New approach for the formulation of High Performance Concrete Valorisation of local materials

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Research Article

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Abstract

High performance concrete (HPC) is an innovative concrete that finds its place in modern buildings. The new high-performance concrete formulation and conception techniques have improved sustainability and acquiring remarkable mechanical properties compared to conventional concretes.

The objective of this work is to make a contribution to understanding the influence of factors such as the W/ C ratio and the granular class on the mechanical and physical properties of high performance concretes. In the formulations of HPC aggregates by their high mass and volume proportion, play an important role, the Sherbrook and Dreux-Gorisse method has been used. When selecting aggregates it is necessary to know their intrinsic properties. These properties influence the performance of concrete in particular the quality of the granulate cimentary adhesion.

At the end of our work, the examination of the results obtained made it possible to establish the correlations between the formulations studied and the physico-mechanical characteristics of the concrete compositions (HPC 25, HPC 16, HPC 8).

The results of this study show that the use of three granular classifications (DMAX8, DMAX16 and DMAX25) and three Report W / C (0.25, 0.30, and 0.35) in two different conservation environment (EP drinking water and sea water), clearly proves that the composition of high performance concrete is HPC25 concrete with an W/ C = 0.25 ratio has reached the largest mechanical strength of 80 MPa for different environments of conservation.

When selecting aggregates it is necessary to know their intrinsic properties, these properties influence the performance of concrete. In general, there is a slight decrease in the compressive resistance of the specimens stored in seawater, it can be said that the conservation life has not had effect on the resistance (28 days). The effect of aggressive environment can appear in the long term.

1. Introduction

High Performance Concrete (HPC) is characterised by high strength, increased durability, and self-desiccation.. Until now HPC has been substantially used in high- rise structures, islands, and canvas-platforms (B. Persson, I999-Helland,S.,). A special operation self-desiccating slabs was used for further than 1 million m 2 floor of dwelling houses in Sweden (Person,B.,) and Finland (Penttala,V.,). Still, for more general use of HPC more research is necessary concerning the longterm properties, especially at early periods (Miiller,H.S. and Kiittner,C.H.,). The size, shape, texture, and grading characteristics of coarse aggregates s significantly affects the fresh and hardened performance of high- strength concrete. When used collectively, there are advantages and disadvantages associated with the use of crushed and naturally rounded coarse aggregates.

The advantages or disadvantages of each depend on the specific properties of the concrete under consideration and the properties of each aggregate. Important properties of aggregates that will determine the optimum mixing ratio include gradation, shape, angularity and hardness.

The limits of achieving the strength of larger-sized coarse aggregates come apparent when trying to produce high- strength concrete. shows the effect of aggregate size when producing plain (Portland cement only) concrete at a fixed slump of 100-mm. Note that at cement contents below 350 kg/ m3; the largest of the three aggregates yielded the loftiest compressive strength at 28 days. At cement contents above 400 kg/ m3, the lowest of the three aggregates yielded the loftiest compressive strength at 28 days. Thus, it's generally agreed that lower size aggregates should be used to produce advanced- strength concrete. The effect of the coarse aggregates size on concrete strength was explored by Cook (1989), who used limestone of two different sizes 10 mm and25 mm. A high- range water- reducing admixture was used in all of the mixtures studied. In general, for a given W/ B rate, the lowest size of the coarse aggregates produced the loftiest strength; still, it was doable to produce compressive strengths in excess of 70 MPa using a 25 mm outside size aggregates when the admixture was correctly proportioned with a high- range water- reducing admixture. A analogous study was conducted by de Larrard and Belloc (1997) using crushed limestone aggregates, Portland cement, silica fume, and high- range water-reducing admixture for eight different mixes.

The results suggested that better performances and frugality could be achieved with 20 to 25 mm outside size mixtures indeed though former experimenters had suggested that 10 to 12 mm is the maximum size of mixtures preferable for making high- strength concrete. The principle that lower coarse aggregates produce advanced- strength concrete can be a delicate conception to embrace, since it's contrary to the same principle in conventional- strength concrete, where lower aggregates reduce strength. In order to understand the relationship between strength and aggregate size, three effects must be known : aggregate size; water-binder rate; and consistency (i.e. slump, slump spread, etc.). (Michael A. Caldarone, 2009).

Water curing is essential to promote nonstop cement hydration, refinement of the capillary porosity, and reduce the threat of cracking due to shrinkage. This can lead to increased strength and the low permeability. This is especially the case when the concrete is proportioned with low water/cementitious materials (w/cm) ratio., thus, recommended that particular attention be paid to cracks in high performance concrete structures similar that this issue can be addressed in an economically effective manner, .and insure that the awaited service life of these structures is achieved. (T.D. MARCOTTE,C.M. HANSSON,). Generally, concrete with high resistance to the marine environment should have high compressive Strength (T. Cheewaket •C. Jaturapitakkul •W. Chalee2014). Service life prediction is getting one of the present major tasks in the design of concrete structures. The durability design must be grounded on coherent models that can describe the deterioration mechanisms more directly (A. Costa andJ. Appleton,).

When the content of silica fume was 10% and the volume content of polyvinyl alcohol fiber was 1% the comprehensive mechanical performance and frost resistance of concrete is the best (Tan,Y.; Xu,Z.; Liu,Z.; Jiang,J. 2022). Likewise, the use of these byproducts increased the durability in terms of erosion and sulfate attack. Also, these mixtures have also great environmental and economic benefits. (Tariq Ali 1, Abdul Salam Buller 2, Fahad ul Rehman Abro 3, *, Zaheer Ahmed 4, Samreen Shabbir 5,. Ali Raza Lashari 3 and Ghulam Hussain,). Visible cracks were formed in the prisms that didn't contain silica fume10% immersed in seawater. (Şakir Erdoğdu1 • Şirin Kurbetci1 • Safa Nayır1,)

2. Materials And Methodology

2.1. Materials

2.1.1. Cement

The cement used was CPJ-CEM II/ A42.5 from the factory of Aïn Touta (wilaya of Batna). The cement used in this expression is a Portland cement conforming of CPJ-CEM/ II-A42.5 N type. This cement is substantially made up of 75% of Clinker, 5% of calcium sulphate is added as a gypsum as a draw controller. 20% blast furnace slag, from the society of the cements of El-Hamma Bouziane and which complies with NA 442 2013.

