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RESEARCH ARTICLE

DEVELOPMENT OF LOW STRENGTH AND GEOPOLYMER CONCRETE MIX UTILIZING DEMOLISHED AGGREGATE.

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Abstract

In this study the potential for using demolition aggregate for lean-mix of cement concrete and geopolymer concrete are investigated. To reduce the production cost of concretes and for reuse of demolished concrete, this study is undertaken. The effects of incorporating demolished aggregates in low strength and geopolymer concrete mixes, on physical and structural properties such as water absorption, split tensile strength, compressive strength, etc., are investigated. This paper identifies various influencing aspects related to the use of demolished aggregates such as replacement level, aggregate sizes, as well as mixing procedure, strength development over time, etc.. In the present study, the lean concrete mixes were prepared in the ratio 1:6:8 with the cement content of 175 and 200 kg/m³, and geopolymer mix with 3M, 4M, 5M and 6M molar concentration. Systematic comparison was carried-out between different types of lean cement concretes and geopolymer concretes, with the experimental test results.

Introduction:-

Reusing, Recycling and Regenerating, this become the very effective principle and method in everyday use and become practice of common people to adapt to the principle of saving. Thus the recycling of wastes has long been accepted to have the possible ways and means to conserve natural resources and to decrease energy used in its production and fit into present day motto of Reusing, Recycling and Regenerating. The use of recycledmaterials in high rather than low-grade applications must alsobe a priority in the near future. In order to be successful in thisapproach, the correct choice of materials, recycling proceduresand manufacturing processes is fundamental.The amount of construction and demolition waste has increased enormously over the last decade in the world, especially in the developing countries like China and India. Recycling of the waste concrete is beneficial and necessary for both environmental preservation and effective utilization of nonrenewable natural resources.

Demolished concrete aggregate (DCA) is generally produced by the crushing of concrete rubble, screening then removal of contaminants such as reinforcement, paper, wood, plastics and gypsum. Concrete made with such demolished concrete aggregate is called demolished aggregate concrete (DAC).

AkashRao, Kumar N. Jha , Sudhir Misra[2] carried out different aspects of the problem beginning with a brief review of the international scenario in terms of C&D waste generated, recycled aggregates (RA) produced from C&D waste and their utilization in concrete and governmental initiatives towards recycling of C&D waste. Along with a brief overview of the engineering properties of recycled aggregates, the paper also gives a summary of the effect of use of recycled aggregate on the properties of fresh and hardened concrete. The paper concludes by identifying some of the major barriers in more widespread use of RA in recycled aggregate concrete, including lack of awareness, lack of government support, non-existence of specifications/codes for reusing these aggregates in new concrete. Ashraf M. Wagih, Hossam Z. El-Karmoty, Magda Ebid, Samir H. Okba[5] carried out the use of recycled aggregatein concrete can be useful for both environmental and economical aspects in the construction industry. This study discusses the possibility to replace natural coarse aggregate (NA) with recycled concrete aggregate (RCA) in structural concrete. Aggregates used in the study were: natural sand, dolomite and crushed concretes obtained from different sources. A total of 50 concrete mixes forming eight groups were cast.Groups were designed to study the effect of recycled coarse aggregates quality/content, cement dosage,use of super plasticizer and silica fume. Tests were carried out for: compressive strength, splitting strength and elastic modulus. The results showed that the concrete rubble could be transformed into useful recycled aggregate and used in concrete production with properties suitable for moststructural concrete applications in Egypt. A significant reduction in the properties of recycled aggregate concrete made of 100% RCA was seen when compared to natural aggregate concrete, while the properties of RAC made of a blend of 75% NA and 25% RCA showedno significant change in concrete properties.VanchaiSata, AmpolWongsa, Prinya Chindaprasirt[7] carried out that the use of recycled aggregates for making pervious geopolymer concrete wasstudied. Pervious geopolymer concrete were prepared from high-calcium fly ash, sodium silicate solution, sodiumhydroxide solution, and two different types of recycled aggregate viz., crushed structural concrete member and crushed clay. The results were also compared with those of natural coarse aggregate. Compressive strength, splitting tensile strength, total void ratio, and water permeability coefficient of the pervious geopolymer concrete were determined. The results indicate that both crushed structural concrete member and crushed clay bricks can be used as recycled coarse aggregatesfor making pervious geopolymer concrete with acceptable properties.

