European Journal of Material Sciences
Vol.4, No.3, pp.6-23, November 2017
Published by European Centre for Research Training and Development UK (www.eajournals.org)

A NOVEL TECHNOLOGY FOR NEW GENERATION USING MODIFIED THERMOCOL WASTE AS AGGREGATES IN CONCRETE

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ABSTRACT: *Thermocol is a commercial name of Expanded Polystyrene (EPS) which is widely used as equipments production tools to absorb vibration during handling and transportation process. After this process, the EPS serves as disposal waste. Disposal is difficult as EPS is non-biodegradable and due to its light weight characteristics, it has the capacity to serve as aggregates in concrete by modifying it by Heat Treatment. The EPS waste was kept in a closed hot air oven at 130^0 C for 15 minutes resulted in Modified EPS aggregates (MEPS). Total 22 series specimens of cubes, cylinders and beams were casted by replacing natural coarse aggregate (NCA) & natural fine aggregates (NFA) with MEPS aggregates individually and jointly. At 28-d, the overall density, compressive strength, split tensile strength and the flexural strength decreased from 2640 kg/m^3 to 846 kg/m^3, 58.51 MPa to 15.85 MPa, 3.72 MPa 1.94 MPa and 4.90 MPa to 2.04 MPa & the pre-wetted MEPS aggregates exhibited retarding action which increased the overall workability.*

KEYWORDS: Thermocol (EPS) Waste Recycling Techniques, LWC, ULWC, Artificial Sand, MEPS Concrete

INTRODUCTION

Concrete is an extraordinary building material in the human history. In its simplest form, concrete is a mixture of paste and aggregates, or rocks. The paste, composed of portland cement and water, coats the surface of fine (small) and coarse aggregates (large). It is no doubt that with the improvement of human civilization, concrete will continue to be a governing construction material in the future. Concrete is probably the most widely used construction material in the world. It is only second to water as the most profoundly consumed substance with about six billion tons being produced every year, increasing the demand of natural aggregates (NA) which is reducing the natural sources and on the other hand industrial by-products, soil wastes such as EPS, plastic, rubber, glass, iron, steel fibres, wood, brick-bats, thermal waste etc. are creating a huge loss to environment. For this reason, the Civil and Environmental Engineers have been challenged to covert the above waste materials to useful construction material. Hence, we require new artificial aggregates (AA) with equal NA properties. Modification to the above waste can result in new constructions material which can replace NA requirements. Hence, it is essential to advancing the new technologies which can result in new construction materials. This will create comfort to the environment pollution and facilitate the natural balance of life. The main objective of this study is to replace NA by EPS waste and to find usability of the MEPS as an aggregate for the structural and non-structural concrete applications.

Print ISSN: 2055-8112(Print), Online ISSN: 2055-8120(Online)

The Structural Lightweight concrete is going to be one of the important materials of the construction. A concrete which is light in weight and sufficient strong to be used in conjunction with steel reinforcement will be a material which is more economical than the conventional concrete. Therefore, a concrete which combines strength and lightness will have the unquestionable economic advantage. According to ACI 213 R, the structural lightweight aggregate concrete can be defined as the concrete which has a minimum 28-d compressive strength of 17 MPa, an equilibrium density between 1120 kg/m^3 and 1920 kg/m^3 and consists entirely of lightweight aggregate or a combination of lightweight and normal density aggregate. The ultra lightweight concrete with weights or densities ranging from 600 kg/m^3 to 1000 kg/m^3 is made from a mixture of cement, sand and EPS beads. The EPS bead size is to be vary from 1mm Ø to 6 mm Ø. The densities lesser than 600 kg/m^3, the sand is to be omitted. The EPS beads products may be treated with bromine solutions for improving the fire retardance & self-extinguishing characteristics. The ultra lightweight EPS concrete mixes can be designed to have compressive strength up to 15 MPa to 20 MPa at densities around 1000 kg/m^3,designed at achieving an economic and optimum density, thermal insulation & strength. In the recent years, there have been made many efforts to maximize the usage of EPS waste in the concrete production but very less significant research was done on modified EPS waste. Abdulkadir kan and Ramazan Demirboga (2007)[13] pointed out that the compressive strength and density of lightweight concrete are effected by cement and EPS beads ratio. They said that it is necessary to add super plasticizer to improve workability and observed the compressive strengths and densities are ranged from 0.11-8.3 MPa and 464-1370 kg/m^3. Babu and Babu (2004)[11] stated that EPS waste can be used as aggregates in ultra lightweight concrete. They observed that there was segregation occurred in mixing due to very low density properties of hydrophobic EPS waste and also reported the density and compressive strength ranged from 585-984 kg/m^3 & 0.10-3.83 MPa. Babu et al. (2005)[21] investigated on properties of lightweight EPS concrete with fly ash and concluded that there is a gain in compressive strength up to 90 days because of fly ash. The 28-d compressive strength increased from 1.1 MPa to 1.5 MPa at density 582 kg/m^3. S.G.Park and D.H.Chisholm (1999)[22] made a study report on polystyrene aggregate concrete and informed that it is very prone to segregation. They suggested that the care must be taken in adding of water, mixing and placing the concrete mix and also observed the 28-d compressive strength of the concrete as 3.8 MPa at 820 kg/m^3 density. Bing Chen and Juanyu Liu (2004)[23] made a research on properties of lightweight EPS concrete reinforced with steel fiber. They observed the poor workability because of the hydrophobic surfaces of EPS aggregates and compressive strength & split tensile strength at the density 876 was 10.6 MPa & 1.32 MPa.

Babu and Babu (2003)[10] studied on the behaviour of lightweight EPS concrete containing silica fume and said that the rate of strength gain is more in increasing of silica fume percentage replaced to cement at the levels of 3%, 5% & 9%. They reported the 28-d density, compressive strength & split tensile strength are ranged from 1552 - 1979 kg/m^3 , 10.6 - 21.2 MPa and 1.5 - 2.16 MPa. K.Miled et al.(2004)[24] investigated on the compressive behaviour, size effect and also on the failure mode of EPS concrete. They found that the tensile failure with no cracks and size effect encountered with the brittle behaviour of EPS concrete. The compressive strength ranged from 7.6 - 8.5 MPa at density 1810 kg/m^3. Muravljov (1991)[25] investigated on application of EPS concrete reinforced with polypropilene fibers for the production of precast element and reported that the 28-days compressive strength and density ranged from 7.73 - 14.62 MPa and 1130 - 1484 kg/m^3. A.Laukaitis et al. (2005)[26] studied the effect of foam polystyrene granules on cement composites and observed the contact of foam cement concrete and polystyrene granules which was very close, without any fractures or micro cracks. They

