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"Improvement in Shear Strength of R.C. Deep Beams with Addition of Steel Fiber, Metakaolin and Marble Dust in Concrete"

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Abstract **-** Conventional concrete deep beams are weak in tension, which results in low tensile strength, shear strength and brittle failure of these beams. In order to overcome these problems, the present work focuses on use of metakaolin, marble dust and steel fibers in concrete mix. Metakaolin can reduce cement content. Metakaolin, marble dust and fibers play an important role in improvement of concrete's flexural tensile strength, impact resistance and split tensile of concrete. This combination is used to improve shear strength of deep beams, in the present study. Partial replacement of cement has been made from 3% to 20% with Metakaolin and Marble dust and 0.5% to 2% of steel fibers are added by volume of concrete. Experimental results of M20 grade of concrete are presented. Test results show that combination of these materials boosts split tensile strength, impact strength and shear strength of R.C.deep beams.

Keywords: Steel fiber(SF), fiber reinforced concrete, metakaolin (MK), marble dust(MD), shear strength.

I. Introduction-

In construction industry, use of cement and steel are increasing day by day as well as cost is also increasing. So to reduce the consumption of cement and steel, a partial replacement of cement with metakaolin and marble dust is done. Additionally steel fibers are added to improve split tensile strength, shear strength of concrete etc. Metakaolin is a valuable admixture for concrete and or cement applications. It is a calcined clay and easily available in Gujrat and Maharashtra. It is dehydroxylated form of the clay mineral kaolinite stone having higher percentage of kaolinite known as China clay or kaolin was traditionally used in the metakaolin of porcelain. The particle size of metakaolin is smaller than cement particles. Usually 8% - 20% (by weight) of Portland cement replaced by metakaolin. Metakaolin improves density and boosts compressive strength of concrete mixes.

Steel fibers are small discrete reinforcing material from steel, effective in increasing toughness, shock resistance and excellent permeability and frost resistance. It has the ability to improve tensile strength, shock resistance, ductility of concrete and adds to crack resistance in concrete.

Marble has been commonly used as a building material since the ancient times. Consequently, Marble waste as a by-product, is a very important material which requires adequate environmental disposal effort. The result is that about 25% of the original marble mass is lost in the form of dust. Leaving these waste materials to the environment directly can cause environmental problems such as increase in the soil alkalinity, affects the plants, affects the human body etc. Marble dust, a solid waste material generated from the marble processing can be used either as a filler material in cement or fine aggregates while preparing concrete. Marble powder can be used as an admixture in concrete, so that strength of the concrete can be increased the production of cheaper and more durable concrete using this waste can help the civil engineer fraternity to ensure economy in the infrastructural project and redress the environmental degradation problem.

II. Objective of study

Based on research gaps identified objectives of the study are as follows.

1. Experimental Study on improvement in strength properties of concrete using steel fibers, metabkoline and marble dust in predefined proportions

2. Arriving at optimum mix of concrete reinforced with steel fibers including metakoline and marble dust from workability and strength point of view.

3. Experimental evaluation of improvement in shear strength of deep beams with steel fibers, metakoline and marble dust

III. Experimental program

A. Materials and mix proportions: Concrete mix M20 was designed using 43 Gr. Ordinary Portland cement, Natural River sand and 20 mm crushed aggregates. Mix proportions obtained for M20 concrete were 1:1.9:2.8 with a water-cement ratio of 0.50. Fe 500 steel bars were used as flexural reinforcement in both conventional & fiber reinforced deep beams --------------.

B. Study of properties of concrete: The concrete was cast exactly as per the requirements of the concrete mix design. During mixing the balling-up of fibres were prevented by feeding the fibres into the mix in small quantities at a time. Standard cubes of size 150 x 150 x 150 mm and standard cylinders of 150 mm x 300 mm & deep beam of 150 x 150 x 700 in length were cast from each mix for assessing the quality of the concrete cast.

