Alterations in concrete samples due to Alkali–Carbonate–Reaction 'ACR'

Altérations dans les échantillons de béton en raison de la réaction alcali carbonate 'ARC'

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Soumis le : 23 /10/2017 *Révisé le : 03/05/2018* *Accepté le : 20/05/2018*

الملخص

مرض تفاعلات الوسط القلوي مع الركام (ت.ق.ر) مع مرور الزمن يسبب تدهور في المباني الخراسانية في مجال منشآت الهندسة المدنية بفضل مادة أملاح صلبة نافخة وهذا ما يمنح ضغط خلالي يؤدي إلى ظهور التشققات و التشقق على شكل خلايا. هذا المقال يتناول بحث مدته ستة أشهر و تناول إستخراج تأثير(ت.ق.ك) على عينات خراسانية « (A) المرجع ، و (B - C) المصابة بتفاعل (ت.ق.ك) ». الأعراض المرضية تم ملاحظتها مجهريا، كيميائيا و فيزيو- ميكانيكيا. النتائج الهامة تم تحليلها في الخرسانة المصابة بتفاعل (ت.ق.ك) مثل: فقد اللون، البقع أو الهالات ، الإنتفاخات، و المكونات الكيميائية ...الخ.

الكلمات المفتاحية: *خرسانة - ركام - قلوي - تفاعل - كربونات*

Résumé

La pathologie de l'Alcali Agrégat Réaction (AAR) au fil du temps détruit les constructions en béton dans le domaine du génie civil, à cause d'un gel solide expansif qui mène à une pression interstitielle jusqu'à la fissuration et le faïençage. Cet article montre une recherche de six mois de durée et qui étudie les effets de l'ARC sur des échantillons en béton « (A) témoin et (B, C) attaqués par l'ACR ». Des symptômes d'endommagement ont été observés microscopiquement, chimiquement et physico-mécaniquement. Des résultats importants ont été analysés au béton atteint de l'ACR comme : la décoloration, les auréoles, les gonflements, les composants chimiques, …etc.

Mots clés : Béton – Agrégat – Alcali – Réaction – Carbonate.

Abstract

The Alkali-Aggregate-Reaction pathology (AAR) over time destroys concrete constructions in the civil engineering field, because of an expansive solid gel that leads to interstitial pressure until cracking and checking-cracks.This article shows a six-month search for the ACR effects on concrete samples "(A) control and (B, C) affected by ACR ". Damage symptoms were observed microscopically, chemically and physico-mechanically. Significant results have been analyzed in ACR concrete such as: discoloration, aureole, swelling, chemical components, etc.

Key words: Concrete – Aggregate – Alkali – Reaction – Carbonate.

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1. INTRODUCTION

In the Civil Engineering field, reactive aggregates used in concrete material present an extreme risk to the engineering structure's life when exposing to a high alkali environment. To prevent in constructions attained by 'AAR', it's necessary to interest to this pathological damages and their mechanisms which are given as several descriptions by the international researchers. Some ones think that 'ASR' damages are due to a destructive solid gel as a main cause with Silico-calco-sodic nature [1]. Other researchers said that the hydrostatic pressure of hydrate silicate in concrete paste is the demolition reason [2]. Other authors think that alteration appeared due to the OH^- ions attacks to silanol- siloxane groups with gel formation which is expanse by imbibitional pressure; this pressure is the difference between water pressures in gel and pore [3, 4, 5, 6, 7, 8]. Some authors said that the expansive gel took place by silica absorption to Ca^{2+}, Na^+ and OH^- ions [9]. By another way 'ACR' is the most complex reaction and there are two contradictory deterioration opinions. The first opinion talks about soluble reactants « Dolomite and alkali hydroxide» that gives expansion, which provides 'AAR' cracks also [10]. Second one considerate 'ACR' as another form of 'ASR', the dedolomitisation increases if microcrystalline quartz is presented in dolomitic granulate. Hence the 'ASR' gel formed in the dolomitie aggregates caused the concrete deteriorations [11, 12, 13, 14, 15].
This research series on mortar bars and concretes confirmed that the 'AAR' problem is present in our country since (2008), and a high reactive aggregate was detected by the same team research at the Civil Engineering laboratory (UBMA) [16]. This granulate contained dolomite in the limestone stone with a few amount of silicate, it was used in this experimental works. The Algerian authorities didn't have any official census about the 'AAR' issue in the attained structures. So in this article, we are intending to attract the local authorities' intention to investigate against 'AAR' attacks like the international comity. We also want to continue discovering the 'ACR' damages, using several scales to explain what happen in a local concrete matrix. Especially when found results presented that 'ACR' damages were different from mortar, reinforced concrete and concrete; which are established by the same local building material with one mix design and have put in the similar conditions and experiments. For these objectives different produced specimens were tested in a laboratory at 'AAR' favourable conditions. Various parameters are chosen to analyse the 'ACR' attacks on the structural concretes in limited conditions: content alkali 1.25 %, moisture 100 % and more than temperature 40 °C.

2. EXPERIMENTS

2.1. Materials

The cement used: Portland cement CPJ-42.5 grade, according to ASTM and ACNOR standards; produced by Hadjar-Essoud cement work (Skikda). The cement composition used in concrete mix design is shown in the table 1.

