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NEURAL NETWORK ASSISTED CONCRETE MIX DESIGN WITH AND WITHOUT MINERAL ADMIXTURE

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ABSTRACT

This paper presents a novel method of predicting concrete mix parameters using design charts developed as per IS 10262:2009 codal provisions and these results are compared with Artificial Neural Network (ANN) predicted values for the concrete mixes, designed with and without partial replacement of cement with Fly ash. The concrete grades selected for preparing design charts are M20, M25, M30, M35, M40 and M45 and an application of ANN is made to design concrete mix for grades M40 and M45 with and without partial replacement of cement with Fly ash. 30% of Cement replacement with Fly ash is considered and the type of concrete for placing is pumpable concrete. Both the design charts and Neural network is used to predict the quantities of cement, Fly ash, water, water cement ratio, coarse aggregates, fine aggregates, chemical admixture & minimum cement content and maximum water cement ratio for various exposure conditions. Six inputs namely the grade of concrete, required slump, maximum size of aggregates, type of aggregates, zone of sand and exposure conditions are used for the neural net. A five layer neural network predicted values are in error range of 0.5% to 6%.

Key words: *ANN, Coarse aggregates, Concrete mix design, Fine aggregates, Fly ash, W/C.*

INTRODUCTION

The concrete mix design is a process of selecting the suitable ingredients of concrete and determining their most optimum proportions which would produce, as economically as possible, concrete that satisfies the job requirements, i.e. the concrete having a certain minimum compressive strength, the desired workability and durability. In addition to these requirements, the cement content in the mix should be as low as possible to achieve maximum economy (Valluru and Hayagriva, 1996 and Nataraja and Lelin Das, 2010). The proportioning of the ingredients of concrete is an important part of concrete technology as it ensures the quality and economy. The design charts are developed for the concrete grades M20, M25, M30, M35, M40 and M45. The work also includes the design of concrete mixes with the application of ANN. Initially mix design values are prepared using Microsoft Excel sheet and the same values are used for training in neural net. Among all the mix design values, 10% of the values are used for testing and the remaining values are used for training the neural network. The science of artificial neural networks made its first significant appearance in the 1940's. Researchers desiring to duplicate the functions of the human brain developed simple hardware (and later software) models of the biological neuron and its interconnection system. Jayaram *et al.,* (2005) published the first systematic study of neural networks. In later work they explored neural paradigms for pattern recognition despite translation and rotation. Ganju (1996) presented a method of design of trial mixes, enabling the direct computation of ingredients using formulae without the use of any charts or tables. Trial mix design examples given by Mindess and Young, Popovics, and Mehta have recalculated using spreadsheet and Microsoft Excel and compared calculated values with other methods based on ACI and British practice. Improvements to the proposed method are possible by including specification constraints, such as tables in spreadsheet. Spreadsheets are the preferred format for calculations as they can be used interactively. Rajendra Prasad (2001) presented a thesis entitled "Neural network assisted concrete mix design and prediction of suitability of the mix using Fuzzy Logic" in which he developed an integrated software which combines the Artificial Neural Network (ANN) and Fuzzy logic in order to design a concrete mix for a given set of input values and predict the suitability of the mix using fuzzy Logic. The grades of concretes considered were M30 and M35 and the mix design method adopted was as per IS:10262-1982. Rishi Garg (2003) presented the thesis entitled "Concrete mix design using artificial neural network" in which he obtained data of mix design experimentally and used the data for training and testing in ANN for concrete mix design.

ARTIFICIAL NEURAL NETWORK

Artificial Neural Network (ANN) is a network of artificial neurons, an information processing units, is inspired by the way in which human brain performs a particular task or function of interest. A neural network is a computational method inspired by studies of the brain and nervous systems in biological organism. Artificial Neural Network represents highly ideological mathematical models of our present understanding of such complex systems (Chapani *et al.,* 2011 and Pushpalatha and Anuradha, 2011). Artificial Neural Network models have the ability to learn and generalize the problems even when input data contain error or incomplete.

CONCRETE MIX DESIGN USING IS 10262:2009

The new code explains the mix proportioning procedure using a typical mix design problem. The new BIS is applicable to ordinary and standard concrete grades only. The durability requirements, limitations on w/c ratio and maximum cement contents are as per IS 456:2000. The requirements for selecting w/c ratio, water content and estimating coarse aggregate content and fine aggregate content have been modified accordingly. Considering that the air content in normal concrete (non air entrained concrete) is not of much significance, the consideration of air content has been deleted. The air content is not part of IS 456:2000 either.