Print ISSN: 2055-8112(Print), Online ISSN: 2055-8120(Online)

concluded that the polystyrene ripped out foam cement foam emerging the holes and reported that there was 0.25 MPa split tensile strength at density ranged from 149-275 kg/m^3. Ben Sabaa and Rasiah Sri Ravindrarajah (1997)[27] investigated engineering properties of LWC containing crushed expanded polystyrene waste replaced to NCA by 30, 50 and 70 % and reported that the creep coefficient for EPS aggregate concrete in the density range of 1600 to 2000 kg/m^3 was between 1.90 and 2.37 at the compressive strength ranged from 8.8 - 21.3 MPa. They concluded that the compressive strength is more sensitive with change in unit weight. R Sri Ravindrarajah et al. (1996)[28] studied on flexural creep of ferro-cement-polystyrene concrete composites in sand witch panels of ferro-cement skin separated by EPS concrete core. The panels had the dimensions of 60 mm X 150 mm X 1200 mm by ferro-cement skin thickness 12 mm and 36 mm of core thickness. They reported that the density, compressive strength and split tensile strength at 28 days was ranged from 1100 - 1920 kg/m^3 8.5 - 37.5 MPa and 0.92 - 4.05 MPa. They concluded that strength and stiffness of ferro-cement-polystyrene concrete increased with increase in densities of the concretes. Abdulkadir Kan and Ramazan Demirboga (2009)[29] presented a study on a novel material for LWC production. In this study they replaced the NCA and NFA with MEPS CA and MEPS FA at the levels of 0% to 100 % with 25% interval by volume. They stated that the density of MEPS concretes are much lesser than that of NA concretes and reported that at 28 days of age the MEPS concrete compressive strength ranged from 12.5 - 23.34 MPa. From these pertinent studies it was concluded that the EPS waste can be used in LWC & ULWC by partially or fully NA replacement. However, thermocol waste has not been used for structural lightweight concrete because of its generally low strength. The strength of concrete is influenced by the strength of the aggregate and it is known that the weak EPS aggregates have almost zero strength. The main aim of this investigation is to overcome these reflections by utilizing the MEPS aggregates as structural lightweight concrete aggregate and maximize usability of waste EPS.

METHODOLOGY TO MODIFY THE WASTE EPS

Unmodified EPS waste consist of assemblage of EPS balls with various diameters ranging from 2 to 10 mm and with a density of only 10 to 50 kg/m^3, Compressive Strength is 0.12 to 0.36 MPa with 0% water absorption. The EPS waste brought to the laboratory and most clean waste EPS is selected to modification process. The hand crushed waste EPS is converted to MEPS aggregates by Heat Treatment Method was used to modify properties of materials in addition to hardening and softening for moldings. These processes modify the EPS waste behavior in a beneficial manner to improve the service life, e.g., strength, density properties. By keeping waste EPS in a hot air oven at different temperatures varying to time period results to changes in different properties of EPS waste. To find the changes in density, compressive strength of the EPS Waste before and after Heat Treatment Method, seven series of sample specimens of cubic (50mm X 50mm X 50mm) and plate sections (300mm X 200mm X 35mm) are kept inside the closed digital controlled electrical hot ait oven at the temperatures 0,100,110,120,130,140 and 150^{0}C for 10,15,20,30,45,60 and 120 minutes. When the EPS waste in hot air temperatures ranged from low temperatures to high temperatures with increase of time period, the EPS waste converts from solid to plastic state. At 130 ^{0}C and 15 minutes, MEPS specimen's structure was too hard and brittle. After 15 min, the Waste EPS Specimens shrunk and deformed to plastic state. The modification process can be better understood from the following figures. Change in density and compressive strength of EPS waste at different oven temperatures at 15 minutes of time period can be seen in the below chart which shows the change of the specimens heat treated at different temperatures. The weight changes of the specimens are affected by the increase of the heat treatment temperatures. It is difficult to suggest any relation of the weight & volume change according to heat treatment temperature. The density of EPS was nearly constant up to the 80^0 C for 15 minutes duration of time period. The variation of density with the temperature is given in chart no 01. From this, it can be seen that the density increased with an increase in temperature. At 80, 100, 110, 120, 130, 140 and 150 ^{0}C for 15 minutes the density of the MEPS increased 168%, 172%, 187%, 1710%, 2060%, 3150% and 3120%, respectively.

Figure No. 01: Processing of Waste EPS by heat treatment

Figure No. 02: Deformed shapes of plate section & cubic specimens at different temperatures.

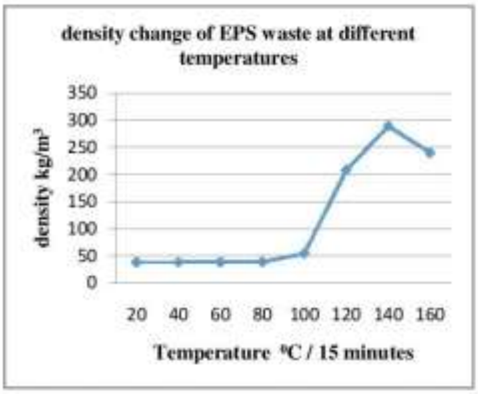

Chart No. 01: density change of EPS waste at different temperatures

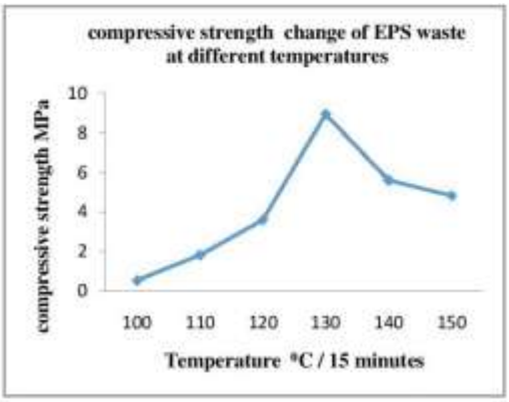

Chart No. 02: compressive strength change of EPS waste at different temperatures

Print ISSN: 2055-8112(Print), Online ISSN: 2055-8120(Online)

The maximum rise of the compressive strength and the density curve was observed at between 130 ^{0}C & 140 ^{0}C temperatures at 15 minutes of time period. With this action, the Waste EPS properties changed completely. The melted matter filled inside the structure leaving air voids on the uppermost surfaces of MEPS aggregates. The rate of increase in density and the compressive strength may differ according to type of unmodified waste EPS used. The increase in temperature up to 130-140 ^{0}C result in increase in density and the compressive strength. Continuing to these temperatures may result constant or decrease in density, but the compressive strength fall was observed. Hence it was noticed that, the heat treatment at 130 ^{0}C for 15 minutes of time period gives the optimum results and the MEPS density was less than 300 kg/m^3 and the compressive strength was up to 9 MPa.

Experimental Details

Several experimental studies had made on MEPS aggregate concrete series of sample specimens according to Indian Codes. The MEPS aggregates divided as MEPS CA & MEPS FA replaced to NCA & NFA individually at the levels of 0% to 100% at 10% interval by volume denoted by M1 to M10 & M11 to M 20 concretes and jointly at the levels of 0% and 100% by volume denoted by M0 and M21 concrete. The materials used, mix design and the results are as follows.

Materials

The modified EPS aggregates are divided with respect to their sizes as per IS 383:1970 and because of nominal size selected is 20 mm, the max. & min. sizes of MEPS coarse aggregates is 20 mm & 4.75 mm. with specific gravity factor 0.24 and lesser to 4.75 mm aggregates as MEPS fine aggregate with specific gravity factor 0.34. These specific gravity factor values are not a true specific gravity, because its value incorporates compensation for absorption of free water by the MEPS aggregates and it can be used in exactly the same way to calculate the aggregate volume relationship. MEPS aggregates consists of density less than 300 kg/m^3 and compressive strength is up to 9 MPa. MEPS are hydrophobic aggregates and they do not absorb water because it is consisting of about million closed cellular and the inside voids also filled with melted matter, but the MEPS Aggregates catches the water included to the voids on the surface thickness caused due to heat treatment process.

