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Experimental investigation on use of pond ash and stone dust as partial replacement of fine aggregate in cement concrete

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Abstract:

The pond ash is a waste product from most of coal based thermal power plants. As the accumulation the pond ash around the thermal power plants is posing threat to environment, its proper management is becoming essential. It is found that it is possible to replace some % of sand by pond ash as fine aggregate in concrete without compromising on strength and durability. In this research work, for experimentation the pond ash is collected from Ukai Thermal Power Plant at Ukai, Gujrat (UTPP) and is checked for the replacement of locally available sand in cement concrete for the strength along with the stone dust which is also a waste material from the stone quarry. Since pond ash is much finer than locally available sand and also does not give the proper grading, hence in this research work, the stone dust is added 10% by weight. In the remaining 90%, the locally available sand is replaced with pond ash in different proportions. The combined grading of locally available sand and pond ash in different proportions and stone dust are used for mix design of M-20 grade concrete. The mix design is done as per BIS: 383:1970 and BIS: 10262:1982 and the quantities of ingredients have been estimated and accordingly concrete cubes as per standard procedure are prepared and tested and the results are analyzed.

Keywords:

Dry Ash, Pond Ash, Stone Dust

1. Introduction:

The power requirement of the country is rapidly increasing due to the increase in the growth of industrial sector. India depends on thermal power as its main source of electrical energy. The 75% of country's total installed electrical power generation is thermal, out of which coal-based generation is 90%. According to an estimate the annual consumption of coal in the country for electrical power generation is 300 million MT. The coal reserves of the country are predominately of lower grades i.e. the average of 35% ash content, thus as a result more than 110 million MT coal ash is being generated every year. The present practice of handling the coal ash generated from thermal power plants in majority of the cases is in wet form by disposing it off in ash ponds, which leads to degradation of land and thus harmful for environment. Out of total ash produced, the fly ash contributes to small percentage, majority being pond ash and bottom ash. As per survey conducted by National Thermal Power Corporation around 20,000 hectares of land is occupied by ash ponds around the various thermal power stations in India. The pond ash is being produced as a waste at every thermal power plant, thus its safe disposal and if possible its utilization with green methods have become the thrust area for researchers. As the pond ash is coarser and contains the alkalis in dissolved form and is washed with water, hence its pozzolanic reactivity is low and thus it's utility as the part replacement of cement in concrete is not a technical feasible option. The pond ash always poses technological problems as far as its disposal and management is concern.

The areas where the pond ash is dumped are characterized by very low density and poor bearing capacity. Thus these sites are usually unsuitable for any construction activities, although it may be possible to improve the geotechnical properties of the pond ash deposits by some suitable in situ stabilization techniques so that these sites may be utilized for light construction activities e.g., low height buildings, parking areas and community centers etc.

1.1. Necessity of pond ash management:

The harmony between man and environment is the essence of healthy life and growth. Therefore, maintenance of ecological balance and a pristine environment must be of the utmost importance. The disposal of the pond ash requires large quantities of land, water and energy. At the same time its improper dumping leads to health hazards and environment damages.

The pond ash generated from thermal power plants may cause three environmental risks i.e. air, surface water and ground water pollution. Air pollution is caused by direct emissions of toxic gases from the power plants as well as wind-blown ash dust from ash mound or pond.

The air-borne dust can fall in surface water system and soil and may contaminate the water and soil system. The wet system of disposal in most power plants causes discharge of particulate ash directly into the nearby surface water system. The long storage of ash in ponds under wet condition and humid climate can cause leaching of toxic metals from ash and contaminate the underlying soil and ultimately the groundwater system. Lot of research has been carried out for effective utilization of fly ash in construction industries due to its fineness and pozzolanic properties, but a very modest literature is available on utilization of pond ash. The pond ash being coarser and less pozzolanic than fly ash thus possibly can be used as fine aggregates in concrete by partial replacement of sand.

2. Materials and methodology:

In this research work, the Indian Standard method of concrete mix design (IS: 10262:1982) for M-20 grade of concrete is used. The Ordinary Portland Cement (OPC) confirming to IS: 269:1987 manufactured by ULTRATECH grade 53 is used in this research work. The physical and chemical characteristics of cement conforms BIS 12269:1987 BIS 12269:1987 and are shown in tables. 1 and 2 respectively.

Table. 1: Physical characteristics of cement

Type of Cement	Fineness %	Soundness by Le-chatelier (mm)	Setting Time		Compressive Strength	
			Initial (mins)	Final (mins)	3 Days N/mm^2	7 Days N/mm^2
53 Grade OPC (IS: 12269:1987)	2.7 %	2.5 mm	52	290	27.5	37.25

Table. 2: Chemical characteristics of cement

Type of Cement	Lime Saturation Factor (%)	Alumina Iron Ratio (%) Min.	Insoluble Residue (%) Max.	Magnesia (%) Max.	Sulphuric Anhydride	Loss on Ignition (%) Max.
53 Grade OPC (IS: 12269:1987)	0.8 Min. 1.02 Max.	0.66	2	6	2.5% Max.	4

The laboratory tests for finding out the specific gravity and water absorption of coarse aggregates are performed which results as 2.61 and 0.5% respectively. The other materials, which are used as fine aggregates are locally available sand, stone dust and the pond ash. The coarse aggregate and stone dust is taken from the local quarry near Laling Ghat, near Dhule town and the sand is taken from the sand mines in river Panzara near Nyalhod. The pond ash is collected from ash pond near the Ukai Thermal Power Plant, Ukai, Songarh Gujrat. The laboratory tests are performed for determination of specific gravity, water absorption and surface moisture content of fine aggregates. The specific gravities of locally available sand, stone dust and pond ash are 2.6, 2.75 and 2.153 the water absorption are 1%, 0.9% and 44.5% respectively and the surface moisture content of are 1.887%, 0.0571% and 31.25% respectively.