Material properties:-

Cement:-

The Portland Pozzolana Cement (PPC) is a kind of Blended Cement which is produced by either intergrinding of OPC clinker along with gypsum and pozzolanic materials in certain proportions or grinding the OPC clinker, gypsum and Pozzolanic materials separately and thoroughly. Pozzolana is a natural or artificial material containing silica in a reactive form. It may be further discussed as siliceous or siliceous and aluminous material which in itself possesses little, or no cementitious properties but will in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. It is essential that pozzolana be in a finely divided state as it is only then that silica can combine with calcium hydroxide (liberated by the hydrating Portland cement) in the presence of water to form stable calcium silicates which have cementitious properties. The cement used in this experimental investigation is PPC conforming to IS 1489 (Part 1) 1991.

Table.1: physical properties of cement

S.No	Physical Properties of cement	Results
1.	Specific Gravity	2.75
2.	Fineness	6.96%
3.	Standard Consistency	33.33%
4.	Initial setting time	42 min
5.	Final setting time	343 min

Fly Ash:-

Fly ash are extracted from flue gases of ground or pulverized or crushed coal or lignite fired boilers by any suitable process such as by cyclone separation or electrostatic precipitation, bottom ash from the boilers shall not be added to the fly ash. Fly ash collected at later stages of electrostatic precipitator are finer than the fly ash collected at initial stages of electrostatic precipitator. The fly ash used in the presentinvestigation is low calcium fly ash referred as Class–F fly ash.

Table.2: Physical properties of fly ash

S.No	Physical Property of fly ash	Results
1.	Specific Gravity	2.31
2.	Chemical Composition	SiO_2 54.6% Al_2O_3 28.8% Fe_2O_3 7.9% CaO 1.9% L.O.I 2%

GGBS:-

It is obtained by quenching molten iron slag from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. It replacement enhances lower heat of hydration, higher durability and higher resistance to sulphate and chloride attack when compared with normal ordinary concrete.

Table.3: Physical properties of ggbs.

S.No	Physical Properties of cement	Results
1.	Specific Gravity	2.75
2.	Chemical Composition	SiO_2 35.00 Fe_2O_3 0.5 Al_2O_3 10 CaO 37.00 MgO 8 MnO 0.07 S_2 0.54

Fine aggregate:-

Fine aggregate used in this investigation is clean river sand without impurities like clay, shell and organic matters passing through 4.75mm sieve. The fine aggregate were tested as per IS 383-1970 conforming to zone - II.

Table.4: Physical properties of fa

S.No	Physical Properties of FA	Results
1.	Specific Gravity	2.6
2.	Fineness Modulus	2.9

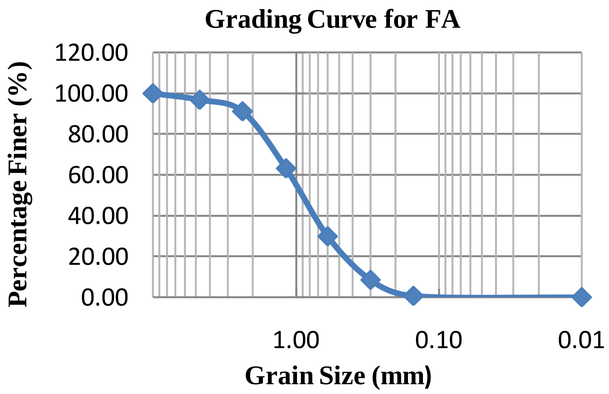

Fig.1 Grading Curve for FA

Coarse aggregate:-

The material retained on 4.75mm sieve is termed as coarse aggregate. Crushed stone and natural gravel are the common materials used as coarse aggregate for concrete. Well graded angular aggregate is use and the maximum size of aggregate is 20 mm and 12.5mm. The coarse aggregate were tested as per IS 383-1970.

Table.5: Physical properties of ca.

S.No	Physical Properties of CA		Results
1.	Specific Gravity	20 mm	3.14
		12.5 mm	2.65
2.	Fineness Modulus	20 mm	7.08
		12.5 mm	6.46

Demolished Aggregate:-

Recycled aggregate is produced by crushing concrete, and sometimes asphalt, to reclaim the aggregate. Recycled aggregate can be used for many purposes. The primary market is road base.As a result of these activities, old construction are being demolished to make new buildings. Due to this large scale demolitions huge amount of debris is generated all over the world which causes serious environmental pollution including disposal problems. Using demolition waste as an aggregate in the preparation of new concrete has immense potential and it has been the object of investigation for a long time.Using this aggregate can reduce the natural aggregate and the problem of mining them. The demolished aggregate used in this investigation is fine aggregate of size 4.75 mm and coarse aggregate of size 20 mm and 12.5 mm was crushed using jaw crusher for required size as mentioned above.