2.1.2.Aggregates

All concretes were made with crushed limestone gravel with maximum periphery (d_max) is 25 mm. Three (03 granular fractions have been used granular fractions (G1) (3/8 granular fractions (G2) (8/15), and granular fractions (G3) (15/ 25), from the career of Chelghoum-Laid Wilaya of Mila.

and having a specific graveness of2.72, immersion of 4% with measure of Los Angeles G1 G2 24% G3 30%. While the fine aggregates used were from two (02) sources; natural and artificial, natural siliceous sand (S1) of granular class (0/1) with a fineness modulus MF1 = 1.86, (drift black from the Wilaya of Jijel), quarry sand (S2) of granular class (0/3) with a fineness modulus MF2 = 3.22 from the Chelghoum-laid wilaya of Mila quarry, and a corrected sand (S3) which was used to improve the fineness modulus obtained by mixing 50% sand S1 and 50% sand S2, with a modulus of fineness MF3 = 2.54, the gradation of sand and aggregate is shown on (Fig. 1)

2.1.3. Superplasticizer

The adjuvant used is a originOABal superplasticizer"MEDAFLOW 30."This is a result of polyacrylates, 30% solid contents, clear colour and PH = 6-6.5. Density 1.07

2.1.4. Silica fume : The SF is an HP MEDAPLAST adjuvant based on micro silica (Granitex), characterized by its absolute density of 2.2, particle size of 0.1 (microns) and silica content of 85 per cent.

2.1.5. Water

The water is drinking water that contains little sulphate and having a temperature of 20 ± 1°C. Its quality conforms to the requirements of standard NFP 18−404.

2.2. Mix proportions

The system espoused for the Mix design of concrete is of the University of Sherbrooke developed by Professor PC Aïtcin and his exploration team (Aïtcin etal., 2001). The durability performance of a completed structure relies on both the design position and its execution quality, the conversion of design parameters to quality control parameters is an important issue, but not straightforward. To estimate the quality of the execution, a conformity control procedure is necessary to guarantee the design demand is fulfilled. (Xinyi Ye. Quanwang Li. Qinming Zhang, 2021). Table 1 present the complete blend design of the 09 concrete mixes for water/ cement or water/ binder rate of 0.25,0.30 and 0.35.

W/ C Water/ Cement. W/ B Water/ Cement Cement + Supplementary Cementitious Materials = Binder.

The study of the percentages of granulates fractions is by the system of Dreux-Gorisse

Table 1
Composition of concrete mixtures for crushed stone of fraction 3/8 and 3/16 and 3/25

Materials									
Dosage en kg/m3									
BHP8 BHP16 BHP25									
W /C	0.25	0.30	0.35	0.25	0.30	0.35	0.25	0.30	0.35
Cement	540	450	385.7	540	450	385.7	540	450	385.7
Water	135	135	135	135	135	135	135	135	135
Superplasticizer	18	15	12.86	18	15	12.86	18	15	12.86
Aggregates 1	1075	1075	1075	771	771	771	458	458	458
A2	-	-	-	300	300	300	335.9	335.9	335.9
A3	-	-	-	-	-	-	275	275	275
Sand 1	369	409.29	438	369	409.29	438	369	409.29	438
S2	369	409.29	438	369	409.29	438	369	409.29	438**2.3.**

Test specimens

2.3.1. Test plan

A total of concrete specimens were cast and tested in this study were cube specimens (150 *150 *150 mm) used to determine the compressive strength, cube specimens (150* 150* 150 mm) were cast to determine the durability characteristics such as water absorption and Softening.

3. Results

3.1. Workability

The most important property of fresh concrete is certainly its workability. The slump test, although used extensively, reaches its practical limit at about 180–200 mm, depending on the maximum aggregate size. When using an SP, the slump increases greatly, and therefore evaluating the workability of the HPC by a slump test has no reliable meaning, and the apparatuses cited above are more convenient. However, their application is not widespread, and they may be deemed impractical in the rid. For this reason, the consistencies of flowing HP are generally determined by means of the ORIMET U. K. Test, the DIN 1048 flow test, the Japanese flow test, or the Nasser Kslump test (Raymundo Rivera-Villarreal,1997).

For each spoiled and just after mixing, the workability of the freshly made concrete is then characterized. Indeed, it is this workability that determines the ease of the concrete to be implemented on site. It encompasses its pumpability, fluidity, resistance to segregation and resistance to bleeding. The consistency of the concrete is therefore measured using a simple site test (abrams cone subsidence) (Figure III.1) Slumps are measured using the Abrams cone according to standard NF P 18–451, it is found a concrete cone under the effect of its own weight. More this Slumps will be bigger and the concrete will be fluid.

Two slump measurements were taken, the first just after mixing and the second after half an hour, the results of which are given in Table 2 below:

Table 2
The slump of concrete with crushed stone of fraction 3/8 and 3/16 and 3/25

HPC	HPC 8			HPC 16			HPC 25			
W/C	0.25	0.30	0.35	0.25	0.30	0.35	0.25 + 8% SF	0.25	0.30	0.35
Slump (10min)	21	21	22	22	22	23	21	22	23	24
Slump (30min)	19	21	20	19	22	20	16	17	22	22

According to the results obtained, it can be seen that:

- Superplasticizers are highly effective water reducers. Their main mode of action is to increase the workability of concretes through the phenomenon of dispersion.

