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Experimental study on the influence of Hydroxypropyl Methylcellulose on the cement mortar reinforced by sawdust

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At the end of this work, I first thank Allah who has enlightened us on the path to knowledge and opened the doors of knowledge.

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Dedications

It is my pleasure to allow myself to dedicate this work:

To my dear parents, the source of love and affection,

because they loved me, taught me and taught me and who

gave me everything to get there since I started my studies.

To my dear brothers and nephews.

To all my teachers throughout all my stages of study.

To my dear friends.

To all the students in my year.

Abstract:

The aim of this work is to study the effect of polysaccharides, especially cellulose esters, on the physical and mechanical properties such as texture and compressive strength of cementitious matrix in the presence of sawdust.

We focused our study on the effect of the chemical composition and molecular weight of these additional organic materials on cement mortar, where we relied on the use of hydroxyl propyl methyl cellulose because it is the most abundant in the markets, in light of the presence of wood wastes (sawdust) that act as a thermal and electrical insulator in addition to its role as plant fibers.

The experimental results showed that cement mixtures containing HPMC had more plastic consistency than normal mixtures even with relatively high proportion of mixing water, as HPMC acted as water retainer which gave it a better workability.

Keywords: Organic auxiliaries (adjuvants), cellulose derivatives, mortar, compressive strength, water retentive, Hydroxypropyl Methylcellulose, Plant fiber.

ملخص:

يهدف هذا العمل إلى دراسة تأثير السكاريد المتعددة وخاصة استرات السليلوز على الخصائص الفيزيائية والميكانيكية مثل الملمس والقوة الانضغاطية للمصفوفة الأسمنتية بوجود نشارة الخشب.

وركزنا في دراستنا على تأثير التركيب الكيميائي والوزن الجزيئي لهذه المواد العضوية الإضافية على ملاط الأسمنت، حيث اعتمدنا على استخدام هيدروكسيل بروبيل ميثيل سليلوز لأنه الأكثر وفرة في الأسواق، في ظل وجود مخلفات الخشب (نشارة الخشب) التي تعمل كعازل حراري وكهربائي بالإضافة إلى دورها كألياف نباتية.

أظهرت النتائج التجريبية أن مخاليط الأسمنت المحتوية على HPMC كانت ذات قوام بلاستيكي أكثر من المخاليط العادية حتى مع نسبة عالية نسبيًا من ماء الخلط، حيث عملت HPMC كحافظة للماء مما أعطاها قابلية تشغيل أفضل.

الكلمات المفتاحية: المواد المساعدة العضوية، مشتقات السليلوز، الملاط، قوة الضغط، الاحتفاظ بالماء، هيدروكسي بروبيل ميثيل السليلوز، الألياف النباتية.

Summary

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General Introduction

General introduction

When studying any project, whether it is a residential building, a bridge or other concrete structures, the main focus is the durability of the building through the phenomena and times it goes through, and this durability comes through several criteria and precise details when choosing the appropriate materials and quantities for each case.

Polymeric auxiliary materials are among the latest and most widespread additives in the field of construction, as their role in providing the maximum amount of fluidity and water retention is clear to ensure avoiding the harmful effects of excess water while facilitating the workability of the cement matrix at the same time.

This study is a laboratory experiment aimed at shedding light on the use of cellulose ethers (Hydroxyl propyl methylcellulose in this case) in cement mixtures due to the possibility of their extraction and processing as well as their wide availability in the markets by obtaining physical and mechanical data.

The work was carried out mainly in the construction works laboratory of the National Institute of Amamra Al-Bachir, under the supervision of professors and laboratory workers, and under the supervision of the Department of hydraulic and Civil Engineering of the University of El Oued.

This thesis consists of four parts:

1. A bibliographic study on cement mortar and the reinforcement fibers.

2. Research on cellulose and its uses in the field of civil engineering.

3. A material and methods section where the operating modes are used

.4. Finally, a section discusses the results of the exploratory tests dealing with the impact of a series of cellulose ether as admixture to fresh and hardened cementitious materials.

Chapter I:

Generality about cement mortar.

Introduction:

Mortar is a composite material, obtained by homogeneous mixing of an inert material (sand) with an active material (binder), all mixed with a certain quantity of water. Mortar can meet various construction requirements. However, there is no universal mortar suitable for all situations.

The Designer will only be able to choose the mixture best suited to a given project if he has a good knowledge of the materials used in the composition of the mortar and their properties.

It is used to connect the different construction elements such as bricks, stones, concrete blocks (concrete blocks), etc. or to carry out coverings and facade coatings.

Choosing the appropriate mortar type is subject to many criteria due to the variety of mortar types. The mortar can be chosen according to the binder (cement, lime or bastard) or according to the destination of use, or on the concentration of the binder.

Figure.1: Cement Mortar and Some of Its Uses.

1. The main components of cement mortar:

1.1 The cement:

1.1.1 Introduction:

Cement is an anhydrous binder used in the construction industry. It generally comes in the form of fine mineral powders and is considered the most consumed substance in the world after water, due to its effectiveness and abundance compared to other binders. It is formed by cooking two compounds, 80% lime and 20% Clay, at a temperature of up to 1450°C in cylindrical kilns.

The product we obtain after sudden cooling is component clinker:

- Tricalcium silicate C_3S ($3CaO.SiO_2$): The C_3S content in clinker ranges between 50 and 65%.
- Dicalcium silicate C_2S ($2CaO.SiO_2$): The C_2S content of the clinker is between 15 and 25%.
- Tricalcium aluminate C_3A ($3Cao.Al_2O_3$): The C_3A content of the clinker is between 4 and 12%.
- Tetracalcium alumino-ferrite C_4AF ($4CaO.Al_2O_3.Fe_2O_3$): The C_4AF content in clinker in range of 2 and 10%.

Figure.2: Famous cement brands in the Algerian market.

Cement also contains other materials in a small percentage, such as MgO, K_2O, Na_2O ...etc. In addition to a percentage not exceeding 5% of gypsum ($CaSO_4$) for setting time.

1.1.2 Different common types of cement:

The NA 442 cement standard determines the type of cement based on the components added to the clinker during the manufacturing process. NA 442 also specifies the components of cement, the types of additives, their percentage and their physical and mechanical specifications, as shown in the table below.

Table.1: Main categories of cements according to the NA 442 standard. [2]

	Composition (% by mass)

		Main constituents										Secondary constituents
					Pozzolans		Ashes					
		Clinker	Blast furan slug	Silica fume	Natural	Natural calcined	Siliceous	Calcium	Calcined Shale	Limestone		
		K	S	D	P	Q	V	W	T	L	LL	
Portland Cement	CEM I	95-100										≤ 5%
Portland cement with slag	CEM II/A-S	80-94	6-20									≤ 5%
	CEM II/B-S	65-79	21-35									≤ 5%
Portland cement with silica fume	CEM II/A-D	90-94		6 - 10								≤ 5%
Pozzolans Portland cement	CEM II/A-P	80-94			6-20							≤ 5%
	CEM II/B-P	65-79			21-35							≤ 5%
	CEM II/A-Q	80-94				6-20						≤ 5%
	CEM II/B-Q	65-79				21-35						≤ 5%
Fly Ash Portland Cement	CEM II/A-V	80-94					6 - 20					≤ 5%
	CEM II/B-V	65-79					21-35					≤ 5%
	CEM II/A-W	80-94						6-20				≤ 5%
	CEM II/B-W	65-79						21-35				≤ 5%
Calcined Shale Portland Cement	CEM II/A-T	80-94							6 - 20			≤ 5%
	CEM II/B-T	65-79							21-35			≤ 5%
Portland Limestone Cement	CEM II/A-L	80-94								6 - 20		≤ 5%
	CEM II/B-L	65-79								21-35		≤ 5%
	CEM II/A-LL	80-94									6 -20	≤ 5%

	CEM II/B-LL	65-79									21-35	≤ 5%
Compound Portland cement	CEM II/A-M	80-94	12-20									≤ 5%
	CEM II/B-M	65-79	21-35									≤ 5%
Blast Furnace Cement	CEM III/A	35-64	36-65									≤ 5%
	CEM III/B	20-34	66-80									≤ 5%
	CEM III/C	5-19	81-95									≤ 5%
Pozzolanic cement	CEM IV/A	65-89		11-35								≤ 5%
	CEM IV/B	45-64		36-55								≤ 5%
Composite cement	CEM V/A	40-64	18-30		12-20							≤ 5%
	CEM V/B	20-38	20-38		21-35							≤ 5%

