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Reduction of ASR-expansion using powders ground from various sources of reactive aggregates

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ABSTRACT

This study assesses the potential of ground reactive aggregates to reduce or suppress expansion associated with ASR. Particular attention is paid to fine admixtures (<80 μm) added to mortars, which contain the reactive aggregates from which the fines were ground. Many varieties of aggregate (quarried and natural, igneous, metamorphic and sedimentary rocks) from different geological settings were subjected to an autoclave test. The replacement of 10–20% of the sand by reactive aggregate powder (RAP) of different surface areas from 11 different reactive aggregates led to the reduction of ASR-expansion by up to 78% compared with control mortars. Increasing the amount of fines led to better performance. No clear relationship was observed between the reactivity degree of the aggregates and the efficiency of their ground powder to reduce expansion. A general trend was found regarding the fineness of ground aggregates: finer particles were more effective in reducing expansion. The reduction of the expansion due to RAP is discussed in terms of parameters affecting its efficiency and of the mechanisms responsible for the reduction.

1. Introduction

Aggregates cannot be considered as totally inert in concrete. Under certain conditions, some siliceous minerals can react, leading to swelling and early deterioration of concrete structures. This deleterious reaction, observed worldwide, is known as the alkali–silica reaction (ASR). It occurs when the reactive silica phase in an aggregate particle is attacked and dissolved by the alkali hydroxides in the concrete pore solution. A reactive product, silica gel, is formed and swells in the presence of water. In this respect, ASR will develop only if the following conditions are found:

- sufficient amount of alkalis in concrete pore solution;
- sufficient moisture level in concrete;
- reactive aggregate (coarse or fine).

In order to limit ASR-expansion, or even to suppress it, engineers must act on one or more of the above factors. Numerous papers have been published regarding the mitigation of ASR with supplementary cementing materials (SCM). It is well-known that SCM, particularly silica fume, metakaolin, low-calcium fly ash, ground glass, high-calcium fly ash and blast furnace slag (these last two at higher dosages), are effective against ASR [1–7]. The reduction of expansion stems from the low permeability of concrete incorporating SCM and a combination of one or more factors such as the alkali dilution effect due to the reduced cement content, the reduction in the pH of the pore solution due to pozzolanic reaction, and a change in the composition of C–S–H which allows more alkalis to be trapped in the C–S–H structure. Lithium solution also appears to be effective in several cases [8,9].

Limiting the moisture level in concrete may appear viable when the affected elements are relatively small (e.g. bridge pier, retaining wall) and when there is no permanent or large water supply. Usually, it is achieved with the application of a seal on the surface of the affected element [10]. In the case of hydraulic structures, such as dams and locks, this measure is ineffective.

Regarding the aggregate reactivity, various tests have been designed and implemented over the past decades to assess the degree of reactivity of rocks in concrete and most of them are efficient. Therefore, aggregates can now be used in concrete without worrying about the further expansion of the structures. However, for economic or technical reasons, the use of innocuous aggregates is not always possible [4]. In addition, SCM or lithium may not be available or would represent excessive costs.

An alternative may be the use of reactive aggregates in combination with powders ground from the same aggregate. A few authors have already reported results on this approach [11–15] but the technique has remained limited to only a small number of aggregates. This study aims to assess the potential of reactive aggregate powders (RAP) to reduce or suppress the expansion associated with ASR. The objective of this paper is to assess

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whether this approach can be extended to any kind of reactive aggregate, rather than to provide a detailed analysis for each type of aggregate. The study tested a variety of aggregates (quarried or natural) from different geological settings. For instance, igneous (intrusive and extrusive), metamorphic and sedimentary rocks were subjected to an autoclave test on mortars, providing a large range of expansion values with respect to the amount of ground aggregate powders. 10% or 20% of the sand was replaced by an equivalent mass of fines (from 11 different reactive aggregates) of low, medium or high specific surface area to test the effect of reactive aggregate powders in suppressing ASR-expansion.

2. Materials and methods

2.1. Materials

The binder was a normal Portland cement CEM I 52.5R, as specified by European Standard EN 197-1, with a density of 3150 kg/m^3 and a surface area of 350 m^2/kg (Blaine). Its chemical composition (Table 1) shows a moderately high content of Na_2O_{eq} (0.8%). Silica fume and class F fly ash were used in two mixtures (composition provided in Table 1).

The potential of ground reactive aggregates to mitigate expansion due to ASR was tested on 11 aggregates from five countries (Fig. 1), which were known to have produced significant expansions and damage associated with ASR (Table 2) [13,16–35]. As shown in Table 2, tests were carried out on two natural aggregates (one sand and one coarse aggregate) and nine crushed ones, taken from the different categories of known reactive aggregates. It must be pointed out that these aggregates were selected in order to cover a wide range of types and geological origins, from low to high kinetics of silica dissolution. Their physical properties are given in Table 3.

Table 1
Chemical composition of cement, silica fume and fly ash (% by mass).

