



REVIEW ON EARLY STRENGTH CONCRETE

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ABSTRACT

A brief literature review about the influence of mineral admixture (alccofine), chemical admixtures on the fresh concrete, and their effect on strength and durability behaviour of concrete is reported and discussed in this paper. Literature regarding mix proportioning of high early strength concrete is also discussed.

KEY WORDS: *Early strength concrete, Alccofine, Chemical admixtures*

1. INTRODUCTION

High early strength concrete achieves its specified strength within a short time. High strength at an early age is desirable for high-speed cast in-place construction, fast track paving, rapid form reuse in winter construction to reduce the length of time temporary protection is required for and many other uses. The additional cost of high-early-strength concrete is often offset by earlier use of structure, earlier reuse of forms and removal of shores and savings in the shorter duration of temporary heating. In road pavement maintenance and rehabilitation, strength at an early age is beneficial when early opening of the pavement is necessary.

2. PREVIOUS STUDIES ON HIGH EARLY STRENGTH CONCRETE

The following is brief information from previous studies

2.1. Research of Products Application Department PT. Semen Indonesia (2015)

In 2015, Research of Product Application PT. Semen Indonesia, developed a high early strength concrete that was called Rapid Strength Concrete (RSC). In this study, effect of various dosages of high range water reducing admixture based polycarboxylate ether were studied. Its composition and strength properties are presented in the Table 1 below:

Table 1. Composition and Strength Properties of Concrete for Various Concrete Mixes [1]

Materials	Mix proportions			
Cement (Kg/m ³)	740	740	740	740
Fine aggregate (Kg/m ³)	542.50	542.50	524.50	542.50
Coarse aggregate (Kg/m ³)	1007.50	1007.50	1007.50	1007.50
W/C Ratio	0.25	0.2	0.25	0.2
Polycarboxylate ether (%)	0.8	0.8	0.6	0.6
Slump (mm)	60	56	56	50
Compressive strength (MPa)				
8 hours	17.99	25.06	21.91	22.48
24 Hours	64.19	65.11	58.22	58.89

2.2. High Early strength concrete by Federal Highway Administration (2001)

In 2001, Federal highway administration conducted various experiments for making high early

strength concrete with several types of mix designs. The compositions along with other information are presented in the Table 2 below.

Table 2. Mix design of high early strength concrete by federal highway administration [2]

Materials	Mix Proportions				
Cement (Kg/m ³)	400	350	450	400	450
Coarse aggregate (Kg/m ³)	1070	1010	780	830	1070
Fine aggregate (Kg/m ³)	600	830	780	810	610
Fly ash (Kg/m ³)	-	-	50	45	-
W/C Ratio	0.45	0.41	0.4-0.48	0.4-0.48	0.4
Air Entraining agent (%)	6	6	6	6	6
Water Reducer	-	-	Use	Use	-
% CaCl ₂	-	-	-	-	1.0
Open Traffic in Time	4-6 hours	4 hours	12-24 hours	24-72 hours	4 hours



2.3. High Early strength concrete by Strategic Highway Research Program (1993)

In 1993, Strategic Highway Research Program provided some data on material specifications, mix designs, and mechanical properties from four

different regions in America: Crushed Granite (CG), Marina Marl (MM), Rounded Gravel (RG), and Dense Crushed Limestone (DL). Its composition and strength properties are presented in the Table 3 below:

Table 3. Mix design of High Early strength Concrete by Strategic Highway Research Program [3]

Materials	DL (Van Buren)	MM (Lilington)	RG (Memphis)	CG (Lilington)
Type III cement (Kg/m ³)	522	522	522	522
Fine aggregate (Kg/m ³)	618	588	540	576
Coarse aggregate (Kg/m ³)	1008	942	990	1032
W/C Ratio	0.34	0.32	0.34	0.32
Naphthalene based HRWR (mL/100 kg cementitious materials)	16	26	26	26
Air Entraining Agent (%)	4	1	1	9
Calcium Nitrite (%)	2.4	2.4	2.4	2.4
Slump (mm)	7.7	17.2	17.8	2.54
Compressive strength for 1 day (MPa)	36.5	38.7	39	37

3. POZZOLANS IN HIGH EARLY STRENGTH CONCRETE

With the emergence of industrialization, industrial solid waste generation has increased in huge amount and the industries are facing difficulty in dumping and disposal of the solid waste generated. Non-engineered industrial waste disposal impacts the atmosphere, which in turn damages the environment. Lot of research is being performed to identify the ways to utilize the industrial solid waste in the construction industry. From the various researches, it can be concluded that the industrial solid waste with pozzolanic nature can be used as replacing material for cement and other ingredients. Efforts are being made to reduce the usage of cement by encouraging the use of industrial waste or by-products, such as Fly Ash (FA), Silica Fume (SF), Ground Granulated Blast Furnace Slag (GGBS), Alccofine (AF), Rice Husk Ash (RHA), Red Mud, Sugarcane Bagasse Ash (SBA), etc., as admixtures in concrete [4].

