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Research paper

Numerical Investigation on Flexural Beams Made with Metakaolin and Shredded Plastic Waste

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Abstract

Among various building materials, concrete is the most widely used conventional material. Nowadays many scientists are on a hunt for a substitute material for constructionthat is eco-friendly and made from industrial waste products and offer sustainable development. In this study, cement was partially substituted by metakaolin of varying percentage as 0%, 2.5%, 5%, 7.5% and 10% by weight of cement. Shredded plastic waste of 0.5% by weight was added to concrete by replacing coarse aggregate in the concrete. M20 grade concrete is used for beams. Optimum replacement percentage of metakaolin was determined from the tests. Ultimate load carrying capacity of beams produced with the optimum replacement percentage was compared with the numerical investigation done by finite element modelling package ANSYS 12.0.

***Keyword**: Metakaolin, Shredded Plastic Waste, Flexural beams, Finite element modeling*

Introduction

According to the increase in population, production and utilization of Portland cement is not only costly and energy intensive but also releases a significant amount of carbon dioxide content into the environment. In recent days, metakaolin is one of the pozzolanic material which has cementitious properties and is used to produce high strength concrete. The binding capacity or free lime content present in metakaolin decides its scale of purity. Metakaolin was partially replaced with cement in percentages ranging from 0%, 2.5%, 5%, 7.5% and 10% by weight of cement.
Growing population also creates a global problem byincreased generation of waste, and it must be taken into consideration in order to solve the world's resource and energy challenges. Increasing consumers around the world produce various types of non-decaying or non-biodegradable waste materials, resulting in disposal crisis. Disposal of waste plastic materials in environment results in a lot of pollution and damage to the natural ecosystem and climatic conditions. Utilization of plastic waste in concrete will be a useful alternate solution to the waste disposal problems. In this study, 0.5% of shredded plastic waste was added with the concrete by replacing the coarse aggregate.

2. Literatures Reviewed

Aiswarya et al. (2013) made a review on the use of metakaolin in concrete and concluded that the replacement of metakaolin in concrete showed better results in strength and durability aspects and made it non-porous. Rakesh Kumar (2014) found that the utilization of metakaolin in concrete would act as flexible particulate filler in concrete and improves its fracture and toughness. Raju and Rajiv Chauhan (2014) conducted an experimental study on the strength behavior of cement concrete with use of plastic fibers and concluded that no cracks were found and smooth surface finish with 1% of plastic fiber by weight which results the decrease in compression and tensile strength .Murali and Surthee (2012) studied the concrete with metakaolin as partial replacement of cement and decided that 7.5% of metakaolin increased the strength parameters when compared with 5% and 10% of metakaolin. Pawar et al. (2016) analyzed three models of reinforced beams in ANSYS 15 modeling to determine the effect of percentages of steel reinforced in flexural behavior. Finite element models of RC models were analyzed in nonlinear FEM analysis, and the flexural responses were considered up to failure.

3. Materials Used

In this study, the following materials were used in the preparation of M20 grade concrete.The materials conformed o various Indian codes such as IS 12269:1987, IS 383:1970 for cement and aggregates respectively. Mix design was done as per the codal guidelines given in IS 10262:2009.

- Ordinary Portland Cement – 53 Grade
  - Standard consistency – 29%
  - Fineness – 6.07%
- Fine aggregate – Zone II
  - Bulking of sand – 1.17%
  - Specific gravity – 2.53
  - Fineness modulus – 3.29
- Coarse aggregate – 20mm

    - Specific gravity – 2.79
    - Fineness modulus – 3.51
    - Crushing strength – 15.96%
- Super plasticizer – CONPLAST SP430
    - Dosage – 2.5%
- Metakaolin - It is mainly composed of Silica (53%)and Alumina (43%), the chemical composition of the metakaolin was described in the figure 1.
    - Specific gravity – 2.50
    - Physical form – Powder
    - Surface area – $15m^2/kg$

