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Flexural Strength and Duarability of Concrete by Partial Replacement of OPC with Biomedical Waste Ash and Metakaolin

B. Prasanth, V. Ranga Rao

Abstract: Biomedical waste is being generating from hospitals, health clinics and laboratories. Disposal of this waste ash is in environmental concern, potentially lead to spread infectious diseases. In India, presently biomedical waste is generating 550.9 tons per day, and it is annually increasing by 8%. There is a scope of utilization of biomedical waste ash in the production of concrete. In this work, compressive strength, split tensile strength and durability of concrete with partial replacement of OPC with biomedical waste ash with different percentages (5%, 10%, 15% and 20%) and keeping Meta kaolin (20% constant were studied and the results were compared with that of control concrete by casting 30 concrete cubes and 25 cylinders. For durability study, concrete cubes were exposed to chloride attack (NaCl) and the results were compared with that of control concrete. Flexural behavior of reinforced concrete beams were also studied by using binder material with biomedical waste ash with Meta kaolin under different loading conditions and finally results were compared with that of ordinary Portland concrete beams.

Index Terms: Biomedical waste ash, Metakaolin, Durability and Flexural behavior.

I. INTRODUCTION

Biomedical waste management is a huge problem. All human activities producing waste. We all know that such waste may be dangerous and needs safe disposal. Industrial waste, sewage and agricultural waste pollute water, soil and air. It can also be dangerous to human beings and environment. Similarly hospitals and other health care facilities generate lot of waste. Cotton dressing and bandages with blood, used needles, used syringes, bottles, plastic bags etc., mostly glass or plastic. Operation theater waste like tissues, blood, and flesh etc., the hospital waste is highly pathogenic like bacteria, fungi and virus. This can transmit infections to the people. These wastes need proper collection, transportation and management. India generates around three million tons of medical waste every year and the amount is expected to grow at eight percent annually.

Biomedical waste management is a basic public health concern and needs to planning for proper collection, safe storage, systematic transportation and disposal. The problem of biomedical waste management needs a safe technology, as also centralized facilities [1, 2]. Developed a software tool is prepared it can estimate the risk values of biomedical waste and useful to the planner, designer, or administrator handling biomedical waste management system [2, 3], but biomedical waste ash containing high concentration of toxic elements, such as Cu, Cr, Ni, Zn, Pb and Cd [3, 4]. The concentration of toxic elements depends up on the different types of incinerator process [4, 5]. In their study biomedical waste ash was mixed with alluvial soil in different proportions and optimum percentage of biomedical waste ash was obtained based on the strength criteria. The results shows decrease in the toxicity with an increase in the strength of solidification/stabilization product [5, 6]. The usage of biomedical waste ash in the production of concrete is more, while the compressive strength decreased accordingly, [6, and 7] low cost concrete can be made by utilization of biomedical waste ash as partial replacement (2%) of cement in concrete without compromising the strength parameters.

II. RESEARCH SIGNIFICANCE

Biomedical waste generation has increased considerably worldwide in the last decades and it is annually increasing by 8**%.** As a consequence, incineration became an alternative for reducing the volume of biomedical waste, leading to the generation of ash as a new waste.

This research is intended to evaluate the feasibility of using biomedical waste ash as partial replacement of cement in concrete. The successful utilization of biomedical waste ash would not only lower the cost of constructions, but would also substantially contribute to reduce the environmental hazards.

III. MATERIALS USED

The following are the materials used for concrete mix.

A. Cement
B. Fine aggregate
C. Coarse aggregate
D. Biomedical waste ash
E. Meta kaolin
F. Water
G. Chemical Admixtures

A. Cement

Cement is the major engineering material after the extinction of lime in the construction industry. OPC 53 grade cement is normally used to cast the special type of concrete structures. The value of specific gravity of cement is 3.12. The main reason behind considering 53 grade cement is because of its specific surface area and fineness makes the process of hydration efficient and provides adequate strength.

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B. Prasanth, P.G. Student, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur district, Andhra Pradesh, India.

V. Ranga Rao, Professor, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur district, Andhra Pradesh, India.

Before selecting the grade of cement trail mixture which gives the density of 556Kg/$m^3$is adopted by varying the cement sand and cements content.

