6 mm produced by subjecting the material to standard ball impact and reciprocal friction in the Los Angeles machine. The granularity of the material under test is selected from six standard granularities, of the granular class 4 / 6.3 mm -6.3 / 10 mm.

The test material must have a granularity conforming to one of the six typical granular classes, washed and dried in an oven at 105 ° C until constant weight. The test sample will be 5 kg.

Start of the test by having the machine perform 500 rotations at a steady speed of between 30 and 35 rpm for all classes except the 25-50 mm class where the number of rotations is 1000. Collect the granulate in a tray placed under the machine, without the loss of aggregate.

Sieve the material in the tray on the 1.6 mm sieve then wash the den at 1.6 mm in a tray, stir well with a trowel. Then pour into the perforated tray, drain and dry in an oven until constant weight.

If p is the material under test, p' the weight of the elements less than 1.6 mm produced during the test, the combined resistance to shock fragmentation and to mutual abrasive wear is expressed by the amount :

$$\text{CLA} = \frac{P - P'}{P} \times 100$$

P: the initial weight of gravel.

P ': the final weight of gravel.

II.3.2.6 Flakiness coefficient "NF P18-561"

The particle shape of aggregates is determined by the percentages of flat and elongated particles contained in it. For aggregates intended to be used in concrete, a high percentage of elongated particles is undesirable because it trigger intrinsic weakness in the concrete.

• Procedure

The determination of the granular classes is carried out on the square mesh sieves used for the particle size analysis defined by the P 18-560 standard. We use sieves with mesh opening dimensions of: 50} 40} 31.5} 25} 20} 16} 14} 12,5} 10} 8} 6,3} 5 and 4 mm.

For the determination of the flattening coefficient of each granular class, a series of grids is used, consisting of parallel cylindrical bars fixed in a square frame. The internal spacings of the bars are respectively: 31.5} 25} 20} 16} 12.5} 10} 8} 6.3} 5} 4} 3.15 and 2.5 mm.

The test consists of double sieving the aggregates on square mesh sieves, to classify the sample studied in different classes d / D (with D = 1.25 d), according to their size G, Then sieving the different granular classes d / D, on grids with parallel spacing slits:

The coefficient of flattening of each granular class d / D corresponds to the sieve pass on the grid with spacing slots d / 1.58, expressed in percentage.

The overall flattening coefficient of the sample is equal to the weighted sum of the coefficients of flattening of the different granular classes d / D composing the sample

The flattening coefficient of each granular class is given by: $\frac{Me}{Mg} \times 100$

The global flattening coefficient is given by: $A = \frac{Me}{M} \times 100$

Figure II.3: Grid Sieves for gravel

II.3.3. Characteristics of the cement

Ordinary Portland cement (CPJ-CEM II/B 42.5N) conforming to NA 442 manufactured by Lafarge.

Figure II.4: Portland cement

II.3.3.1. setting time t "EN 196-3"

When cement is mixed with water, it hydrates and makes cement paste. The time to which cement can be molded in any desired shape without losing it strength is called Initial setting time.

The tests are done using the Vicat needle, which gives two practical references, the beginning and the end of setting.

• Procedure

Take 500g of cement, place it in a tray, and add water. Once a paste with a normal consistency is obtained, we fill the mix in Vicat mold then Release the Plunger and allow it to sink into the mold. Repeat the operation at suitably spaced intervals (~ 10-15min) until d = 4mm ± 1mm.

The time period elapsed between the moment water is added to the cement and the time, the needle fails to penetrate the mold of 5mm, is the initial setting time of cement.

II.3.4. Water

II.3.4.1. Chemical analysis "NF P 18-305"

The water used in the mix of concrete must be pure, clean, free of salts and organic matter, in this experiment we used normal drinkable "tap water" provided at the university. Water used for concrete production should be clean and has no pronounced taste or odor is acceptable.

II.3.5. Glass powder

The glass powder that we used extracted grinding after crushing glass waste, to obtain glass powder in posse a set of steps as following:

1. Collecting and cleaning the glass to remove all impurities that can change glass properties.

2. Crush the glass into small pieces and put them in the ball mill.

3. Leave the crushed glass in the ball mill for 15 minutes.

4. Sieve the glass for the desired particle size.

4. Sieve the glass for the desired particle size.

II.4. designing Concrete Mix

The study of the composition of a concrete mix consists in defining the optimum mixture of the aggregates as well as the proportions in cement and water, and this with the intention of accomplishing the desired concrete qualities. Generally, the qualities sought from a composition are Strength and Workability at the time of the implementation **[15]**.

II.4.1. DREUX-GORISSE method

There are several methods for designing a Concrete Mix that have been elaborated by ABRAMS, BOLOMEY, CAQUOT, and FAURY. However, in this study, we chose to work with the DREUX-GORISSE method since it is a very practical and simplified method **[15]**.

II.4.1.1 Basic data.

- **a. Nature of structure:** The knowledge of structure nature is necessary. It would be necessary to know if structure is massive or high, if it is thin or thick, or if it is heavily reinforced or not. The position of the reinforcement must be known as well.
- **b. Required strength:** In general, it is the sought compressive strength at 28 days.
  - **c. Required workability:** It is the required plasticity measured using Abrams cone test, and depends on the type of the structure **[15]**.

II.4.1.2. Aggregates maximum dimension

The determination of the aggregates maximum dimension D (Dmax) depends on the characteristics of the structure part to be concreted and the environment aggressiveness **[15]**.

II.4.1.3. Cement content

The cement content differs from the aggregates content. The cement/water ratio (C/W) is approximately evaluated using the overage strength at 28 days and the required plasticity **[15]**.

II.4.1.4. Water content

The choice of the cement content C and the C/W ratio values lead to water content, which will be adjusted subsequently through plasticity and workability tests **[15]**.

II.4.1.5. Aggregates quality

Gravels must be of good mineralogical quality, hard and very clean. Sand must also be clean, its required fineness modulus value must range from 2.2 to 2.8 and its corresponding granulometric curve must be compared with the optimum distribution **[15]**.

II.4.2. Concrete mix composition

The proportions of aggregates are determined from the reference curve. This curve is drawn through the granulometric curves of the aggregates. The mixes that will be used in this study are the following figure:

Figure II.5: compositions of the concrete mixtures

II.5. concrete characteristics

II.5.1. Concrete slump test "NF EN12350-2"

The workability of the concrete was assessed using Abrams cone test, the concrete slump test measures the consistency of fresh concrete prior to specimen fabrication.

The cone is placed on a hard non-absorbent surface then filled in three layers, each time; each layer is tamped 25 times by a rod of Ø16 mm. The mold is slowly lifted vertically and the measurement of the slump of the concrete is measured by measuring the distance from the top of the slumped concrete to the level of the slump cone.

II.5.2. Making and curing of test pieces "NF EN12390 -1"

In this experiment, we used the prismatic molds (7 x 7 x 28) cm3 for the manufacture of test specimens. For all tests carried out in this study, we have prepared about 150 specimens for the physical and mechanical characterization of concrete with different percentages of glass powder content.

The fresh concrete mixing was carried out according to a weighting of aggregates and in accordance with the French standard NF P18 - 404, which consists of:

- Introduce, in the first place, in a concrete mixer, the constituents in the following order: coarse aggregates, fine aggregates, glass powder, and cement.
- Dry mix the elements of the order of 1 min.
- Add the mixing water and continue mixing.

Figure II.6: concrete samples

II.5.3. Flexural strength test "NF P 18 - 407"

Flexural test evaluates the tensile strength of concrete. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending, the results of flexural test on concrete expressed in MPa.

The flexural test on concrete is conducted using either three-point load or four-point load test.