COMPUTATIONAL WORK

The work involves manual preparation of mix design values as per IS 10262:2009 and IS:456:2000 using spreadsheet considering various sizes and types of coarse aggregates, various zones of sand, various slump values, different exposure conditions. Sizes of coarse aggregates include 10mm, 20mm, 40mm. Types of coarse aggregates include Angular aggregates, sub angular aggregates, gravel with crushed particles, rounded gravel. Different zones considered are zone1, zone2, zone3, zone4. Various slump values considered are 50mm, 75mm, 100mm, 125mm, 150mm. Different exposure conditions taken into account are mild, moderate, severe, very severe and extreme. Mix design is carried out for M20, M25, M30, M35, M40, M45 grades of concrete with and without mineral admixture (Fly ash). Water cement ratio is varied in successive mix designs with change in exposure conditions, type of aggregates, size of aggregates, slump values. But same set of w/c values are retained for all the four zones since W/C ratio don't change for different zones as per procedure mentioned in IS 10262:2009. Only proportion of fine aggregates to coarse aggregates will change with change in zone of sand. An increment of 0.005 is adopted for W/C for different exposure conditions. Design charts are prepared which enable concrete mix designing accurately without referring to any code book and without requiring any expertise in the field of concrete mix design. Among various grades of concretes M40 and M45 grades are trained in ANN. 10% of the mix design values are used for testing. Different topologies were tried with different error tolerance, learning parameter, number of hidden layers to reach at the optimum topology.

RESULTS AND DISCUSSION

Variation of W/C with type of coarse aggregates for different grades of concrete(without flyash replacement) is shown below. Here 1-Angular aggregates,2- Subangular aggregates, 3-Gravel with crushed particles, 4-rounded gravel, S.A- Size of aggregates. Mix design values obtained from spreadsheet are also used for preparation design charts. A set of design charts are shown for M40 grade concrete with slump 100mm, size of aggregate 20mm and zone I. Similar graphs can be developed for various slump, size of aggregates and different zones. The mix design procedure using those charts is illustrated below.

Step1: Referring to Fig. A, W/C ratio can be found out for the known aggregate type, slump, size of aggregates, Zone of sand and exposure condition. Here 1, 2, 3, 4, 5 refers to mild, moderate, severe, very severe and extreme exposure conditions respectively.

Step2: From the value of W/C ratio obtained from fig A, cement content required in kg/m^3 can be found out using fig B. For concrete without the partial replacement of fly ash, the value obtained from Fig.B is taken as cement content (or cementitious material content). In case of concrete with flyash replacement, the value obtained from Fig.B should be multiplied with the percentage replacement of flyash to get Flyash content. Flyash content(kg/ m^3)= Cement content(from Fig.B)*Percentage replacement of flyash.

Step 3: Water content can be found out by the values of cement content and W/C as below Water content (kg/m^3) =Cement content (kg/m^3)*(W/C).

Step4: Quantity of fine aggregates and coarse aggregates can be found out from the known value of cement content using fig C and fig D respectively.

RESULTS

Among the various topologies tried, the topology with error tolerance 0.001, learning parameter 0.1and layer sizes 6-50-50-50-8 and 6-50-50-8 gave the best results for mix design without mineral admixture. And for mix design with mineral admixture, the topology with error tolerance 0.001, learning parameter 0.1and layer sizes 6-50-50-50-9 and 6-50-50-9 gave the best results.

ANN program provides mix proportion values for M40&M45 with and without mineral admixtures with error as least as 0.5% for only 25000 cycles.

The Fig. E shows the error convergence for different topologies. Here the trial mix values developed for M40 concrete without fly ash are being used as an illustration Similar charts can be deveoped for M40(Cement+Fly ash), M45(Cement), M45(Cement+Fly ash), M40+M45 (Cement), M40+M45 (Cement +Fly ash).