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	LOI
Cement	20.1	5.6	2.0	62.5	3.1	0.2	0.9	3.2	1.7
Silica fume	95	–[a]	–[a]	–[a]	–[a]	0.6[b]	–	0.1	1.5
Fly ash	57	27	6	2.9	0.7	0.1	2.0	0.6	2.5

[a] $Al_2O_3 + Fe_2O_3 + CaO + MgO = 1.0\%$.

[b] Na_2O_{eq}.

Reactive aggregate powders (RAP) were obtained by grinding sand or coarse aggregates to specific surface areas (Blaine) ranging from 290 to 1040 m^2/kg. In order to study the influence of fineness in counteracting expansion, three ranges of surface areas were targeted: low (290–540 m^2/kg), medium (550–750 m^2/kg) and high (890–1040 m^2/kg).

All mortars had constant cement mass. An amount of 10% and 20% of fines (<80 μm) were used in mortars as replacement of sand, meaning that the total amount of reactive aggregate within mortars remained constant. These values were chosen according to preliminary results from another study [14,15]. The particle size fractions of aggregates and fines in mortars are given in Fig. 2.

2.2. Methods

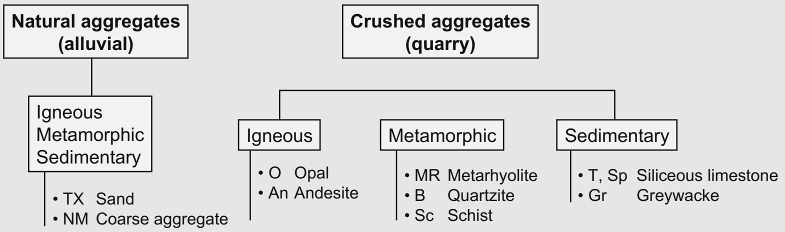
The expansion tests were carried out according to the French standard NF XP P 18-594 [36], which is an autoclave accelerated mortar test. This test enables very fast classification of the aggregates with respect to their potential reactivity to alkali hydroxides in concrete. Three mortar bars per mixture were prepared with an alkali-boosted cement (4% cement mass Na_2O_{eq}). The provisions of the French NF XP P 18-590 standard were followed regarding the mortar constituents: water–cement ratio of 0.5, aggregate–cement ratio of 2. Length variations of mortar specimens were measured after 5 h at 127 °C and under a pressure of 0.15 MPa.

Some modifications were made to the provisions of the standard as follows:

- Due to the limited amount of aggregates available, it was decided to cast mortar bars of size 2 × 2 × 16 cm instead of 4 × 4 × 16 cm (as required by the standard). As discussed in Section 4.2, this may have had an effect on the amount of alkali leached during testing.
- The particle size distribution of the sand ranged between 0.315 and 4 mm, instead of the 0.160–5 mm required by the standard. The increase of the lower limit was intended to highlight the effect of fines.

Fig. 1. Geographical locations of reactive aggregates.

Table 2
Geological categories and mineralogy of reactive aggregates.



I.D.	Name	Source	Mineralogy (XRD)	References[a]
TX	Texas sand	USA	Quartz, feldspars, volcanic glass	[16]
NM	New Mexico	USA	Quartz, feldspars, cristobalite, volcanic glass	[16–18]
O	Opal	France	Amorphous material, tridymite, quartz (tr)	[19–23]
An1	Pyroxene andesite	Japan	Cristobalite, feldspars, pyroxene, glass	[24,25]
An2	Pyroxene andesite	Japan	Cristobalite, feldspars, pyroxene, quartz, montmorillonite (from altered volcanic glass)	[24,25]
MR	Hylas	USA	Quartz, cristobalite, feldspars, micas, chlorites, calcite, glass	[26,27]
B	Brix	France	Quartz, micas (tr), amorphous material (tr)	[20,28,29]
Sc	Sherbrooke	Canada	Quartz, chlorites, micas, feldspars	[30,31]
Sp	Spratt	Canada	Calcite, dolomite, quartz	[19,20,30,32,33]
T	T limestone	Belgium	Calcite, quartz, micas (tr), feldspars (tr)	[13,20,29]
Gr	Sudbury	Canada	Quartz, feldspars, chlorites, micas	[32,34,35]

tr: Trace.
[a] Expansion and damage due to ASR.

Table 3
Physical properties of aggregates.