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Table.1: Physicochemical and mechanical characteristics of cement used CPJ- 42.5

<table>
<tr><td colspan="7">Chemical characteristics (%)</td></tr>
<tr><td>C_3S 55-65</td><td>C_2S 10-25</td><td>C_3A 8-12</td><td>C_4AF 7-13</td><td>Clinker ≥ 74</td><td>Limestone 0</td><td>Slag ≤ 20</td></tr>
<tr><td colspan="7">Physical characteristics</td></tr>
<tr><td colspan="2">Initial & Final setting time minutes</td><td>Expansion mm</td><td>Mortar Shrinkage µm/m</td><td>Blaine cm²/g</td><td colspan="2">Density g/cm³</td></tr>
<tr><td>≥ 60</td><td>150-250</td><td>≤ 10</td><td>≤ 800</td><td>3300-4000</td><td colspan="2"><0.12</td></tr>
<tr><td colspan="7">Mechanical characteristics</td></tr>
<tr><td>Age/Strength</td><td colspan="3">Compression test</td><td colspan="3">Bending test</td></tr>
<tr><td>Days</td><td>3</td><td>7</td><td>28</td><td>7</td><td colspan="2">28</td></tr>
<tr><td>MPa</td><td>≥12</td><td>≥19</td><td>≥28</td><td>5.0-6.5</td><td colspan="2">6.2-8.5</td></tr>
</table>

Alkalis could be with high rates to activate internal chemical reactions between (Alkali and Reactive aggregates), they came from two sources in concrete: Alkalis cement which were with a weak content 0.3 % Na_2O_{eq} and additional alkalis to the water (Sodium-Potassium solutions) for mixing as shown in equation (1) according to Canadian and French standard codes: AFNOR-587; AFNOR-585; AFNOR-594 and ACNOR-14A.

$$Na_2O_{eq}\ (\%) = [Na_2O + 0.658 K_2O]\ (\%) \qquad (1)$$

The concrete mix design had a water-cement and a cement-aggregate ratio as shown in the second equation:

$$w/c = 0.4 \quad \text{and} \quad c/a = 1 / 2.25 \qquad (2)$$

Aggregates used were highly reactive; they are tested with accelerated tests for 'AAR' detection on mortar bars in the previous research works in UBMA laboratory, which gives an 'ACR' as chemical reaction [17]. These sands and gravels were taken with the same type (Limestone) from the quarry of Bouhachana - Guelma. Their grading curve was in the figure 1, according to the French standards, satisfied the physical test requirements: AFNOR-301; AFNOR-304; AFNOR-309; AFNOR-554; AFNOR-555 and AFNOR.EN-933.2 [18-23]. Distributed on three following classes:

- Crushed gravel (15-25) mm
- Crushed gravel (5-15) mm
- Crushed sand (0-5) mm (fineness modulus 2.75 FM).

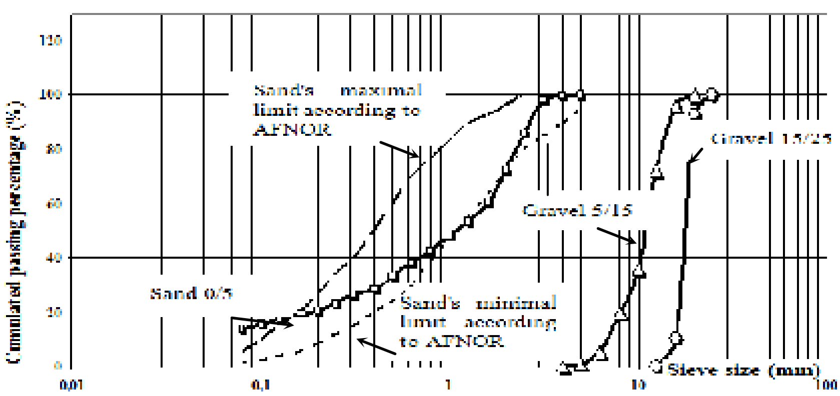

Figure.1: The grading curve.

To produce an ordinary concrete, its same mix design was based on Dreux Gorisser's Method for two concretes (A and B) of 350 kg/m^3. Standards codes AFNOR-451 or ACNOR-5C were used to casting and slump tests [24, 25]. Samples were demoulded 24 to 48 hours after casting; cured for 30 minutes at 23°C according to AFNOR-405, resealed and heated to 20° and 48°C; the moisture was 100 % to accelerate 'AAR' attack table 2 [26].

Table.2: Concretes mix-Design and storage conditions for specimens used

Constituent Concrete types	Sand 0-5 kg/m^3	Gravel 5-15 kg/m^3	Gravel 15-25 kg/m^3	Concrete kg/m^3	H_2O L/ m^3	Alkali NaOH & KOH kg/m^3		Storage (T, RH) (°C, %)
A	740	430	715	350	157	-	-	(20, 100)
B	740	430	715	350	157	2	3	(50, 100)

For all samples, the reference length was measured just before storage to start the program tests

(Tab. 3):

- Reference Concrete (A): [RH= 100 %; T= 20 °C; Na_2O_{eq} = 0.3 %]
- Reactive Concrete (B): [RH= 100 %; T= 48 °C; Na_2O_{eq} = 1.25 %], alkalis addition are as shown in equation (1).

Table.3: program tests for all structural elements used with concretes (A and B)

Concrete types	Form and dimension of specimens cm			Age weeks	Doping in Na_2O_{eq} %	Number
1A 2A 3A	Cylinder (h 22, Ø 11)	Prism 7x7x28	Cube 10x10x10	26 13 4	0.3 Reference Concrete (A)	3 3 3
1B 2B 3B	Cylinder (h 22, Ø 11)	Prism 7x7x28	Cube 10x10x10	26 13 4	1.25 Doped Concrete (B)	3 3 3
Total						**18**

In table 4 specimen forms were cylindrical, prismatic and cubic shape; they were prepared according to the Canadian and French standards for measuring length variations due to the 'AAR'.