1.1.3 Hydration of cement paste:

Although cement is a very common material, due to its abundance and ease of forming and handling, the physical and chemical phenomena that occur in the hydration process are very complex and are still a question for many researchers.[1]

- Hydration of tricalcium silicates:

  Upon first contact with water, calcium silicates begin to dissolve immediately, as they interact with each other to form what are called cement hydration products, C-S-H and C-H, according to the equation (1) and (2). C_3S is the main responsible for giving resistance at early ages.

$$2C_3S + 6H \longrightarrow C.S.H + 3C.H \;.....(1)[1]$$

- Hydration of dicalcium silicate:

  Unlike tricalcium silicate, the hydration process of dicalcium silicate takes more time and has fewer reaction products, which works to achieve hardness and long-term resistance of the cement according to Equation (2).

$$2C_2S + 4H \longrightarrow C.S.H + 3C.H \;.....(2)[1]$$

- Hydration of tricalcium aluminate:

  Tricalcium aluminate is considered the most reactive component, and this happens very quickly according to equation (3). This speed causes a disruption in the hydration of the other components, so one resorts to adding gypsum to slow down this reaction and give more time to hydrate the other components according to equation (4).

$$2C_3A + 21H \longrightarrow C_4A.H_{13} + C_2A.H_8 \longrightarrow 2C_3A.H_6 + 9H \text{... (3)[1]}$$

$$C_3A+3C.S.H_2+ 26H \longrightarrow C_6A.S_3.H_{32} \qquad \text{... (4) [1]}$$

- Hydration of tetracalcium alumino-ferrite:

  The tetracalcium alumino-ferrite reaction is considered secondary to the solidification reactions, as it is added for the purpose of reducing the heat resulting from the aluminate reaction according to Equation (5).

$$C_4AF+ (7 +n)\, H \longrightarrow C_3A.H_6+F.Hn+ C.H \text{ ... (5). [1].}$$

In conclusion, the products of cement hydration can be summarized in the table shown below.

Table.2: the products of cement hydration [3].

Denomination	Detailed chemical formula	Abbreviation
Portlandite	$Ca(OH)_2$	CH
Hydrated Calcium Silicate	$3CaO.2SiO_2.3H_2O$	C-S-H
Tri Sulfo-aluminate or ettringite	$3CaO.Al_2O_3.3CaSO_4.32H_2O$	$C_6A\underline{S}_3H_{32}$
Mono Sulfo-aluminate	$3CaO.Al_2O_3.CaSO_4.12H_2O$	$C_4A\underline{S}H_{12}$
Hydrated tetracalcium aluminate	$4CaO.Al_2O_3.13H_2O$	C_4AH_{13}
Hydrated dicalcium aluminate	$2CaO.Al_2O_3.8H_2O$	C_2AH_8
Hydrated tricalcium aluminate	$3CaO.Al_2O_3.6H_2O$	C_3AH_6

2. The sand:

The choice of sand grain size depends on the work to be carried out; for masonry work, 0/5 mm sand is often used. However, for brickwork or rendering work, the sand is finer, 0.5 and 2 mm.

The role of sand in a mortar is to:

- Divide the mass of the binder to allow setting (air binder).
- Lower the cost price of mortar.
- Reduce shrinkage and its consequences (cracking) due to the fact that the sand is incompressible and shrinkage is reduced.

Figure.3: sand used in construction work. [4]

3. Mixing water:

The choice of mixing water is also of great importance because it fulfills a dual role: it serves to hydrate the cement and, more importantly, it contributes to its workability.

Mortars should contain the maximum quantity of water compatible with optimal workability. Water should be clean and free from harmful products such as acids, alkalis or organic matter. When it is drinkable it can be used.

4. The admixture:

Admixtures are used for masonry mortars and in certain cases their use is certainly advantageous. However, their use is generally not recommended.

They give the plasticity and water retention power that lime gives to cement and lime mortars. Some masonry cements are mixtures of Portland cement and hydrated lime with the addition of admixtures.

5. The fibers:

5.1 History of fibers:

Historically, there is no certainty as to when the concept of fiber-reinforced concrete and mortar arose. A comprehensive analysis of this concept tells us that this idea is very old and dates back to ancient times. Thus, throughout history materials technology has been characterized by the emergence of composite materials with increasingly complex compositions.

According to Exodus 5:6, the Egyptians used straw to strengthen mud bricks. It is also certain that asbestos fibers were used to strengthen clay pottery in Finland 5,000 years ago. Other sources (Antoine, E.N and Mars 1985 and ACI Comtte 554 March - April 1984) indicate that straw was used to strengthen bricks by the ancients, and the ancient Muslims also used it in building the famous Quba Mosque, while animals were used to strengthen the bricks. Brick. Hair fibers and asbestos were introduced to reinforce the plaster and Portland cement putty. We can also observe the creation of metal alloys using carbon fiber in the mid-20th century.

At the end of the 19th century, fibrous materials began to become very popular and many fields began to exploit this new material. But the real development of this type of material can be attributed to Joseph Lambot. His patent, filed in 1847, proposed adding continuous fibers in the form of wires or steel strips to create a new material. Twenty-seven years later, the American A. Bernard came to California and created artificial stone by adding plasticized iron aggregates to a concrete mixture. Then, in 1899, Lachelke developed a process for manufacturing composite elements based on cement and asbestos.

Figure.4: different uses of fibers. [5]

5.2 Types and classifications of fibers:

Because fibers are a major research topic, they are generally classified according to two basic criteria shown in the following table:

Table.3: common Fibers classification (Venuat M.1983).

Natural fibers			Artificial fibers	
Plants	**Animals**	**Minerals**	**Minerals**	**Organic**

Linen	Hair	Rock asbestos	Blast furnace slags	Long polymers whose molecules are oriented in the fiber axis
Hemp	Horsehair	Silicomagnesians	Carbone	
Cotton	Wool		Rock wool (basalt)	
Celluloses	Silk		Ceramic	
Sisal			Metals (steel, cast iron)	
			Special glasses	

5.3 The role of fibers and their uses:

Fibers are considered a reinforcement for the cement matrix, as they give the matrix its special properties, such as mechanical resistance to internal and external action or conductivity, or they can be used as a filler material to increase volume, reduce density, or for an economic purpose.

The optimal choice of fibers is the most important reason for achieving the best results, and this choice is represented by the following two criteria:

- Physical characteristics of fibers:
  - A. Slenderness ratio:

    It is defined as the geometric ratio of the length of the fiber over its thickness or diameter, and we symbolize it as (L/d).
  - B. The residual resistance value:

    It is the last resistance of the fibers, as it acts as a catcher for the two separated ends.