We used the superplasticizer Sika Tempo12, our concrete had a segregation so we changed the superplasticizer Sika Tempo12 by the superplasticizer Medaflow30 (Granitex), this one is compatible with the CPJ-CEM/II-A 42.5N cement.

- All BHP mixes have fluid concretes with slump values around 170 mm to 240 mm.

- Decrease in slump after 30 minutes of mixing, which is quite logical, we checked the workability of the ready-mixed concrete, the duration of 30 minutes corresponds to the duration of transport by the mixers to when placing the concrete.

- BHP with a reduced W/C ratio are slightly workable at the first slump measurements, however, we see the decrease in workability after 30 min of mixing due to the high dosage of superplasticizer and a small quantity of mixing water. The more the W/C ratio is reduced, the more the concrete is viscous and requires vibration.

Over the W/ C or W/ B is reduced more concrete is viscous and requires the vibration. The fluidity of concrete is increased with the use of silica cloud, because of their small globular patches and their huge face area that can fill the space between the cement grains rather it's enthralled by the water and generally causes a reduction in the quantum of water needed for concrete workable .(lesser quantum of free water will flow the concrete) (Aïtcin etal., 2001). The slumptest results are presented in table 3. In general, the flow is dominated by the behavior of the cement paste (cement + superplasticizer + silica fume +) and the effect of hydrodynamic interactions generated by the presence of aggregates is minimal. In practice, this amounts to transforming a concrete of traditional consistency into an HP concrete, that is to say a fluid and viscous concrete. (Benmessaoud 2011)

3.2. Compressive strengh

SF: Silica Fume.

NP: Natural Pozzolan.

Compressive strength is generally considered to be the main characteristic property of concrete.. Strength gains are not the only advantages of these concretes, which derive their properties from a strong reduction in their porosity. They are also more resistant to aggressive agents, to freeze/thaw phenomena and in general, have increased durability. (BEN MESSAOUD SABAH2018)

From the curve shown in Figures (2,3,4,5) there was a significant increase in strength of samples prepared with W/C 0.35, 0.30 and 0.25, and a characteristic strength at 28 days greater than 82 MPa. The use of superplasticizers (water reducers) makes it possible to reduce the W/C by avoiding the flocculation of the cement grains (Aïtcin et al., 2001). Continuing to further reduce the W/B ratio will lead to a reduction in the density of paste and with it strength Note that this is a fundamental principle of high strength concrete technology (Michael A. Caldarone, 2009).

The specific W/B ratio at which density is maximized will depend on the constituents of the dough. Optimal density with a combination of constituents the water/paste ratio and the incorporation of silica fume into the concrete help reduce the width and improve the strength of the transition zone (Mindess et al., 1994). The rapid conversion of $Ca(OH)_2$ to CSH by silica fume is thought to be of particular importance. The reduced bleeding into the paste also reduces the potential for water accumulation around the aggregate particles. (John Newmann, 2003) resistance against such effects can be enhanced if the microstructure is very dense with few or no capillary pores. From a technological point of view, this can be achieved by reducing the w/c ratio and adding silica fume as described (Dr.-Ing. R. Breitenbiicher Philipp Holzmann A G, Frankfurt, 1997)

Therefore, the structure and the thickness of the aggregate-dough interface are mainly attributed to the properties of the aggregates, in particular the porosity of the aggregates and the water absorption. of high performance concrete (Arman Montazerian1 • Mahmoud Nili1 • Negin2021)

When the transition zone between paste and aggregate is improved, the transfer of stresses from the paste to the aggregate particles becomes more efficient. Therefore, the mechanical properties of the aggregate particles themselves may be the "weakest link" leading to the limitation of the achievable strength of concrete. Fracture surfaces in HSCs often pass through aggregate particles rather than around them. Crushed rock aggregates are generally preferred over smooth gravels because there is evidence that the strength of the transition zone is weakened by smooth aggregates (Aitcin and Mehta, 1990). The aggregate must have a high intrinsic strength and granites, basalts and limestones have been used successfully, as have crushed glacial gravels. During the crushing process, aggregate particles can be severely microcracked. The number of microcracks will be higher in larger particles, therefore it is common to use smaller particles (nominal size 10–14 mm) for high strength concrete (Mehta and Aitcin, 1990a).

It is assumed that small aggregate particles will contain less internal defects and hence produce higher concrete strength. It should be emphasized that the selection of appropriate sources of aggregates is much more critical for high strength concrete than for conventional concretes (John Newman, 2003)

Nevertheless, the smaller size aggregate decreases the permeability of permeable concrete.

The properties of permeable concrete greatly depend on many factors such as the type and gradation of aggregate, cement content, water-cement ratio (w/c), aggregate-cement ratio (a/c), and type and degree of compaction. The dosage of the pervious concrete mix is intended to obtain a good balance between void content, dough content, workability and strength (Erhan Gu¨neyisi • Mehmet Gesog˘lu Qays Kareem • Su¨leyman I˙pek,2016)

3.3. Conservation in sea water :

Over a long period of service under external environmental conditions, civil infrastructure inevitably experiences a deterioration in its performance. Continuous deterioration in performance not only reduces the level of safety but also the life of a structure, so huge costs are incurred to upgrade or repair damaged structures. Among the many causes of deterioration of reinforced concrete (RC) structures, reinforcement corrosion predominates. Corrosion damage to structures is more severe in marine environments than in urban areas due to their exposure to high sea salt and humidity (Guo Anxin†, Yuan Wenting‡, Li Haitao‡ and Li Hui†, 2018).

The marine environment presented here all the ingredients for the following deterioration mechanisms:

• Corrosion, Sulfate attack, Substitution of magnesium ions, Abrasion and erosion, Frost damage, Carbonation, Salt crystallization (A. Goyns PIPES CC, Pretoria, 2013)

When several deterioration mechanisms occur simultaneously, the net effect is often greater than the sum of the individual factors. The study of the aggressiveness of the marine environment is therefore very complex and the design of the materials turns out to be just as conservative, as in this specific case (M. Alexander et al., 2013).

