Experimental Study on Structural Light Weight Concrete for Partial Replacement to Coarse Aggregate by Sintered Fly Ash Aggregate

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Abstract- The use of Lightweight concretes has gained acceptance and popularity worldwide in the recent years in the construction and development of both the infrastructure and residential buildings. Light weight aggregate concrete has become more popular in recent advancements owing to the tremendous advantages it offers over the conventional concrete but at the same time light in weight and strong enough to be used for structural purposes. Replacement of natural aggregate with concrete such as light weight concrete by using sintered fly ash aggregate (natural aggregate), The main disadvantage of conventional concrete it is high self -weight. This heavy self-weight will make it to some extent an uneconomical structural material. Light weight concrete having low density facilitates reduction of dead load and to increase thermal insulation.

I. INTRODUCTION

A. Review Stage Importance of Aggregate

Aggregate in concrete is structural filler, but its role is more important than what that simple statement implies. Aggregate occupies most of the volume of the concrete. It is the stuff that the cement paste coats and binds together.

The composition, shape, and size of the aggregate all have significant impact on the workability, durability, strength, weight, and shrinkage of the concrete. Aggregate can also influence the appearance of the cast surface, which is an especially important consideration in concrete countertop mixes. Aggregates contribute to overall strength of concrete. Aggregate is inexpensive and it does not enter into the complex chemical reactions with water. To get better results with concrete, it is necessary the gradation of aggregates. Good gradation of aggregates can increase the workability of concrete. Good gradation can also reduce the air voids. Economy is another reason for thoughtful aggregate selection. You can often save money by selecting the maximum allowable aggregate size.

Using larger coarse aggregate typically lowers the cost of a concrete mix by reducing cement requirements, the costliest ingredient. Less cement (within reasonable limits for durability) will mean less water if the water-cement (w/c) ratio is kept constant. A lower water content will reduce the potential for shrinkage and for cracking associated with restrained volume change

B. Problems of Natural Aggregates with Respect to Environment

The problem we face with natural aggregate is Silica alkali reaction due to reactive aggregates. In this the reactive aggregates in presence of moisture and alkaline medium produce an expansive gel which exerts bursting pressure on concrete and cracks the matrix of concrete. Nearly every community in nearly every industrialized or industrializing country is dependent on aggregate resources (sand, gravel, and stone) to build and maintain their infrastructure. Unfortunately, aggregate resources necessary to meet societal needs cannot be developed without causing environmental impacts.

The most obvious environmental impact of aggregate mining is the conversion of land use, most likely from undeveloped or agricultural land use, to a (temporary) hole in the ground. This major impact is accompanied by loss of habitat, noise, dust, blasting effects, erosion, sedimentation, and changes to the visual scene. Mining aggregate can lead to serious environmental impacts. Societal pressures can exacerbate the environmental impacts of aggregate development.

In areas of high population density, resource availability, combined with conflicting land use, severely limits areas where aggregate can be developed, which can force large numbers of aggregate operations to be concentrated into small areas. Doing so can compound impacts, thus transforming what might be an innocuous nuisance under other circumstances into severe consequences. In other areas, the rush to build or update infrastructure may encourage relaxed environmental or operational controls. Under looser controls, aggregate operators may fail to follow responsible operational practices, which can result in severe environmental consequences. The geologic characteristics of aggregate deposits (geomorphology, geometry, physical and chemical quality) play a major role in the intensity of environmental impacts generated as a result of mining.

C. Sintered Fly Ash Aggregate:

Product:	Sintered fly ash light weight aggregates.
Application:	As aggregate in concrete for lightweight construction works.
Features:	The fly ash nodules made with the help of water are fired at 1200-degree Celcius. The fine particles of fly ash melt at the surface and are welded together. The nodules crumble during the sintering process. Mixing 5, 10 & 20% plastic clay in fly ash produce good quality aggregate. The sintered fly ash aggregate concrete is spherical in shape, possessing 5-20 mm size and light grey color. Water absorption is 15-20% in uncrushed material and 40-50% in crushed material; bulk density: 640-750 kg/m3, aggregate crushing strength: 5-8.5 t.
Economy:	50 tpd.
Equipment:	Sintering machine, ribbon mixer, conveyor, handling equipment.
Raw Materials:	Fly ash, plastic clay.

