FUNCTIONALLY GRADED CONCRETE: AN EXPERIMENTAL ANALYSIS

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Abstract - *The ongoing problems of the era like price hiking of cement, increasing pollution, extreme environmental situations, advancement in construction industry etc are forcing structural engineers & researchers to work on appropriate concrete ingredient substitute for the sake of economy, strength, durability & sustainability. Material amalgamation technologies invigorating researchers the development of new class of concrete called as functionally graded concrete (FGC). This paper presents a review of the recent developments in areas of functionally graded materials (FGMs). A detailed study of literatures on FGM in construction industry is presented. The experimental work is aimed at analyzing characteristics and mechanical properties of functionally graded concrete. In this study FGC is designed with two concrete one is conventional M35 concrete in compression zone & another is M35 concrete with partial replacement of cement by dolomite powder in tension zone. FGC is designed for two interfaces. In this regards, the focus is made to understand the specific applications of FGMs in civil engineering. In the way of structural concrete evolution this work is a supplementary hand in stream of functionally graded concrete.*

***Key Words*: cement optimization, functionally graded concrete, mix design, two layered specimens, dolomite powder, mechanical properties**

1.INTRODUCTION

Modernizing of construction techniques have been increasing with focus on high strength, dense and uniform surface texture, more reliable quality, improved durability and faster construction on the behalf of economy. Recently as a result of two driving forces much advancement in concrete industry have took place as_the speed of construction and durability of concrete. Functionally graded concrete comprises of multi-phase material in a pre-determined profile with varying fractions of the constituents gradually, yielding an inhomogeneous microstructure having continuous graded properties. The functionally graded concept can be used to design more economical structural systems by varying concrete constituents (e.g. fibers, aggregate type or air voids) to provide extra flexibility resulting in more efficient designing of structural systems. Functional gradation of material properties makes it possible to optimally align the internal elements within, with the specified requirements. Accordingly, zones subject to high loads use high-strength materials whereas areas under comparatively small loads can substitute with porous materials. As construction industry is growing so fast, the concept of functional gradation to concrete or reinforced-concrete elements can be applied which opens up promising prospects particularly if the individual structural component is to meet inhomogeneous or varying requirements.

Composite materials have contributed to very large extent in solving complex challenges in many fields like aerospace, mechanical, defense, automobile, chemical, medical & structural industry. Till date lots of studies have been conducted on the behavior of functionally graded materials and the literature is very rich on this because of the wide areas of application of this novel material. A. Edwin et.al [1] has reviewed the recent developments in research of recent composite material called as functionally graded material.FCM is developed by varying the microstructure from one material to another material with a specific gradient. Michael Herrmann and Werner Sobek [2] worked on mass optimization of structural components supplementing experimental & analytical results. Numerical design methods were used to develop the gradation layout that served as a digital blueprint for components. Aylie Han et.al [3] conducted a study on the methodology for producing functionally graded concrete & evaluated the behavior of graded concrete experimentally as well numerically. Lots of analytical work has been done on functionally graded beams by lower as well higher grade beam theories but the work of experimental validation of such analytical models is available not so far. P.Nithya & M.P.Sureshkumar [4] performed experimental analysis on functionally graded concrete incorporating fly ash with partial replacement of cement in lower zone and normal concrete in upper zone. Compressive strength was the only parameter considered. As a result, interface level at 50 mm from bottom with 15% replacement is turned out to be the best combination while considerable decrease in compressive strength of concrete is seen above 15% replacement. Balamoorthi.K et.al [5] has carried out experimental studies on flexural behavior of reinforced concrete beam with grade variation in tension zone under the aim of reducing the material & cost of structure without losing strength & serviceability. RCC beam has been investigated on crack load & deflection curves criteria. Crack patterns were observed & analyzed. Conclusively graded reinforced concrete beam gave much better results than conventional one due to increase in initial crack & decrease in ultimate load and deflection. Bibek Pardhe Bhattarai and Niti Bhattarai [6] worked on the idea of providing hollow sections to the beam by incorporating PVC pipe in order to reduce the weight of the structure under which they studied flexural behavior of reinforced solid and hollow concrete beams. Check on flexural strength, deflection profile and crack pattern of the solid and hollow beam samples were taken with samples being solid & with longitudinal circular hollow section below neutral axis at calculated depth. Hengbao Zhao et.al [7] explored the ultimate bearing capacity of thick walled cylinder assimilating functional gradation of concrete. Graded characteristic were achieved by certain variations of the compressive strength and elastic modulus.