Table.4: Specimen preparation according to ASTM, ACNOR and AFNOR standards

Specimen types cm	Test according to AFNOR and ACNOR	Length changes test due to 'AAR'
Cylinder (h 22, Ø 11)	AFNOR-400 AFNOR-406 or ACNOR-2C ACNOR-3C and ACNOR-1D	ACNOR-14A and AFNOR-587
Prism 7x7x28	AFNOR-407 and ACNOR-14A	ACNOR-14A and AFNOR-587
Cube 10x10x10	AFNOR-407	ACNOR-14A and AFNOR-587

2.2. Tests

In literatures we can accelerate this chemical reaction when we have high levels of reactivity in aggregates, high alkalinity in concrete paste, important temperature and moisture also [27, 28]. In this research, experiments are studied in various parameters and at different scales with microscopic examination, physico-mechanical characteristics... etc.

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2.2.1. Physico-chemical changes

1. Expansion test for concrete

We have used ACNOR-A14 test in alkali reactive concrete or (AFNOR- 594 or AFNOR-587 modified test); which is for expansion detection due to 'AAR' without specifying the reaction type, but the physical changes especially in the longitudinal direction (length) [29,30, 31]. Specimens are equipped with inserts in the longitudinal direction for all samples; the cubes are fitted for both directions. Returning to initial measurements, two concrete sample types (A and B) lengths are taken with a digital comparator (1/1000) mm one time each month for six months after 4, 13 and 26 weeks of storage. (Fig.2)

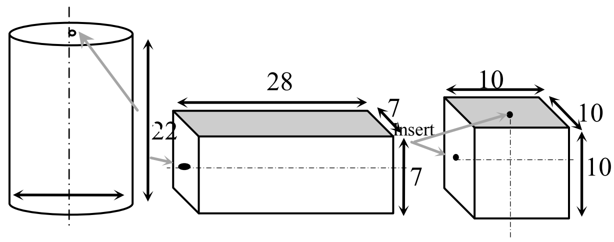

Figure.2: Cylinder specimens (h 22, Ø 11) cm, prisms 7 x 7 x 28 cm and cubes 10 x 10 x 10 cm.

2. Textural alterations in concrete attacked by 'ACR'

Textural study of these alterations mainly means monitoring symptoms: colour concrete, cracks with their form and evolution during the storage time, checking-cracks and network formation. Then we have represented cracks by (Opening cracks-Time) graph bars; checking-cracks by (Mesh per surface-Time) graph bars and discoloration by Photography method is used by with a digital camera as a control Method. With a fissurometer device used also for opening cracks measurement to monitor evaluating 'ACR' cracks and formed meshing per external surface sample [32, 33]. So three scales are used for this study type:

- Macroscopic scale for internal and external concrete matrix; photos are just taken.
- Mesoscopic scale with a magnifying glass; the magnification was 24 times (M24X).
- Microscopic scale for this examination a Polarized Optical Microscopy 'P.O.M' is used with photographing; that took place in the geology department (UBMA) on a thin section (30 x 45) mm as shown in the figure 3.
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Figure.3: Thin section '30 x 45' mm for microscopic examination

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- Chemical analyses (X-ray fluorescence XRF) are done according to AFNOR test code NF P 15- 467 in Hadjar-Essoud cement work laboratory (Skikda); for concrete mix design and 'AAR' gel also.

2.2.2. Mechanical characteristics

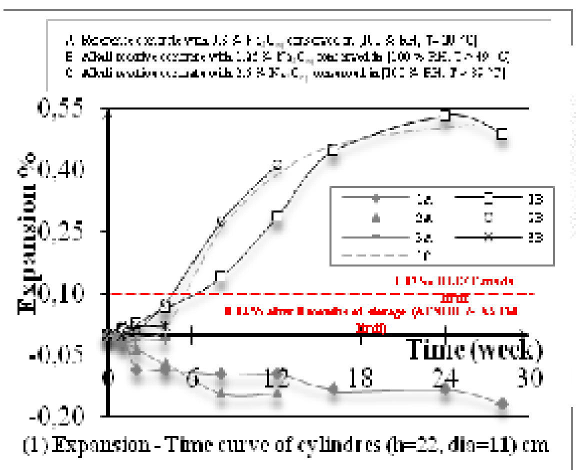
In this article, the same specimens of retractometer tests with concrete types (A and B) were tested for compression and traction behaviours. First, cylinder and cube samples were chosen for compression tests according to standard codes AFNOR-406 and ACNOR-9C [34, 35]. A hydraulic machine was used in this test which referenced by Weissgerber with 200 tonnes as a stroke machine, with static loading at regular load intervals (10 KN). We could represent these tests by (Failure strength -Time) curves. Then, prism specimens were tested with bend testing (four points) in concordance with (AFNOR-407) to identify indirectly the tensile strength [36].