II. CONCRETE MIX DESIGN

1. Cement: Birla shakti cement (M43 Grade)
2. Grade of concrete: M20
3. Target strength= fck + (1.65+S)
   = 20+ (1.65 x 4)
   = 26.60 N/mm^2
4. Specific Gravity
   a. Cement: 3.15
   b. Sand: 2.99
   c. Natural Aggregate: 3.12
   d. Sintered Fly Ash Aggregate: 2.02
5. Cement content: 335 kg/ m^3
6. W/C ratio: 0.450
7. Cementitious material content: 335x 1.0 = 335 Kg/m^3
8. Water content: 335 x 0.450 = 150.75 Kg/m^3
9. Sand content[fa]: 892.595 Kg/m3
10. Coarse aggregate [Ca]: 1274.81Kg/m^3

Final Mix Proportion using natural aggregate

Cement	Sand	Natural Aggregate	Water	Chemical
335	892.6	1273.063	150.75	0.8% of Cement by Weight
1	2.664	3.80	0.45	

Work done using Replacement of cement with Sintered Fly Ash Aggregate

Sr. No.	Design IDS	Natural Aggregate	Sintered Fly Ash Aggregate
1	A	100%	0%
2	B	90%	10%
3	C	80%	20%
4	D	70%	30%
5	E	60%	40%
6	F	50%	50%

Material Required for Casting 6 Cubes of Each Replacement

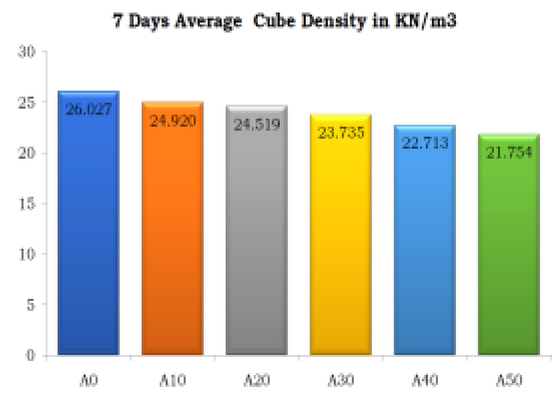
Design ID	Cement (Kg)	Sand (Kg)	Coarse Agg. (Kg)	Sintered Fly Ash Agg. (Kg)	Water (Kg)
A	7.919	21.099	30.0923	-	4.088
B	7.4621	19.8824	25.5568	1.365	3.6079
C	7.4622	19.8822	22.7172	2.7304	0.0792
D	7.4620	19.8825	19.8772	4.096	3.8531
E	7.4620	19.8825	17.0379	5.7684	3.8531
F	7.4642	19.8884	14.1821	6.8284	3.3587

III. RESULT ANALYSIS

A. With Respect to Density

a. 7 Days Cube Density Result using Sintered Fly Ash Aggregate

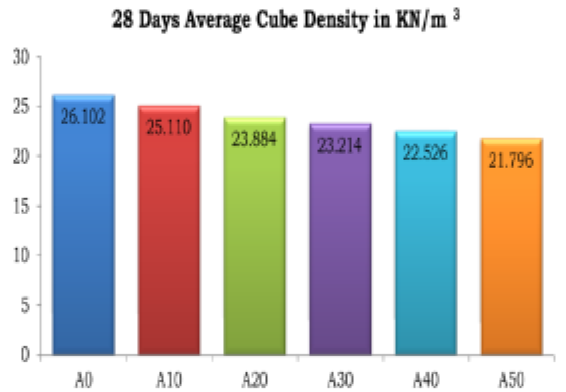
ID Mark	Weight of Cube Kg	Volume	Density	Avg Density KN/m^3
A0	9.200	3441782.2	26.196	26.027
A0	9.100	3430347.4	25.997	
A0	8.960	3391675.7	25.889	
A10	8.680	3387344.0	25.112	24.920
A10	8.660	3403145.0	24.938	
A10	8.578	3402043.8	24.710	
A20	8.531	3397537.0	24.607	24.519
A20	8.510	3415656.2	24.416	
A20	8.610	3439481.5	24.532	
A30	8.210	3374736.0	23.841	23.735
A30	8.167	3368250.0	23.762	
A30	8.210	3408825.0	23.603	
A40	7.795	3287908.0	23.234	22.713
A40	7.817	3407639.3	22.481	
A40	7.681	3356986.0	22.423	
A50	7.650	3415630.0	21.949	21.754
A50	7.680	3434753.4	21.912	
A50	7.518	3442722.0	21.401	



