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REQUIREMENT OF SOFT COMPUTING METHOD FOR CONCRETE COMPRESSIVE STRENGTH –A REVIEW PAPER

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ABSTRACT

This research is prepared to explore the possibilities of applying soft computing methods to save time and cost involved in conventional design mix process. Concrete mix design methods available till date were listed and research articles following these procedures were reviewed. The purpose of review was to understand the difficulties encountered in the follow up process of these design mix process. Use of soft computing methods like Artificial Neural Network Neuro Fuzzy were reviewed in purview of these difficulties.

KEYWORDS: Design Mix, Soft Computing, Artificial Neural Network and Neuro Fuzzy Method.

INTRODUCTION

Nominal concrete mixes were earlier used for determining the amount of conventional concrete materials that is for of cement, fine and coarse aggregate. The nominal concrete mixes without any specified performance were sufficient for small constructions. But with the passage of time, the demand of high rise building and use of non-conventional materialsin mix led the need of more sophisticated design based on strength.As a result, various mix deign methods came into existence. This research paper first reviews the existing system of concrete mix design. Then the research articles applying these methods were also reviewed to understand the limitations of and problems associated with these methods. Latter on, the scope of Artificial Neural Network (ANN) and Neuro Fuzzy System were explored as an alternative of design mix.

General Procedures

The concrete mixes can be classified into three types first is nominal mix, second is standard mix and third is design mix. The proportions of cement, fine aggregate and coarse aggregates were only specified in the past. These mix proportion on the basis of fixed cement-aggregate ratio are termed as nominal mixes. The nominal mix is the simplest method of proportioning. However, strength varies considerably due to the variation in the property of mix ingredients and under- or over-rich mixes are often encountered. To avoid this problem, the minimum compressive strength has been made the standard criterion of concrete and mixes based on minimum compressive strength are termed as “standard mixes”.

IS 456-2000 has designated M10, M15, M20, M25, M30, M35 and M40 as the standard grades of concrete. Mix proportions for M10, M15, M20 and M25 can have approximate ratios of cement, fine aggregate and coarse aggregate as (1:3:6), (1:2:4), (1:1.5:3) and (1:1:2) respectively.

The third type of mix that is “design mix” is the most rational approach with some unique characteristics of the mix ingredients as the necessary criteria. The design mix procedure gives most economic concrete with required appropriate properties in hand.

The Bureau of Indian Standards (BIS) has finalized the code IS 10262:2009 in December 2009 as the standard for concrete mix proportioning. Before this the old IS 10262:1982 was practiced for proportioning. Some of the commonly used mix designs methods are: British mix design method, United States Bureau of Reclamation (USBR) mix design practice and American Concrete Institute (ACI) mix design method.

CONCRETE WITH ADMIXTURES

Aggarwal et al. (2007) Reported that the use bottom fly ash up to 20% replacement of cement gain the compressive strength and varies from 56-65% at 7 days 75-85% at 28 days and varies between 86-90% at 56 days. The bottom ash concrete gains strength at a slower rate in the initial period and acquires strength at faster rate beyond 28 days. Bottom ash concrete attains splitting tensile strength in the range of 121-126% at 90days of splitting tensile strength of normal concrete at 28 days. To gain the workability commercially available superplasticizer, Aqueous Solution of modified polycarboxylate with density as 1.10 (approx.) and pH as 5.0 (approx.) was used.

Dhiyaneshwaran (2013) Concluded that the replacement of cement by fly ash up to 30% can enhance the mechanical properties like compressive, split and tensile strength of concrete. This replacement level is optimum for flowability mechanical properties and durability aspects. Beyond this replacement level reduction in strength was found.

Guneyisi and Gesoglu (2008) Concluded that the using fly ash in concrete slightly increase the flow diameter of mixtures. It affects the initial and final setting time of mixture and compressive strength of fly ash based concrete was more than that of reference concrete at 10% replacement level.

Hadchiti and Carrasquillo (1988) Investigated that, the Type A and Type B fly ashes at 0, 25, and 35 percent replacement of cement by volume were casted out and their test specimens at 50, 73, and 100°F and 50 and 100 percent relative humidity were cured. According to the two durability tests the abrasion resistance test and the resistance to deicing scaling test the strength is the most important factor influencing the abrasion resistance of concrete. With the level of different temperature the curing practices were found to influence the abrasion resistance of the concrete in that they affected the concrete strength.

