International Journal of Engineering & Technology, 7 (3.35) (2018) 82-89

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Study on Strength and Deflection of Beams Using Metakaolin and Shredded Plastic Waste as Cement and Coarse Aggregate Replacer

M.Sivaraj*[1], Dr. R. Sundararajan[2], Dr. T. Senthil Vadivel[3]

[1]*Research Scholar, Department of Civil Engineering, Karpagam Academy of Higher Education, Coimbatore-641021, Tamilnadu.*
[2]*Registrar, Department of Civil Engineering, Karpagam Academy of Higher Education, Coimbatore-641021, Tamilnadu*
[3]*Professor & Head, Department of Civil Engineering, School of Engineering & Technology, Adamas University, Kolkata – 700126. West Bengal*
**Email: sivaraj.myilsamy@gmail.com*

Abstract

Concrete is a composite material made from cement, water, fine aggregate and coarse aggregate. But present researchers are in interest of finding new cementing materials by waste materials or waste products produced from industries. Metakaolin is a cementitious material used as an admixture to produce high strength and is used for maintaining the consistency of concrete. The usage of plastics is increasing day by day although steps were taken to reduce its consumption. This creates substantial garbage every day which is much unhealthy. The cement is partially replaced by metakaolin (2.5%, 5%, 7.5% and 10% by weight) to improve the strength, durability and reduces the porosity of concrete. Also, it is the best way of environmentally friendly disposal of plastic. The properties of materials (Physical & Chemical) were studied meanwhile the strength characteristics (M20) such as compressive strength, split tensile strength and flexural strength test results were found by casting cubes, cylinders, prisms and beams.

Keywords: *Cement, compressive strength, metakaolin, plastic waste, partial replacement, split tensile strength, flexural strength*

1. Introduction

Concrete is one of the most extensively used man-made construction material in the world. The Raw materials needed for the manufacture of Portland cement are available in most part of the world. The use of alternative binders of cement and coarse aggregate replacement materials has become a necessity for the construction industry because of the economic, environmental and technological benefits derived from their use. Use of Metakaolin in Construction industry as partial replacement of cement has been started in the 1960's. The interest in this material has considerably increased in recent years.
Leaving the plastic wastes into environment directly results lot of pollution and the damage of natural climatic conditions. In this paper the cements are partially replaced by metakaolin (0%,2.5%,5%,7.5%and 10% by weight) and coarse aggregate is partially replaced by Shredded plastic waste (0.5% by weight) to improve the strength and durability of concrete and also finding out the safe and environmentally friendly disposal of plastics.

2. Objectives

To study the effects of metakaolin on resulting properties of concrete.
Also, to study the effects of shredded plastic waste on resulting properties of concrete.
Finding out the safe and environmentally friendly disposal of plastic wastes.
This experimental study focuses the usage of metakaolin and plastic wastes on strength development in concrete.

3. Experimental Programme

3.1. Materials*:*

3.1.1. Cement:

In this experimental investigation Ordinary Portland Cement (OPC) of 53 Grade was used.

3.1.2. Metakaolin:

Metakaolin is derived from naturally occurring mineral and is manufactured specially for cementing application.

3.1.3. Fine aggregate:

Locally available river sand free from impurities was used. This size of it is less than 4. 75mm.The specific gravity and finess modulus of fine aggregate were found to be 2.53 and 3.29 respectively. The percentage of passing within the limits as per IS 383-1970.

3.1.4. Coarse aggregate:

The coarse aggregate used is 20mm in size, crushed, angular in shape and free from dust. The specific gravity and finess modulus of coarse aggregate were found to be 2.81 and 4.50 respectively. The percentage of passing within the limits as per IS 383-1970.

3.1.5. Shredded Plastic Waste:

Plastic collected from the disposal area were sorted to get the superior one. These were crushed and removed the foreign matters then heated at particular temperature and crushed down as aggregates. Specific gravity and crushing value 0.95 and 2.5% respectively.

3.1.6. Water:

Potable water free from injurious salt was used for mixing and curing.

3.1.7. Super plasticizer:

To impart the additional desired properties, a superplasticizer (CONPLAST SP-430) was used. Dosage of plasticizer was added 2.5% by weight of cement. (8.80 Lit/m^3)

4. Grade of Concrete

The mix proportion of this investigation was 1:2.27:3.28 as per and M20 grade of concrete was adopted.