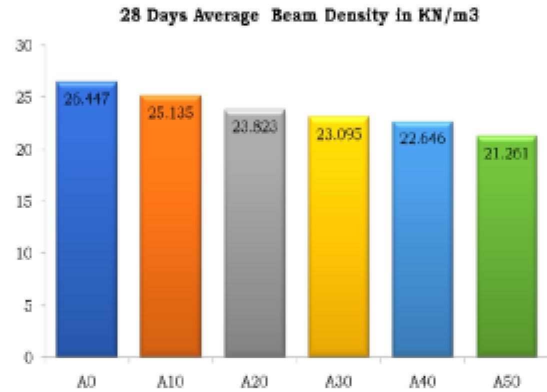
7 Days Average Cube Density Result using Sintered Fly Ash Aggregate

b. 28 Days Cube Density Result using Sintered Fly Ash Aggregate

ID Mark	Weight of Cube Kg	Volume	Density	Avg Density KN/m^3
A0	9.240	3456530.4	26.197	26.102
A0	9.205	3458827.1	26.081	
A0	9.120	3433832.1	26.028	
A10	8.750	3424583.3	25.040	25.110
A10	8.820	3447385.8	25.073	
A10	8.792	3416539.1	25.219	
A20	8.240	3413075.8	23.660	23.884
A20	8.350	3429101.7	23.863	
A20	8.315	3377199.0	24.129	
A30	8.105	3411029.6	23.286	23.214
A30	8.200	3466632.8	23.181	
A30	8.098	3424381.4	23.175	
A40	7.900	3372726.0	22.955	22.526
A40	7.865	3408453.4	22.613	
A40	7.762	3456277.6	22.009	
A50	7.650	3388323.7	22.126	21.796
A50	7.680	3441632.3	21.869	
A50	7.518	3443873.0	21.393	



28 Days Average Cube Density Result using Sintered Fly Ash Aggregate



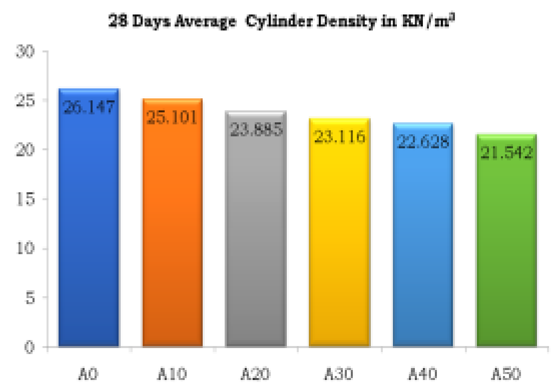
28 Days Average Beam Density Result using Sintered Fly Ash Aggregate

c. 28 Days Beam Density Result using Sintered Fly Ash Aggregate

ID Mark	Weight of Cube Kg	Volume	Density	Avg Density KN/m^3
A0	13.310	5000000	26.088	26.447
A0	13.650	4970000	26.754	
A0	13.520	4980000	26.499	
A10	12.817	4955000	25.121	25.135
A10	12.805	5050000	25.098	
A10	12.850	5060000	25.186	
A20	12.168	5012500	23.849	23.823
A20	12.198	5028000	23.908	
A20	12.098	5032500	23.712	
A30	11.821	5005000	23.169	23.095
A30	11.795	4990000	23.118	
A30	11.733	4988000	22.997	
A40	11.528	4989000	22.595	22.646
A40	11.586	4965000	22.709	
A40	11.548	5012500	22.634	
A50	10.867	5035000	21.299	21.261
A50	10.834	5050000	21.235	
A50	10.842	5005000	21.25	

d. 28 Days Cylinder Density Result using Sintered Fly Ash Aggregate

ID Mark	Weight of Cube Kg	Volume	Density	Avg Density KN/m^3
A0	4.205	1546457	26.224	26.147
A0	4.197	1548016	26.174	
A0	4.176	1550825	26.043	
A10	4.056	1566475	25.295	25.101
A10	4.005	1543340	24.977	
A10	4.014	1577792	25.033	
A20	3.864	1574645	24.097	23.885
A20	3.805	1547704	23.729	
A20	3.821	1558953	23.829	
A30	3.715	1563652	23.168	23.116
A30	3.700	1576607	23.075	
A30	3.705	1543340	23.106	
A40	3.658	1577792	22.813	22.628
A40	3.622	1574645	22.588	
A40	3.605	1547704	22.482	
A50	3.429	1560519	21.384	21.542
A50	3.438	1555199	21.441	
A50	3.496	1580929	21.802	