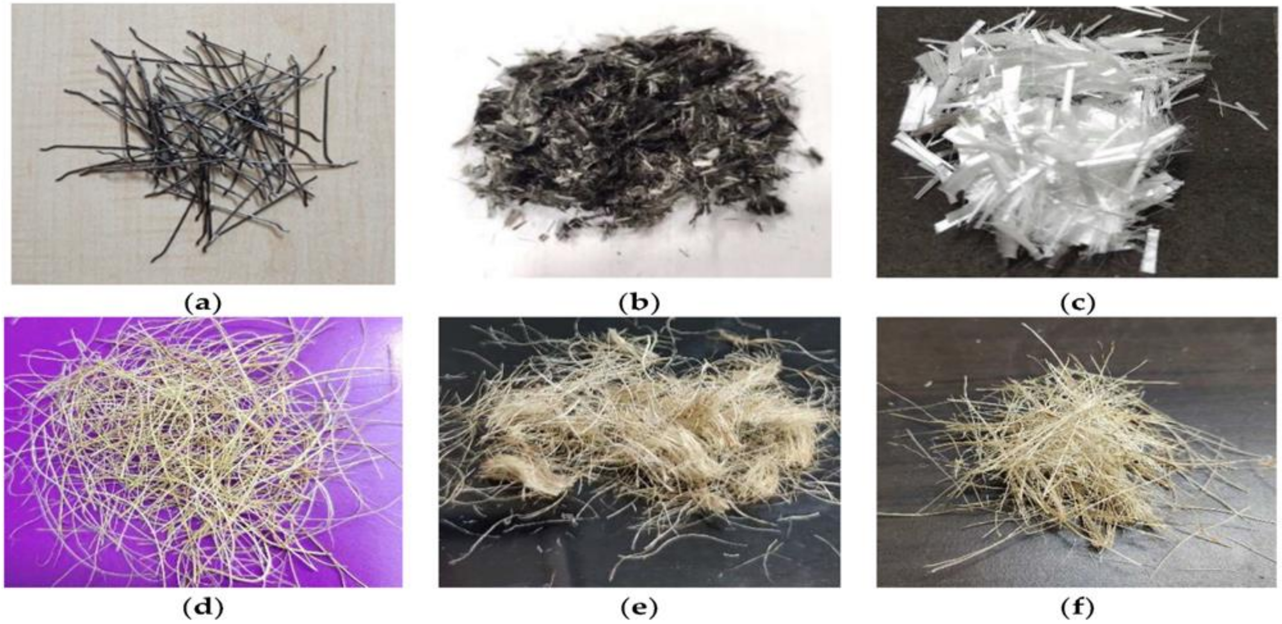


Figure.5: Some common types of fibers.

- Mechanical characteristic of fibers:

A. Tensile stress:

It is the resistance to the vertical tensile force.

B. Sustainability:

It is the ability of fibers to withstand aggressive environments.

Chapter II:

Generality about the cellulose derivatives.

Introduction:

Cellulose is the most abundant and widely used organic chemical in the world. As the main component of plant matter, billions of tons of it are created each year through photosynthesis. In the form of wood, paper, cotton textiles, rayon, films, plastics, coatings, and a myriad of other uses including fuel, humans worldwide consume approximately 100 billion tons of cellulose annually. Naturally, this basically important material has been the subject of an enormous amount of investigation. Studies of its occurrence, formation, isolation and purification, chemical and physical structures, properties, reactions, and uses have led to considerable understanding of its nature and behavior. In fact, studies leading to recognition of the polymeric nature of cellulose were among the first on polymers of any sort, and many of the basic principles of polymer chemistry were worked out during cellulose investigations. These principles contributed to the understanding of the behavior of the other two important classes of naturally occurring polymers, proteins and rubber, and they have been the basis for the development of the numerous and rapidly growing family of synthetic polymers.

1. The definition of cellulose:

Cellulose is the essential structural element of many living species, especially plants. This polysaccharide is a homopolymer which belongs to the β-D-glycan family. It (between 200 and 14,000) connected is made up exclusively of β-D-glucose units (figure 5) between them by β type bonds (1→ 4) which form chains associating into micro fibrils of variable size depending on the sources of cellulose.[6]

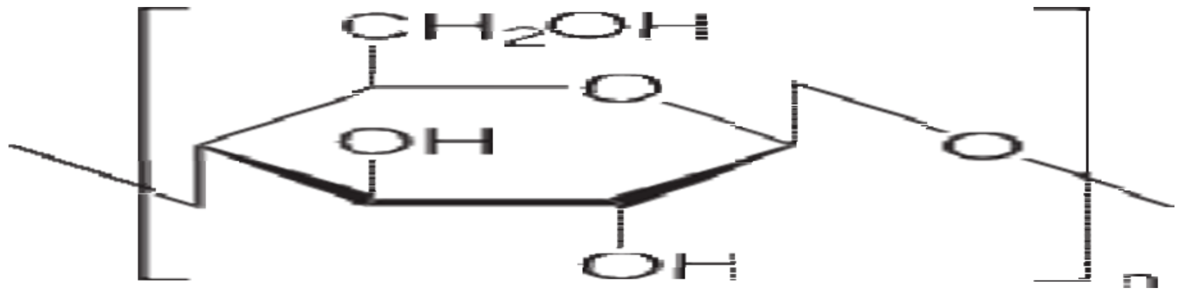


Figure.6: Repeating pattern in cellulose. [6]

2. Sources of cellulose:

Modern industrial requirements for vast amounts of cellulose are met by materials obtained from many different botanical sources. Woody matter, seed hairs, bast fibers, straw, stalks, hulls, and even marine plants and peat are used for various purposes.

2.1 Wood cellulose:

Wood, the most widely used of all cellulosic materials, is found all over the world since it is the substance of which the branches and trunks of the higher plants are composed. There are two main classes of wood. The hardwoods or angiosperms, such as oak, are generally composed of closely packed cells with thick walls; the softwoods or gymnosperms, such as pine or cedar, are usually composed of large cells with thin walls. The composition of wood varies with the species and with the part of the tree from which it is taken. In round numbers, on a dry basis, wood contains 40 to 50% cellulose, 20 to 30% lignin, and 10 to 30% hemicelluloses and polysaccharides other than cellulose.

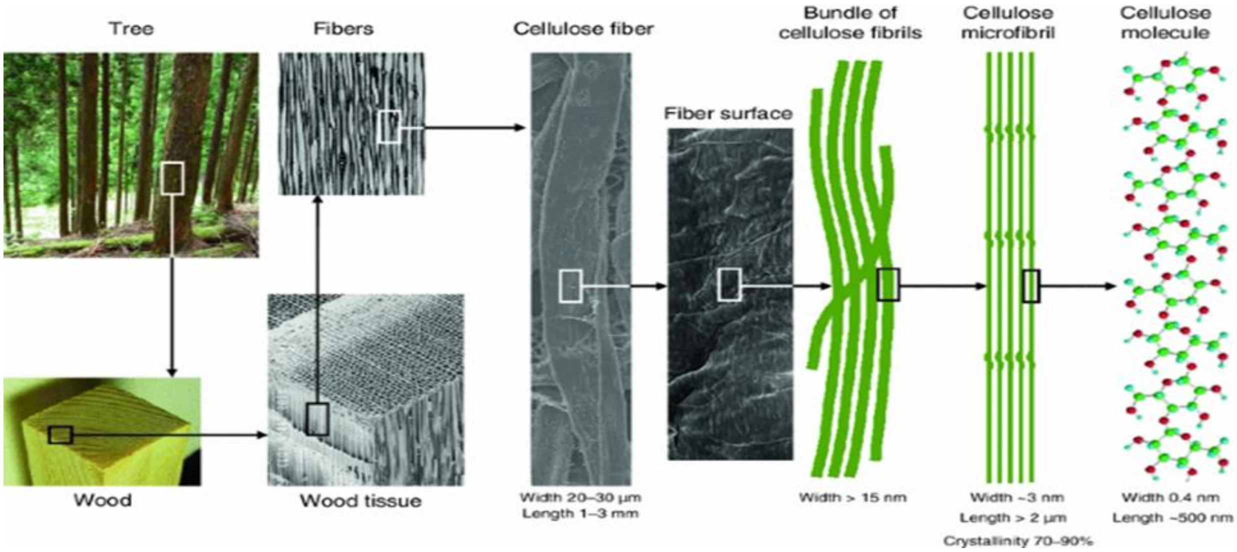


Figure.7: Cellulose in wood.

2.2 Seed hairs:

The most important of the seed hairs is cotton. Of all the commercial raw materials for cellulose, cotton fiber contains the lowest percentage of non-cellulosic material, 4 to 12% [46]. This makes purification simpler than for most cellulosic materials. In considering the cotton plant from the standpoint of cellulose, it is necessary to recognize that two types of hair lint and linters are developed on the cotton seed. Since not only the seed hairs, but also the stalks, burs, and leaves of the cotton plant are cellulosic in nature, it has been proposed that the whole plant be utilized for cellulose pulps.

Figure.8: Seed hairs (cotton).

2.3 Bast fibers:

The bast fibers are the long fibers of the inner bark of various plants. It includes flax, hemp, jute, ramie, and many other less important fibers. Although widely used in textiles and paper, they have found no industrial utilization for pulps high in alpha-cellulose. The yields of the bast fibers are very small, based on the green weight of the stems. The flax plant (Linum usitatissimuni) is the source of the important textile fiber linen, which contains 80-90% cellulose. The fiber is most easily obtained from plants that have not fully matured, and the best linseed oil is from completely ripened plants. The short fiber separated from the seed-flax straw is utilized by the paper industry. Many different vegetable fibers are loosely referred to as hemp. The common hemp is Cannabis sativa, the same plant that produces the narcotic marijuana. Bleached hemp contains approximately the same amount of cellulose as bleached linen and is similarly produced and processed. Hemp is widely used for ropes and cordage and for bagging although other fibers have largely replaced it.

