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THEME

**Influence Of Aggregate
Size On The Qualities Of
High-Strength Concrete**

Led by:

Dr: ZITOUNI S

Presented by:

CHERGUI ABDELBASSET

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Abstract

This theme provides an in-depth study on the properties and behavior of High Strength Concrete (HSC) with a focus on the characteristics of various materials used in its production. It details the physical, chemical, and mechanical properties of aggregates and their impact on concrete performance. Key aspects include the water absorption, fragmentation resistance, and alkali-silica reaction of aggregates, highlighting their significance in HSC. The study also explores different combinations of gravel fractions, examining their apparent and absolute densities to determine optimal mixtures for concrete formulation. Additionally, it evaluates the cement used, including its chemical and mineralogical composition, and investigates the effectiveness of superplasticizers in enhancing concrete properties. The research provides comprehensive test procedures and results, contributing valuable insights into the production and quality control of HSC.

Key words: High Strength Concrete (HSC), Aggregates, Aggregates Size, Porosity, Compressive.

Résumé

Ce thème propose une étude approfondie des propriétés et du comportement du béton à haute performance (BHP) en mettant l'accent sur les caractéristiques des différents matériaux utilisés dans sa production. Il détaille les propriétés physiques, chimiques et mécaniques des granulats et leur impact sur les performances du béton. Les aspects clés incluent l'absorption d'eau, la résistance à la fragmentation et la réaction alcali-silice des agrégats, soulignant leur importance dans les BHP. L'étude explore également différentes combinaisons de fractions de gravier, en examinant leurs densités apparentes et absolues afin de déterminer les mélanges optimaux pour la formulation du béton. De plus, il évalue le ciment utilisé, y compris sa composition chimique et minéralogique, et étudie l'efficacité des super plastifiants pour améliorer les propriétés du béton. La recherche fournit des procédures et des résultats de tests complets, apportant des informations précieuses sur la production et le contrôle qualité des BHP.

Mots clés: Béton à Haute Performance (BHP), Granulats, Taille des granulats, Porosité, Compression.

خلاصة

يوفر هذا الموضوع دراسة متعمقة حول خصائص وسلوك الخرسانة عالية القوة مع التركيز على خصائص المواد المختلفة المستخدمة في إنتاجها. يوضح الخصائص الفيزيائية والكيميائية والميكانيكية للركام وتأثيرها على أداء الخرسانة. تشمل الجوانب الرئيسية امتصاص الماء، ومقاومة التفتت، كما تستكشف الدراسة تركيبات مختلفة من أجزاء الحصى، فحص الكثافات الظاهرية والمطلقة لتحديد الخلطات المثلى لتشكيل الخرسانة. بالإضافة إلى ذلك، تقيم الدراسة الأسمنت المستخدم، بما في ذلك تركيبه الكيميائي والمعدني، وتحقق في فعالية الملدنات الفائقة في تعزيز خصائص الخرسانة. توفر الأبحاث إجراءات اختبار شاملة ونتائج، مما يساهم في تقديم رؤى قيمة في إنتاج ومراقبة جودة الخرسانة عالية القوة.

الكلمات المفتاحية: الخرسانة عالية القوة، الركام، حجم الركام، المسامية، الضغط

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GENERAL INTRODUCTION

High-strength concrete (HSC) is a vital material in modern construction, offering enhanced durability and loadbearing capacity for infrastructure such as high-rise buildings, bridges, and various civil engineering projects. The quest for stronger, more resilient concrete has led to extensive research into its composition and the factors that influence its properties. Among these factors, the size of aggregates used in the concrete mix plays a pivotal role in determining the final strength and quality of the concrete.

This thesis explores the **Influence of Aggregate Size on the Qualities of High-Strength Concrete**, delving into the complex interplay between aggregate size and concrete performance. Aggregates, typically composed of sand, gravel, or crushed stone, constitute a significant portion of the concrete mix, influencing its workability, density, and ultimately, its strength.

Previous studies have shown that the size and gradation of aggregates can significantly affect the mechanical properties of concrete. For instance, larger aggregates tend to reduce the surface area that needs to be coated with cement paste, leading to a reduction in water demand and potentially increasing the concrete's strength. Conversely, smaller aggregates may enhance workability but require more cement paste to fill the gaps, affecting the mix's economy and strength.

This research aims to provide a comprehensive analysis of how varying aggregate sizes impact the structural integrity and performance of high-strength concrete. Through a series of experimental investigations, including compressive strength tests and flexural strength assessments, the thesis will evaluate the optimal aggregate size for maximizing the quality of high-strength concrete. The findings of this study could have significant implications for the construction industry, offering insights into more efficient and effective concrete mix designs.

This dissertation is divided into 3 chapters as follows:

- The first chapter contains general information on HSCs as well as the constituents adopted for their formulations.
- The second chapter covers the identification of the aggregates, their origins and their general characteristics, as well as the presentation of the materials used for making the different concrete mixtures studied.
- The third chapter summarizes the tests and the results of the experiments carried out during our study.

*CHAPTER I:
GENERAL
INFORMATION
ON HSC*

I.1. INTRODUCTION

A High Strength Concrete (HSC) is ordinary hydraulic concretes (sand + water + gravel + cement) to which additives (fluidifying and possibly ultra-fine) are added to increase their performance, including resistance, which must exceed 50 MPa at 28 days [01]. However, high compressive strength is not the only and main property of HSCs, as several other properties are improved, such as very low permeability and therefore increased durability.

HSC also brings multiple advantages over ordinary concrete, including, by way of example:

Maneuverability is increased without risk of segregation during implementation.

- ❖ The durability of the structures is improved by the high compactness of the concrete with reduced air and water permeability, resistance to attack and better resistance to alkali reaction, greater resistance to abrasion and better resistance to freeze/thaw cycles.
- ❖ It makes it possible to design thinner structures thanks to the increase in mechanical characteristics (compression, traction, modulus of elasticity) both at a young age and in the long term.

However, the improved properties of HSCs can only be achieved through several simultaneous provisions regarding:

- ❖ The aggregates must be of good quality, as the strength of the concrete may be limited by that of the aggregates themselves.
- ❖ The use of specific additives, including water-reducing superplasticizers as well as mineral additives such as fly ash, blast furnace slag, silica fume, etc. Etc.
- ❖ The use of high class cements at dosages between 400 and 550 kg/m³. Recent years have seen the use of higher depleted compressive strength concretes ranging from 50 MPa up to 400 MPa and even 800 MPa using appropriate thermal and mechanical treatments and special products such as metal powder [02]. Such high strengths have given a new classification of concretes, they are currently called high-strength concretes (BHR), high performance concretes (BHP), very high performance concretes (BTHP), reactive powder concretes (BPR), and high-performance fiber concretes (BFUP).

I.2. Definition:

High Performance Concrete (HSC) is characterized by:

- ❖ A 28-day compressive strength greater than 50 MPa .
- ❖ An equivalent Effective Water/Binder ratio of less than 0.4[03].

High performance also means ease of implementation and flexibility to adapt to the execution constraints of the structures .Indeed , HSCs also offer exceptional resistance in the fresh state (rheology, pumpability, etc.)and performance at young ages, which makes it possible, for example, to accelerate manufacturing rates in the factory or on site or to pump the material over long distances. They give architectural durability to structures and considerably increase their durability by correspondingly reducing maintenance and upkeep costs [04].

HSCs are also, due to their reduced extreme porosity, more resistant to aggressive agents and generally have increased durability. They make it possible to optimize structures, to carry out structures subject to high stresses or undergoing a severe environment (climate, marine aggressions, effects of frost, acid attacks, etc... [05].

I.3. Different classes of BHPs:

The division of HSCs into five classes is not as arbitrary as it may seem at first glance, but rather derives from the current state of knowledge. HSCs are divided into five broad categories, each corresponding to a strength range of 25 MPA [06].

The following table defeated those classes of the HSC classes:

Table I.1: the different classes of BHP.

CS(MPa)	50	75	100	125	150
System Organ Class	Class I	Class II	Class III	Class VI	Class V

I.4. The Constituents of Concrete:

I.4.1. Aggregates:

The aggregate consists of a set of mineral grains which, depending on its size (between 0 and 125mm), falls into one of the following 7 families: girls, sand, sand, gravel, gravel, gravel, ballast, rockfill.

Aggregates are obtained by exploiting original sand and gravel deposits terrestrial or marine alluvial, by crushing massive rocks (limestone or eruptive) or by recycling products such as demolition materials. Their nature, shape and characteristics vary according to the deposits and production techniques.

The aggregates are classified according to their granularity (dimensional distribution of the grains) determined by particle size analysis using sieves.[6]

I.4.1.1. Rolled aggregates and crushed aggregates: [6]

Regardless of their mineralogical origin, aggregates are classified into two categories:

I.4.1.1.1. Aggregates of loose rock:

So-called rolled rock, the shape of which has been acquired by erosion. These aggregates are washed to remove clay particles, which are harmful to the strength of the concrete, and screened to obtain different size classes. Although different rocks can be found depending on the region of origin, the aggregates used for concrete are most often siliceous, limestone or silico – limestone

So-called crushed rock aggregates are obtained by felling and crushing, which gives them angular shapes. A pre-screening phase is essential for obtaining clean aggregates. Crushed aggregates have characteristics that depend on a large number of parameters: origin of the rock, regularity of the bench, degree of crushing.



Figure. I.1: Gravel type

I.4.1.2. Characteristics of aggregates:

A. Particle size:

The granulometry makes it possible to determine the staggering of the dimensions of the grains contained in a gravel. It consists of sieving the aggregates on a series of square mesh sieves, with decreasing opening dimensions and weighing the waste on each sieve. The square openings of the screens are standardized and range from 0.08 mm to 80 mm. The curve particle size expresses the cumulative percentages, by weight, of grains passing through the successive sieves. The particle size curves of the different aggregates can be determined by the particle size analysis test (NF P 18-560).[7]

B. Granular classes:

Aggregates are sorted by size using sieves (square meshes) and strainers (circular holes) and a class of aggregates is designated by one or two digits .If only one figure is given, it is that of the maximum diameter D expressed in mm; if two figures are given, the first denotes the minimum diameter d, of the grains and the second the maximum diameter D. An aggregate is characterized from the granular point of view by its class d/D. When d is less than 2 mm, the aggregate is designated 0/D. There are five main granular classes characterized by the extreme dimensions d and D of the aggregates encountered. (NFP18-101) [7]:

- The 0/D ends with $D \leq 0.08$ mm.
- Sands 0/D with $D \leq 6.3$ mm.
- D/D chippings with $d \geq 2$ mm and $D \leq 31.5$ mm.
- D/D pebbles with $d \geq 20$ mm and $D \leq 80$ mm.

C. Aggregate shape:

1. Volumetric coefficient:

For a grain, it is the ratio between the volume v of the grain in question and the circumscribed sphere of diameter d, d being the largest dimension of the grain. A grit.

$$C = \frac{v}{\pi \frac{d^3}{6}} \quad (1.1)$$

For an aggregate consisting of a set of grains.

$$C = \frac{\sum v}{\sum \pi \frac{d^3}{6}} = \frac{v}{\frac{\pi}{6} \sum d^3} \quad (1.2)$$

A low coefficient corresponds to an aggregate with a number of chips and needles. A high coefficient corresponds to a so-called "cubic" or "rounded" aggregate.

2. Form index

The shape of an aggregate is defined by three geometric quantities (Fig. II.2):

- Length L, maximum distance of two parallel planes tangential to the ends of the Aggregate
- The thickness E, minimum distance of two parallel planes tangent to the aggregate.
- The size G, dimension of the minimum square mesh of the sieve that allows the aggregate to pass.

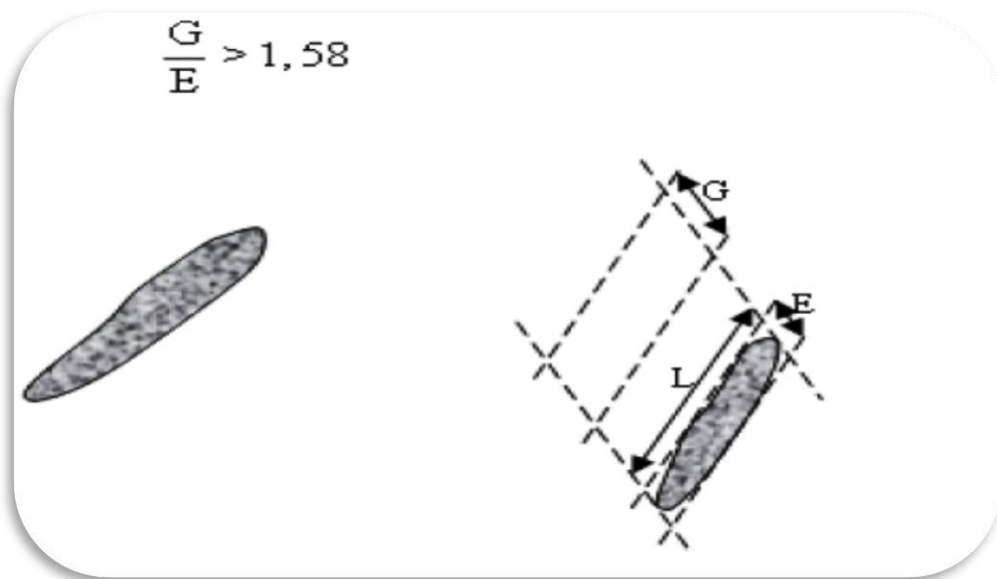


Figure. I.2: The shape of an aggregate

We distinguish the following various forms:

- ❖ Cubic shape (with the ratio of length to thickness less than 2)
- ❖ Irregular shape (with length to thickness ratio of 2 to 3)
- ❖ Angular shape (with ratio of length to thickness greater than 3)
- ❖ This latter shape included the needle shapes is platelet

In practice it is difficult to procure cubic shaped gravel. rolled gravel with smooth Surfaces and round shapes give good maneuverability, while stone crushed with angular shapes And rough surfaces gives poor maneuverability Under the same conditions:

Researchers have indicated the negative behavior of needle-shaped grains and wafer Which can make the gravel more porous, can decrease the maneuverability and concrete strength, and cause difficulties for compaction, therefore the expense in cement will be larger, which is why we prefer cubic aggregates to platelets and switch-tongues

D. coefficient of excess:

Flattening coefficient characterizes the shape of the aggregate from its largest size and thickness. It is determined by double sieving first through the series of square mesh sieves used for the study of particle size. Then by a second sieving of the waste retained on the different sieves on a series of grids with parallel slots. The ratio between the dimensions of the screens and grids is 1.58. Standard NF P 18-561 defines the modalities of its measurement. [8]

$$A_i = \frac{M_i}{R_i} \quad (1.3)$$

E. Bulk density:

This is the mass of dry aggregate occupying the unit of volume. It depends on the settlement, shape and grain size. It is measured in accordance with a precise operating procedure (standards NF P 18 554 and 18 555). It is between 1400kg/m³ and 1600kg/m³ for silico-limestone rolled aggregates.

The apparent value is used in the case where the volume assays of the different components of concrete.

F. Porosity:

It is the ratio of the volume of voids contained in the grains to the volume of the grains, expressed as a percentage. The porosity of common aggregates is generally very low. However, porosity is important in the case of lightweight aggregates. The porosity is measured according to the standard (NF P 18 554 and 18 555).^[10]

$$P\% = \left(1 - \frac{\rho_{app}}{\rho_{abs}}\right) * 100 \quad 1.4$$

G. Water absorption of aggregates:

Most aggregates stored in a dry atmosphere for some time, can subsequently absorb water. The process by which liquid enters the rock and the resulting increase in weight is called absorption. Absorption can vary to very large extents depending on the nature of the aggregate. It can vary from 0 to more than 30% of the dry weight for lightweight aggregate. In general, natural aggregates used to make concrete are not very porous and hardly absorb water when mixed with cement and water. On the other hand, artificial aggregates, such as lightweight expanded clay aggregates, are porous. It is then necessary to take into account the absorption of water by the aggregates when determining the amount of water required to make the concrete.

