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Review on Application of Machine Learning On the Study of Cement- Superplasticizer Compatibility

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Abstract
Superplasticizers are an improved version of plasticizers. The workability of concrete can be increased by adding superplasticizers without adding much water. For different dosages of superplasticizer in relation to cement mass, the variation of flow time is different. In this study, the cement paste is examined by varying the water-cement ratio and dosage of superplasticizers. Two different types of superplasticizer (Polycarboxylate Ether PCE, Sulphonated Naphthalene Formaldehyde SNF) with varying dosage and two different types of Cements (Portland fly ash based and Portland slag based) are used to find the flow behaviour of the cement paste. The mash cone, mini slump and setting time tests are conducted to evaluate the optimum dosage of cement paste. Furthermore, the strength test were performed on the concrete with optimum superplasticizer dosage to predict the correct water-cement-ratio by using artificial intelligence.
***Keywords**: Superplasticizers, Water-Cement-Ratio, PCE, SNF.*

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I. INTRODUCTION

Concrete is a composite material consisting of a mixture of cement, sand, granite/gravel, water and/ or admixture. Various studies have shown that concrete strength not only depend on water-to-cement ratio, but is also related to the other additive constituents and admixtures.

An admixture for concrete is a material added during the mixing process of concrete in a quantity not more than 5% by mass of the cement content of the concrete, to modify the properties of the mix in the fresh and or hardened state. While a concrete additive is a substance whose content exceeds 5% of the cement mass**,** the admixtures for concrete may be both organic and inorganic compounds. The use of chemical admixtures in concrete is rapidly growing in India. The number of admixture manufacturing industries has increased tremendously with the growing awareness of the usefulness of these admixture. Admixtures are classed according to their functions. There are several distinct classes of chemical admixtures: water reducers**,** air-entraining, viscosity-enhancing, accelerating the bonding and hardening reactions, retarding (delaying the rate of setting), and sealing. Among them water reducers are those chemicals that are added to the concrete to reduce the water demand resulting in high strength. Water reducers can be low range or high range superplasticizers.

Superplasticizer is also known as high range water reducers. it produces extreme workability flowing concrete. It has the efficiency of dispersing fine-grained particles like cement, fly ash, ground granulated blast furnace slag, and silica. They increase slump for ease of placement, creates the denser and more durable concrete. There are different types of superplasticizers according to their flow properties: Sulfonated Melamine-Formaldehyde condensate (SMF); Sulfonated Naphthalene-Formaldehyde condensate (SNF); Modified Lignosulfonates (MLS); Polycaboxylic Ether (PCE); and others including sulfonic acid esters, polyacrylates, polystyrene sulfonates, etc.

However, some unexpected phenomena, such as poor initial fluidity, rapid stiffening and abnormal setting, can always be found through by the addition of superplasticizers, which is usually called the incompatibility of admixtures with cement. Water to cement (w/c) ratio is one crucial parameter for the preparation of concrete, which can significantly affect its workability, mechanical property and durability. By, fast development of superplasticizers, it is now possible to produce a high performance or ultra-high performance concrete with a low w/c ratio and high dosage of superplasticizer. However, the decreased w/c ratio is more likely to trigger the incompatible problem. Although the strong influence of w/c ratio on the compatibility of superplasticizer with cement has been found for a quite long time, the consensus on the intrinsical mechanism of w/c ratio leading to the incompatibility is still not reached.

Hence in this study, the effect of w/c ratio on the flowability and setting time of cement paste is examined through the addition of different superplasticizers (PCE, SNF). Furthermore to predict the correct w/c ratio by implementing Artificial Neural Network (ANN) method using java environment. Thus the issues associated with trial and incorrect mixes of concrete can be solved. These methods will enhance the model prediction accuracy.

II. LITERATURE REVIEW

The main aim of this section is to present an overview of research work carried out by various researchers in the field of cement admixture compatibility.

2.1 CEMENT

The history of cementing material is as old as the history of engineering construction. Some kind of cementing materials were used by Egyptians, Romans and Indians in their ancient constructions. It is believed that the early Egyptians mostly used cementing materials, obtained by burning gypsum. In the early period, cement was used for making mortar only. Later the use of cement was extended for making concrete. As the use of Portland cement was increased for making concrete, engineers called for consistently higher standard material for use in major works.

In India, Portland cement was first manufactured in 1904 near Madras, by the South India Industrial Ltd. But this venture failed. Between 1912 and 1913, the Indian Cement Co. Ltd., was established at Porbander (Gujarat) and by 1914 this Company was able to deliver about 1000 tons of Portland cement. By 1918 three factories were established. Together they were able to produce about 85000 tons of cement per year. The early scientific study of cements did not reveal much about the chemical reactions that take place at the time burning. A deeper study of the fact that the clayey constituents of limestone are responsible for the hydraulic properties in lime (as established by John Smeaton) was not taken for further research. It may be mentioned that among the earlier cement technologists, Vicat, Le Chatelier and Michaelis were the pioneers in the theoretical and practical field [1].