Figure.9: Famous Bast cellulose resources.

2.4 Leaf fibers:

Many of the vegetable fibers used in industry are obtained from the leaves of plants. The most important of these are the so-called hard fibers which are extensively used for cordage. Many of these are roughly and improperly classed as "hemp." The most important hard fiber is probably abaca or Manila hemp which is obtained from the leaf stalks of Musa textilis. The fiber is separated mechanically from the pulp, purified, and sun-dried.

Figure.10: Stages of the converting from leaves to fibers.

2.5 Grasses, Straws, and Agricultural Residues:

Since cellulose is the major constituent of the cell wall of plant life, those plants which have no industrial utilization, as well as the residual wastes from utilized plants, form a huge potential source of cellulose. By far the most important of these wastes and residues, as far as their present utilization is concerned, belongs to the grass family. Cereal straws have long been used in the manufacture of paper and paperboard.

Figure.11 Biomass wastes.

3. The structure of cellulose:

Cellulose is a homopolymer with a very long regular stereo chain composed of very numerous D-Anhydro glucopyranose (AGU) units linked together by ß-(1 4) glycosidic bonds. The repeat motif is the cellobiose dimer. The AGUs are in a chair conformation and have 3 hydroxyls functions: 2 secondary alcohols and a primary alcohol [6].

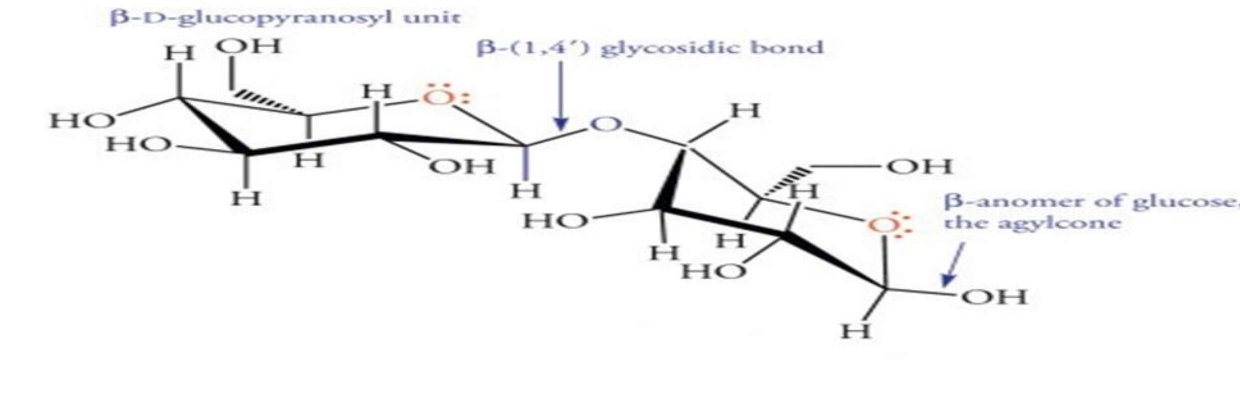


Figure.12: The structure of cellulose [6].

All the hydroxyl functions are in an equatorial position by reference to the plane of the cycle of the glucose molecule. The molecules are stabilized between them through the intermediary of a hydrogen bridge which gives the whole a strong cohesive power.

4. Methods obtaining cellulose:

Several methods of obtaining cellulose from biomass have been described, all these methods consisting of the gradual depletion of plant cell walls. Treatments applied to plant samples may be chemical, mechanical, or Chemo-mechanical.

4.1 Chemical method:

Chemical treatment has been commonly used in normal fibers to extract non-cellulosic materials, but it can weaken the crystalline structure. Numerous analysts have focused on the extraction by chemical treatment of cellulose from rural waste fiber using chlorine bleaching, alkali treatment, and acid hydrolysis.

4.2 Mechanical method:

To isolate fiber cellulosic materials a few mechanical techniques, such as homogenization, ultrasonic, and electro-spinning, have been used. Refining, cry crushing, crushing, and micro fluidization may also be viewed as other mechanical methodologies in addition to the disengagement process of fiber cellulose by homogenization. [8].

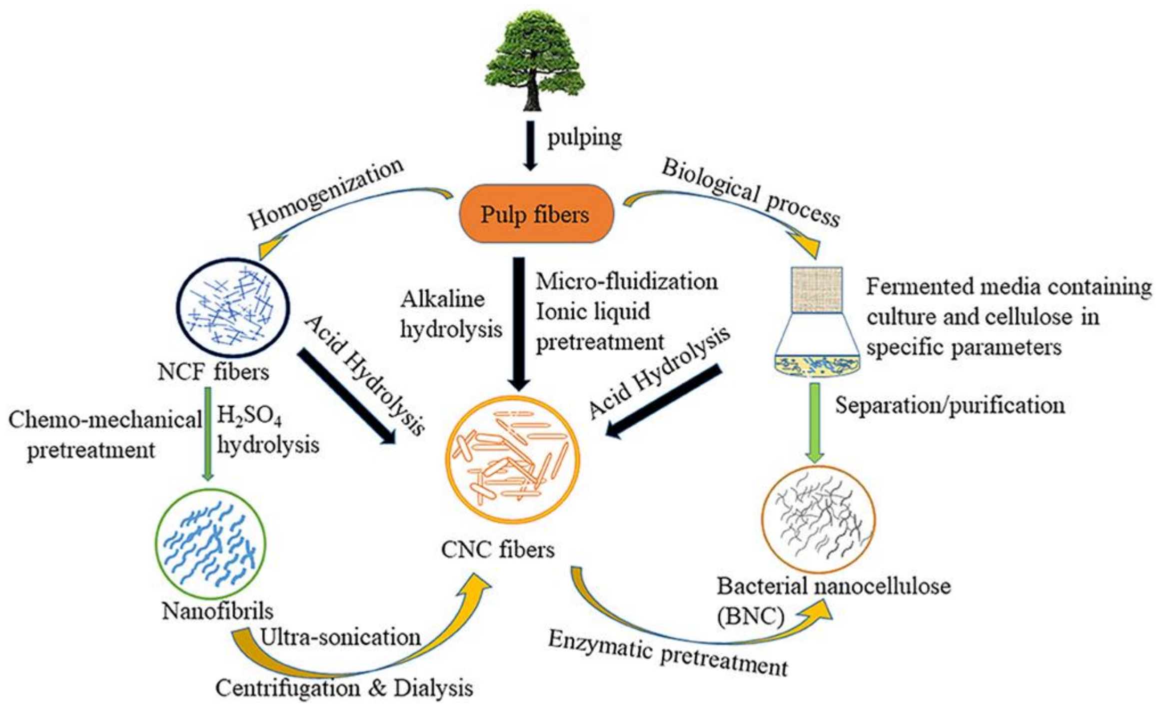


Figure.13: The transformation process for obtain cellulose. [7]

5. Cellulose derivatives:

The hydroxyl groups of cellulose can react partially or entirely with different chemical reagents to give cellulose derivatives with their properties. The main families of cellulose derivatives are:

- Cellulose esters such as cellulose acetate and Nitrocellulose.
- Cellulose ethers.

5.1 Cellulose ethers:

Cellulosic ethers are polymers derived from cellulose (anhydro glucose links linked by a glycosidic bond), and soluble in water. Indeed, cellulose is not soluble in water, the substitution of hydroxyl groups on the cellulose chain modifies this property, and the table below shows the main types of cellulose derivatives.

