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PERFORMANCE OF COMMERCIAL BLENDED CEMENTS IN ALLEVIATING ASR

A K Mullick, R C Wason and C Rajkumar

National Council for Cement and Building Materials
M-10, South Extension II, New Delhi, India

ABSTRACT

This paper presents results of an exhaustive laboratory investigation on the performance of blended cements like portland pozzolana cements commercially produced in India in combination with natural aggregates, which have now been proved to be reactive and with pyrex glass. Investigations have shown that beneficial effect can be realised even when the proportion of pozzolan is lower i.e. around 15 percent, as long as the total alkali content in the blended cement is restricted to 0.8 - 0.9 percent.

1 INTRODUCTION

With the reported cases of distress to concrete irrigation structures due to Alkali-Silica reaction (ASR), considerable attention is being paid in India to this aspect of durability in future constructions (1). As a result of evaluation of different varieties of natural aggregates proposed in these constructions, comprehensive guidelines have now become available for the characterisation of potential reactivity of aggregates (2). Similarly, the choice of appropriate cementing systems for use with such reactive aggregates prompted an investigation of the role of blended cements, i.e., portland pozzolana cement and portland slag cement to be taken up. Results of investigations with portland pozzolana cement are presented in this paper.

Use of low alkali ordinary portland cement (0.6% Na_2O equivalent) for use with alkali reactive aggregates and the beneficial role of pozzolan or slag addition in reducing the risk of alkali silica reaction in concrete are well known. In the context of Indian conditions, it has to be borne in mind that the alkali levels in the cements have gone up over the decades, primarily due to modern dry process cement plants which require hot exit gases containing volatile as well as the kiln dust to be recirculated in the process stream and not vented to the atmosphere (3). On the other hand, a considerable proportion of the cements manufactured in India are blended cements where the pozzolans or the slags are interground with the cement clinkers in the plant itself.

In deciding on the use of such blended cements with reactive aggregates, a few uncertainties arise. The first is that the reported beneficial effect of pozzolans and slags are with higher dosages of these additives - atleast 25 to 30 percent in case of pozzolans and atleast 50 percent in case of slags; both of which are in excess of what is interground in commercially blended cements

in India. The second relates to the fact that in many cases, the samples of pozzolans interground with cement clinkers at the plants would not be separately available for evaluation as per ASTM C-441. On top of this, the pozzolans or slags may themselves contain alkalies higher than generally obtained in OPC and, therefore, the total alkali level in blended cements would normally be higher than the original OPC. In such a situation, a threshold limit of total alkali content in the blended cements in line with 0.6 percent limit in case of OPC would be useful for practising engineers. The present investigation aimed at establishing such a threshold limit for portland pozzolana cements.

2. EXPERIMENTAL

18 different types of natural aggregates owing their potential reactivity to the presence of strained quartz alongwith one sample of pyrex glass were used for the investigations. The aggregate samples included different rock types namely quartzites, orthoquartzites, granites, granite-gneiss, biotite-gneiss, augen-gneiss, sandstones and phyllites. Studies were also conducted on composite aggregates containing various rock types. The angle of undulatory extinction (UE) in different rocks varied from 15^{o} to 40^{o} and the percentage of quartz showing strain effect varied from 15 to 90 (4).

In the Phase I, mortar bar expansion tests were carried out incorporating these aggregates with six samples of ordinary portland cement along with 12 commercially manufactured portland pozzolana cement samples containing either flyash or calcined clay pozzolans. The total alkali as Na_2O equivalent in the ordinary portland cement varied from 0.25 to 1.12 percent and that in portland pozzolana cement from 0.49 to 1.91 percent. The percentage of pozzolans in such commercial cements is expected to be between 12 to 18 percent with 15 percent as an average. In Phase II, nine different pozzolans having total alkalies from 0.1 to 1.52 percent were blended with ordinary portland cement samples in varying proportions upto 25 percent. The mortar-bar tests with natural aggregates were carried out at 60^{o} C and with pyrex glass at 38^{o}C (4).

3. RESULTS AND DISCUSSIONS

3.1 Series I

The influence of commercial portland pozzolana cements on the expansions of mortar-bars containing either natural reactive aggregates or pyrex glass, are typically shown in Fig. 1 and 2 respectively, when the alkali content in both ordinary portland cement and portland pozzolana cement were in the range of 1.04 to 1.12 percent. It was noticed that commercial PPC's containing about 15 percent pozzolan interground with clinker, lowered the mortar-bar expansions substantially - a trend which is borne by a summary of all the results shown in Fig 3. Fig 3 clearly depicts that the use of PPC had definite beneficial effect in that the expansions of mortar-bars were always suppressed with the use of PPC. Even with high alkali content PPC samples (alkali content approximately 1%) 180-day expansions were lower than 0.06% limit suggested (2). For natural aggregates containing strained quartz which are relatively slowly reactive, the beneficial effect of pozzolan addition in the blended cement appeared to be more prominent at later ages, i.e., around 180 days. This could possibly be due to the beneficial effects of pozzolan in depressing the OH ion concentrations at later ages as reported by other investigators (5).