CONCLUSIONS

Based on the computational experimental work and analysis of the results, the following conclusions can be drawn:

- The mix design values prepared using MS Excel sheet satisfies both theoretical and practical requirements; since all necessary codal provisions have been incorporated as per latest codes and to satisfy field conditions reasonable increment in minimum cement content has been made with the suggestions from experienced personnel in the field of concrete mix design. Also an increment of 0.005 in water cement ratio values with change in exposure conditions ensure more acceptable mix design values.
- Design charts prepared using values obtained from MS Excel sheet are highly useful to arrive at mix design values without the use of any codebooks and without any expertise in the field of concrete mix design as these charts are prepared using from the mix design values obtained as per latest revised code IS:10262-2009.
- From the ANN results it is observed that percentage error reaches below 1% for 10000 cycles itself with error tolerance 0.001 and learning parameter 0.1 for the topologies 6-50-50-8 and 6-50-50-50-8 for concrete without the partial replacement of fly ash.
- For concrete with the partial replacement of Fly ash, the percentage error reaches below 1% for 20000 cycles for concrete grades tested individually. For combined data (M40 &M45 together) the percentage error reaches below 1% at 15000 cycles. In both the cases the error tolerance and learning parameter were 0.001 and 0.1 respectively. This error convergence is observed in topologies 6-50-50-9 and 6-50-50-50-9.
- From the ANN test results we can conclude that there is remarkable reduction in the percentage of error with more lower error tolerance values (0.001) for the same learning parameter (0.1). However number of cycles also has the significant impact on the percentage error values. 4 layered and 5 layered topologies along with error tolerance 0.001 gave the optimum results.
- Since least percentage error values have been achieved in ANN, these results can be used directly in the laboratories and field which takes no time in arriving at mix design values.

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REFERENCE

Chapani H. V ., Pradhan, V. H and M. N. Mehta, 2011. Numerical solution of boussinesq equation arising in infiltration phenomenon using quadratic b-spline finite element method, *Global J. of Engineering and Applied Sciences,* 1(3): 147-150.

Ganju, T.N., *Spread sheeting mix designs*, Concrete International v 18, n 12 Dec. 1996, P 35-38.

Jayaram M.A., M.C.Nataraja, C.N.Ravikumar, *A Fuzzy-neuro hybrid system for design of light weight concrete mixes*, Proceedings of the International Conference on Advances in Concrete Composites and Structures, January 6-8,2005, Structural Engineering Research Center, Chennai, India, pp.787-796.

Nataraja M.C. and Lelin Das, "Concrete mix proportioning as per IS:10262-2009- Comparison with IS:10262-2009 and ACI 211.1-91", The Indian concrete journal September 2010.

Pushpalatha. N and B. Anuradha. 2011. Study of various methods of wireless ad-hoc sensor networks using multidimensional scaling for position estimation, *Global J. of Engineering and Applied Sciences,* 1(3): 76-81.

Rajendra Prasad D.S., *Neural network assisted concrete mix design and prediction of suitability of the mix using Fuzzy Logic*. MCA Thesis, IGNOU, New Delhi, 2002.

Rishi Garg, *Concrete Mix Design Using Artificial Neural Network*.

Valluru B.rao, Hayagriva V. Rao, Neural Networks and Fuzzy Logic using C++, BPB Publications, New Delhi,1996.

Table 1: Analysis of topology

Topology	Error Tolerance	Learning Parameter	Layers	Layer sizes
1	0.01	0.1	4	6-50-50-8
2	0.001	0.1	4	6-50-50-8
3	0.01	0.1	5	6-50-50-50-8
4	0.001	0.1	5	6-50-50-50-8