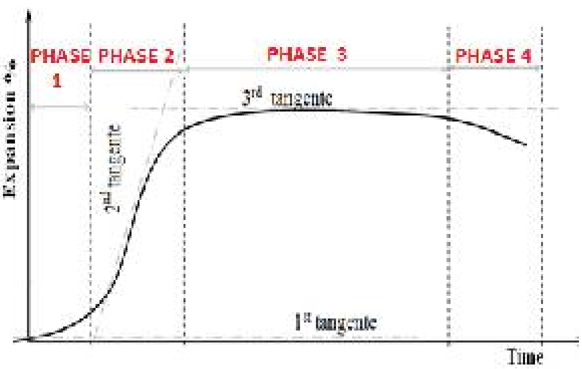
3. RESULTS AND DISCUSSION

3.1. Physical study

3.1.1. The length change tests

After be stored for 4, 13 and 24 weeks concretes noted by (3A, 2A, 1A) and (3B, 2B, 1B) during expansion test the Reference concretes (A) present normal shrinkage with safety external faces for all sample types. However, for all specimen types the doped concretes (B) show expansions of 'AAR' attacks as in figure.4.1 comparing with figure.4.2 of Larive's Method (Three-tangents-method TTM) [37]. The (Expansion- Time) curves showed that the cylindrical samples (2B and 3B) concrete; the expansion is in two first phases (1 and 2) only. Then, the specimens of (1B) have a complete expansion form, which is similar to the Larive's shape as (S form) with four phases from 1 to 4.





(2) Three-tangents-method TTM, the general form of Expansion-Time curve in 'AAR' [28]

Figure.4: Expansion test with cylindrical samples (h 22, Ø 11) cm with (3B, 2B and 1B) concrete from 1 to 24 storage weeks.

In the prismatic samples noted by (1B), the expansion curve had a linear form along the length change test which conducts to save the four phases with an unclear manner even for (2B and 3B) in the figure 5.

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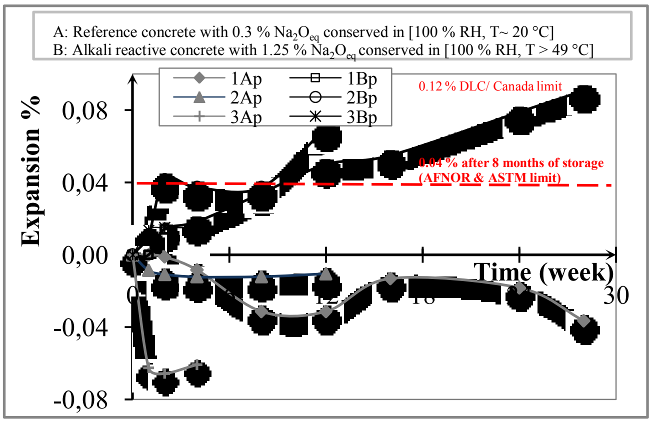

Figure.5: Expansion test with prismatic samples (7 x 7 x 28) cm with (3B, 2B and 1B) concrete from 1 to 24 storage weeks.

In expansion curves in the figure 6 of cubic specimens with (1B, 2B and 3B) concretes; the expansion phases were incomplete in both directions horizontally and vertically.

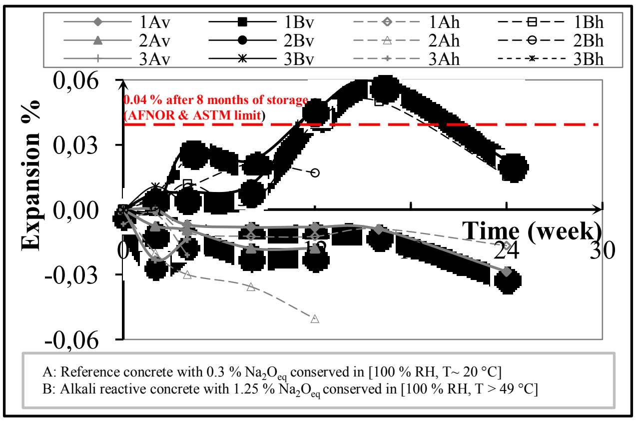

Figure.6: Expansion test with cubic specimen (10 x 10 x 10) cm with (3B, 2B and 1B) concrete from 1 to 24 storage weeks.

After 6 months of expansion test in cylinders (1B) had an extreme expansion with (5.34 ‰) comparing with Mohamed (1.34%, the aggregate used is Opal) [33], prism shown (0.9 ‰) comparing with Habita (1‰) [38], the cubes were (0.59; 0.50) ‰ in the both directions vertical and horizontal. However, as we have said that concrete (A) presented shrinkage for all sample types with an extreme rate in cylinders of (-1.66 ‰). Our aggregate reactivity is important in (B) concretes; it's confirmed that the aggregate used is "Highly reactive" with DLC limit- Canada as tabulate in the table 5. These expansion rates put these aggregates as "Reactive Aggregate" for the American and French code tests ASTM-1105.95 and AFNOR-587 [31, 39].

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Table.5: The expansion limits according to standards ASTM, ACNOR and AFNOR

Test	**Original test**	**Sample cm**	**Curing**		**Na_2O_{eq} %**	**Expansion limit %**
			T °C	**RH %**		
ACNOR 94 ACNOR-14	ASTM	7.5 x 7.5 x 28.5 Concrete	38 ± 2	Moist room or reactor AFNOR RH (isn't specified)	0.9 ± 0.1	Measures time 1, 2, 4, 8, 13, 18, 26, 39, 52 weeks Limit (isn't limited)
AFNOR 90 AFNOR-587 Replaced by AFNOR-594 (2004)	AFNOR-585 on mortar bars 2.5 x 2.5 x 28.5 and ACNOR-14	7 x 7 x 28	38	100	1.25	Measurement at: 1, 2, 3, 4, 6,8, 12 months Limit > 0.04 % at 8 months
AFNOR 90 AFNOR-585	ASTM C227	2.5 x 2.5 x 28.5	38	100	1.25	-

3.1.2. 'ACR' alterations' investigation

In this research, the Macroscopic and Mesoscopic scales present two monitoring kinds: internal and external examination of concrete samples without magnification device; photos are taken to be physically analysed.