C. Workability:

Fibre-reinforced concrete does not respond well to slump test due to stiffness rendered by metallic fibres used in it. Therefore, the compaction factor (CF) test is preferred & accordingly workability was measured in terms of compaction factor . It is observed that the workability of concrete decreases with increasing per cent of fibre content. It is further observed that mixes up to 1 per cent steel fibre satisfy the medium workability limit (C.F.>0.85). Whereas, steel fibre mixes beyond 1% are found non-workable.

Table 1.1 Properties of steel fibers

Parameters	Results
Length	60 mm
Diameter (mm)	0.75 mm
Aspect ratio	80
Specific gravity	7.85
Water absorption	0.0
Density in kg/m3	7850

D. Compressive strength: It is observed that, the compressive strength of the M20 Steel fibers include with MK& MD beam increases mildly with the increasing percentage of fibre content. The maximum increase in compressive strength observed in comparison with conventional concrete is 22.48% at a combination of 1 % SF + 15% MK and 10% MD.

E. Split tensile strength: It is observed that due to inclusion of fibres in concrete, significant improvement in the split tensile strength of concrete takes place.for M20, the split tensile strength of modified concrete has increased by 34.01 %,

F .Design of deep beams It is well known that concrete is very good in resisting compressive forces but it is found to be the week against and tensile forces. it has the qualities of flexibility and ability to redistribute stresses, but it possesses a limited ductility and a very little resistance to cracking. the addition of fibres to concrete further improves its properties like shear strength, tensile strength, ductility ,resistance to cracking etc in this experimental investigation the physical properties such as aspect ratios, specific gravity, water absorption, density and ultimate strength are studied.

For casting of deep beams to maximize workability, shear strength we have done experiment on cubes for 14 days and 28 days. In that we have studied workability and maximum strength observed from 1 % of Steel fibre, 15% of metakaolin and 10% of marble dust.

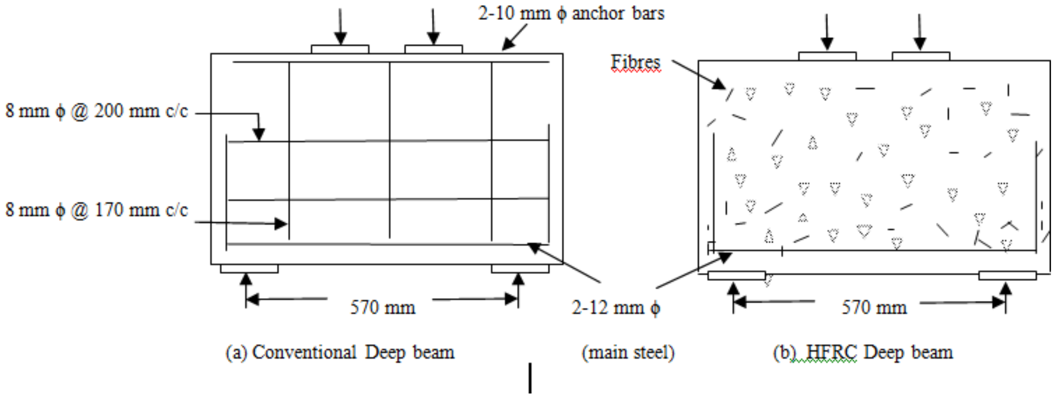

Fig.1: Reinforcement details of deep beams.

G. Conventional Deep Beams

The cracking patterns of conventional deep beams observed during the present experimentation. In Conventional R.C. deep beams, cracks start close to the support near the beam's bottom and move diagonally upwards toward the loading point with increasing load. As the loading increases, the crack moves toward centre of the shear span. A further rise in loading causes 2-3 cracks to combine, and at the moment of ultimate loading, these cracks become continuous and deepen even further. This results in breaking of the beam along this diagonal and brittle kind of shear failure of deep beams occurs. Spalling of concrete was witnessed at some places. All the beams failed in the brittle mode of shear failure.