The water absorption coefficient is measured according to the standard (NFP 18554 and 18555).[6]

The water absorption by immersion Abs is expressed as a percentage of the dry mass and is calculated by the following relationship:

$$Abs = \frac{M_{humide} - M_{sech}}{M_{sech}} * 100$$

With:

M_{wet} the constant wet mass of the sample after immersion.

M_{dries} the constant dry mass of the sample after drying in an oven 105°C.

H. Fragmentation resistance:

In concretes, the aggregates are subjected to stresses that can cause them to break: The measurement of their resistance to fragmentation is obtained by the Los Angeles (LA) test. It is the subject of standard NF P 18-573. It is an impact resistance test, based on the measurement of the particle size degradation of materials subjected to impacts. The Los Angeles coefficient is calculated from the passage through a 1.6 mm sieve, measured at the end of the test, characterizes the aggregate and The resistance to fragmentation is all the better as its value is small.[10]

I.4.1.3. Chemical characteristics (Alkali-silica reaction)

Under this term are grouped all the reactions that can occur between the aggregates of the concrete and the alkalis of the cement paste. The aggregates must be inert with respect to the alkali reaction when there is an identified risk to the structure or a concrete structure element. It must be possible to know the content of active alkalis in order to be able to establish a balance for a concrete formulation and determine the presence of partially reactive or unqualified aggregates. The disorders caused by the alkali-reaction are in the form of cracking or bursting of the concrete.[8]

- **The cement paste/aggregate interface:** [11]

The bond that is established during hydration between the cement paste and the aggregates results in a particular paste area called the "transition halo" or interface dough/aggregates [Maso, 1980]. Several models describe this transition zone [Monteiro, 1986]. In (Fig.2.3), [Diamond, 1986] 's model for ordinary concrete is presented.

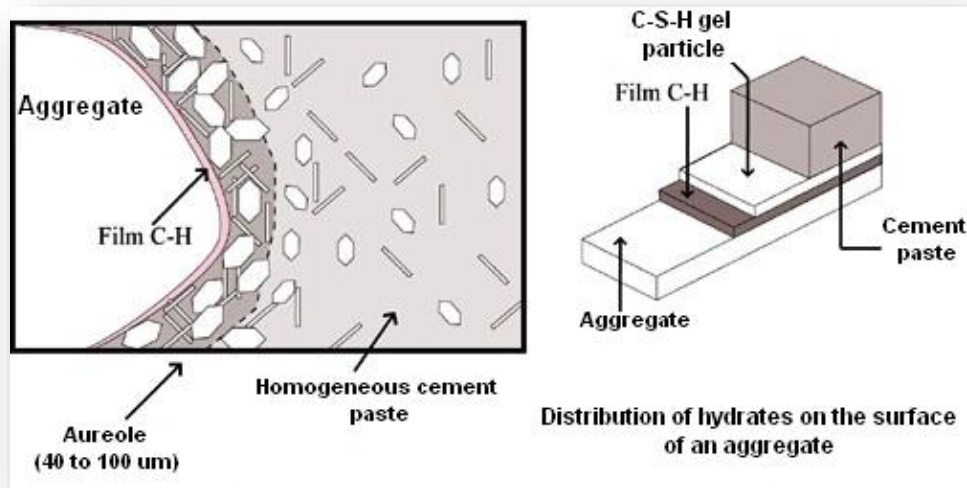


Figure. I.3: Model of the morphology of the transition halo of an ordinary concrete
Diamante

The nature of the aggregates influences the quality of the transition zone. Limestone aggregates (reagents) have the strongest bonds with cement paste due to chemical reactions that occur over time and increase adhesion forces. The reaction between CaCO_3 from calcareous aggregates and tricalcium aluminates and tetra-calcium alumino-ferrites results in the formation of monocarbo-aluminates from calcium ($[\text{Ca}_2\text{Al}(\text{OH})_6 \cdot \text{H}_2\text{O}]_2\text{CO}_3 \cdot 9\text{H}_2\text{O}$). Thus, the transition zone between aggregates limestone and the cement paste is thus more resistant and of lower permeability [Gaweska Hager, 2004]. The increase in the strength of the concrete material obtained with aggregates of this nature was observed by [Malier, 1992], unlike aggregates of quartz type (such as siliceous aggregates) which are neutral with respect to cement paste. ^[11]

The formation of these C-S-H generates a reduction in porosity also accentuated by the filling effect (filler effect) of this fin, thus improving the mechanical performance of the material.

I.4.2. Sand:

I.4.2.1. Definition:

Sands are defined as the fraction of stony aggregates whose grains have dimensions between 80 μm and 05 mm; this is a global definition, whose bounds vary from one classification to another. In fact, the granulometric definition of sand is more complicated, it varies according to the epoch and differs according to the country and according to the destination. ^[12]

I.4.2.2. Origin of the sands: ^[12]

Available sands are the result of an often complex process of erosion and sedimentation. It involves, to varying degrees, on-site decomposition of the various rocks followed by river and sometimes wind transport.

The fraction between 0.2mm and 0.5mm is most often more than 75% quartz. Depending on the importance and nature of their transport.

I.4.2.3. Classification of sands:**I.4.2.3.1. Coarse sand:**

More than 20% of the elements are greater than 2mm and more than 50% of the elements greater than 80µm are between 0.5 and 5mm. These sands have properties that bring together serious ones.

I.4.2.3.2. Medium sand:

Less than 20% of the elements are greater than 2mm and more than 50% of the elements greater than 80µm are between 0.2 and 2mm.

I.4.2.3.3. End sand:

More than 75% of elements greater than 80 µm, are less than 0.5mm. These sands must be significantly corrected to acquire properties comparable to those of serious.^[7]

I.4.2.4. Finesse module (FM):

The fineness module (FM) is an important feature especially when it comes to sands. A good concrete sand must have a fineness modulus (FM) between 2.2 and 2.8; below, the sand has a majority of fine and very fine elements, which requires an increase in the water dosage; above, the sand lacks fineness and the concrete loses workability.^[7]

French Standard [FSP18-540]

The fineness modulus is equal to 1/100th of the sum of the cumulative refusals expressed in percentages on sieves of the following series: 0.16 - 0.315 - 0.63 - 1.25 - 2.5 - 5 mm.

$$M_{Finesse} = \sum \frac{(Refuscumulésdetamis[(5,2.5,1.25,0.63,0.315,et 0.16)])}{100} \quad (1.6)$$

- For $1.8 < M_f < 2.2$, sand should be used if ease of use is particularly sought at the probable expense of strength.

- For $2.2 < M_f < 2.8$ sand should be used if satisfactory workability and good resistance are sought with limited risks of segregation.
- For $2.8 < M_f < 3.2$ sand should be used if high strengths are sought at the expense of workability and with risks of segregation.
- For $M_f > 3.2$, the sand must be rejected.

Table. I.2: Classification of sands according to fineness modulus values

Sand	fineness modulus	Cumulative rejection on 0.633 sieves in %
Big	3.4 to 5.2	50 to 75
Medium	2.5 to 1.9	35 to 50
Fine	2.0 to 1.5	20 to 35

I.4.2.5. Sand equivalent according to standard (NA454)^[13]

The sands used in different areas are not all clean, they contain a more or less significant proportion of harmful fine clays that can reduce Material quality

This relative proportion of impurity in the able can be determined through the cleanliness test called "sand equivalent". This test consists in flocculating, under standardized conditions of time and agitation, the impurities of the sand.

This test can be carried out by two types of measurement:

- Measuring with a measuring ruler (ESV).
- Piston measurement (ESP).

$$ESV = \frac{h_2}{h_1} * 100\%$$

(1.7)

$$ESP = \frac{h'_2}{h_1} * 100\%$$

(1.7)

Table. I.3: Recommended value for sand equivalent

E.S.V	E.S.P	Property type and quality:
< 65	< 60 years	clay sand; to be discarded for quality concretes
$65 \leq E_{sv} < 75$	$60 \leq E_{sp} < 70$	slightly clayey sand; acceptable for common quality concretes
$75 \leq E_{sv} < 85$	$70 \leq E_{sp} < 80$	clean sand with a low percentage of fine clay; ideal for quality concretes.
≥ 85	≥ 80	very clean sand: almost total absence of fine clay

I.4.3. Cement:

The usual cements are also called hydraulic binders because they have the property of hydrating in the presence of water and because this hydration transforms the binder paste, which has a more or less fluid consistency, in a practically water-insoluble solid.

Cement, a powder sold in bags or in bulk, before mixing with water; cement paste, at the time of mixing the cement with water; hydrated cement or cement paste hardened when the mixture of water + cement has solidified.^[10]

I.4.3.1. The constituents of cement ^[7]

I.4.3.1.1. Clinker manufacturing

The basic compound of cements is a mixture of lime provided by limestone rocks and alumina, silica and iron oxide provided by clays. Limestone and clays are extracted from quarries, then crushed, homogenized, heated to high temperature (1450°C) in a furnace. The product obtained after rapid cooling (quenching) is Portland clinker. The clinker, to which some percentage of gypsum is added, is then finely ground to obtain a powder with an absolute density ranging from 3.0 to 3.2 kg/dm³.

I.4.3.2. Other Constituents of Cements

They modify the properties of cement thanks to their chemical or physical characteristics. Due to their nature, they also make it possible to lower the cost price.

- A. Granulated blast furnace slag (S):** It is obtained by rapid cooling of slag from the smelting of iron ore in a blast furnace. Slag has hydraulic properties.
- B. Natural pozzolanas (Z):** These are rocks of volcanic or sedimentary origin with an appropriate composition, or thermally activated clays and shales. Pozzolanas do not have hydraulic properties, but in the presence of the lime released by the clinker during hydration, they form stable hydrates: they are said to have pozzolanic properties.
- C. Fly ash (V or W):** They come from the dedusting of combustion gases from coal-fired power plants. We distinguish: Siliceous fly ash (V) which has pozzolanic properties; Calcium fly ash (W) which has hydraulic and sometimes pozzolanic properties.
- D. Calcined shales (T):** These are shales heated to a temperature of 800°C in a special furnace. Finely ground, they have strong hydraulic properties and also pozzolanic.
- E. Limestone (L):** They must consist of at least 75% CaCO_3 .
- F. Silica fumes (D):** From the silicon and alloys industry. They have pozzolanic properties
- G. Fillers(F):** These are secondary constituents and do not exceed 5% in the composition of the cements. These are natural or artificial mineral materials that act by their particle size on the physical properties of the binders (workability, water retention capacity).

I.4.3.3. Classification of cements:

I.4.3.3.1. Classification according to their composition: standard NFP15-3

Table. I.4: The different cements and the mass proportions of their constituents.
Components marked with a star are secondary (less than 5%)

	Portland cements	Portland cement compound		Portland-blast furnace cement 35 to 80			pozzolanic cement		Slag and ash cement	
	CPA-CEM I	CPJ-CEM II/A	CPJ-CEM II/B	C HF-CEM III/A	C HF-CEM III/B	C LK-CEM III/C	CP Z-CEM IV/A	CP Z-CEM IV/B	C LC-CEM V/A	C LC-CEM V/B
Clinker (K)	≥ 95%	≥ 80% ≤ 94%	≥ 65% ≤ 79%	≥ 35% ≤ 64%	≥ 20% ≤ 34%	≥ 05% ≤ 19%	≥ 65% ≤ 90%	≥ 45% ≤ 64%	≥ 40% ≤ 64%	≥ 20% ≤ 39%
Slag (S)	-	06% ≤	21% ≤	≥ 36% ≤ 65%	≥ 66% ≤ 80%	≥ 81% ≤ 95%	-	-	≥ 18% ≤ 30%	≥ 31% ≤ 50%
Pouzzolana (Z)	-	total	total	-	-	-	10% ≤ total	36% ≤ total	18% ≤ total	31% ≤ total
Siliceous ash (V)	-	≤ 20%	≤ 35%	-	-	-	≤ 35%	≤ 55%	≤ 30%	≤ 50%
Silica fume	-	(Silica fume ≤ 10%)		-	-	-	(Fume ≤ 10%)	(Fume ≤ 10%)	-	-
Calcium Ash (W)	-			-	-	-	-	-	-	-
Shale (T)	-			-	-	-	-	-	-	-
Limestone (L)	-			-	-	-	-	-	-	-
Fillers (F)	-	-	-	-	-	-	-	-	-	-

I.4.3.4. Classification according to their resistance:

Three classes are defined according to the normal resistance at 28 days; subclasses are associated with the 3 main classes to designate cements whose resistance to young age are high.

The classes must comply with the specifications indicated in (Table 2.4) below. The values in brackets are guaranteed values when they can be less than the specified values.^[7]

Table. I.5: Classes according to normal resistance at 28 days

	<i>Resistance Compression strength (MPa)</i>		<i>28 day withdrawal</i>	<i>initial set</i>	<i>Stability</i>
	<i>Standard EN 196-1</i>		<i>standard</i>	<i>standard</i>	<i>standard</i>
	<i>young</i>	<i>28 days</i>	<i>P 15</i>	<i>*196*3#</i>	<i>*196*3#</i>
<i>Class</i>	<i>2 days</i> <i>7 days</i>	<i>min.</i> <i>max.</i>	<i>(m/m)</i>	<i>(min.)</i>	<i>(mm)</i>
32.5	(17.5)	$\geq$ 32.5 (30) 5.	800	90	≤ 10
32.5 R	$\geq$ 13.5 (12)	$\geq$ 32.5 (30) 5.	$\leq 1,000$	90	≤ 10
42.5	$\geq$ 12.5 (10)	$\geq$ 42.5 (40) 5.	$\leq 1,000$	≥ 60	≤ 10
42.5 R	20 (18)	$\geq$ 42.5 (40) 5.	$\leq 1,000$	≥ 60	≤ 10
52.5	20 (18)	$\geq$ 52.5 (50)		≥ 60	≤ 10
52.5 R	30 (10)	$\geq$ 52.5 (50)		≥ 60	≤ 10

I.4.4. Mixing water:

It must comply with standard NF P 18-303."Spoiling" is the irreversible operation of water to cement. This operation is continued by kneading. Mixing water is the total amount of water that is used to make concrete. The final strength of a concrete depends on the W/C ratio of the mixture.

Not all water can be used to spoil concrete because it contains, in some cases, an excess of impurities that deteriorates the properties of concrete, including physical and mechanical properties (grip and strength), aesthetic properties (stains, efflorescences), durability (corrosion of reinforcements, stability of concrete).

These impurities, possibly contained in the mixing water, are either chemical compounds that can be active against cement, aggregates or reinforcements, or suspended particles that, because of their quantity or quality, are undesirable[14].

I.5. Adjuvants:

Added in low quality (less than 5% of the mass of the cements), the admixtures are becoming common ingredients in the manufacture of concretes. The standards of the **NF EN934-2 series** finish the different types of adjuvants.

I.5.1.1. Superplasticizers:

Superplasticizers have the property of deflocculating fine particles and cement grains and improving their distribution in the cement matrix. They also make it possible to remove the shear threshold in the cement paste in the fresh state. Thus, HSCs, although having a viscous and sticky appearance, flow easily. They are generally dosed between 1 and 3% of the cement mass.

During the formulation study, the accounting between the cement and the admixtures should be checked in order to maintain satisfactory workability throughout the concrete installation period [15].

I.5.1.2. Areas of use of super plasticizers

Super plasticizers are used in the following cases: [15]

- ❖ Concrete with compactness, and therefore durability;
- ❖ High-performance
- ❖ Self-adhesive concretes;

I.5.2. Mineral additions:

Different mineral additions can be added to the concrete, substituting or not a part of the cement, in order to improve some of its properties or to give it particular properties. These are finely divided materials among which we mention fillers, silica fume, fly ash and blast furnace slag that come mainly from industry. These fines have several advantages in the industry and the formulation of concert [16].