The difference between the resistances of concretes stored in drinking water and those of concretes stored in seawater is small and sometimes even negligible. So, there were no chemical reactions that lead to appreciable resistance drops, we can say that the shelf life had no effect on the resistance (28 days,Fig. 5). The effect of the aggressive environment can appear in the long term.

On the other hand, it has been observed that the presence of silica fume limits the composition and the formation of corrosion products: the addition of silica fume in high performance concretes can be considered beneficial (T. D. MARCOTTE, C. M. HANSSON, 2003).

3.4. Absorption of water

Along with the strength of concrete, durability is one of the major components of the rational design of concrete structures. The durability of concrete largely depends on its ability to prevent the penetration of aggressive chemical species. Therefore, the permeability of concrete is a major index of this ability. Common measurements of the permeability coefficient with water or chloride become inaccurate and unsuitable when used to test the permeability of HPC, because the essential use of chemical and mineral additives in HPC makes the paste much denser and more resistant hardened cement (Hui-sheng Shi Æ Bi-wan Xu Æ Tao Shi Æ Xiao-chen Zhou, 2007).

From Fig. 7, it can be seen that the absorption coefficients obtained are less than 5%, which means that our concrete is a very good concrete according to standard NBN B15-211 (1989). It is clearly visible that our absorption coefficient HPC can be reduced due to the fact that the porosity has been reduced (according to the composition: HPC25 concrete with an W/ C = 0.25 ratio), which improves the performance of the concrete, and greatly increases the durability of the concrete., which determines the service life of structures.

The water absorption rate of the sample was calculated as follows (T. A. Buari1 • F. A. Olutoge2 • G. M. Ayinnuola3 • O. M. Okeyinka3 • J. S. Adeleke1,2019) :

W_w **=** $Msat - Mdry / Mdry$ **100%**

3.5 Softening

The softening measure characterizes the accoutrements water resistance of materials, and the test is performed over a aggregate of 28 days. We see from the results attained in Fig. 8 that the HPC concrete softening measure increased, which is related to the reduced permeability of concrete with aggregates DMAX25 (BHP25 concrete with an W/ C = 0.25 ratio), and this greatly increases the durability of concrete.

4. Conclusion

Mixed design and concrete fabrication with a28-day compressive strength of up to 68 MPa or more of 90 MPa, can now be used in Jiel (Algeria), and it should no longer be considered to be used only in a experimental doman. Addition of SF in concrete showed good development of strength between 7 and 28 days, depending on on the design of the mix. Concrete containing 8% SF with a W/B of one 0.25 has higher compressive strength than the otherconcretes, and concretes with SF are more resistant than co ncretes without SF, so it is possible to have concrete with a compressive strength of 82 MPa for W/C 0.25 without SF. Like as a result, one can avoid the use of SF to affect the strength of concrete at compressive strength of 68 MPa, and a slump of 21 cm, because the SF is the most expensive ingredient used in the composition of concrete and is therefore very important economically. One of the main factors of production high strength concrete above 90 MPa is to use aggregates Dmax25, which is stronger with W/B of 0.25 and 0.30. This mixtures leads to a very dense microstructure and low porosity and produces increased permeability of high-grade concrete strong and able to resist the penetration of aggressive agents. This combination has a positive effect on the economy of concrete.

The longer the duration of curing, the greater the reduced permeability and results in a finer pore structure. This is very important for the direct exposure of concrete to an aggressive environment, because the curing also reduces autogenous shrinkage of HPC and concrete which W/B of 0.25 is the most durable. The excellent resistance of silica fume to sulphate can be attributed to its pore filling and refining effect due to the conversion of portlandite into secondary C–S–H gel. The severity of deterioration can be significantly reduced when silica fume is added to concrete