Table.4: Main characteristics of cellulose derivatives. [8]

Cellulose ether	reagent	the group	Water solubility	Application
Methylcellulose (MC)	Chloromethane	$-CH_3$	soluble in cold water	
Ethyl-cellulose (EC)	Chloroethane	$-CH_2CH_3$	Water-insoluble	A commercial thermoplastic used in coatings, inks, binders, and controlled-release drug tablets
Ethyl methyl cellulose (EMC)	Chloromethane /chloroethane	$-CH_3$ or $-CH_2CH_3$		
Hydroxyethyl cellulose (HEC)	Ethylene oxide	$-CH_2CH_2OH$	Cold/hot water-soluble	Gelling and thickening agent
Hydroxypropyl cellulose (HPC)	Propylene oxide	$-CH_2CH(OH)CH_3$	Cold water-soluble	filming properties, coating properties, pharmaceuticals, cultural heritage restoration, electronic applications, cosmetic sector
Hydroxyethyl methyl cellulose (HEMC)	Chloromethane /ethylene oxide	$-CH_3$ / $-CH_2CH_2OH$	Cold water-soluble	Production of cellulose films
Hydroxypropyl methyl cellulose (HPMC)	Chloromethane and propylene oxide	$-CH_3$ or $-CH_2CH(OH)CH_3$	Cold water-soluble	Viscosity modifier, gelling, foaming and binding agent
Carboxymethyl cellulose (CMC)	Chloroacetic acid	CH_2COOH	Cold/Hot water-soluble	Often used as its sodium salt, sodium carboxymethyl cellulose (NaCMC)

Chapter III: Materials, method and experimental study.

Introduction:

In this chapter, we will discuss the materials and tests used in the study of the effect of a cellulose derivative on cement mortar reinforced by sawdust.

1. Materials used:

The physicochemical behavior of cement pastes and mortars were studied on mixtures composed of different materials. The preparation of these mixtures followed precise prescriptions regarding formulation and mixing.

Figure.14: Materials used in cement mortar.

1.1 Cement powder study:

To study the real effect and obtain more accurate and detailed results about the products of cement hydration reaction, we chose cement of type CEM I 52.5 N-SR according to NA 442v2013. This type of Portland cement contains a small percentage of secondary components as shown in the table below.

Table.5: The compound of cement powder (NA 442v2013).

the components	Percentage (%)
CaO	63.4
SiO_2	18.3
Al_2O_3	5.7
Fe_2O_3	5.3
MgO	1.3
Na_2O	0.78
SO_3	3.6
Cl^-	0.07

This type is also characterized by the physical and mechanical properties shown in the table 6.

Table.6: physical and mechanical properties.

	Units	Results	Specifications Standard
Water requirement	%	30	
initial setting time	hh:mm	3:10	≥ 0:45
final setting time	hh:mm	4:10	≤ 12:00
Stability	mm	≤1	≤10
Compressive strength	N/mm^2		
1 day		22	
2 days		38	≥ 20
28 days		69	≥ 52.5
Blaine Specific Surface	cm^2/g	3840	

Area			
Absolute density	Kg/m^3	3160	
Refusal at 200 µm sieve	%	≤0.5	≤ 3.0
Value C	-	1.20	

1.2 Description of used sand:

We used in this experimental study alluvial sand sourced from Baage (El Meghaier, Algeria). The maximum particle size of the sand was 4 mm. it possessed a fineness modulus of 1.87 and absolute density of 2.7g/cm3.

Table.7: Physical proprieties of alluvial sand. [9]

Sand	Apparent density(kg/m^3)	Specific Density (kg/m^3)	Sand equivalent (%)	Fineness modulus (%)
Alluvial	1640	2700	80	1.87

1.3 Mixing water:

Water is one of the essential ingredients of cement paste. Indeed, the water introduced into the mortar during its manufacture will fulfill two essential functions: a physical function that gives the fresh mortar the rheological properties of a liquid and a chemical function that contributes to the development of the hydration reaction and therefore mechanical resistance.

The mixing water must have the properties of drinking water according to the Algerian standard NA 815. It is excluded to use seawater that contains sodium chloride because the salts dissolved in the water can intervene in the rheology of the mortar, the setting of the cement paste and the durability of the hard material.

1.4 The fibers:

In this experiment we resorted to using plant fibers (sawdust) for several reasons:

- It is economical alternative to conventional building concrete method and material. As well as it's made of ecologically pure stuff.
- Reducing the total weight of the cement matrix.
- Getting thermal insulation.

the use of sawdust as a filling material in cement mortar will greatly affect the decrease of its compressive strength, sawdust still can be used to substitute the sand in mortar mixture with optimum percentages of 2% to 8% .[10]

1.5 The adjuvants:

In this study we used hydroxyl propyl methyl cellulose (HPMC) as an adjuvant as it is available in the market, and the table below shows some of the physical and chemical properties of this type of cellulose ethers.

Table.8: Physical and chemical proprieties of HPMC. [11]

Proprieties	Value	unit
Appearance	White powder	/
Particle size (mesh passing rate)	98.5	%
Carbonization	280-300	°C
Apparent density	0.25-0.7	g/cm3
Specific density	1.26-1.31	g/cm3
Mole weight	$7.10^{\wedge 4}$	g/mol

2. Methods and tests:

2.1 Compressive/flexural test:

2.1.1 Principe:

The test consists of determining the compressive strength and, optionally, the bending strength of prismatic specimens with dimensions of 40 mm × 40 mm × 160 mm. [12]

These test specimens are formed from a plastic mortar mixture containing one part by mass of cement, three parts by mass of uniform sand CEN and slightly more than half a part of water (water-cement ratio 0.70).

In the reference procedure, the mortar is prepared by mechanical mixing and clamped in a mold using an impact device. The specimens are kept in their mold in a humid atmosphere for 24 h and, after demolding, they are kept under water until the time of the resistance tests [12].

At the required age -28 days- the specimens are removed from their humid storage environment, they are broken in bending, with determination of the bending resistance when required or simply broken by other suitable means which do not subject the half-prisms to harmful stresses, then each half-prism is subjected to the compressive strength test [12].

2.1.2 Formulation and preparation of the model mortar:

To study the effect of adding cellulose derivatives to cement mortar, we fixed the proportion of sawdust and made gradual changes in the proportions of additives, so that we had three types of mixtures as shown in the tables below.

Figure.15: Preparation of mixtures compounds.

Table.9: formation of the reference sample.

component	cement	sand	water	Adjuvant	Sawdust
Quantity (g)	400	1200	280	00	24

Table.10: Formation of the first mixture.

component	cement	sand	water	Adjuvant	Sawdust
Quantity (g)	400	1200	280	04	24

Table.11: Formation of the second mixture.

component	cement	sand	water	Adjuvant	Sawdust
Quantity (g)	400	1200	280	08	24

The laboratory in which the test specimens are prepared must be maintained at a temperature of (20 ± 2) °C and at a relative humidity greater than or equal to 50%.

- Introduce the water or the admixture solution and the cement into the bowl, taking care to avoid any loss of water or cement.
- As soon as the water (admixture solution) and the cement come into contact, immediately start the mixer at low speed, while starting the timing of the mixing

steps. After 30s of mixing, regularly introduce all the sand during the next 30s. Switch the mixer to high speed and continue mixing for another 30s.

- Stop the mixer for 90s. During the first 30s, remove all the mortar adhering to the walls and bottom of the bowl and place it in the middle of the bowl.
- Resume mixing at high speed for 60s.
- Mold the test pieces immediately after preparing the mortar.
- Place each covered mold without delay on a horizontal support in the humid chamber maintained at a temperature of (20 ± 1) °C and a relative humidity greater than or equal to 90%.
- Demold between 20h and 24h after molding.
- Immediately immerse the suitably marked test pieces in the tanks containing water at (20.0 ± 1.0) °C.
- Remove from the water the test pieces intended to be tested at a particular age 2, 7 or 28 days.
- Place the half-prism in compression on the lateral molding faces.
- Center each half-prism in the test compartment.

Figure.16: Test specimen for bending and compression.

- Apply the load vertically and increase the load uniformly until failure.

$$\sigma = \frac{F}{S} \text{ [13]}$$

- F: applied load in KN.
- S: Surface area of the half-prism cm2.
- σ : Applied stress MPa.

- If Fc is the breaking load, the breaking stress will be:

$$Rc = \frac{Fc}{B^2} \text{ [13]}$$

This constraint is called compressive strength and, if FC is expressed in newtons, this resistance expressed in mega Pascal's is:

$$Rc = \frac{Fc(N)}{1600}[13]$$

- Fc: is the load applied to the middle of the prism at break (Newton).
- 1600: $40_{mm}x40_{mm}$ the section of the trays or auxiliary plates in (mm^2).