Table 1: Mix design for M20 grade

Materials	Cement	Fine aggregate	Coarse aggregate	Water
Weight in kg per m^3 volume of concrete	352	800	1155	158.40
Proportion	1	2.27	3.28	0.45

5. Preparation of Specimen

The strength characteristic of concrete with varying percentage of Metakaolin+0.5% of shredded plastic waste were studied by casting cubes, cylinders, prisms and beams. The specimens were removed from the mould after 24 hours and the specimens were cured within the water for 7, 14, 28, 56 and 90 days. (Beams -28Days Curing)

6. Testing

Concrete specimens were taken out of curing chamber and cubes were tested for compressive strength using compression testing machine, cylinders were tested for split tensile strength using compression testing machine, prism were tested for flexural strength using UTM and beams were tested for flexural strength using loading frame.

6.1. Compressive Strength Testing Procedure:

Fig.1: Compressive Strength Test

Table 2: Test Result for Compressive Strength

Mix ID	7 days	14 days	28 days	56 days	90 days
NMC	19.73Mpa	22.55Mpa	30.10Mpa	35.62Mpa	40.10Mpa
MP1	20.91Mpa	24.02Mpa	32.08Mpa	38.04Mpa	42.70Mpa
MP2	21.50Mpa	24.67Mpa	32.96Mpa	39.00Mpa	43.94Mpa
MP3	22.60Mpa	25.84Mpa	34.49Mpa	40.44Mpa	45.95Mpa
MP4	21.34Mpa	24.40Mpa	32.57Mpa	38.54Mpa	43.38Mpa

Note: NMC - Nominal Mix Concrete, MP1 – Metakaolin (2.5% by Weight of cement) Plastic Waste (0.5% by Weight of coarse aggregate), MP2 – Metakaolin (5.0% by Weight of cement) Plastic Waste (0.5% by Weight of coarse aggregate), MP3 – Metakaolin (7.5% by Weight of cement) Plastic Waste (0.5% by Weight of coarse aggregate), MP4 – Metakaolin (10.0% by Weight of cement) Plastic Waste (0.5% by Weight of coarse aggregate)

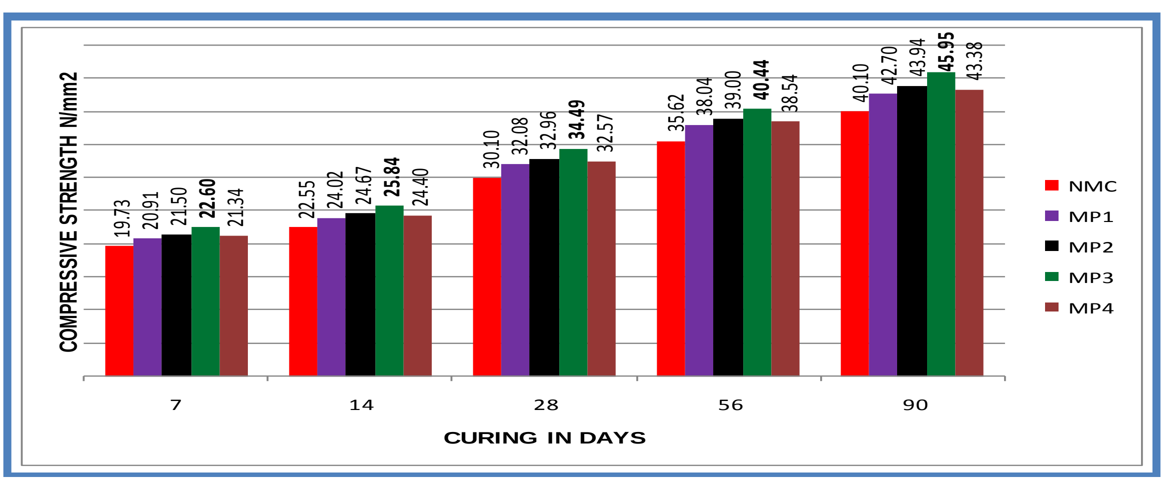

Fig.2: Comparison of Compressive Strength Test Results

6.2. Split Tensile Strength Testing Procedure:

Fig.3: Spilt Tensile Strength Test

Table 3: Test Result for Split Tensile Strength

Mix ID	7 days	14 days	28 days	56 days	90 days
NMC	1.476Mpa	1.930Mpa	3.210Mpa	3.300Mpa	3.420Mpa
MP1	1.540Mpa	2.010Mpa	3.350Mpa	3.440Mpa	3.570Mpa
MP2	1.570Mpa	2.060Mpa	3.410Mpa	3.510Mpa	3.640Mpa
MP3	1.590Mpa	2.080Mpa	3.460Mpa	3.560Mpa	3.690Mpa
MP4	1.560Mpa	2.040Mpa	3.400Mpa	3.500Mpa	3.630Mpa