Agg.		TX	NM	O	MR	An1	An2	B	Sc	Sp	T	Gr
Density (kg/m^3)		2630	2640	2080	2670	2630	2600	2630	2740	2670	2660	2700
Surface area of fines	Low	–	290	370	460	–	–	380	310	420	540	420
(Blaine, in m^2/kg)	Medium	550	550	580	–	660	680	600	650	640	750	630
	High	970	910	930	910	900	890	1000	890	1040	930	1010

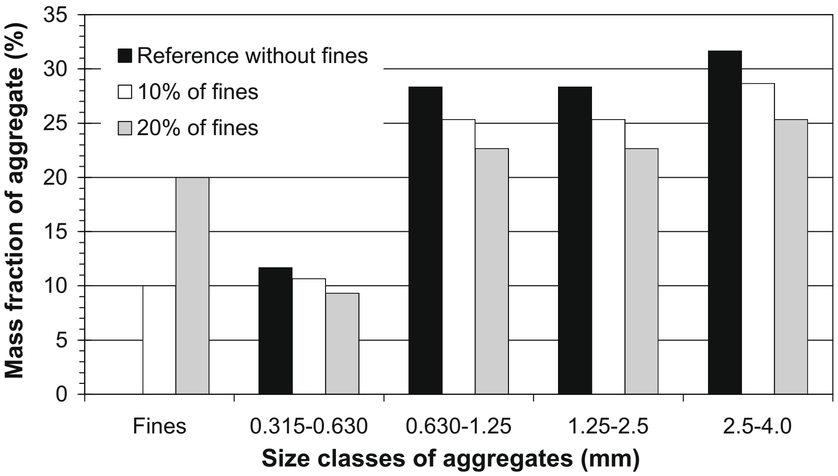


Fig. 2. Particle size fractions of aggregates, except for Texas sand (TX) which naturally presented a finer grading.

– In mortars with fines, 10% or 20% of the sand was replaced by an equivalent mass of fines of low, medium or high specific surface area (<80 μm) to test the effect of reactive aggregate powders in suppressing ASR-expansion.
– Two mortars were prepared with 20% of fly ash or silica fume to compare the effect of reactive aggregate powders with well known supplementary cementing materials.

The bars were prepared and stored in compliance with the standard provisions: bars were demolded 24 h after casting and soaked in water at 20 °C for 24 h. The bars were retrieved from the water and their length was measured with an accuracy of ±10^{-3} mm. Then the bars were stored in the autoclave and fully soaked in water. The autoclave temperature was raised to 127 °C over 1 h±10 min, and this temperature was maintained for

5 h ± 10 min. The autoclave pressure was then released and the system cooled down: samples were taken out and cooled in the water where they were stored. The final length L_2 was measured 18 h ± 1 h after the end of autoclave treatment. The length variation was obtained using Eq. (1) ($L_0 = 160$ mm).

$$\varepsilon = \frac{L_2 - L_1}{L_0} \tag{1}$$

3. Results

3.1. Expansion of control specimens

Table 4 gives the expansion of mortar bars subjected to the autoclave test. The mean dispersion of the results is around 3%. It can be seen that the 11 aggregates presented different reactivity levels, as confirmed by the large range of expansions.

Andesites An2 and An1 produced the highest expansions (7624 and 5517 μm/m, respectively). These aggregates have high kinetics of silica dissolution and they are already known to be very reactive in concrete, especially in Japan [24,25].

Aggregates MR, Gr and Sc presented expansions less than 2000 μm/m. These aggregates are considered to be moderately reactive in concrete [26,27,30,32,34].

Table 4
Expansion of mortar bars submitted to autoclave test (μm/m).

Agg.	Amount of fines (%)	Surface area of fines (see Table 3)		
		Low	Medium	High
TX	0		4379 ± 93[a]	
	10			
	20		3003 ± 97	2315 ± 44
NM	0		3812 ± 155	
	10	3997 ± 68		
	20	3983 ± 116	3008 ± 79	2636 ± 50
O	0		3927 ± 86	
	10	3728 ± 62	3664 ± 96	
	20	2906 ± 31	2878 ± 47	2647 ± 36
An1	0		5517 ± 207	
	10			
	20		4840 ± 225	3957 ± 221
An2	0		7624 ± 396	
	10			
	20		4440 ± 197	4476 ± 140
MR	0		1921 ± 38	
	10	2009 ± 74		
	20	1623 ± 61		1288 ± 117
B	0		2331 ± 77	
	10	2276 ± 66	2211 ± 131	
	20	1546 ± 35	1364 ± 56	522 ± 54
Sc	0		1825 ± 76	
	10	1633 ± 57		
	20	1288 ± 54	1086 ± 7	1139 ± 75
Sp	0		2791 ± 22	
	10	2710 ± 111	2637 ± 31	
	20	2421 ± 42	2618 ± 42	2274 ± 63
T	0		3309 ± 42	
	10	3125 ± 41		
	20	2744 ± 81	2761 ± 67	2656 ± 23
Gr	0		1887 ± 72	
	10	1778 ± 24	1780 ± 39	
	20	1455 ± 28	1277 ± 37	996 ± 22

[a] Expansion of control mortar (without fines) is indicated in the medium column.

3.2. Expansion of specimens containing RAP

A rapid analysis of the results presented in Table 4 shows that, in most cases, the use of fines from reactive aggregates led to a reduction of mortar expansion, which was more or less significant depending on the type of aggregate, as well as on the fine content and fineness.

