Characterization of Portland Cements, Expansive cement and High-Alumina Cement, and their Variation in Properties with Different Components

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Abstract:

Cement is a hydraulic mineral binding material. The properties of cement vary with chemical composition and degree of fineness. Different types of cement are manufactured by changing the percentages of their raw materials. The recent interest is to find alternatives for cement and change the properties the cement and concrete by using different additives. Choice of cement depends on the physical condition and various hazardous it may approach in future. Various kinds of cement are available in market, Portland cements, Expansive cement and high alumina cement are the major type among them. This paper disuses the various work done to change the property of cement and concrete.

Keywords: *Cement, Cement Additives, Expansive cement and high-alumina cement, Portland cements*

1. Introduction

The property of cement in its action varies with chemical composition and degree of fineness. The different types of cements are prepared by changing their raw materials. The hydration kinetics, microstructure development, and ultimate properties of cement depend on original size, spatial distribution and composition [1]. Computer simulation and a few experimental studies help to know cement particle distribution on a variety of performance. The properties of cement examines are setting time, heat release, capillary porosity percolation, diffusivity, chemical shrinkage, autogenous shrinkage, internal relative humidity evolution, and interfacial transition zone microstructure[2]. The recent interest is to reduce the water to cement ratio systems, develop cement which show superior performance, and give choice of the components of cement concrete and reducing production costs of the manufacturing. The modern cements differ from those produced past years. Gypsum addition controls the setting of cement, gypsum in regulating the initial hydration and abnormal expansion. The influence of rate hydration and strength volume change of the hardened cement are to be considered for characterization [3].

2. Type of cements

2.1 Portland cement

Calcium oxide (CaO), silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), and ferric oxide (Fe_2O_3) are the main components used for the manufacture of ordinary Portland cement [4]. If there is no exposure to sulfates in the soil or ground water, these cement uses for the construction. Lime saturation factor (0.66-1.02) is less compared to other cement. Low lime saturation factor make burning in the kiln difficult and fineness not less than 2250 cm^2/g [5].

Recycled tire rubber in a Portland cement concrete mixture is investigated as possible alternative for nonconventional Portland cement concrete. Fine crumb rubber and coarse tire chips are

useful to mix with Portland cement concrete [6]. Rubberized Portland cement concrete mixes can be made and are workable to a certain degree with the tire rubber content being as much as 57% of the total aggregate volume. Large reductions in strength would prohibit the use of such high rubber content. Rubber contents should not exceed 20% of the total aggregate volume. Lightweight concrete walls, building facades, and architectural units can be built with rubberized concrete. Fire hazards are of major concern and need to be thoroughly investigated before recommendations for practical implementation [6, 7].

The evaluation of biocompatibility and sealing ability of Portland cement which is mixed with calcium nitrate, calcium chloride, and calcium formate accelerators will be future concern. X-ray diffraction and differential thermal analysis had done 10% mineral additive Portland cement, the hydration products in Portland cement +slag and Portland cement and fly ash system were found to be almost similar to that of pure Portland cement, except with low quantity of $Ca(OH)_2$ during the early period of hydration. The final setting time of cement pastes were generally accelerated when the natural pozzolan replaced part of the cement [8, 9]. Natural pozzolan exhibited a significant retarding effect when used in combination with colemanite ore waste. The replacement of Portland cement by 10–15% of natural pozzolan in the presence of fixed quantity of colemanite ore waste improves the bending strength of the specimens compared with control specimens after 60 days of curing age. Rice husk ash has been used as a highly reactive pozzolanic material to improve the microstructure of the interfacial transition zone between the cement paste and the aggregate in high-performance concrete. Mechanical studies had shown the blending efficiency of cement varies with addition rice husk ash. Porosity, pore-size distribution, surface area and drying shrinkage are determined for silica fume. Portland cement blends, paste blends a discontinuous pore structure is formed after as little as seven days of curing due to reaction of $Ca(OH)_2$ with silica fume. The pores are not too large as those in mortar owing to the lack of interface effects. The development of the strength, heat, porosity, bound water, and calcium hydroxide content was measured. Higher strengths were observed after 14 days, whereas in cement replacement higher strength was observed after 91days [10].