Fig.2 Jaw Crusher

Fig.3 Demolished Aggregate.

Table.6: Physical properties of da.

S.No	Physical Properties of DA			Results
1.	Specific Gravity	FA		2.49
		CA	20 mm	2.98
			12.5 mm	2.44
2.	Fineness Modulus	FA		2.82
		CA	20 mm	6.91
			12.5 mm	6.26

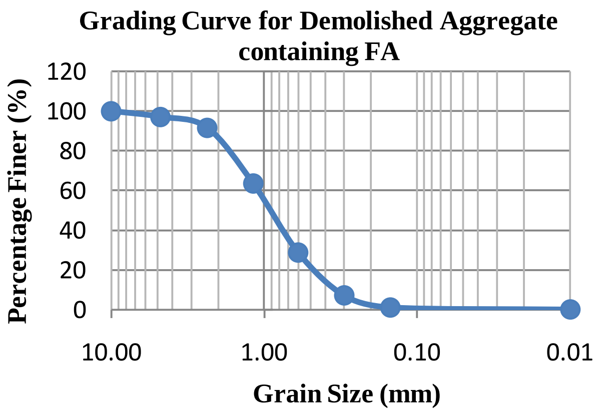

Fig.4 Grading Curve for Demolished aggregate containing FA

Preparation Of Alkaline Solution:-

Fig.5 Preparation Of Alkaline Solution With 3, 4, 5, 6Molar Concentration.

Alkaline solution are prepared as per the basic standard. In this study 3, 4, 5, 6 molar concentration is prepared. For that 120, 160, 200, 240 grams [3*40 = 120 g and same as for 4, 5 and 6 molarity is also prepared, where 40 is the molecular weight of NaOH] of NaOH pellets are made up in 1 litre of distilled water. The ratio of Na2SiO3 to NaOH is chosen as 2.5. This solution must be prepared 24 hours prior to the use.

Experimental details:-

Mix Proportions:-

The low strength concrete mix such as 1:6:8, 1:6:10, 1:7:10 ratio are taken with w/c ratio 0.6 with different cement content as 125 kg/m³, 150 kg/m³, 175 kg/m³ and 200kg/m³.As there is no appropriate mix design for low strength concrete mix, the ratio's are assumed as per IS 10262:2009. The fine aggregate of size 4.75mm and coarse aggregate of size as 40% of 20mm & 60% of 12.5mm are taken and are replaced by demolished aggregate such as 1/3rd and 2/3rd for FA and 1/3rd, 2/3rd and 100% for CA.

From the experimental test result it has been seen that the mix 1:6:8 with 175 and 200 kg/m³ has attained the maximum strength of 10 N/mm^2. Table.7 and 8 give the various proportion with different replacement.

The Geopolymer concrete mix is made with different molarities such as 3M, 4M, 5M and 6M. From the test result we take 6M with different % replacement of demolished aggregates is given in Table.9.

Table.7: Mix proportion for the ratio 1:6:8 with 175 kg/m³ cement content.

Assigned Name	**Cement kg/m³**	**FA kg/m³**	**CA kg/m³**		**DCA kg/m³**			**% of replacement**		**w/c ratio**
			20 mm	12.5 mm	FA	CA 20 mm	CA 12.5 mm	CA	FA	
M_1	175	1050	560	840	-	-	-	0	0	0.6
M_1A	175	897.54	375.2	562.8	152.46	184.8	277.2	33	33	0.6
M_1B	175	745.08	375.2	562.8	304.92	184.8	277.2	66	33	0.6
M_1C	175	745.08	190.4	258.6	304.92	369.6	554.4	33	66	0.6
M_1D	175	440.16	190.4	285.6	609.84	369.6	554.4	66	66	0.6
M_1E	175	588	0	0	465	560	840	33	100	0.6
M_1F	175	126	0	0	924	560	840	66	100	0.6

Table.8: Mix proportion for the ratio 1:6:8 with 200 kg/m³ cement content.