Present experimental analysis is mainly aimed to analyze effect of various layers of specific material placed at optimal location and thickness on overall performance of concrete. Also to study the effect of partial replacement of cement with dolomite powder on concrete characteristics in the chase of cost effective concrete constituent in order to achieve a high performance concrete sustainable to extreme environmental conditions. Many studies have been done on concrete with partial replacement of cement with dolomite powder. Olesia Mikhailova et.al [8] presented the details of the investigation carried out on effect of dolomite limestone powder on the compressive strength of concrete also Athulya Sugathan [9] has examined the possibility of using dolomite powder as a partial replacement material to cement as dolomite powder has some similar characteristics that of cement.

2.EXPERIMENTAL PROGRAMME

Conventional M35 grade concrete was designed according to IS10262-2000. Two concrete mixes one conventional M35 concrete as Normal concrete & other Lean Concrete with partial replacement of cement with dolomite by 20, 30 & 40 % was prepared. For each specimen Lean concrete is provided in lower zone followed by Normal concrete to get desire geometry. The Casting of specimen were done as- Cube of size 150×150×150 mm with change of interface at 75 mm and 125mm, cylinder of size 150×300 mm with change of interface at 150 mm and 200 mm and beam of sizes 150×150×700 mm with change of interface at 75 mm and 125mm.

2.1 CONCRETE MIX DESIGN

For this study M35 grade concrete is designed as per IS 10262-2009. The mix proportion is given in table No.1

Table -1: Mix Proportion for M35 Grade Concrete

Water	Cement	Fine aggregate	Coarse Aggregate
186 lit	443kg/m^3	675 kg/m^3	1055 kg/m^3
0.42	1	1.52	2.38

2.2 SPECIMEN DETAIL

For the experimental work four combinations of mixes were used. Out of which one is controlled concrete mix another three with addition of dolomite powder in certain percentage (20%, 30%, and 40%) by cement replacement. For controlled mix 9 cube, 9 beam & 9 cylinders are casted while for other combinations 18 cube, 18 beam & 18 cylinders were casted with two interface levels to chase the aim of graded concrete.

Table -2: Details of Different Type of Mix

Sr. No.	Mix Identi-fication	%OF Dolomite added	% Of Cement	Height of Lean concrete from the bottom (mm)
1.	M0	0	100	00
2.	M1	20	80	00
3.	M2	30	70	00
4.	M3	40	60	00
5.	M4	20	80	75
6.	M5	30	70	75
7.	M6	40	60	75
8.	M7	20	80	125
9.	M8	30	70	125
10.	M9	40	60	125
11.	M10	20	80	150
12.	M11	30	70	150
13.	M12	40	60	150
14.	M13	20	80	200
15.	M14	30	70	200
16.	M15	40	60	200

3.RESULTS AND DISCUSSION

3.1 Workability Test

To measure the workability of fresh concrete this test is carried out according to IS 7320-197. Properties of fresh concrete are presented in chart.1.Slump value of concrete found to be decrease with increase in dolomite content from 20 to 40 %. So, concrete was found to be less workable due to high grade of concrete, low water content, absence of any plasticizer, addition of dolomite.

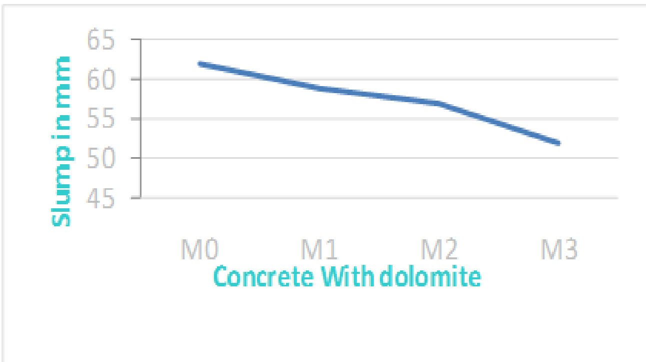

Chart -1: **Workability of Concrete**

3.2 Compressive Strength Test

The test is carried out according to IS: 516-1959 & IS: 10086-1982. For this concrete cube of size 150 mm x 150 mm x 150 mm is used.chart.2 shows compressive strengths test results. It is observed that M5 mix which is having 30% dolomite with interface at 75 mm gives the maximum compressive stress of 46.22 MPa, comparative study shows the gain of strength is slow due to addition of dolomite.

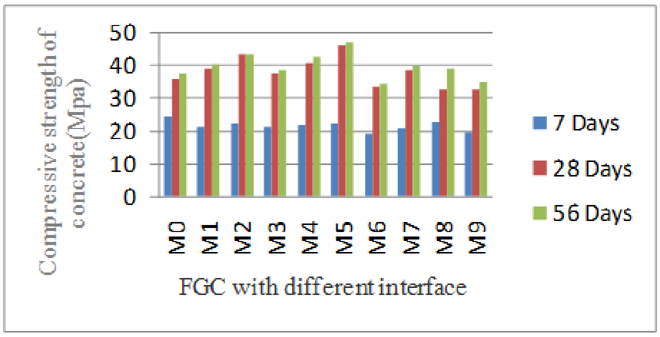

Chart -2: Compressive Strength of FGC

3.3 Flexural Strength Test

According to IS: 516-1959 the standard beam specimen of size 150mm x 150mm x 900mm were tested under Universal testing machine (UTM). The test results for flexure are shown in chart.3. Flexural Strength for M4 concrete mix found to have higher value than controlled concrete.