The different general groups of Portland cement are ordinary (type I), modified (type II), rapid hardening (type III), low heat (type IV), and sulfate resisting (type V). There are also some other special types. Portland blast-furnace cement (type IS) is made by intergrading or blending Portland cement clinker with granulated blast-furnace slag, which is a waste product in the manufacture of pig iron. The hydration of slag is initiated when lime liberated in the hydration of Portland cement provides the correct alkalinity. Subsequent hydration does not depend on lime. The slag cement is comparable to type I with regard to fineness, setting times, and soundness, but its early strengths are lower. It typically is used in mass concrete because of the lower heat of hydration and in sea-water construction because of better sulfate resistance due to lower C_3A content [2].

2.1.1 Portland Pozzolana Cement (PPC)

The constituents of PPC are OPC clinker and pozzolanic materials such as fly ash, calcinated clay or other siliceous and aluminous materials. It possesses physical properties like low heat of hydration and greater resistance to the attack of aggressive water. The PPC used conforms to IS 1489-1991.

2.1.2 Portland Slag Cement (PSC)

The constituents of PSC are Portland cement clinker, gypsum, granulated blast furnace slag. In general, this cement possess physical properties like low heat of hydration, refinement of pore structure, reduced permeability, increased resistance to chemical attack, better resistance to corrosion of steel reinforcement. The cement used conforms to IS 455-1989 [3].

2.2 SUPERPLASTICIZERS

Superplasticizers are able to enhance the placing characteristics of concrete mixtures by increasing the workability level at a given w/c. Therefore they allow easier placement of concrete mixtures, even with low w/c when required for strength or durability reasons. The main difference between plasticizers and superplasticizers is in the extent rather than in the type of performances. The slump increase at a given mix composition is about 150-200 mm for the latter and about 50-70 mm for the former. On the other hand, a super-plasticizer is capable of reducing water requirements at a given slump by about 20-30%, whereas a plasticizer can reduce water contents by only about 5-12% [4]. Superplasticizers are classified in four basic groups: Modified lignosulfonates (MLS) Sulfonated melamine formaldehyde condensate (SMF) Sulfonated naphthalene formaldehyde condensate (SNF) Polycarboxylate ether (CE) [5].

2.3 CHARACTERISTICS OF DIFFERENT SUPERPLASTICIZERS

Different interaction between cement and superplasticizers are classified as physical and chemical. The physical interaction includes electrostatic repulsion and steric hindrance [6].

Superplasticizers are generally supplied as liquid formulations, with active solid content in the range of 30-40%. Lignosulphonate salts of sodium and calcium hydroxycarboxylic acids (citric and gluconic acids) and carbohydrates are examples of normal water reducers.

Lignosulphonates are generally regared as 1st generation superplasticisers, while the sulphonated formaldehyde condensates are called 2nd generation, and the polycarboxylates and polyacrylates are termed as 3rd generation superplasticizers. Currently, the most widely used superplasticizers are the sulphonated formaldehyde condensates and the polycarboxylates.

Polycarboxylic ether (PCE) and Sulphonated Melamine Formaldehyde (SMF) are almost equal, Suplphonated Naphthalene Formaldehyde (SNF) is about half the cost of the PCE, while lignosulphonate is the cheapest (about one-fourth the cost of PCE). However, in terms of effectiveness to achieve a specific workability of the concrete, the amount of PCE required is significantly lesser than SNF or lignosulphonate. Thus, the overall cost of a plasticised concrete need not increase with the unit cost of the superplasticizer used [7].

2.4 EFFECTS OF SUPERPLASTICIZERS ON FRESH CONCRETE

Dramatic improvement in workability is not showing up when plasticizers or superplasticizers are added to very stiff or what is called zero slump concrete at nominal dosages. A mix with an initial slump of about 2 to 3 cm can only be fluidised by plasticizers or superplasticizers at nominal dosages. A high dosage is required to fluidity no slump concrete. An improvement in slump value can be obtained to the extent of 25cm or more depending upon the initial slump of the mix, the dosage and cement content. It is often noticed that slump increases with increase in dosage. But there is no appreciable increase in slump beyond certain limit of dosage [8]. The fluidity of the mix depends greatly on the type of superplasticizer and mixing method [9].

