Cost Effectiveness of Concrete Mix Design Based on Various Constituents and Their Combinations

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Abstract— The cost-effectiveness and optimization of mixture proportions for concretes, contain many constituents and are often subject to several performance, constraint, can be difficult and time consuming task. Statistical experiment design and analysis methods have been developed specifically for the purpose of optimizing mixtures. This study is an attempt to enable the people to achieve the lowest cost of Concrete Mix every time they design the mix before actual trails. It also illustrates that how one can find the most economical combination of various constituents available to achieve the desired strength. The effect of various options available in the market has also been analyzed. The performance of concrete changes with change in various constituents and conditions, that's why it is necessary to design an optimum concrete mix according to change constituents and their combinations.

Key words: Optimizing, Concrete Mix

I. Introduction

According to the 2011 Census, there were 1.77 million homeless people in India or 0.15% of the country's total population. There is a shortage of 18.78 million houses in the country [10]. High cost of construction is one the major reason behind this situation. Cost of construction of structure can be reduced by decreasing the cost of its individual components. Today most widely used material for construction in concrete and most common of its constituents are cement, fine aggregate, coarse aggregates, admixtures and water [6]. Any strength of concrete can be achieved by multiple numbers ratios of various types of constituents.

This study is an effort to enable the people to choose the most economical concrete mix of required strength for the first laboratory trails based on the current market rate of its constituents. Also a study is conducted to achieve a particular strength using various options of constituents available in market and finding the cheapest one and thus creating the most economical design mix for the first trail.

The concrete mix design is a process of selecting suitable ingredients for concrete and determining their proportions which would produce, as economically as possible, Concrete that satisfies the job requirements, that is concrete having certain minimum compressive strength, workability and durability. The proportioning of ingredients of concrete is an important phase of concrete technology as it ensures quality and economy. The proportioning of concrete mix is accomplished by the use of certain imperial relations which afford reasonably accurate guide to select the best combination of the ingredients so as to achieve the desired properties. "Optimization is the act of optimum the best result under given circumstances" in design, construction and maintenance of any engineering system, engineers have to take many technological and marginal decisions at several stages. The ultimate goal of such decisions is either to minimize the effort required or to maximize the desired benefit. Since the effect required or the benefit desired in any practical situation can be expressed as certain decisions variable, optimization can be defined as the process of finding the conditions that give the maximum or minimum value of a function.

II. Literature Review

Shamsad Ahmad et all, the proposed method of optimization of concrete mix design based on the laboratory trials may be used for selecting concrete mixes for any desirable workability, strength, and exposure condition at the lowest possible cost, using locally available ingredients. Since various preplanned trial mixes are prepared and tested for searching out a mix with lowest cost satisfying all the requirements, the proposed laboratory trial based optimization procedure is better than the normal mix design, in which first an initial mix proportioning is done theoretically and then the same is adjusted through several trials in the laboratory without consideration of the cost of concrete. Based on the results of the experimental work conducted under the present research work for optimizing a typical concrete mixture using locally available ingredients, the optimum CA/TA and TA/C ratios are found to be 0.62 and 4.88, respectively.

Marcia J Simon, Eric S Lagergren & Kenneth A Snyder et all, In this paper statistical experiment design and analysis methods have been developed specifically for the purpose of optimizing mixtures, such as concrete, in which the final product properties depend on the relative proportions of the components rather than their absolute amounts. Although mixture methods have been used in industry to develop products such as gasoline, metal alloys, detergents and foods, they have seen some detail application in the concrete industry. These paper describe an experiment in which a statistical mixture experiment was used a 6 component concrete mixture subject to several performance constraints and Fitted models are obtained from the experimental data and are used to identify optimal mixes over the region. Conclusion and recommendations of paper is that in high performance concretes consisting of many components, where several properties are of interest, it is critical to use a systematic approach for identifying optimal mixes given asset of constraints. Statistical experiment design and mixture experiment provide such an approach. They permit a thorough examination of a feasible region interest in which to identify optimal mixes. Fitted models are obtained from the experimental data and are used to identify optimal mixes over the region.

