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Development of user Friendly Software Packages for Concrete Mix Design in Accordance to IS 10262:2009

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***Abstract*— Concrete mix proportioning is a crucial process of preparing concrete and in today's era it is not sufficient to make concrete with desired workability, durability and strength but also there in a need to develop eco-friendly concrete. So to achieve an eco-friendly and thrifty concrete mixes, fly ash plays a very important role. Usually mix design is worked out using IS 10262:2009 to calculate the material's quantity, which is a tedious job. In order to reduce time for mix design calculation and make variety of mixes, three mix design software packages have been developed for standard (without chemical admixtures), high strength concrete in which chemical admixtures can be used and last in which fly ash can be used as partial replacement of cement. The packages developed are powerful tools for concrete mix design especially for those design engineers who are not well acquainted with IS codes based calculations.**

Keywords— Concrete mix design, workability, durability, admixtures, software

I. INTRODUCTION

Concrete is an amalgamated substance produced artificially by hardened blend of cement, fine aggregate (sand), coarse aggregate and water in fixed ratios. It is authentically the backbone of construction industry due to its ability to set in any architecture in raw state and on consolidation it becomes sturdy rock-solid structure, attaining desired workability, durability and strength requirements. The properties of concrete in its fresh and hardened state depend on the performance of its constituents, so it becomes very important to find relevant relationship among its ingredients. Concrete mix design is the technique of determining the proportions of exquisite natured ingredients of concrete to accomplish satisfactory workability in fresh state, durability and strength in hardened state most thriftily. Fly ash is a waste generated by thermal power plants. Introducing fly ash to concrete chemically reacts with calcium hydroxide released due to the chemical reaction between cement and water to form additional cementitious products that enhances several properties of concrete. All fly ashes show evidence of cementitious properties to varying degrees depending on the chemical and physical properties of both the fly ash and cement. Fly ash helps in increasing the rate of hardening of concrete. In India, the commonly used mix design methods are: firstly, nominal concrete mix, are mixes of fixed cement-aggregate ratio which ensures adequate strength; secondly, trial and adjustment method is based on experimental approach and aims at producing a concrete mix which has minimum voids and hence, maximum density; thirdly, the IS guidelines for concrete mix proportioning in accordance to IS 10262:2009, targets on achieving the particular properties, i.e., workability of fresh concrete, and strength and durability requirements of hardened concrete at specific age keeping in mind the overall economy of the concrete.

Some of research papers related to this study have been discussed below:

Sahu & Mishra[18], (2015) developed concrete mix design for normal strength concrete and using it the presented functional formulas to determine parameters for high strength concrete using locally available materials. The paper concluded that concrete mix using the mathematical equation developed gave approximately satisfactory results for high strength concrete mixes. Wankhede & Fulari[19], (2014) presented that concrete containing fly ash is an ecofriendly material and has several environmental benefits. It saves cement and improves properties like durability and compressive strength. Deo[6], (2014) reviewed a number of papers to show positive as well as negative aspects of high volume fly ash concrete (HVFAC). He concluded that HVFAC is capable of increasing the durability and workability of concrete and also highlighted the need for individual codal provisions which specify the need of higher curing in order to eliminate the risk of lower strength of concrete at 28-days. Abdeldader, Saud, & El-Baden[1], (2013) found the Three Equations Method (Bolomeya Method) for concrete mix proportionong and observed that this method efficiently meets the compressive strength requirements. Gupta[8], (2013) demonstrated the applicability of artificial neural networks, a trained back propagation neural network model in concrete mix proportioning and predicting accurately the compressive strength of concrete. The research wrapped up with the fact that artificial neural network model saves time giving accurate results, curtails the labor and material bills and also the number of trials in field and laboratory and lastly is more user-friendly. Aginam, Umenwaliri, & Nwakire[3], (2013) investigated the variation of concrete compressive strength using four different methods for concrete mix design and proved that the 28-days compressive strength in all four methods exceeded the chareacteristic compressive strength by 50%. Onwuka, Okere, Ibearugbulem, & Onwuka[16], (2013) developed computer programmes coded in Visual Basic Language, based on simplex and modified regression theories for the prediction of every likely combinations of concrete mix proportions if desired compressive strength of concrete is specified. Conversely, they could predict the compressive strength of concrete if the mix proportion is specified. The programs developed are user friendly, easy and economical and yield quick and accurate results. Okere, Onwuka, Onwuka, & Arimanwa[15], (2013) formulated a mathematical model for the optimization of concrete cube strength using simplex method. The model generated all the probable mix proportions that capitulates the required concrete cube strength. It can also generate the concrete cube strength if mix proportions are given in addition to the optimum value. Statistical tests verified the satisfactoriness of the model and approved to the recognition of the model. Patil, Kale, & Suman[17], (2012) proved that the fly ash generated from Deep Nagar thermal power plant of Jalgaon district can be efficiently disposed by using it as a partial replacement of cement in making concrete. It saves cost of disposal of waste (fly ash) and the cost of cement incured in concrete is also lowered resulting in environmental friendly as well as economic concrete construction. Mohammed, Al-Gburi, Al-Ansari, Jonasson, Pusch, and Knutsson[13], (2012) designed a system for concrete mix proportioning using locally available materials having three main properties which are water, water-cement ratio and total aggregate-cement ratio. The system prognosticates concrete mix proportions, compressive strength and also decreases a large number of trial mixes and labor, cost and finally gives easy work schedule on the construction site. Aggarwal, Gupta, & Sachdeva[2], (2012) introduced green concrete which aims at making use of fly ash as a part replacement of cement so that the green house gas emission during concreting reduces to some extent, thereby saving the environment and making use of waste product which are a threat as they degrade the environment when disposed in landfills. Nataraja & Das[14], (2010) reviewed BIS and ACI codes for concrete mix proportionong and have shown through comparative studies the advances made in new IS code. Ahmad[4], (2007) explored the locally availabe materials for optimum design of concrete mixes based on laboratory trials. He found that the projected method is capable of selecting concrete mixes with desired workability, strength, and exposure condition at minimum cost. Yaqub & Bukhari[20], (2006) emphasized on using locally available materials in making high strength concrete mix, in least expenditure. They found that small size aggregates, fineness modulus and amount of cement play vital role in development of concrete compressive strength. Bargaheiser & Butalia[5], (2003) revealed that high volume fly ash has the ability to resist corrosion damages in concrete structures. Reduced permeability, lower water/cement ratio, decreased drying shrinkage/cracking, increased durability and serviceability are all benefits of fly ash concrete.