Note: NMC - Nominal Mix Concrete, MP1 – Metakaolin (2.5% by Weight of cement) Plastic Waste (0.5% by Weight of coarse aggregate), MP2 – Metakaolin (5.0% by Weight of cement) Plastic Waste (0.5% by Weight of coarse aggregate), MP3 – Metakaolin (7.5% by Weight of cement) Plastic Waste (0.5% by Weight of coarse aggregate), MP4 – Metakaolin (10.0% by Weight of cement) Plastic Waste (0.5% by Weight of coarse aggregate)

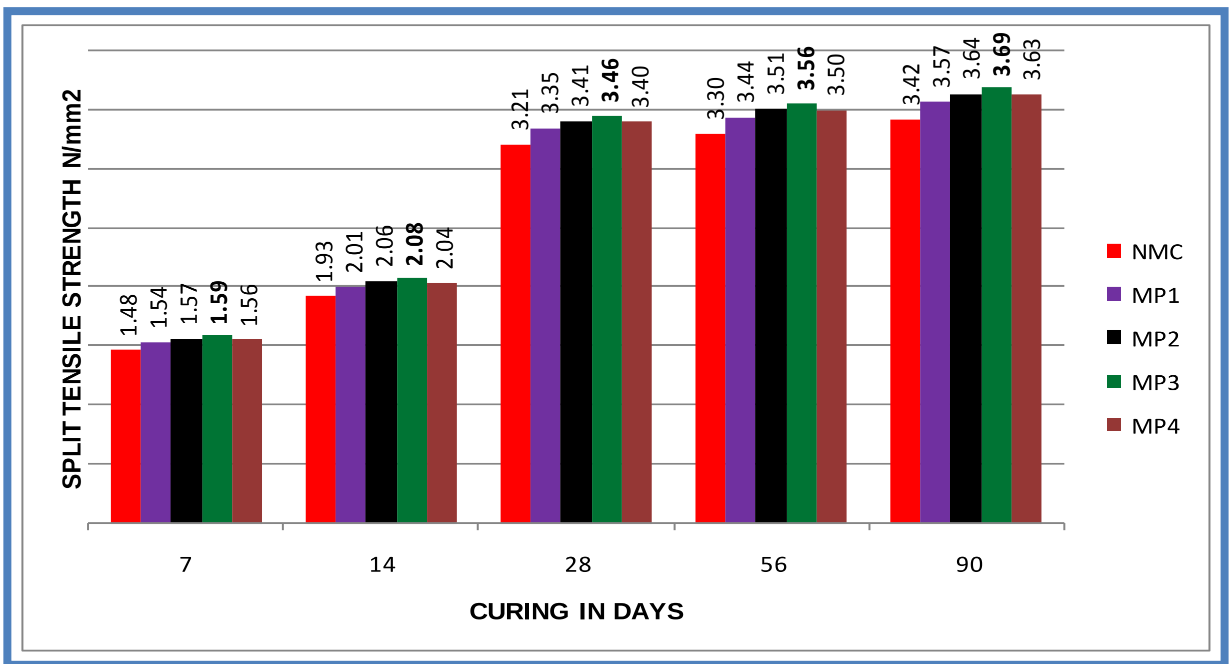

Fig.4: Comparison of Split Tensile Strength Test Results

6.3. Flexural Strength Testing Procedure

Table 4: Test Result for Flexural Strength

Mix ID	7 days	14 days	28 days	56 days	90 days
NMC	2.850Mpa	3.780Mpa	6.290Mpa	6.470Mpa	6.770Mpa
MP1	2.980Mpa	3.950Mpa	6.580Mpa	6.770Mpa	7.080Mpa
MP2	3.010Mpa	4.090Mpa	6.650Mpa	6.840Mpa	7.160Mpa
MP3	3.120Mpa	4.140Mpa	6.890Mpa	7.080Mpa	7.410Mpa
MP4	2.990Mpa	3.970Mpa	6.610Mpa	6.790Mpa	7.120Mpa

Fig.5: Flexural Strength Test

Note: NMC - Nominal Mix Concrete, MP1 – Metakaolin (2.5% by Weight of cement) Plastic Waste (0.5% by Weight of coarse aggregate), MP2 – Metakaolin (5.0% by Weight of cement) Plastic Waste (0.5% by Weight of coarse aggregate), MP3 – Metakaolin (7.5% by Weight of cement) Plastic Waste (0.5% by Weight of coarse aggregate), MP4 – Metakaolin (10.0% by Weight of cement) Plastic Waste (0.5% by Weight of coarse aggregate)