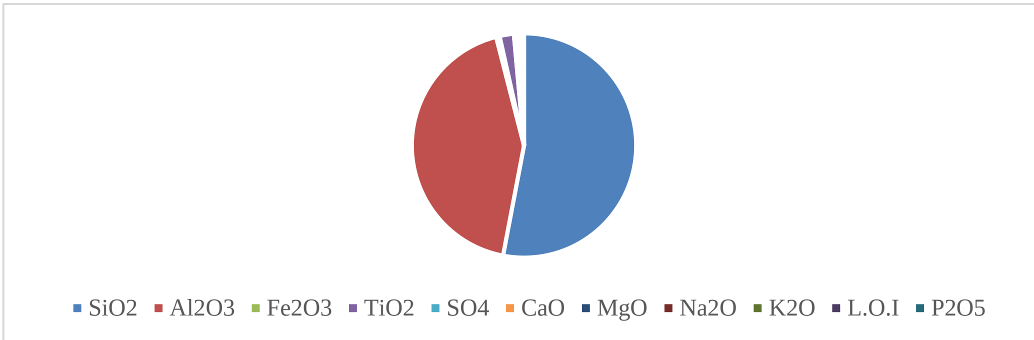

Figure 1: Chemical composition of Metakaolin

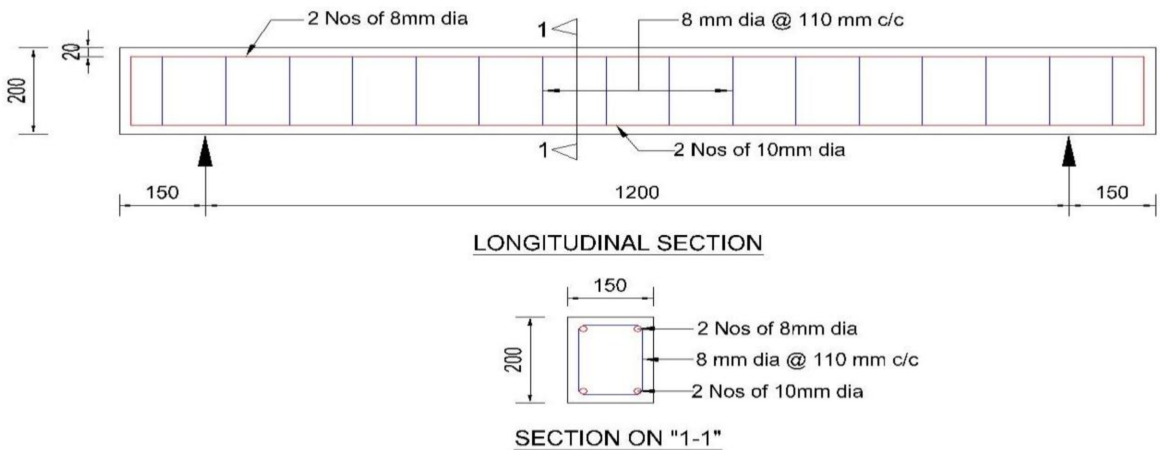

Figure 2: Reinforcement details of RC flexural beam

- Shredded plastic waste –Theyarecrushed,foreign matters removed and then heated under temperature and crushed down to the required size of aggregates.
    - Specific gravity – 0.95
    - Crushing value – 2.5%
    - Density – 0.90 g/cc

Table 1: Mix design for M20 grade

Materials	Cement	Fine aggregate	Coarse aggregate	Water
Weight in kg	352	800	1155	158.40
Proportion	1	2.27	3.28	0.45

Table 2: Properties of fresh concrete at 0.45 w/c ratio

Test	Mix ID				
	NMC	**MP_1**	**MP_2**	**MP_3**	**MP_4**
Slump value (mm)	58	65	78	89	100
Compaction factor	0.90	0.91	0.94	0.96	0.92

4. Strength Characteristics

The strength characteristics of M20 grade concrete with varying percentage of metakaolin in addition with 0.5% of shredded plastic waste were tested by casting cubes, cylinders, prisms and beams. The specimens were allowed for the curing periods of 7, 14, 28, 56 and 90 days in water.