• Procedure

- Clean the surface of the sample.
- Place the specimen on the loading points. The hand-finished surface of the sample should not be in contact with loading points.
- Center the loading system in relation to the applied force.
- Load the specimen continuously without shock till the point of failure at a constant rate

The tensile strength is calculated with the following equation:

$$Rf = \frac{1.5 \times Ff \times l}{b^3}$$

Figure II.7: Flexural strength machine

II.5.4. Compressive strength test "NF EN 12390 – 3"

The compressive strength of any material is described as the resistance to failure under a compressive force, the Compressive strength is measured by breaking a sample of known sizes of cylindrical or cubical shape in a compression testing machine usually after 28 days of curing. The compressive strength is calculated from the failure load divided by the cross-sectional area resisting the load and recorded in MPa.

• Procedure

- Clean the surface of the sample.
- Clean the surface of the testing machine
- Place the sample in the machine.
- Align it centrally on the base plate of the machine.
- Apply the load gradually without shock and continuously until the sample fails.
- Record the maximum load.

The Concrete strength is calculated by the following formula: $Rc = \frac{F}{Ac}$

With:

- F: the maximum load (in Newton).
- Ac: the area of the charged section (in mm)

Figure II.8: compression-testing machine

II.5.5. Ultrasound velocity test "EN 12504-4"

Ultrasonic testing of concrete is a non-destructive test to assess the homogeneity and integrity of concrete. Ultrasonic pulse velocity test consists of measuring the ultrasonic wave propagation time T in a concrete sample, produced by an electro-acoustical transducer, held in contact with one surface of the concrete member under test and receiving the same by a similar transducer in contact with the surface at the other end.

Higher the elastic modulus, density and integrity of the concrete, higher is the pulse velocity. It can also provide an indication of the Homogeneity and Compressive strength of the concrete. The propagation velocity is calculated by the following formula:

$$V=D/T$$

With:

- D: the distance between the two probes in meters,
- T: Wave propagation time in seconds.
- V: Wave propagation velocities, expressed in meters per second.

Figure II.9: ultrasound test

II.5.6. Porosity "NF P 18-459"

Concrete is a porous material, it has pores or voids. These pores are critical to the strength and durability of concrete. The porosity test is carried on samples after 28 days. The determination of the porosity is done as follows:

- Place the sample for 24 hours in an oven and weighs its dry mass Ms.
- Place the sample in water for 48 hours and then weighs its hydrostatic mass Ma
- The mass of the sample is weighed in the water Me

The porosity is obtained by the following formula: $\eta = \frac{Ma - Ms}{Ma - Me}$

Figure II.10: porosity test

II.6. Conclusion

In this experimental research several preliminary test were done on the different materials (dune sand, construction sand, gravel, cement, glass powder and mixing water) that was used to characterize them and ensure theirs quality and also to be able to determine the best concrete mix that we use in making the test samples. These different samples will be used to test theirs physical and mechanical properties (ultrasonic, compressive strength and resistance to tensile bending).

CHAPTER III

Results and Discussion

III.1. Introduction

This chapter discusses the results of the different tests that was carried on the used materials, and on concrete samples to determine the compressive strength, tensile strength, porosity and ultrasound tests. The purpose of these tests is to verify if the substitution of cement and sand by glass powder with variable proportions is suitable to be applied in the manufacturing of concrete.

III.2. Analysis results of used materials

III.2.1. sand

III.2.1.1. particle size analysis

The curve in Figure III.1 for construction sand shows that we have normal sand with good granularity appropriate for concrete production.

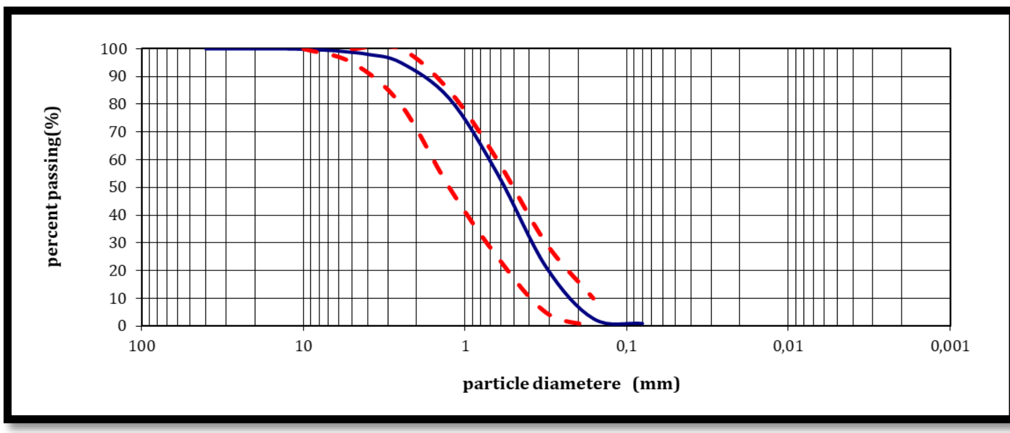

Figure III.1: construction sand's granulometric curve

The second curve in Figure III.2 for dune sand corresponds to a sand with a majority of fine grains.

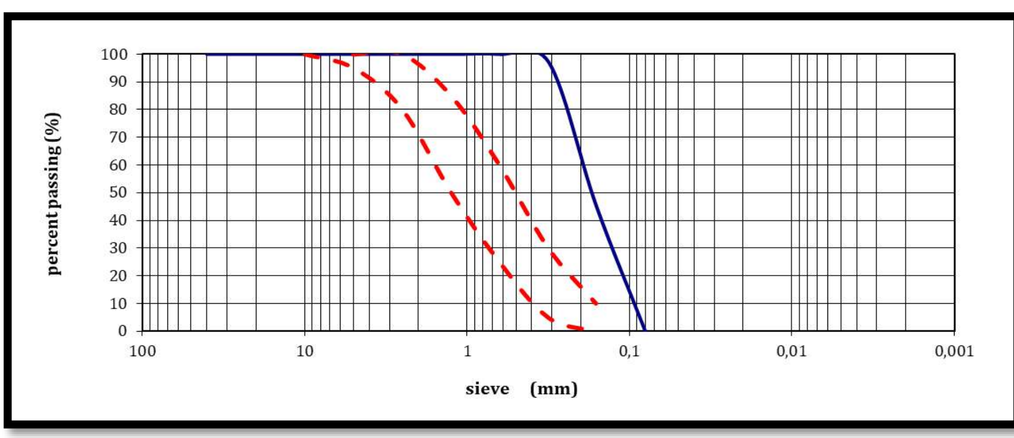

Figure III.2: Dune sand's granulometric curve

III.2.1.2. finesse module

According to NF P18 540 standard, sand with finesse module value between 1,8 and 3,2 is acceptable to be used in concrete. The values for the sands are in the following Table:

Table III.1: finesse module test results

construction sand	**2.46**
dune sand	**1.29**

III.2.1.3. Sand equivalent

According to NF P18 598 standard, a sand with a value of SE> 80 is a Very clean sand and acceptable to be used in the production of concrete. The results obtained are in the following table:

Table III.2: Sand equivalent test results.

construction sand	**88%**
dune sand	**77%**

III.2.1.4. volumetric mass

Tableau III.3: Volumetric mass test results.

Absolut volumetric mass	**2.61**
Apparent volumetric mass	**1.62**

III.2.2. Gravel

III.2.2.1. Granulometric analysis

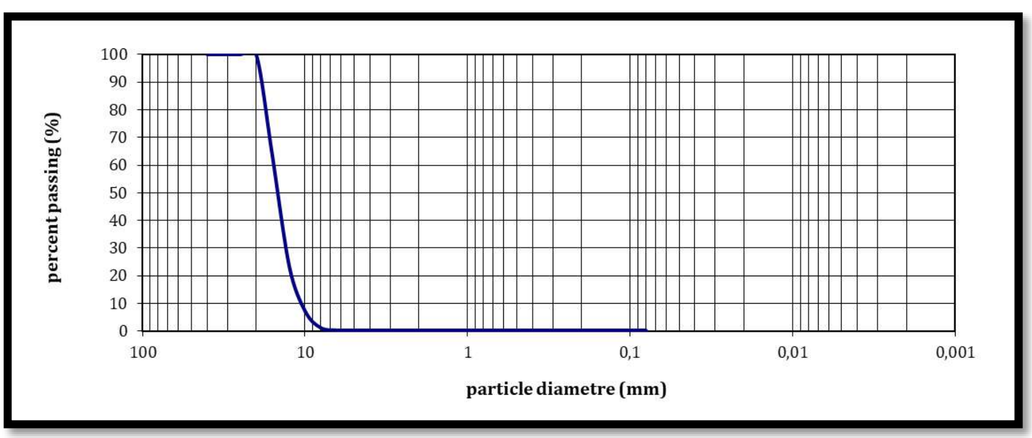

Figure III.3: gravel (8/15) granulometric curve.

