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STRENGTH EFFICIENCY OF ZEOLITE CONCRETE WITH AGE

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Abstract:

The utilization of supplementary cementitious materials is well accepted, because of the several improvements possible in the concrete and due to the overall economy. One such supplementary cementitious material is natural zeolite. There are large variations in physical and chemical composition in supplementary cementitious materials; it requires mix design method for their effective use in concrete. In this work, the concept of strength efficiency is applied as a measure of the relative strength performance of natural zeolite with ordinary Portland cement (OPC), and to quantify the 7 day & 28 day strength efficiency of zeolite in concrete at the various replacement levels from literature. Experimental data from literature indicate that the contribution of zeolite to the strength of concrete is not a constant value determined entirely by its physical and/ or chemical characteristics like cementitious compounds, fineness etc., but can also vary depending on the type of cement, water cement ratio, percentage of replacement and curing conditions. The "overall strength efficiency"(k) of zeolite was established through a "general efficiency factor"(ke), depending upon the age and a "percentage efficiency factor"(kp), depending upon the percentage of replacement, as was the case with a few other cementitious materials like fly ash and silica fume reported earlier.

Keywords: Natural zeolite, efficiency, compressive strength, water cement ratio, pozzolan.

I Introduction

Natural zeolites are hydrated alumino-silicate minerals containing alkaline and alkaline-earth metals, formed by the alteration of volcanic ash, which is mainly an amorphous, silicious materials. They are considered as materials with high pozzolanic activity of their open structure and chemistry [1].

The structure of the zeolite minerals is characterized by a large number of channels and cavities, which exhibit a high surface area. In addition, they are capable of adsorbing more lime than ordinary tuffs and some other glassy mixtures, because the amount of dissolved SiO_2 of zeolites is 3 to 7 times higher than that of some other pozzolans. This results in the formation of higher amounts of hydration products, which are responsible for strength development [2].

Though there are several methods for the design of normal concretes of a specified strength grade, the design of concretes containing supplementary cementitious materials is not yet well established. In general, concretes containing supplementary cementitious materials are produced through methods like simple addition, direct replacement or modified replacement. In recent times the cementitious efficiency of the supplementary cementitious materials is used in the modified replacement methods for achieving a specific strength. This methodology was successfully implemented earlier for the design of concretes containing supplementary cementitious materials like fly ash, silica fume, blast furnace slag etc [3-5]. In specific, the cementitious efficiency factor of zeolite in concrete was established through a systematic evaluation of the available results from literature, at the different percentages of replacement and with ages at 7 and 28 days.

The term "efficiency" for zeolite is defined as the number of parts of cement that could be replaced by the one part of zeolite without changing the property being studied. This efficiency factor is not a constant, among other factors; it varies depending on the property being studied. The concrete age and the quantity of zeolite used, physical properties like particle shape, size and distribution, chemical properties like composition etc.

In general, it was observed that zeolite exhibits little cementing efficiency at the early ages and acts rather like fine aggregate (filler), but at later ages the pozzolanic property becomes effective leading to a considerable strength improvement. This obviously means that the cementing efficiency of zeolite improves with age due to the pozzolanic reaction. The variation of strength with age was also discussed by [6-7]. In spite of all these investigations, it is felt that there is a lack of quantitative understanding of the behaviour of zeolite in concrete. The present paper deals with the efficiency of zeolite in concrete, through the strength to water cement ratios relations of these concretes at different ages and at the varying percentages of replacements.

II EFFECT OF ZEOLITE ON CONCRETE STRENGTH AND DURABILITY

Both the strength development rate and the ultimate strength, which are important to the construction engineers, are controlled by the kinetics of hydration reaction of components of Portland cement and mineralogical phases of the admixture. This is because strength development is a function of the pore filling process which takes place with the formation of hydration products, with highly active pozzolans like zeolite, the pozzolanic reaction may start as soon as calcium and hydroxyl ions are available from the hydration of Portland cement components. It is generally agreed that the pozzolanic quality depends on the proportion of the glassy phase, the content of active silica, and the fineness of the pozzolans. These factors effect especially the early strength gain [8].