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Figures

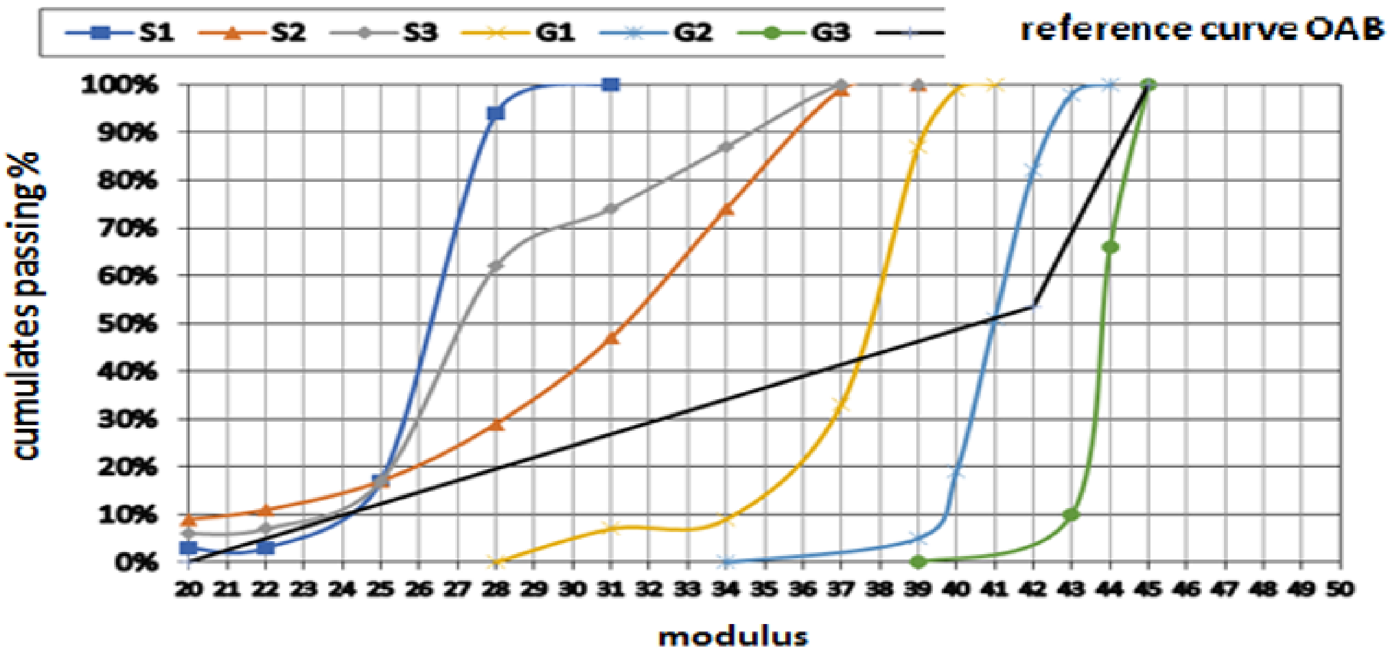
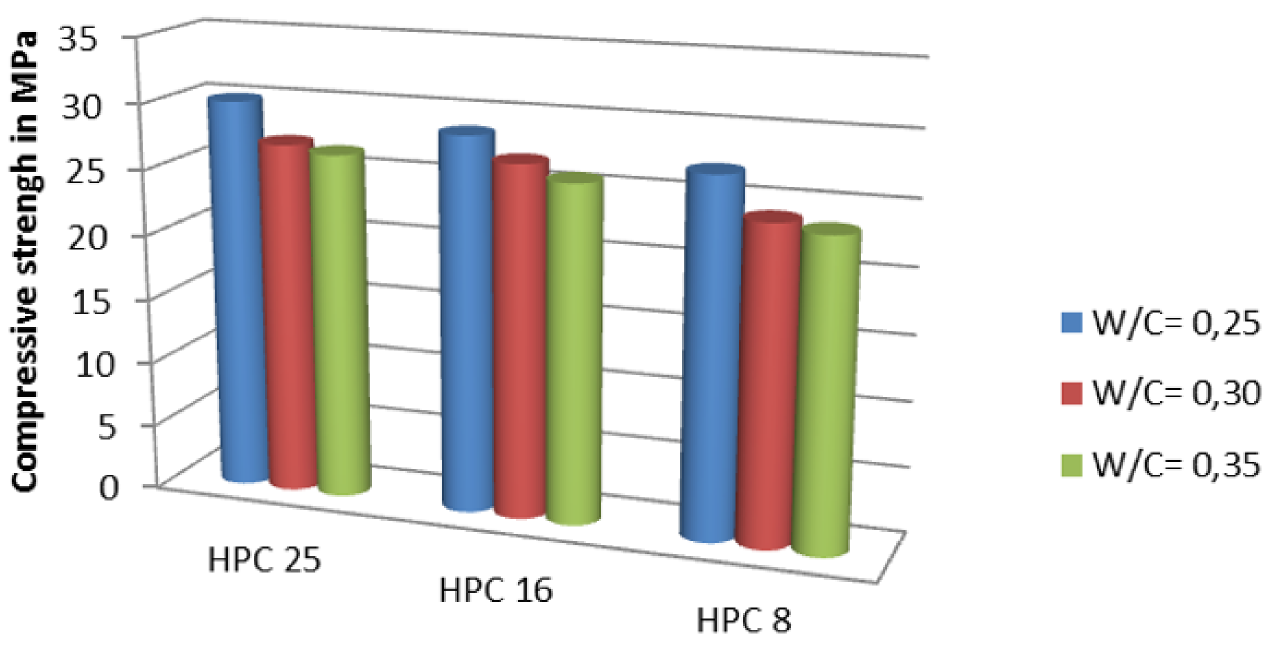


Figure 1

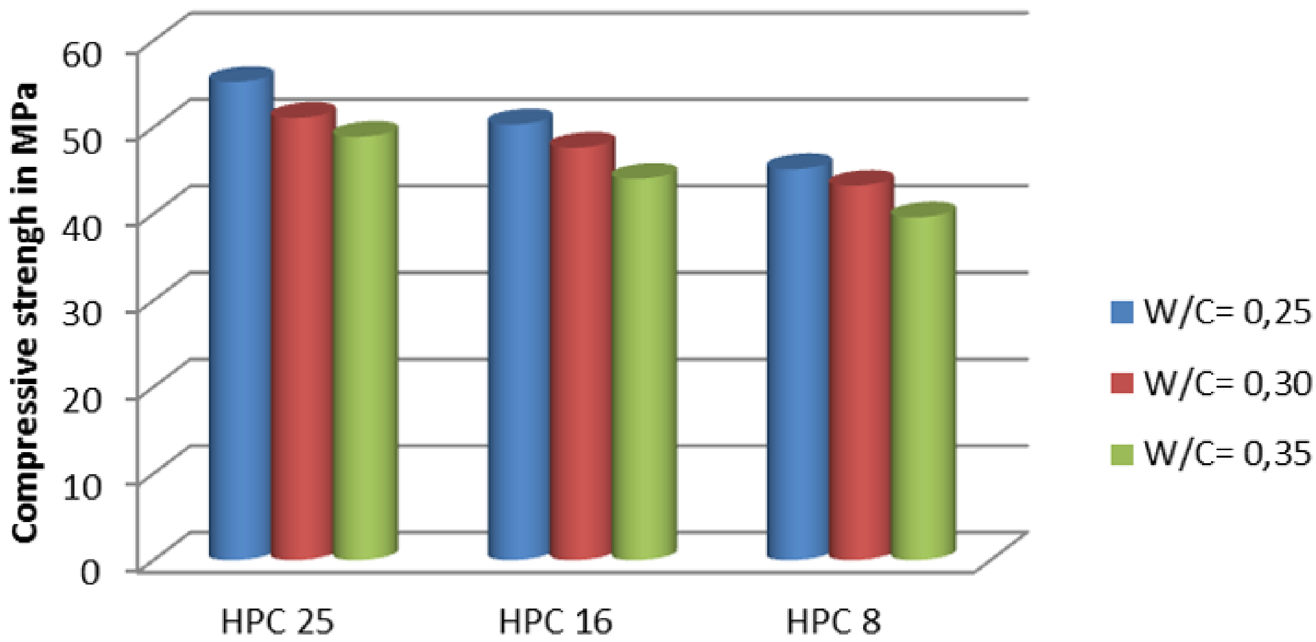
Gradation of used aggregates



Fig,2: Compressive strengh of HPC with different W/C ratio after 24 hours

Figure 2

See image above for figure legend.