OPC 53 Grade chettinad brand cement confining to IS 12269:1987 code whose specific gravity is 3.15 (IS 2720 part 3) is used. The tests to know the physical properties like fineness (4%), Standard Consistency (31%), Initial setting time (120 min.), Final setting time (250 min.), soundness (3 mm) and compressive strength (53 MPa) are conducted and the test results satisfied the requirements of IS 4031 code. The crushed aggregate available from the local quarry was used as natural coarse aggregate (NCA) whose specific gravity is 2.73 with max. size 20 mm (Nominal size) and tested as per IS: 2386-1963(I, II, III) specifications. The fineness modulus of NCA observed was 4.60. Locally available sand collected from River Tungabhadra was used as natural fine aggregate (NFA) whose specific gravity is 2.65 with max. size 4.75 mm. and the sand is confirmed to Zone-II according to BIS. Tests are conducted on fine aggregate according to IS: 383-1987 and Fineness modulus & Bulk density observed is 2.81 & 1650 kg/m^3. Water used for mixing and curing was pure domestic water, conforming to IS 3025: 1964 part 22, part 23 and IS 456: 2000. BASF MasterGlenium Sky 8233 brand High-performance super plasticizer based on poly-carboxylic ether is used as water reducing agent. It is a Light brown colour liquid whose pH & specific gravity is 6 & 1.08, comply with ASTM C494 Type F.

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Mix Design

Mix design is similar as conventional concrete mix without grade designation, based on the previous investigation studies and several trails, the mix proportions are selected. Previous studies on EPS concrete concluded that there is need to increase the strength of mortar for low strength aggregates. Because of the variations in the amount and rate of free water, the true w/c ratio cannot always be determined accurately enough to be of practical value. Hence, after several trails, the W/C Ratio is fixed to 0.32 and min. & max. of effective water content, Volumes of aggregates values are taken from the codes IS 456:2000 & IS 10262:2009 for 20 mm nominal size. It is usually more practical to establish proportions by a series of trails mixtures proportioned on a cement content basis for the required degree of workability. The replacement calculations of MEPS to the natural coarse aggregate, the yield of concrete, additional quantity are based on the specific gravity factor to the total volume in litres. The MEPS aggregates become electro statically charged during process which makes them difficult to wet during mixing, Hence the MEPS Aggregates was immersed in water for 24 hours after weighing the required quantity to give them free water and are dried before they are introduced to mix. The prediction is difficult to make, since throughout the mixing process the effective water is progressively reduced through absorption by aggregate except when completely saturated aggregate is used. The free water do not participate in the chemical reaction but helps in internal curing. The effective water remains same quantity as calculated. BASF 8233 SP is generally used in self compacting concrete which is taken 1.5% of weight of cement. By the average of trails, effective water is reduced up to 29%.The Volume of NCA is required to increased by 0.02 for every w/c 0.10 lower when it is decreased from 0.50. The Volume of NCA & NFA per unit volume of Total Aggregate is 0.565 & 0.344. The MEPS coarse & fine aggregates is replaced in the place of natural coarse & fine aggregates by volume and the other ingredients are remains same in all 22 concrete mix samples. For each mix, the specimens of cubes (150 mm x 150 mm x 150 mm), cylinders (150 mm x 300 mm) and beams (500 mm x 100 mm x 100 mm) was casted. A Pan mixer of capacity 40kg is used for mixing of concrete which is done according to IS: 516-1959. Conventional techniques can be used for casting and placing. Because of less weight of aggregates, no vibrator is used and only hand compaction is done. The specimens are covered with wet gunny bags for 10 hours after casting, de-moulded after 24.5 hours and were kept immersed in a clean water tank for curing. After 28 days of water curing, the specimens were tested for compressive strength, split tensile strength and flexural strength. The arrangement for test as done as shown in the figure numbers 03 to 08.

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Figure No. 03: Cube before testing.

Figure No. 04: Cube after testing.

Figure No. 05: Cylinder before testing.

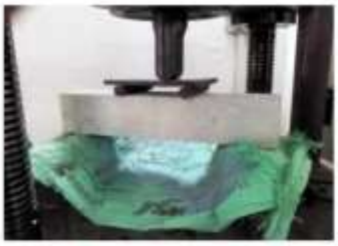

Figure No. 06: Cube before testing

Figure No. 07: Beam after testing

Figure No. 08: Cylinder after testing.

RESULTS AND DISCUSSIONS

Replacement of the MEPS aggregates to the Natural aggregates reduced compressive strength, split tensile strength, flexural strength and also density. The strengths and densities decreased with an increase in MEPS aggregate volume. Low specific gravity of the MEPS aggregates due to which there is a reduction in overall density of the concrete. Density affects the compressive strength, split tensile strength, flexural strength i.e., an increase in the density of the mix will increase its compressive strength, split tensile strength, flexural strength. This can be clearly understood and visualize by observing the following discussion on results, tables and the graphs in the following.

MEPS CA Replaced Concretes

The slump obtained for M0 concrete was 120 mm compared to 202 mm for the M10 concrete. Overall, The slump was increased from 120 mm to 220 mm with the MEPS CA replacement to NCA. The fresh density of M0 concrete was 2571 kg/m^3 compared to 1559 kg/m^3 for the M10 concrete. Density of the fresh concrete mix in MEPS CA concretes decreased from 2571 kg/m^3 to 1559 kg/m^3 in MEPS CA replacement to NCA. Density is the one of the most important parameters, which control many physical properties of the concrete. The density of M0 concrete was 2640 kg/m^3 compared to 1675 kg/m^3 for the M10 concrete. The compressive strength of M0 concrete was 58.51 MPa compared to 22.96 Mpa for the M10 concrete. These individual density and compressive strength of MEPS aggregate concrete at 100% replacement satisfies the strength and density requirements of structural light weight concrete applications. The split tensile strength of M0 was 3.72 Mpa compared to 2.09 Mpa for the M10 concrete. The flexural strength of M0 was 4.90 Mpa compared to 2.25 Mpa for the M10 concrete. The compressive strength is more sensitive than other properties of MEPS CA concretes and the density is directly proportional to the compressive strength, split-tensile strength and flexural strength.