2.2 Setting time test (initial and final):

2.2.1 Principe:

Cement paste of standard consistency has a specified resistance to penetration by a standard probe. The water required to obtain such a paste is determined by penetration tests on pastes containing different amounts of water.

Setting time is determined by observing the penetration of a needle into a cement paste of standard consistency until it reaches a specified value.

2.2.2 Initial and final setting time:

- Place the mold filled with normal dough in the automatic Vicat (see figure.16), add water at a temperature (20 ± 1.0) °C so that the surface of the dough is covered with at least 5mm of water.
- The automatic Vicat driven by a steel needle is used to determine both the initial time and the end time of setting, and must have the shape of a right cylinder with an effective length of (50 ± 1) mm and a diameter of (1.13 ± 0.05) mm.
- The automatic Vicat device makes spikes every 5 min automatically, the first one touching the bottom of the mold is indicated as the time (t = 0) and the last spike on the surface of the standardized paste (h = 40 mm) designates the final of setting time.

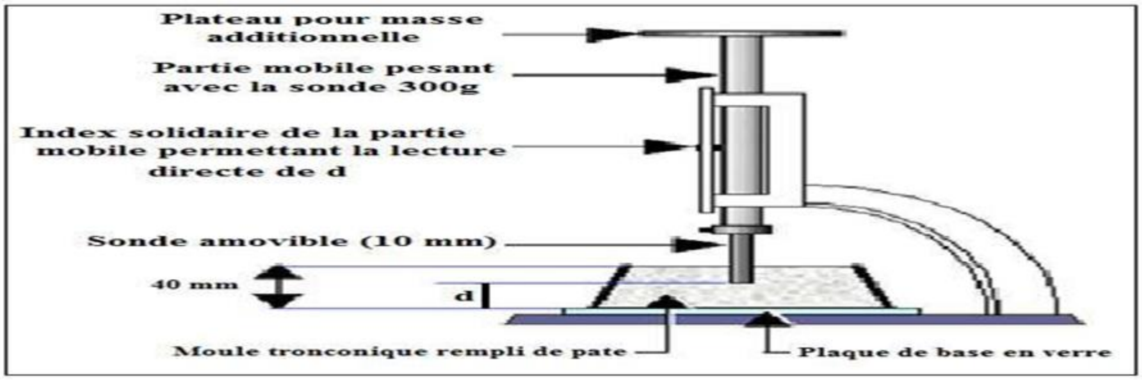


Figure.17: Vicat apparatus with consistency probe. [14]

Chapter IV:

Results and discussion

Introduction:

The objective of this experimental part of our work is the characterization of mortars and cement pastes admixed with amphiphilic polymer (HPMC) and their corresponding mixtures.

All standardized tests were carried out within the framework of Algerian standards and the tests are carried out after the incorporation of organic adjuvants with studied dosages. The physicochemical tests will be presented in the following order:

First carried out on grouts through the determination of:

- The duration of the start and end of setting (or hardening).

Then, on mortars through:

- The compressive strength test of the specimens at the age after 7, 14, 21 and 28 days of the specimens.

Samples were prepared in a ratio of 1:3 (cement/aggregate) with a fixed ratio of sawdust (2% of the aggregate weight), and a variable ratio of auxiliary materials. The first reference sample contained 0% HPMC, the second 1% and the third 2%. As for the water-cement ratio (w/c), due to the unavailability of the device, we chose the highest possible ratio (0.7) to know the effect of the material at the maximum possible condition.

1. Performance of fresh cement mortar mixtures:

1.1 Setting time:

The aim of the experiment is to determine the initial and final setting time of the cement matrix.

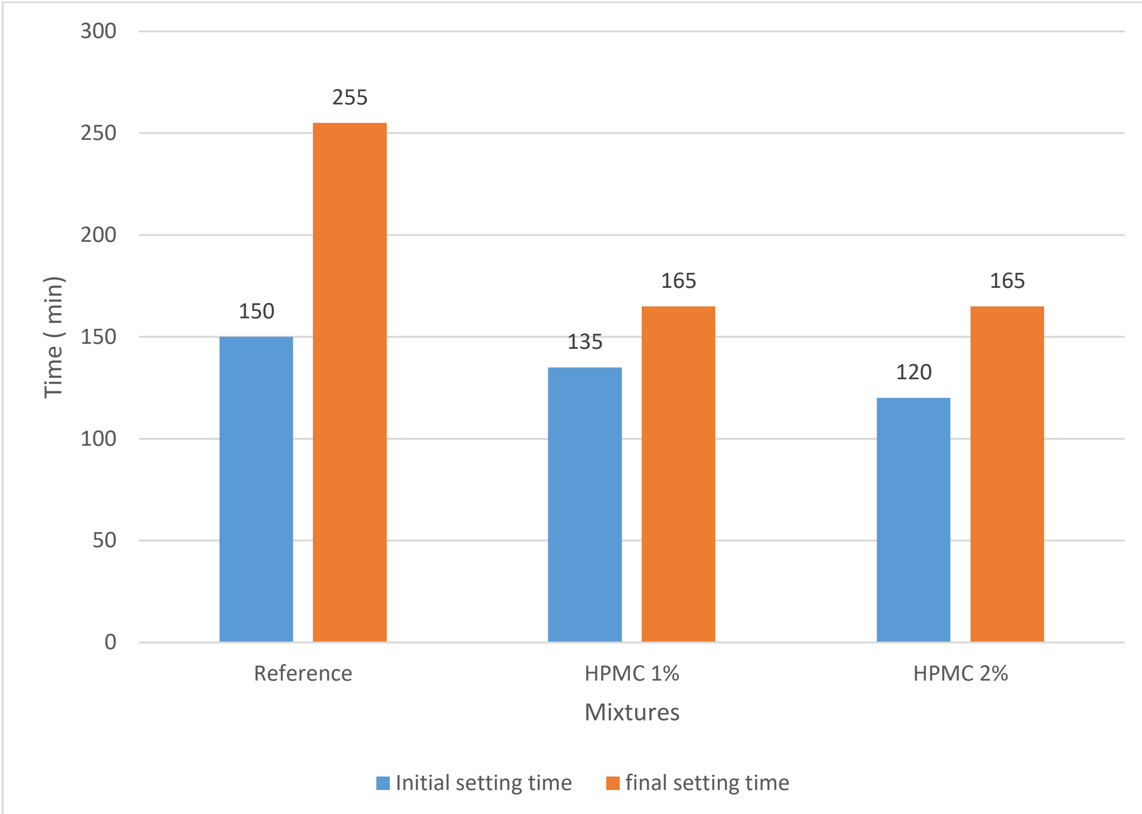


Figure.18: Determination of the setting time of mixtures with different proportions of HPMC in the presence of reference.

Compared to the reference mixture, we can see that cellulose ethers can make setting faster in mixtures with high water content.

Figure.19: using Vicat apparatus for determine setting time.

2. Performance of hardened cement mortar mixtures:

2.1 .Flexural strength test:

This experiment is done to determine the sample's resistance to flexural forces and is placed as shown in the figure.20.

In the bending experiment, three types of mixtures were used, where the difference was in the percentage of hydroxyl propyl methyl cellulose, while three samples were made from each mixture in order to obtain the average value and avoid errors.

- We call the reference cement mixture “Mixture 01” as it contains 0% of HPMC.
- We call the reference cement mixture “Mixture 02” as it contains 1% of HPMC.
- We call the reference cement mixture “Mixture 03” as it contains 2% of HPMC.

Figure.20: Preparing the spacemen in flexural machine.