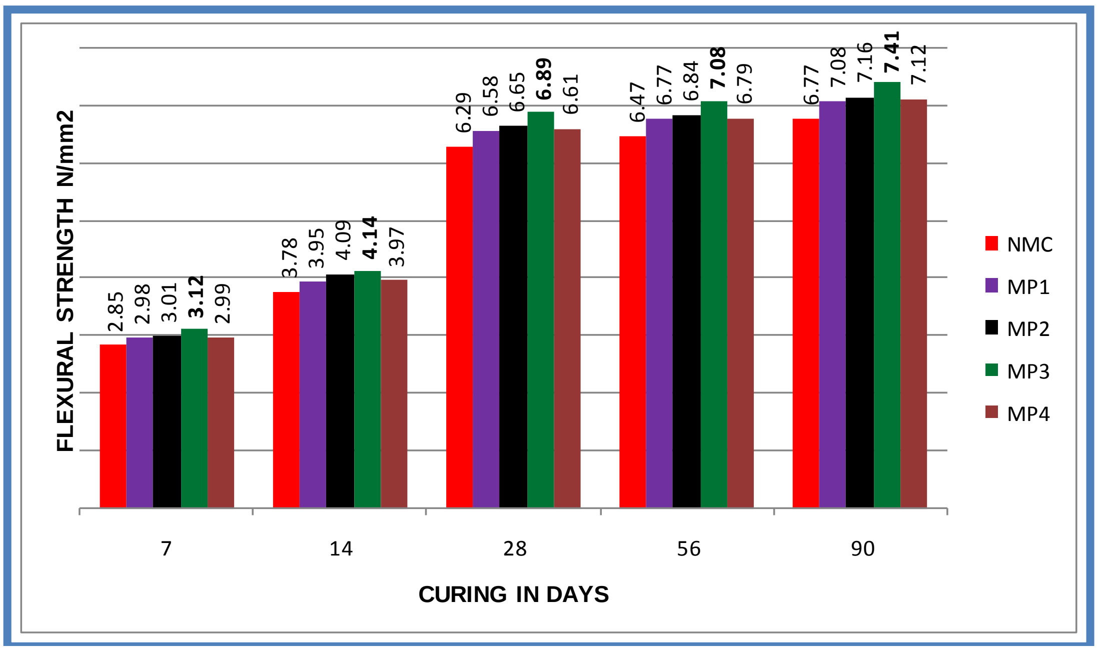

Fig.6: Comparison of Flexural Strength Test Results (Bending stress Vs curing in days)

7. Details of RC Flexural Beam

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.

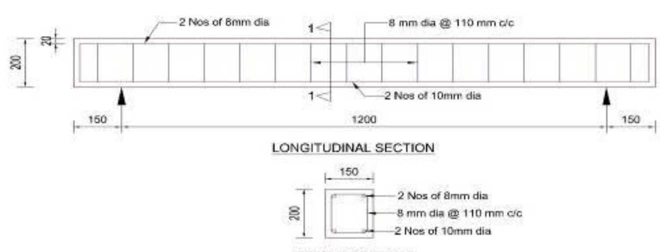

Fig.7: Reinforcement details of RC flexural beam

Fig.8; Preparation of Reinforced concrete beams

Fig.9: Experimental test setup

8. Results and Discussion

8.1. Normal Flexural Beam Deflection:

Table 5: Test Result for Strength and deflection of normal flexure beam

SL.NO.	MIX ID	LOAD kN	DEFLETION AT		
			L/3 mm	L/2 mm	2L/3 mm
1	NMC1	28	8.10	11.89	5.35
2	NMC2	28	5.40	10.58	5.20
3	NMC3	30	6.89	8.12	6.50