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Table 1: Mix Proportions of MEPS CA Concretes

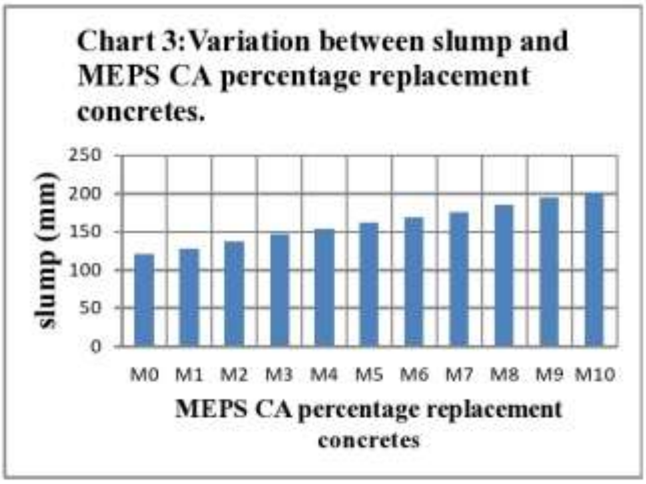
Mix No.	Replacement Details	Meps Ca (Kg/M³)	Meps Fa (Kg/M³)	Nca (Kg/M³)	Nfa (Kg/M³)	Cement (Kg/M³)	Water (Kg/M³)	Sp (Kg/M³)
M0	0% MEPS CA & MEPS FA	0	0	1226.83	624.48	437.50	139.98	6.07
M1	10% MEPS CA	10.78	0	1104.14	624.48	437.50	139.98	6.07
M2	20% MEPS CA	21.57	0	981.46	624.48	437.50	139.98	6.07
M3	30% MEPS CA	32.35	0	858.78	624.48	437.50	139.98	6.07
M4	40% MEPS CA	43.14	0	736.09	624.48	437.50	139.98	6.07
M5	50% MEPS CA	53.92	0	613.41	624.48	437.50	139.98	6.07
M6	60% MEPS CA	64.71	0	490.73	624.48	437.50	139.98	6.07
M7	70% MEPS CA	75.49	0	368.04	624.48	437.50	139.98	6.07
M8	80% MEPS CA	86.28	0	245.36	624.48	437.50	139.98	6.07
M9	90% MEPS CA	97.06	0	122.68	624.48	437.50	139.98	6.07
M10	100% MEPS CA	107.85	0	0	624.48	437.50	139.98	6.07

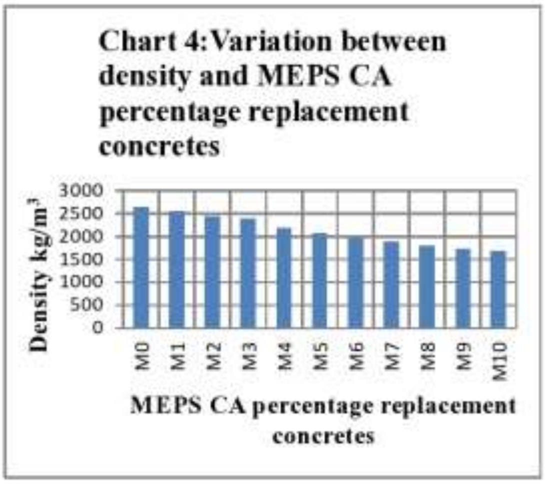
Table 2: Workability & Strength Results of MEPS CA Concretes

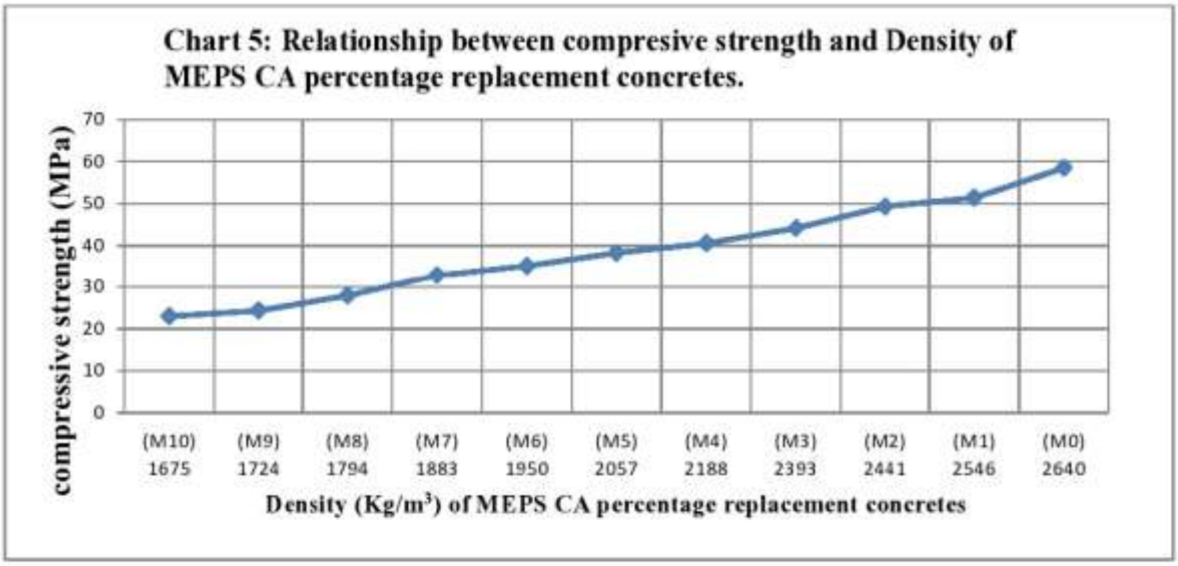
Mix No.	Replacement Details	Slump (Mm)	Fresh Density (Kg/M³)	Density (Kg/M³)	Compress-ive Strength (Mpa)	Split Tensile Strength (Mpa)	Flexural Strength (Mpa)
M0	0% MEPS CA & MEPS FA	120	2571	2640	58.51	3.72	4.90
M1	10% MEPS CA	128	2428	2546	51.40	3.46	4.78
M2	20% MEPS CA	137	2349	2441	49.33	3.11	4.24
M3	30% MEPS CA	146	2335	2393	44.14	2.97	3.92
M4	40% MEPS CA	153	2121	2188	40.58	2.78	3.64
M5	50% MEPS CA	162	1973	2057	38.26	2.52	3.28
M6	60% MEPS	168	1854	1950	35.17	2.41	3.05

European Journal of Material Sciences
Vol.4, No.3, pp.6-23, November 2017
Published by European Centre for Research Training and Development UK (www.eajournals.org)

	CA						
M7	70% MEPS CA	176	1781	1883	32.84	2.38	2.93
M8	80% MEPS CA	185	1685	1794	27.90	2.35	2.61
M9	90% MEPS CA	194	1612	1724	24.32	2.26	2.37
M10	100% MEPS CA	202	1559	1675	22.96	2.09	2.25