Poon et al [9] concluded that natural zeolite as a pozzolanic material, with reactivity between that of silica fume and fly ash. And also he said, in blended cement pastes with a lower water to cementitious materials ratio, the natural zeolite contributes more to the strength of the pastes. But in the pastes with higher water to cementitious ratio and a lower cement replacement level it undergoes a higher degree of reaction

S.Y.N. Chan [10] observed that regardless of the replacement levels, zeolite increased the 28-day strength. However, at 7 days, when the cement replacement level by zeolite was upto 30%, the concrete compressive strength was found to have decreased to a level similar to that of the control concrete. Their result indicates that when the replacement level reached 30%, zeolite concretes developed their early strength to a slower rate similar to that of the control concrete.

Sandor [11] said that water leaching of caesium (Cs) – loaded cement ion exchange resin and the mechanism of Cs immobolization were studied in the cement – resin – zeolite system. Addition of natural zeolites decreased Cs released by up to 70 – 75% (of the quantity originally bonded in the resin) in the course of a 3 – year leading period. It has also found application in the recovery of Cs from radioactive wastewater and ammonia from municipal wastewater [12]. It was also observed that incorporation of zeolites in concrete increased the viscosity, decreased bleeding, and reduced the segregation in fresh concrete, thus satisfying the requirements of pumping concrete for construction, and is capable of controlling slump loss of high strength concretes when it is used as the career for superplasticizer and plasticizer [2,13].

III EVALUATION OF EFFICIENCY

This paper attempts to assess the cementitious strength efficiency of zeolite in concrete at the various replacement percentages and at the 7 & 28 days age through the efficiency concept, by establishing the variation of the strength to water cementitious materials ratio relations of zeolite concretes from the normal concretes. In principal this was done by using "Δw" concept, which attempts to bring the water cementitious materials ratio [w/(c + z)] near to the water cement ratio of the control concrete (w/c_0) by applying the cementitious efficiency factor 'k' of zeolite at any particular strength.

In this paper the results available from literature [2,6,7,15] were all compiled for an evaluation. In all about 40 concretes from the above investigations were chosen for evaluation.

To start with, the water cementitious materials ratio [w/(c+z)] to compressive strength relations at the different percentages of replacement, were plotted for all the concretes at the age of 7 days (Fig. 1). Similar figure for the 28 days was already reported earlier [14]. It can be seen from Fig. 1 that at 7 days the compressive strength of concretes containing zeolite up to 20% replacement were all slightly above that of normal concretes and at all other percentages the relationships were below that of normal concrete.

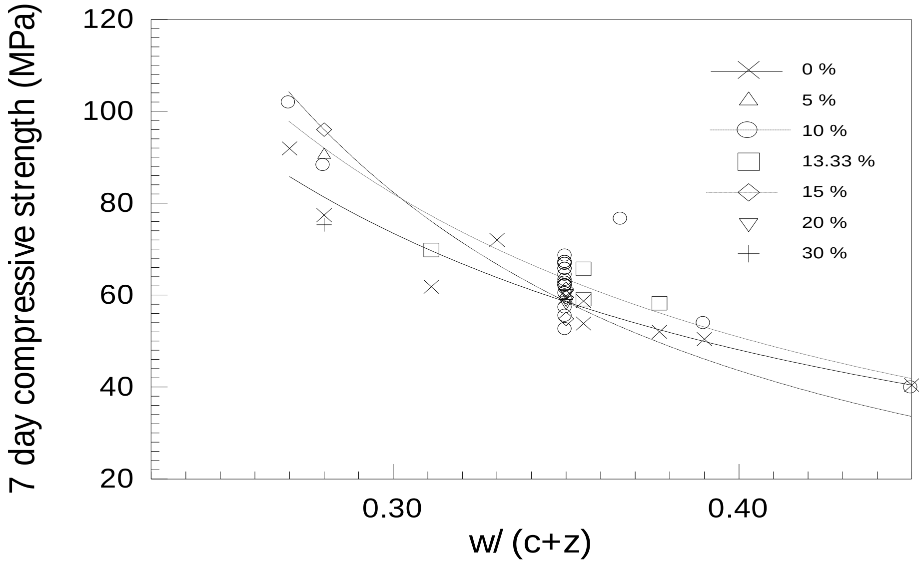

Fig. 1 Variation of compressive strength with [w/(c+z)]