B. Fine aggregate

The role of the fine aggregates (sand) is providing workability and good finishing characteristics is not as critical as in conventional strength mixes. River sand with a fineness modulus (FM) of about 3.0 is taken as coarse aggregate has been found to be satisfactory for production high compressive strength and good workability. For special strength of 50MPa or greater, FM should be between 2.8 and 3.1.

C. Coarse aggregate

The important parameters of coarse aggregates that influence the performance of concrete are its texture, shape and the optimum size. Since the aggregates are generally stronger than the paste, its strength is not major factor for normal strength of concrete. The nominal size of the aggregates used was 20mm crushed aggregates.

D. Biomedical waste ash (BMWA)

The ash used for this research work taken from the incineration point of "M/S. SAFE ENVIRON", Chinakakani (v), Mangalagiri (M), and Guntur District as shown in Figure 1.

Figure 1: Biomedical waste plant

E. Meta Kaolin

Meta kaolin is the anhydrous calcined type of the mud mineral kaolinite. Meta kaolin is smaller than the cement particles .it is increased compressive and flexural strengths, and also increased resistance to chemical attack as show in Figure 2.

Figure 2: Meta kaolin

F. Chemical Admixtures

Chemical admixtures such as high-range water-retarders are needed to ensure that the concrete is easy to place and finishing. Super plasticizer is used to check the early setting problem. The combination of mineral and chemical admixtures is nearly always essential to ensure achievement of the required strength.

IV. EXEPERIMENTAL WORK

The experimental work was carried out by the basic properties of compressive strength, split tensile strength of cubes (150×150×150mm) and cylinders (150mm diameter, H=300mm) respectively by using binders with various proportions Of Biomedical waste ash and Meta kaolin . The experimental work consists of casting and testing of total 30 cubes and 25 cylinders. All specimens were cast with M30 grade concrete. In this case Meta kaolin was considered as a constant value of 20% and the replacement of biomedical waste ash by considering percentage 5%, 10%, 15% and 20%.

Table I: M30 -Mix Design of Concrete

Cement	437.3kg/m^3
Coarse aggregate	1128 kg/m^3
Fine aggregate	666.6 kg/m^3
Water	197

Table II: Chemical Composition of Cement

Compound	Percentage
Sio_2	21.25
Al_2O_3	4.33
TiO_2	1.85
Cao	0.13
MgO	1.81
SO_3	3.70
K_2O	0.71
Na_2O	0.17
Loss of Ignition	1.50

Table III: Chemical Composition BMWA

Compound	Percentage
Sio_2	20.01
Al_2O_3	11.13
Fe_2O_3	6.50
TiO_2	3.59
CaO	40.21
MgO	2.23
SO_3	4.59
K_2O	0.07
Na_2O	2.69
Specific gravity of BMWA	2.40

Table IV: Chemical Composition of Meta kaolin

Compound	Percentage
Sio_2	51.85
Fe_2O_3	0.99
Al_2O_3	43.87

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TiO_2	1.72
CaO	0.20
MgO	0.18
K_2O	0.12
Na_2O	0.01

Table V: Workability values for different mix

Mix No	Slump (mm)
M-1	72
M-2	68
M-3	62
M-4	62

It is found that optimum value is obtained for the samples of 60% cement, 20% Meta kaolin and 20% biomedical waste ash is the most effective combination to give optimum results.

V. RESULTS AND DISCUSSION

A. Compressive strength

The compressive strength of concrete with Ordinary Portland cement, biomedical waste ash and Meta kaolin and concrete at the age of 7days and 28days were conducted as shown in Figure 3, and Figure 4. The maximum 28days cube compressive strength of M30 grade with replacement in combination of 20% biomedical waste ash and 20% Meta kaolin was 43.71MPa. Compressive strength results were shown in Table VI. and graphically shown in Figure 5 below.