I.5.2.1. Silica fumes (EN 13 263-1 and NF P 18-502):

Also called "silica fumes" or "silica dust" or "microsilica", silica fumes are a by-product of silicon electrometallurgy and fouling.

A furnace is charged with quartz, coal and sometimes metal chips. The whole is brought to a very high temperature (1500-2000°C) by electric arcs. We obtain on the one hand liquid silicon and on the other hand dust-laden gases, some of which oxidize in the open

air to give silica fumes.

As industrial by-products, their nature is not controlled during fabrication. Their physico-chemical characteristics can be quite dispersed, not only from one plant to another but also within a manufacturing unit:

Silica fume is a highly variable material.

I.5.2.2. Areas of application (NFP Standard 18-502)

- ❖ High-Strength concretes;
- ❖ Highways, airport runways;
- ❖ Works of art, hydraulic works;
- ❖ Highly demanded concrete;
- ❖ Concrete subject to impacts and shocks;
- ❖ Concrete subjected to aggressive environments;
- ❖ Industrial Flooring
- ❖ Silos

I.6. Methods for formulating BHPs:

I.6.1. Dreux – Gorisse method:

The method of G. Dreux and L. Gorisse (1970) brings together the different methods of the time (Valette, Faury, Joisel, etc.) and deduces a practical and simplified method

the formulation adapted to the materials used even today, especially HSCs with some clean adjustments. This method is based on obtaining a continuous granulometric curve making it possible to produce a granular skeleton as dense as possible, and to optimize the cement and water dosage of ordinary concretes [17].

The reference granular curve is expressed in semi-logarithmic scale (scale of particle size analyses), and the breaking point is defined by:

- ❖ Its abscissa: $D_{\max}/2$ if $D_{\max} < 25$ mm and $(D_{\max}-5 \text{ mm})/2$ if $D_{\max} > 25$ mm, and its ordinate: $Y = 50 - D_{\max} + K + K_s$.

With K a granular arrangement corrector term taking into account the dosage of fines (cement and fillers), the angularity of the aggregates and the clamping power; K_s a function of the sand fineness modulus [18]

I.6.2. Debaron – Lesage method:

The classic approach adopted in France is the Baron-Lesage method drawn from experimentation and developed at the LCPC in the 1980s.

This practical method is based on tests with the LCPC maneuverability meter and makes it possible with this tool to determine the maximum maneuverability of the concrete according to the ratio of sand to gravel (S/G). It has the advantage of leading to concretes that present minimal risks of segregation [17].

Baron's theory - Lesage is based on the following hypotheses that have been verified by experiment (Rossi, 1998):

- For a fixed W/C ratio, the most manageable concrete is the one with the most compact granular skeleton;
- The S/G ratio corresponding to this optimum compactness is independent of the quantity of cement paste [17]

I.6.3. LARRAD method:

Theoretical models have the major advantage of reducing the number of batches carried out in the laboratory. The CSM Compressible Stacking Model was developed by Sedran and de Larrard. The advantage of this model is that it mathematically describes a granular stack taking into account the granular skeleton as a whole, from micrometric particles to centimetric particles, while relying on the notions of virtual compactities. It aims to predict the compactness of a mixture with several granular classes, based on the characteristics of the grains that make it up (shape, granular distribution, compactness of the one-dimensional slices) and for an energy of installation of the granular stack described by an index representative of its degree of tightening, reflecting the energy provided during the installation. This optimization method has the advantage of taking into consideration the particle size, their shape and the interaction between the grains. This model has been successfully used for the formulation of ordinary, high-performance and self-leveling concrete mix. The René-LCPC software was developed as a result of this work and programs the MEC on the basis of granular optimization. It predicts plastic viscosity, shear threshold, cone sag and different properties of concrete (strength, delayed deformations, *etc.*) from its composition and granular model. This makes it possible to evaluate the importance of a formulation parameter on the performance of concrete [17].

I.6.4. Sherbrooke's method:

The formulation method developed at the University of Sherbrooke makes it possible to formulate a HSC without entrained air; it can also be used to formulate a HSC with entrained air provided that account is taken of the reduction in compressive strength due to the presence of the network of air bubbles contained in the concrete [18].

This very simple method follows the same approach as the ACI 211-I standard. it is a combination of empirical results and calculation based on the absolute volumes method. The amount of water contained in the super plasticizer is considered part of the amount of mixing water [18].

The formulation procedure begins with the choice of five particular characteristics of the BHP or the materials used:[18]

- 1) The water/binder ratio;
- 2) Water dosage;
- 3) The dosage of super plasticizer;
- 4) Dosing in large aggregates;
- 5) Air content

I.7. Characteristics of HSCs:

I.7.1. Physical characteristics:

I.7.1.1. Sustainability:

Given the denser pore structure of high-performance concrete, this material shows better behavior against aggression mechanisms. Most degradation processes are indeed caused by the entry of aggressive substances, such as chlorides, carbon dioxide, acids, etc. If the penetration of these substances into the concrete is hindered, as in the case of HSC, the related degradation processes can obviously only occur much later. In any case, it is always necessary to ensure the purity of the constituent elements of the concrete, in order to avoid any aggression

by internal mechanisms (presence of sulphates, alkalis, reactive aggregates, etc.) [19].

I.7.1.2. Workability

Maneuverability (workability) can be defined as the ease of placing concrete without defects. Workability is not a measurable physical quantity, it is the result of several factors.

There are many trials and tests. The test applied here is that of collapse at the Abrams cone (NF P 18-541) [20].

I.7.1.3. Porosity:

When the anhydrous silicates of cement grains come into contact with water, their hydration always begins with a solution. In other words, the liquid phase saturates with different ions that then combine to form the different hydration products that gradually occupy part of the space initially filled with water. As hydration develops and the size of the capillary pores decreases, the movements of the water in the system become more and more difficult, so that the hydration of the large cement particles is rather by diffusion.

Regardless of the time during the hydration reaction, spaces not filled with solid products (hydrates and anhydrous cement particles) can be considered as voids or capillary pores [21]. The dimensions and volume of the capillary pores are the main parameters that govern the physical and mechanical properties of concrete.

The porosity is essentially a function of the W/C ratio of the concrete. It has been shown that for a given concrete, the only reduction in the W/C ratio from 0.5 to 0.22, reduced by a factor of 3 total capillary pore volume.

The addition of slag or fly ash does not change the total porosity but leads to a general decrease in pore size [22]. The addition of ultrafine and in particular silica fume results in a reduction in porosity and a characteristic decrease in pores.

I.7.1.4. Permeability:

The permeability is characterized by the value of the transport flow of fluids and gases (water, chloride, sulphates, oxygen, etc.) through capillary pores and cracks in the concrete [23].

Because of their great compactness, BHPs are waterproof. This fact can be seen when breaking concrete samples kept for a year in water, we find that the core of the test piece is absolutely dry. This impermeability can also be explained by the presence of many water-hungry unhydrated cement particles that stop the progression of water towards the inside of the concrete while making it even more impermeable [24].

I.7.2. Mechanical specifications:

I.7.2.1. Compressive strength:

The compressive strength of concretes is the most appreciated property among builders. The compressive strength of HSCs is higher than that of conventional concretes. In some parts of the world, a concrete is considered high performance when its strength exceeds 60 MPa.

In Algeria, it is accepted that as soon as the resistance exceeds 40 MPa, concrete can be considered high performance [25].

If it is desired to manufacture workable concretes with ordinary aggregates, it will be necessary to limit, in the current state of technology, to values between 100 and 120 MPa in average resistance at 28 days. One explanation for this increase in resistance is due to the accelerating role of silica fume, according to Fret's new law expressed by:

$$f_{c28} = \frac{K_g}{\left[1 + \frac{3,4 E/C}{1,4 - 0,4 \exp(-\frac{115}{C})} \right]^2}$$

Where:

- f_{c28} : the average compressive strength of concrete at 28 days.
- E, C and S: the respective weight of water, cement and silica fume per cubic meter of concrete.
- K_g : parameter depending on the quality of the aggregates (for common aggregates the K_g value = 4.91).

Figure (I-4) confirms the information provided by the Fret law about the influence of time and the W/C ratio on the compressive strength of concretes.

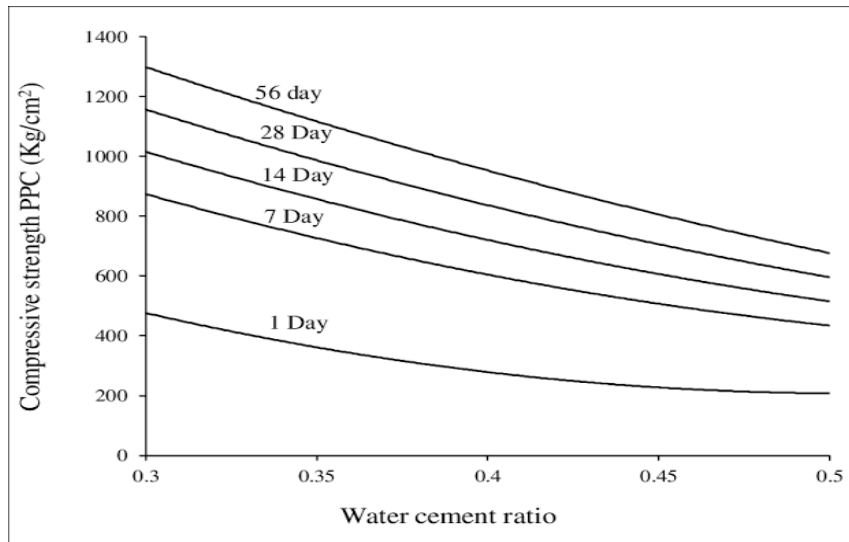


Figure. I.4: Influence of the W/C ratio on the compressive strength of concrete.

I.7.2.2. Bending tensile strength:

The bending strength increases significantly with respect to the compressive strength; the relationship between the compressive strength and the tensile strength is of the order of 1/10 to 1/13, or 0.10 to 0.077; but when the compressive strength is of the order of 100 MPa, the value of the ratio (f_t/f_c) is much smaller, of the order of 1/20.

The densification of the matrix and the paste-aggregate interface is at the origin of the improvement in tensile strength. During the splitting tests, the fracture face is systematically trans granular (even with siliceous aggregates), which shows the mechanical homogeneity of the material

I.7.2.3. Tensile strength:

As in the case of compressive strength, it was established and verified that the tensile strength of the HSCs increased linearly as a function of the compactness of the hardened cement paste [26]. Numerous studies have shown a correlation between compressive strength and tensile strength. In particular, Pedeches who during a study on HSCs based on silica fume showed that all the points (R_c and R_t) were above the curve representing the relationship adopted by the regulations for reinforced concrete [27] and prestressed concrete [28]:

$$R_t = 0.6 + 0.06 R_c$$

He proposed the following relationship for compressive strengths between 30 and 130 MPa

$$R_t = 5.5 + 0.027 R_c$$

Another model had already been proposed by Ahmed for compressive strengths greater than 84 MPa [29]:

$$R_t = 0.44 R_c^{2/3}$$

I.7.3. Elastic characteristics:

I.7.3.1. Elastic modulus:

The modulus of elasticity of HSCs is higher than that of traditional concretes [19].

BAEL rules provide an expression that evaluates the value of the module

E_i , depending on the compressive strength by the formula:

$$E_{ij} = 11000.f_{cj}^{1/3}$$

I.7.3.2. Withdrawal:

The total shrinkage of HSC is broadly identical to that of a traditional concrete but with different kinetics (it occurs earlier and develops mainly during the first few days after pouring). The desiccation shrinkage in the cured state is lower given the low water dosage. The endogenous (or self-drying) shrinkage, given the fineness of the microstructure and the sharp reduction in the W/C ratio, is a higher coefficient (150 to 250×10^{-6}) for a BHP than for a traditional concrete (60×10^{-6}). The lower the E/C ratio, the earlier and higher the self-discharge withdrawal [05].

I.7.3.3. Creep:

Clean creep kinetics are very fast (creep is accelerated and manifests itself from the young ages of concrete) and stabilizes faster. Desiccation creep is very low.

The higher the compressive strength, the lower the creep.

In the prestressed structure, the use of HSC makes it possible to reduce the prestressing losses associated with the delayed deformations of the concrete. This low creep makes it possible to increase the effectiveness of the prestressing and to facilitate the geometric control of the structures.

The use of HSC with silica fume therefore leads to reductions in delayed deformations and lower force redistributions [03].

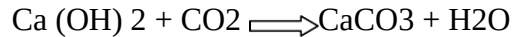
I.8. More Properties:

HSCs have a lower creep (delayed deformation under permanent loading) than traditional concretes.

I.8.1. Carbonatation:

It is a reaction between carbon dioxide (CO₂) existing either in the gas phase, or as a result of solubility in water (rainwater) with lime (Ca(OH)₂) released during the hydration

of dicalcium (C2S) and tricalcium (C3S) silicates to form calcium carbonate (CaCO₃) (also called calcite).



This reaction is not in itself pathological and should be considered as a normal evolution of concrete. However, it gradually consumes the alkalinity reserve of the lime-saturated medium, which has an initial pH of between 12 and 13, and evolves towards neutrality (pH ~ 9). As a result, alkalinity is no longer able to maintain the passivity of the oxide film. Such a situation considerably increases the vulnerability of the reinforcements to corrosion phenomena, especially if aggravating factors (salts, chlorides, water, etc.) are present. Atmospheric carbonation degrades reinforced concretes and is mainly responsible for exposing its steel reinforcements. Carbonation of concrete leads to strength problems on reinforced concrete structures. The steel bars, supposed to guarantee this resistance, swell under the effect of corrosion and burst the concrete coating, the steels are then exposed [19].

I.8.2. Impermeability:

Their low capillary porosity gives HSCs a very low permeability[20].

I.8.3. Resistance to chemical:

The low permeability of HSCs gives them good resistance to the penetration and transfer into the concrete mass of aggressive agents in the gaseous or liquid phase (sea water, sulphated water, acid solutions, carbon dioxide, etc.)[20].

I.8.4. Freeze/Thaw Attack Outfits:

Properly formulated HSCs are resistant to freeze/thaw cycles due to their high compactness and high mechanical strength [30].

I.8.5. Chloride ion migration:

The resistance of HSCs to chloride ion migration is higher than that of common concretes, thanks to its denser microstructure [20].

I.9. Benefits:

I.9.1. Fresh state:

- ❖ Its fluidity facilitates implementation, both on site and in a prefabrication plant;
- ❖ Its good stability, guaranteeing the absence of segregation;
- ❖ Its low viscosity allows pumping over long distances;

- ❖ Its high resistance at a young age promotes the optimization of the cycles of formwork removal, shoring removal, implementation of possible prestressing, handling and transport of prefabricated elements [30].