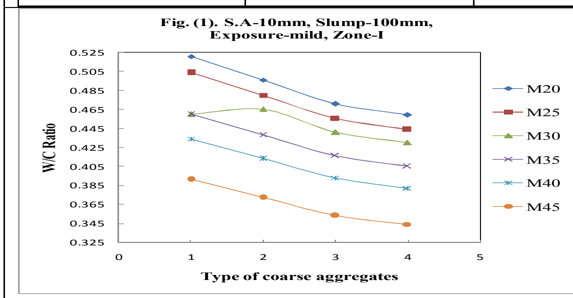

Fig. (1). S.A-10mm, Slump-100mm, Exposure-mild, Zone-I

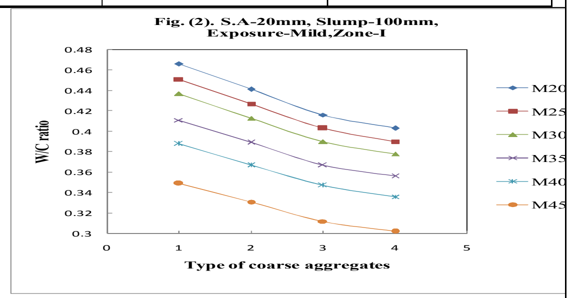

Fig. (2). S.A-20mm, Slump-100mm, Exposure-Mild,Zone-I

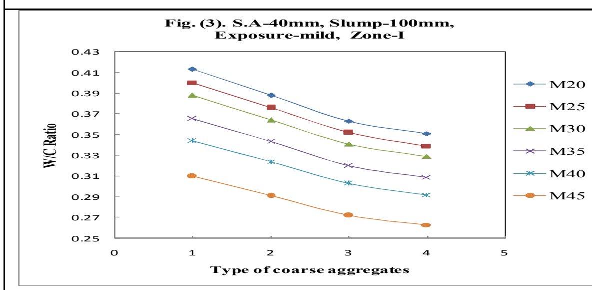

Fig. (3). S.A-40mm, Slump-100mm, Exposure-mild, Zone-I

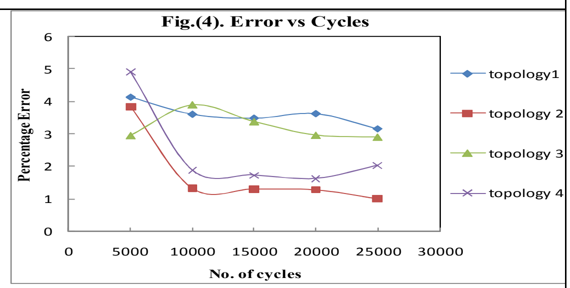

Fig.(4). Error vs Cycles

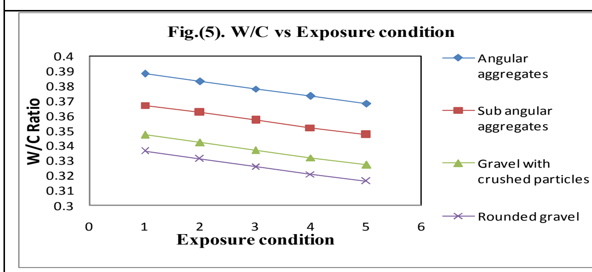

Fig.(5). W/C vs Exposure condition

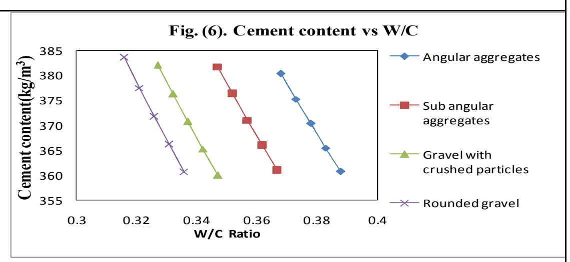

Fig. (6). Cement content vs W/C

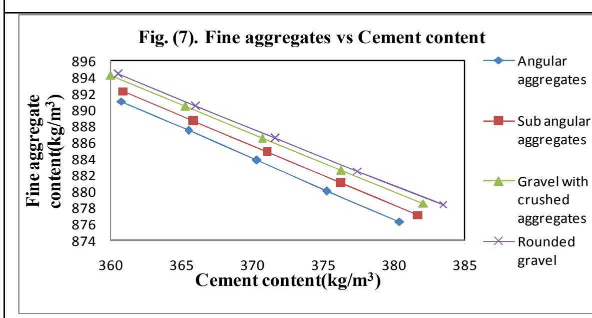

Fig. (7). Fine aggregates vs Cement content

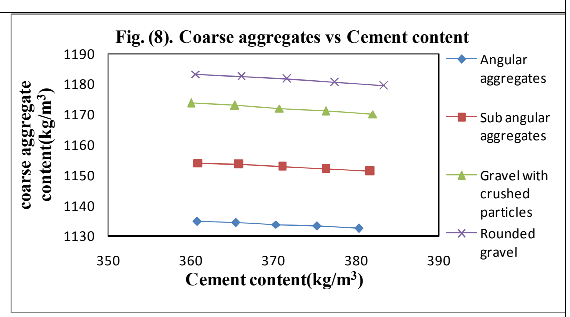

Fig. (8). Coarse aggregates vs Cement content

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