International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 02 Issue: 04 | July-2015 www.irjet.net p-ISSN: 2395-0072

Comparative study of M35 and M40 grades of concrete by ACI, DOE, USBR and BIS methods of mix design using rounded aggregate

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Abstract - *As the demand of the concrete is increasing day by day and it has become the largest consumption material now a days. The constituents of the concrete are selected on the basis of availability, economic, feasibility of the work for which it is to be used. But sometimes the requirements of the material is altered (i.e. aggregate) due to various reasons, so in that case to maintain the particular standards, it is must to know the best method in terms of strength and economy. There are various methods for concrete designing which are being adopted by different countries i.e. Bureau of Indian standard method, British mix method, United States bureau of reclamation. So therefore, similarities and differences between the design mixes should be studied, as these will help in selecting the best method for different condition. These methods are mostly based on empirical relations, charts, graphs, and tables developed through extensive experiments and investigations using locally available materials.*

The main objective of present work is to compare different methods of concrete mix design for economy, locally available material and also for the properties of concrete with different aggregates.

Key Words: Mix design methods, types of aggregates, feasibility.

1. INTRODUCTION

In its simplest form, concrete is a mixture of paste and aggregates. The paste, composed of Portland cement and water, coats the surface of the fine and coarse aggregates. Through a chemical reaction called hydration, the paste hardens and gains strength to form the rock-like mass known as concrete. Within this process lies the key to a remarkable characteristic of concrete: it is plastic and malleable when freshly mixed, strong and durable when hardened. The key to achieving a strong, durable concrete rests in the careful selection and proportioning of its constituent ingredients. The properties and proportion of these ingredients plays a vital role in deciding the physical and chemical properties. Design mix methods helps in deciding the proportions, thus helps in promoting the best method. All the four methods (ACI, DOE, USBR and BIS) are proportionate ingredients according to standard procedure, empirical relations, charts, graphs, and tables developed through extensive experiments. By designing the same design mixes, these methods can be compared completely, in terms of strength and also deviation can be determined. From this process, best method will be projected and to carry out this procedure some methodology has to be applied, as the variation in the aggregate is included. So the interpretation between these samples has to be compared for various parameters i.e. strength, economy. The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labour. The variations in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. Some time site conditions often restrict the quality and quantity of ingredient materials. Concrete mix design offers a lot of flexibility on type of aggregates to be used in mix design. Mix design can give an economical solution based on the available materials if they meet the basic IS requirements. This can lead to saving in transportation costs from longer distances. The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure.

2. LITERATURE REVIEW

K. Baskaran et.al. (2013) [1] A comparative study on both ACI and DOE mix design methods, to select the initial mix proportion for the paving blocks was carried out. Quantities of constituents were estimated for characteristic compressive strengths (cylinder strength for ACI method and cube strength for DOE method), from 15 N/mm^2 to 50 N/mm^2. Based on the estimated proportions, trial mixes were cast and tested for compression at 7 and 28 days. When paving blocks are mix proportioned as per ACI mix design method, the achieved compressive strengths are higher than the compressive strength requirements of Sri Lankan Standard for paving blocks. Whereas a correlation being observed between the achieved compressive strength of paving blocks and the grade designation. Similarly, when paving blocks are mix

designed as per the DOE mix design method, the achieved compressive strengths satisfied the compressive strength requirements of Sri Lankan Standard for Classes 2, 3 and 4 roads.

G. Rishi, (2003) [2] In his research concrete mix design has been done by ACI design method. Locally available sands of fineness modulus 2.4 and 2.6 are used. Coarse aggregates of 10mm and 20mm are used in the ratio of 50:50 and 67:33 of total volume. For each mix proportion nine cubes of 150 mm size were casted in the laboratory and tested in Automatic Compression Testing Machine (ACTM) for 7,14and 28 days. He observed that as the water cement ratio increases, compressive strength decreases irrespective of the amount of cement, fineness modulus or the ratio of aggregate used. The strength of concrete by using 20 mm & 10 mm size aggregate in the ratio (67:33) is higher than the strength by using the ratio of 50:50. The effect is more pronounced at lower w/c ratio.

M.c. Nataraja et.al. (2010) [3] This paper examines the similarities and differences between the ACI and BIS concrete mix designs. The studies shows that design calculations for aggregates content, cement content, and water cement (w/c) ratio are different in these methods. In the ACI method, sand content is calculated after calculating coarse aggregate content, while in the old BIS method the process is other way around. However, in the new BIS, coarse aggregate calculation sequence follows the ACI method. The results show that old BIS code consumes more cement content when generalised w/c curve is used. It is due to the relatively low grade of cement available at that point of time in India and also due to the limited research data. The ACI mix design method results in a higher w/c ratio. Although in both the methods, the sand content decreases as the strength requirement increases, a lower sand content in the old BIS method differentiates it from the ACI mix design method. The IS 10262:2009 is an adoption of ACI method. It requires a designer to develop the w/c curve for the type of materials to be actually used to form the basis for the mix design rather than using any available curves. In the absence of such a data, the w/c ratio is to be assumed based on such available relationship as already established to start the process. Table 5 of IS 456:2000 can also be used to select the w/c ratio.8 It means one should be careful while selecting the initial w/c ratio, as it decides the calculated cement content. For example, for an M20 concrete mix, one can assume w/c as 0.5 or 0.55 to start with and accordingly cement content will vary. The scope of this study is to compare BIS and ACI recommended mix design guidelines. The calculation processes in the two codes are summarised by illustrating the design steps. A typical M20 mix design is presented using these methods.