II. METHODOLOGY

This study has introduced very efficient MS. Excel spreadsheets for concrete mix proportioning for standard concrete mix (i.e., upto M25 grade of concrete) without using chemical admixture, high strength concrete mix (i.e., above M25 grade of concrete) using chemical admixtures, and concrete mix design using fly ash as partial replacement of cement according to the guidelines given in IS 10262:2009. The steps are described below:

1. In basic data sheet the user has to input the values of various parameters. Table 1 shows the list of input parameters for mix proportioning package.

Table 1: The basic data sheet for input parameters for concrete mix proportioning

S. No.	INPUT PARAMETERS	CONCRETE MIX FOR STANDARD STRENGTH	HIGH STRENGTH	FLY ASH (PARTIALLY)
1.	Grade of concrete	✓	✓	✓
2.	Grade of cement	✓	✓	✓
3.	Type of mineral admixture	×	×	✓
4.	Maximum nominal size of aggregates	✓	✓	✓
5.	Minimum cement content	✓	✓	✓
6.	Maximum water-cement ratio	✓	✓	✓
7.	Workability	✓	✓	✓
8.	Exposure conditions	✓	✓	✓
9.	Method of concrete placing	✓	✓	✓
10.	Degree of supervision	✓	✓	✓
11.	Type of aggregate	✓	✓	✓
12.	Maximum cement content	✓	✓	✓
13.	Chemical admixture type	×	✓	✓
14.	Entrained air percentage	✓	✓	✓
15.	Specific Gravity of cement	✓	✓	✓
16.	Chemical admixture quantity	×	✓	✓
17.	Specific Gravity of chemical admixture	×	✓	✓
18.	Specific Gravity of mineral admixture	×	×	✓
19.	Reduction in water content due to admixture	×	✓	✓
20.	Specific Gravity of Coarse aggregate	✓	✓	✓
21.	Specific Gravity of Fine aggregate	✓	✓	✓
22.	Water absorption of Coarse aggregate	✓	✓	✓
23.	Water absorption of Fine aggregate	✓	✓	✓
24.	Free (surface) moisture of	✓	✓	✓

	Coarse aggregate			
25.	Free (surface) moisture of Fine aggregate	✓	✓	✓
26.	Sieve analysis of Coarse aggregate	✓	✓	✓
27.	Sieve analysis of Fine aggregate	✓	✓	✓

2. The parameters to be input have been specified in their respective range as per codal provisions (which includes IS 383:1970, IS 10262:1982, IS 10262:2009 and IS 456:2000).
3. All the calculations are done using the input data and the outputs generated are shown in Table 2.