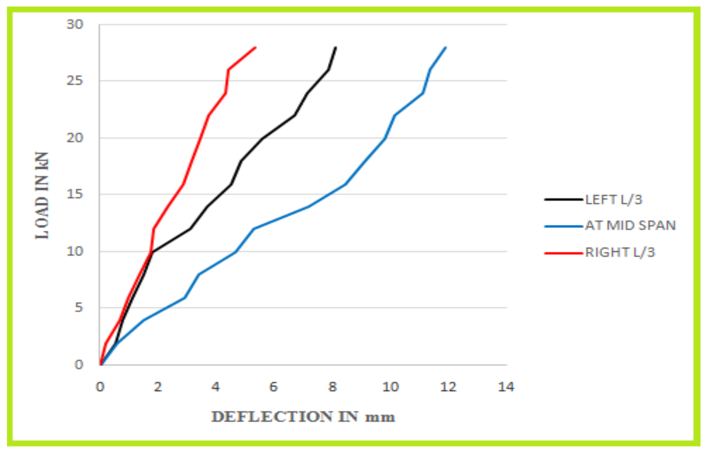

Fig.10:NMC1--Beam Deflection

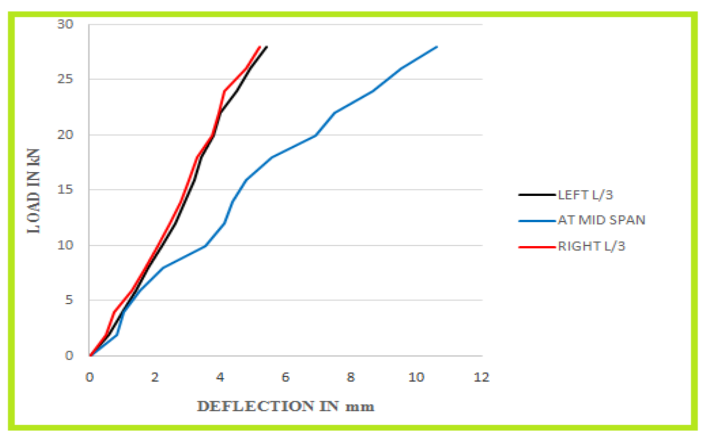

Fig.11: NMC2--Beam Deflection

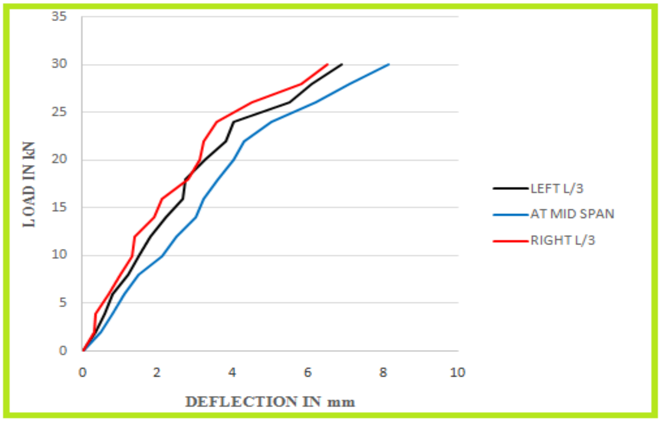

Fig.12: NMC3--Beam Deflection

8.2. Control Flexure Beam Deflection:

Table 6: Test Result for Strength and deflection of control flexure beam.

SL.NO.	MIX ID	ULTIMATE LOAD kN	DEFLETION AT		
			L/3 mm	L/2 mm	2L/3 mm
1	MP3(1)	34	5.90	7.16	4.20
2	MP3(2)	34	4.20	7.50	4.12
3	MP3(3)	32	5.80	9.15	5.61