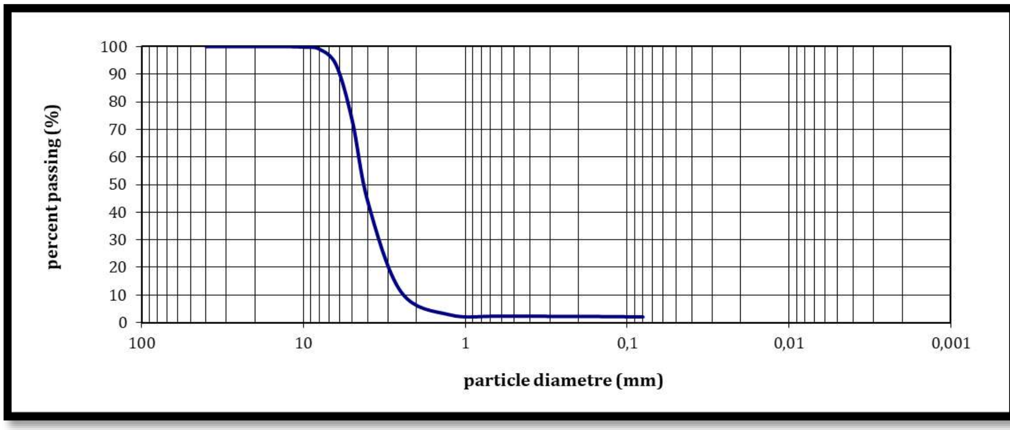

Figure III.4: gravel (3/8) granulometric curve.

II.3.2.2. Volumetric mass

Table III.4: Volumetric mass test results.

Gravel	Absolut volumetric mass	Apparent volumetric mass
(3/8)	2.60	1.62
(8/15)	2.61	1.31

III.2.2.3. Gravel cleanliness

According to NF P18 540 standard, the gravel is clean and admissible for the production quality concrete. The values for the sands used in this study are in the following Table:

Table III.5: Gravel cleanliness test results.

Gravel	Cleanliness	OBS
(3/8)	2.60	< 5%
(8/15)	3.85	

III.2.2.4. Absorption coefficient

According to NF P18 540, the Absorption coefficient of gravel used in production of hydraulic concrete must have a value equal or inferior to <5.

Table III.6: Absorption coefficient test results.

Gravel	Absorption
(3/8)	2.85
(8/15)	1.68

III.2.2.5. Los Angeles abrasion test

The abrasion coefficient for both types of gravel is under 30, which makes them acceptable in concrete production.

Table III.7: abrasion test results.

Gravel	LA coefficient	OBS
(3/8)	27.60	< 30
(8/15)	23.82	

III.2.2.6. Flakiness coefficient

According to NF P18 540 standard, a gravel Flakiness coefficient = 17,77 <30, acceptable for use in concrete.

Table III.8: Flakiness coefficient test results.

granular class d/D (mm)	Mg (g)	Grids spacing (mm)	passing Me (g)	Me / Mg x 100
20 - 25	0	12,5	0,00	0,00
16 - 20	0	10	0,00	0,00
12,5 - 16	0	8	0,00	0,00
10 - 12,5	2,9	6,3	0,00	0,00
8 - 10	10,6	5	4,60	43,40
6,3 - 8	85,2	4	22,70	26,64
5 - 6,3	306	3,15	90,90	29,71
4 - 5	443,4	2,5	149,20	33,65
M = ∑ Mg =	848,10	∑ Me =	267,40	
A = ∑ Me / M x 100 =		17,77		

III.2.3. Cement

According to NF EN 197-1 standard the setting time for Ordinary Portland cement 42.5N must be ≥ 60 min, the following table shows the analysis results of cement:

Tableau III.9: setting time test results.

Setting	time
start of setting (h)	2:33
end of setting (h)	3:38
setting time (h)	1:05

III.2.4. Water

According to NF EN 1008 standard, the water used in this study is acceptable to be used in the production of concrete. The analysis results are shown in the table below:

Table III.10: water chemical analysis test results.

Settings	Analysis results	Limit standard NF EN 1008
sulphates $[So_4^{-2}]$ mg/l	893,06	< 2000 mg/l
chlorides $[Cl^-]$ mg/l	710	Prestressed concrete <500 mg/l
		Reinforced concrete < 1000 mg/l
		Concrete <4500
pH	7,54	≥4

III.3. Concrete mix composition

Basic data:

σ = 28 Mpa, 5< A < 9, Minimal cement dosage = 350 Kg/m^3, E/C= 0.5

Coefficient of compactness γ = 0.825 => K = 2 => Y = 50 – (D)1/2 + K = 43.52

D = 20 mm => X = 10 mm

Reference curve: A= $\begin{pmatrix} x=20 \\ y=100 \end{pmatrix}$ B= $\begin{pmatrix} x=0.08 \\ y=0 \end{pmatrix}$ O= $\begin{pmatrix} x=20/2 \\ y=43.52 \end{pmatrix}$

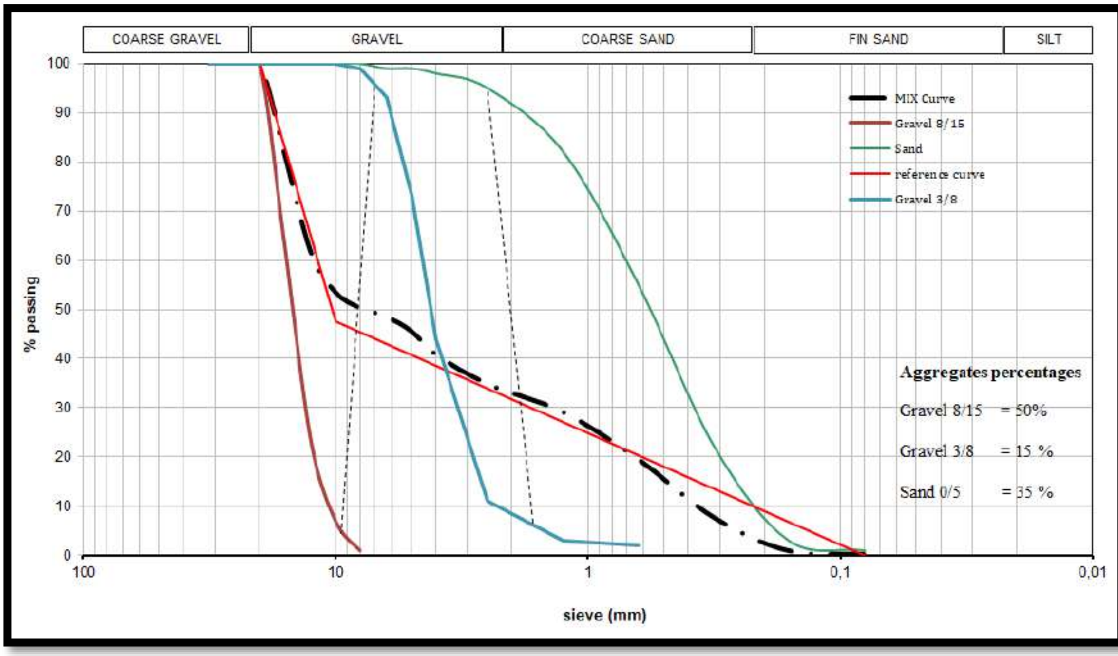

Figure III.5: mixing curves

Table III.11: Mix Constituents by weight.