The results of the experiment are shown in the following bar graph:

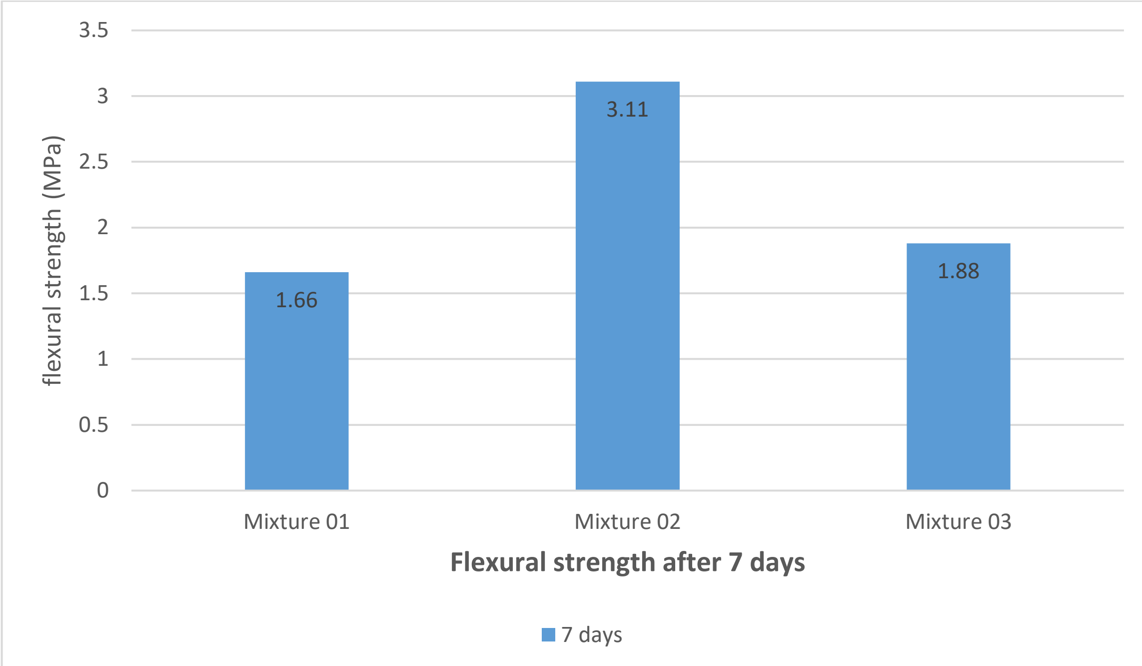


Figure.21: Bar chart showing the flexural strength of the samples after 7 day.

It is clearly observed that after 7 days the samples containing 1% of HPMC were more resistant to bending.

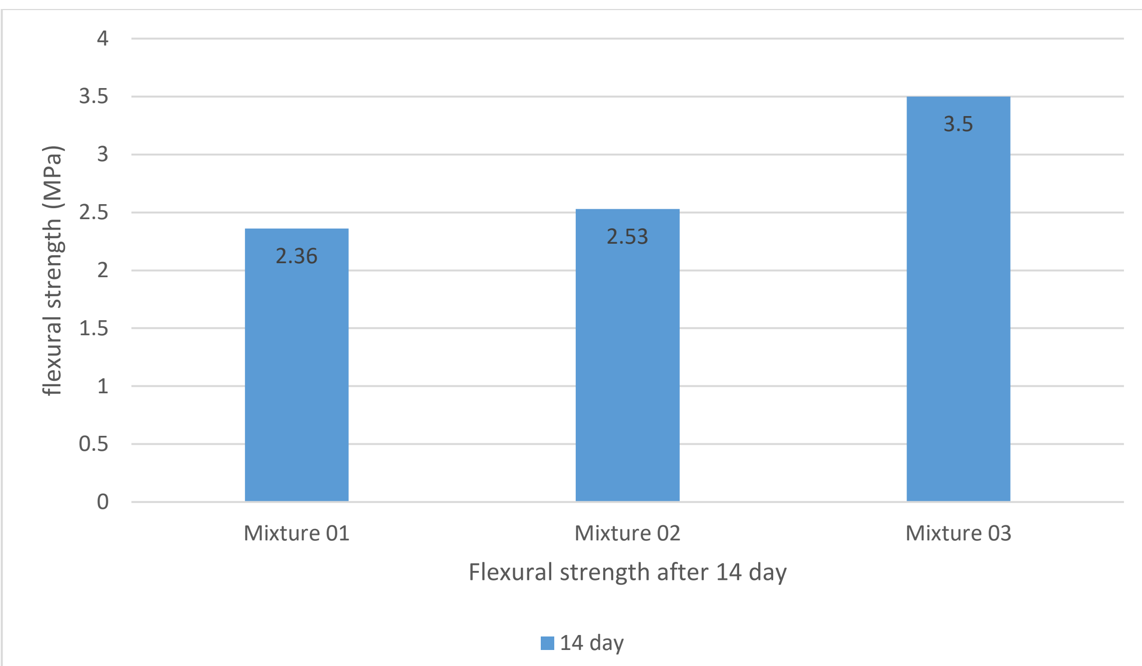


Figure.22: Bar chart showing the flexural strength of the samples after 14 day.

After 14 days, we see from the bar charts that the difference in flexural resistance of the mixtures decreased, with a gradual increase in the resistance of the third mixture sample.

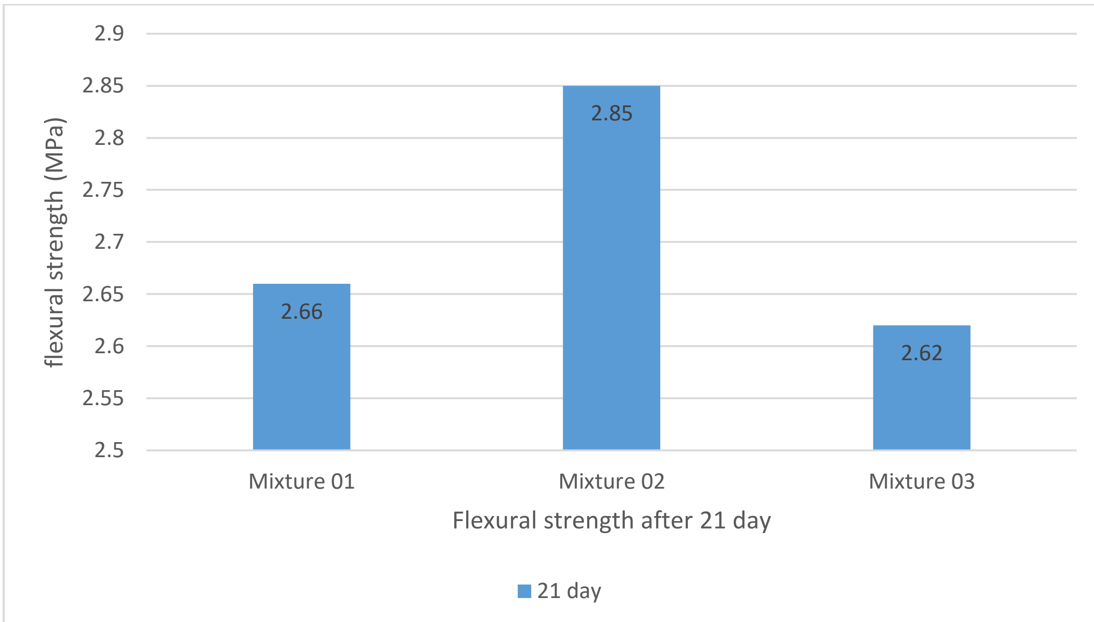


Figure.23: Bar chart showing the flexural strength of the samples after 21 day.

After 21 days, we notice an increase in the flexural strength of the mixture 02 sample compared to the other samples.