3.2.1. Reduction of expansion vs type of aggregate

Fig. 3 shows the reduction of expansion for mortars containing 20% of fines having the highest specific surface area. A comparison of efficiency with silica fume and fly ash is also included for aggregate B. The expansion reduction due to reactive aggregate powders lies between 19% and 78%, with an average of 38% for the 11 aggregates tested.

Fines of quartzite B were very efficient in reducing the expansion. This rock has a high silica content, mainly in the form of quartz, which is usually considered as non-reactive. However, grinding increases the specific surface area of quartz, and may also generate microcracks within crystals. Both phenomena probably made the quartz reactive as a powder. The testing conditions (pressure and temperature) likely also contributed to increase the pozzolanic reactivity. This may also explain the significant fineness effect for this rock, i.e. greater expansion reduction with finer powder (Table 4).

Both limestone aggregates, i.e. Sp and T, showed the lowest efficiency. It could be related to their low silica content. For instance, Spratt limestone contains a large amount of clayey materials and about 3–4% of reactive silica, found as chalcedony and chert. Another point that can be put forward is that limestones are rich in calcium, which may have an effect.

Although the above expansion reductions are significant, they may appear quite low compared with those due to conventional SCM, such as fly ash or silica, well known for their effectiveness in suppressing ASR-expansion. The effectiveness of ground reactive aggregate with respect to SCM was assessed by preparing two mortars with aggregate B. The first mortar was made with 20% silica fume, the second with 20% class F fly ash.

The reductions of expansion for silica fume and fly ash were 64% and 62%, respectively (Fig. 3). These values are lower than the reduction of 78% obtained for the same amount of fine B (high surface area). Thus, the orders of magnitude of the reductions when reactive aggregate powders are used can be assumed to be satisfactory.

3.2.2. Reduction of expansion vs surface area of fines

Fig. 4 gives the reduction of expansion of mortars containing 20% of fines of different surface areas. A general trend may be observed: the increase in surface area led to better effectiveness in expansion reduction. This effect was obvious for the following aggregates: TX, NM, An1, MR, B, and Gr. On the other hand, the effect of surface area did not appear to be conclusive for aggregates An2 and T. Reduction levels for aggregates O, Sc and Sp were more or less affected by the surface area. On average, and for all aggregates, the reduction reached 19% with low surface area, 27% with medium surface area, and 38% with high surface area.

3.2.3. Reduction of expansion vs fines content

3.2.3.1. Low surface area. For all the aggregates tested, the reduction of expansion increased when the fine content was boosted from 10% to 20%, for both low and medium surface area (Table 4). The average reduction for 10% of fines with low surface area was 3.9%, excluding the value from NM, for which no reduction was observed. Maximum reduction was obtained with Sc aggregate (10.5%). When the content of fines increased to 20%, the average reduction increased to 23%.

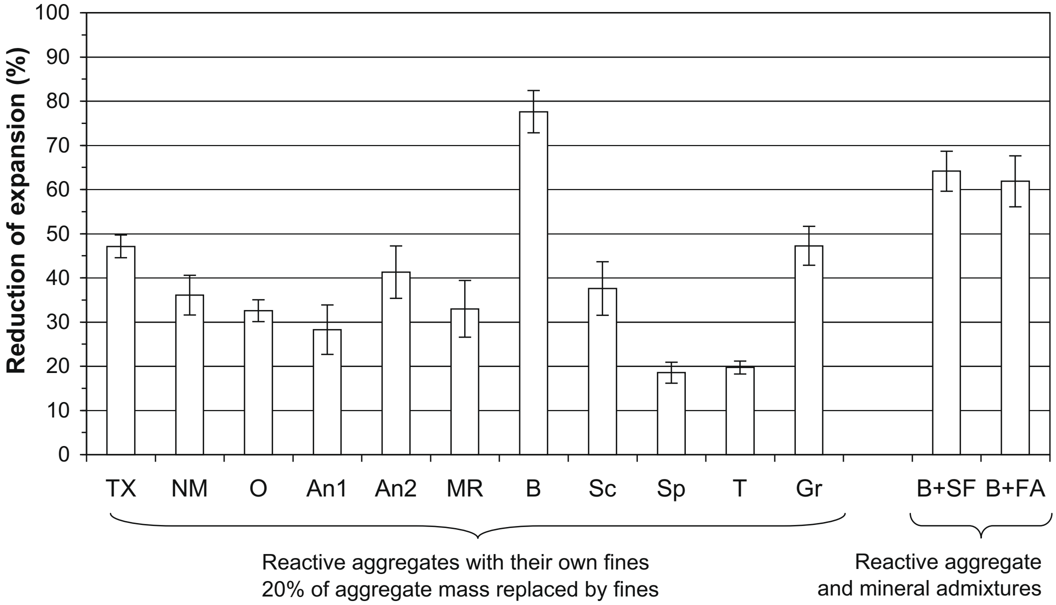


Fig. 3. Reduction of expansion for mortars with 20% of fines of highest specific surface area. Comparison with mortars made with aggregate B and 20% of silica fume or fly ash.