In order to bring the strength values at all replacement levels nearer to that of normal concrete the water cementitious materials ratio were modified through an efficiency factor, termed as "general efficiency factor (k_e)" replacing the [w/(c + z)] by [w/(c + k_ez)]. After several trials with "k_e" values varying from 1 to 3, the appropriate "k_e" values were found to be 1.4 and 2.05 for the 7 and 28 day strengths of these concretes. It can be seen that the k_e values were increasing with the age but rate of increase was lower at higher ages (Fig. 2). As already reported earlier [3-5], it was observed that this general efficiency factor "k_e" could not bring the [w/(c + k_ez)] to strength relations very close to the water cement ratio of normal concrete (w/c_0) at all percentage replacement levels. At this stage, the effect of percentage replacement in efficiency, which can bring the zeolite concretes strength values closer to that of normal concrete were found by evaluating the remaining difference through a "percentage efficiency factor (k_p)".

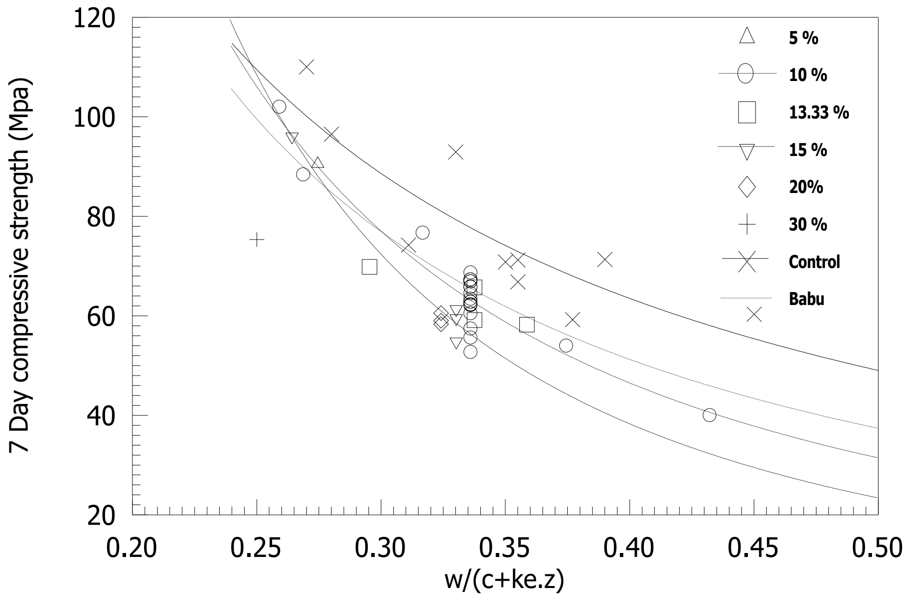

Fig. 2 Variation of compressive strength with [w/(c+k_ez)]

The variation of the "percentage efficiency factor (k_p)" with the zeolite replacement percentage at both the ages of 7 & 28 days was found to be the same and is presented in Fig. 3. This shows that the value of the "percentage efficiency factor (k_p)" was the same at both the ages studied and varies from (1.2) to (-0.9). While the "general efficiency factor (k_e)" was the one that was varying with age.

The percentage efficiency factor was decreasing with increasing the replacement level and at about 14% replacement; the value of k_p was almost zero. This is due to the fact that, firstly the high efficiency expected at the lower percentages of replacement would result in a considerable reduction in the available cementitious materials (which particularly in lower strength concretes will not be sufficient to coat all the aggregates for effective binding) and secondly the small quantity of zeolite at this lower percentage will be completely utilized in the filler effect without much material being available for additional pozzolanic strength development. The variation of k_p with the percentage replacement [p = z (c + z)] was found to be defined by the relation

$$k_p = 3.07 - 2.67 \log (p) \qquad (1)$$

The "overall cementing efficiencies ($k = k_e + k_p$)" at the two ages studied were also presented in the same Fig. 3. The corresponding relationships for the overall cementing efficiencies at 28 days (k_{28}) & 7 days (k_7) for replacement levels varying from 5 -30% were found to be