I.9.2. Hardened state:

- ❖ Its high compressive strength makes it possible, for the same design, to reduce the bulk of the structural elements or, for identical sections, to increase their bearing capacities (loads, bearing surfaces);
- ❖ Its higher modulus of elasticity reduces the deformability of structures (increased stiffness), in particular deflections, and improves the aerodynamic stability of structures;
- ❖ Its creep is both lower and shorter, simplifying the development of the interfaces with the second work and allowing the reduction of the initial tension values of the possible prestress;
- ❖ Its low porosity, hence its increased resistance to actions due to the environment (rain, sea water, sulphated water, chlorides and frost) and therefore its durability[30];

I.9.3. Other benefits:

- ❖ Improved durability in aggressive environments (high resistance to penetration of aggressive agents and freeze/thaw cycles, reduction of alkali-silica reaction);
- ❖ Speed of formwork rotation (high resistance at a young age);
- ❖ Reduction of loading times for structures (accelerated prestressing);
- ❖ Decrease in reinforcement sections and densities and increase in spans (High final strength);
- ❖ Easy implementation thanks to fluidity (heavily scraped areas, long-distance pumping, Improved siding). This feature facilitates concrete processing, even in areas with high reinforcement density;
- ❖ Elevation of the modulus of elasticity with reduction of creep;
- ❖ Decreased shrinkage for crack limitation;
- ❖ Increased abrasion resistance;
- ❖ Strengthening of steel/concrete adhesion;
- ❖ High compressive strength, making it possible to reduce the cross-sections of the concrete elements [04];
- ❖ A high amount of cement greater than 350 kg/m³;

- ❖ Lower E/C through the use of high water-reducing super plasticizers;
- ❖ Use of fines with a pozzolanic effect (in particular silica fumes) at about 10% of the weight of cement;

I.10. Fields of application:

High-strength concrete (HSC), which has a high durability, ensures a high level of structural performance, compared to the traditionally used normal-strength concrete (BRN). Previously used for bridges, offshore construction and infrastructure, it is increasingly used in high-rise buildings, especially for poles. Its greater compressive strength makes it possible to produce posts of reduced diameter, which reduces bulk [31].

I.11. Conclusion

Although the different characteristics of HSCs offer several advantages over usual concretes, there is still room for improvement, HSCs, like all other materials, still have weak points. In addition, there are and there will always be many cases where a concrete of 20 to 30 MPa will be the ideal concrete to meet particular needs: the development of HSCs will not eliminate the use of usual concretes

CHAPITRE
II
CHARACTERISTICS
OF MATERIALS
USED

II.1. Introduction:

In this chapter, we will present the characteristics of the materials used to make concrete.

The materials used are:

- ❖ The fine sand of the DJAMAA region;
- ❖ Gravel 3/8, 8/16 and 16/25 mm;
- ❖ Portland composite cement CRS- CEM-I/A 42.5;
- ❖ Drinking water from the laboratory (civil engineering laboratory);
- ❖ Super plasticizer with a dosage of 1.5% of the weight of cement;
- ❖ Silica fume 5% by weight of cement;

II.2. DJAMAA sand dunes:

The basic sand of our research comes from the outskirts of El Oued Souf (DJAMAA).

II.2.1. Physical characteristics of the sands used:

The sand was subjected to several tests at the Civil Engineering Laboratory of the University of M'sila.

II.2.1.1. Absolute density:

It is the mass of the unit of volume of the substance, that is to say the ratio between its mass and its absolute volume. The aggregates studied gave densities (Absolute) which meet the specifications of standard **NF P18-555**.

Operating mode:

The absolute density of the sand is determined using the **1000** ml capacity container. **03** mass samples are taken **300g**.

The sample is placed in the **1000** ml capacity container and **300** ml of previously prepared water is poured into the **2nd** graduated container, then the contents are carefully mixed to expel the air that exists there. After this operation, the final volume occupied by the sand-water mixture is determined. Let (V) be this volume.

Knowing that the volume of poured water is 300 ml, it would be easy to determine the volume occupied by sand alone.

Volume of sand: $V_1 = V - 300$ (ml)

Masse of sand: $M = 300$ g.

$$\rho_{abs} = \frac{M}{(V_2 - V_1)}$$

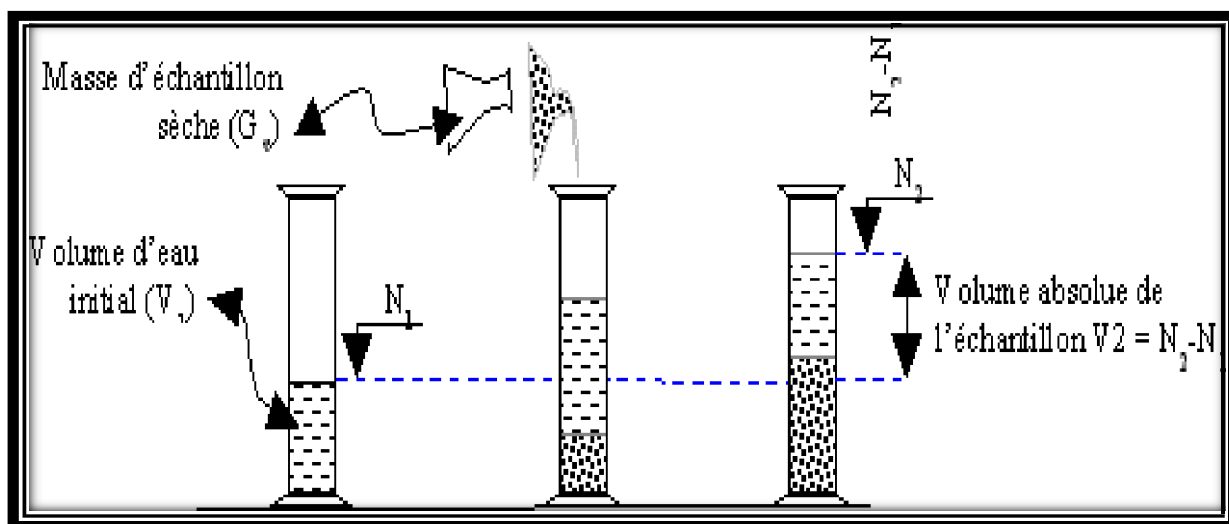


Figure II.1: absolute density of DJAMAA sand

Table II.1: absolute density of DJAMAA sand

Test No.	M_1 (g)	V_1 (cm ³)	V_2 (cm ³)	ρ (g/cm ³)	ρ (g/cm ³) avg
1	300	416	300	2.58	2.55
2	300	416	295	2.43	
3	300	416	302	2.64	

- ❖ M_1 : mass of the sand.
- ❖ V_2 : volume of water + sand.

II.2.1.2. Apparent density:

The aggregates studied gave (Apparent) densities that meet the specifications of standard NF P18-555.

Operating mode:

- The apparent density of the sand is determined using a standardized funnel with a capacity of 2 to 2.5 liters.
- The funnel is filled with dry sand.
- The empty container M_1 is weighed.
- The container is placed under the funnel at a distance of 10 to 15 cm and filled with sand.
- Once the container is filled, the surface of the sand is levelled and everything is weighed. Let M_2 be this weight.
- Container volume $V_r=900\text{cm}^3$.

$$\rho_{app} = \frac{M_2 - M_1}{V}$$

The results obtained are given in the following table.

Table II.2: apparent density of DJAMAA sand.

Test	M ₁ (g)	M ₂ (g)	App (g/cm ³)	App avg (g/cm ³)
01	117.4	1404	1 430	1,451
02	117.4	1431	1,460	
03	117.4	1435	1 464	

❖ **M₁**: Mass of the empty container.

❖ **M₂**: Mass of the container plus sand.

II.2.1.3. Porosity (NF P18-554):

This is the volume of voids between the grains of sand. The porosity can be determined by the following formula:

$$\rho_{PL}(\%) = 1 - \frac{[\rho_{app}]}{[\rho_{abs}]} \times 100$$

II.2.1.4. Compactness:

The compactness of a material is a proportion of its volume actually occupied by the solid matter that constitutes it, that is to say the ratio of the absolute volume of the grains to the apparent volume of the material.

The compactness given by the formula: $c = \frac{\rho_{app}}{\rho_{abs}} = 100 - \rho$

II.2.1.5. Index of voids:

The void index is the ratio between the volume of the void and the volume of solid.

With P as a percentage (%): $e = \frac{P}{100-p} = \frac{V_V}{V_S}$

The results for porosity, compactness and vacuum index are grouped in the following tables:

Table II.3: porosity, compactness and void index for DJAMAA sand

Porosity P (%)	Compactness C (%)	Index of voids.
43.09	56.91	0.75

II.2.1.6. Sand equivalent NF P18-598:

Evaluate the harmfulness of the fines contained in the sand. The principle of the test consists in flocculating the fines contained in the sand by means of a suitable washing solution. The results obtained are presented in the following table:

Operating mode:

- Sieve a quantity of sand (mass greater than **500 g**).
- Take a **120 g** weighing.
- Fill the test tube with solution until the first mark (**10cm**) is reached.
- Using the funnel, pour the test sample (**120g**) into the test tube and tap hard several times with the palm of the hand to expel all air bubbles and promote the wetting of the sample.
- Let sit for 10 minutes.
- Close the test piece with the rubber stopper and print **90** cycles of **20cm** of horizontal course in **30** seconds by hand using a mechanical agitator.
- Then remove the cap, rinse it with the solution the panel above the test tube, then rinse the walls of the latter.
- Lower the washer tube into the test tube, roll it between the thumb and forefinger by slowly rotating the tube and the test tube and at the same time impart a slight prick to the tube. The purpose of this operation is to wash the sand and raise the fine and clayey elements. Carry out this operation until the solution boasts it reaches the 2nd mark. Then let stand for 20 minutes.

A /Visual Sand Equivalent (VSE):

- After 20 minutes of sand deposition, read the height h_1 of the upper level of the flocculants to the bottom of the test piece using a ruler.
- Also measure with the ruler the height h_2 between the upper level of the sedimentary part and the bottom of the specimen.

With:
$$ESV = \frac{h_2}{h_1} \times 100[\%]$$

- ❖ h_1 : clean sand + fine elements.
- ❖ h_2 : clean sand.

B /Piston sand equivalent (ESP):

- Insert the plunger into the test tube and allow it to descend gently until it rests on the sediment. At this moment, block the piston sleeve and take it out of the test tube.
- Insert the ruler into the notch of the piston until the zero abuts against the inner face of the piston head. Let h_2 be the height read and corresponding to the height of the sedimented part.

$$ESP = \frac{h'_2}{h_1} \times 100[\%]$$

With: h'_2 : The height of the sand

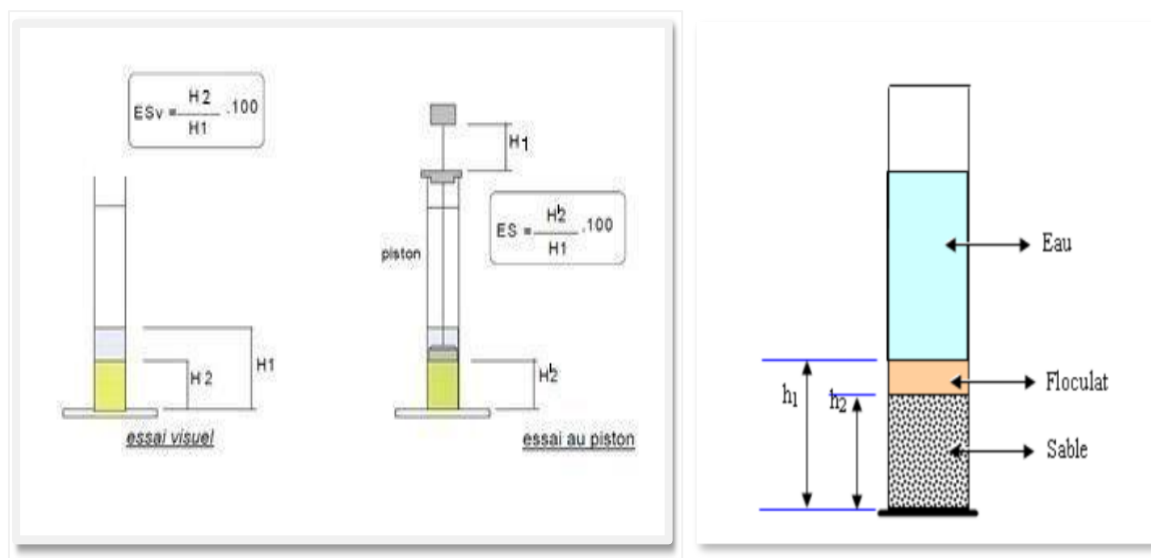


Figure II.2: the sand equivalent test [52].

Table III.6: DJAMAA sand equivalent

Sample tube	h_1 (cm)	h_2 (cm)	h'_1 (cm)	VES	PES
1	11.8	9.2	8.6	77.96	72 - 88
2	12.5	9.2	9	73 6.	72
3	12.4	9.2	9	74.19	72 04 58
Mean ES (%)		75.25		72.48	

For DJAMAA sand clean sand with a low percentage of clay flour is perfectly suitable for high quality concretes.

II.2.1.7. Moisture content NF P18-555:

Sand has the ability to retain a very large amount of water (it can reach 20 to 25% of its weight), if its humidity is between the limit of 0 to 3%, it is called cells

Operating mode:

- Weigh a sample of wet sand, or M_h its weight (**500 g**).
- Leave the sample in an oven at a temperature in the range of **105°C** to **110°C** for **24hours**.
- Weigh the sample again, i.e. M_s its weight.

The water content of the sand is: $W = \left(\frac{M_h - M_s}{M_h} \right) \times 100[\%]$

❖ M_h : Weight of wet sand in (g).

❖ M_s : Weight of dry sand in (g).

The results obtained are given in the following table.

Table II.5: water content of DJAMAA sand

Test No.	M_h (g)	M_s (g)	W (%)	W_{avg} (%)
1	500	498	0.28	0.42
2	500	498	0.34	
3	500	496	0.66	

II.2.1.8. Degree of water absorption NF P18-555:

It is the power of a material to absorb and retain water, it is defined as a percentage according to the following formula.

$$A = \left(\frac{M_2 - M_1}{M_1} \right) \times 100[\%]$$

❖ M_1 : The mass of the dry material in(g);

❖ M_2 : The mass of the material saturated with surface dry water

The results obtained are presented in the following table:

Table II.6: Degree of absorption of DJAMAA sand

Test	M ₁ (g)	M ₂ (g)	A (%)	A _{avg} (%)
1	500	512	2.4	2.46
2	500	513	2.78	
3	500	511	2.2	

II.2.1.9. Granulometry analysis:

Particle size analysis makes it possible to measure the dimensional distribution by weight of the Elements of a material, it comprises two operations:

1. Sieving :
2. Sedimentation

Operating mode:

- Take (2 kg) of material (dry sand).
- Weigh each sieve under vacuum to the nearest 1 g, i.e. m_i the mass of the sieve.
- Constitute a column of clean and dry sieves whose mesh opening is respectively:

Top to bottom: 5-2.5-1.25-0.63-0.315-0.125 and possibly 0.08mm. The column is capped by a bottom to collect the elements passing to the last sieve and a lid to prevent the dispersion of dust. We start by weighing the sieves and the bottom.

- Pour the material (dry sand) on the column and carefully fix it on the mechanical stirring machine, stirred for 5 minutes. Stop the agitator, then carefully separate the different sieves.
- Weigh each sieve separately to the nearest 1 g. Let M_i be the mass of the sieve (I) + the sand. The difference between M_i and m_i (sieve of larger mesh) corresponds to the partial rejection R_1 of the sieve 1.
- Resume the operation for the sieve immediately below.
- Add the rejection obtained on the sixth sieve to R_1 , i.e. R_2 the mass of the cumulative rejection of sieve 2 ($R_2 = R_1 + \text{Partial rejection on sieve}$).
- Continue the operation with the rest of the sieves to obtain the masses of the different cumulative rejections R_3 , R_4 , etc.