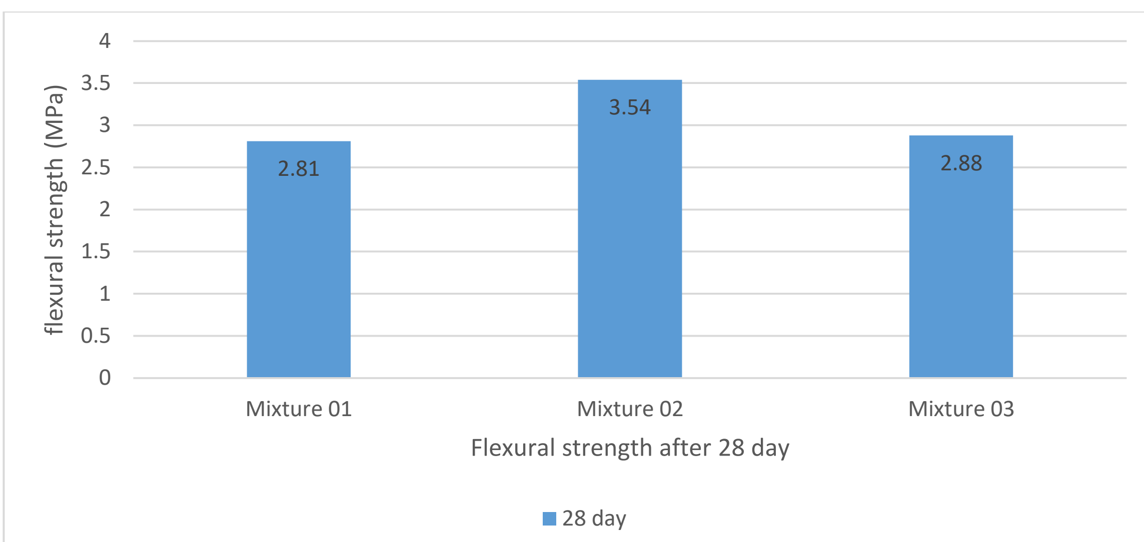
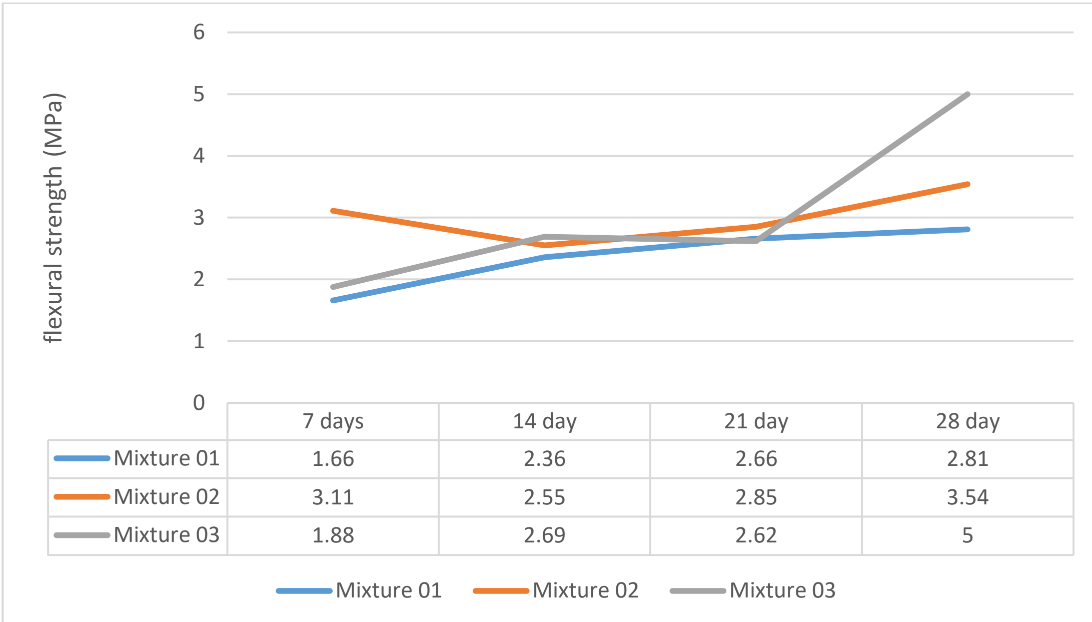


Figure.24: Bar chart showing the flexural strength of the samples after 28 day.

Another increase in resistance is observed at the sample level, clearly appearing in the mixture 02 sample.



	7 days	14 day	21 day	28 day
Mixture 01	1.66	2.36	2.66	2.81
Mixture 02	3.11	2.55	2.85	3.54
Mixture 03	1.88	2.69	2.62	5

Figure.25: Graph showing changes in flexural strength over time.

1.3 Compressive strength test:

The experiment aims to know the resistance of the mortar to pressure, as one end of the sample from the previous experiment, (the flexural strength test), is placed under continuous pressure until it breaks.

Figure.26: compressive strength test.

After performing the experiment, we summarize the results obtained in the graph columns:

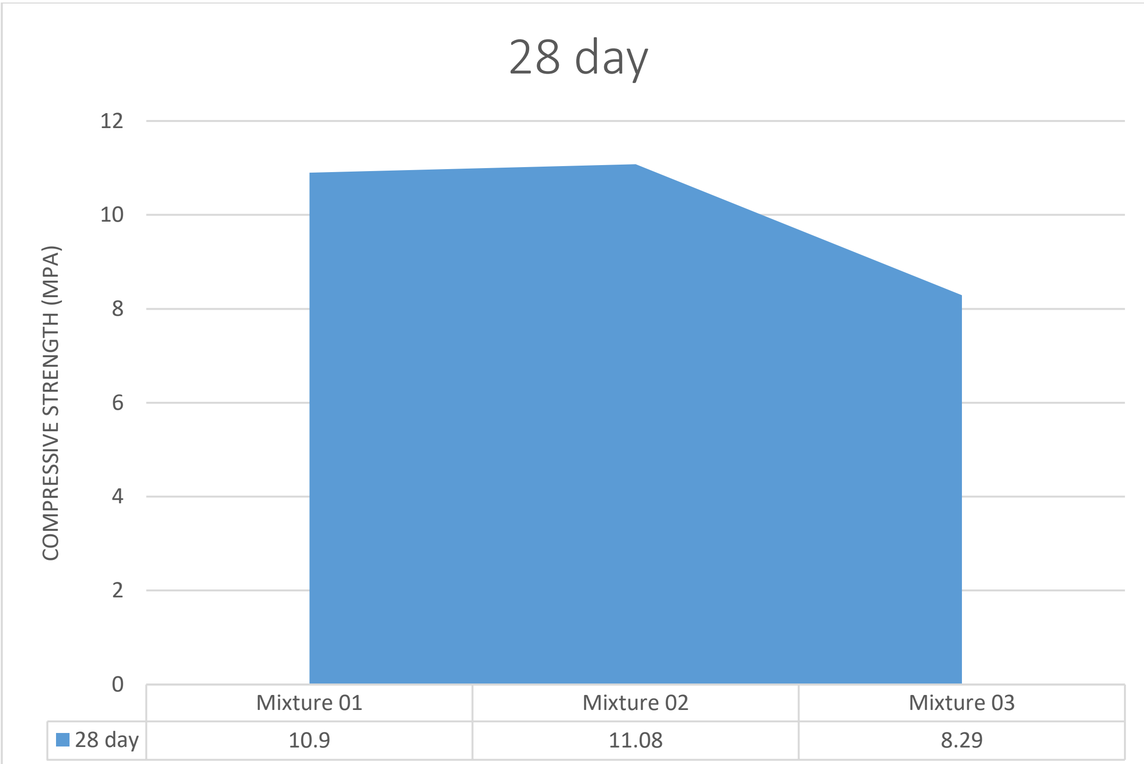


Figure.27: Bar chart showing the compressive strength of the samples after 28 day.

After crushing the samples in 28 day, we noticed that the samples containing 1% of HPMC gave better compressive strength compared to the samples with 2% as well as the reference sample.

General conclusion

General conclusion

Cellulose ethers of the Hydroprobyl methylcellulose (HPMC) type are systematically introduced into the formulations of industrial mortars. The macroscopic effects of these adjuvants on the hydration reaction are perfectly known, but they remain unexplained. Indeed, while cellulose ether gives good workability and excellent water retention properties to the mortar, losses in mechanical stress resistance properties occur and are not controlled.

This work was conducted in order to know the physical and mechanical properties that occur in cement mortar when adding HPMC, which in turn contains sawdust that act as fibers and weight reducer.

After conducting many tests, we will find that HPMC has some defects that must be detected, as it works as a slower for the hydration process of the cement, as well as increasing porosity and air spaces, which leads to a decrease in mechanical resistance.

After we concluded that 1% of the HPMC give better results in the previous experiments, we will in subsequent experiments set another percentage (0.5, 0.75, 1.25, and 1.5) in order to determine a more accurate value or range for adding HPMC

Many experiments have been neglected due to the lack of resources, research and tools at the local level. Therefore, further investigations should be carried out using appropriate techniques in order to obtain results and explanations on the phenomena that occur, especially with regard to the phenomena that occur. Texture and water retention, as well as the mechanism of absorption of polysaccharides.

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