$$K_7 = 4.5 - 2.7 \log p \qquad (2)$$

$$K_{28} = 5.14 - 2.7 \log p \qquad (3)$$

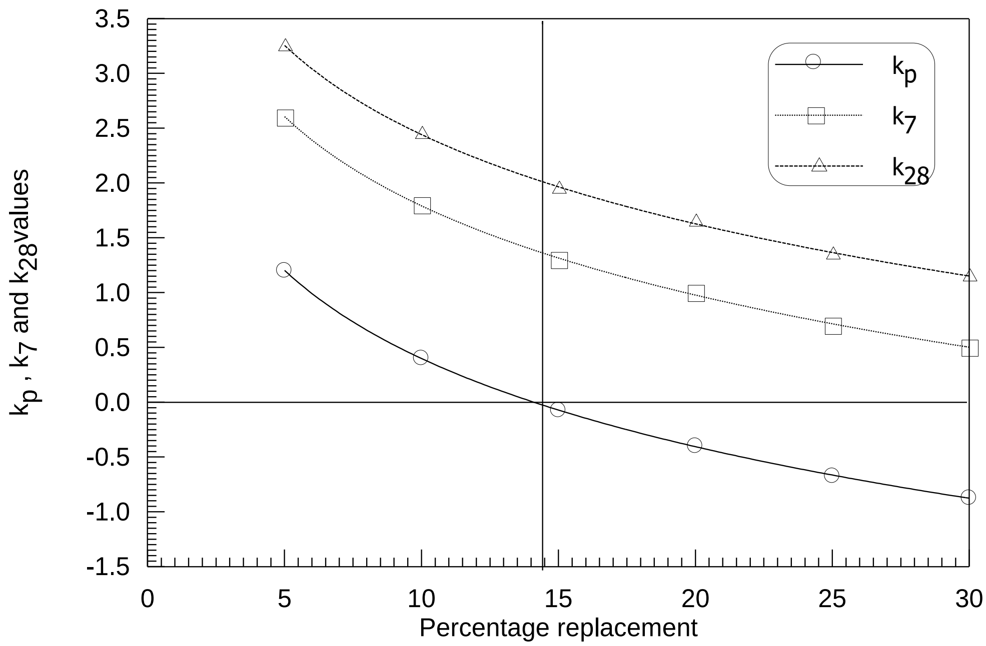

Fig. 3 Variation of k_p and k_{28} with replacement percentage [z/(c+z)]

The combined variation of strength with [w/(c + k_ez + k_pz)] or [w/(c + kz)] at 7 day at all replacements was presented in Fig. 4. Similar figure for the 28 days was already reported earlier [14]. Fig. 5 presents a comparison of overall predictions at 7 and 28 days after modifying with "k_e" and "k_p".

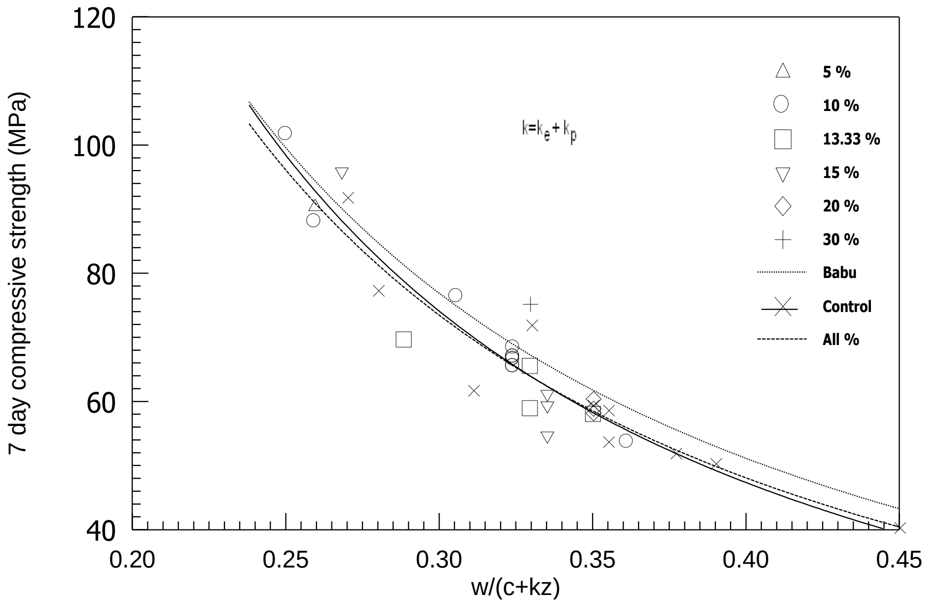

Fig. 4 Variation of compressive strength with [w/(c+k_ez+k_pz)]