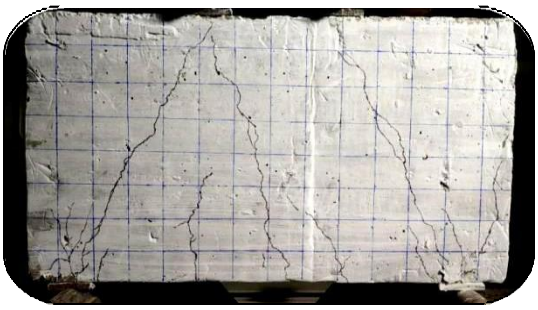

Fig 2.Conventional deep beam crack pattern

I. Conventional & Fiber Reinforced Concrete Deep Beams

the FRC deep beam. The addition of fibers to the concrete, which helps to control the crack width.

The cracking pattern of FRC deep beams observed during the experimentation. In FRC deep beams, the first hair crack that appeared was inclined and situated close to the midpoint of shear span's along the diagonal joining loading point to support. The second crack began with the rising loading in the same direction as the first crack, but after a brief intermittent gap from the earlier crack. There was a slow rate of cracking observed in

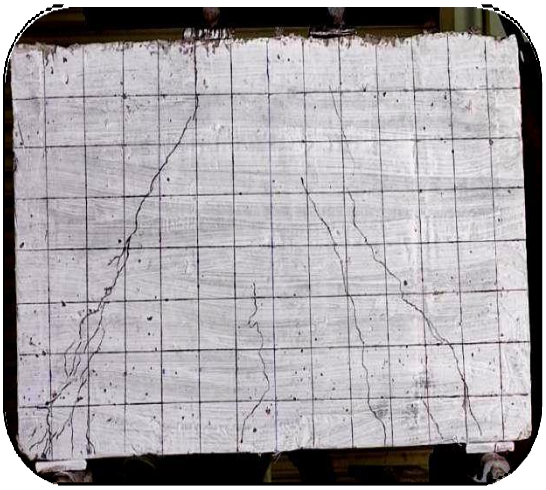

Fig 3. Modified deep beam crack pattern

Table 1.2 Results for 28 days of Curing of Flexural Strength of Slender Beams

Types of concrete	Sample Name	Max. Load (kN)	Max. Strengths (N/mm^2)	Avg. Flexural Strengths (N/mm^2)	Percentage improvement in modified concrete than conventional
Conventional concrete	CB1	18	5.63	6.10	---
	CB2	20	6.22		
	CB3	21	6.46		
Modified concrete	MB1	26.5	8.40	8.13	33.27%
	MB2	26	8.21		
	MB3	25	7.78		

J .Testing of deep beams

Deep beam was tested after 28 days curing under two point loading. Markings were made on deep beam to indicate where strain, deflection, and other measurements were to be taken. M.S. bearing plates 150 mm long,

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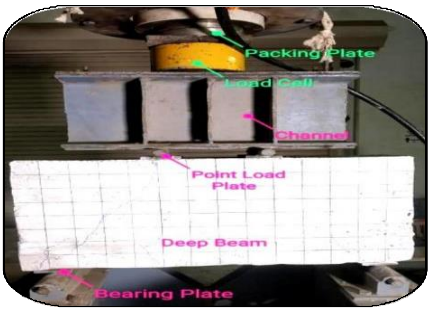
Fig.3 Testing of deep beams



70 mm wide, and 5 mm thick were used at loading points and supports to keep the bearing stress within allowable limits. In accordance with I.S. 516 (2021) recommendations, the loading rate was kept constant at 4 kN/min. The applied load and resulting deformations, as well as the initial crack load and Ultimate load, were recorded for each specimen. From the initial crack inspection, the first crack load was carefully recorded for each beam. Then loading was continued and the ultimate load was recorded. Strains were discovered in the shear and flexural regions. The central deflection and crack widths of the beam specimen were recorded up to the point of failure.

The cracking pattern of FRC deep beams observed during the experimentation. In FRC deep beams, the first hair crack that appeared was inclined and situated close to the midpoint of shear span's along the diagonal joining loading point to support. The second crack began with the rising loading in the same direction as the first crack, but after a brief intermittent gap from the earlier crack. There was a slow rate of cracking observed in the FRC deep beam. The addition of fibers to the concrete, which helps to control the crack width. Additionally, no concrete spalling was noted, fibers play a key role in preventing spalling.