Dr S.A. Deepa, (2014) [4] The comparative studies on different methods of design mix

1. The compressive strength in decreasing order are found as follows for the different methods IS10262-1982, IS 10262-2009, ACI method and DOE method.
2. It is seen that the IS 10262-1982 mix design method gives higher strength but also consumes more cement and has much higher factor of safety.
3. DOE method gives desire compressive strength of concrete in economical way, thus being the most economical method of design.
4. The fine aggregate content in ACI method is higher compared to new BIS method.
5. Coarse aggregate is substantially more with BIS method. Thus, ACI mix will lead to higher workability. Presumably, it would also contribute to increased strength as the voids are filled by fine aggregate.
6. In the case of BIS, fine aggregate content is reduced as the design strength requirement goes up. Therefore voids are likely to be higher for high strength concrete which may lead to decreased strength in such cases.
7. We conclude that in above four methods minimum cement content used in DOE methods and it gives desire compressive strength of concrete economical way for both the tests.

Prof. Dr. B. Ahmed Memon et.al. (2014) [5] has studied the recycled concrete aggregates used in the preparation of concrete for new construction. According to them, demolished concrete is collected from the Nawabshah city and processed to maximum of 1" size. Basic properties of these aggregates (water absorption and specific gravity) are evaluated and compared with those of natural aggregates to have good insight of the aggregates. 30 RC beams in five batches with # 4 bars as main bars and #2 bars as stirrups are prepared with 0%, 50%, 60%, 70% and 80% replacement of the natural coarse aggregates. The dimensions of all beams is kept 36"x6"x6" with 1:2:4 concrete mix and 0.45 - 0.55 water cement ratio. After curing for 28 days, beams are tested using central point load for flexural strength and cracking behaviour. The test result of this research work shows that minimum and maximum reduction in flexural strength in 12% and 26.6% respectively in comparison to beams made with 100% natural aggregates. Although the first crack appeared at lesser load than reference concrete but the behaviour and position of crack is same in both cases. Based on the result of this research work it is concluded that 88% strength can be achieved with 50% replacement of natural aggregates with demolished waste concrete aggregates. Therefore we can effectively be used in the areas of moderate or low load.

A.M. kannak et.al. (2013) [6] Studied the design of normal strength concrete mixtures that use recycled concrete aggregates as replacement for virgin natural aggregates. Three mix design methods utilizing

direct weight replacement, equivalent mortar replacement, and direct volume replacement are compared based on concrete workability, compressive strength, and elastic modulus. A total of 42 mixes were made with different aggregate replacement amounts. It was determined that the concrete workability changes significantly depending on the replacement method used, with the direct volume and equivalent mortar methods resulting in the best and worst workability, respectively. The compressive strength and elastic modulus of the mixes with recycled concrete aggregates showed little variation from concrete with natural aggregates.

R. Tugrul Erdem et.al. (2012) [7] studied the properties of concrete by using the crushed and rounded aggregate in concrete. These affect the properties like, workability, pumpability, placement, bleeding and segregation of fresh concrete. In hardened concrete, strength, density, permeability, pore amount, shrinkage and creep are substantially affected. Crushed aggregate is formed by the cracking of rocks in crushers, whereas the rounded aggregate is formed by erosion caused by the natural forces. Crushed aggregates reduce the workability of fresh concrete due to their irregular surfaces and friction effect. Round shaped aggregates require less water and cement usage for a specific workability and strength in normal strength concrete. On the other hand, angular and rough shaped aggregates shall be used in high strength concrete due to their superior internal friction and bonding provision.

Turan Özturan et.al. (1997) [8] studied the effect of the type of coarse aggregate on the compressive, flexural and splitting tensile strength on concrete produced at different strength levels. Concretes with 28 day target compressive strengths of 30, 60 and 90 MPa were produced using basalt, limestone and gravel coarse aggregates. The gravel aggregate concrete with 90 MPa target strength was also replicated by using a cement of higher strength, keeping the other parameters same. Twenty eight day test results have indicated that, in high strength concrete, basalt produced the highest, whereas gravel gave the lowest compressive strengths. Higher tensile strengths were obtained with crushed basalt and limestone compared to the gravel aggregate when used in high strength concrete.

Suryakanta (2014) [9] he studied that the Angular aggregate are superior to rounded aggregate from the following two points of view. Angular aggregate exhibit a better interlocking effect in concrete, which property makes it superior in concrete used for roads and pavements. The total surface area of rough textured angular aggregate is more than smooth rounded aggregate for the given volume. By having greater surface area, the angular aggregate may show higher bond strength than rounded aggregate. The higher surface area of angular aggregate with rough texture requires more water for a given workability than rounded aggregate. This means that for a given set of conditions from the point of view of water-cement ratio and consequent strength, rounded aggregate gives higher strength.

3. CONCLUSION

After reviewing the literature, it has been observed that most of the studies are focused on the two methods or comparison of two methods of design mix i.e. ACI, BIS methods. All four methods have not been compared simultaneously for strength and economy parameters. Most of the researchers have used crushed aggregates and recycled aggregates and very little work is done on using rounded aggregate. The comparison based on strength parameters have been carried out, but no comparison has been done on determining the deviation of the proportions of design mix apart from strength parameters and overall economy.

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