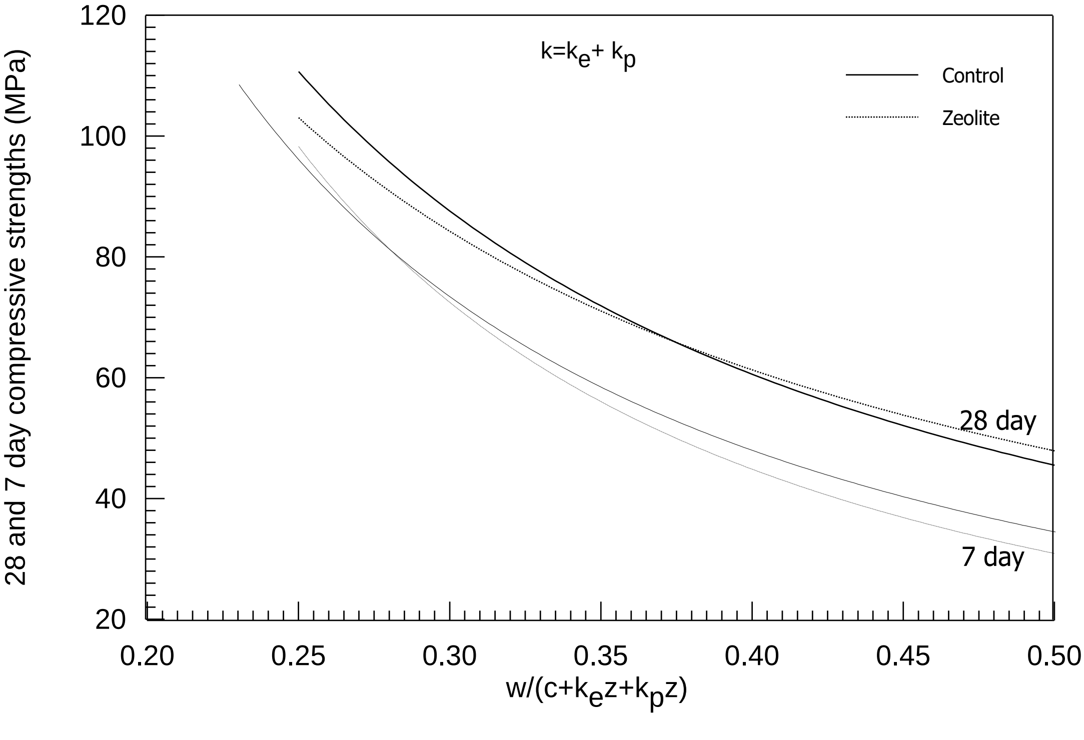

Fig. 5 Variation of compressive strength with [w/(c+k_ez+k_pz)], at different ages.

The above investigation clearly shows that the efficiency of zeolite is dependent on both age (k_e) and the percentage replacement (k_p). It was observed that the overall cementing efficiencies of zeolite varied from a value of about (2.6) – (0.5), (3.25) – (1.15) for replacement percentages varying from 5 – 30% at the 7 & 28 days studied. These efficiency values "k_e" "k_p" and "k" at the different percentages of replacement are valid only for concretes containing ordinary Portland cement, normal type of aggregates and normal curing condition.

IV Conclusions

Strength efficiency of the relative strength performance of natural zeolite with ordinary Portland cement (OPC), and to quantify the 7 day & 28 day strength efficiency of zeolite in concrete at the various replacement levels from literature. Experimental data from literature indicate that the contribution of zeolite to the strength of concrete is not a constant value determined entirely by its physical and/ or chemical characteristics like cementitious compounds, fineness etc., but can also vary depending on the type of cement, water cement ratio, percentage of replacement and curing conditions. The "overall strength efficiency"(k) of zeolite was established through a "general efficiency factor"(ke), depending upon the age and a "percentage efficiency factor"(kp), depending upon the percentage of replacement, as was the case with a few other cementitious materials like fly ash and silica fume reported earlier.

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