Figure 3: Cubes with BMWA

Figure 4: Compressive testing machine

Table VI: Compressive strength values

Mix proportions	7 DAYS	14 DAYS	28 DAYS
5%	19.4	26	36
10%	19.44	27.88	37.11
15%	21.11	28.44	41.11
20%	22.88	32.88	43.71
CM	20.81	28.42	39.51

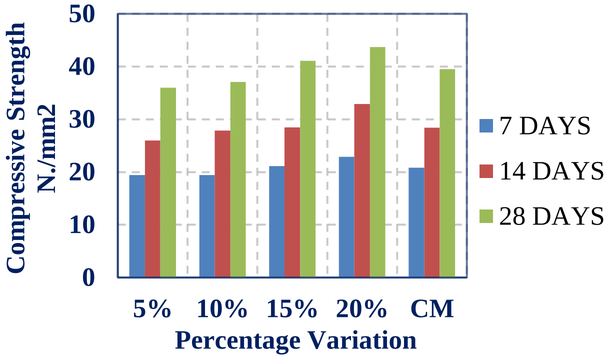

Figure 5: Compressive Strength of BMWA- OPC Concrete

B. Split tensile strength

The Split tensile strength of concrete with Ordinary Portland cement, biomedical waste ash and Meta kaolin concrete at the age of 7days and 28days are conducted as shown in Figure 6. The maximum 28days cube split tensile strength of M30 grade with replacement in combination of 20% biomedical waste ash and 20% Meta kaolin was 1.41Mpa. The test results of Split tensile strength are showed in Table VII. After performing the various tests on cubes and cylinders, it is found that optimum value is obtained for the samples of 60% cement, 20% biomedical waste ash and 20% Meta kaolin is the most effective combination to give optimum results as shown in Figure 7.

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Figure 3: Testing of cylinder

Table VII: Split tensile strength values

Mix Proportions	7 DAYS	14 DAYS	28 DAYS
5%	0.6366	0.8488	1.061
10%	0.707	0.848	1.20
15%	0.70	1.061	1.34
20%	0.84	1.20	1.48
CM	0.77	1.13	1.41

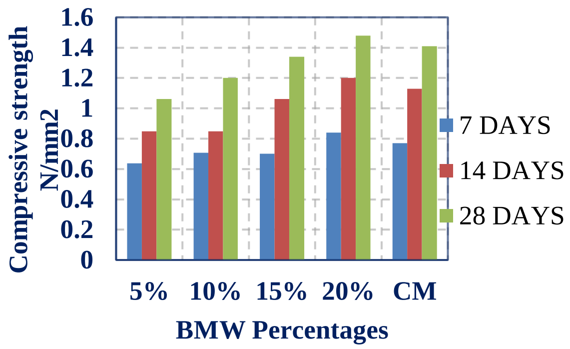

Figure 7: Split Tensile Strength of BMWA- OPC Concrete

C. Chloride Attack

Table VIII shows that compressive strength of concrete cubes exposed to chloride attack. And the compressive strength values as graphically shown in Figure 9 below gives compressive strength of 20% mix have better compare to other mixes.

Table VIII: Compressive strength of concrete cubes

Mix Proportions	7 DAYS	14 DAYS	28 DAYS
5%	18.1	24	34.23
10%	20.82	12.58	36.45
15%	21.23	26.01	39.21
20%	21.98	26.01	39.21
CM	17.4	26.42	36.41

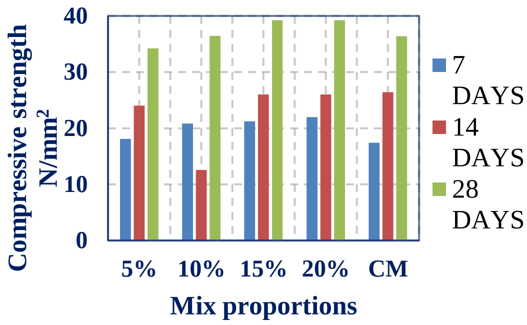

Figure 8: Compressive strength of specimens exposed to chloride

D. Flexural strength

The flexural strength tests were carried out the casted beams. The experimental results of flexural strength with OPC along with the replacement of biomedical waste ash and Meta kaolin .The maximum 28 days flexural strength of M30 grade of concrete replacement of cement by 20% biomedical waste ash of and 20% of Meta kaolin under three point load, four point load, and uniformly distributed load as shown in figure 9 to 14.