- External texture: in the external faces for all samples during 24 weeks of test; concrete textures are different from (A to B) concretes: (A) showed a normal texture aspect (no deteriorations). Though, (B) type was attacked by 'ACR' damages after a few storage days; expansion was appeared with concrete discoloration due to the white 'AAR' gel which was as fine grain coming from internal to external concrete matrix until a completely whitish colour for face samples. This moving gel was in the pores, aggregates, cracks as shown in figure 7.

Figure.7: Cracks, checking cracks, gel exudation and discoloration faces in the cylinder and prismatic samples with (B) concrete during 6 storage months (M24X).

In other hand, at the first conservation month and as a function of storage time crack started, could be measured, with 120 ° as angle which noted also by Y-Form (Isle of Man's form), in three directions propagated (3D) until giving the polygonal form of 'AAR' checking cracks networks. The first micro-cracks were seen at the specimen boundaries; the biggest open crack was about 1.0 mm measured in cubic samples (M24X). Then we had saved (0.65) and (0.34) mm in the cylinder and prism elements successively comparing with Habita (0.1mm in the cylinder16x32cm) [40]. Cracks graph bars started approximately at 1 month, checking cracks graph bars had taken place at 3 months in figures 8 and 9.

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The (Mesh-Time) graph bars had achieved by extreme mesh numbers with (15306.1, 9001.5 and 4671.8) Mesh/m² for the prisms, cubes and cylinders respectively.

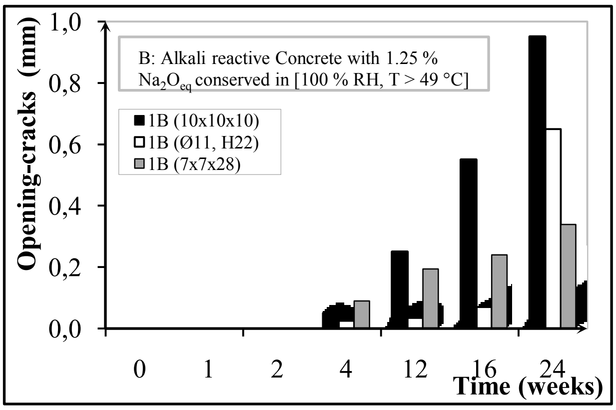

Figure.8: Opening-cracks evolution in ACR concrete (B) with specimens: cylinder (h 22, Ø 11) cm, prisms (7 x 7 x 28) cm and cubes (10 x 10 x 10) cm, after 6 storage months.

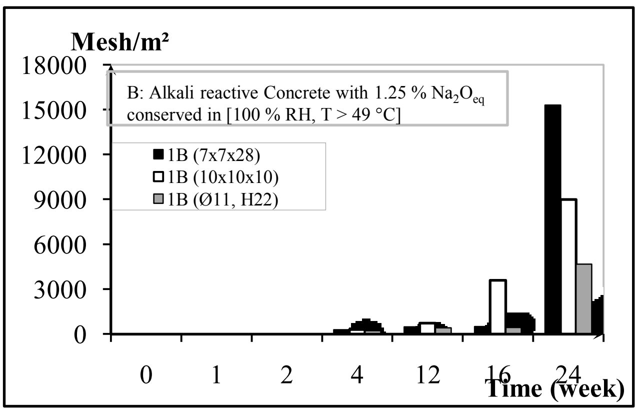

Figure.9: Checking cracks evolution in cylindrical specimens (Ø11, H22) cm, prisms (7 x 7 x 28) cm, cubes (10 x 10 x 10) cm with concrete B attacked by 'AAR' after 6 storage months.

- Internal texture: after mechanical tests when analysing internal concrete in the middle area of the failure section in the prismatic specimens with (7 x 7) cm dimension; abnormal discolorations are seen with a similar colour (Brown) and shape in all (B) samples which known by (AAR AUREOLES). This aureoles appear clearly beyond two months in 7 x 7 x 28 cm prisms with doped concrete (2B) and the gel was on the pulled granulate especially in (granulate-cement) adherence area. On the other hand, (A) concrete remained a normal internal textures equally without aureoles (fig. 10).

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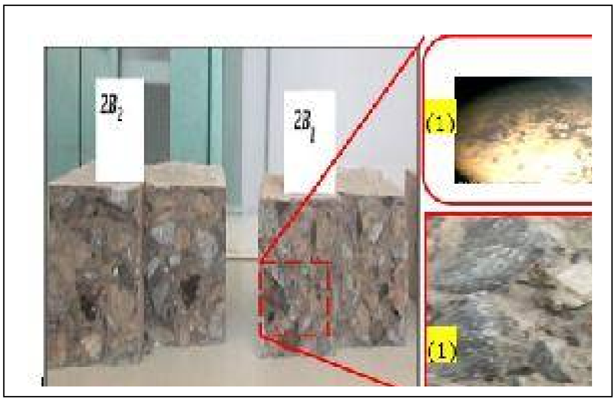

Figure.10: Brown aureoles and 'AAR' gel around granulates in samples with prismatic section 7 x 7 x 28 cm in doped concrete (2B) with 3 months age (M24X).