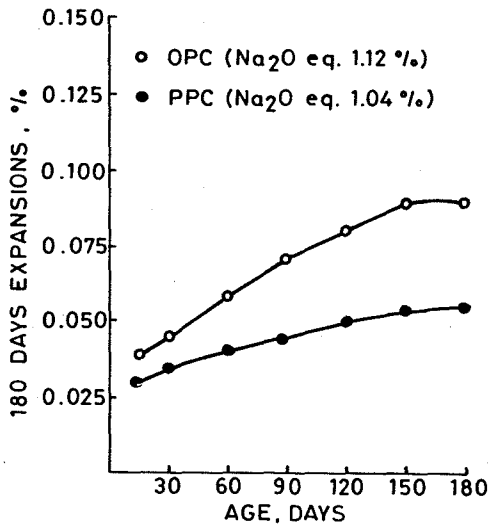

Fig. 1. Typical results with natural aggregate (Series I).

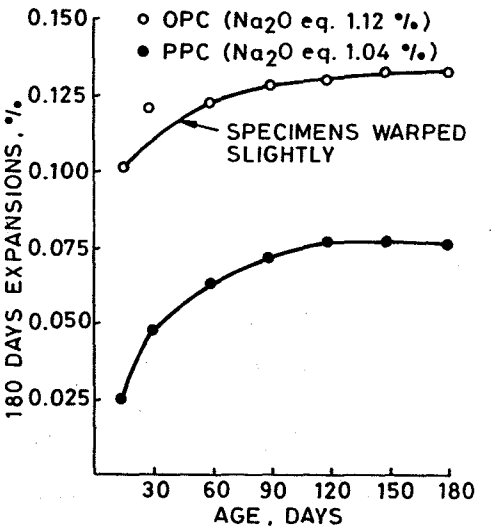

Fig. 2. Typical results with pyrex glass (Series I).

It is generally believed that the use of low alkali OPC (i.e. OPC with total alkali content expressed as Na_2O equivalent less than 0.60 percent) does not lead to problem of deleterious reactions due to reactive aggregates. It can be noted from Fig 4 that the expansions with low alkali OPCs' were within 0.04 percent at an exposure time of 180 days. These expansions are much lower than the permissible limit of 0.06 percent recommended for the test on evaluation of such aggregates in similar regime but with OPC having total alkali content as Na_2O equivalent to 1.0 percent (2). Thus, mortar-bar expansion upto 0.04 percent obtained with low alkali OPC could be considered safe and while evaluating any other cementing system this guideline has to be kept in mind and the cementing systems successful in suppressing expansions within such safe orders could be considered as suitable. Based on these guidelines, a limit of 0.8 to 0.9 percent total alkalies can be considered as safe in case of PPC, as against 0.6 percent in OPC (Fig 4).

3.2 Series II

For studying the effect of pozzolan content, tests were conducted by replacing OPC in different percentages of pozzolan up to 25%. Generally, a high alkali OPC was chosen for studies along with different samples of flyash, calcined clay and rice husk ash pozzolans. The beneficial effect in reducing ASR expansion increased with the dosage of pozzolan added, both with natural aggregates (Fig 5) and pyrex glass (Fig 6). It can be seen from Fig 5 that at 25% level of pozzolan substitution, the expansion in almost all the cases were within permissible limits, irrespective of total alkali content in the blend. While such trends were quite consistent in case of flyash, the results in case of calcined clay pozzolana or rice husk ash were somewhat erratic.

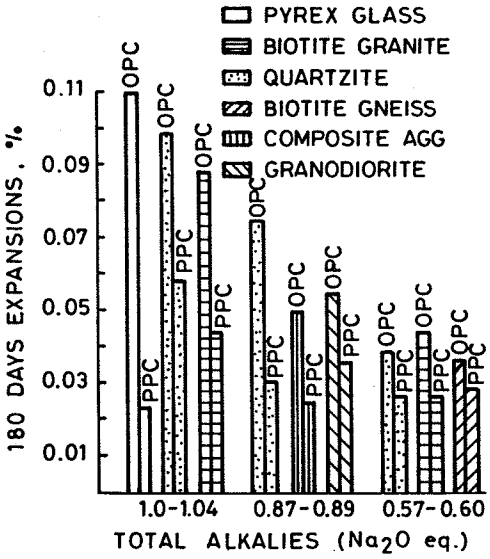

Fig. 3. Comparative performance of OPC and PPC samples. (Series I)

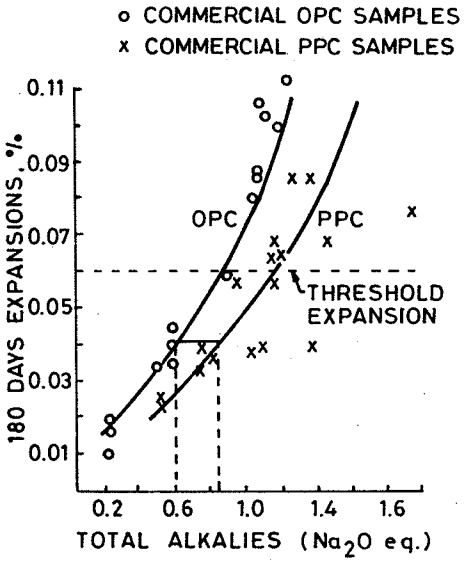

Fig 4. Influence of alkali content in OPC or PPC samples. (Series I)