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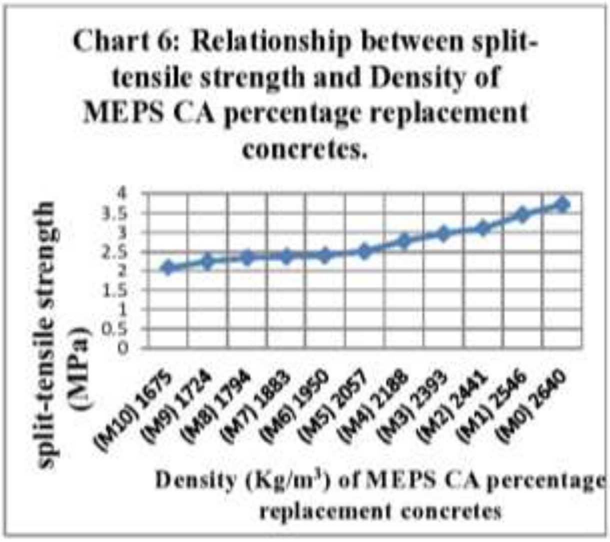
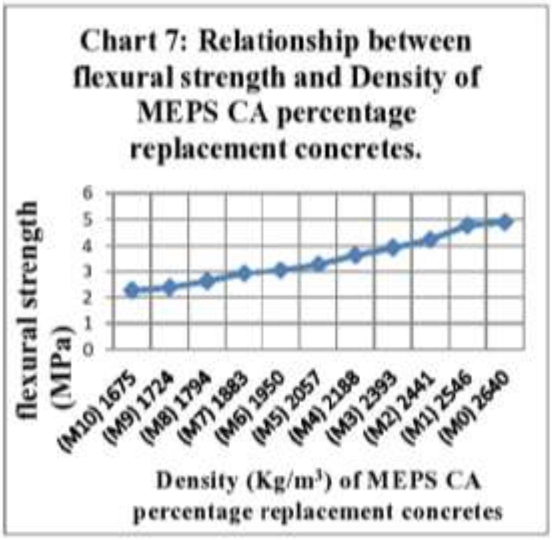




MEPS FA Replaced Concretes

The slump obtained for M0 concrete was 120 mm compared to 150 mm for the M20 concrete. Overall, The slump was increased from 120 mm to 150 mm with the MEPS FA replacement to NFA. The fresh density of M0 concrete was 2571 kg/m^3 compared to 1804 kg/m^3 for the M20 concrete. Density of the fresh concrete mix in MEPS CA concretes decreased from 2571 kg/m^3 to 1804 kg/m^3 in MEPS FA replacement to NFA. The density of M0 concrete was 2640 kg/m^3 compared to 1916 kg/m^3 for the M20 concrete. The compressive strength of M0 concrete was 58.51 MPa compared to 34.67 MPa for the M20 concrete. The split tensile strength of M0 was 3.72 MPa compared to 2.23 MPa for the M20 concrete. The flexural strength of M0 was 4.90 MPa compared to 2.33 MPa for the M20 concrete.

Table 3: Mix Proportions of MEPS FA Concretes

Mix No.	Replacement Details	Meps Ca (Kg/M^3)	Meps Fa (Kg/M^3)	Nca (Kg/M^3)	Nfa (Kg/M^3)	Cement (Kg/M^3)	Water (Kg/M^3)	Sp (Kg/M^3)
M0	0% MEPS CA & MEPS FA	0	0	1226.83	624.48	437.50	139.98	6.07
M11	10% MEPS FA	0	8.01	1226.83	562.03	437.50	139.98	6.07
M12	20% MEPS FA	0	15.99	1226.83	499.57	437.50	139.98	6.07
M13	30% MEPS FA	0	24.02	1226.83	437.11	437.50	139.98	6.07
M14	40% MEPS FA	0	32.02	1226.83	374.67	437.50	139.98	6.07
M15	50% MEPS FA	0	40.00	1226.83	312.24	437.50	139.98	6.07
M16	60% MEPS FA	0	48.05	1226.83	249.77	437.50	139.98	6.07

Print ISSN: 2055-8112(Print), Online ISSN: 2055-8120(Online)

M17	70% MEPS FA	0	56.05	1226.83	187.33	437.50	139.98	6.07
M18	80% MEPS FA	0	64.08	1226.83	124.87	437.50	139.98	6.07
M19	90% MEPS FA	0	72.08	1226.83	62.43	437.50	139.98	6.07
M20	100% MEPS FA	0	80.11	1226.83	0	437.50	139.98	6.07

Table 4: Workability & Strength Results of MEPS FA Concretes

Mix No.	Replacement Details	Slump (Mm)	Fresh Density (Kg/M^3)	Density (Kg/M^3)	Compressive Strength (Mpa)	Split Tensile Strength (Mpa)	Flexural Strength (Mpa)
M0	0% MEPS CA & MEPS FA	120	2571	2640	58.51	3.72	4.90
M11	10% MEPS FA	123	2469	2577	55.70	3.32	4.72
M12	20% MEPS FA	126	2424	2516	53.24	3.29	3.67
M13	30% MEPS FA	128	2391	2475	51.55	3.19	3.42
M14	40% MEPS FA	131	2289	2328	48.97	3.06	3.39
M15	50% MEPS FA	134	2239	2285	44.44	2.94	3.21
M16	60% MEPS FA	136	2094	2195	42.78	2.79	3.02
M17	70% MEPS FA	139	2028	2134	40.16	2.60	2.69
M18	80% MEPS FA	142	1958	2064	38.72	2.49	2.51
M19	90% MEPS FA	146	1887	1989	35.91	2.30	2.45
M20	100% MEPS FA	150	1804	1916	34.67	2.23	2.33

Chart 8: Variation between slump and MEPS FA percentage replacement concretes.

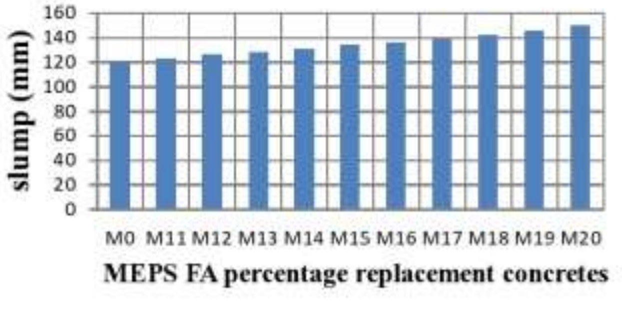
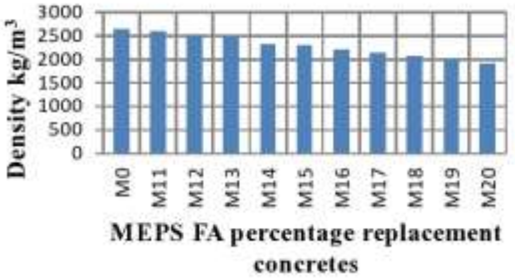


Chart 9: Variation between density and MEPS FA percentage replacement concretes



Print ISSN: 2055-8112(Print), Online ISSN: 2055-8120(Online)

European Journal of Material Sciences
Vol.4, No.3, pp.6-23, November 2017
Published by European Centre for Research Training and Development UK (www.eajournals.org)

Chart 10: Relationship between compresive strength and Density of MEPS FA percentage replacement concretes.