The cumulative sieve is given by the following relation: $T = 100 - R_c$

Where:

- T: Sieve in %
- RC: Cumulative refusals in %



Figure II.3: Sifter & sieves

Table II.7: Particle size analysis of DJAMAA sand

Mass of the sample under test: M =2000 g						
Mesh (mm)	Empty sieve (Kg)	Full sieve (Kg)	Refuse (Kg)	Cumulative refusals (Kg)	Cumulative refusals in (%)	Cumulative sieve (%)
5	0.856	0.857	0.001	0.001	0.05	99.95
2.5	0.752	0.778	0.026	0.027	1.35	98.65
1.25	0.653	0.751	0.098	0.125	6.25	93.75
0.63	0.621	1.659	1.038	1.163	58.15	41.85
0.315	0.561	1.135	0.574	1.737	86.85	13.15
0.160	0.519	0.733	0.214	1.951	97.55	2.45
0.08	0.507	0.551	0.044	1.995	99.75	0.25
Bottom	0.566	0.571	0.005	2	100	0

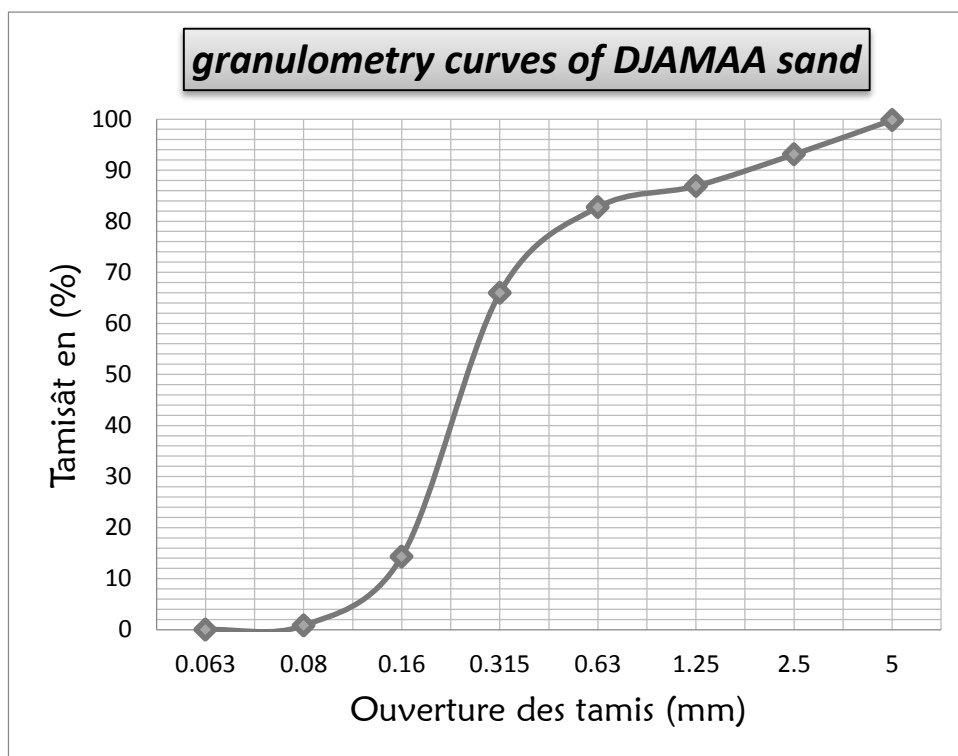


Figure II.4: granulometry curves of DJAMAA sand

II.2.1.10. Fineness modulus:

The fineness modulus is equal to 1/100 of the sum of the cumulative rejects expressed as percentages on the sieves of the following series: 0.16 - 0.315 - 0.63 - 1.25 - 2.5 – 5mm.

$$M_{Finesse} = \sum \frac{(cumulative refusals of tamis[(5,2.5,1.25,0.63,0.315,et 0.16)])}{100}$$

$$M_f = 2.528$$

Soviet standards specify sands as follows:

- Coarse sand $M_f > 2.5$
- Medium sand $2 < M_f < 2.5$
- Fine sand $1.5 < M_f < 2$
- Extremely fine sand $1 < M_f < 1.5$

Based on this classification, we find the following result:

✓ For DJAMAA sand: $1.5 < M_f < 2$: It is a **fine sand**.

II.3. Gravel:

In this section, we present the characteristics of the gravel used in not search.

II.3.1. Crushed gravel:

The basic rolled gravel of our research comes from: the outskirts of Oued MAITAR (BOUSAADA).

II.3.2. Granular classes:

Gravel fractions are:

- ❖ Fraction 3/8 mm;
- ❖ Fraction 8/16 mm;
- ❖ Fraction 16/25 mm;

II.3.3. Physical characteristics of the gravel used:

II.3.3.1. Apparent density:

The aggregates studied gave (apparent) densities that meet the specifications of standard NF EN 12620.

➤ Trial purpose

The purpose of this test is to determine the mass of a granular fraction when, for example, a concrete composition is produced. This parameter makes it possible, in particular, to determine the mass or volume of the gravel to obtain a concrete whose characteristics are imposed.

➤ Test procedure

In this test, the following steps are carried out: The sample is placed in the graduated container, and the container is weighed using a scale. Then we note the masses and volumes to calculate the density.

$$\rho_{app} = \frac{M_2 - M_1}{V}$$

- ❖ **M₁**: mass of the empty container.
- ❖ **M₂**: container + gravel

Table II.8: apparent density of gravel

Test		M ₁ (g)	M ₂ (g)	V (ml)	ρ _{savg} (g/ml)
3/8	1	1362.2	1247.2	900	1.4
	2	1363.7	1248.7	900	
	3	1365.6	1250.6	900	
8/16	1	1390.3	1275.3	900	1.41
	2	1384.5	1269.5	900	
	3	1379.3	1264.3	900	
16/25	1	1360.8	1245.8	900	1.39
	2	1361.2	1246.2	900	
	3	1365.8	1250.8	900	

II.3.3.2. Absolute density:

This test is governed by the NFP 18-301 standard; 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.

➤ Trial purpose

The purpose of this test is to determine the mass of a granular fraction when, for example, a concrete composition is produced. This parameter makes it possible, in particular, to determine the mass or volume of the various granular classes mixed to obtain a concrete whose characteristics are imposed.

In this work we used the graduated test tube method, it is simple, fast and uses common laboratory equipment.

➤ Operating mode:

- Fill a graduated test tube with a volume V₁ of water.
- Weigh a dry sample M of Gravel (about 300 g) and introduce it into the test tube, taking care to remove all air bubbles.
- Read the new V₂ volume.

$$\rho_{abs} = \frac{M}{(V_2 - V_1)}$$

❖ M₁ : mass of the gravel;

❖ V₂ : volume of water + gravel;

Table II.9: Absolute density of gravel

Test		M (g)	V ₁ (cm ³)	V ₂ (cm ³)	ρ avg (g/ml)
3/8	1	100	150	188	2.63
	2	100	150	188	
	3	100	150	188	
8/16	1	100	150	188	2.63
	2	100	150	188	
	3	100	150	188	
16/25	1	100	150	188	2.63
	2	100	150	188	
	3	100	150	188	

II.3.3.3. Porosity, compactness and void index:

This test was conducted from standard NF P18-554

➤ **Porosity:**

$$P\% = \left(1 - \frac{\rho_{app}}{\rho_{abs}}\right) \times 100$$

➤ **Compactness:**

$$C = \frac{\rho_{app}}{\rho_{abs}}$$

➤ **Void index:**

$$I = \frac{P}{C}$$

Table II.10: porosity, compactness and voids index.

Gravel fraction (mm)	Porosity (%)	Compactness (%)	The void index (%)
3/8	46.76	53.23	0.88
8/16	46.37	53.61	0.86
16/25	47.14	52.85	0.89

II.3.3.4. Degree of water absorption:

Measurements of water absorption by the aggregate were therefore carried out according to the procedure of standard [NF EN 1097-6, 2001].

$$A = \left(\frac{M_2 - M_1}{M_1}\right) \times 100[\%]$$

Table II.11: degree of water absorption from gravel.

Gravel	Test	M ₁ (g)	M ₂ (g)	A (%)	A _{avg} (%)
3/8	01	500	507.8	1.56	1.42
	02	500	507	1.4	
	03	500	506.5	1.3	
8/16	01	500	505	1	1.13
	02	500	505	1	
	03	500	507	1.4	
16/25	01	500	503	0.6	0.53
	02	500	501	0.2	
	03	500	504	0.8	

❖ M₁:mass of gravel

❖ M₂:mass of gravel

II.3.3.5. Water content:

$$W = \left(\frac{M_h - M_s}{M_h} \right) \times 100[\%]$$

Table II.12: Gravel moisture content

Gravel	Test	M _h (g)	M _s (g)	W (%)	W _{avg} (%)
3/8	01	500	494	1.2	1.13
	02	500	494	1.2	
	03	500	495	1	
8/16	01	500	497	0.6	0.66
	02	500	497	0.6	
	03	500	496	0.8	
16/25	01	500	499	0.2	0.33
	02	500	498	0.4	
	03	500	498	0.4	

II.3.3.6. Granulometry analysis:

The particle size analysis was carried out according to NA 2607.

TableIII.13: Particle size analysis of 3/8 mm gravel

Mass of the sample subjected to the test: M =1500 g						
Mesh (mm)	Empty sieve (g)	Full sieve (g)	Refuse (g)	Cumulative refusals (g)	Cumulative refusal (%)	Cumulative sieve (%)
8	638.2	641	2.4	2.4	0.16	99.81
6.3	638.6	784.9	146	148	9.89	90.11
5	625.2	1079.9	454	603.1	40.2	59.8
4	602.6	1224.7	622.1	1225	81.68	18.32
3.15	604.4	771	167	1392	92.81	7.16
Bottom	451.4	561.1	109.7	1500	100	0

Table III.14: particle size analysis of 8/16mm gravel.

Mass of the sample subjected to the test: M =3200 g						
Mesh (mm)	Empty sieve (g)	Full sieve (g)	Refuse (g)	Cumulative refusals (g)	Cumulative refusals in (%)	Cumulative sieve (%)
16	932	1125	193	193	6.031	93.969
12.5	891	1702	811	1004	31.375	68.625
10	957	2195	1238	2242	70.062	29.937
8	827	1581	754	2996	93.625	6.375
Bottom	561	768	207	3200	100	0

Table II.15: particle size analysis of 16/25 mm gravel.

Mass of the sample subjected to the test: M =3200 g						
Mesh (mm)	Empty sieve (g)	Full sieve (g)	Refuse (g)	Cumulative refusals (g)	Cumulative refusals in (%)	Cumulative sieve (%)
25	932	1125	193	193	6.031	93.969
20	891	1702	811	1004	31.375	68.625
16	957	2195	1238	2242	70.062	29.937
Bottom	561	768	207	3200	100	0

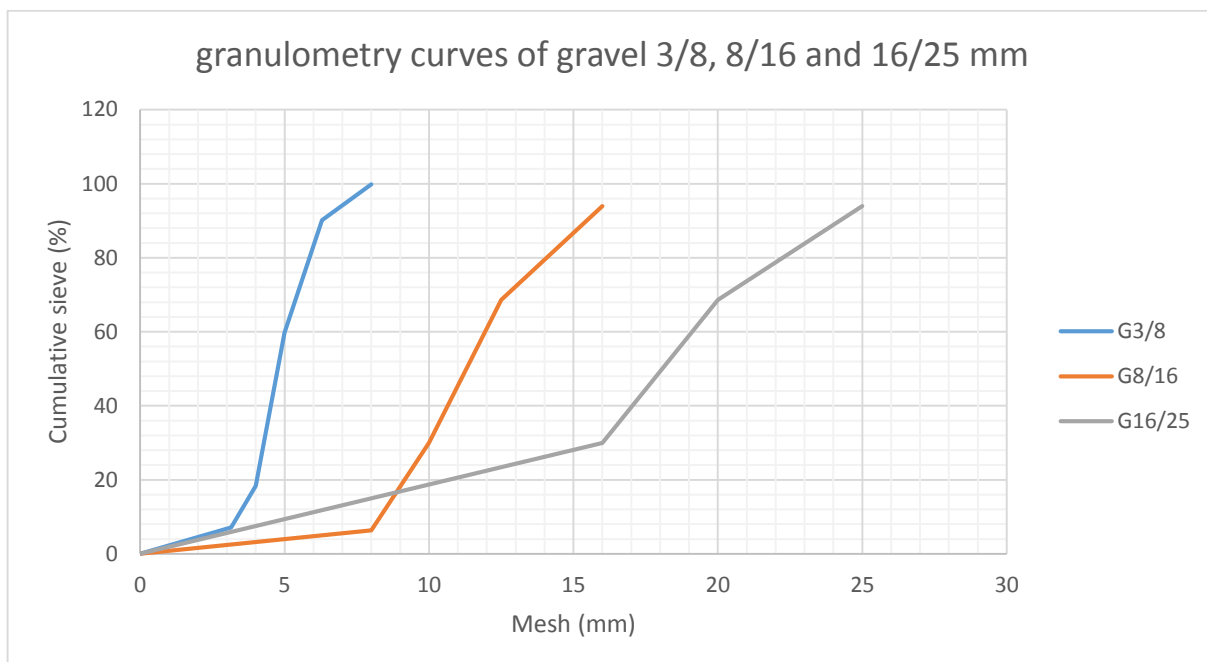


Figure II.5: granulometry curves of gravel 3/8, 8/16 and 16/25 mm

II.3.4. The mechanical characteristics of the gravel used:

These are important tests for road aggregates. Indeed, the repeated passage of vehicles leads to dulling, gradually polishing the aggregates and thus reducing the adhesion of the tires on the roadway.

These characteristics also make it possible to estimate the quality of the aggregates used in the manufacture of concretes.

II.3.4.1. Impact test (Los Angeles test) NFP18-573.

The results obtained are given in the following table.

Table II.16: Mechanical characteristics of gravel used

Gravel Fraction	Number of balls	M (kg)	m (kg)	Coef LA %
Gravel 3/8	7	5	1.13	22.6
Gravel 8/16	11	5	1.14	22.8
Gravel 16/25	12	5	1.02	20.4

❖ **M**: Dry mass of the sample;

❖ **m**: 1.6 mm screen rejection;

Classification:

A classification table has already been drawn. It allows you to classify rocks according

to the Los Angeles coefficient.

Table II.17: rock classification according to the LA coefficient

Coefficient LA	Rock material:
<20	Hard Very hard
20-25	Hard
25	Moderately hard
30	Put hard
40	Tender
> 50	Very tender

Comment:

The gravel used: it is a hard gravel.

II.3.4.2. Micro-deval test (NF P 18-576):

Measure the resistance to frictional wear between the grains of the same aggregate and an abrasive load (attrition wear) on a given granular class of a chippings.

The results obtained are given in the following table.

Table II.18: Micro-deval

Gravel Fraction	Mass of balls (Kg)	M (kg)	m (kg)	Coef Md %
Gravel 3/8	2	5	4.89	22
Gravel 8/16	2	5	4.91	18
Gravel 16/25	2	5	4.93	14

M: Dry mass of the sample;

m: mass of the sieve at 1.6 mm;

II.4. Cement:

The basic cement used in our research is a Class 42.5 Portland CRS-CEM-I/A cement from the M'sila cement plant.

II.4.1. Chemical and mineralogical analyses of the cement used [54]:

The information from these analyses is extracted from the technical data sheet of the M'sila cement plant.

II.4.1.1. Chemical analyses:

Table II.19: Chemical composition of

Chemical analyses	Value
Melting loss (%)	0.5 to 3
Sulphate content (%)	1 to 3
Magnesium oxide content Mgo (%)	1 2
Chloride content (%)	0.01 to 0.05 %

II.4.1.2. Mineralogical composition:

Table II.20: Cement composition

Cement composition	Value
C3A aluminate content	< 3.0%

II.4.1.3. Physical Popularities:

Table II.21: Physical properties of cement

Physical Popularities	Value
Normal Consistency	25 to 28
Finesse according to the blain method (cm ² /g) (NA231)	3200 to 3800
Withdrawal at 28 days (µm/m)	< 1000
Expansion	≤ 0,2
heat of hydration	< 270 d/g

II.4.1.4. Setting time at 20° (NA 230):

Table II.22: Setting time at 20°C of cement

Setting time at 20° (NA 230)	Value
Set start time (min)	>60
completion of setting	to 400

II.4.1.5. Compressive strength:

Table II.23: Cement Compression Resistance

Compressive strength	Value
2 days (MPa)	≥ 10
28 days (MPa)	42,5

II.5. The adjuvant: super plasticizer MEDAPLAST SP 40 [55]:

The super plasticizer MEDAPLAST SP 40 (high water reducer) is a concrete setting and hardening modifying admixtures.

