PERFORMANCE OF SOME ITALIAN CEMENTS TESTED FOR ALKALI-SILICA REACTION

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ABSTRACT

The Alkali-silica reaction has been identified as cause of concrete deterioration even in some Italian structures. The Hydraulic and Structural Research Centre (CRIS) of the Italian Electricity Board (ENEL) has carried out a short experimental test on mortar bars made with two types of Pyrex glass and several types of Italian cements: ordinary portland, portland-pozzolana, portland blast furnace and sulphate resisting cements.
The effectiveness of the latest ones in reducing the dangerous expansions taking place with some ordinary portland cements have been verified.
Besides the pessimum percentage of Pyrex glass has been found out.

KEY WORDS : Portland cements, Blended cements, Pyrex glass, expansion

INTRODUCTION

Even if the Alkali-Silica Reaction (ASR) has been studied in many countries for forty years, Italy has only been taking interest in it for a few years. Today it is time to hold into due consideration this problem for several factors:

1 - In concreting it is often necessary to use aggregates from little known quarries
2 - The alkali content in Portland cement has recently increased and it is now often more than 1% of equivalent sodium oxide
3 - Also in Italy deterioration of some concrete structures is surely due to this reaction. One example is reported in Mrs.Baronio's paper.

Therefore it's always suitable to carry out investigations on cements and aggregates before designing important concrete structures to make sure of their durability and safety.
That is the reason why this matter closely concerns the Hydraulic and Structural Research Centre (CRIS) of the Italian Electricity Board (ENEL) which is also particularly interested in employing fly as from power plants like addition to concrete mix to reduce expansion and damage caused by the Alkali-Silica Reaction.
Till now aggregates from Italiana quarries were considered non reactive to alkali but no exhaustive study about this subject has been made yet. However recently the presence of some reactive siliceous impurities has been found in quarries along the Adriatic Riviera /1/ where "pop outs" seriously damaged a lot of industrial pavements. These are just the most frequent cases of deterioration by Alkali-Silica Reaction in Italy.
For the time being a first short investigation on the performance of some cements usually produced in Italy has been carried out considering the ordinary portland cement on one hand and the portland-pozzolana, portland-blast furnace and sulphate resisting cements on the other. The effectiveness of the latest ones in reducing the dangerous expansions taking place with ordinary portland cement within acceptable values has been verified.
Like standard reactive aggregate Pyres glass has been used /2/ because it is the only one readily available and taken into consideration by the ASTM standard, even if someone considers the fuced silica or a Beltane opal rock

more suitable to descrive the behaviour of real alkali susceptible aggregates in concrete.
The ASTM Test Method for Effectiveness of Mineral Admixtures in Preventing Excessive expansions of concrete due to Alkali-Aggregate Reaction (C 441-81) and the Standard Specification for Blended Hydraulic Cements (C 595-82) compel to use Corning Glass Works' borosilicate Pyrex Glass number 7740 like standanrd reactive aggregate.
Nevertheless some different cements have been evaluated with regard to alkali-silica reactivity using both the above glass and an Italian available one, comparing the expansions obtained on mortar bars made with 100% of Pyrex glass. In fact this was found out to be its critical reactive percentage or Pessimum.

MATERIALS AND PROCEDURE

Resistance to alkali-aggregate reaction was tested by measurements of expansion after 14, 28, 56 days on 25 by 25 by 285 mm mortar bars made in accordance with ASTM C 227 Standard Test Method.
Several cements have been considered. That is:
- two types of Ordinary Hardening Portland Cement named, according to the Italian Legislation:
  . High strength and Rapid Hardening Portland Cement (28 days strength on normal mortar = 52,5 MPa) with more than 1% of Equivalent sodium oxide
  . High strength Portland Cement (28 days strength on normal mortar = 42,5 MPa) with 0,82% of Equivalent Sodium oxide
- A Portland-pozzolana cement with fly ash
- A low heat Portland-blast furnace cement
- Two types of Sulphate-resisting cement:
  . A sulphate resisting cement like American type V
  . A sulphate resisting cement named Ferrico-Pozzolanico and made with clinker of Ferrari cement and natural pozzolana

The samples of the two types of Pyrex glass were pulverised and analysed for chemical composition.
The results showed a light difference: the silica oxide content of the American glass was about 75% while the content of the Italian one was 81%.
On the contrary the alkali content was slightly higher in the American one.
In both cases X-ray diffraction pattern showed the same small picks on a broad flat hump due to the vitreous glass phase.
The glass was crushed according to the grading stated by the ASTM C 227 Standard Method.