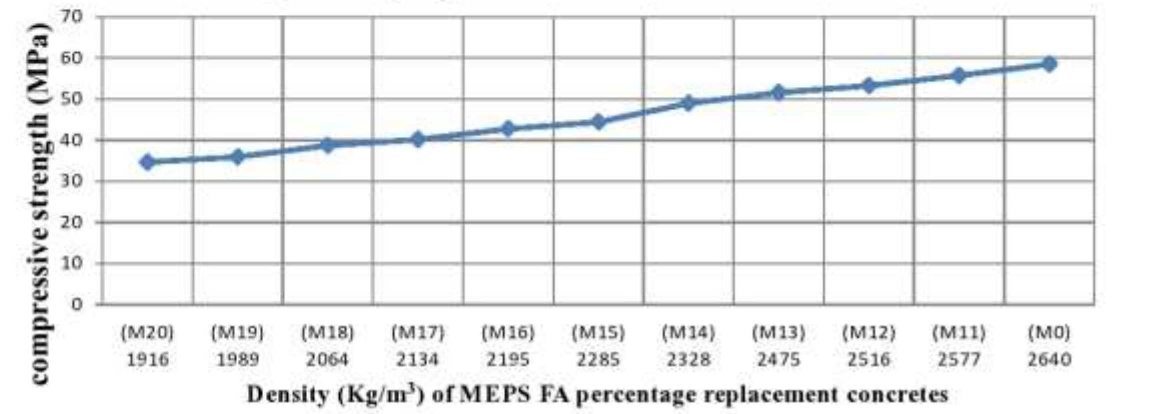


Chart 11: Relationship between split-tensile strength and Density of MEPS FA percentage replacement concretes.

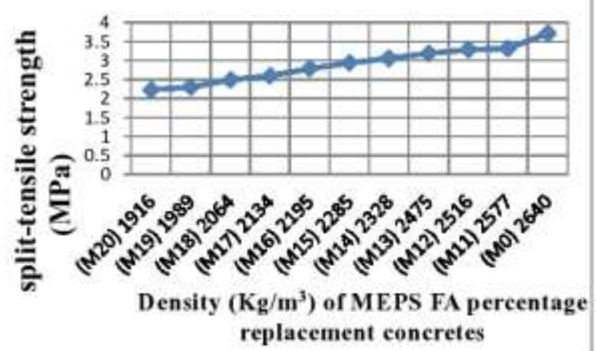
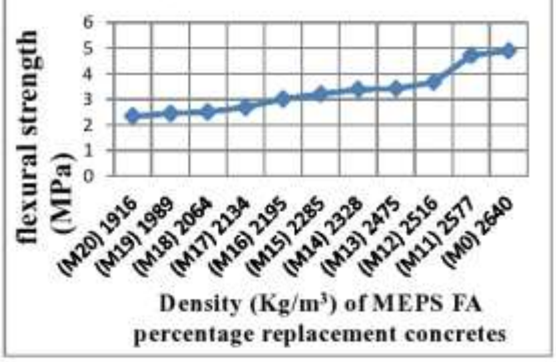


Chart 12: Relationship between flexural strength and Density of MEPS FA percentage replacement concretes.



MEPS CA & FA Replaced Concrete

The slump obtained for M0 concrete was 120 mm compared to 220 mm for the M21 concrete. Overall, The slump was increased from 120 mm to 220 mm with the MEPS CA & FA replacement to NCA & NFA. The fresh density of M0 concrete was 2571 kg/m^3 compared to 786 kg/m^3 for the M21 concrete. Density of the fresh concrete mix in MEPS CA & FA concretes decreased from 2571 kg/m^3 to 786 kg/m^3 in MEPS CA & FA replacement to NCA & NFA. The density of M0 concrete was 2640 kg/m^3 compared to 864 kg/m^3 for the M21 concrete. The compressive strength of M0 concrete was 58.51 MPa compared to 18.85 MPa for the M21 concrete. The split tensile strength of M0 was 3.72 MPa compared to 1.94 MPa for the M21 concrete. The flexural strength of M0 was 4.90 MPa compared to 2.04 MPa for the M21 concrete.

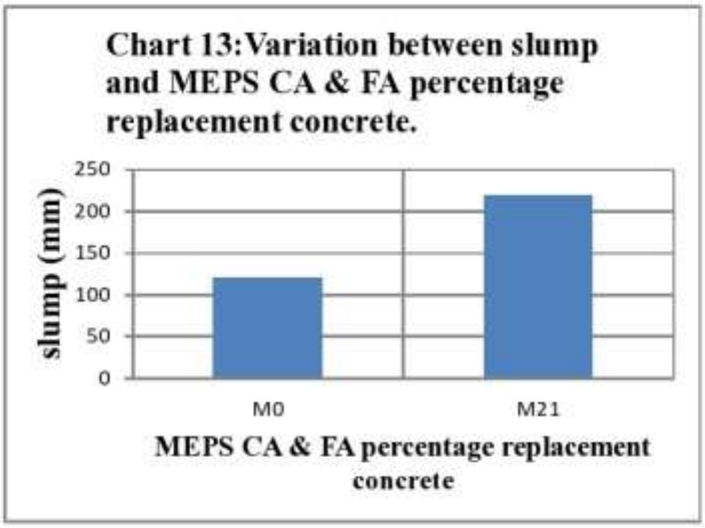
Print ISSN: 2055-8112(Print), Online ISSN: 2055-8120(Online)

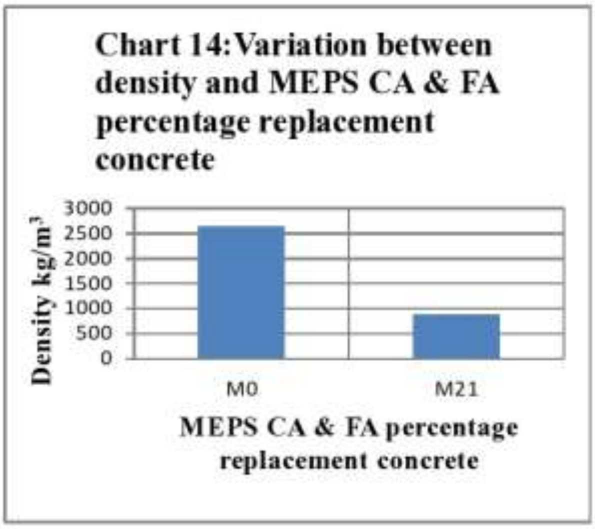
Table 5: Mix Proportions of MEPS CA & FA Concretes

Mix No.	Replacement Details	Meps Ca (Kg/M^3)	Meps Fa (Kg/M^3)	Nca (Kg/M^3)	Nfa (Kg/M^3)	Cement (Kg/M^3)	Water (Kg/M^3)	Sp (Kg/M^3)
M0	0% MEPS CA & MEPS FA	0	0	1226.83	624.48	437.50	139.98	6.07
M21	100% MEPS CA & MEPS FA	107.85	80.11	0	0	437.50	139.98	6.07