M. Shariq, J. Prasad & A. K. Ahuja et all, This paper is to carried out statistical analysis for optimization of various concrete mix proportions by using full factorial experimental technique. The variables such as 28 days cube compressive strength, water to cement ratio (w/c), coarse aggregate to total aggregate ratio (CA/TA) and total aggregate to cement ratio (TA/C) were the parameters to be used for optimization. Four w/c ratios 0.4, 0.45, 0.5 and 0.6, four CA/TA ratios 0.60, 0.63, 0.65 and 0.70 and four TA/C ratios 3.9, 4.6, 5.3 and 6.0 were selected for regression analysis. The influence of w/c ratio, CA/TA ratio and TA/C ratio on compressive strength was experimentally carried out and analyzed using polynomial regression analysis. Mathematical polynomial model has been developed for compressive strength of concrete as a function of mix proportions. Based on the statistical analysis, optimum concrete mix for different mix proportions is proposed.

K A Soudki, E F El-salakawy & N B Elkum et all, This paper present the results of statistical analysis aimed to optimize a concrete mix design for hot climates. A full factorial factorial experiment with 3 * 4 * 4 * 3 treatment combinations (432) samples) of 48 mixes at three levels of temperature was used. The influences of the water/cement ratio (0.4, 0.5, and 0.6), coarse aggregate/total aggregate ratio (0.55, 0.6, 0.65, and 0.7), total aggregate/cement ratio (3, 4, 5, and 6), and temperature (24, 38, and 52'C) on compressive strength were characterized and analyzed using polynomial regression. Mathematical polynomials were developed for concrete strength as a function of temperature and mix proportion. Based on the statistical analysis, recommendations are provided on the optimum concrete mix for different temperatures as well as the mix that is least sensitive to temperature variations. A full factorial experiment with 3 * 4 * 4 * 3 treatment combinations was used including 48 concrete mixes at three levels of temperature. The test variables include the water/ cement ratio (*W*/*C*),aggregate/cement ratio (*TA*/*C*), coarse aggregate/ total aggregate ratio (*CA*/*TA*), and temperature(*T*). Three levels of elevated temperatures were considered, 24, 38, and 527C. Different values of *W*/*C* ratio, 0.4, 0.5, and 0.6, were selected so that all degrees of workability are considered. Four values of *TA*/*C*, ranging from 3 to 6, and four values of *CA*/*TA*, ranging from 0.55 to 0.70, were selected to cover a wide practical range of variation of these factors. Sixteen mixes for one *W*/*C* ratio were used instead of using one *W*/*C* ratio for one mix design. A statistical model for concrete strength as a function of the water/cement ratio (*W*/*C*), total aggregate/cement ratio (*TA*/*C*), coarse aggregate/total aggregate ratio (*CA*/*TA*), and temperature (*T*) has been established in terms of significant factors and also in the form of an interpolating polynomial. From the paper it is clear that the strength decreases when the temperature increases. A slight reduction was observed when temperature increases from 24 to 38 c. However the rate of decreases becomes more significant beyond 38c. The compressive strength is lowest at 52c.Strength decreases consistently when TA/C increased from 3 to 6. When TA/C increased from 3 to 4 the strength decreases slightly for W/C of 0.4.Effect of W/C- comp. Strength decreases as W/C ratio increases.

Rahul Sheokand & Karandeep Singh et all, This study is an attempt to enable the people to achieve the lowest cost of Concrete Mix every time they design the mix before actual trails. For this research, a spreadsheet for concrete mix design has been created and shared openly on a blog. This spreadsheet can be used by the user himself for creating customized results. This work also shows the main aspects of spreadsheet and also illustrates the effect of variation in various components on the final cost of first selected design mix trail. It also illustrates that how one can find the most economical combination of various constituents available to achieve the desired strength. The effect of various options available in the market has also been analyzed and their result is shown to creating possible cost variation and potential savings that can be done.