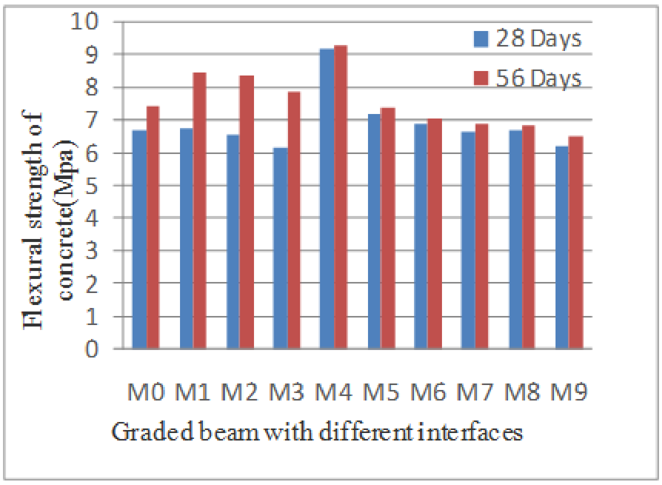

Chart -3: Flexural Strength of Functionally Graded Beam

3.4 Split Tensile Strength Test

Tensile strength of concrete is determined according to (IS: 5816-1999) for this concrete cylinder specimen of size 150mm diameter and 300 mm length are used. This test is conducted on compression testing machine.chart.4 gives split tensile strength test results from which It is noticed that addition of dolomite slows down the process of strength gain. M10 mix gives good performance than the M0 mix for Spilt tensile strength. The rate of increasing strength is slow compared to the compressive strength but, reduction in strength is smaller due to dolomite in concrete.

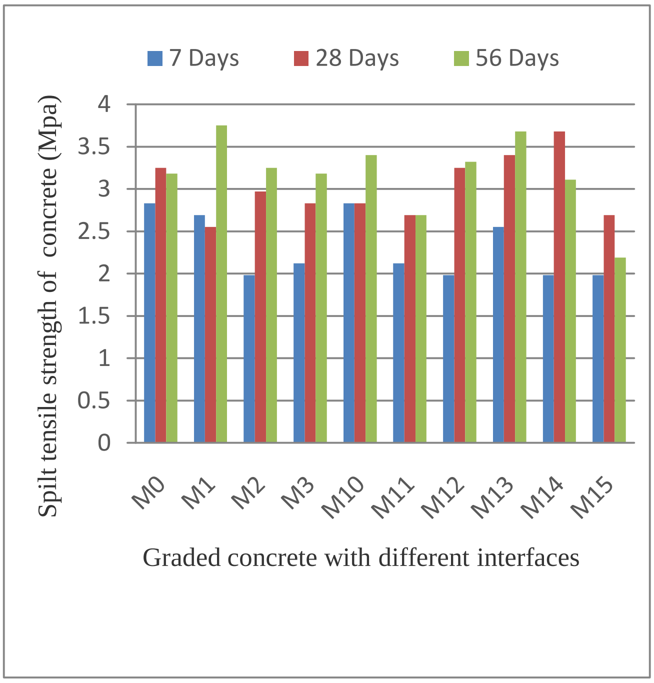

Chart -4: Split Tensile Strength of Graded Concrete

3. CONCLUSION

From literature review and present study it is concluded that

1. FGC serves optimum to requirements.
2. Locally available materials can serve best to achieve desire functionality and properties in high strength concrete.
3. It is possible to have any specific characteristics in structural elements at severe conditions when basic of gradation is adopted.
4. Graded concrete proved as most effective and economical alternative.
5. Demand of increasing specifications of concrete may fulfill by graded design effectively.

ACKNOWLEDGEMENT

It is matter of great pleasure for me to publish this paper on “Functionally Graded Concret: An Experimental Analysis”. I am thankful to my project guide Prof. P.A Nikam, HOD R.S Kale & PG-Co-ordinator Prof. S.A Karale of S.N.D College Of Engineering, Yeola, for their constant encouragement, inspiration and able guidance. I take this opportunity to express my deep sense of gratitude towards those, who have helped me in various ways for this work. At the last but not the least, I am thankful to my parents, who had encouraged & inspired me with their blessings.

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