Deflection: Figure 9 beam contains bio medical waste with Meta kaolin under three point shows 1.93 mm, 8.43 mm deflection at initial and ultimate loading point of 57.5 kN and 87.3 kN. It forms flexural cracks maintain less than 25^0 angle with center of beam specimen occur 0.01 mm, 0.02mm at initial flexural crack load and 0.5 mm, and 0.8 mm at ultimate load point.

Figure 9: BMW with Meta Kaolin under Three Point Load

Figure 10 beam control specimen under three point shows 4.04 mm, 11.65 mm deflection at initial and ultimate loading point of 52.5 kN and 79.1 kN. It forms flexural cracks maintain less than 25^0 angle with center of beam specimen occur 0.2 mm, at initial crack load and 0.8 mm at ultimate load point.

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Figure 10: Control Specimen under Three Point Load

Figure 11 beam contains bio medical waste with Meta kaolin under four point shows 4.04 mm, 11.65 mm deflection at initial and ultimate loading point of 79 kN forms flexural and diagonal cracks and 128 kN. It forms flexural cracks maintain greater than 25⁰ angle with center of beam specimen occur 0.1 mm, and 0.2 mm at initial flexural crack load and 0.5 mm, 0.8 mm at ultimate load point. At ultimate load point beam fail through diagonally and occur flexural shear failure.

Figure 11: BMW with Meta Kaolin under Four Point Load

Figure 12 beam control specimen under four point shows 3.9 mm, 9.02 mm deflection at initial and ultimate loading point of 83 kN forms flexural and diagonal cracks and 115 kN. It forms diagonal cracks maintain greater than 25⁰ angle with center of beam specimen occur 0.1 mm, and 0.2 mm at initial flexural crack load and 0.5 mm, 0.8 mm at ultimate load point. At ultimate load point beam fail through diagonally and occur diagonal shear failure.

Figure 13 beam contains bio medical waste with Meta kaolin under uniformly distributed load shows 7.04 mm, 9.35mm deflection at initial and ultimate loading point of 150.07 kN forms flexural and diagonal cracks and 231.7 kN. It forms flexural cracks maintain greater than 25⁰ angle with center of beam specimen occur 1 mm, and 2 mmat initial flexural crack load and 5 mm, 6 mm at ultimate load point. At ultimate load point beam fail through diagonally and occur diagonal shear failure.

Figure 12: Control Specimens under Four Point Load

Figure 13: BMW with Meta Kaolin under Uniformly Distributed Load

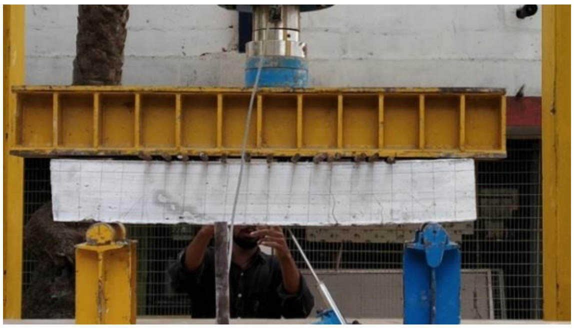

Figure 14: Control Specimen under Uniformly Distributed Load

Figure 14 beam control specimen under four point shows 5.06 mm, 11.88 mm deflection at initial and ultimate loading point of 95 kN forms flexural and diagonal cracks and 190 kN. It forms flexural cracks less than 25⁰ and form diagonal crack greater than 25⁰ angle with center of beam specimen occur 0.2 mm at initial flexural crack load and 0.5 mm, 0.8 mm at ultimate load point. At ultimate load point beam fail through diagonally and occur diagonal shear failure.

Biomedical Waste Ash specimen under four point load Figure 15 shows that 20 percentage of biomedical waste ash with meta kaolin gives better results than control specimen under three point loading condition form flexural shear failure.