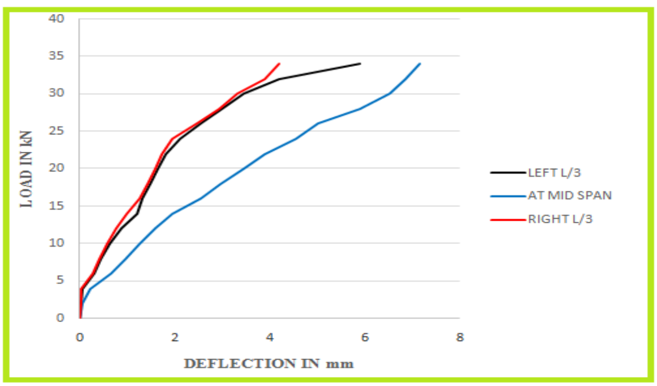

Fig.13: MP3(1) --Beam Deflection

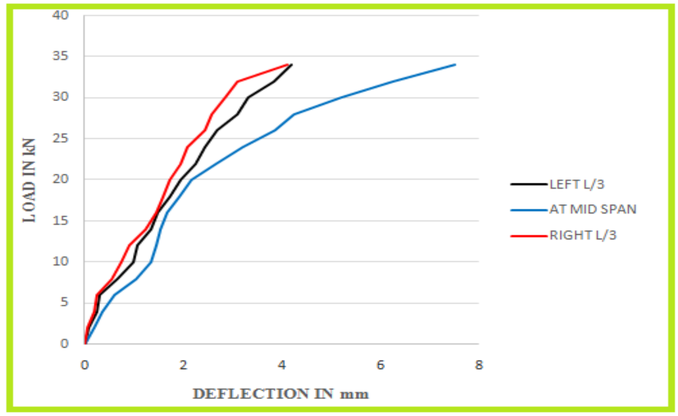

Fig.14: MP3(2) --Beam Deflection

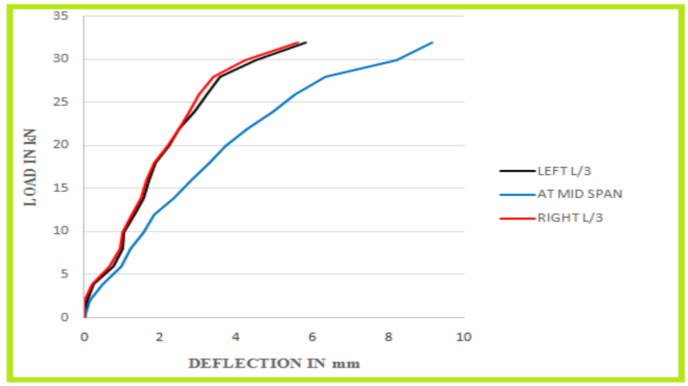

Fig.15: MP3(3) --Beam Deflection

Table 7: Ultimate load and Mid span deflection

MIX ID	28th days	
	Average Ultimate load (kN)	Average Mid span deflection (mm)
NMC	28.66	10.197
MP3	**33.33**	**7.936**

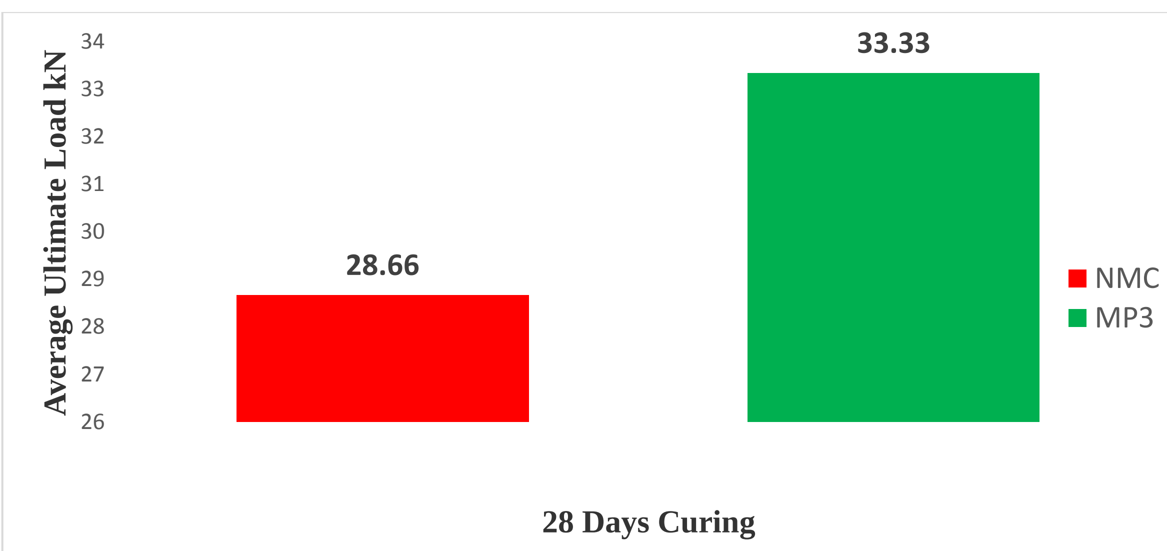

Fig.16: Average Ultimate Load (Abstract)