Constituents	Absolut volumetric mass	Apparent volumetric mass	Weight (Kg)	1 prism 28x7x7
cement	3,1	1,25	350	3,842
sand	2,61	1,62	655	7,190
Gravel 8/15	2,61	1,31	936	10,271
Gravel 3/8	2,61	1,24	281	3,081
Water	1	1	175	1,921
Absorbed water	1,00	1,00	23,72	0.033

III.3.Concrete characteristics

III.3.1. Concrete slump test

The slump test results show that all mixes have Medium workability ranging from 55mm to 69mm.

Table III.12: slump test results.

MIX	percentage	slump (mm)
MIX1	0%	68
	10%	69
	20%	66
	30%	68
MIX2	0%	68
	10%	65
	20%	60
	30%	63
MIX3	0%	60
	10%	57
	20%	55
	30%	55
MIX4	0%	68
	10%	65
	20%	69
	30%	63

III.3.2. Ultrasonic velocity test

The influence of replacing cement and alluvial sand by glass waste on the characteristics of the concrete are the main objective of our study. The results obtained through the experiments have shown that for the ultrasound velocity test the values obtained are practically above 4000 m/s, which means that the quality of the concrete is good (3500-4500) [16] and can be regarded as a homogeneous material [17]. Where for the majority of samples for the different mixtures the quality is excellent (over 4500), especially in the case of the mixture 2 where the replacement of the cement by the glass powder was 10% and 20%. When comparing the mixtures, the maximum values were generally in the case of mixture 2 where we have values that range between 4300 (case of the control sample) and more than 4500 in the case of samples where the glass content was 10% to 20%. The lowest values are recorded in the case of mix1 with a minimum value for the samples of 10% (<4200), the absence in correlation between the UVP and the percentage of replacement may Indicates a different homogeneity between the percentages and the presences of pores in the concrete.

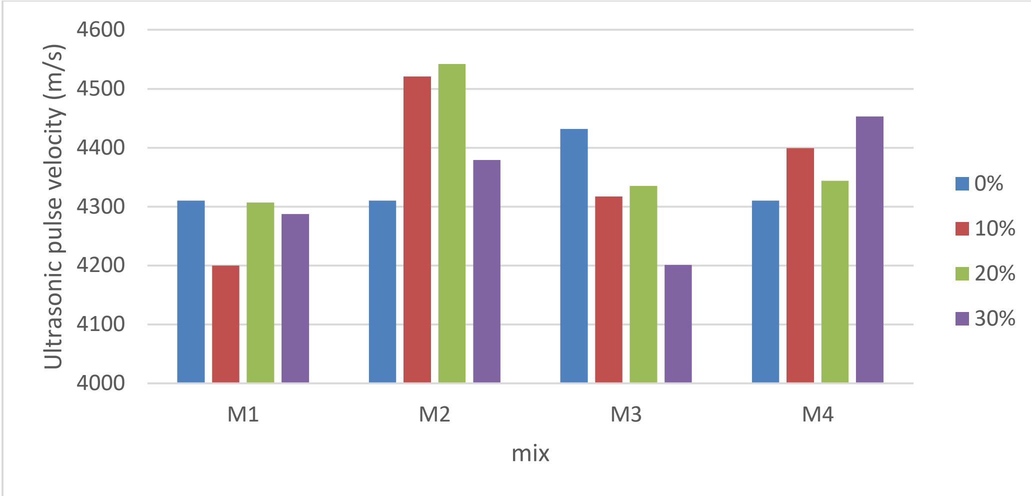

Figure III.6: Evolution of Ultrasonic pulse velocity at 28days.

III.3.3. Porosity

The results obtained show that the different mixtures have low porosity, the recorded values do not exceed 10%, which just reinforces the results obtained in the ultrasound test which stipulates the good quality of concrete (ref) except for mixture 1 where the samples were of low porosity (<8%). The rest of the mixtures had porosities approaching 10%. The different histograms show that there are positive correlations, which is not always feasible for all the samples of a given mixture, for the mixture 1 the correlation is positive between 0% and 20%, and then the porosity decreases. The same observation was made in the case of mixtures 3 and 4, for mix2, we see that there is a clear positive correlation between the percentage of glass waste replacement and the porosity.

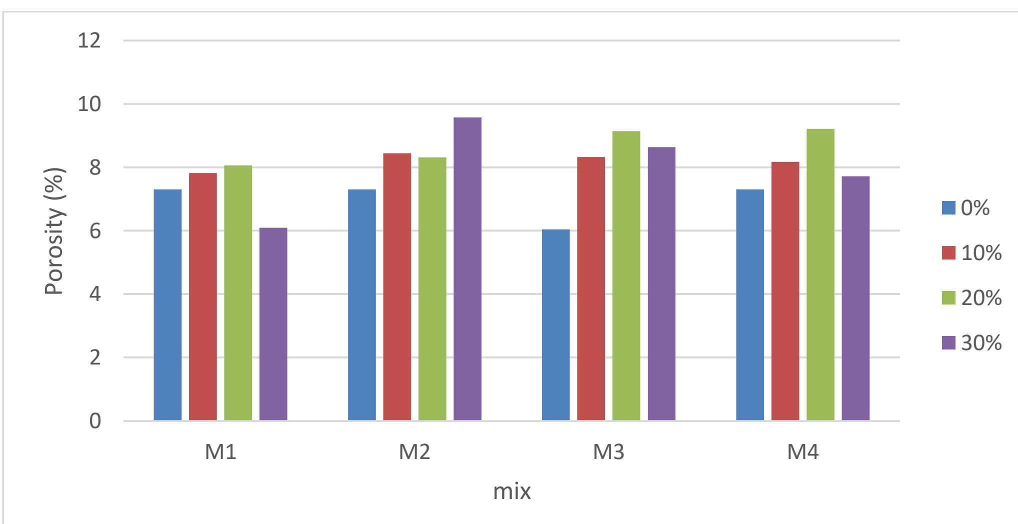

Figure III.7: Porosity according to mixes and percentages.

III.3.4. Flexural strength test

After 28 days, the bending strength for the concrete of mix1 and mix3 are good and very close to the control concrete, while the bending strength for mix2 and mix4 is very high compared to control sample. The results shown in Figure (III.8) show that flexural strength for all mixes at28 days.

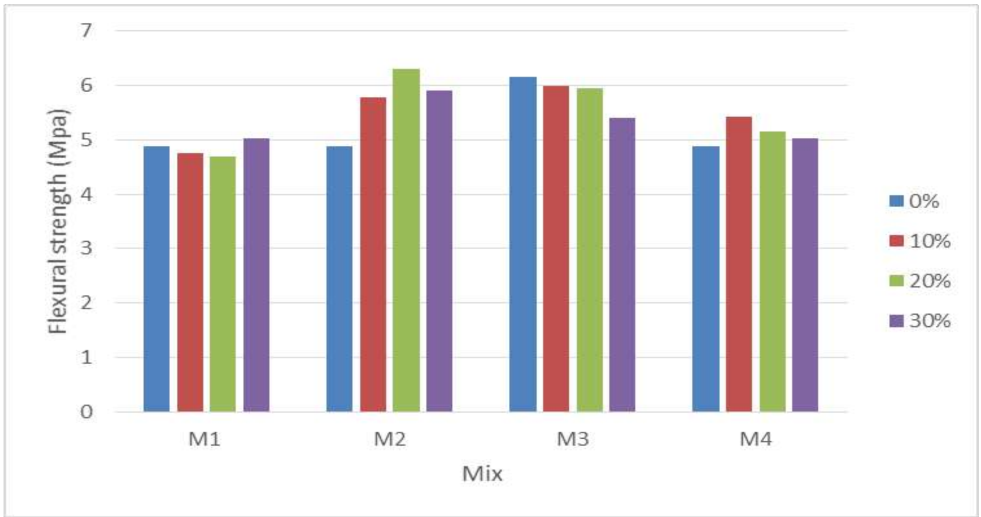

Figure III.8 : flexural strength results at 28 days

The results shown in Figure (III.9) for mix1, After 07 days show a slight increase in strength for the 10% and 20% glass powder replacement, of 6.4% and 7.79% respectively then a decrease at 30% of 4.68% compared to control sample. After 28 days, we can notice a significant increase in strength for 10%, 20% and 30% replacement with glass powder of 18.43% and 28.95% respectively then an increase at 30% of 21.09% compared to control sample.