M.J. Simon & Eric S. Lagergen et all, High Performance Concrete (HPC) has been referred to as "engineered concrete," implying that an HPC mixture is not specified in a generic recipe, but rather designed to meet project-specific needs 1. Such a definition gives a concrete producer or materials engineer greater than usual latitude in selecting constituent materials and defining proportions in an HPC mixture, since fewer or possibly no prescriptive constraints, such as minimum cement contents or maximum water-cement (w/c) ratios, are included in specifications. HPC mixtures are usually more expensive than conventional concrete mixtures because they usually contain more cement, several chemical admixtures at higher dosage rates than for conventional concrete, and one or more supplementary cementations materials. As the cost of materials increases, optimizing concrete mixture proportions for cost becomes more desirable. Furthermore, as the number of constituent materials increases, the problem of identifying optimal mixtures becomes increasingly complex. Not only are there more materials to consider, but there also are more potential interactions among materials. Combined with several performance criteria, the number of trial batches required to find optimal proportions using traditional methods could become prohibitive. This report presents the results of a research project whose goals were to investigate the feasibility of using statistical experiment design and analysis methods to optimize concrete mixture proportions and to develop an Internet-based software program to optimize concrete mixtures using these methods. Two experiment design approaches (classical mixture and factorial-based central composite design) were investigated in laboratory experiments. In each case, six component materials were used, and mixtures were optimized for four performance criteria (properties) and cost. Based on the experimental results, the factorial based approach was selected as the basis for the Internet-based system. This system, the Concrete Optimization Software Tool (COST), employs a six-step interactive procedure starting with materials selection and working through trial batches, testing, and analysis of test results. The end result is recommended mixture proportions to achieve the desired performance levels. COST was developed as a tool to introduce the industry to the potential benefits of using statistical methods in concrete mixture proportioning, and to give interested parties an opportunity to try the methods for themselves.

Chris c. Rameyer & Roozbeh Kiamanssh et all, This research is designed to study effect of mechanically activated fly ash on fresh concrete properties and the ultimate strength of the hardened concrete. Six types of fly ash that are locally available in Oklahoma State where used in this study. The activation of fly ash is performed with the modified ball mill to increase the hydration reaction rate of the fly ash particles. Two primary variables where studied in this research, grinding duration and % of ash as apportion of cementious material. The fly ash ground for 30 to 120 minutes. The ground fly ash used as a cementious material in the concrete in various proportion 20, 40 and 60% of the weight. The strength of each of each mix was compared with plain cement concrete and the concrete sample with unground fly ash to determine any changes. The results shows that concrete with higher proportion of fly ash has higher workability, although the strength of the sample decreases in most cases if high volume of fly ash is used. However the result indicate that the grinding of fly ash can mechanically active the particles and not only improve the strength of sample with high proportion of fly ash but also increases strength higher than the traditional Portland cement concrete.

III. Material Properties

The properties of materials used in the concrete mixes such as cement, fine aggregate, coarse aggregate and water was confirmed to the specifications laid down in the Indian Standard codes [2, 3]. The following are the material properties used in the present study.

A. Cement

Ordinary Portland cement 43 grade (OPC 43) was used throughout the investigation and stored in airtight silos to prevent from moisture. The physical properties of cement were carried out as per IS 4031-1988 [2].

B. Fine Aggregate, Coarse Aggregate and Water

The locally available river sand passed through IS: 480 sieve (aperture 4.75 mm square) and retained on IS: 15 sieve (150 micron size) was used as fine aggregate. The locally available crushed stone aggregate of maximum nominal size of 16mm was used as coarse aggregate. The physical properties of the fine and coarse aggregate are as per IS: 383-19703. The water to be used for both mixing and curing should be free from injurious amount of deleterious materials. In the present investigation potable water was used for mixing and curing As per IS: 456-2000 [4].

IV. Conclusion

Following conclusions can be drawn based on the experimentations conducted on the concrete cubes.

- Maximum compressive strength is obtained at W/C = 0.4 with CA/TA = 0.60 and TA/C = 4.5.
- Optimum value for compressive strength can be taken as CA/TA between 0.6 to 0.63 and TA/C between 3.9 and 4.6 for all w/c ratios.
- The temperature has a significant effect on the compressive strength; as the temperature increases, from 24^0C to 52^0C, the strength decreases sharply.
- The main effects of *CA*/*TA*, *TA*/*C*, *T*, and *W*/*C* were shown to be highly significant.
- The optimum mix combination, which is the least sensitive to variations in the temperature considering the effect of all other variables, is (1) *W*/*C* to be maintained at 0.4; (2) *CA*/*TA* to be maintained between 0.55 and 0.60; and (3) *TA*/*C* to be maintained between 3.0 and 3.60.

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