Fig,3: Compressive strengh of HPC with different W/C ratio after 2days

Figure 3

See image above for figure legend.

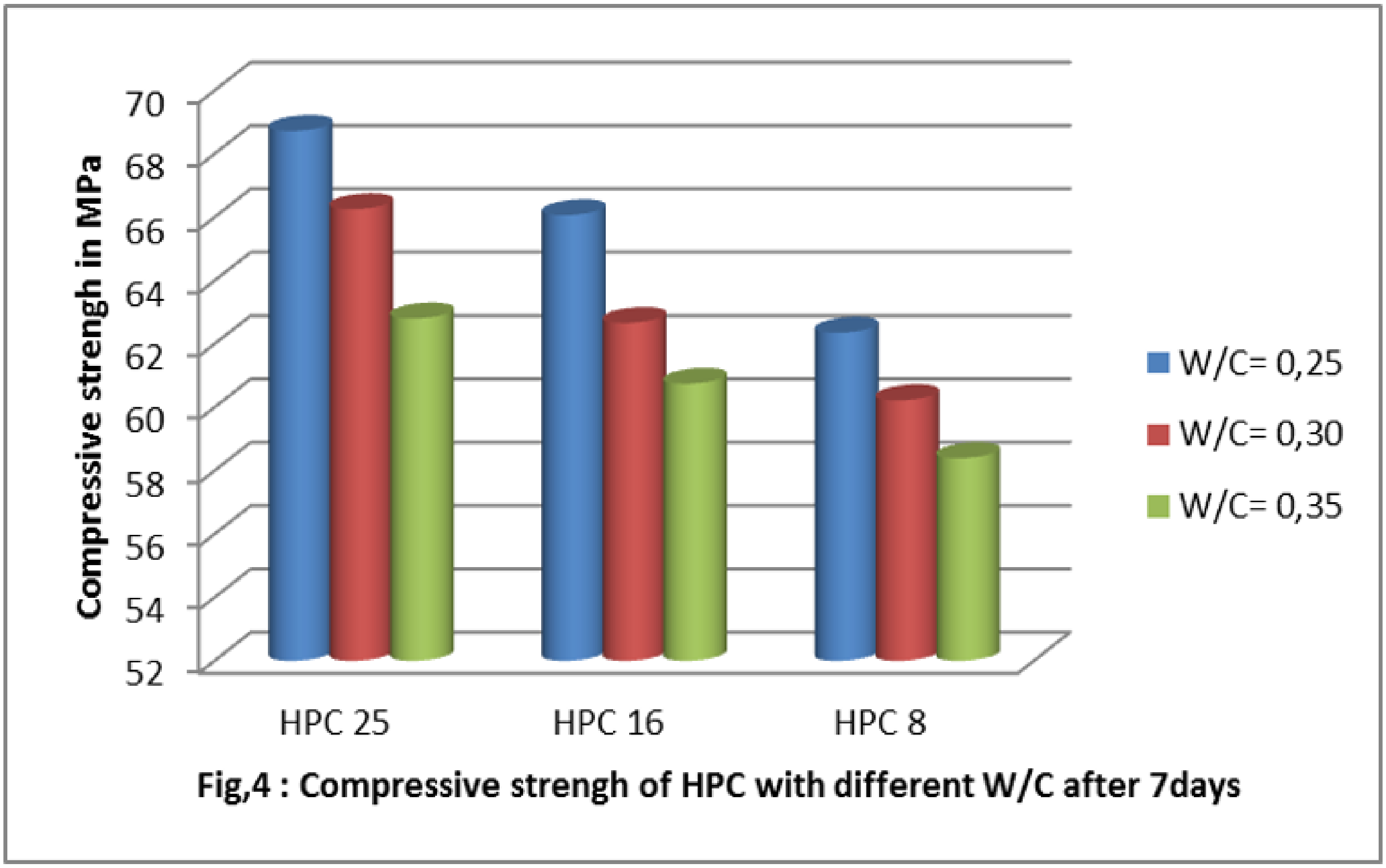
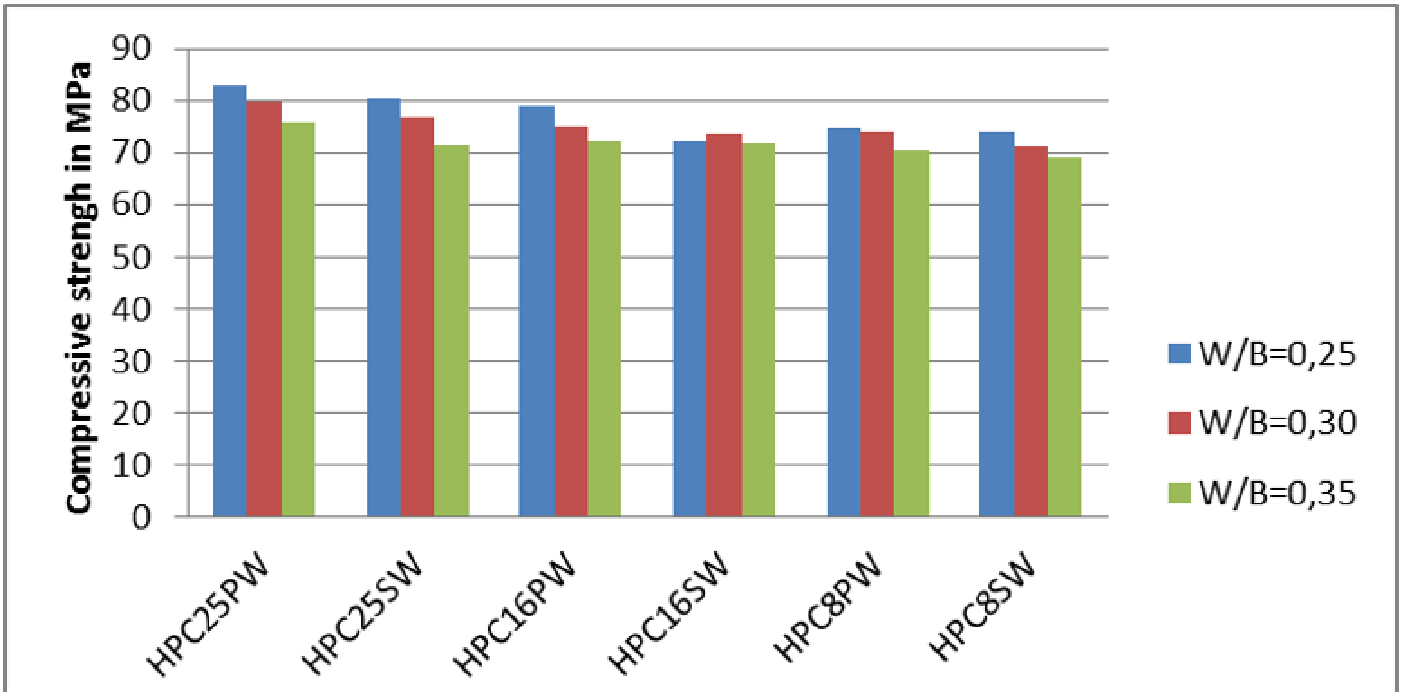