II.5.1. Description:

The **MEDAPLAST SP 40** is a water-heightening superplasticizer that makes it possible to obtain very high quality concretes and mortars.

In addition to its main function as a superplasticizer, it significantly reduces the water content of concrete. The MEDAFLOW 30 does not have a retarding effect.

II.5.2. Dosage:

Recommended dosing range:

- ❖ 0.6% to 2.5% of the weight of cement, i.e. 0.5L to 2L per 100 kg of cement.
- ❖ The optimal dosage must be determined on site according to the type of concrete and the desired effects.

II.5.3. Features:

- ❖ Appearance.....Liquid
- ❖ Color Brown
- ❖ pH..... 8.2
- ❖ Density 1.20 ± 0.01
- ❖ Chlorine content.....< 1g/L
- ❖ Dry extract 40%

II.6. Mixing water NF EN 1008:

For the mixing of our concrete, we used tap water available at our university.

II.7. Conclusion:

In this chapter, the different physical, chemical and mechanical characteristics of the components have been established. The grain size curves of all grain classes are presented. It was important to define the normative part that the different mixtures must meet. The formulation method was developed and the calculation of the proportion of the constituents was made. We set a few parameters such as the water/cement ratio, the aggregate–sand ratio. The Abrams cone test allowed us to determine the consistency of the concretes studied. Compression and tensile bending tests are described. They will be used to obtain the compressive and tensile strength values of all the mixtures.

CHAPITRE
III
RESULTS
AND
DISCUSSIONS

III.1. Introduction:

The results of the tests will allow us to generate a set of data that will be used to validate the choice of specific granular classes. For this, the formulation of several concrete mixtures was developed. The study is done on the characteristics of aggregates, granular classes, the percentage of platelets and needles in our gravels and concretes.

III.2. Results of mixing different aggregates sizes (gravel 3/8, 8/16 and 16/25):

III.2.1. Combination 01: 2kg of mixing ($G_{3/8}$ with $G_{8/16}$)

a) Apparent density:

Table.III.1: Apparent density of mixing gravel ($G_{3/8}$ with $G_{8/16}$)

Test N°	$G_{3/8}$ (%)	$G_{8/16}$ (%)	$G_{16/25}$ (%)	V (cm ³)	M1 (g)	M2 (g)	M3 (g)	Moy (g)	App Density (g/cm ³)
1	10	90	0	1000	1226	1230.7	1243	1233.233	1.233233
2	20	80	0	1000	1256.5	1267.4	1261.3	1261.733	1.261733
3	30	70	0	1000	1310.8	1312	1313.9	1312.233	1.312233
4	40	60	0	1000	1300.3	1302.8	1305.1	1302.733	1.302733
5	50	50	0	1000	1292.5	1296.6	1300.1	1296.4	1.2964
6	60	40	0	1000	1317.4	1318.4	1303.7	1313.167	1.313167
7	70	30	0	1000	1276	1284.5	1274.5	1278.333	1.278333
8	80	20	0	1000	1285.2	1272.7	1280.4	1279.433	1.279433
9	90	10	0	1000	1275.8	1263.6	1266.2	1268.533	1.268533

With:

- **V:**
- **M1:** Mass 01 of mixing $G_{3/8}$ with $G_{8/16}$
- **M2:** Mass 02 of mixing $G_{3/8}$ with $G_{8/16}$
- **M3:** Mass 03 of mixing $G_{3/8}$ with $G_{8/16}$

b) Absolute density:

Table.III.2: Absolute density of mixing gravel ($G_{3/8}$ with $G_{8/16}$)

Test N°	$G_{3/8}$ (%)	$G_{8/16}$ (%)	$G_{16/25}$ (%)	V1 (cm ³)	V2 (cm ³)	V2-V1 (cm ³)	M (g)	Abs Density (g/cm ³)
1	10	90	0	150	188	38	100	2.631579
2	20	80	0	150	188	38	100	2.631579
3	30	70	0	150	188	38	100	2.631579
4	40	60	0	150	188	38	100	2.631579
5	50	50	0	150	188	38	100	2.631579
6	60	40	0	150	188	38	100	2.631579
7	70	30	0	150	188	38	100	2.631579
8	80	20	0	150	188	38	100	2.631579
9	90	10	0	150	188	38	100	2.631579

With:

- **V1:** Volume of water
- **V2:** Volume of water + gravel mixture
- **M:** Mass of gravel mixture

c) Porosity:

Table.III.3: Porosity of mixing gravel ($G_{3/8}$ with $G_{8/16}$)

Test N°	$G_{3/8}$ (%)	$G_{8/16}$ (%)	$G_{16/25}$ (%)	Abs Density (g/cm ³)	App Density (g/cm ³)	Porosity (%)
1	10	90	0	2.631579	1.233233	53.13713
2	20	80	0	2.631579	1.261733	52.05413
3	30	70	0	2.631579	1.312233	50.13513
4	40	60	0	2.631579	1.302733	50.49613
5	50	50	0	2.631579	1.2964	50.7368
6	60	40	0	2.631579	1.313167	50.09967
7	70	30	0	2.631579	1.278333	51.42333
8	80	20	0	2.631579	1.279433	51.38153
9	90	10	0	2.631579	1.268533	51.79573

III.2.2. Combination 02: 2kg of mixing ($G_{8/16}$ with $G_{16/25}$)

a) Apparent density:

Table.III.4: Apparent density of mixing gravel ($G_{8/16}$ with $G_{16/25}$)

Test N°	$G_{3/8}$ (%)	$G_{8/16}$ (%)	$G_{16/25}$ (%)	V (cm ³)	M1 (g)	M2 (g)	M3 (g)	Moy (g)	App Density (g/cm ³)
1	0	10	90	1000	1233.6	1241.2	1239.3	1238.033	1.238033
2	0	20	80	1000	1226.8	1220.2	1222.9	1223.3	1.2233
3	0	30	70	1000	1243.3	1228.4	1231	1234.233	1.234233
4	0	40	60	1000	1251.3	1257.4	1255.5	1254.733	1.254733
5	0	50	50	1000	1258.9	1258.6	1244.6	1254.033	1.254033
6	0	60	40	1000	1257.9	1263.2	1258.1	1259.733	1.259733
7	0	70	30	1000	1266.2	1261.6	1259.4	1262.4	1.2624
8	0	80	20	1000	1230	1225.3	1237.2	1230.833	1.230833
9	0	90	10	1000	1236.4	1224.9	1246.1	1235.8	1.2358

With:

- **V:** Volume of gravel mixture
- **M1:** Mass 01 of mixing $G_{8/16}$ with $G_{16/25}$
- **M2:** Mass 02 of mixing $G_{8/16}$ with $G_{16/25}$
- **M3:** Mass 03 of mixing $G_{8/16}$ with $G_{16/25}$
-

b) Absolute density:

Table.III.5: Absolute density of mixing gravel ($G_{3/8}$ with $G_{8/16}$)

Test N°	$G_{3/8}$ (%)	$G_{8/16}$ (%)	$G_{16/25}$ (%)	V1 (cm ³)	V2 (cm ³)	V2-V1 (cm ³)	M (g)	Abs Density (g/cm ³)
1	0	10	90	150	188	38	100	2.631579
2	0	20	80	150	188	38	100	2.631579
3	0	30	70	150	188	38	100	2.631579
4	0	40	60	150	188	38	100	2.631579
5	0	50	50	150	188	38	100	2.631579
6	0	60	40	150	188	38	100	2.631579
7	0	70	30	150	188	38	100	2.631579
8	0	80	20	150	188	38	100	2.631579
9	0	90	10	150	188	38	100	2.631579

c) Porosity:

Table.III.6: Porosity of mixing gravel ($G_{3/8}$ with $G_{8/16}$)

Test N°	$G_{3/8}$ (%)	$G_{8/16}$ (%)	$G_{16/25}$ (%)	Abs Density (g/cm ³)	App Density (g/cm ³)	Porosity (%)
1	0	10	90	2.631579	1.238033	52.95473
2	0	20	80	2.631579	1.2233	53.5146
3	0	30	70	2.631579	1.234233	53.09913
4	0	40	60	2.631579	1.254733	52.32013
5	0	50	50	2.631579	1.254033	52.34673
6	0	60	40	2.631579	1.259733	52.13013
7	0	70	30	2.631579	1.2624	52.0288
8	0	80	20	2.631579	1.230833	53.22833
9	0	90	10	2.631579	1.2358	53.0396

III.2.3. Combination 03: 2kg of mixing ($G_{3/8}$, $G_{8/16}$ with $G_{16/25}$)

a) Apparent density:

Table.III.7: Apparent density of mixing gravel ($G_{3/8}$, $G_{8/16}$ with $G_{16/25}$)

Test N°	$G_{3/8}$ (%)	$G_{8/16}$ (%)	$G_{16/25}$ (%)	V (cm ³)	M1 (g)	M2 (g)	M3 (g)	Moy (g)	App Density (g/cm ³)
1	10	10	80	900	1285	1273.4	1287.5	1281.967	1.424407
2	10	20	70	900	1311.5	1295.7	1290.8	1299.333	1.443704
3	10	30	60	900	1306.7	1307.2	1310.7	1308.2	1.453556
4	10	40	50	900	1267.5	1270.5	1253.4	1263.8	1.404222
5	10	50	40	900	1265.4	1268.8	1283.5	1272.567	1.413963
6	10	60	30	900	1289.7	1279.8	1269.4	1279.633	1.421815
7	10	70	20	900	1275.2	1282	1279.4	1278.867	1.420963
8	10	80	10	900	1263.6	1263.7	1258.5	1261.933	1.402148
9	20	10	70	900	1302.9	1305.1	1296	1301.333	1.445926
10	20	20	60	900	1282.1	1287.4	1285	1284.833	1.427593
11	20	30	50	900	1266.1	1274.9	1273.5	1271.5	1.412778
12	20	40	40	900	1284.1	1275.8	1277.2	1279.033	1.421148
13	20	50	30	900	1285.7	1286.1	1284.1	1285.3	1.428111
14	20	60	20	900	1297.5	1291.4	1275.5	1288.133	1.431259
15	20	70	10	900	1288.4	1290.4	1297.5	1292.1	1.435667
16	30	10	60	900	1341	1327.2	1335	1334.4	1.482667
17	30	20	50	900	1342	1342.2	1342.9	1342.367	1.491519
18	30	30	40	900	1338.1	1329.1	1326	1331.067	1.478963
19	30	40	30	900	1314.1	1315.5	1311.6	1313.733	1.459704
20	30	50	20	900	1313.7	1318.4	1316.1	1316.067	1.462296
21	30	60	10	900	1297	1286.1	1285.7	1289.6	1.432889
22	40	10	50	900	1319	1321.3	1323.7	1321.333	1.468148
23	40	20	40	900	1333	1339.9	1332	1334.967	1.483296
24	40	30	30	900	1329.6	1315.8	1331.3	1325.567	1.472852
25	40	40	20	900	1309.3	1315.5	1306.3	1310.367	1.455963
26	40	50	10	900	1279.3	1297.1	1297.6	1291.333	1.434815
27	50	10	40	900	1349	1338.4	1347.8	1345.067	1.494519
28	50	20	30	900	1322.2	1327.2	1316	1321.8	1.468667
29	50	30	20	900	1328.8	1325.5	1324.1	1326.133	1.473481
30	50	40	10	900	1329.1	1312.3	1314.5	1318.633	1.465148
31	60	10	30	900	1354.4	1358.2	1345.2	1352.6	1.502889
32	60	20	20	900	1365.5	1354.1	1367.7	1362.433	1.513815
33	60	30	10	900	1341.3	1353.3	1361.4	1352	1.502222
34	70	10	20	900	1337.3	1327.4	1333.5	1332.733	1.480815
35	70	20	10	900	1303.6	1396.7	1306	1335.433	1.483815
36	80	10	10	900	1284.7	1302.1	1308.1	1298.3	1.442556

b) Absolute density:

Table.III.8: Absolute density of mixing gravel (G_{3/8}, G_{8/16} with G_{16/25})

Test N°	G _{3/8} (%)	G _{8/16} (%)	G _{16/25} (%)	V1 (cm ³)	V2 (cm ³)	V2-V1 (cm ³)	M (g)	Abs Density (g/cm ³)
1	10	10	80	150	188	38	100	2.631579
2	10	20	70	150	188	38	100	2.631579
3	10	30	60	150	188	38	100	2.631579
4	10	40	50	150	188	38	100	2.631579
5	10	50	40	150	188	38	100	2.631579
6	10	60	30	150	188	38	100	2.631579
7	10	70	20	150	188	38	100	2.631579
8	10	80	10	150	188	38	100	2.631579
9	20	10	70	150	188	38	100	2.631579
10	20	20	60	150	188	38	100	2.631579
11	20	30	50	150	188	38	100	2.631579
12	20	40	40	150	188	38	100	2.631579
13	20	50	30	150	188	38	100	2.631579
14	20	60	20	150	188	38	100	2.631579
15	20	70	10	150	188	38	100	2.631579
16	30	10	60	150	188	38	100	2.631579
17	30	20	50	150	188	38	100	2.631579
18	30	30	40	150	188	38	100	2.631579
19	30	40	30	150	188	38	100	2.631579
20	30	50	20	150	188	38	100	2.631579
21	30	60	10	150	188	38	100	2.631579
22	40	10	50	150	188	38	100	2.631579
23	40	20	40	150	188	38	100	2.631579
24	40	30	30	150	188	38	100	2.631579
25	40	40	20	150	188	38	100	2.631579
26	40	50	10	150	188	38	100	2.631579
27	50	10	40	150	188	38	100	2.631579
28	50	20	30	150	188	38	100	2.631579
29	50	30	20	150	188	38	100	2.631579
30	50	40	10	150	188	38	100	2.631579
31	60	10	30	150	188	38	100	2.631579
32	60	20	20	150	188	38	100	2.631579
33	60	30	10	150	188	38	100	2.631579
34	70	10	20	150	188	38	100	2.631579
35	70	20	10	150	188	38	100	2.631579
36	80	10	10	150	188	38	100	2.631579

c) Porosity:

Table.III.9: Porosity of mixing gravel (G_{3/8}, G_{8/16} with G_{16/25})

Test N°	G _{3/8} (%)	G _{8/16} (%)	G _{16/25} (%)	Abs Density (g/cm ³)	App Density (g/cm ³)	Porosity (%)
1	10	10	80	2.631579	1.424407	45.87252
2	10	20	70	2.631579	1.443704	45.13926
3	10	30	60	2.631579	1.453556	44.76489
4	10	40	50	2.631579	1.404222	46.63956
5	10	50	40	2.631579	1.413963	46.26941
6	10	60	30	2.631579	1.421815	45.97104
7	10	70	20	2.631579	1.420963	46.00341
8	10	80	10	2.631579	1.402148	46.71837
9	20	10	70	2.631579	1.445926	45.05481
10	20	20	60	2.631579	1.427593	45.75148
11	20	30	50	2.631579	1.412778	46.31444
12	20	40	40	2.631579	1.421148	45.99637
13	20	50	30	2.631579	1.428111	45.73178
14	20	60	20	2.631579	1.431259	45.61215
15	20	70	10	2.631579	1.435667	45.44467
16	30	10	60	2.631579	1.482667	43.65867
17	30	20	50	2.631579	1.491519	43.3223
18	30	30	40	2.631579	1.478963	43.79941
19	30	40	30	2.631579	1.459704	44.53126
20	30	50	20	2.631579	1.462296	44.43274
21	30	60	10	2.631579	1.432889	45.55022
22	40	10	50	2.631579	1.468148	44.21037
23	40	20	40	2.631579	1.483296	43.63474
24	40	30	30	2.631579	1.472852	44.03163
25	40	40	20	2.631579	1.455963	44.67341
26	40	50	10	2.631579	1.434815	45.47704
27	50	10	40	2.631579	1.494519	43.2083
28	50	20	30	2.631579	1.468667	44.19067
29	50	30	20	2.631579	1.473481	44.0077
30	50	40	10	2.631579	1.465148	44.32437
31	60	10	30	2.631579	1.502889	42.89022
32	60	20	20	2.631579	1.513815	42.47504
33	60	30	10	2.631579	1.502222	42.91556
34	70	10	20	2.631579	1.480815	43.72904
35	70	20	10	2.631579	1.483815	43.61504
36	80	10	10	2.631579	1.442556	45.18289

Note:

We will chose the three minimal porosity of mixing different aggregates sizes to make three different concrete types

Table.III.10: Chose the three different concretes types

Concrete types	$G_{3/8}$ (%)	$G_{8/16}$ (%)	$G_{16/25}$ (%)	Porosity (%)
HSC-I	60	10	30	42.89022
HSC-II	60	20	20	42.47504
HSC-III	60	30	10	42.91556

III.3. Concrete formulation:

The objective of all concrete formulation methods is to determine the combination of materials to be used to produce the concrete which will have the desired properties and which will be as economical as possible.