Partial replacement of cement with diatomite can be done for cement mortar production. Diatomite was used at 0%, 5%, 10% and 15% replacement by weight for cement while sand and water quantities were kept constant. Compressive and flexural strength, freeze–thaw resistance, sulfate resistance, water absorption and dry unit weight of the mortars were determined. The compressive and flexural strength decreased with increasing diatomite content for all curing periods. Compressive strength of the cement mortar which was produced with 5% diatomite content complied with the minimum specified value of given in the standards. Water absorption of the mortars decreased with the increase of diatomite content except the mortar containing of 15% diatomite. Due to high porosity of diatomite, dry unit weight of the cement mortar was lower than the control motor. When diatomite content is increased, the expansion of cement mortar bars is observed in 5% sodium sulfate solution [11].

Compressive strength of Portland cement is affected with boric acid was acid waste such as reactor waste, borogypsum and sludges were studied. It is reported that compressive strength decreases with percentages sludges[12]. Compressive nature, tension with bending strength and deformability of the composites are affected by addition of active mineral zeolite to the cement [13]. When properly selected, processed, and used, pozzolans will reduce costs, improve quality of concrete, protect concrete against effects of reaction between aggregate and cement alkalies, and inhibit attack by aggressive waters. Pozzolans available as waste or materials which can be converted into pozzolans by grinding and calcinations can be used. Natural pozzolans are mainly

volcanic glass, opal, clays, and the quality of proposed materials and need for special processing usually can be predicted from petrographic analyses [14].

Calcium carbonate-aluminate formed in the system affect favorably the strength of concretes formed. Like other pozzolanic materials such as silica fume and fly ash, zeolite contributes to concrete strength mainly through the pozzolanic reaction with $Ca(OH)_2$. The compressive strength, degree of pozzolanic reaction, and porosity of zeolite modified cement pastes, natural zeolite contributes more to the strength of the pastes. Pastes with higher water cementitious ratio and a lower cement replacement level it undergoes a higher degree of reaction [15].

Wood pulp natural fibre replaces asbestos in the beleaguered global fibre cement industry. Natural cellulose fibres can be used as reinforcement [16]. Some natural fibers tends to disintegrate in alkaline environment of cement, long term performance is the recent research interest [17]. Cement with nano-phase Al_2O_3 particles has been studied. Al_2O_3 nanoparticles with the average diameter of 15 nm were used with four different contents of 0.5%, 0.1%, 1.5% and 2.0% by weight. The results showed that the use of nano- Al_2O_3 particles up to maximum replacement level of 2.0% produces concrete with improved split tensile strength. The use of nano- Al_2O_3 particles up to maximum replacement level of 2.0% produces concrete with improved split tensile strength. The ultimate strength of concrete was gained at 1.0% of cement replacement. The flexural strength of fresh concrete was increased by increasing the content of Al_2O_3 nanoparticles. The setting time of fresh concrete was decreased by increasing the content of Al_2O_3 nanoparticles. It is concluded that partial replacement of cement with nanophase Al_2O_3 particles improves the split tensile and flexural strength of concrete but decreases its setting time [18]. Strength of pozzolanic cement is lower than that of plain Portland cement at early ages, but can reach the same order of strength at longer curing periods [19].

2.2 Expansive cement

The expansive cement consists of a portland cement component and a calcium-sulfoaluminate anhydrite component. Chemical composition of the components, fineness of the sulfoaluminate component, proportions of the two components in the total cementing material, ratio of water to total cementing material, richness of mix, conditions of curing, and degree of restraint are the factors influencing the magnitude and rate of the expansive reaction. Concrete exhibits free expansions up to 6 percent or more. Predetermined characteristics within a practical range can be obtained by proper mix proportioning and curing, with compositions, proportions, and fineness of components fixed [20, 21].