All the specimens failed in shear. The ductile nature of concrete was revealed as a result of improved post-cracking behaviour.

Types of deep beam	Sample number	Percentage of steel Fiber	Percentage of admixture		First crack load in kN	Avg. Improvement in first crack load in modified concrete w.r.t. conventional beam in %	Max. load in kN	Max. shear strength in N/mm2	Avg. Improvement in Max.shear strength w.r.t. conventional beam in %	Deflection at designed load of 225 kN	Deflection at first crack load (mm)	Maximum Deflection (mm)
			MK	MD								
Conventional	Sample 1	---	---	---	350		550	5.23	--	1.35	2.15	2.62
	Sample 2	---	---	---			550	5.23	--	1.32	2.15	2.82
	Sample 3	---	---	---			550	5.23	--	1.32	2.17	2.9
Modified	Sample 1	0.5	5	5	400	14.29	900	8.57	63.64	1.21	2.13	3.95
	Sample 2	0.75	10	10	450	28.57	920	8.76	67.27	1.2	2.12	4.23
	Sample 3	1	15	10	550	57.14	950	9.04	72.73	1.2	2.12	4.23

Table 1.3 Shear strength test on conventional and modified R.C.Deep beams

Conclusions:

1. Concrete with inclusion of 1% steel fiber(SF) by volume of concrete, 15% metakaoline (MK) by weight of cement and 10% marble dust (MD) by weight of cement is observed to be an optimum mix from workability and strength point of view.

2. Improvement in compressive strength of optimum mix of concrete with .SF,MK and MD is observed to be 22.48 % in comparison with conventional concrete.

3. Improvement in split tensile strength of optimum mix of concrete with .SF,MK and MD is observed to be 34.01 % in comparison with conventional concrete.

4. Compared to conventional concrete, the optimum mix of concrete with SF, MK, and MD has a 33.27% increase in flexural strength.

5.The first crack strength and maximum shear strength of RC deep beams cast using an optimum mix with addition of 1% of steel fiber by volume of concrete,15% of metakaoline and 10% of marble dust by weight of cement are higher by 57.14% and 72.73 % respectively than the conventional concrete deep beams.

6. Conventional shear reinforcement in deep beams can be completely replaced by using the concrete with optimum mix obtained in the present investigation and mentioned above.

References:

1. Galhate, S. S., Sawant, R. M., Gaikwad, J. R., & Phulpagar, S. R. Experimental Investigation on Metakaolin, Glass Powder and Marble Dust in Concrete as Partial Replacement of Cement.
2. Ding, J. T., & Li, Z. (2002). Effects of metakaolin and silica fume on properties of concrete. *Materials Journal*, *99*(4), 393-398
3. Narmatha, M., & Felixkala, T. (2016). Meta kaolin–the best material for replacement of cement in concrete. *IOSR Journal of Mechanical and Civil Engineering*, *13*(4), 66-71
4. Kulkarni, S. K., Kekade, G. A., & Halkude, S. A. (2017). Experimental study on hybrid fiber reinforced concrete deep beams. *International Journal of Civil Engineering*, *4*(2), 38-44.
5. Khamchin Moghaddam, F., Sri Ravindrarajah, R., & Sirivivatnanon, V. (2015, September). Properties of Metakaolin Concrete–A Review. In *International Conference on Sustainable Structural Concrete*.
6. Asadi, S. S., Raju, M. V., Kumar, B. H., Prakash, P. A., & Mehta, D. (2017). A Critical Evaluation On Pozzolonic Properties of Selected Materials and Their Replacement in Cement. *International Journal of Civil Engineering and Technology*, *8*(1).
7. Nikhila, C. J., & Kumar, J. C. (2015). Partial replacement of cement with metakaolin in high strength concrete. *Int. J. Engg. Res. & Sci. & Tech*, *4*(4), 336-349Aiswarya, S., Prince Arulraj, G., & Dilip, C. (2013). A review on use of metakaolin in concrete. *Engineering Science and Technology*, *3*(3), 592-597.
8. Bentur, A., & Mindess, S. (2006). *Fibre reinforced cementitious composites*. Crc Press.