Figure 4

See image above for figure legend.

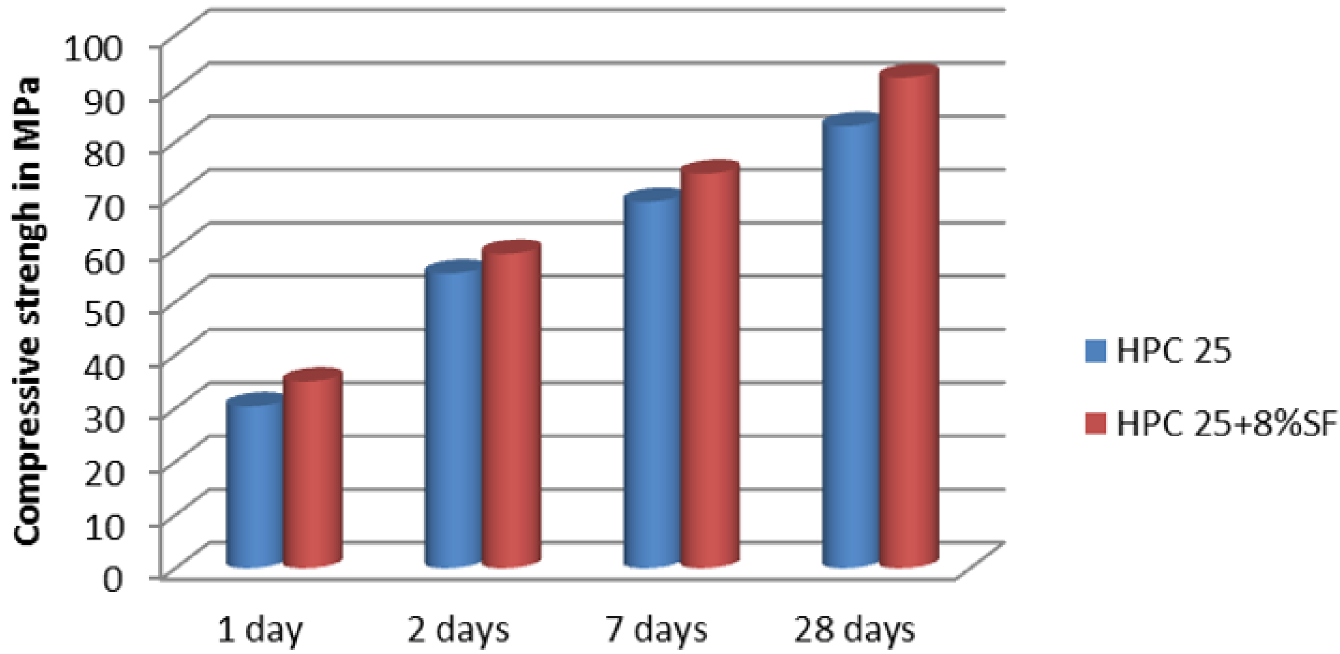


Fig,5: influence of conservation environment on the strengh of HPC with different W/C ratio after 28 days

SW :sea water, PW :potable water

Figure 5

See image above for figure legend.



Fig,6: Compressive strengh of HPC with silica fume and without silica fume for W/C =0,25

Figure 6

See image above for figure legend.