It has always been very difficult to develop a universal theoretical method for formulating concrete with any combination of portland cement, admixture, aggregate and admixture. Even if all these base materials must meet more or less strict acceptance criteria, a concrete with the desired properties in the cured state can be obtained in different ways by using the same materials.

The study of the composition of a concrete consists in defining the optimal mixture of the various aggregates available as well as the dosage of cement and eu in order to produce a concrete whose qualities are those sought for the construction of the structure or element of the structure in question.

Several methods are proposed, including the simplified practical method known as the "Dreux-Gorisse" method

III.4. Mixture Calculation

❖ **Basic formulation according to Dreux-Gorisse formulation**

- Cement dosage: $C = 350 \text{ kg/m}^3$
- Water dosage: $E = 112 \text{ kg/m}^3$
- Quantity of Sand: $S = 498.62 \text{ kg/m}^3$
- Quantity of Gravel 3/8: $G_{3/8} = 540.80 \text{ kg}$
- Quantity of Gravel 8/15: $G_{8/15} = 730.23 \text{ kg}$

III.5. Mix Results:

In table IV.1, we present the quantities of materials, water, addition, and adjuvant used in each HSC.

Table.III.11: HSC Concrete Formulation Results

Concrete types		HSC-W		HSC-I		HSC-II		HSC-III	
Number of test pieces used		[9] Cubic 10*10*10cm and [3] prismatic 7*7*28cm test pieces							
Cement (kg)		6.06		6.06		6.06		6.06	
Sand (kg)		9.39		9.39		9.39		9.39	
Water dosage (kg)	necessary	1.62	2.5	1.62	2.12	1.62	2.36	1.62	2.02
	Added	0.88		0.5		0.74		0.4	
Quantity of gravel 3/8	(%)	57.46		60		60		60	
	(kg)	7.74		10.92		10.92		10.92	
Quantity of gravel 8/16	(%)	42.54		10		20		30	
	(kg)	10.46		1.82		3.64		5.46	
Quantity of gravel 16/25	(%)	/		30		20		10	
	(kg)	/		5.46		3.64		1.82	
Silica fumes	(%)	8		8		8		8	
	(kg)	0.485		0.485		0.485		0.485	
Super plasticizer	(%)	1.3		1.3		1.3		1.3	
	(kg)	0.079		0.079		0.079		0.079	

III.6. Fresh concrete test:

With these optimal mixtures that gave a maximum apparent density (minimum porosity), we made our concretes and measured the different densities in the fresh state.

III.6.1. Densities of different concrete mixes:

(10* 10*10 cubic test pieces) cm and (7*7*28) cm.

Table.III.12: Density of witness concrete HSC-W

Concrete Type	Piece (cm)	Density (kg/cm3)	Density avg (kg/cm3)
Witness concrete HSC-W	7*7*28	2.490	2.489
		2.473	
		2.504	
	10*10*10	2.39	2.355
		2.361	
		2.409	
		2.369	
		2.412	
		2.382	
		2.386	
		2.410	
		2.376	

Table.III.13: Density of HSC-I

Concrete Type	Piece (cm)	Density (kg/cm3)	Density avg (kg/cm3)
HSC-I	7*7*28	2.516	2.503
		2.490	
		2.504	
	10*10*10	2.4	2.373
		2.378	
		2.384	
		2.39	
		2.348	
		2.331	
		2.368	
		2.371	
		2.39	

Table.III.14: Density of HSC-II

Concrete Type	Piece (cm)	Density (kg/cm ³)	Density avg (kg/cm ³)
HSC-II	7*7*28	2.459	2.464
		2.473	
		2.460	
	10*10*10	2.354	2.388
		2.383	
		2.354	
		2.331	
		2.368	
		2.371	
		2.384	
		2.39	
		2.348	

Table.III.15: Density of HSC-III

Concrete Type	Piece (cm)	Density (kg/cm ³)	Density avg (kg/cm ³)
HSC-III	7*7*28	2.482	2.486
		2.494	
		2.484	
	10*10*10	2.354	2.364
		2.355	
		2.354	
		2.383	
		2.354	
		2.342	
		2.355	
		2.341	
		2.364	

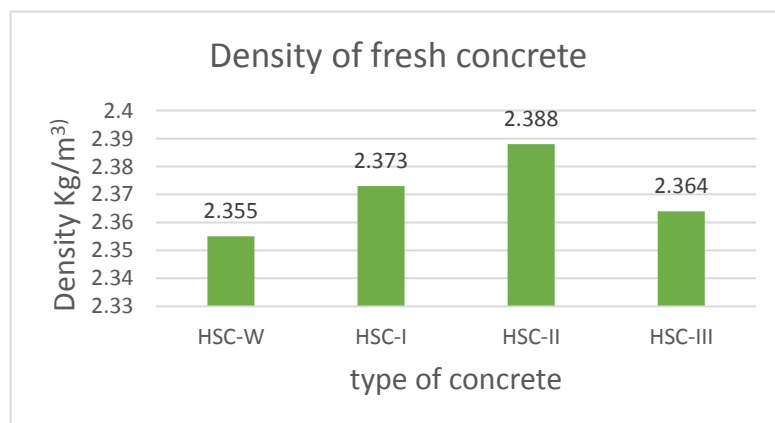


Figure.III.1: Density of different types of concretes

Note:

It can be seen from the results of the density of the mixtures, that the mixture HSC-II, gives the highest density, while HSC-W gives the lowest density

III.6.2. Sagging:

Normal Consistency between 6 ± 1 cm at the Abrams cone, we obtained the results presented below.

Table.III.16: Water subsidence and reduction

Concrete Types	Sagging (cm)
HSC-W	6.5
HSC-I	6
HSC-II	5.5
HSC-III	6.5

It is noted here that the subsidence is taken almost constant between 6 and 7 cm, but the water reduction is counteracted.

III.7. Tests on hardened concretes:

III.7.1. Densities of different concrete mixes:

Table.III.17: the results of measurements of the density of concrete in the cured state (7, 14.28 days)

Concrete Types	Density (kg/m ³)		
	7 Days	14 Days	28 Days
HSC-W	2.37	2.378	2.386
HSC-I	2.386	2.378	2.386
HSC-II	2.402	2.4	2.409
HSC-III	2.4	2.37	2.394

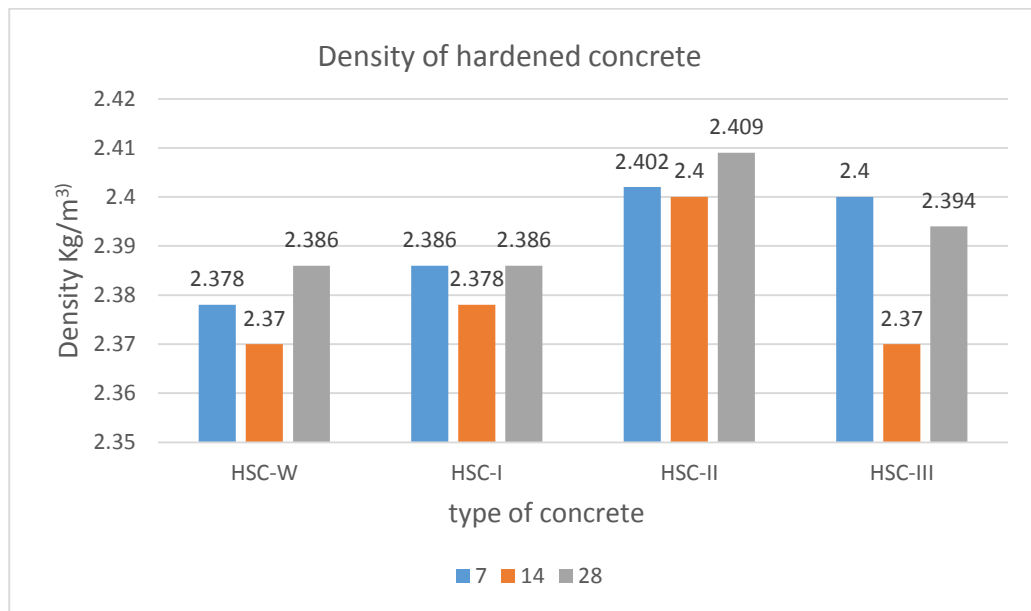


Figure.III.2: Density of concretes in the hardened state (7, 14, 28 days)

- The **HSC-II** blend gives the best density in the cured state for different ages. The results found are better than this for the **HSC-W** control concrete.
- The **HSC-W** mixture with the worst density value.

III.7.2. Compressive strength:

Figure. Represents the evolution of the compressive resistance 7d under the effect of conservation in water in relation to each HSC.

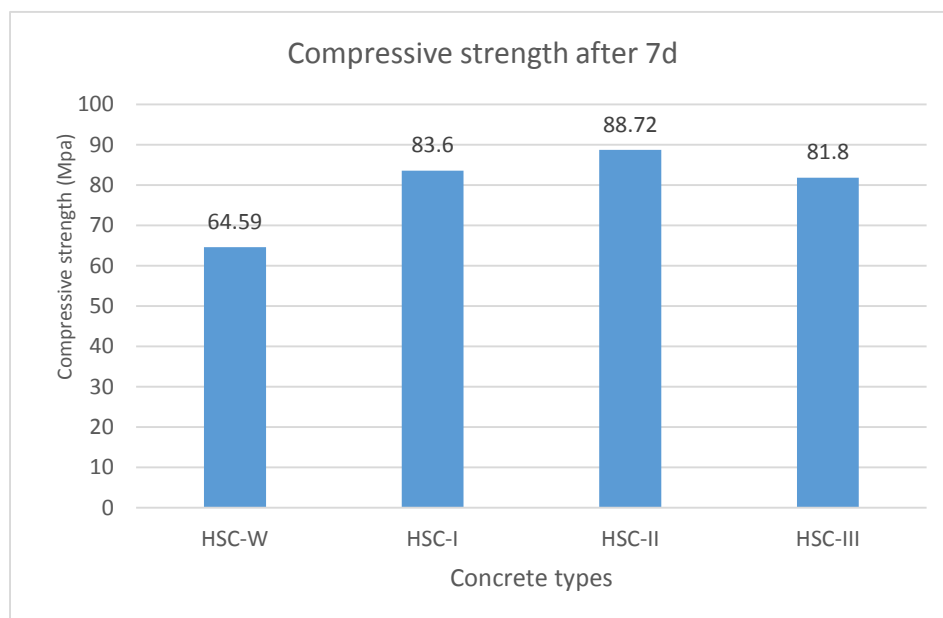


Figure.III.3: Evolution of compressive strength at 7 days

- From the results obtained, we find that **HSC-I**, **HSC-II** and **HSC-III** gave better results than the control concrete **HSC-W** on compressive strength at 7 days.

Figure. Represents the evolution of the compressive resistance 14d under the effect of conservation in water in relation to each HSC.

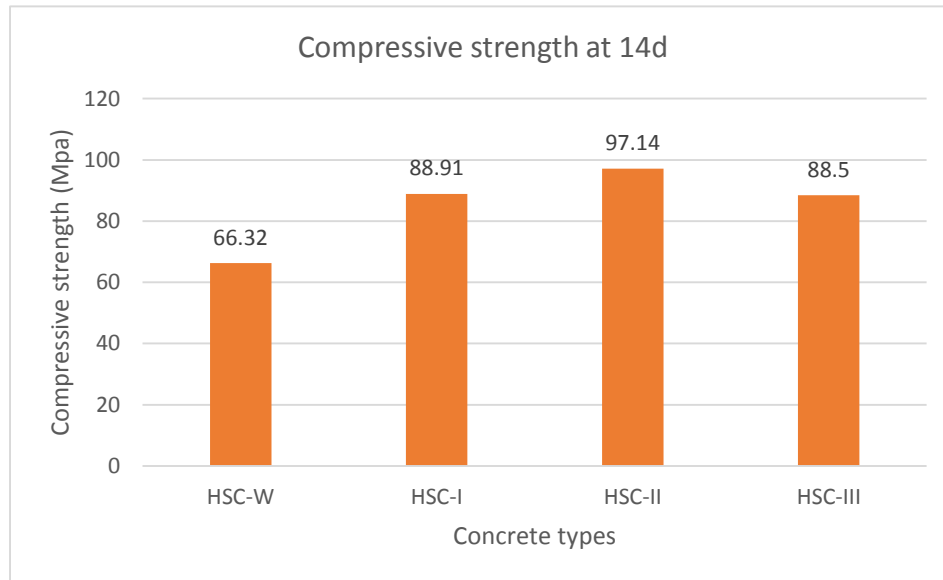


Figure.III.4: Evolution of compressive strength at 14 days

- From the results obtained, we find that **HSC-I**, **HSC-II** and **HSC-III** gave better results than the control concrete **HSC-W** on compressive strength at 14 days.

Figure. Represents the evolution of the compressive resistance 28d under the effect of conservation in water in relation to each HSC.

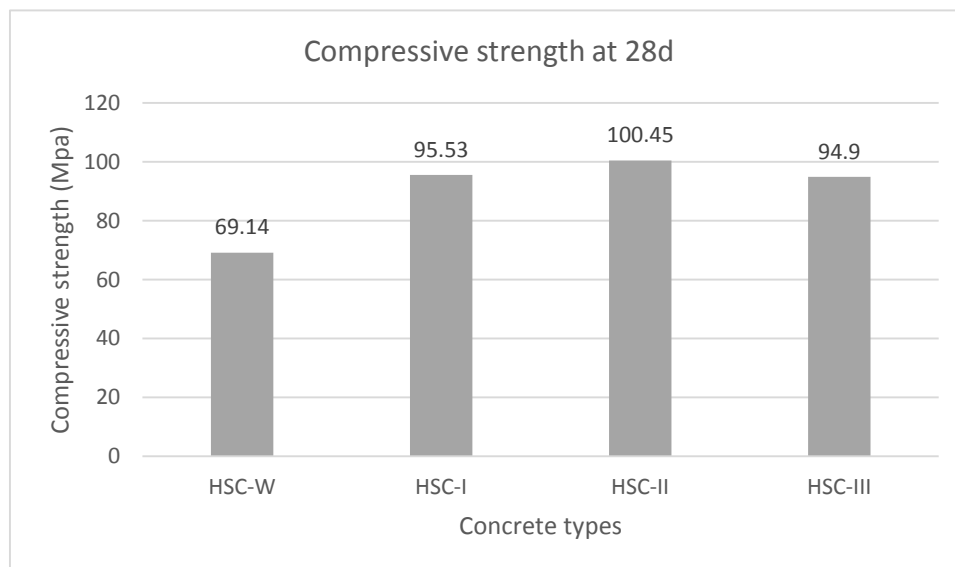


Figure.III.5: Evolution of compressive strength at 14 days

- From the results obtained, we find that **HSC-I**, **HSC-II** and **HSC-III** gave better results than the control concrete **HSC-W** on compressive strength at 28 days.