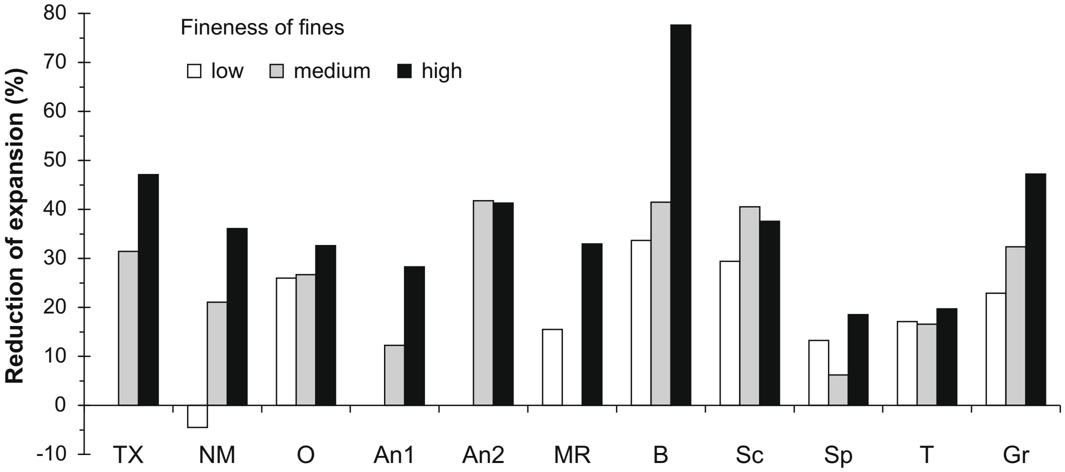


Fig. 4. Effect of surface area of aggregate fines on the reduction of mortar expansion (mixtures with 20% of fines).

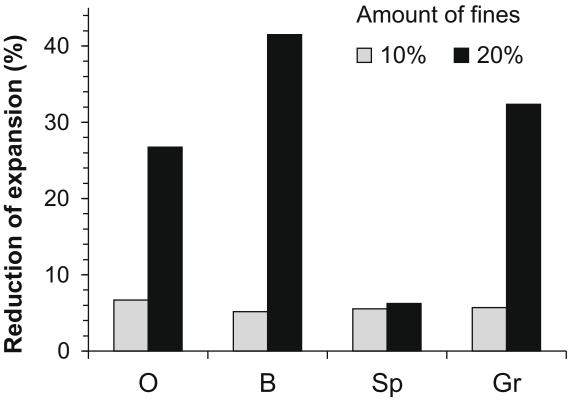


Fig. 5. Effect of fines contents on the reduction of mortar expansion (medium surface area).

3.2.3.2. Medium surface area. Fig. 5 shows the trend obtained with a medium surface area. The reduction performance of an amount of 10% of fines was about the same for the four aggregates tested, with an average reduction of 5.8%. However, significant differences were observed when the amount of fines was raised to 20%. The ground powder for the Brix quartzite was the most effective in the reduction of expansion (41.5%), while Spratt limestone showed poor results (6.2%). The average expansion reduction was 27% for this surface area.

4. Discussion

The results showed reductions of expansion for all aggregates tested in this study. The efficiency of RAP thus seems to be clear for several categories of aggregates. It has been pointed out [14] that RAP might be considered as pozzolans, since they contain reactive silica, such as conventional SCM (fly ash, silica fume, etc.). So it can be inferred that both kinds of materials will present similar behavior when used in cement based materials. This section discusses the reduction of the expansion in terms of parameters affecting its efficiency, and the mechanisms responsible for this phenomenon. The effects of experimental conditions on the expansion of mortars and on the efficiency of the reduction of expansion are also discussed.

4.1. Parameters affecting the efficiency of RAP

4.1.1. Silica content

The highest reductions of expansion were obtained with RAP having high silica contents. This was the case for quartzite, although an important fraction of this silica was crystallized as quartz, which is much less soluble than amorphous silica. The less effective RAP were obtained from siliceous limestones (Sp and T) and these aggregates were also those containing less silica.

Considering that the active silica content is believed to be significant in reducing the expansion, one could have inferred that the most reactive aggregates would generate very reactive fines, thus leading to the highest reductions. However, there was no significant correlation between the expansion of the control mortar and the effectiveness of the associated fines in reducing the expansion (Fig. 6). Powders of aggregates showing the larger expansions (e.g. andesite An1) did not systematically lead to high reductions of expansion. This could be due to the fact that the amount of RAP required to prevent expansion depended on the nature of the reactive aggregate since, generally, the more reactive the aggregate, the higher the level of pozzolan required. So in the case of very alkali-reactive aggregates (e.g. andesite), more RAP is needed to reduce the expansion significantly.