28 Days Average Cylinder Density Result using Sintered Fly Ash Aggregate

B. With Respect to Strength

a. 28 *Days Compressive Strength using Sintered Fly Ash Aggregate*

Cube ID Mark	Compressive Strength in N/mm^2	Average Compressive Strength in N/mm^2
A0	37.445	36.677
A0	36.574	
A0	36.011	
A10	34.51	33.924
A10	33.871	
A10	33.389	
A20	32.544	32.257
A20	31.89	
A20	32.337	
A30	30.7	30.247
A30	29.796	
A30	30.245	
A40	29.053	28.392
A40	28.329	
A40	27.794	
A50	24.609	25.181
A50	25.296	
A50	25.638	

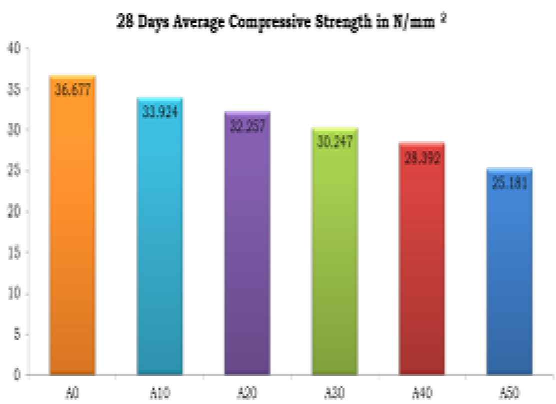
b. 28 Days Flexural Strength using Sintered Fly Ash Aggregate

ID Mark	Flexural Strength in N/mm^2	Average Flexural Strength in N/mm^2
A0	4.4	4.467
A0	4.4	
A0	4.6	
A10	4.4	4.267
A10	4.2	
A10	4.2	
A20	3.6	3.667
A20	3.8	
A20	3.6	
A30	3.8	3.4
A30	3.2	
A30	3.2	
A40	3.4	3.267
A40	3.2	
A40	3.2	
A50	3	3.067
A50	3	
A50	3.2	

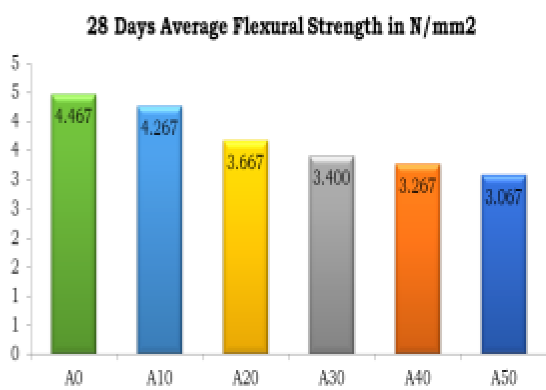
c. 28 Days Split Tensile Strength using Sintered Fly Ash Aggregate

ID Mark	Split Tensile Strength in N/mm2	Average Split Tensile Strength in N/mm2
A0	6.682	6.576
A0	6.491	
A0	6.555	
A10	6.3	6.342
A10	6.3	
A10	6.427	
A20	5.855	5.855
A20	5.918	
A20	5.791	
A30	5.218	5.239
A30	5.155	
A30	5.345	
A40	4.836	4.858
A40	4.964	
A40	4.773	