Amer et al. (2005) reported expansive soil was stabilized using lime, cement, combinations of lime and cement, Sarooj (artificial pozzolan) and heat treatment. The addition of 6% lime, both the swell percent and swell pressure reduced to zero. Heat treatment reduced swelling potential to zero. The use of lime showed superior results when compared with the other stabilizers [22]. High-performance concrete incorporated with expansive agent and hybrid fibers, i.e., steel fibers, polyvinyl alcohol fiber, and polypropylene fiber, was produced. Hybrid fibers of different types and sizes could reduce the size and amount of crack source at different scales; hybrid fibers combined with expansive agent provided better enhancement for shrinkage resistance and impermeability of High-performance concrete than monoincorporation of hybrid fibers or expansive agent. Amount of expansive agent, types and sizes of hybrid fibers, total volume fraction of fibers, proportions of hybrid fibers affect shrinkage resistance and the impermeability of the concrete. Tricalcium aluminate has typically been targeted as the chief contributor to sulfate attack, iron oxide or tetracalcium aluminoferrite content, combined with total equivalent alkalis, showed a much stronger negative correlation with expansions at all ages [23, 24].

Calcium sulfoaluminate and lime based expansive admixtures and discusses the expanding mechanism, chemical prestressing, and typical properties of expansive cement concrete [25]. Colloidal ettringite can adsorb large quantities of water, thereby causing slump loss in fresh concrete and expansion in hardened concrete [26]. Additive like MgO retards the initial hydration of cements and increase the setting time. MgO hydration in a high alkali medium such as the liquid phase of hydrating cements, precipitates with a tiny crystallite size on the cement grains and forms a protective layer, which retards further hydration of the cements. Neither expansive agent used separately, can definitively and safely avoid the risk of cracking caused by drying shrinkage in real concrete structures under the practical conditions of curing on many job-sites [27, 28].

Investigation experimental data were developed to evaluate the behaviour of concrete members laterally confined with fibre-reinforced plastic composites. Specimens were loaded quasi-statically under cyclic flexure with and without axial compression. Two different types of fibre-reinforced plastic confinement technologies were investigated. For the latter jacketing type, specimens with both circular and rectangular cross-section were tested. It was found that flexural strength and ductility are enhanced by the use of fibre-reinforced plastic jackets. Improvements depend on jacketing method, shape of member cross-section, level of the axial load, and failure mode [29, 30].

2.3 High-alumina cement

Calcium aluminate cements have a radically different chemistry to Portland cements. Due principally to their higher cost, they do not compete directly with Portland cements [31]. Nevertheless, concretes based on these cements have very high performance in specific applications. High-alumina refractory castables with compositions in the systems $CaO–Al_2O_3$ and $CaO–Al_2O_3–SiO_2$, the effect of accelerators, and in particular lithium salts and citric acid solutions, on the setting time of high alumina cement has been studied using calorimetry, solution analysis and X-ray diffraction techniques [32]. Lithium salts function as accelerators by precipitation of a lithium aluminate hydrate which acts as a heterogenous nucleation substrate. It is suggested that retardation by citric acid is due to the precipitation of protective gel coatings around the cement grains which impede hydrolysis or inhibit growth of the hydration products. Composite resin layers were incrementally condensed into the mold to fill up the mold and each layer was light polymerized for 40 s. The composite blocks were bonded to the surface-conditioned ceramic blocks using a resin cement system. The set of high alumina cement pastes may be considerably influenced by the addition of very small quantities of chemical compounds. The effects on the time of setting may be summarized as follows:- for cations $Li-Na < e < K < Ca < Mg < Sr < NH_4^+$ for anions $OH - < Cl < NO_3^- < Br <$ acetate [33, 34].

The set of high alumina cement may be considerably influenced by addition of small quantities of alkali metal salts. The lithium cation has greater effect on the setting time than other alkali cations. The effect of hydroxyl ion on setting time is greater than the effect of other investigated anions. Along with rapid setting, lithium salts cause the strength development at early ages. The integral analyses of the results have been made in order to test the process of hardening. The process obeys a simple first-order reaction rate in the period of 6 h after first appearance of the strength. The action of lithium-containing setting accelerators is based on a shortening of the induction period, while they have no effect on the rate of hardening. Lithium salts remove the nucleation barrier, caused by an initially fast precipitation. The lithium salts cause decreasing of flexural and compressive strength of high alumina cement mortars but also cause the strength development at early ages. . The lithium cation has more effect on the setting time than other

alkali cations because of its ability to form tetrahedral symmetry while the others will form the octahedral type [35, 36].