Around some aggregates in (B) concrete aureoles with brown colour are present as in the 'ASR' case, Shrimer author has thought that the 'ASR' gel appears with movement from granulate to the cement paste frequently [41]. It could be the silica effect for our concretes because we have about 20 % of SiO_2 in the aggregate used in figure 11.2. Chemical components of some used materials as quarry aggregates and cement, also produced materials as 'ACR' Gel are in figure 11.

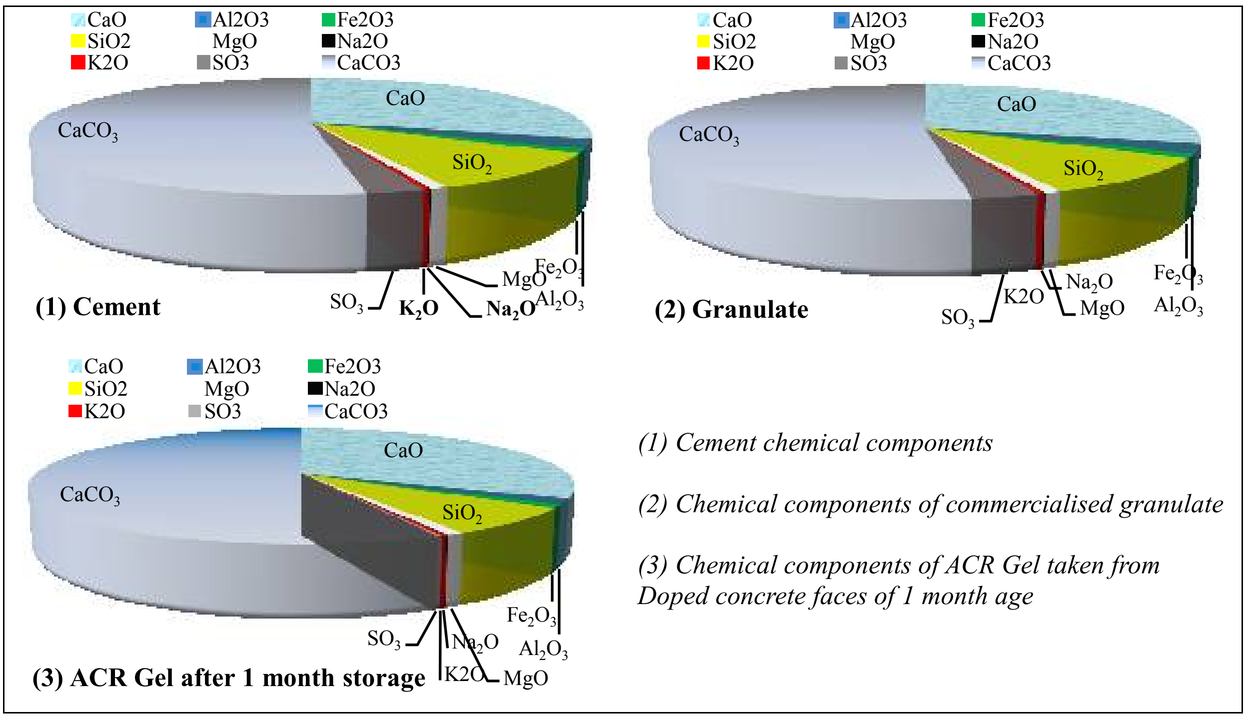

Figure.11: Chemical components of cement, ACR Gel at 1 month aging and commercialized quarry granulate tested by XRF test and plotted in 3D with Excel- STAT professional.

In the internal cross area of prismatic specimens with (B) concretes, gel appears around the pulled granulate and aureoles appear also in the mortar section adherence that around this granulate. These observations guide us to think about the gel and the aureoles effect on the (cement-granulate) adherence, because we have scouted two aggregate types in specimen cross sections which are: Pulled and crashed granulates. When counting these tow aggregate types and comparing them in (B & A)

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concretes we could see easily the gel and aureoles effect on the adherence zone (fig. 12). Figure 12 presents pulled granulate percentage, crashed granulate and aureoles also in (A and B) prisms cross section 7 x 7 cm when we have a symmetric behaviour and simultaneously increasing and decreasing:

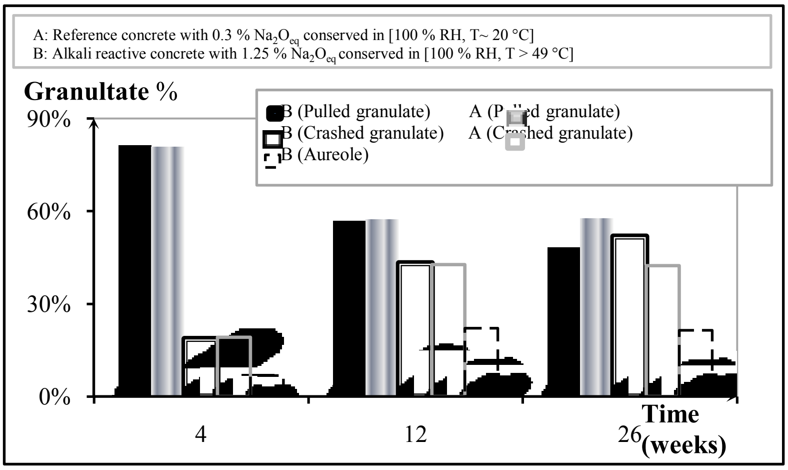

Figure.12: Pulled and crashed granulates distribution in the cross section (7 x 7) cm at the prism's middle section 7 x 7 x 28 cm in concretes (A and B) of 28 days, 3 et 6 storage months after bending test.