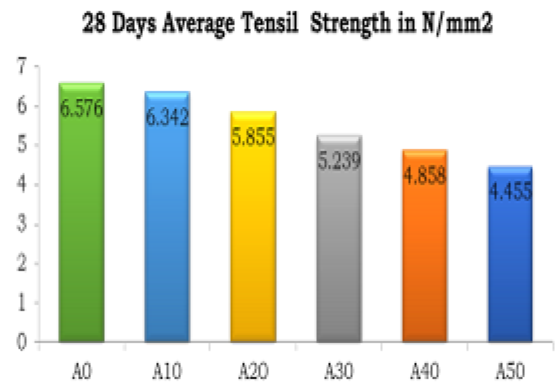
ID Mark	Split Tensile Strength in N/mm2	Average Split Tensile Strength in N/mm2
A50	4.518	4.455
A50	4.645	
A50	4.2	



28 Days Average Compressive Strength using Sintered Fly Ash Aggregate



28 Days Average Flexural Strength using Sintered Fly Ash Aggregate



28 Days Average Tensile Strength using Sintered Fly Ash Aggregate

CONCLUSION

A. STRENGTH

For M20 grade of concrete design mix, it has been seen that compressive strength decreases with increase in pumice percentage. Compressive strength is maximum for 0 % i.e., for conventional concrete. We achieved optimum Compressive Strength for 50 % replacement of sintered fly ash. We achieved the optimum strength of respectively. It has been observed that the strength of concrete for 50% replacement is reduced by 40% (for cube), 27% (in beam) & 14.77% (in beam) respectively.

Compressive, Flexural and Split Tensile Strength of concrete for 28 days

Grade of concrete	M20
28 Days Compressive Strength of Conventional Concrete (N/mm^2) For concrete design mix	32.24
28 Days Flexural Strength of Conventional Concrete (N/mm^2) For concrete design mix	3.933
28 Days split tensile Strength of Conventional Concrete (N/mm^2) For concrete design mix	5.748
28 Days Compressive Strength of Concrete of 50% replacement sintered fly ash(N/mm^2)	22.435

28 Days flexural Strength of Concrete of 50% replacement sintered fly ash(N/mm^2)	2.867
28 Days split tensile Strength of Concrete of 50% replacement sintered fly ash(N/mm^2)	3.352

B. DENSITY

For M20 grade of concrete design mix, it has been seen that density goes on decreasing with increase in the percentage of pumice. Density is maximum for conventional concrete. We achieved optimum density required for light weight concrete at 50% are 20.361 KN/m3 ,20.565 KN/m3 ,20.365 KN/m3 respectively.

It has been observed that the density at 50% replacement is lowered by 16.12%, 15.29% &16.41% than conventional concrete in cube, beam and cylinder respectively.

Density of concrete

Grade of concrete	M20
28 Days density of cube Conventional Concrete (N/mm^2) For concrete design mix	24.274
28 Days density of beam Conventional Concrete (N/mm^2) For concrete design mix	24.276
28 Days cylinder of Conventional Concrete (N/mm^2) For concrete design mix	24.365
28 Days density of Cube for 50% replacement sintered fly ash (N/mm^2)	20.361
28 Days density of beam for50% replacement sintered fly ash(N/mm^2)	20.565
28 Days density of cylinder for50% replacement sintered fly ash(N/mm^2)	20.365

Considering all above factors, it is interesting to say that we are slightly near to achieve lightweight concrete at 50 % replacement of natural aggregate by pumice stone in terms of density and strength. And further replacement of artificial aggregate can make difference in the results as per density and strength point of view to achieve light weight concrete.

REFERENCES

[1] AbdulKadir Ismail Al-hadithi, Self-Compacting Light Wt concrete containing ponzo. Aggregate, University of Anbar, Iraq (Jan-2019).

[2] AFAF Mo.wedatalla, Abubaker A.M Ahmed, Effect of curing and Period of Curing on Concrete,(Sep, 2018).

[3] Ahsan Ali, Shahid Iqabab, Thomas Bier, Yuri Ribakov, Study on structure of concrete, Germany, (March,2016).

[4] Amalu R.G, Azeef Ashraf, Muhammat Hussain, Use of waste plastic as fine aggregate substitute in concrete, UKF COE,India, (April,2016).

[5] Amir Hossein Niknamfar, Generating structural Light wt. Concrete, AIISE, USA (Nov,2017).

[6] A.R. Pourkhorshidi,M. Najimi, T. Parhizkar (July 2012), “Application of Pumice Aggregate in Structural Lightweight Concrete”Asian Journal of Civil Engineering (Building and Housing) Vol. 13, No. 1, Issue 1.