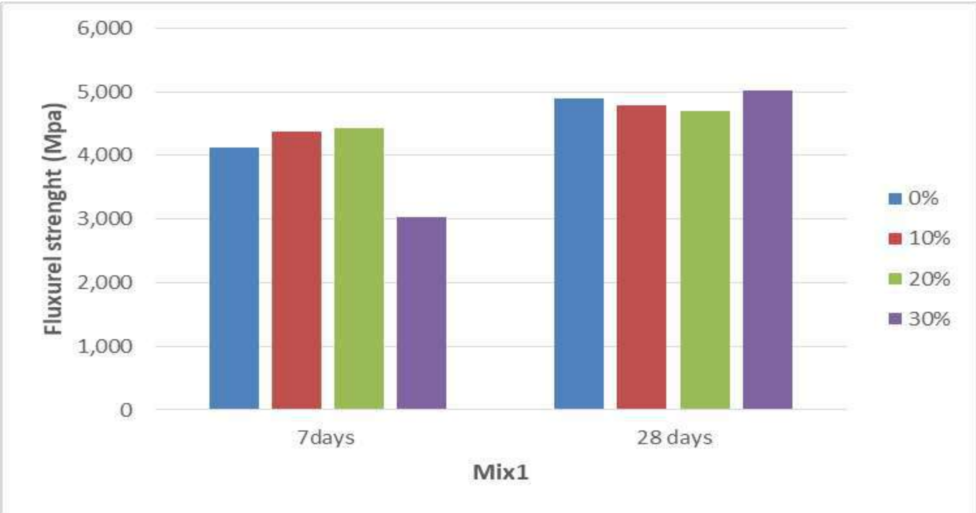

Figure III.9: flexural strength test mix1.

For mix2, After 07 days the results for 10% and 20% glass content show a slight increase in strength of 7.16% and 15.59% respectively then a decrease at 30% of 3.13% compared to control sample. After 28 days, we see at 10% and 20% glass content a slight increase in strength of 7.16% and 15.59% respectively then a decrease at 30% of 3.13% compared to control sample.

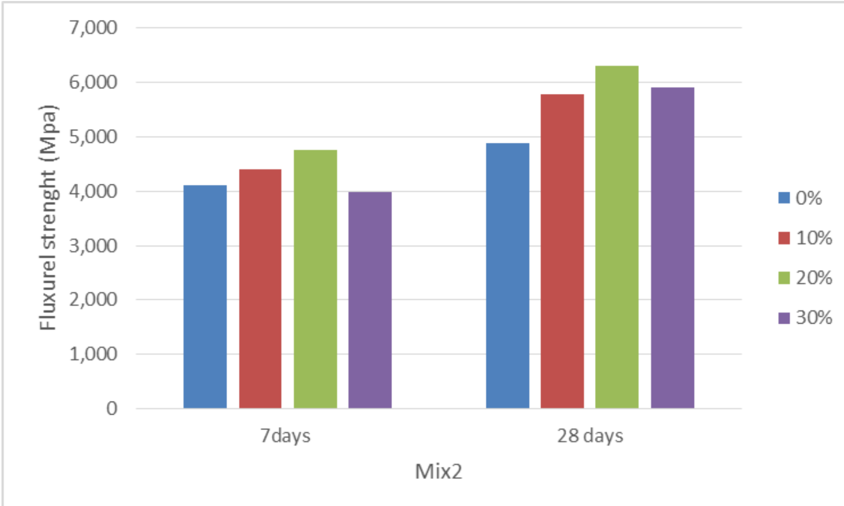

Figure III.10: flexural strength test mix2

For mix3, After 07 days there is a slight decrease in strength for 10%, 20% and 30% glass content, with a value of 5.71% 7.44% and 15.62% respectively. After 28 days, the strength decreased for 10%, 20% and 30% glass content with a value of 2.76% 3.18% and 12.17% respectively.

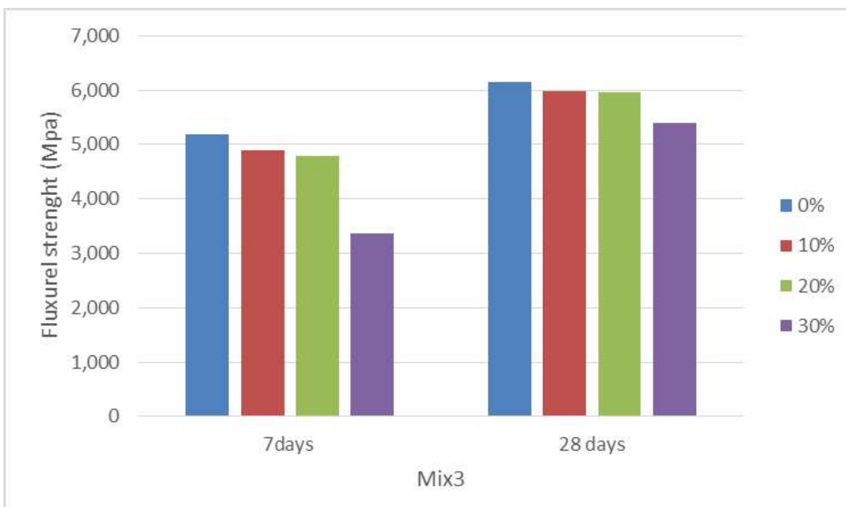

Figure III.11: flexural strength test mix3

The results shown in Figure (III.12) for mix4, show significant increase After 07 days in flexural strength for 10%, 20% and 30% replacement with glass powder of 18.65%, 15,76%, and 6.24% respectively.

After 28 days, there is an increase in strength for 10%, 20% and 30% glass powder content, of 10.80%, 5.27%, and 2.63% respectively.

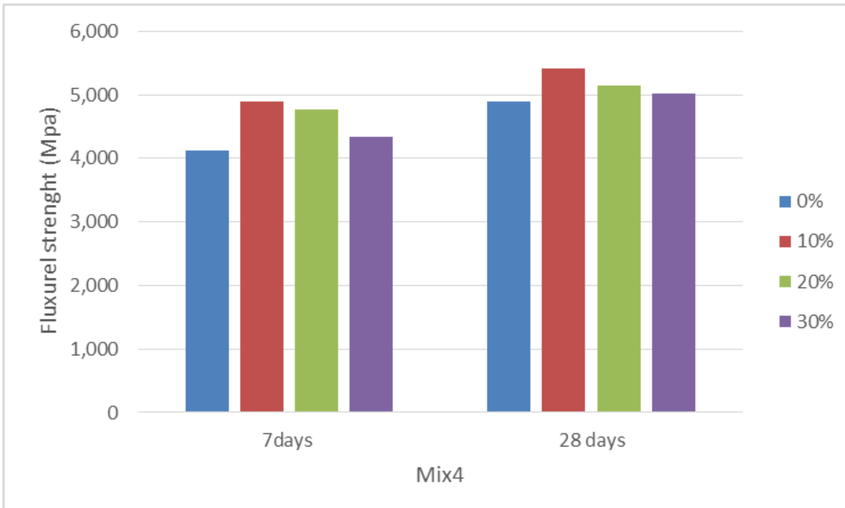

Figure III.12: flexural strength test mix4

III.3.5. Compressive strength test

The results shown in Figure below for compressive strength at 28 days, show that the test samples have good results in compressive strength that increases over time.