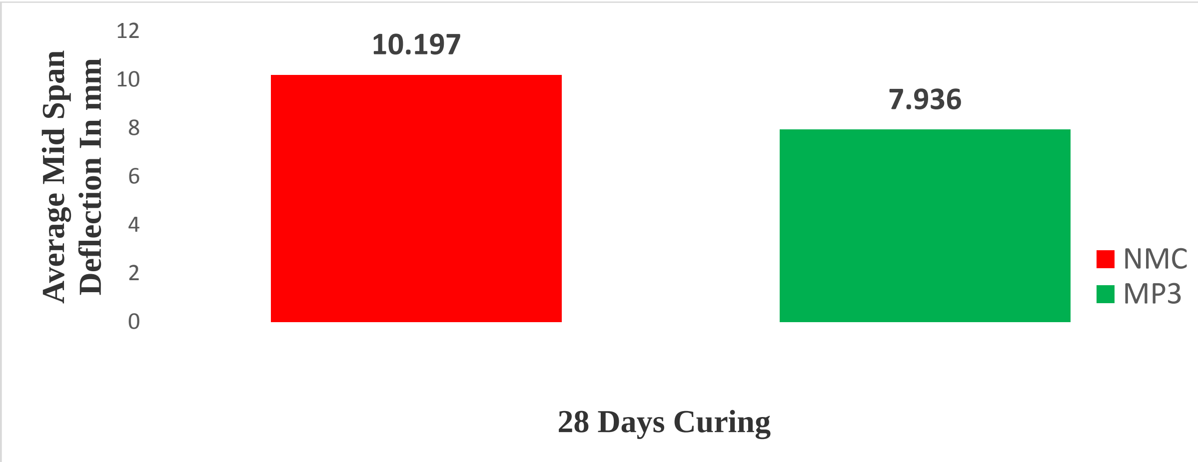

Fig.17: Mid Span Deflection (Abstract)

9. Results and Discussion

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

After 7 Days curing

2.5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 6.07%, 2.74% and 4.56% respectively.

5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile and Flexural strength of concrete by 7.20%, 4.79% and 5.61% respectively.

7.5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 13.27%, 7.53% and 9.47% respectively.

10% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 6.33%, 4.11% and 4.91% respectively.

After 14 Days curing

2.5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 5.98%, 3.12% and 4.50% respectively.

5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile and Flexural strength of concrete by 9.38%, 8.33% and 8.20% respectively.

7.5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 14.54%, 8.85% and 9.52% respectively.

10% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 8.16%, 4.17% and 5.03% respectively.

After 28 Days curing

2.5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 4.28%, 4.73% and 4.61% respectively.

5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile and Flexural strength of concrete by 13.29%, 5.99% and 5.72% respectively.

7.5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 17.71%, 8.83% and 9.54% respectively.

10% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 11.36%, 5.36% and 5.09% respectively.

After 56 Days curing

2.5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 1.31%, 2.37% and 4.64% respectively.

5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile and Flexural strength of concrete by 5.75%, 3.56% and 5.72% respectively.

7.5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 11.16%, 5.64% and 9.43% respectively.

10% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 5.04%, 2.67% and 4.95% respectively.

After 90 Days curing

2.5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 3.22%, 2.31% and 4.58% respectively.

5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile and Flexural strength of concrete by 7.00%, 4.91% and 5.76% respectively.

7.5% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 13.23%, 7.23% and 9.45% respectively.

10% of metakaolin + 0.5% of shredded plastic waste increases the Compressive Strength, Split Tensile Strength and Flexural strength of concrete by 4.88%, 3.47% and 5.17% respectively.

After 28 Days curing – Beam

7.5% of metakaolin + 0.5% of shredded plastic waste decreases the Mid span deflection of the beam by 28.49%.

7.5% of metakaolin + 0.5% of shredded plastic waste increases the Ultimate strength of the beam by 16.29%

Table 8: Strength and Deflection

Description	Compressive Strength (MPa)			Split Tensile Strength (MPa)			Flexural Strength (MPa)			Mid Span Deflection (mm)	Ultimate Load (kN)
	7th day	14th day	28th day	7th day	14th day	28th day	7th day	14th day	28th day	28th day	28th day
NMC	18.46	19.73	28.00	1.46	1.92	3.17	2.85	3.78	6.29	10.197	28.66

MP3	**20.91**	**22.60**	**32.96**	**1.57**	**2.09**	**3.45**	**3.12**	**4.14**	**6.89**	**7.936**	**33.33**
% of Increase	13.27	14.54	17.71	7.53	8.85	8.83	9.47	9.52	9.54	-	16.29
% of Decrease	-	-	-	-	-	-	-	-	-	28.49	-

10. Conclusion

After the abovementioned observation the current study concluded that

- 7.5% of metakaolin and 0.5% of shredded plastic waste shows an optimal percentage of replacement which provides high strength in compression, tensile and flexural properties in 7, 14 and 28 days.
- The best combination of 7.5% of metakaolin + 0.5% of shredded plastic waste increases the Ultimate strength of the beam by 16.29%
- The best combination of 7.5% of metakaolin + 0.5% of shredded plastic waste decreases the mid span deflection of the beam by 28.49%
- This study provides an effective disposal measure against solid waste and protects the environment.