Table 3: Compressive strength test results

Mix ID	Average Compressive Strength (N/mm^2)				
	7 days	**14 days**	**28 days**	**56 days**	**90 days**
NMC	18.64	19.73	28.00	32.72	37.26
MP_1	19.58	20.91	29.20	33.15	38.46
MP_2	19.79	21.58	31.72	34.60	39.87
MP_3	**20.91**	**22.60**	**32.96**	**36.37**	**42.19**
MP_4	19.63	21.34	31.18	34.37	39.08

Table 4: Split tensile strength test results

Mix ID	Average Split tensile Strength (N/mm^2)				
	7 days	**14 days**	**28 days**	**56 days**	**90 days**
NMC	1.46	1.92	3.17	3.37	3.46
MP_1	1.50	1.98	3.32	3.45	3.54
MP_2	1.53	2.08	3.36	3.49	3.63
MP_3	**1.57**	**2.09**	**3.45**	**3.56**	**3.71**
MP_4	1.52	2.00	3.34	3.46	3.58

Table 5: Flexural strength test results

Mix ID	Average Flexural Strength (N/mm^2)				
	7 days	**14 days**	**28 days**	**56 days**	**90 days**
NMC	2.85	3.78	6.29	6.47	6.77
MP_1	2.98	3.95	6.58	6.77	7.008
MP_2	3.01	4.09	6.65	6.84	7.16
MP_3	**3.12**	**4.14**	**6.89**	**7.08**	**7.41**
MP_4	2.99	3.97	6.61	6.79	7.12

Based on the obtained results, Mix ID MP_3 (Metakaolin 7.5% With 0.5% of Shredded Plastic Waste) was considered as the optimum replacement percentage of metakaolin for improving the strength of concrete with the addition of 0.5% of shredded plastic waste. For this mix proportion, RC flexural beams were cast with the dimension 150 x 200 x 1500mm. Reinforcement details provided in the flexural beam are mentioned in figure 2. The beams were tested under two-point loading at L/3 distance from both the supports.

Figure 3: Preparation of Reinforced concrete beams

5. Finite Element Modeling

Finite element analysis on the reinforced concrete beams were done by the software package ANSYS 12.0. The beams were modeled and tested either in APDL or GUI. The specimens were loaded under two-point loading conditions and non-linear buckling analysis was done to determine the characteristic of the sections. The correlation was done by comparing the predicted analytical results in ANSYS and with the experimental results. The following elements were adopted for material idealization.

Table 6: Description of used elements in ANSYS

Beam Components	Elements used from ANSYS library	Element Characteristics		
		Number of nodes	Type of element	DOF per node
Concrete	SOLID65	8	Brick element	3 – T*
Bearing steel plate of loading	SOLID45	8	Brick element	3 – T*
Steel reinforcing bars	LINK8	2	Discrete element	3 – T*

T* - Translational Degree of Freedom; R** - Rotational Degrees of Freedom

Modeling a structural element for the behavior of flexural members made with partial replacement of cement and gravel by metakaolin and shredded plastic waste respectivelywas a difficult task. The properties of concrete were found based on the guidelines of IS456:2000.

Table 7: Material properties assigned for SOLID65 element

S. No.	Definition	Value
1	Young's modulus of elasticity	25491 MPa
2	Poisson's ratio	0.24
3	Characteristic compressive strength	20MPa
4	Density	2410kg/m^3
5	Ultimate compressive & tensile strength	32.96MPa& 3.45 MPa
6	Shear transfer parameter	0.2 to 0.7

Table 8: Material properties assigned for SOLID45 element

S. No.	Definition	Value
1	Young's modulus of elasticity	2.1 x 10^5MPa
2	Poisson's ratio	0.3

Table 9: Material properties assigned for LINK8 element

S. No.	Definition	Value
1	Young's modulus of elasticity	2.1 x 10^5 MPa
2	Poisson's ratio	0.3
3	Yield stress	415MPa

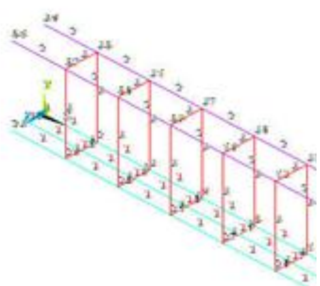

Figure 4: Reinforcement details in ANSYS

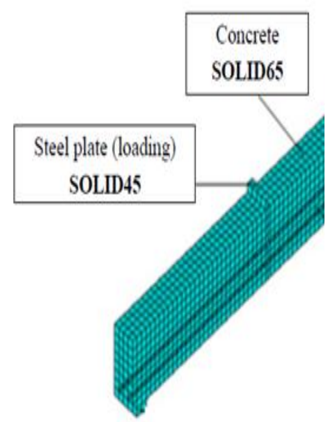

Figure 5: Element types used in ANSYS

6. Experimental Investigation

All the beams were cast for the Mix ID – MP_3 and the water-cement ratio of 0.45. The beam specimens were cured for 28 days and then tested. The size of beam cast was 150 x 200 x 1500mm, two numbers of 10mm& 8mm diameter rods were at bottom and top.