Huang et al. (2013) Found that the class F fly ash with 4.6% and 7.8% loss on ignition with the rational mix design method for concrete with 20–80% fly ash replacement for cement and shows the significant improvement at late ages of 91 and 365 day in flexural and compressive strength.

James et al. (2011) Found that the use of fly ash as replacement of cement by mass with recycled aggregate shows the similar properties like fresh concrete (e.g., slump, unit weight, air content and temperature). Also in compressive strength, tensile strength and flexural a slight reduction was observed.

Jatale et al. (2013) Concluded that the density and air content of concrete mix are generally unaffected with the use of fly ash. Normally use of fly ash slightly retards the setting time of concrete, but it is compensated by reduction in the admixture dosage to maintain the same workability. The high range water reducing and retarding super plasticizer conforming to ASTM C-494, Type G was used. The base of admixture used in this study was sulphonated naphthalene formaldehyde and water reduction of admixture was around 20%.

Jones et al. (2016) Investigated that the Conditioned fly ash can be used up to 15% by mass as a fine aggregate substitute in concrete. It was observed that the long term storage of material can affect the workability of concrete, so superplasticizing admixture can be the solution. The fly improved cohesion, finishability and lower the bleeding. Increase in compressive strength was 10-15%, compared to the reference concrete.

Kanthi and Kavitha (2014) Found that the compressive strength and split tensile strength increases with increase in percentage of fly ash with replacement level of 40% in the concrete. The workability of fly ash concrete decrease when compare to referral concrete. Superplasticizer conplast SP430A1, 1% is used to maintain workability of fly ash

Kou et al. (2007) Reported that, the class F fly ash 0 and 25% addition of cement, the recycled aggregates 0%, 20%, 50% and 100% replacements of coarse aggregates with the water cement ratios of 0.55%, 0.50%, 0.45% and 0.40% were used to prepare concrete mixture. It was found the use of recycled aggregate had a negative effect on the mechanical properties of concrete but the addition of fly ash was able to mitigate this detrimental effect. Addition of fly ash reduced the drying shrinkage and enhanced the resistance to chloride ion penetration of concrete prepared with recycled aggregate and increases the compressive strength.

Mohammed et al. (2009) Investigated that the compressive strength of fly ash concrete with OPC concrete was equivalent to each other at the replacement level of 15% 30% and 45% of fly ash with OPC and the temperature was standard (20^0C).To gain the workability the superplasticizer used was polycarboxylate polymer (FosrocStructuro 11180).

Munteanu and Georgescu (2013) Presented that the gain of water cement ratio at the time preparation of concrete mixtures was obtained using a polycarboxylate type superplasticizer. The influence proportion fly ash, associated with superplasticizer, on the properties of fresh concrete was pointed out by using the slump method, for consistency determinations. The performances of hardened concretes, containing different proportions of fly ash, associated with polycarboxylic superplasticizer additive, were assessed by the mechanical strengths and the freeze - thaw resistance.

Naik and Singh (1997) Investigated that the replacement of fly ash with cement with the range of 0 to 100 percent by mass of cementitious medium greatly affected the initial setting time and final setting time. It is also observed that the delay in setting time generally occurred up to certain replacement level, after about 60 percent replacement rapid hardening occurred.

Nambiar and Ramamurthy (2007) Concluded that the foam concrete with fly ash as filler showed lesser dependency on pore parameters than with sand as filler. The strength-gel space ratio model for foam concrete with fly ash can be further improved by incorporating the effect of volume of hydration products of fly ash in the model.

Nath and Serkar (2011) Found that the Concrete mixtures with fly ash 30% and 40% can results the variation in compressive strength from 65 to 85MPa after 28 days of curing. Inclusion of fly ash reduced sorptivity and chloride ion permeation significantly at 28 days. Also the less drying shrinkage than the control concrete samples has shown by fly ash concrete samples after 28 days compressive strength tests.

Ondova (2012) Reported that the partial cement replacement with supplementary cementing materials i.e. fly ash can reduces greenhouse gas emission and prevents the depletion of natural resources. Testing of the interesting environmental parameter such as the hexavalent water-soluble chromium and its impact to health will be next aim of our study.