[7] Anil Godara, Anurag Maheswari, Ashish Kumar Meena, Rakesh Kumar Saini (May 2018), “Experimental study on light weight concrete with pumice stone as a partial replacement of coarse aggregate”, ISSN: 2277-2723, Volume 7, Issue 5.

[8] B. Devi Pravallika, K. Venkateswara Rao (2015), “The study on strength properties of light weight concrete using light weight aggregate” International Journal of Science andResearch(IJSR) ISSN: 2319-7064, Volume 5, Issue 6.

[9] B. Jose Ravindra Raj, V. Ravikumar (April 2017), “Experimental behaviour of light weight aggregate and mineral admixtures based light weight concrete”, International Journal of Emerging Technologies in Engineering Research (IJETER) ISSN: 2454-6410, Volume 5, Issue 4.

[10] Chrdsaqusiri Pattanponga, Properties of cellular light wt. concrete using calcium bottom ash, Portland cement,geopolymer mortar (January,2020).

[11] Davoud Tavakoli, Use of Waste material in Concrete, Iran (April,2018).

[12] Dr. K Rajeskhar, M Praveen Kumar, (Sept 2016) Light weight concrete by partial replacement of coarse aggregate by pumice stone and cement by GGBS using M30 grade of concrete.

[13] Dr.Sunila George, Rajeshwari S, (2015), "Experimental study of light weight concrete by partial replacement of coarse aggregate using pumice aggregate", International Journal of Scientific Engineering and Research (IJSER) ISSN: 2347-3878, Volume 4, Issue 5.

[14] Dr. U. Rangaraju, Lakshmi Kumar Minapu, M K M V Ratnam, (Dec 2014), "Experimental study on light weight aggregate concrete with pumice stone, silica fume and fly ash as a partial replacement of coarse aggregate" International Journal of Innovative Research in Science, Engineering and Technology ISSN: 2319-8753, Volume 3, Issue 12.

[15] G. Gunasekaran, Light wt. Concrete by using Cocunut shell as Aggregates, SRM University,India (Feb,2008).

[16] HirzoMihashi TomoyaNishiwaki, Development of Engineered self-healing & self-Repairing concrete, Hirzostate of Art-Report (April,2012).

[17] Issac Ibukan Akinwumi, Curing effect on Properties of high strength Concrete, Convenant University (June, 2014).

[18] Jose Barrose De Aguiar, Habib Trouzine, Malika Medine, Structural light wt. concrete properties, USA (August,2017).

[19] K. Mahendra ,K. Venkataramana, L. Hari Krishna ,M.Rajasekhar, S. Prashanth "Experimental Investigation On Structural Lightweight Concrete By Partial Replacement Of Coarse Aggregate Using Pumice Aggregate"International Journal of Engineering Applied Sciences and Technology, 2020 Vol. 4, Issue 11, ISSN No. 2455-2143, Pages 429-433.

[20] Khashayar Jafari Mostafa, Vahab, Study of Behaviour of Concrete under Axial & Triaxial load, USA (August,2017).

[21] Kothari Akash and Chaudhari Balasaheb(April 2017) Study of lightweight precast concrete using polystyrene.

[22] Kourosh Kabiri, Super Absorbant Polymer, Iran (June,2008).

[23] Lakshmi Kumar, Minapu, et al (Dec 2014) Study on Light Weight Aggregate Concrete with Pumice Stone, Silica Fume and Fly Ash as a Partial Replacement of Coarse Aggregate.

[24] M. Indumathi,P. Selvaprasanth, S. Mathan Kumar, and (Feb 2019) "Development of Light Weight Concrete Using Pumice Stone"International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056, Volume: 6, Issue: 2.

[25] M. Maghfouri, Quality control of light wt. aggregate concrete based on initial and final water absorption Test, Iraq (June,2017).

[26] Sukmin Kwon, Tomoya Nishiwaki, Takatsune Kikuta, Material Design Method for light wt. Cement base & its Applications (June,2017).

[27] Thousif Khan, et al (May 2018) floating concrete using lightweight materials.

[28] Vinod Goud, et al (oct 2016) Experimental study of partial Replacement of Cement with Fly as InConcrete and Its Effect.

[29] Xing –et al, Patent self-Healing, USA (October,2018).