Most of the admixtures are pozzolanic in nature and help in enhancing strength and durability properties of the concrete with age. The combination of different admixtures with cement may lead to many benefits such as reduction in usage of cement, recycling the solid waste produced from industries, improvement in physical characteristics along with the enhancement of rheological properties, mechanical properties and durability of concrete and

reduced environmental impact through reduction of greenhouse gases [5].

3.1. Techniques Used in Attaining Early Strength

High early strength concrete can be achieved by using one or a combination of the following techniques:

- High Early Strength cement
- High conventional cement content
- Low water - cement ratio (water to cement ratio of 0.3-0.45 by mass)
- Chemical admixtures
- Mineral admixtures
- Steam or autoclave curing

The above listed techniques can be used interchangeably or combined to achieve the desired strength. High early strength gain is not limited to the use of special cements such as Type III cement. It is now possible to achieve early strength by using locally available Portland cements, aggregates, and selected admixtures. This research uses a combination of Type III-High Early Strength Cement and chemical admixtures on one hand and a low water-cement ratio and/or high conventional cement content on the other hand to attain early strength and will compare the combination of these techniques and of the individual techniques used [6].



3.2. Chemical Admixtures in Early Strength Concrete

Calcium chloride is perhaps the most efficient and economical accelerator for use in concrete. Several theories have been suggested on its accelerating action. Calcium chloride accelerates the hydration of tricalcium silicate. There is evidence that calcium chloride exists in different states in the C₃S paste. Based on thermal analysis and leaching studies, Ramachandran (1995) has concluded that depending on the time of hydration, the chloride may exist in the free form (extractable by ethyl alcohol), or may be incorporated strongly into the C-S-H phase (unleachable with water) or may be chemisorbed or in interlayer position (leachable with water). From the literature review, it has been found that CaCl₂ improves the early strength of concrete, mortar and cement paste [7].

Shideler's (1952) work suggests that at 2% CaCl₂ in Type II cement at different cement contents, the strengths are always higher in chloride-containing concrete up to 5 years [64-67]. The strength development in concrete depends on the amount of initially added CaCl₂. Higher amounts decrease strength. The optimum dosage suggested varies between 1 and 4%. Most practitioners, however, recommend a dosage not exceeding 2% flake CaCl₂ or 1.5% anhydrous CaCl₂. The acceleration of strength development is also achieved at temperatures lower than the ambient temperature. Figure 2.1 shows the relative strengths developed in concrete cured for periods 1, 3, 7 and 28 days and at random temperatures of -4.0, -4.5, 13 and 23°C.

Alccofine is a new generation, ultrafine, low calcium silicate product, manufactured in India. It has distinct characteristics to enhance 'performance of concrete' in fresh and hardened stages. Alccofine performs in superior manner than all other mineral admixtures used in concrete within India. Due to its inbuilt calcium oxide (CaO) content, Alccofine triggers two-way reactions during hydration [8].

- Primary reaction of cement hydration.
- Pozzolanic reaction: ALCCOFINE also consumes by product calcium hydroxide from the hydration of cement to form additional C-S-H gel

Workability of concrete requires a balance between W/B ratio and required strength. Comb-shaped copolymers are the last-generation super plasticizers (SPs) and were introduced in the mid-1980s. This category includes many types of SPs exhibiting the same common comb-like structure. The structure of comb-shaped SPs generally consists of a main chain called backbone, bearing carboxylic groups, to which non-ionic side chains made of polyethers are attached. These superplasticizers are also called polycarboxylate ethers or polycarboxylate esters or polycarboxylates. The carboxylic groups when mixed with water confer a negative charge to

the backbone. The negatively charged backbone is responsible for the adsorption of the superplasticizer on to the positively charged cement particles. The dispersing ability of polycarboxylate ethers comes from the non-adsorbing side chains, which are responsible for the steric hindrance effect [9].

Binder paste is required for binding the inert aggregate and for filling the void space between the aggregate. In this way, the stress concentration can be reduced, leading to an increase in strength, Chang and Peng (2001).