Results from Series I and II were compared to find out relative merits of either intergrinding the pozzolan with cement clinker or blending with OPC in the laboratory (Fig 7). In general, there was no discernible difference between the results of Series I (interground pozzolans) and Series II (blended pozzolans)

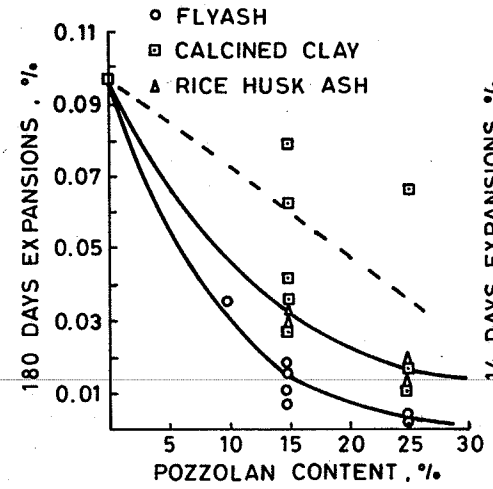

Fig 5. Influence of pozzolan content - Natural aggregates(Series II)

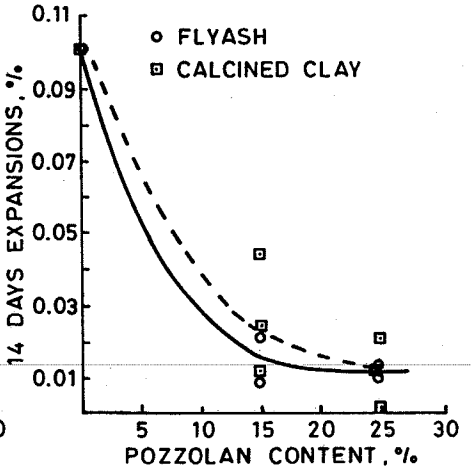

Fig 6. Influence of pozzolan content - Pyrex glass (Series II)

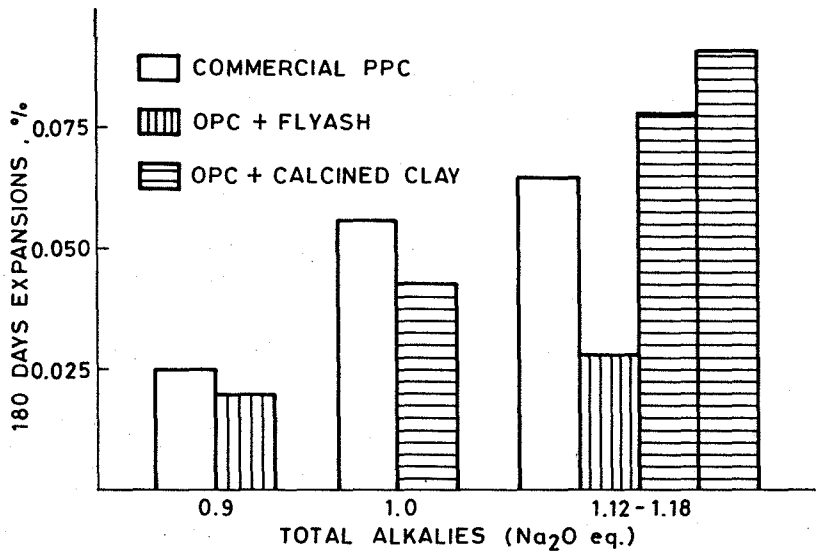

Fig. 7. Comparative performance of interground and blended pozzolans.

for identical alkali content in the blend. However, in so far as the reactivity of the pozzolans is a significant factor, it is felt that intergrinding the pozzolan with cement clinker, specially flyash, could be beneficial as grinding could break the particles of the flyash and increase the surface area substantially.

4 CONCLUSIONS AND RECOMMENDATIONS

The commercially available portland pozzolana cements in India have superior performance both with natural reactive aggregates and pyrex glass when compared to ordinary portland cements. Based on the data, a limit of 0.8 to 0.9 percent total alkalies can be considered as safe in case of PPC as against 0.6 percent in OPC. Although, the performance of PPC's improve with the increase of pozzolan content but a dosage of around 15 percent as is common in India is adequate, provided the suggested total alkali limit is satisfied. The flyash pozzolan had the best and consistent beneficial effects. Appreciable reductions in expansions were obtained with 25 percent dosages of pozzolans hence greater advantage can be obtained by blending the pozzolans at site when OPC is available. The various trends of results reported were obtained with active pozzolans (with lime reactivity more than 40 kg/cm^2), thus, a minimum lime reactivity of 40 kg/cm^2 when tested as per Code is recommended. A few trends were somewhat erratic particulary with calcined clay pozzolans and therefore prior evaluation of the proposed cementing systems with the reactive aggregates is recommended.

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