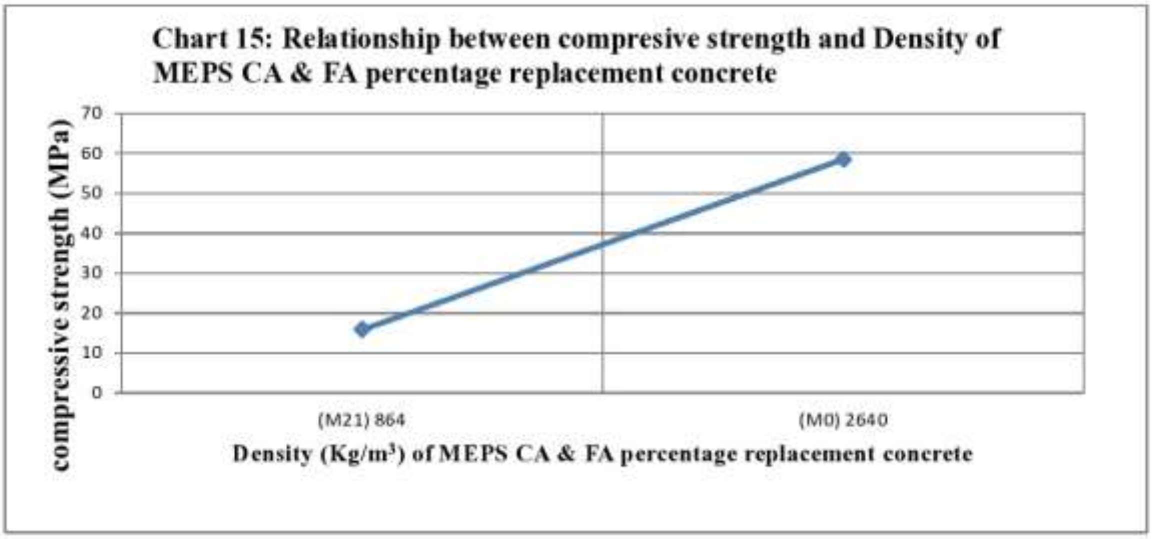
Table 6: Workability & Strength Results of MEPS CA & FA Concretes

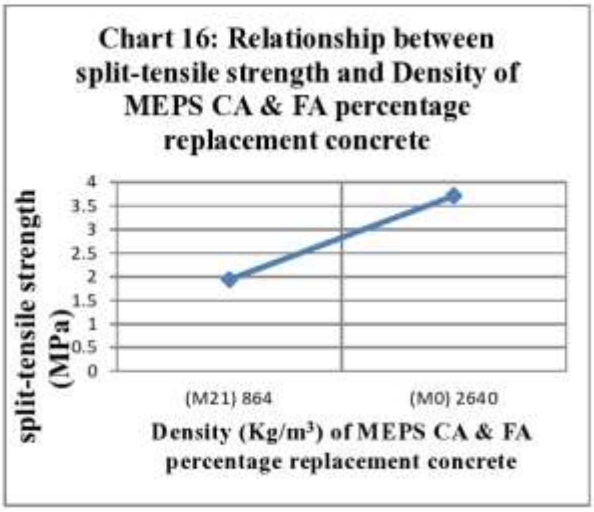
Mix No.	Replacement Details	Slump (Mm)	Fresh Density (Kg/M^3)	Density (Kg/M^3)	Compressive Strength (Mpa)	Split Tensile Strength (Mpa)	Flexural Strength (Mpa)
M0	0% MEPS CA & MEPS FA	120	2571	2640	58.51	3.72	4.90
M21	100% MEPS CA & MEPS FA	220	786	864	15.85	1.94	2.04

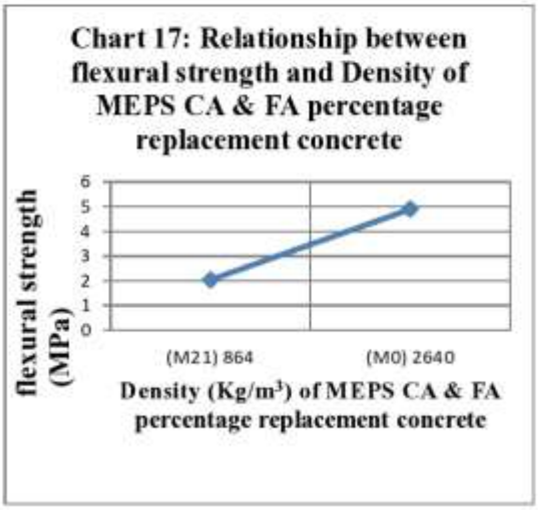




Print ISSN: 2055-8112(Print), Online ISSN: 2055-8120(Online)







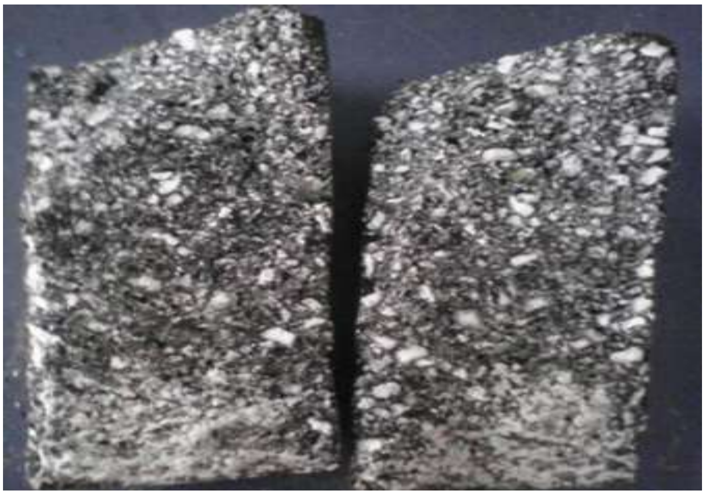


Figure 09: Failure of M21 Concrete cylinder

Print ISSN: 2055-8112(Print), Online ISSN: 2055-8120(Online)

Table No. 07: Comparison of EPS & MEPS Concretes

References	Concrete Mix	Density (Kg/M^3)	Compressive Strength (Mpa) At 28 Days	Split Tensile Strength (Mpa) At 28 Days	Flexural Strength (Mpa) At 28 Days
Kan [13]	EPS+C	464-1370	0.11-8.53	-	-
Babu [11]	EPS+FA+S+C	585-984	0.10-3.83	-	-
Babu[21]	EPS+C+S+FA	582	1.1	-	-
Park [22]	EPS+S+C	820	3.8	-	-
Chen [23]	EPS+NA+C	876	10.6	1.32	-
Babu [10]	EPS+NA+SF+C	1552	10.2-21.4	1.5-2.16	-
Miled [24]	EPS+S+C	1810	7.6-8.5	-	-
Muravljov [25]	EPS+S+PP+C	1130-1484	7.73-14.62	-	-
Laukaitis [26]	EPS+C	149-275	-	0.25	-
Sabaa [27]	EPS+C+NA	1600-2000	8.8-21.3	-	-
Ravindrarajah [28]	EPS+C+NA	1100-1920	8.5-37.5	0.92-4.05	-
Abdulkadir [29]	MEPS+C	980	12.58	1.82	-
	MEPS+C+NA	1734	17.65	2.38	-
Present study	MEPS FA+NCA+C	1916	34.67	2.23	2.33
	MEPS CA+NFA+C	1675	22.96	2.09	2.25
	MEPS CA & FA+C	864	15.85	1.94	2.04

Abbreviations: NA: Natural Aggregates; NCA: Natural Coarse Aggregates; NFA: Natural Fine Aggregate; EPS: Unmodified Expanded Polystyrene; MEPS: Modified Expanded Polystyrene, MEPS CA: Modified Expanded Polystyrene Coarse Aggregate, MEPS FA: Modified Expanded Polystyrene Fine Aggregate, FA: Fly Ash, C: Cement, S: Natural Sand, SF: Silica Fume, PP: Polypropylene.