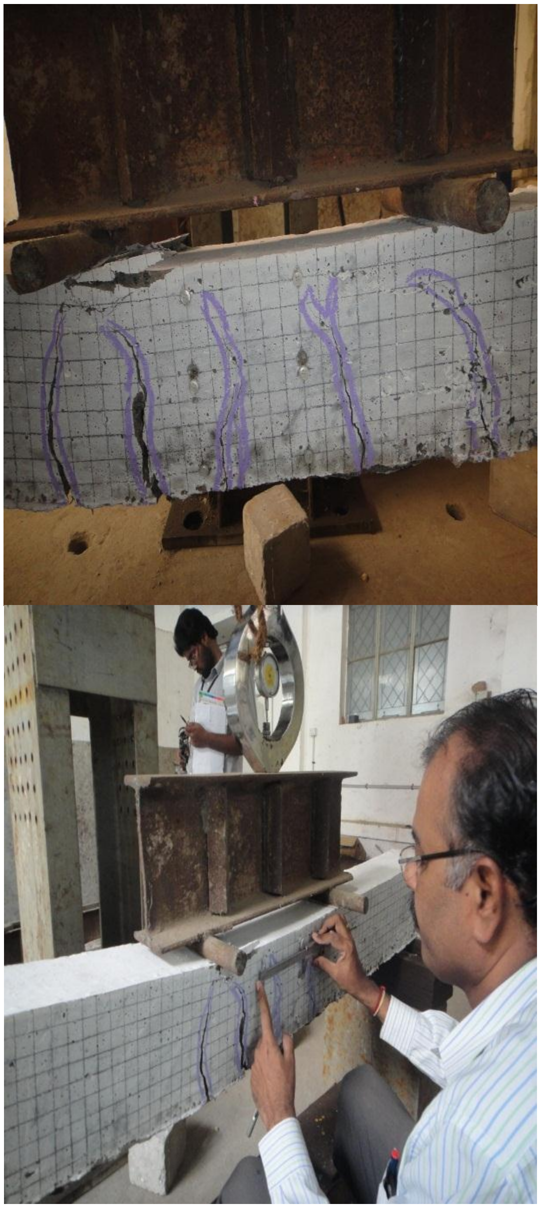

Figure 6: Experimental test setup

7. Comparison of Results

The results of experimental investigation was compared with the finite element model made with ANSYS and the results are tabulated below:

Table 10: Comparison of Ultimate load carrying capacity and Midspan Deflection

S. No	Mix ID	Ultimate load carrying capacity (kN)			Midspan Deflection (mm)		
		Experimental	Numerical	P_{Exp}/P_{FEA}	Experimental	Numerical	$\Delta_{Exp}/\Delta_{FEA}$
1	NMC	28.67	32	0.90	10.197	12.14	0.84
2	MP_3	33.33	38	0.88	7.936	8.53	0.93