Selzler and Watson (2012) Reported that the to restrict stringent sulphur dioxide content use of fly ash as replacement of cement can be a solution and it also restrict the cost. It would also reduce the effect of sulphur and the ash contents of coal.

Shicong and Poon (2006) Investigated that the compressive strength of concrete was decreased as the recycled aggregate with fly ash contents increased. But up to 25% of fly ash replacement, the resistance to chloride ion penetration and pore diameters reduced.

Wang and Li (2007) Emphasised that the influence of fly ash content on the key micromechanics properties relevant to composite ductility. Concluded that the high volume faction of fly ash tends to reduce the polyvinyl alcohol (PVA) fiber/matrix interface bond and matrix toughness in favour of attaining high tensile strain capacity. The limit of cement substitution with ash is constrained by compressive strength development.

EMPIRICAL AND SEMI-EMPIRICAL PROCEDURES

Numerous analytical, empirical and semi-empirical solution exist to model concrete compressive strength.Some of them are discussed here.

Atis and Celik (2001) Reported that the use of High volume flies ash as replacement of cement can enhance the abrasion resistance with enhancement in flexural tensile strength of concrete. It was observed that the at 70% replacement of cement by fly ash, the abrasion resistance was greater than the 50% i.e. 4 to 5Mpa. Also the comparison was done between the relation of abrasion to compressive strength and abrasion to flexural tensile strength made in terms of R^2 of the linear regression and a stronger relation existed between abrasion and flexural tensile strength than that of abrasion to compressive strength of the concrete.

Chaulia and Das (2008) Investigated that the optimum requirement of fly ash in fly ash brick using Taguchi method of parameter design. The estimated optimum values of the process parameters are corresponding to water/binder ratio of 0.4, fly ash of 39%, coarse sand of 24%, and stone dust of 30%. The mean value of optimal strength is predicted as 166.22 kg.cm–2 with a tolerance of ± 10.97 kg.cm^{-2}. Confirmatory experimental result obtained for the optimum conditions is 160.17 kg.cm^{-2}.

Jailani et al (2009) Found that the using Taguchi’s orthogonal array with grey relational analysis for the density and hardness aspects of concrete, the values of the optimum process parameters are temperature 600°C, fly ash content 5 wt.% and compacting pressure 512 MPa respectively. ANOVA results also satisfies the significance of compacting pressure and the test showed optimum combinations satisfied the real requirement of sintering process of Al–Si alloy/fly ash composite.

Rao et al. (2011) Observed that the shear strength of the beams increases with an increase in longitudinal tensile steel ratio. Failure becomes more sudden and explosive for longitudinal tensile steel ratios 2.0% and 2.98% of control and 50% fly ash replacement beams. The experimental shear stress values were compared with control concrete, codes of practices and other empirical formulae. The shear strength of reinforced concrete beams without shear reinforcement made with high volume fly ash used as cement replacing material

LIMITATIONS OF THEORETICAL AND EMPIRICAL PROCEDURES

Review of above literature revealed that fly ash greatly affected the initial setting time and final setting time. The curing practices were found to influence the abrasion resistance of the concrete with the level of different temperature. The workability of concrete decreased with the increase in bottom ash content due to the increase in water demand. Though, water content was decreased due to addition of superplasticizer. The density of concrete was also decreased with the increase in bottom ash content due to the low specific gravity of bottom ash as compared to fine aggregates. In addition, long term storage of material (Fly ash) also affected the workability of concrete.All these problems increased the effort in casting. Repeated casting and destructive method of testing resulted in wastage of materials several folds. Consequently, Nondestructive testing method came into existence. Due to high cost of instruments, the nondestructive testing methods were also remained unpopular. To overcome these problems, soft computing method can be used as an alternative of design mix to minimize expenditure and laboratory effort involved in above mentioned methods.

ANN IN CONCRETE TECHNOLOGY

ANN are popular artificial intelligent method that can model the behavior of physical phenomenon. Neural networks are capable of realizing non-linear functions by learning from examples offered to them. There have been massive number of research on the use of soft computing in the field of concrete technology.

Basyigit et. Al., (2010) tested 7, 28 and 90 days compressive strength of heavyweight concrete made from baryte aggregates. ANN and fuzzy logic models were developed for compressive strength using cement rate, water rate, curing period and baryte rate as input parameters. Both models showed strong agreement with experimental results for compressive strength.