CONCLUSIONS

The following conclusions were made from the study:

- By using EPS waste for MEPS aggregate production not only solves the EPS disposal problems, but also helps to preserve natural resources. A new recycling technology to shrink waste EPS was developed by using Heat Treatment Method. Complete replacement of MEPS aggregates with natural aggregates in conventional concrete gives maximum usage of EPS. Particle size distribution of MEPS CA & FA differs from NCA & NFA, but it can be equalize as per code specifications.
- The pre-wetted MEPS aggregates exhibited retarding action. All the pre-wetted MEPS aggregate concretes without any special bonding agent exhibited good workability and

Print ISSN: 2055-8112(Print), Online ISSN: 2055-8120(Online)

it was easy to compact and finish. Workability increases with the increase in pre-wetted MEPS aggregate volume.

- Increase in the MEPS CA & FA volume reduces the compressive strength, split tensile strength, flexural strength and density of the conventional concrete. The compressive strength, split tensile strength and flexural strength is directly proportional to the density of the MEPS aggregate concrete. Compressive strength is more sensitive to the density compared to split tensile strength and flexural strength in MEPS aggregate concretes.

- M10 concrete can be used as Light weight structural concrete as it suits all the requirements and can apply in high rise buildings, offshore structures and long span bridges. M20 concrete can be used for semi-structural applications like shear walls and M21 concrete has scope for non structural applications, like wall panels, partition walls, Aesthetic Decors,Sun Shades, Custom made wardrobes, False Ceilings, thermal & sound insulation etc.

- In Concrete construction, Self Weight represents a very large portion of the load on the Structure and MEPS concrete can reduce the self weight up to 60% and are considerably advantages in reducing the cross-section dimensions of beams, columns & footing. This will have the double advantage of reduction in the cost of construction materials and also cost of waste disposal.

SCOPE FOR THE FUTURE STUDY

The following proposals are made for future study

- Silica fume addition to M21 concrete to develop compressive strength.
- The present study can be extended to investigate other properties such as the water absorption and/or permeability.
- Reinforcement protection and bond.
- Acoustic information e.g. sound transmission class.
- Compaction techniques for full scale applications.
- self-compacting reinforced MEPS aggregate concretes.
- Freezing resistance, Thaw resistance and Fire performance.
- Durability aspects such as, Sulphate resistance, Alkali resistance, RCPT (Rapid Chloride Penetration Test), can also be investigated.
- The superplasticizer content was kept constant in the present study; by varying the superplasticizer content, effect of water/cement ratio and compressive strength can be compared at different ages.
- The study can be further extended by incorporating other filler materials like silica fume, Rice Husk Ash etc, and studying chloride resistance of these supplementary materials.

Acknowledgement

The Author is thankful to the authorities of the department of civil engineering, G. Pulla Reddy Engineering College, Kurnool City, India for the facilities and guidance to carry out this research work.

REFERENCES

[1] IS 383:1970 "Specifications for coarse and fine aggregates from natural sources for concrete", Bureau of Indian Standards, New Delhi.
[2] Is 456:2000 - "Code of practice for plain and reinforced concrete", Bureau of Indian Standards, New Delhi.
[3] IS 516:1959, (Reaffirmed 1999) “Methods of Test for Strength of Concrete”, Bureau of Indian Standards, New Delhi.
[4] IS 2386:1963, “Methods of tests for aggregates for concrete”, Bureau of Indian Standards, New Delhi.
[5] IS: 12269:1987, "Specification for 53 grade ordinary Portland cement" Bureau of Indian Standards, New Delhi.
[6] IS: 10262:1982, "Recommended guidelines for concrete mix design" Bureau of Indian Standards, New Delhi.
[7] IS 4031:1999, "Methods of physical tests for Hydraulic cement"
[8] Handbook on concrete mixes, SP 23-1982, Bureau of Indian Standards, New Delhi.
[9] http://www.sciencedirect.com
[10] Babu, K.G., Babu, D.S., 2003. Behavior of lightweight expanded polystyrene concrete containing silica fume. Cement and Concrete Research 33, 755–762.
[11] Babu, K.G., Babu, D.S., 2004. Performance of fly ash concretes containing lightweight EPS aggregates 26, 605–611.
[12] Hantila, F., Maricaru, M., Popescu, C., Ifrim, C., Ganatsios, S., 2007. Performances of a waste recycling separator with permanent magnets. Journal of Materials Processing Technology 181, 246–248.
[13] Kan, A., Demirboga, R., 2007. Effect of cement and EPS beads ratios on compressive strength and density of lightweight concrete. Indian Journal of Engineering & Materials Sciences 14, 158–162.
[14] http://www.elsevier.co.in/web/default.aspx
[15] Neville, A.M., "Properties of concrete", long man group limited, fourth and final edition, 2000, p.831
[16] A text book of "concrete Technology" by M.S.Setty.
[17] A text book of "concrete Technology" by M. L. Ghambir.
[18] A text book of "concrete Technology" by S. Chand.
[19] Vivian, W.Y., Tam, C.M., 2006. Evaluations of existing waste recycling methods: a Hong Kong study. Building and Environment 41, 1649–1660.
[20] Yanhong, L., Yunge, F., Jianbiao, M., 2001. Thermal, physical and chemical stability of porous polystyrene-type beads with different degrees of crosslinking. Polymer Degradation and Stability 73, 163–167.
[21] Babu DS, Babu KG, Wee TH. Properties of lightweight expanded polystyrene aggregate concretes containing fly ash. Cem Concr Res 2005;35(6):1218–23.
[22] Park SG, Chilsholm DH. Polystyrene aggregate concrete. Building Research Association of New Zealand, study report, SR 85 Judgeford; 1999.

[23] Chen B, Liu J. Properties of lightweight expanded polystyrene concrete reinforced with steel fiber. Cem Concr Res 2004;34(7):1259–63.
[24] Miled K, Le Roy R, Saab K, Boulay C. Compressive behavior of an idealized EPS lightweight concrete: size effects and failure mode. Mech Mater 2004;36(11):1031–46.
[25] Muravljov M, Jevtic D, Radosavljevic V. The application of EPS concrete reinforced with polypropilene fibres for the production of precast elements. 9. In: Congress of Yugoslav civil engineers alliances, Cavtat; 1991. 09–12.
[26] Laukaitis A, Zurauskas R, Keriene J. The effect of foam polystyrene granules on cement composite properties. Cem Concr Compos 2005;27(1):41–7.
[27] Sabaa B, Ravindrarajah RS. Engineering properties of lightweight concrete containing crushed expanded polystyrene waste. In: Materials research society, fall meeting, symposium MM, advances in materials for cementitious compos, Boston, USA; 1–3 December 1997.
[28] Ravindrarajah SR, Camporeale MJ, Caraballo CC. Flexural creep of ferrocement. In: Polystyrene concrete composite, second international conference on advances in composites, Bangalore, India; 18–20 December 1996.
[29] Abdulkadir Kan, Ramazan Demirboga. A novel material for lightweight concrete production. In: elsevier journal of Cement & Concrete Composites 31 (2009) 489–495.
[30] News Papers on EPS waste disposal issues.