- The pulled granulate percentage had a good cohesion because it indicates a weak number in it; it also means when structural element is loaded strengths can pass through cement paste to granulate successfully. So, 80 % of pulled granulate at first test month significant that 'Cement-Granulate' cohesion is weak for the both concretes (A and B).
- After the 3rd month; the cohesion has increased and showed 60 % for pulled granulate in both concretes also but Aureoles are more than 20 %; at that age 'ACR' gel formation and opening cracks are considerable as shown in the figure 8. Hence; (A and B) concrete strength is progressing as a function of time and formed gel participated by compacting the concrete matrix when filling cavities.
- At the end of the 6 month test; we could see some stability by maintaining of the crashed and pulled granulate percentage and even the aureole amount; it indicates chemical reaction's last stage for strength and 'ACR' alterations. We noted a small difference between (A and B) concretes because of the gel diffusion through crack network in the concrete external skin.

Microscopic examination, to analyse these concretes the petrography method is chosen; samples were on a thin section (45 x 30 x 1.5) mm analysed in the Geology department laboratory (UBMA). Many photos were taken from the structural elements's skin in the concretes (A and B) when this method is applied by means of the polarized optical microscopy POM. We choose some photos to identify the concrete matrix components in the reference concrete (A) we try to compare them with the affected concrete (B) in order to extract the 'ACR' effects microscopically.

In the first storage month; the concrete sands (A) were drowning in cement paste its boundaries were badly seen. The gravels were with black cracks coming from the origin rock which is Limestone; this stone type has a broken aspect usually. These cracks are parallel cracks sometimes filled with a white material noted by Calcite ($CaCO_3$) in the figure 13.1. At the 'cement-granulate' adherence area when it was Marly limestone aggregate this area was clear with about 60 µm of width; and when it was a limestone aggregate this area contained empty cracks as shown in figure 13.2. At the first storage month the alkali reactive concrete sands (B) were composed from Limestone and some Quartz rocks;

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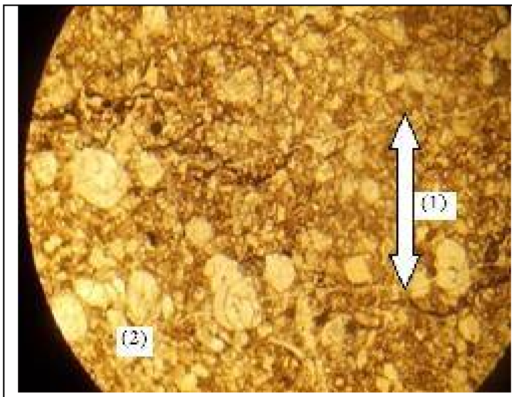
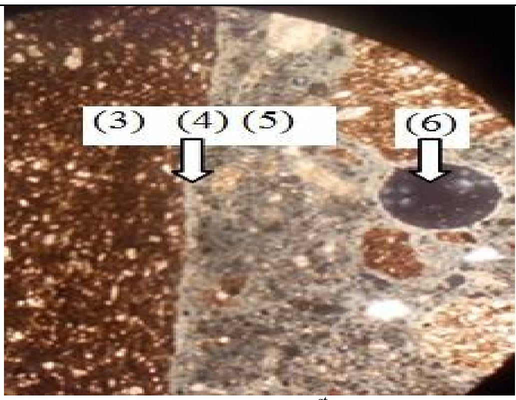
the boundaries were clearly seen. The gravels were composed from dark Marly Limestone and Limestone stones also and rich in microfossil; and boundaries were clearly seen with grey colour and the circular pores but cracks were in cement paste only.

The 'AAR' gel was absent from granulate and cement paste; it equally absent from cracks and pores observed for both concretes (A and B) at this early age of the first month storage.



(1) Limestone granulate with Parallel cracks filled with Calcite at 1st storage month. (2) Microfossil.

(1) Parallel cracks filled with a white Calcite in (A) concrete. [LN, M10X]



(3) Limestone granulate at 1st storage month. (4) 'Gravel - cement' boundary. (5) Cement paste. (6) Pore.

(2) 'Gravel - cement' boundary cohesion area in (A) concrete. [LP, M10X]

Figure.13: Microscopic examination by means of POM in geology laboratory of UBMA

3.2. Mechanic characteristics

The graph bars of compressive and tensile failure strengths presented the progress of these mechanical characteristics for both concretes used (A and B) for all samples in the first test month when textural alterations are in early stage in the figure 14. The concrete strengths (A) were more important during these tests than (B) concretes; except at 3 months when (B) was higher than (A) in compressive behaviour. At three storage month, 'AAR' gel filled concrete pores and made our material more compact; so it participated in strength cross. Then, when gel had moved through these cavities, pores and network cracks to the exterior medium; the concrete compactness became weaker and strength decreased.