Assigned Name	**Cement kg/m³**	**FA kg/m³**	**CA kg/m³**		**DCA kg/m³**			**% of replacement**		**w/c ratio**
			20 mm	12.5 mm	FA	CA 20 mm	CA 12.5 mm	CA	FA	
M_2	200	1200	640	960	-	-	-	0	0	0.6
M_2A	200	1025.76	428.8	643.2	174.24	211.2	316.8	33	33	0.6
M_2B	200	851.52	428.8	643.2	348.48	211.2	316.8	66	33	0.6
M_2C	200	851.52	217.6	326.4	348.48	422.4	633.6	33	66	0.6
M_2D	200	503.04	217.6	326.4	696.96	422.4	633.6	66	66	0.6
M_2E	200	672	0	0	528	640	960	33	100	0.6
M_2F	200	148	0	0	1056	640	960	66	100	0.6

Table.9: Mix proportion for geopolymer concrete.

Molarity	Flyash kg/m³	FA kg/m³	CA kg/m³		NaOH kg/m³	Na_2SiO_3 kg/m³
			20 mm	12.5 mm		
3M	406.15	561.6	524.16	786.24	0.84	1.68
4M	406.15	561.6	524.16	786.24	1.12	2.24
5M	406.15	561.6	524.16	786.24	1.40	2.8
6M	406.15	561.6	524.16	786.24	1.68	3.36

Casting and curing of specimens:-

The required mix such as lean and geopolymer concrete has been mixed as per the ratio in table 7, 8, 9. These materials are mixed together, and then they are conveyed to cube mould of size 150 mm* 150 mm* 150mm, cylinder mould of size 150mm*300mm and was compacted using vibrating table. For each mix of lean concrete, six cubes and six cylinders were casted and three cubes and three cylinders were casted for geopolymer concrete. After casting, the specimens were kept for 24 hours at ambient temperature and then demoulded. They were cured under water for 7 days and 28 days and tests have been conducted. Before testing for compressive strength of lean mix, the same cube specimens were utilized to evaluate the water absorption of concrete at 7 days and 28 days. The six cylinders of lean mix were utilizedfor split tensile strength test at 7 days and 28 days.

Fig.6 Mixing of materials.

Fig.7 Casting of cubes and Cylinders of lean mix.

Fig.8 Casting of cubes and Cylinders of geopolymer mix.

Fig.9 Curing of Specimens.

Testing of specimens:-

Workability of concrete:-

Fig.10 Slump Test.

The workability was determined as per IS 1199 – 1959 for various mix proportions of demolished aggregate are shown in Table.10.

Table.10:slump test values.

Assigned Name	Slump (cm)
M_1	26
M_2	27.1
M_1A	28.3
M_2A	29
M_1B	29.4
M_2B	29.9
M_1C	30.7
M_2C	31.3
M_1D	31
M_2D	32
M_1E	32.1
M_2E	33.2
M_1F	33
M_2F	34

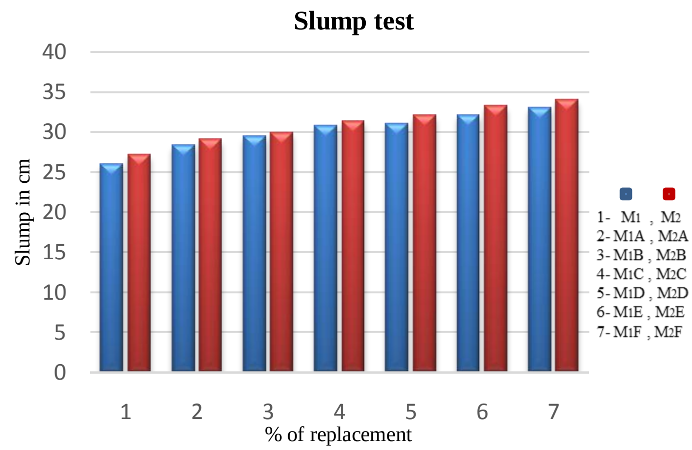

Fig.11: Graphical representation of Slump Test

Water Absorption test:-

Fig.12: Water Absorption test.

The determination of water absorption of the prepared sampleswas carried out as per standard practice.

$$Waterabsorption = \frac{wetweight - dryweight}{dryweight}$$

Table.11:water absorption test values.