Reference

[1] T. Subramani, T. Senthil Kumar, Jayalakshmi, Analysis of Admixtures and Their Effects of Silica Fumes, Metakaolin and Pfa on the Air Content, International Journal of Modern Engineering Research 4(6)(Version 4) (2014) 28-36.
[2] P.M. Subramanian, Plastic recycling and waste Management in the US, Resources, Conservation and Recycling 28 253-263.
[3] T. Subramani, D. Sakthi Kumar, S. Badrinarayanan, S, Fem Modelling and Analysis of Reinforced Concrete Section with Lightweight Blocks Infill, International Journal of Engineering Research and Applications 4(6)(Version 6) (2014) 142-149.
[4] C.H. Chen, R. Hwang, Waste E-glass particles used in cementious mixtures, Cement and Concrete Research 36 (2006) 449-456.
[5] Shi, Caijun, Corrosion of glasses and expansion mechanism of concrete certaining waste glasses as aggregates, Journal of Materials in Civil Engineering ASCE (2009) 529-534.
[6] Park, Secung Bum, Lee, Bong Chun, Studies on expansion properties in mortar containing waste glass & fibering, Cement and Concrete Research 34 (2004) 1145-1152.
[7] Ahamed, Shayan Xu, Aimin, Value added utilization of waste glass in concrete, Cement and Concrete Research 34 (2004) 81-89.
[8] B. Harini, K.V. Ramana, Use of Recycled Plastic Waste as Partial Replacement for Fine Aggregate in Concrete, International Journal of Innovative Research in Science, Engineering and Technology 4(9) (2015) 8596-8603.
[9] Ghernouti, Youcef, Rabehi, Bahia, Safi, Brahim, Chaid, Rabah, Use of Recycled Plastic Bag Waste in The Concrete, Journal of International Scientific Publications: Materials, Methods and Technologies 8 (2013) 480-487.
[10] IS: 383-1970: Specification for coarse and fine aggregate, Bureau of Indian Standards, New Delhi, 1970.
[11] Akçaözog, Semiha and Ulu, Cüneyt, Recycling of waste PET granules as aggregate in alkali-activated blast furnace slag/metakaolin blends, Construction and Building Materials 58 (2009) 31-37.
[12] Dr. N. Balasundaram, R. Sakthivel, Experimental Investigation on Behaviour of Nano Concrete, International Journal of Civil Engineering and Technology 7(2) (2016) 315-320.
[13] Dr. N. Balasundaram, S. Paulraj, Experimental Studies on Strength and SCC Characteristics of Basalt Fiber Reinforced Concrete, International Journal of Civil Engineering and Technology (IJCIET) 8(1) (2017) 704-711.
[14] P. Muthupriya , Dr.K. Subramanian, Dr.B.G. Vishnuram, Investigation on Behavior of High Performance Reinforced concrete columns with metakaolin and fly ash as admixture, International journal of advanced Engineering Technology 11(1) (2011) 190-202.
[15] Raju, Rajiv Chauhan, An experimental study on strength behavior of cement concrete with use of plastic fibre, International journal of Engineering Research & Applications (2014) 30-34.
[16] Ankur.A.Patel, Deepa.A.Sinha, An Experimental Investigation On The Effect Of Fly ash 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, 2011.
[17] Basu, C. Prabir, High Reactivity metakaolin: a new pozzolana, proceedings of the national seminar on innovative construction materials, VJTI, Mumbai, Jan 21-22.
[18] M.S. Shetty, Concrete Technology (Theory and Practice), S.Chand Publishing, New Delhi.
[19] B.L. Gupta, Amit Gupta, Concrete Technology, Jain Book Agency, New Delhi.
[20] M.L. Gambhir, Concrete Technology (Theory and Practice), Tata McGraw Hill Publishing Co Ltd, New Delhi.
[21] A.R. Shanthakumar, Concrete Technology, Oxford University Press, New Delhi.
[22] N.Krishnaraju, Design of Concrete Mixes, CBS Publishers & Distributors, New Delhi.
[23] Satish Chandra, Waste Materials used in Concrete Manufacturing, Noyes Publication, Westwood, New Jersey, U.S.A.
[24] V.S. Ramachandran, Concrete Admixtures Hand Book (Properties, Science and Technology), Noyes Publication, New Jersey, U.S.A.