2.5 EFFECTS OF SUPERPLASTICIZERS ON HARDENED CONCRETE

The superplasticizer does not affect the properties of the hardened concrete significantly [10]. Naphthalene sulfonate-formaldehyde condensate was found to has the higher efficiency in improving the mechanical properties of the hardened pastes than that of sodium lignosulfonate superplasticizer [11]. Plasticizers or superplasticizers do not participate in any chemical reactions with cement or blending material used in concrete. Their actions are only physical in fluidizing the mix, made even with low water content. Their fludifying action lasts only as long as the mix is in plastic condition. Once the effect of adsorbed layer is lost, the hydration process continues normally. It can be categorically said that the use of right quality of plasticizers or superplasticizers when used in usual small dose (say up to 3% by weight of cement) there is no bad effect on the properties of hardened concrete. Only in case of bad quality lignosulphonate based plasticizer is used, it may result in air-entrainment, which reduces the strength of concrete. Since plasticizers and superplasticizers improve the workability, compatibility and facilitate reduction in w/c ratio, and thereby increase the strength of concrete, it contributes to the all-round improvement in the properties of hardened concrete [1].

2.6 COMPATIBILITY OF SUPERPLASTICIZERS AND CEMENT

The compatibility of a superplasticizing admixture with cements different in composition are, Cement content providing the highest strength gain in concrete changes with the kind of cement used. This indicates that the effect of a superplasticizing admixture depends on the composition of cement rather than the amount used [12]. In high-performance concrete, which necessarily means superplasticized concrete with a low water-to-cement (w/c) ratio, the high initial workability is sometimes short-lived and followed by a rapid slump loss. In such cases, the cement and superplasticizer are said to be rheologically incompatible [13].

The cement paste fluidity is affected by the amount of mixing water, for this reason the fluidity was tested for several w/c ratio. The fluidity of the cement paste is related to the cement hydration and chemical interactions in the cement paste system and can be affected by the combination of cement type and chemical admixture, mineral admixture or water–cement ratio. The fluidity of the paste increases with the increase of w/c ratio but does not always increase with the superplasticizer dosage. All mixes present an increase of the fluidity according to the increase of w/c ratio, leading in reduction of saturation dosage of superplasticizer [14].

The w/b ratio exhibit a great effect on mini-slump, plastic viscosity and compressive strength. The increase in w/b ratio has an influence on increasing mini-slump and induced bleeding, and decreasing plastic viscosity, plate cohesion meter and compressive strength [15].

Many hypotheses have been put forward for the explanation of the incompatible issue. Some researchers argued it is caused by the hindered dissolution of sulfate carrier through the adsorption of superplasticizer, through which a sulfate starved condition is triggered and a fast reaction of C_3A is followed. While some others hold the opinion that the directly accelerated dissolution of C_3A through the addition of superplasticizer is the dominating reason. Besides, it is also found the incompatible issue is related to the content of soluble alkali content in cement. An optimum soluble alkali content of 0.4–0.5 wt% is found for a good compatibility of superplasticizer with cement, but the reason for such phenomenon is still unclear [16].

2.7 ARTIFICAL NEURAL NETWORK (ANN)

Artifical Neural Network (ANN) has been investigated to deal with the problems involving incomplete or imprecise information. Several authors have used ANN in structural engineering [17]. Furthermore, some researchers have recently proposed a new method of mixing design and predicting the strength of concrete using neural networks. Additionally, the system is developed with single architecture of ANN in an initial development. The initial system involved a problem, which it cannot appropriately predict the concrete strength when the curing temperature of a specific curing day is changed. This is because it uses the single architecture, which all nodes are fully connected, and thus it could show too plastic response. As a trial to solve this problem, modular ANN is proposed, which has multiple architectures composed of five ANNs [18]. ANNs are non-linear statistical data modeling tools for relations between input and output data, which can be an adaptive system that changes its structure based on information that flows through the network during the learning phase. Feed-forward networks have their neurons arranged in layers. All the neurons in the different layers are connected to each other; however, there are no connections between neurons in the same layer. The first layer known as the input layer, which includes the ANN input parameters and the same number of neurons as inputs, and the last layer is entitled the output layer, which contains the results of the ANN, with the same number of neurons as problem outputs. The other layers that are between these two are named the hidden layers. The number of hidden layers and the number of neurons in each hidden layer may not be identified beforehand due to depending on the problem under investigation [19].

Deep neural networks (DNNs) are best suited for this problem because of the complex relationships between components in the concrete mix. Thus, to address the issues associated with trial and incorrect mixes of concrete, we adopt this robust technique to manage the require water for concrete mixes to reduce wastage associated with trial mixes and those originating from collapse structures due to incorrect concrete mixtures. The concrete considered in the study is ordinary concrete for general construction purposes with no superplasticizer or admixtures. In developing automatic concrete mix designs, we employ multilayer deep feedforward neural networks to predict the required water content for the different concrete mix proportions [20].

III. CONCLUSION

To identify the ideal dose of concrete's constituents, admixture-cement compatibility and admixture-admixture compatibility must be researched. The flow of the cement paste increases with increase in the superplasticizer dosage and remains constant after a particular dosage called saturation dosage or optimum dosage. Different superplasticizers act differently with the Portland cement pastes. Various factors influence the cement superplasticizer compatibility both external and internal.

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