The effect of anions, except for the hydroxyl ion, causes retardation in the setting as a result of replacement of OH^- groups linked to Al, referred to as ion penetration, preventing the formation of oxobridges. The retardation of sot will be governed by the rate of replacement of OH^- by other anions and the stability of the new species formed. The dramatic effect of OH^- is due to the replacement of H_2O by OH^- in the Al environment leading to a further centre for oxobridge formation [34].

Mullite and magnesium-aluminate spinel sols were used separately as bonding agents in a high-alumina based ultra low cement castable composition prepared by simple tapping technique and their performances have been compared in terms of bulk density, apparent porosity, cold crushing strength, flexural strength, slag corrosion, thermal shock. The results confirm that the mullite sol excels while the spinel sol degrades the refractory castable quality [37].

The phase composition of high alumina cement clinkers may affect the strength development behaviour of concrete made from them and so a method of quantitatively determining these phases is needed. The reaction products belonged to the tobermorite group of calcium silicate hydrates and the term crystallinity was defined as the percentage of 11.3 tobermorite out of the total amount of calcium silicate hydrates. The shrinkage decreased with increasing crystallinity while the compressive strength increased up to an optimum value. The strength also increased with increasing amounts of hydrates and with decreasing porosity [38].

The kinetics of fluoride removal from water by the adsorbent alumina cement granules examined, exploring the mechanisms involved. Alumina cement exhibited a biphasic kinetic profile of sorption with an initial rapid uptake phase followed by a slow and gradual phase. The surface reactions involving the heterogeneity of the surface site bonding energy or other reactions occurring on the surface of alumina cement were found predominant in defining the rate-limiting step. The dominant mechanism of fluoride removal appeared to be a chemisorptive ligand exchange reaction involving the formation of inner-sphere complexation of fluoride with alumina cement [39].

Possibility of producing calcium sulfoaluminoferrite-calcium aluminoferrite based cements using lime, red mud, bauxite and gypsum had been investigated. The characteristics of the cements produced have been found to be strongly dependent on the raw mix composition and firing temperature but not so much on firing time. Some of these cements possess strengths comparable to and at times even more than ordinary Portland cement. Since the red mud used contains significant amount [40, 41].

Physical and mechanical tests are applied to the samples prepared from bauxite/fused brown corundum 50%, SiC 15%, calcined alumina 15%, reactive alumina 10%, calcium aluminate cement 5%, micro silica 5%. Phases of the samples heat-treated at 110°C, 1000°C, and 1500°C are investigated by using X-ray diffraction and scanning electron microscopy techniques. Bauxite-based samples, which have higher porosity than corundum-based samples, show higher cold crushing strength and modulus of rupture than corundum-based samples. Samples fired at 1000°C have higher cold crushing strength than those fired at 1500°C for both types of samples. The same behavior is not observed for modules of rupture of bauxite-based samples, but only observed for fused corundum-based samples. It is found that hot modules of rupture of bauxite-based samples at 1000°C and 1500°C are better than corundum-based samples. The possible

reason for better properties of bauxite-based samples is the new mineral phase formation obtained by XRD results and pore size distribution [42].

Conclusion

Many researches have been going on to find different additives for cement as well as concretes. The hydration behavior properties of the cement can be varied with different additives. Different types of cement or its alternatives should be available for the choice of availability of water, sand and gravels. The research work about cement to reduce the carbon foot print and energy demand is continuing. When supplementary cementitious materials like slag, limestone, fly ash, silica fume, natural pozzolan are used, use of cement clinkers can be reduced. Calcined clay with kaolinite content has similar cementious property; it can be also used to replace quantity of cement in concrete mixture.

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