4.1.2. RAP content

Other factors, such as the fineness of RAP, the available alkali content and the rate of the pozzolanic reaction, certainly play an important role. Fig. 7 summarizes all the reductions of expansion as a function of the surface area of RAP, for 10% and 20% replacement of sand. It is seen that, as for conventional pozzolans, the effect of surface area and RAP content cannot be neglected.

General trends can be highlighted. The first one concerns the RAP content: a beneficial effect of RAP is observed when they are used in sufficient proportion (more than 10% of the sand). Insufficient RAP content had a variable effect: reduction of expansion or increase in expansion (e.g. 10% of NM and MR). Similar results are to be found in the literature for conventional pozzolans such as fly ash and natural pozzolan, for which a pessimum effect occurs sometimes: up to a certain pozzolan content, expansion can increase instead of decreasing [37–40]. This effect "*could be due to a more rapid rise of alkali concentration and pH of the pore solution caused by the addition associated with a delayed beginning of the pozzolanic reaction.*" [4].

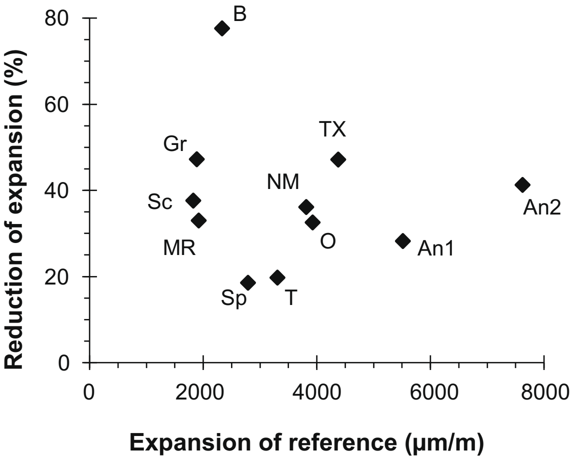


Fig. 6. Reduction of expansion for mortars with 20% of fines of highest specific surface area versus expansion of control mortars.

Thomas and Folliard [41] report a range of minimum replacement levels of cement required for various conventional SCM to control expansion associated with ASR: minimum of 20% for low-calcium fly ash to 60% for high-calcium fly ash, 8–12% for silica fume, 10–20% for metakaolin and 35–65% for slag. So according to these authors, the high silica content (combined to low calcium and low alkali) in some SCM allows the decrease of the required SCM contents to limit expansions due to ASR.

In our case, RAP were used in replacement of sand and made up 20% and 40% of the cement mass, since the mortar mixtures were composed of two parts of aggregate and one part of cement and that 10% and 20% of the aggregate mass were replaced by RAP. These values are of the order of magnitude of those for conventional SCM found in the literature. It is quite probable that more RAP would be needed for very active aggregates and/or less efficient fines having either a low silica content or a high alkali content.

4.1.3. RAP fineness

The other observed trend concerns the fineness of RAP, since the highest surface area often involved higher reduction of expansion. As for the RAP content, an insufficient surface area generally involved a small reduction or even a harmful effect (see for example NM on Fig. 7).

On the one hand, it has been shown by a few authors that the same trend is obtained for conventional SCM such as fly ash and pozzolans: higher surface areas led to lower expansion due to ASR [42–44]. On the other hand, the case of silica fume is an interesting one, since it has been reported by several authors that, when the particles are not adequately dispersed, large agglomerates sometimes provoke ASR even without other reactive aggregate in the concrete [45–51]. These large silica fume particles act as amorphous silica aggregates, thereby participating in the formation of an ASR gel. However, agglomerations of silica fume do not act as reactive aggregate in all cases [52].

So it is concluded that a material containing active silica can be considered as a pozzolan or as a reactive aggregate, depending on the particle size. Thus the effect of surface area is significant in one way (a ground reactive aggregate becomes a pozzolan) or another (an agglomerated pozzolan becomes a reactive aggregate).

The pozzolanic reaction and the alkali–aggregate reaction are very similar since, in both cases, Si–O–Si bonds are attacked by OH^- ions from the pore solution to form SiO^- groups. The main difference is related to the cations balancing the groups.

In the pozzolanic reaction, the kinetics of silica dissolution is fast due to the high specific surface area of the reactive particles. The availability of calcium near the reactive sites leads to the formation of low C/S C–S–H, which have a relatively rigid structure that is responsible for the increased strength of the cement paste.

In the alkali–aggregate reaction, the kinetics of silica dissolution is much slower since it is controlled by the diffusion of species into the aggregate. After the breakdown of the silica framework, alkali ions are probably more readily available to balance the SiO^- groups than calcium ions, which are far from reactive sites and already bound in the cement hydrates. Thus it results in the production of a high-alkali-content gel which is harmful for the concrete.