Figure. Represents a comparison of the development of compressive strength for different times (7, 14 and 28d) under the influence of preservation in water for each HSC

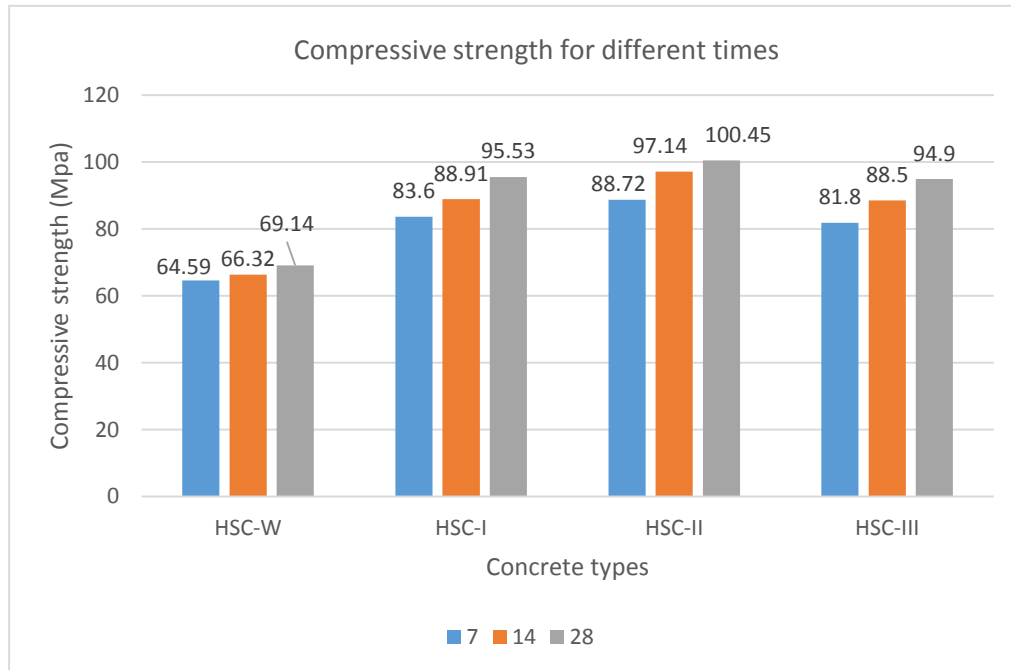


Figure.III.6: Evolution of compressive strength for different times (7, 14 and 28 days)

From the results obtained, we find

- HSC-II** outperforms the other types at all-time intervals, showing the best strength development and highest final compressive strength.
- HSC-I** and **HSC-III** also show good strength development over time, though **HSC-I** has a slight edge over **HSC-III**.
- HSC-W** is the least consistent, with a decrease in strength at 28 days.

III.7.3. Bending tensile strength:

Figure IV.22. Represents the evolution of the tensile strength by bending at 7d under the effect of conservation in water in relation to each **HSC**

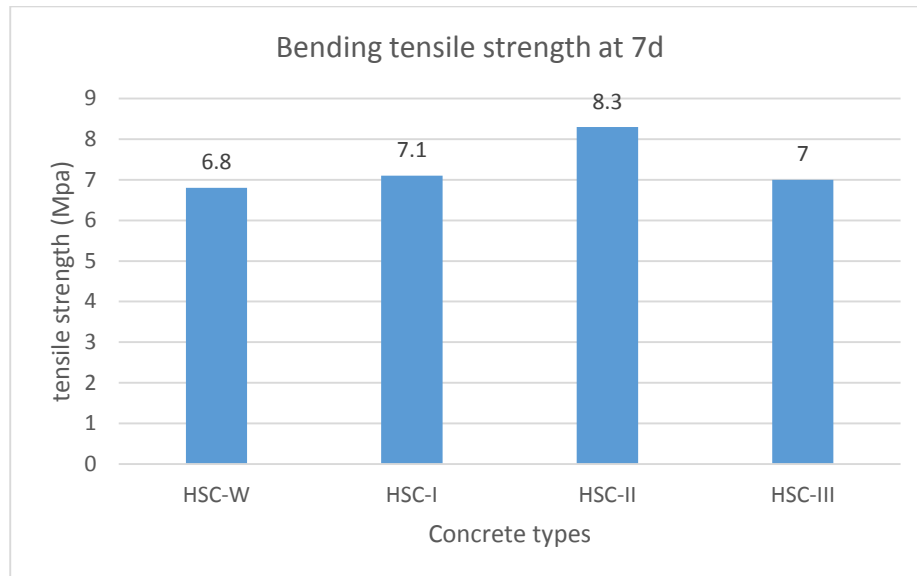


Figure.III.7: Evolution of the tensile strength by flexion at 7 days in water

- The tensile strength by bending at 7 days of **HSC-W**, **HSC-I**, and **HSC-III**, they are close in value, while **HSC-II**, we notice that it is somewhat better than them

Figure IV.22. Represents the evolution of the tensile strength by bending at 14d under the effect of conservation in water in relation to each **HSC**

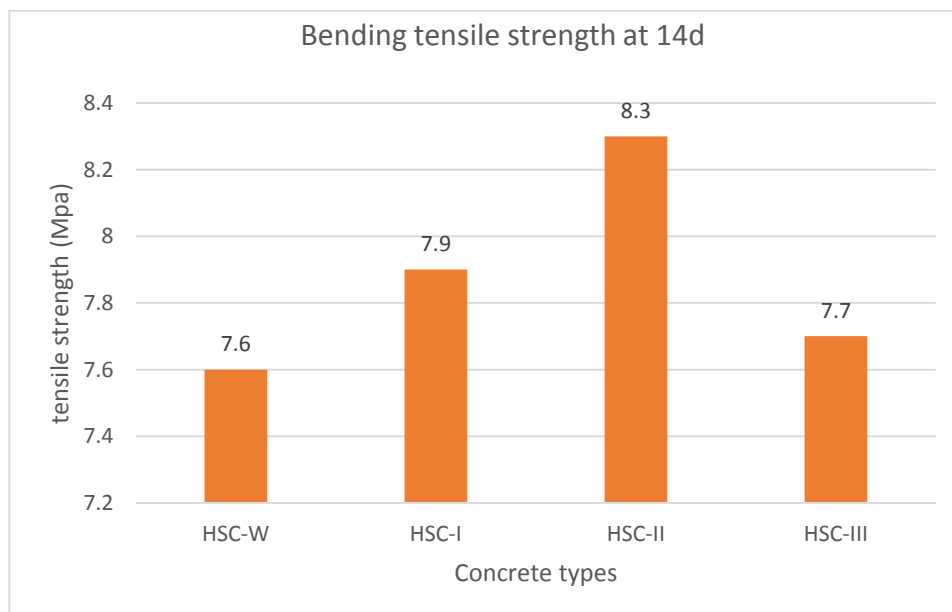


Figure.III.8: Evolution of the tensile strength by flexion at 14 days in water

- The tensile strength by bending at 14 days of **HSC-W**, **HSC-I**, and **HSC-III**, they are close in value, while **HSC-II**, we notice that it is somewhat better than them

Figure IV.22. Represents the evolution of the tensile strength by bending at 28d under the effect of conservation in water in relation to each **HSC**

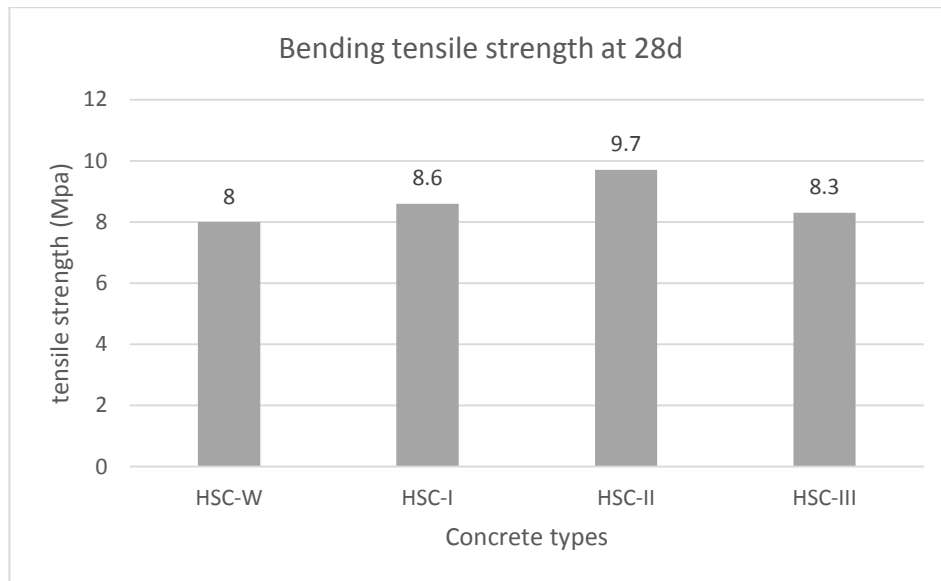


Figure.III.9: Evolution of the tensile strength by flexion at 28 days in water

- The tensile strength by bending at 28 days of **HSC-W**, **HSC-I**, and **HSC-III**, they are close in value, while **HSC-II**, we notice that it is somewhat better than them

Figure. Represents a comparison of the development of tensile strength by bending for different times (7, 14 and 28d) under the influence of preservation in water for each HSC

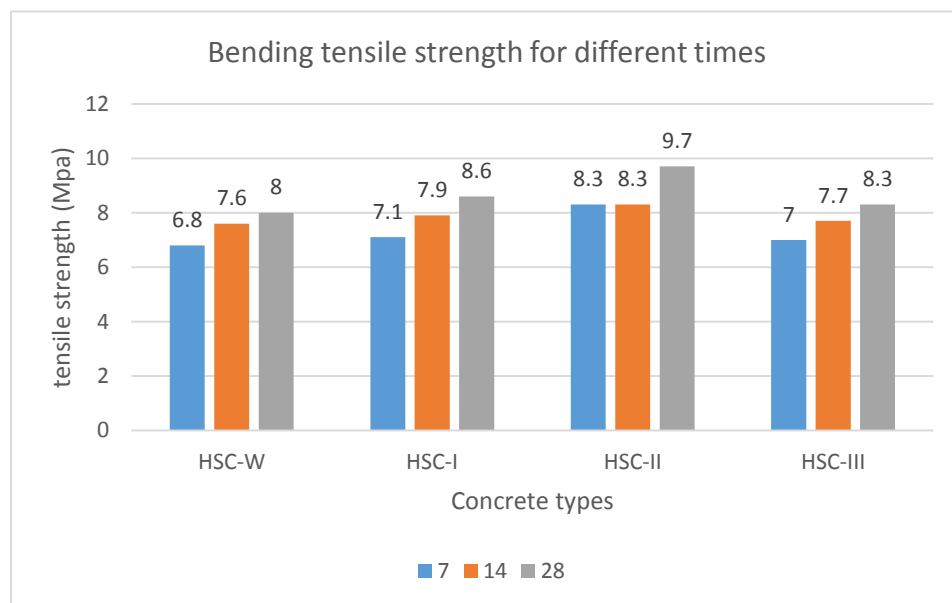


Figure.III.10: Evolution of tensile strength by bending for different times (7, 14 and 28 days)

From the results obtained, we find the following:

- **HSC-II** outperforms the other types at all-time intervals, demonstrating the best strength development and highest final compressive strength.
- Both **HSC-I** and **HSC-III** show good strength development over time, with **HSC-I** having a slight edge over **HSC-III**.
- **HSC-W** is the least consistent, exhibiting a decrease in strength at 28 days.

III.8. Conclusion:

From the detailed analysis and experimental results presented in Chapter III, the following conclusions can be drawn:

1. High-Strength Concrete Performance:

- **HSC-II** consistently demonstrated superior performance in terms of compressive and tensile strength across all time intervals (7, 14, and 28 days). It achieved the highest final compressive strength and displayed the best overall strength development.

- **HSC-I** and **HSC-III** also showed good strength development, with **HSC-I** performing slightly better than **HSC-III**.

- **HSC-W** was the least consistent, showing a notable decrease in strength at 28 days, indicating inferior performance compared to the other high-strength concrete types.

2. Aggregate Size Influence:

- The different combinations of aggregate sizes significantly impacted the performance of the concrete mixes. The optimal mixtures for **HSC-I**, **HSC-II**, and **HSC-III** were identified based on minimal porosity and superior strength characteristics.

3. Concrete Formulation and Density:

- The formulation process aimed to optimize the mixture of available aggregates and cement dosage to achieve desired properties. **HSC-II** had the best density in the cured state for different ages, whereas **HSC-W** had the worst density value.

4. Strength Development over Time

- The results confirmed that **HSC-II** not only outperformed other mixes but also maintained a consistent and high level of strength development over time. This makes it a preferred choice for applications requiring high-strength concrete with reliable performance.

Overall, the study highlights the critical role of proper aggregate mixing and formulation in achieving high-strength concrete with desirable properties. The findings emphasize the importance of selecting the right combination of materials to enhance the performance and durability of concrete structures.

GENERALE CONCLUSION:

The thesis provides a comprehensive study on high-strength concrete (HSC) with a focus on the impact of aggregate size on its properties. Here are the key conclusions drawn from the document:

1. Significance of High-Strength Concrete (HSC):

- HSC is essential in modern construction for its enhanced durability and load-bearing capacity, making it ideal for high-rise buildings, bridges, and other infrastructure projects.

2. Role of Aggregates:

- Aggregates, which make up a large portion of concrete, significantly influence its workability, density, and strength.
- The size and gradation of aggregates play a crucial role in determining the mechanical properties of concrete.

3. Influence of Aggregate Size:

- Larger aggregates tend to reduce the surface area that needs to be coated with cement paste, potentially increasing concrete strength by reducing water demand.
- Smaller aggregates improve workability but require more cement paste, which can affect both the economy and strength of the mix.

4. Comprehensive Analysis:

- The research aims to analyze how different aggregate sizes affect the structural integrity and performance of HSC.
- Through experimental investigations, including compressive and flexural strength tests, the study evaluates the optimal aggregate size for maximizing HSC quality.

5. Benefits of HSC:

- HSC offers increased maneuverability without segregation, improved durability, and the ability to design thinner structures due to its enhanced mechanical characteristics.
- High-quality aggregates and specific additives, including superplasticizers and mineral additives like fly ash and silica fume, are essential for achieving the improved properties of HSC.

6. Durability and Resistance:

- HSC exhibits very low permeability, increasing its durability against environmental attacks, alkali reactions, abrasion, and freeze/thaw cycles.
- Its reduced porosity makes it more resistant to aggressive agents and enhances the longevity of structures.

7. Classification and Standards:

- HSC is classified into different categories based on compressive strength ranges and characterized by a 28-day compressive strength greater than 50 MPa.
- Various standards and tests, such as particle size analysis and the Los Angeles test, are used to determine the properties and quality of aggregates.

8. Practical Implications:

- The findings provide valuable insights for the construction industry, aiding in the development of more efficient and effective concrete mix designs that optimize performance and structural integrity.

In conclusion, the thesis underscores the critical importance of aggregate size in the composition and performance of high-strength concrete, offering a detailed examination of its effects and practical recommendations for the construction industry.

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[36] Notice Technique : Group Grantex conforme a la norme EN 934-2 :TAB 1, TAB 3.1 ET TAB 3.2 NA 774.