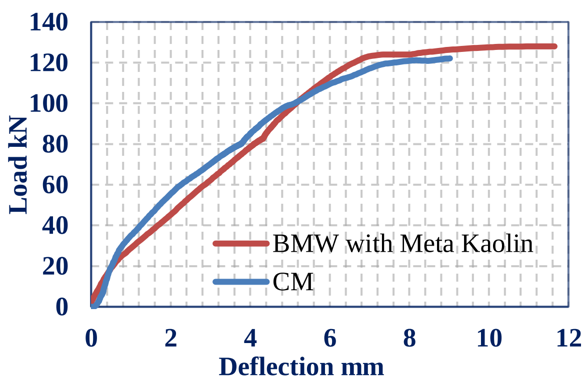

Figure 15: Comparison between control specimen

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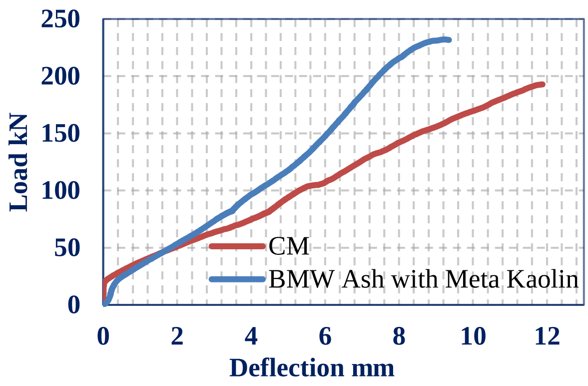

Figure 16: Comparison between control specimen and BMW Ash specimen under uniformly distributed load

Figure 16 shows that 20 percentage of biomedical waste ash with Meta kaolin gives better results than control specimen under uniformly distributed loading condition form diagonal shear failure.

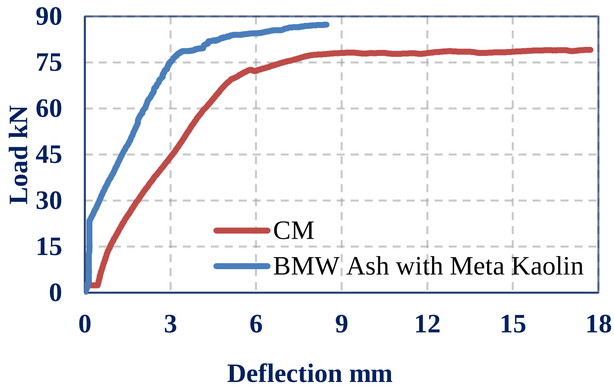

Figure 17: Comparison between control specimen and Bio Medical Waste Ash specimen under three point load

Figure 17 shows that 20 percentage of biomedical waste ash with Meta kaolin gives better results than control specimen under three point loading condition form flexural failure.

VI. CONCLUSION

Based on experimental investigations, the following conclusions were made:

1. It was observed that at 28 days, M30 grade of concrete in compressive strength and split tensile strength were increased for combination of 20% BMWA and 20% Meta kaolin when compared with that of controlled concrete.
2. There was a decrease in workability (slump) as the replacement level increases.
3. For three different loading conditions of three point loading, four point loading, uniformly distributed loading gives better flexural and shear failure resistance compare to control specimens.
4. Under three point loading mode of failure is perfect flexural failure.
5. Under four point loading mode of failure is flexural shear failure.
6. Under uniformly distributed loading mode of failure is diagonal shear failure.
7. Compare to other loading conditions uniformly distributed load have better failure resistance.

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AUTHORS PROFILE

B. PRASANTH is doing his Master of Technology in Structural Engineering at Koneru Lakshmaiah Education Foundation (Deemed to be University), Vaddeswaram, Guntur district, Andhra Pradesh, India. He complected bachelor of technology in Vikas College of engineering and technology in 2017.

Dr. V. Ranga Rao is working as Professor in Department of Civil Engineering at Koneru Lakshmaiah Education Foundation (Deemed to be University), Vaddeswaram, Guntur district, Andhra Pradesh, India. He is pursuing Doctorate from Ph. D. on "**Conventionally reinforced concrete columns with cement from industrial wastes under uniaxial bending**" from Andhra University, awarded in the year 1999, and M. E. on Structural Engineering from Annamalai university, awarded in the year 1990 with First class, and M. Tech. on C. S. C. from Vinaya Mission, awarded in the year 2007 with first class, and B. Tech on Civil Engineering from NIT-Bhopal, awarded in the year 1985 with first class. He published 20 journals in International and national. He is having 28-years of teaching experience. His research area is concrete Structures and Building materials.