4.1.4. Unexpected effect of RAP

A final remark should be made on the use of RAP or even conventional SCM in concrete containing non-reactive aggregate. In this case, care should be taken to avoid unexpected expansion that could be due to the use of the fine itself, i.e. if the particles are not fine enough, or sometimes when high contents of very active material are used. Guédon-Dubied et al. [13] reported expansions ob-

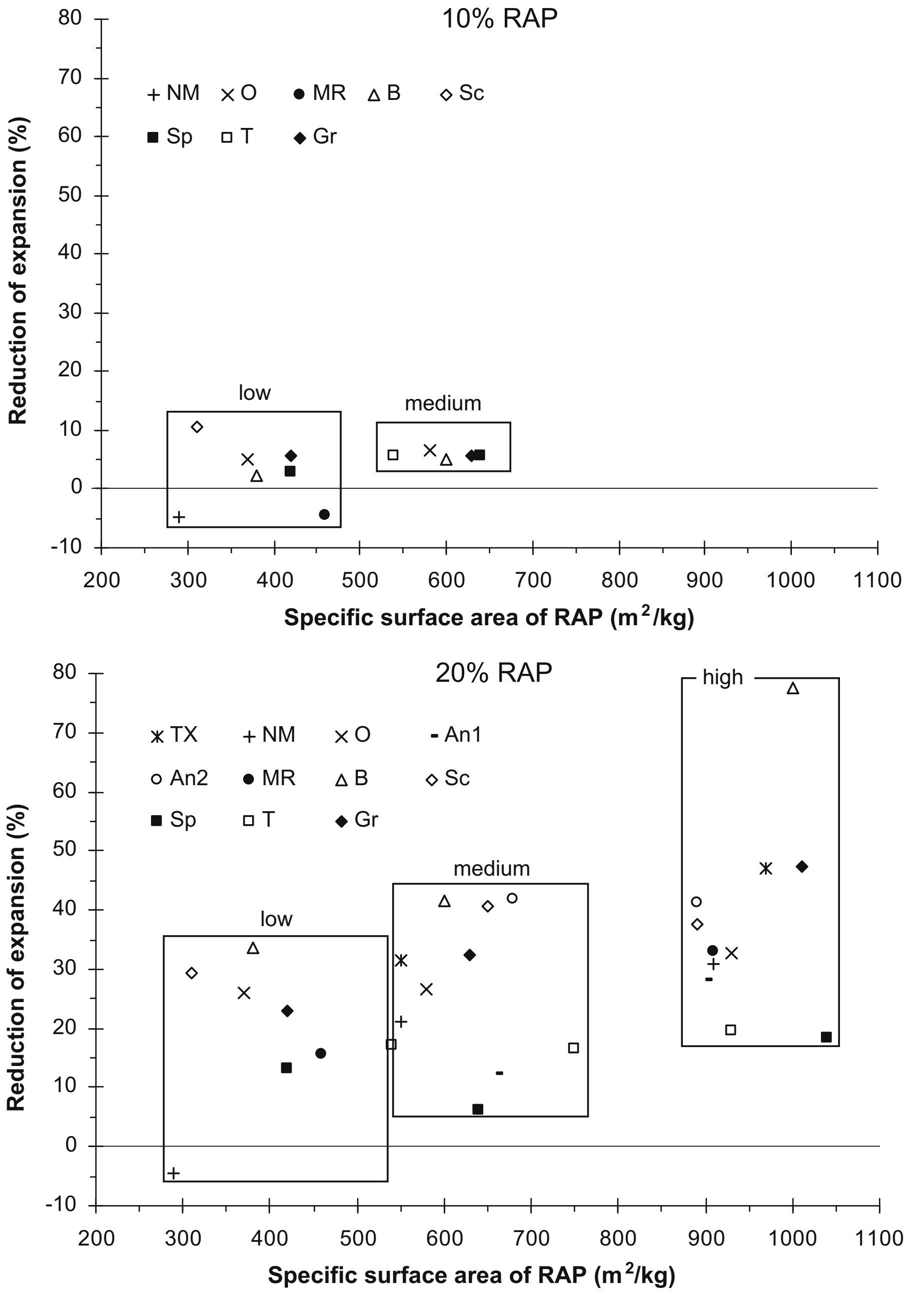


Fig. 7. Effect of surface area and RAP content on the reduction of expansion.

tained on concrete made with a non-reactive aggregate and containing 15% and 30% of fines from a reactive siliceous limestone. Shayan et al. [53] showed a slight increase in expansion of concrete with non-reactive basalt aggregates when 20% of cement was replaced by silica fume. Finally, Carrasquillo and Snow [54] found that very high silica fume replacement (45%) also caused expansion with non-reactive aggregate, when the cement contained a high percentage of alkalis (0.66%).

4.2. Potential effects of accelerated testing and specimen size

Due to the large number of tests to be carried out (total of 52), it was decided to use an ultra-accelerated test, which consisted in measuring the length variation of mortars autoclaved for 5 h at 127 °C and under a pressure of 0.15 MPa. Moreover, small specimens (2 × 2 × 16 cm) of mortar were used because of the limited available amounts of some aggregates.