"PESSIMUM" OF PYREX GLASS

Usually expansions caused by the alkali-silica reaction increase with increasing content of reactive aggregate until a maximum which corresponds to the "pessimum" weight of reactive aggregate.
However the expansion is sometimes a maximum when a 100% reactive aggregate is used.
To find out the "Pessimum" of Pyrex glass like percentage by weight of total aggregate, six groups of mortar bars were made, using different percentages of Italian Pyrex glass and ordinary non-reactive sand from Lake of Massaciuccoli near Lucca.
A high strength Portland cement with 0,82% of Equivalent Sodium oxide was used.

Test results of average expansions in per cent at given ages are shown in Table I.
In Figure 1 there are the same results in a curve with the expansions of mortar bars versus the reactive aggregate content.
They show how Pyrex glass produces relatively flat curves. In fact, when the content of Pyrex glass is more than 50%, the expansions are practically the same.
These results lead to evaluate different cements with regard to alkali-silica reactivity using a 100% of Pyrex glass like standard aggregate.

COMPARISON BETWEEN AMERICAN AND ITALIAN PYREX GLASS

Also comparative tests were carried out on mortar bars made with the same cement and two different types of Pyrex glass: Corning Glass Work's number 7740 and an Italian available one.
The results obtained on some of above mentioned cements and particularly on two ordinary Portland cements and a Portland Pozzolana cement with fly ash are shown in Table II.
Even if the American glass causes a little higher expansion, examination of results reveals that the performance of cements is not substantially modified by the type of Pyrex glass, so that the employ of Italian Pyrex glass instead of the American number 7740 can be justified.

TEST RESULTS OF CEMENT EXPANSIONS

The expansions of mortar bars made with Italian Pyrex glass and the several Italian cements above mentioned reveals the different performance of these cements against the alkali-silica reaction.
This investigation clearly shows that the use of Portland-Pozzolana and Portland-Blast furnace cements is an effective preventive measure against the expansive reaction of concrete.
When interpreting the available results (Table III), one may consider that also the cements with any or low content of C_3A like the sulphate resisting ones have a good performance.
Practically dimensional changes noticed on mortar bars made with Portland-Pozzolana, Portland-Blast furnace and sulphate resisting cements are very similar to those observed on mortar bars made with non reactive sand, cured at the same conditions of temperature and humidity.
The mechanism of the alkali silica reaction has not been completely understood and particularly an exhaustive explanation of the effect of Pozzolana or Blast furnace slags has not been found yet. Even if they are very rich in alkali and silica, they reduce the ultimate expansion. It seems that these additions have an advantageous effect by sharing the silica and reducing the alkali concentration./3/
In this way the local chemical attack, whose differentiated expansions are the principal cause of concrete damages, are avoided.
When suspecting that the available aggregate for concrete has some dangerous silica impurities, without having enough time to carry out the necessary test methods about the Alkali-Silica reactivity, it is recommended to choose straight away the Portland-Pozzolana or the Portland-Blast furnace cement.
Also the sulphate resisting cement, which in these tests behaved like the others, seems to be suitable to reduce the expansions but a conclusion needs a wider and more exhaustive study that is still lacking in the scientific literature.

CONCLUSION

Results of expansions obtained on mortar bars made with Pyrex glass and several types of cements, storaged at the temperature and humidity conditions stated by ASTM C 227 Standard Method, show what follows:

1 - the reactive pessimum percentage of Pyrex glass, considered like standard aggregate with regard to Alkali-Silica reactivity is 100%
2 - the Corning Glass Works' number 7740 and the Italian available Pyrex glass, even if lightly different in chemical composition, cause very similar expansions
3 - the effectiveness of some Italian Portland-Pozzolana, Portland-Blast furnace and Sulphate resisting Cements in reducing the expansions induced in mortar bars by the Alkali-Silica reaction has been verified. Therefore they can successfully replace the Portland cement when the aggregate is suspected to be reactive to alkali in concrete.