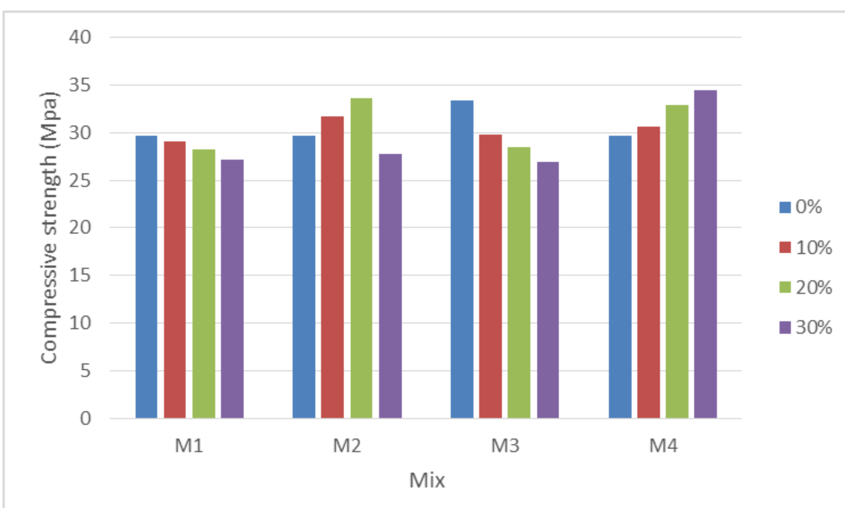

Figure III.12: compressive strength results at 28days

According to the figure (III.13) for mix1, we observe that there is a reduction in strength across all percentages compared with the control sample, and the Compressive strength was more important in the case of 10%, with slightly more reduction in strength in the case of 20% and 30% between 28 and 56 days.

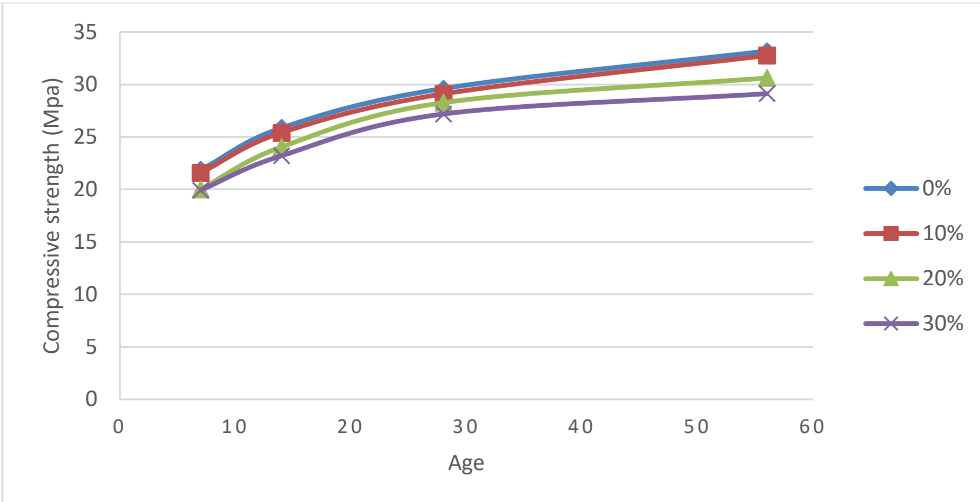

Figure III.13: Evolution of Compressive strength with age for MIX1.

Moreover, the results for mix2 shown in Figure (III.14), we see the age 7 and 14 days a significant improvement of compressive strength in comparison to control samples, the strength increased for 10% and 20% replacement with glass powder then goes down slightly at 30% replacement.

The slope of variation becomes weak between 14 and 28 days, which shows a low growth of strength, then between 28 and 56 days the gain of strength is lowest among all ages.

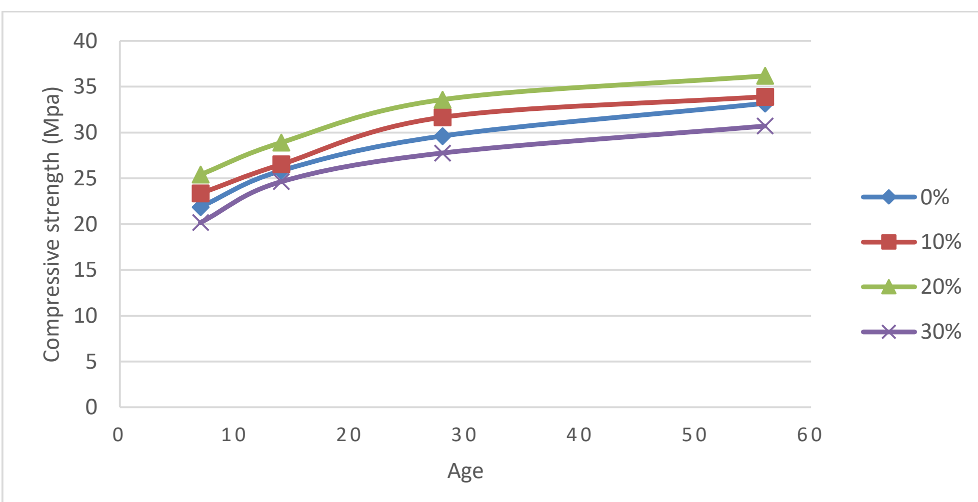

Figure III.14: Evolution of Compressive strength with age for MIX2.

In the case of mix3, the figure (III.15) shows a slight drop in strength for all percentages in comparison to control sample. The gain of strength was much important from the age 7 and 14 days, which becomes weaker between 14 and 28 days, with a higher drop for 10% glass content, which varies in a different way compared to other percentages in this age. Between 28 and 56 days, all specimens gain strength but at a lower rate compared to other ages.

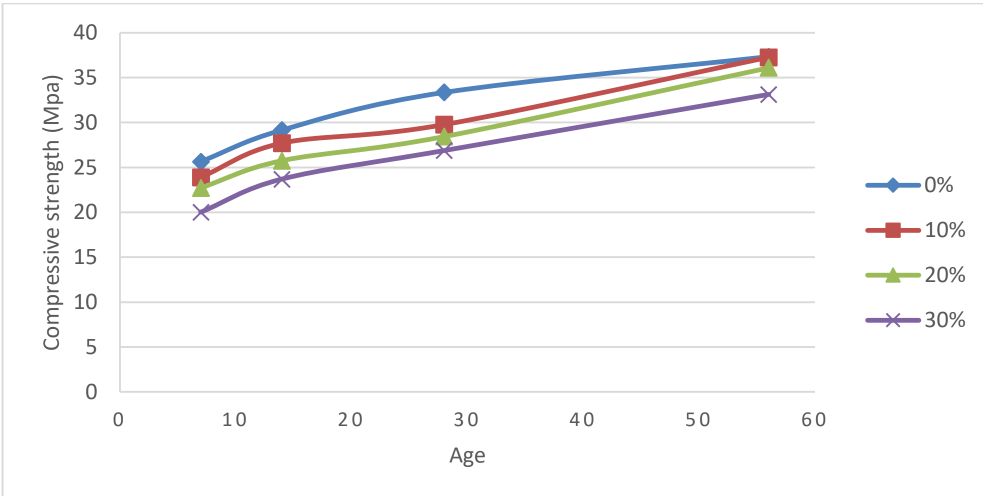

Figure III.15: Evolution of Compressive strength with age for MIX3.

For mix4, all percentages have better results for compressive strength than the control sample with a consistent improvement without any loss of strength, the 30% glass content had the better result followed by 20% and 10%.We notice a higher increase in strength from the age 7 and 14 days for all percentages. Between 14 and 28 days, the slope of variation has a decreasing trend. Then from 28 and 56 days, the strength gain becomes weaker but remains consistent.