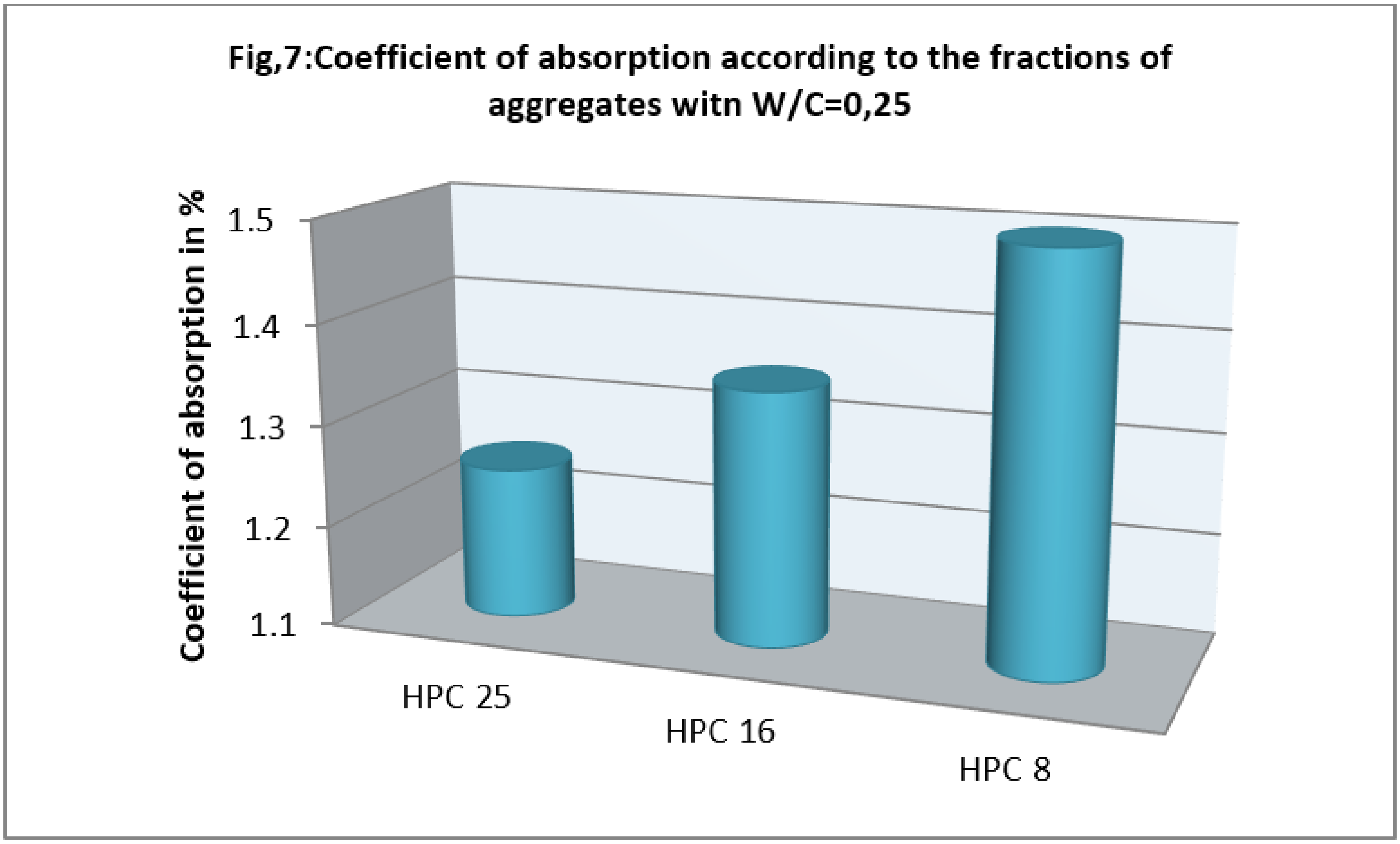
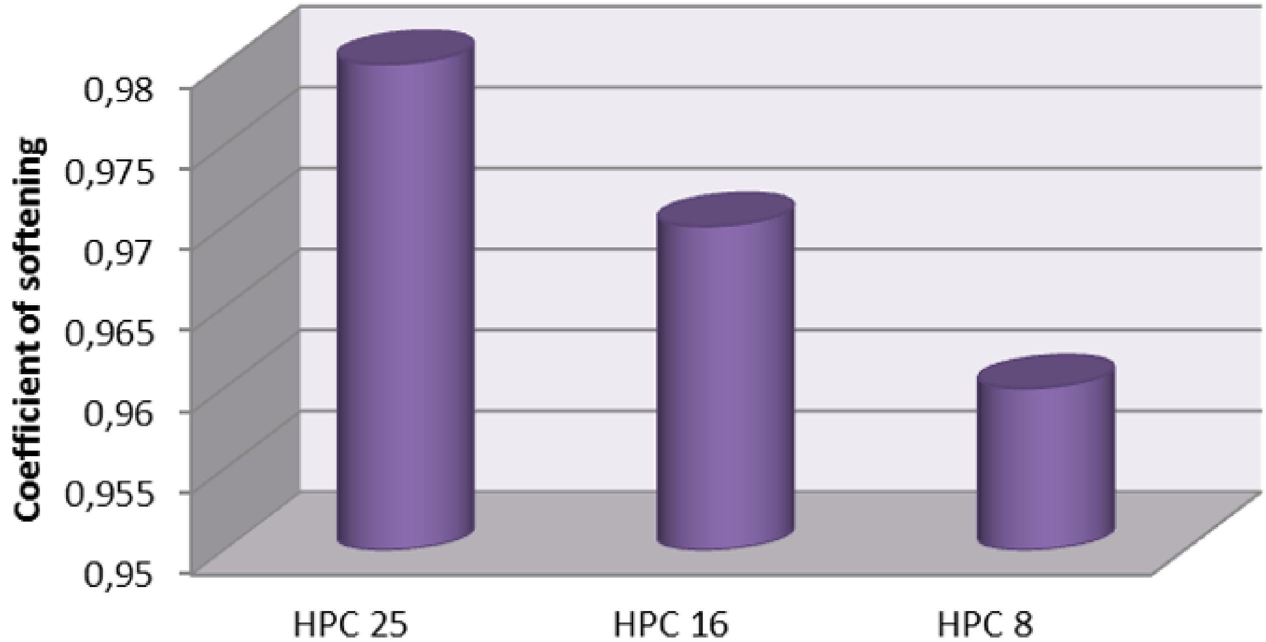


Figure 7

See image above for figure legend.



Fig,8:Coefficient of softening according to the fractions of aggregates with W/C=0,25

Figure 8

See image above for figure legend.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Photo1.png