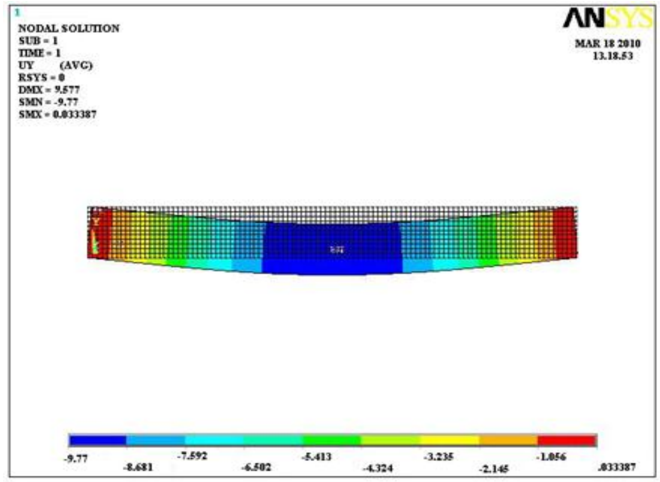

Figure 7: Deflection behavior of Flexural beam NMC

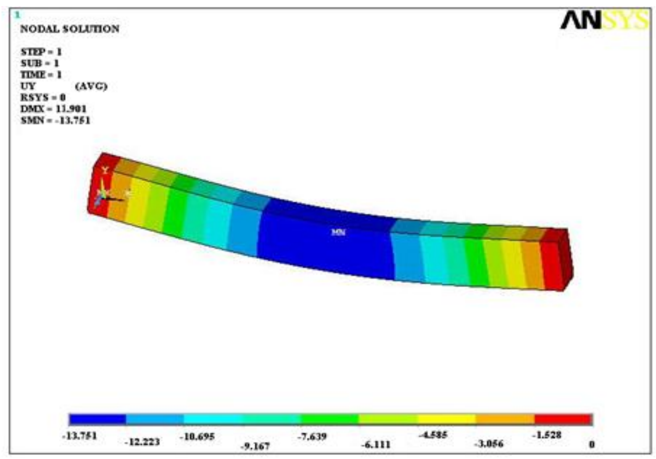

Figure 8: Deflection behavior of Flexural beam MP_3

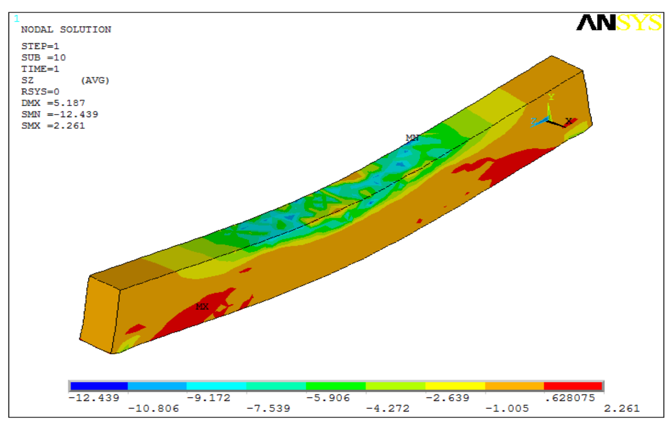

Figure 9: Stress contour for Flexural beam NMC

7. Conclusions

Following are the conclusions made after the investigation on flexural beams made with metakaolin and shredded plastic waste as partial replacement materials for cement and coarse aggregate.

- The admixtures like metakaolin and 0.5% shredded plastic waste used at optimum quantity tends to increase the strength of the concrete mix when compared with conventional concrete.

- 7.5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete at curing periods of 7, 14, 28, 56 and 90 days. Increase of 7.5% of metakaolin increases the strength drastically.
- Numerical analysis results mostly coincide with the experimental results.
- The initial cracking does not affect failure load.
- There is no sudden failure of concrete and failure is gradual due to yielding of steel which is preferred for safety mode of failure.
- Numerical analysis shows ultimate load carrying capacity of 14.01% improved results compared to experimental results.

References

[1] Smarzewski, Piotr (2016). Numerical solution of reinforcedconcrete beam using arc-length method, Biuletyn WAT, Vol.LXV, Nr 1.

[2] P. Muthupriya ,Dr.K.Subramanian& Dr.B.G.Vishnuram,"Investigation on Behaviour of High Performance Reinforced concrete columns with metakaolin and fly ash as admixture "- March 2011 International journal of advanced Engineering Technology, Vol.11 , No.1., Pages 190-202

[3] Raju & Rajiv Chauhan,"An experimental study on strength behavior of cement concrete with use of plastic fibre"- March 2014 International journal of Engineering Research & Applications , Pages 30-34

[4] Ankur.A.Patel., Deepa.A.Sinha (2011)., "An Experimental Investication On The Effect Of Flyash And Metakaolin On Steel Fibre Reinforced Concrete At Temperature At 20° C", Proceeding Of The National Conference On "Recent Trends In Engineering And Technology", 13-14th May Organized By BVM Engineering Collage, Vallabh,vidhyanagar-388120.Dist. Anand. (Gujarat), Paper Id-101067

[5] Sallam H.E., Badawy A.A., and El-Emam H. M. (2013). Numerical Simulation of the Performance of Strengthened RC Beams Using Smeared Crack Approach, Journal of Jazan University-Applied Sciences Branch, Vol.2, No.2, May, (Rajab1434 H).

[6] Basu, Prabir C, et al, High Reactivity metakaolin: a new pozzolana, proceedings of the national seminar on innovative construction materials, VJTI, Mumbai, Jan 21-22.