These experimental conditions had an effect on the magnitude of expansion, since high temperature and pressure in the autoclave chamber involved conditions that were very different from those met in situ or even with a conventional accelerated expansion test. These conditions probably increased the potential pozzolanic reactivity of the RAP relative to field conditions. So the absolute values of reduction should be judged with precaution and, as for other accelerated tests, relative values of expansions between the different mortars should be preferred to absolute values.

The use of smaller prisms (2 × 2 × 16 cm) also had an effect on the total expansion of mortars. A few tests made with bigger specimens (4 × 4 × 16 cm) on mixtures containing aggregates B, T and O showed expansion values between 10% and 25% higher (+300 to +1400 μm/m) than for small prisms. These differences are probably due to the leaching of alkalis, which may have been accelerated by the combined effect of conditions in the autoclave and the small size of specimens. The autoclave provides conditions that promote

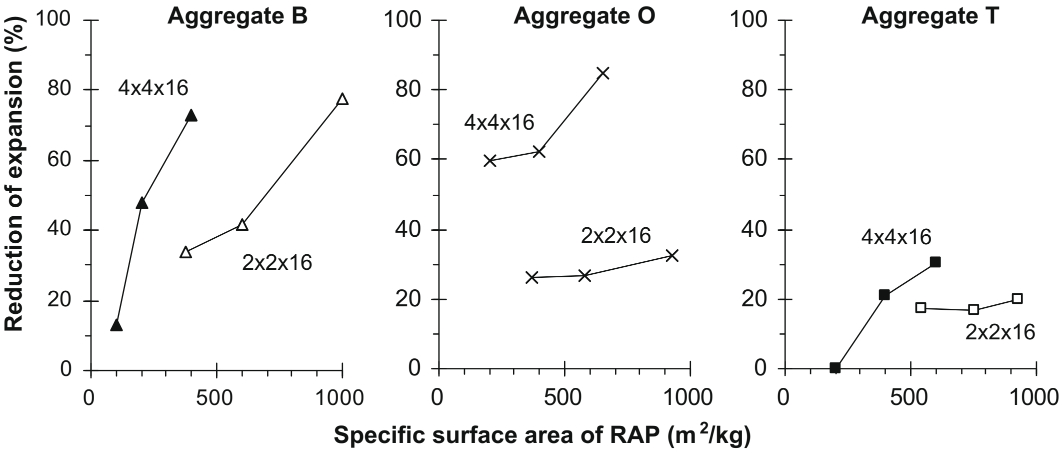


Fig. 8. Reduction of expansion obtained in mortars containing aggregates B, O and T and their RAP (20%), for two specimen sizes.

leaching of alkalis. The leaching phenomenon associated with the accelerated environment, where temperature and humidity are very high, has been reported previously [55–57]. Rivard et al. [57] showed that the amount of leached alkalis varied with the aggregate type and reactivity. It has also been shown that the alkali leaching rate is higher with small sized specimens [58,59].

It has been noted that the reduction of expansion was lower in this study than in others found in the literature and using the same test [15]. Fig. 8 compares the reduction of expansion obtained for aggregates B, O and T (2 × 2 × 16 cm specimens) with results taken from another study performed in our laboratory [15] and involving the same aggregates (4 × 4 × 16 cm specimens). It can be seen that bigger prisms systematically led to higher reductions and that lower surface areas of RAP were needed. So it can be concluded that the apparently low efficiencies obtained in this study could be related to the size of the specimens tested. This is the reason why comparative tests were carried out with known SCM. The results confirmed the efficiency of RAP (Fig. 8).

5. Conclusion

The results obtained from this study carried out with an autoclave suggest that ground reactive aggregates may be used to reduce the expansion associated with ASR in concrete. Powder obtained from ground reactive aggregates was incorporated in mortar bars subjected to an ultra-accelerated test to assess the expansion associated with alkali–silica reaction. The replacement of 10–20% of the sand by fines from 11 different reactive aggregates led to a reduction of ASR expansion compared with control mortars. The replacement amount of 10% was found to be more or less effective. However, increasing the amount of fines led to better performance; the reductions of expansion with a replacement of 20% of fines with the highest surface area varied from 19% to 78%, with an average of 38%. The highest reduction was obtained for the quartzite whereas the lowest reductions were obtained for the two limestone aggregates. Reactive aggregate powders could be regarded as pozzolans and the mechanisms responsible for the reduction of expansion are probably the same as for conventional SCM.

No clear relationship was observed between the reactivity degree of the aggregates and the efficiency of their ground powder to reduce expansion. A general trend was found regarding the surface area of ground aggregates: increased surface area was more effective in reducing expansion.

The findings presented here should be judged with caution. The high temperature and application of pressure (in the autoclave test) likely increased the potential pozzolanic reactivity of the RAP relative to field conditions. Further tests should be performed according to standard laboratory procedures, such as accelerated mortar bar or concrete prism tests, to more fully assess the performance of ground powder from reactive aggregates.

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