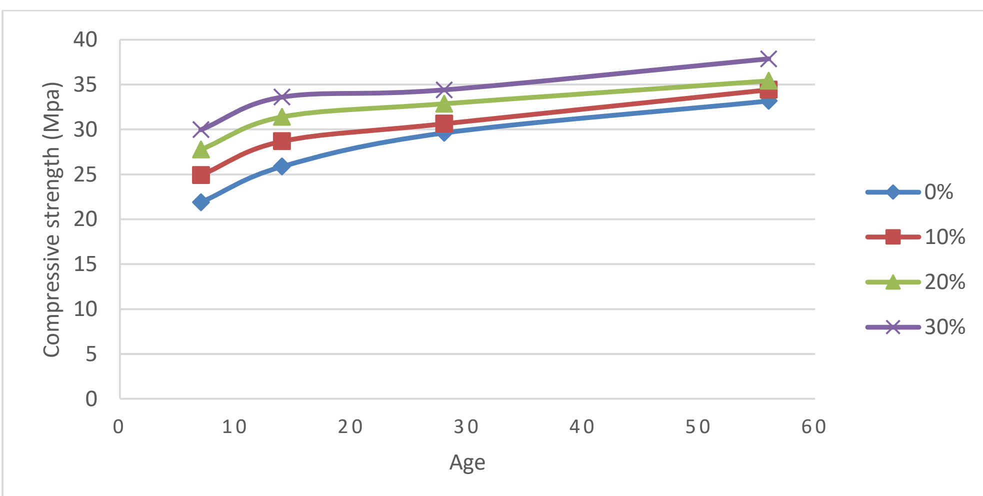

Figure III.16: Evolution of Compressive strength with age for MIX4.

III.4. Discussion

The results obtained the destructive tests showed that there are differences between the values and trends in the different mixtures. First, we will discuss the flexural strength results then discuss the results for the compressive strength.

The variation in bending strength in function of change in the amount of glass powder replacing cement and alluvial sand has shown that from one mixture to another the value of the resistance changes. For the first mixture where the cement is partially replaced by the glass powder, the resistance decreases when the amount of glass powder increases for percentages between 0% and 20% but resumes its maximum value at 30% of glass powder. This last result is the same obtained by several authors for an interval of 0% to 20% **[18]**, **[19]**. In the second mixture, where the size of the glass powder is larger compared to the mix1 (80-160 micrometer), the trend changes and the resistance increases when the replacement percentage increases except for the case of 30%, where the resistance decreases but remains higher than that of the control sample. These results are consistent with those of Patil and Strangle **[20]**. who state that resistance increases as the replacement percentage increases. Consequently, with the third mixture where the size of glass powder is the same as the first mixture, with a partial replacement difference of alluvial sand by dune sand, the results showed that there is an inversely proportional relationship between flexural strength and replacement of cement with glass powder, which means that, despite the presence of dune sand, resistance increases compared to that of mix1. The presence of dune sand in addition to glass powder reduces the resistance to bending. Finally, for the fourth mixture where we replaced a portion of alluvial sand with glass aggregates (0/5mm), there was a clear trend that between 10% and 30% where the resistance decreases as the percentage of replacement increases; but the values were all higher than that of the control sample. These results are consistent with those of Iqbal et al. **[21]** who noticed a decrease in the resistance between 10% and 30% of sand replacement by glass aggregates. For the variation of flexural strength as a function of age, the histograms of the different mixtures show that the rate of increase varies from one mixture to another.

The variation of flexural strength in function of age show that all mixtures gained strength at different rate of increase and it varied from one mixture to another. In the case of mix1 and 3 are the lowest compared to mix2 and mix4 where we see that the strength gain is slightly larger. However, when it comes to variation of percentage, the strength gain was practically the same for the two ages, with the exception of samples with 30% glass content where the gain in strength was faster across all four mixtures and for the two ages studied.

Furthermore, in the case of compressive strength, the results of the variation of the resistance in function of the variation of cement and sand replacement rates by the glass powder showed that for the mixes 1 and 3, the tendency is the same, when the replacement percentage increases the compressive strength decreases, but the difference is in the values that are large in the case of third mixture. These results, together with those of several authors who have noted that the presence of glass powder as a partial replacement of cement decreases compressive strength in concrete or mortar **[22]**, **[23]**. For the second mixture, the results showed that there is an increase in resistance when the replacement percentage increases to 20%; then there is a drop in resistance to 30%, which gives a value lower value than that recorded in the control sample. These results are consistent with those of Patil and Sangle **[20]**, but for percentages of 10% and 20%. Finally, in the case of the fourth mixture, the results showed that there is a proportional relationship between compressive strength and replacement percentage and this goes with that of Iqbal et al. **[21]**.

For the variation of compressive strength in function of age, the figures of the different mixtures show that the rate of increase varies from one mixture to another and from one sample to another. In the case of the first three mixtures, the compressive strength is the lowest in the case of cement replacement samples with 30% glass waste for the four ages studied. However, the maximum values for these ages are different from one mixture to another. In the first mixture, they are the maximum in the samples of 0% and 10% where the values for the four ages are almost identical (curves combined). In the second mixture, the maximum values for different ages are recorded in the case 20% replacement. For the case of third mixture, the maximum values are as in the case of the first mixture in the control sample (0%). The case of the samples of the fourth mixture is different, because the presence of glass aggregates as a partial substitute for alluvial sand meant that the maximum values for the four ages of our study are recorded in the case of 30% and the weak ones in the case of the control sample. In the latter case zainab et al **[24]**, report that pozzolanic reactions seem to compensate for this tendency at a later stage of hardening and have contributed to improving the compressive strength at 28 days **[25]**. reported a similar observation in which the author concluded that high levels of resistance improvement could be achieved when the pozzolanic effect became significant at an advanced age of 28 days. This also explains the steep slope between ages before the age of 28 days and the slight slope noticed after the age of 28 days (between 28 days and 56 days).

GENERAL CONCLUSION

GENERAL CONCLUSION

The partial replacement of cement and sand with waste glass powder is an alternative to traditional building materials. Using waste glass powder in the production of concrete is extremely beneficial and advantageous in the field of civil engineering and construction, since it contributes to the reduction of CO_2 emissions, the reduction of the consumption of sand deposits, provides a new recycling waste glass and reduces the cost of concrete.

In addition to the advantages listed above, using glass powder can also increase the strength of concrete. The results obtained in this research have shown that replacing cement with glass powder of particle size 80-160µm at 10% and 20% glass increase the compressive and flexural strength compared to ordinary concrete. While using 0/5mm particle size waste glass as sand replacement, increased the compressive and flexural strength for all glass content percentages (10%, 20%, 30%).

The test results for porosity and ultrasonic velocity pulse also confirm that for the mixes containing glass with a particle size of 80-160µm, at 10% and 20% as cement replacement, and the 0/5mm particle size at 10%, 20%, And 30%, sand replacement, the test samples had low porosity with a maximum value under 10%. While theirs ultrasound results were above 4000 m/s which reassert theirs strength and quality.

Finally, it is indispensable to carry additional and extensive research for a better understanding of the influence of glass powder in the production of concrete. It is recommended to study the effect of replacing cement and sand while varying glass the glass color, the particle size and mixtures, and experiment with the partial replacement of gravel for concrete, It is also recommended to carry additional test for an extended period to know its influence on the Alkali-Silica Reaction and the effects on concrete characteristics in the long term.