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Group number	Pyrex (%)	Sand (%)	Expansions %		
			14-day	28-day	56-day
I	0	100	0,008	0,010	0,011
II	15	85	0,055	0,119	0,183
III	33,3	66,7	0,151	0,265	0,293
IV	50	50	0,152	0,344	0,398
V	66,7	33,3	0,131	0,323	0,362
VI	100	0	0,296	0,385	0,409

Table I - Expansion of mortar bars made with different percentages of Italian Pyrex glass and non reactive sand

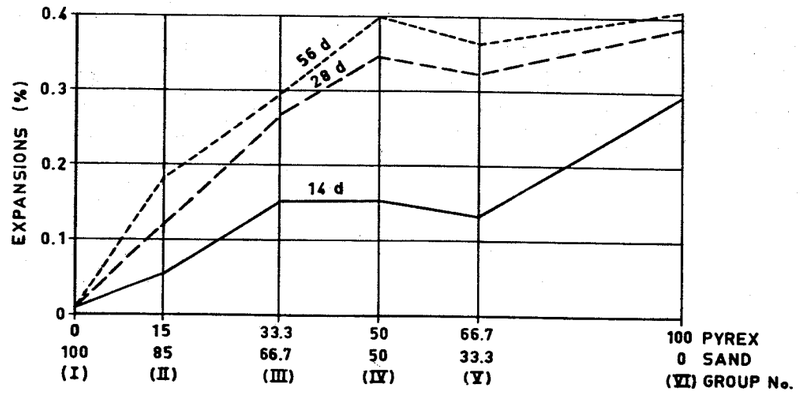

Fig. 1 - Influence of reactive aggregate content upon expansion of mortar bars at given ages

Type of cement	Type of Pyrex glass	Expansions %		
		14-day	28-day	56-day
High strength and Rapid Hardening Portland	Italian	0,296	0,385	0,409
	American	0,310	0,400	0,425
High strength Portland	Italian	0,337	0,469	0,495
	American	0,360	0,460	0,490
Portland - Pozzolana	Italian	0,028	0,030	0,032
	American	0,035	0,036	0,039

Table II - Comparison between the expansions of mortar bars made with Italian and American Pyrex glass

Type of cement	Expansions %		
	14-day	28-day	56-day
High strength and Rapid Hardening Portland	0,296	0,385	0,409
High strength Portland	0,337	0,469	0,495
Portland - Pozzolana (fly ash)	0,028	0,030	0,032
Portland - blast furnace	0,018	0,022	0,040
Sulphate Resisting like Type V	0,011	0,018	0,041
Sulphate Resisting "Ferrico Pozzolanico"	0,021	0,036	0,040

Table III - Expansions of mortar bars made with the Italian Pyrex glass and the above mentioned cements

RAPID METHOD FOR DETERMINING THE PREVENTIVE EFFECT OF MINERAL ADMIXTURES ON ALKALI-SILICA REACTION

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ABSTRACT

A rapid method was worked out by us for the identification of alkali reactivity of aggregates, for which only two days are needed. In this paper, this method was used to examine the effectiveness of various mineral admixtures in preventing alkali-silica reaction. The examined admixtures included tuff, fly ash, blast furnace slag, finely ground quartz sand, limestone and dolomite, with different amounts of admixtures to replace the cement in the mortar bars made. The results are well in agreement with that obtained by ordinary methods, but the time needed is much shorter. Moreover, we also proved that it is more effectiv when the amount of admixture is increased. Thus the examination of the effectiveness of an admixture can be completed in two days.

KEY WORDS: Rapid method, Preventiveness, Admixture

1. INTRODUCTION

In the same way as the mortar bar test(ASTM C227-71)(1), the standard test for effectiveness of mineral admixtures in preventing excessive expansion of concrete due to alkali-aggregate reaction(ASTM C441-69)(2) also requires a long time to obtain a result, because mortar bars are ...ged at a temperature of 38°C, at which the reaction proceeds slowly. A rapid method for identification of alkali reactivity of aggregate was suggested by us with mortar bars autoclave-treated in a 10% KOH solution(3). Now this method was used to compare the preventive effect of some mineral admixtures on alkali-silica reaction.

2. EXPERIMENTAL METHOD

The admixtures used were tuff, fly ash, slag, quartz sand, limestone and dolomite. The chemical compositions of clinker, tuff, fly ash and slag were similar to that described in reference(4). The fineness of these adxtures expressed by sieve test was:

	R_{70} %
Tuff	8.40
Fly Ash	0.50
Slag	0.72
Quartz Sand	2.28
Limestone	2.88
Dolomite	3.60

Mortar bars of 1x1x4cm of cement:aggregate(opal)=10:1, w/c=0.3 and sizes of aggregate=0.15-0.75mm were made and demolded after a one-day curing.