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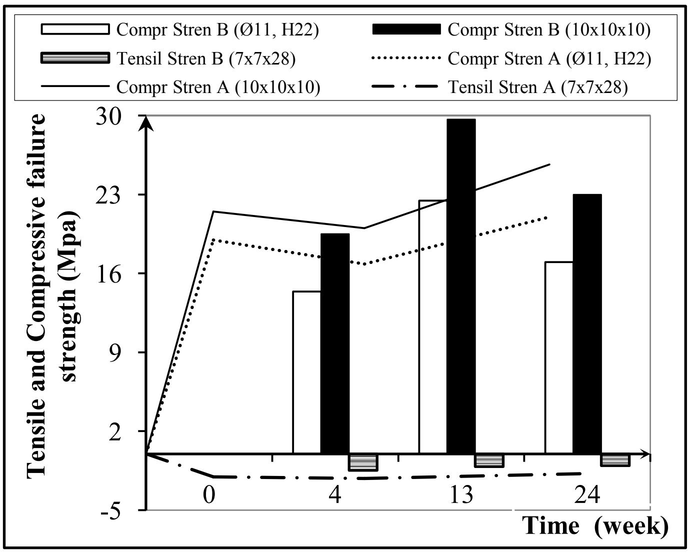

Figure.14: (Tensile and Compressive strength –Time) curves graph bars at failure of cylindrical specimens (h 22, Ø 11) cm, cubes (10 x 10 x 10) cm and prisms (7 x 7 x 28 cm) with concrete types (A and B).

At the end of these tests, the extreme compressive strengths saved in concrete (A) for cylinders and cubes were 21.0 and 25.67 MPa respectively. The extreme tensile strength in prisms was 3.65 MPa after 3 storage month.

In concrete (B), extreme compression strength was at third month 22.46 and 29.67 MPa in cylinder and cubes, respectively. Then they had reduced to achieve (18.15 and 17.95) % at the end of the test, comparing with the strength at 4 weeks conservation. In concrete (B), extreme tensile strength was 2.42 MPa measured after storage 4 weeks.

When comparing (B) to (A) tensile and compression results; differences at 4, 13 and 26 conservation weeks for all samples were respectively:

- Prism specimens: 28.74 %, 48.60 % and 10.97 % (B decreases compared to A)
- Cylinder specimens: 24.07 % (decrease), 33.33 % (increase) and 19.05 % (B decreases compared to A).
- Cubic specimens: 09.30 % (decrease), 48.33 % (increase) and 10.39 % (B decreases compared to A).

4. CONCLUSION AND RECOMMENDATIONS

To detect (ACR) attacks after six months of tests on several specimens on concrete we found:

- Reference concretes (A) after 4, 13 and 26 test weeks: Material (A) maintains its normal texture, good mechanical proprieties and microstructure for all tests and specimens.
- Concretes (B) attacked by (AAR): which was conserved in high levels of (HR - T°) with adding alkalis to its mix design, we detected concrete damages, as:
  - *Physical and texture deteriorations: expansion, opening crack, discoloration.*
- Length changes were measured in all samples, extreme expansion rates were in cylinders then cubes expanse in both directions (Horizontal and vertical).
- (Expansion-Time) curves had an (S) form according to a three-tangents-method. This curve shape is complete and clear for cylinders only, but in prisms it is a linear and incomplete form; in cubes it is a curve line and unclear.

- Expansion is combined with concrete discoloration after a few days of test begging; a white gel was diffused through specimen faces and became whitest for all samples as a function of time.
- At the first conservation month crack started; (Y) form is created and progressed during tests. And the extreme opening crack was measured in cubes at the end of tests.
- Cracks propagated at concrete faces in both directions transversal and longitudinal, even in depth. When they meet, a polygonal form of checking cracks occurred in alkali reactive concrete; and the extreme meshing was measured in prisms at the end of tests.
- Cracks started at the 1st month approximately, checking cracks had started at 3rd month in the expansion tests.

- *Mechanical deteriorations:* The concrete strengths (A) were more important than (B) for compression and traction tests; except at 3rd month when (B) was higher than (A) in compressive behaviour. At three storage month, 'AAR' gel filled concrete pores and made our material more compact; gel participated to strength progress. Then, when it had moved through these cavities, pores and network cracks to the exterior medium; the concrete compactness became weaker and strength decreased due to empty cavities.
- *Microscopic examination:* At the 1st storage month, in concretes skin (A and B) there is a good micro-structural aspect which explains the strength progress at the first test month for these materials; it's the first stage of 'ACR' reactive without important material damages.

In general, the damages are physico- chemically higher until 1st storage month for the alkali reactive concrete; after that the mechanical aspect is highly affected. So we confirmed that for all structural elements our aggregates are "reactive" and "High reactivity" except cubes, according to standard codes ASTM-1105.95, AFNOR-587 and DLC- Canada.

We recommend more studies for this attack types with local material, and we also recommend varying the exposition medium with other parameters to identify this chemical issue. When combining these proprieties sand symptoms which participate in the mechanism of 'AAR' pathology; in order to limit this internal reaction effect.

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Nomenclature

Ø	Diameter of Cylindrical specimen or dia (cm)
ACNOR-CSA	Canadian Association for standardization
ACR	Alkali Carbonate Reaction
AFNOR	French Association for standardization
AS or NS	Algerian standard (National)
ASR	Alkali Silica Reaction
ASTM	American Standard Testing Materials
CPA	Cement Portland Artificial
CPJ	Cement Portland Composite
DLC Canada	Laboratory roadway direction/ Canada
FM	Fineness modulus
H	High of Cylindrical specimen (cm)
LCPC	Recommendation for damage prevention due to 'AAR', and central laboratory of roads and bridges (LCPC – 1994)
M20X	Magnification (e.g: zoom 20)
Na_2Oeq	Equivalence alkali (%)
NC	Normal consistency
NL	Natural light
PL	Polarize light
POM	Polarized optical microscopy
RH	Relative Humidity or Hygrometry (%)
T	Temperature (°C)
UBMA	University of Badji Mokhtar-Annaba
XRF	X-ray fluorescence

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