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Appendix 1

Quality of concrete given by IS code (BS, 1881, 1983) as a function of UPV	
UPV(m/s)	Concrete quality
Above 4500	Excellent
3500 to 4500	Good
3000 to 3500	Medium
Below 3000	Doubtful

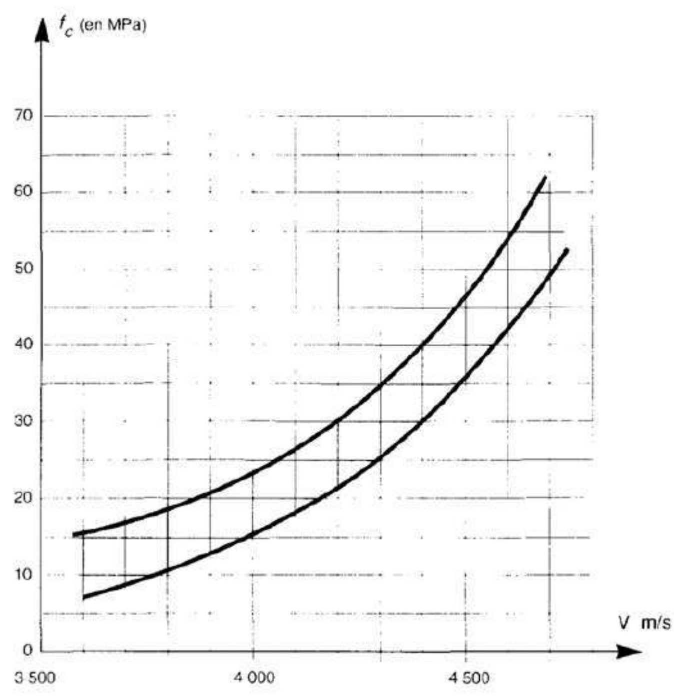

Fig. XIV-2 – Relation approximative entre la vitesse du son (en m/s) et la résistance en compression f_c (en MPa).

Appendix 2

ALGÉRIE

متين
Matine

50kg

LAFARGE
Construire des villes meilleures

Ciment portland au Calcaire

NA442 CEM II/B-L 42,5 N

Matine Ciment gris pour bétons de haute-performance destiné à la construction des Ouvrages d'Art, infrastructure et superstructure pour bâtiments

Matine
NA442 CEM II/B-L 42,5 N

Matine est certifié, conforme à la norme Algérienne (NA442 – 2013) et Européenne (EN 197-1)

AVANTAGES PRODUIT

- Une résistance initiale élevée pour vos ouvrages nécessitants un décoffrage rapide
- Favorise la maniabilité du béton et le maintien de sa rhéologie
- Une Classe Vraie qui offre une haute performance au béton.
- Meilleure durabilité du béton.

A member of LafargeHolcim

APPLICATIONS RECOMMANDÉES

- Construction des Ouvrages d'Art, infrastructure et superstructure pour bâtiments
- Préfabrication légère
- Béton de haute performance

FORMULATION CONSEILLÉE

	Ciment	Sable (sec) 0/5	Gravillons (sec) 8/15mm	Gravillons (sec) 15/25mm	Eau (litres)
Dosage pour béton c25/30	X 1 (50 kg) +	X7 +	X5 +	X4 +	25 L

Remaque: un bidon = 10 Litres

CARACTÉRISTIQUES TECHNIQUES

• Analyses chimiques	Valeur
Perte au feu (%) (NA5042)	10.0±2
Teneur en sulfates (SO_3) (%)	2.5±0.5
Teneur en oxyde de magnésium MgO (%)	1.7±0.5
Teneur en Chlorures(NA5042) (%)	0.02-0.05

• Temps de prise à 20° (NA 230)	Valeur
Début de prise (min)	150±30
Fin de prise (min)	230±50

• Composition minéralogique du Clinker (Bogue)	Valeur
C3S (%)	60±3
C3A (%)	7.5±1

• Résistance à la compression	Valeur
2 jours (MPa)	≥ 10.0
28 jours (MPa)	≥ 42.5

• Propriétés physiques	Valeur
Consistance Normale (%)	26.5±2.0
Finesse suivant la méthode de Blaine (cm^2/g) (NA231)	3 700 - 5 200
Retrait à 28 jours (µm/m)	< 1 000
Expansion (mm)	≤ 3.0

Appendix 3

A091-10

Jar mills

(*Aggregates-Rocks*)

Designed to reduce from 5 mm to powder granulometric materials like: cement, stones, rocks, hard materials. Supplied **without** jar to be ordered separately (see needed accessory).
Jar is in prokorund material with relevant hard porcelain spheres.
The noise reduction steel cabinet and microswitch are conforming to CE safety Directive.

Built in timer. Rpm: about 400. **It can be used only for wet tests.**

Power supply: 230 V 50 Hz 1ph 750W
Dimensions: 350x710x410 mm
Weight: 50 Kg

Different jars capacities available:

- **A091-10**: Capacity 300 or 1000 cc.
- A091-02: Capacity 1500 cc., supplied **complete** with jar and spheres

Abstract

Concrete is one of the most used building materials in the world. Although it represents only a small portion of the composition of concrete, cement production releases a large amount of CO2 emissions that has a negative impact on our habitat. In addition, concrete making requires the consumption of large quantities of sand which is considered the second most consumed natural resource In response to these problems we propose the use of glass as alternatives to these building materials. Glass is one of the most used materials around the world, in this research we experiment with recycling waste glass into a powder with three different sizes, and use it as a partial replacement of cement and sand in concert in different percentages like 0%, 10%, 20%, and 30%. The objective of this experiment is improving its strength, reducing the cost and reducing the emissions of CO2 that results from the production of cement.

KEY WORDS: Cement, Concrete, recycling, environment, waste glass, Glass Powder, construction, Compressive Strength, Flexural Strength.

ملخص

تعتبر الخرسانة واحدة من أكثر مواد البناء استخدامًا في العالم. على الرغم من أنه لا يمثل سوى جزء صغير من تركيبة الخرسانة، فإن إنتاج الأسمنت يطلق كمية كبيرة من انبعاثات ثاني أكسيد الكربون التي لها تأثير سلبي على بيئتنا. بالإضافة إلى ذلك، تتطلب صناعة الخرسانة استهلاك كميات كبيرة من الرمال التي تعتبر ثاني أكثر الموارد الطبيعية استهلاكًا. استجابةً لهذه المشكلات اقترحنا استخدام الزجاج كبديل لمواد البناء هذه. يعتبر الزجاج أحد أكثر المواد استخدامًا في جميع أنحاء العالم، حيث نجرب في هذا البحث على إعادة تدوير نفايات الزجاج إلى مسحوق بثلاثة أحجام مختلفة، واستخدامه كبديل جزئي للإسمنت والرمل في الحفلات بنسب مختلفة مثل 0٪، 10 ٪ و20٪ و30٪. الهدف من هذه التجربة هو تحسين قوتها، وخفض التكلفة وتقليل انبعاثات ثاني أكسيد الكربون الناتجة عن إنتاج الأسمنت.

الكلمات المفتاحية: الاسمنت، الخرسانة، إعادة التدوير، البيئة، زجاج، مسحوق الزجاج، البناء، مقاومة الانضغاط، مقاومة الشد.

Résumé

Le béton est l'un des matériaux de construction les plus utilisés au monde. Bien qu'il ne représente qu'une petite partie de la composition du béton, la production de ciment libère de grandes quantités de CO2, ce qui a un impact négatif sur notre habitat. En outre, la fabrication du béton nécessite la consommation de grandes quantités de sable, ce qui est considéré comme la deuxième ressource naturelle la plus consommée. En réponse à ces problèmes, nous proposons d'utiliser le verre comme alternative à ces matériaux de construction. Le verre est l'un des matériaux les plus utilisés dans le monde. Dans cette recherche, nous expérimentons le recyclage des déchets de verre en une poudre de trois tailles différentes. Nous l'utilisons comme remplacement partiel du ciment et du sable, dans des pourcentages différents tels que 0%, 10 %, 20% et 30%. L'objectif de cette expérience est d'améliorer sa résistance, de réduire les coûts et les émissions de CO2 résultant de la production de ciment.

MOTS CLÉS : Ciment, Béton, recyclage, environnement, déchets de verre, poudre de verre, construction, résistance à la compression, résistance à la flexion.