Table 2: Output of various Mix Design Packages

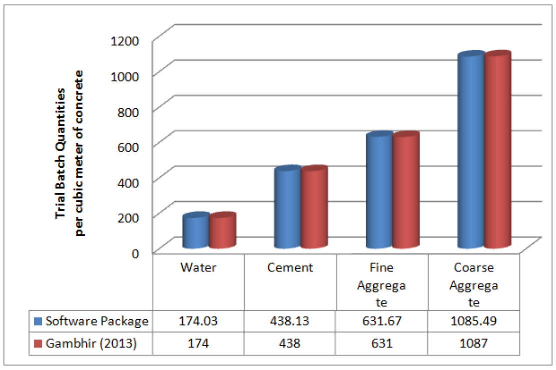
S. No.	OUTPUTS GENERATED	CONCRETE MIX PROPORTIONING FOR		
		STANDARD STRENGTH	HIGH STRENGTH	FLY ASH (PARTIALLY)
1.	Water	✓	✓	✓
2.	Cement	✓	✓	✓
3.	Fly Ash	×	×	✓
4.	Fine Aggregate	✓	✓	✓
5.	Coarse Aggregate	✓	✓	✓
6.	Fraction I	×	✓	×
7.	Fraction II	×	✓	×
8.	Admixture	×	✓	✓

III. APPLICATION OF MIX DESIGN PACKAGE

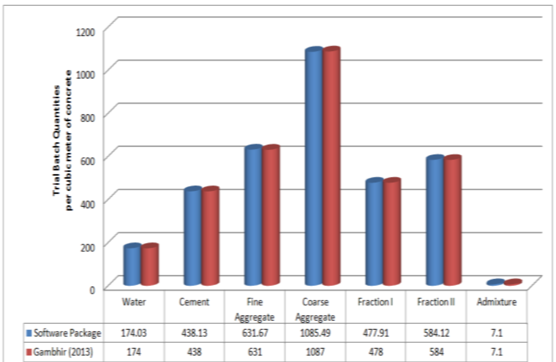
Concrete mix proportioning is a monotonous process which can be done by an experienced Civil Engineer only. So, in order to make design of concrete mix manageable by ordinary people, software packages have been developed so that a person who does not have an expertise in this field can also design concrete mix just by putting the input parameters in the basic data sheet. All the basic parameters can be varied and fed as per the site conditions and materials used, and the calculations will be carried out in accordance with IS 10262:2009 keeping in account both the upper and the lower limits wherever required. The concrete mix proportioning done by software package has been checked using Gambhir [7], (2013) and the results are given in Table 3 and its validation is shown in Figure 1.

Table 3: Validation of Results

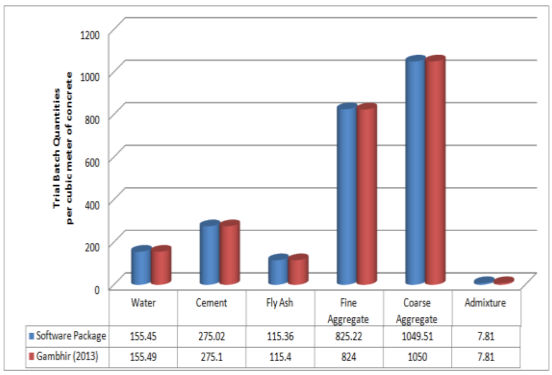
Grade of Concrete	Trial Batch Quantities per cubic meter of concrete	Concrete Mix Proportions		Percentage Error
		Software Package	Gambhir (2013)	
M25	Water	174.03	174	0.02
	Cement	438.13	438	0.03
	Fine Aggregate	631.67	631	0.11
	Coarse Aggregate	1085.49	1087	0.14
M35	Water	111.20	111.27	0.07
	Cement	354.80	355	0.06
	Fine Aggregate	882.77	883	0.03
	Coarse Aggregate	1062.03	1062	0.00
	Fraction I	477.91	478	0.02
	Fraction II	584.12	584	0.02
	Admixture	7.10	7.1	0.06
M40	Water	155.45	155.49	0.02
	Cement	275.02	275.1	0.03
	Fly Ash	115.36	115.4	0.04
	Fine Aggregate	825.22	824	0.15
	Coarse Aggregate	1049.51	1050	0.05
	Admixture	7.81	7.81	0.03



(a) M25



(b) M35



(c) M40

IV. CONCLUSION

The study has following conclusions:

1. The mix design packages are user friendly.
2. It saves lot of time, energy and material incurred in trial mixes.
3. Results are very accurate and have percentage error less than 0.2.
4. It includes all the provisions of IS codes and can design all grades of concrete specified in codes.
5. Fly ash concrete is environment friendly, cost effective and corrosion resistant construction material.

This study can be extended by making use of locally available and recycled materials as a partial replacement of cement by glass powder, blast furnace slag aggregates replacing coarse aggregates and copper or ferrous slag for fine aggregates which will result in a more economic concrete mix.

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