Bilim et. al., 2008 carried out an interesting laboratory work in which compressive strength of ground granulated blast furnace slag concrete was determined for 3, 7, 28, 90 and 360 days of curing periods. Three different cement contents, three different water cement ratios and four partially replaced percentages of blast furnace slag (BFS) were used to prepare and test 45 concrete samples. Later on ANN models were developed from which compressive strength was successfully predicted.

Chou et. al., (2010) determined the concrete compressive strength using ANN. Four different data mining tools were used apart from ANN. They used two machine learning methods that is ANN and support vector machine, one statistical model that is multiple regression, and two metaclassifier models that is multiple additive regression trees (MART) and bagging regression trees (BRT). They used cement content, fly ash, blast-furnace slag, water, superplasticizer, curing period, coarse and fine aggregate as the function of compressive strength of high performance concrete (HPC). However, their results indicated superiority of MART over other methods.

Diab et. al., 2014 developed ANN model to predict compressive strength loss, weight loss and expansion due to sulfate attack on concrete and its subsequent deterioration. They prepared design chart for loss in concrete compressive strength after certain period of time and concentration of sulfate for different concrete compositions. cement content, water cement ratio, C3A content and sulfate concentration were used as informative measure to develop this chart.

Eskandari et. al., (2016) developed ANN model for cement mortar. four this purpose cement grades, water cement ratio and sodium chloride solution content (NaCl) were used as input parameters. Increasing sodium chloride solution of 0%, 5% and 10% were used to test the compressive strength of cement mortar after 60 days.

Kostic and Vasovic (2014) carried out distinct experiment on concrete samples by exposing them to freezing and thawing cycles. Total 75 samples (subjected to varying water cement ratios) were tested for compressive strength on 7, 20 and 32 days of curing period. Later on ANN models were developed for permutation and combination of four different learning algorithm (namely Levenberg–Marquardt, scaled conjugate gradient, one-step secant algorithms and Broyden–Fletcher–Goldfarb–Shannon algorithm.) and three different nodes viz., 2, 6 and 9. ANN models successfully modeled concrete compressive strength using water cement ratio, freeze thaw cycles and curing period as the input parameters.

Nikko et. al., (2015) predicted concrete compressive strength from ANN with genetic algorithm (GA) based optimization of ANN parameters. ANN parameters like number of hidden layer, number of nodes and synaptic weights were optimized using GA. However, study undertaken on cylindrical samples instead of cubes. 3/4 sand, 3/8 sand, maximum sand size, cement content, gravel content, water-cement ratio and coefficient of soft sand parameters were considered as input parameters for modeling concrete compressive strength.

Tayfur et. al., (2013) developed fuzzy logic and ANN models from 60 sets of high strength concrete (HSC) data. Various percentage of Silica fume (SF) were used along with varying binder content. Compressive strength was modeled from fuzzy logic and ANN using binder content, silica fume content and curing period. Apart from modeling the extrapolation capability was also examined and was found satisfactory in both soft computing method

Uysal et. al., 2011 developed an empirical model for loss in compressive strength self-compacting concrete (SCC) with the help of ANN technique. The test considered the replacement of portland cement with six different mineral additive viz., fly ash, granulated blast furnace slag, zeolite, limestone powder, basalt powder and marble powder in various proportion. In addition, polypropylene fiber were mixed in some samples. The prepared were exposed to 200, 400, 600 and 800 °C temperature on 56th day of curing to understand the effect of temperature on concrete compressive strength.

NEURO-FUZZY SYSTEM

Another computational method used for the purpose of characterization is neuro-fuzzy technique, which integrates ANN with well known computing framework fuzzy inference system (FIS). Integration helps overcome the drawbacks of individual systems resulting in enhanced predictability. Unlike ANN, neuro-fuzzy covers narrow range of application in civil engineering since it is relatively a new concept not more than two decades old.

CONCLUSIONS

Review of conventional concrete and concrete with admixture indicated that wastage of materials and time is very high in design mix process. Workability is also compromised without having prior information on optimum percentage of admixtures. Nevertheless, limited number of cubes based on design mix is important to form the basis of soft computing modelling. ANN has been successfully applied in modelling compressive strength of concrete and scope of applying other soft computing method is still available. Non-destructive methods are very costly and they are beyond reach of ordinary persons. Hence, application and limitations of soft computing methods may be studied.

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