Assigned Name	Water Absorption (%) 7 days
M_1	1.92
M_2	2.13
M_1A	2.09
M_2A	2.27
M_1B	2.13
M_2B	2.34
M_1C	2.26
M_2C	2.43
M_1D	2.33
M_2D	2.51
M_1E	2.57
M_2E	2.66
M_1F	2.69
M_2F	2.74

Compressive strength test:-

Fig.13: Compression test set up **Fig.14**: Crack pattern

The compressive strength were determined as per IS 516-1959. The cubes were tested for 7 days and 28 days for the various mix proportion as mentioned in table.12 with the rate of loading as 140 kg/cm^2/min and calculated by the formula given below,

$$compressivestrength, N/mm^2 = \frac{\max\ loadatfailure * 1000}{loadedsurfacearea}$$

Table.12:compressive strength test values.

Assigned Name		Compressive strength in N/mm^2	
Lean concrete	**Geopolymer concrete**	**7 days**	
M_1	3M	9.8	5.1
M_2		11.9	
M_1A	4M	8.53	7.16
M_2A		11.2	
M_1B	5M	7.7	8.66
M_2B		10.7	
M_1C	6M	7	10.7
M_2C		10.3	
M_1D		6.44	
M_2D		9.77	
M_1E		6.05	
M_2E		8.89	
M_1F		5.71	
M_2F		7.77	

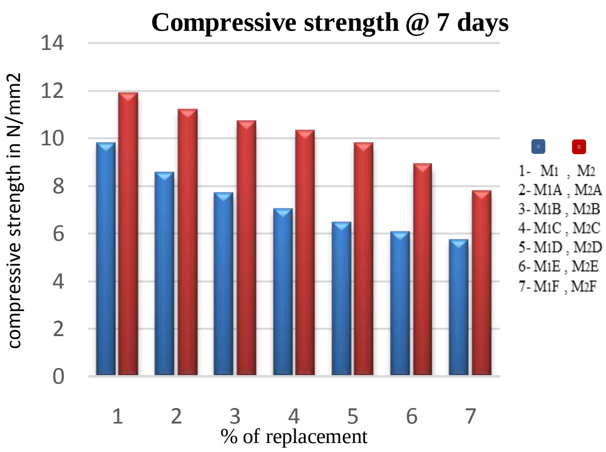

Fig.15: Graphical representation of compressive strength.

E. Split Tensile test


Fig.16: Split Tensile test set up.**Fig.17:** Crack pattern.

The split tensile strength were determined as per IS 5816: 1999. The cylinders were tested for 7 days and 28 days for the various mix proportion as mentioned in table.13 with the rate of loading as 2.3 $N/mm^2/min$ and calculated by the formula given below,

$$split\ tensile\ strength, N/mm^2 = \frac{2 * breaking\ load}{\pi * dia.of\ cylinder * L}$$

Table.13split tensile strength test values.

Assigned Name		Split Tensile strength in N/mm^2	
Lean concrete	**Geopolymer concrete**	**7 days**	
M_1	3M	0.82	0.43
M_2		1.11	
M_1A	4M	0.68	0.51
M_2A		0.94	
M_1B	5M	0.57	0.67
M_2B		0.8	
M_1C	6M	0.48	0.78
M_2C		0.71	
M_1D		0.35	
M_2D		0.56	
M_1E		0.24	
M_2E		0.43	
M_1F		0.15	
M_2F		0.33	

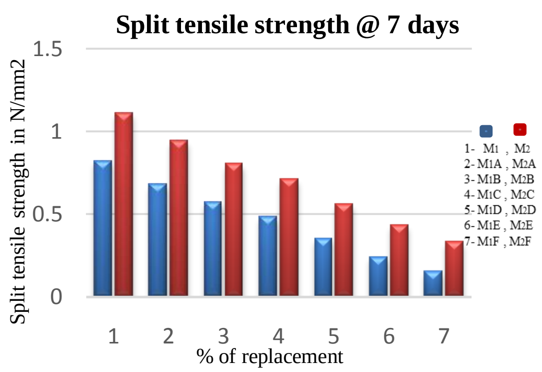

Fig.18: Graphical representation of split tensile strength.

Conclusion:-

- From the test result we observe that the slump value increases with increase in demolished aggregate.
- Water absorption capacity increases when the amount of demolished aggregate increases.
- The compressive and split tensile strength decreases with respect to demolished aggregate.
- When compared to the above results, 200kg/m^3 cement content is increased with respect to 175kg/m^3 cement content.
- The geopolymer concrete mix with 6M attains the same strength of lean concrete mix when compared to 3M, 4M and 5M.

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