Marine structures are subjected to aggressive environment. Durability is the subject of major concern in the marine environment. Ocean structures are exposed to seawater directly. Therefore, coastal and offshore structures are exposed to simultaneous action of several physical and chemical deterioration processes. The effect of sulphuric acid was analyzed in alccofine added concrete with and without chemical admixtures to find out the mass loss and strength deterioration factors. It was observed visually that alccofine added concrete cubes were more affected than chemical admixture based alccofine added concrete [10].

Sulphate attack on the concrete is a result of chemical disintegration mechanism where sulphate ions attack components of cement paste. The compounds responsible for sulphate attack in concrete are water-soluble salts such as alkali (potassium and sodium) and alkali earth (magnesium and calcium) sulphates that are capable of chemically reacting with concrete components (Bogues compounds) [11].

After soaking in Na₂SO₄ solution for a long time, the sample surfaces have high concentrations of sulphate. This results in gypsum crystallization/erosion occupying the dominant position because of relatively low sulphate concentration in the internal part causing ettringite crystallization. Initially, there was no sulphate penetration in the core of the hardened cement paste. Also, there was no gypsum and ettringite. The destruction of the porous structure, and the growth of the ettringite crystal can lead to crystallization pressure and water absorption swelling, with fine needle-like and flaky crystals. The increase in the internal stress causes expansion of cracks in the cement-based material. On the other hand, crystallization of the gypsum can induce two adverse effects: (i) the volume of gypsum crystal increases by about 124%, causing the expansion and cracking of cement-based materials and (ii) the hydration product calcium hydroxide (CH) contributes to the mechanical properties of the hardened paste. As the reaction of sulphate and hydration product produce gypsum, the consumption of CH result in decrease of strength and durability, inducing decrease in the mechanical properties of the paste, which ranges



from lacking edge or even resulting in the collapse of the structure [12].

The alkali-silica and alkali-carbonation reactions in mortar or concrete cause expansion. Silicious gel formed by reaction between the cement alkalis and silica minerals absorb water and exert a swelling pressure. The factors that affect the reactivity of silica include cationic nature of hydroxide (OH^-) in solid solution, the micropore structure, internal strain and the degree of crystalline disorder. The reaction mechanism of reactive silica with alkalis is generally described as involving the penetration of hydroxyl ions into the aggregate to break siloxy linkages between sulfate (SO_4) tetrahedra or to react with terminal acidic silanol groups. The negative charge of silicate fragments is electrically balanced by positive ions of sodium and potassium from the cement paste pore fluid forming a sodium-potassium-silicate gel. The gel imbibes water and swells upto cracking limit thereby generating sufficient hydraulic pressure in surrounding concrete [13].

The formation and distribution of hydration products of hydrated cement paste for the concrete mix proportions are pictured below. The microstructure of the different mixes was examined and compared with the reference mix. The microstructure and strength properties of all the concrete mixes were correlated based on the hydration products formed after 28 days. The reason being that the strength of concrete was analyzed and explained based on the growth of hydration products in the microstructure of concrete mixes [14].

HRWR admixtures are mainly classified into two groups based on their generation. Those are

- Second generation Type F admixtures are reduced water reduction by 20% (Gluconate, Ligno Sulphonate, melamine and Naphthalene Sulphonate)
- Third generation Type F admixtures are water reduction by 40% (Polycarboxylate Ether, Modified Polycarboxylate and Vinyl Copolymers)

HRWRA are polymers capable of chemically and physically interacting with cement particles. The physical interaction happens for the dispersion of cementitious power while utilizing the HRWRA into concrete. There are mainly three ways of interacting happen in physical interaction [15].

- Due to Van der Waals and Electrostatic forces, the superplasticizer molecules are absorbed on the cement particles.
- Induction of interparticle repulsive forces owing to the negative charge transmitted to the particles (dispersion) and reduction of attractive forces between opposite charged particles (defloculation) by the adsorbed charged particles.

- Steric hindrance effects between adsorbed polymer molecules and adjacent particles.

4. CONCLUSION

We can conclude from some of the explanations in this document

- HESC was developed to address the setting time issues that arise in buildings and construction industries. It usually takes 7 to 14 days to complete concrete hardening and achieve the minimum strength of 0.7 to 0.85 f_c' . HESC implies that the concrete's compressive strength at 24 hours after site pouring could achieve structural concrete pouring (Compressive strength > 21MPa).
- There are four significant variables to consider including cement type, cement quantity, type of admixture and W/C ratio.

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