The suitability of pond ash in concrete as partial replacement of sand is tested through experimentation. In this research work, the materials used are coarse aggregates of 20 mm and 12 mm nominal size, locally available sand, pond ash and stone dust as a fine aggregates in different proportions. The locally available sand is partially replaced with pond ash and stone dust in fine aggregates and different proportions designated as Mix-I, Mix-II, Mix-III, and Mix-IV with pond ash percentage as 30%, 40%, 50% and 60%. The stone dust is added 10% by weight in each mix. The coarse aggregates of 20 mm and 12 mm are designated as CA-I and CA-II. The results of sieve analysis for CA-I, CA-II, locally available sand, pond ash and stone dust are shown in tables 3-A to 3-E.

The combined grading of (CA-I :CA-II) : SD : FA (LAS :PA) for all proposed proportions of LAS and PA is estimated and are shown in table 3-F and 3-G. The mix design of M-20 grade of concrete as per BIS: 383:1970 and BIS: 10262:1982 for all proposed proportions is worked out and actual mix calculated for Mix-I, Mix-II, Mix-III and Mix-IV is given below.

Table. 3:

Water	**Cement**	**Fine aggregates**	**Coarse aggregates**
MIX - I			
19.69 L	50 kg	90.79 kg	166.314 kg
0.3939	1	1.815	3.3262
MIX - II			

17.48 L	50 kg	91.496 kg	166.314 kg
0.3497	1	1.829	3.3262
MIX - III			
15.63 kg	50 kg	92.172 kg	166.314 kg
0.3126	1	1.843	3.3262
MIX - IV			
14.00 kg	50 kg	88.64 kg	170.0853 kg
0.28	1	1.7726	3.4017

2.1. Observations and results:

The concrete cubes of size 150 x 150 x 150 mm, six numbers for each proportion are prepared as per BIS procedure and tested in compression testing machine (CTM). The results of density of concrete and compressive strengths tests after 7 days and 28 days curing are shown in table 4 and 5.

Table. 4: Density of concrete

Sl.No.	Mix Designation	% of Pond Ash and Stone Dust in Concrete	7 - DAYS			28 - DAYS		
			SIZE - 150 x 150 x 150 mm			SIZE - 150 x 150 x 150 mm		
			Density (KN/m^3)			Density (KN/m^3)		
			Wt (gm)	Density	Avg	Wt (gm)	Density	Avg
1	Mix-I LAS: PA: SD 60: 30: 10	30 - 10	8498	24.701	24.737	8520	24.765	24.827
			8510	24.736		8555	24.867	
			8523	24.774		8549	24.849	
2	Mix-II	40 - 10	8410	24.445	24.426	8378	24.352	24.397
			8398	24.410		8391	24.390	

	LAS: PA: SD 50: 40: 10		8402	24.422		8411	24.448	
3	Mix-III LAS: PA: SD 40: 50: 10	50 –10	8310	24.154	24.124	8301	24.128	24.194
			8302	24.131		8345	24.256	
			8287	24.088		8325	24.198	
4	Mix-IV LAS: PA: SD 30: 60: 10	60 - 10	8128	23.625	23.604	8139	23.657	23.651
			8137	23.652		8148	23.684	
			8097	23.535		8123	23.611	

Table. 5: Compressive strength of concrete

Sl. No.	Mix Designation	% of Pond ash and stone dust in concrete	7 - DAYS			28 - DAYS		
			SIZE - 150 x 150 x 150 mm			SIZE - 150 x 150 x 150 mm		
			Compressive strength (N/mm^2)			Compressive strength (N/mm^2)		
			Load (T)	CS	Avg	Load (T)	CS	Avg
1	Mix-I LAS: PA: SD 60: 30: 10	30 – 10	32	13.952	15.260	64	27.904	26.596
			38	16.568		58	25.288	
			35	15.26		61	26.596	
2	Mix-II LAS: PA: SD 50: 40: 10	40 – 10	35	15.26	15.696	67	29.212	30.375
			37	16.132		69	30.084	
			36	15.696		73	31.828	

3	Mix-III LAS: PA: SD 40: 50: 10	50 –10	34	14.824	15.841	79	34.444	35.171
			38	16.568		81	35.316	
			37	16.132		82	35.752	
4	Mix-IV LAS: PA: SD 30: 60: 10	60 – 10	29	12.644	13.371	72	31.392	30.520
			32	13.952		70	30.52	
			31	13.516		68	29.648	

3. Conclusions:

It is found by the study, that, it is possible to use pond ash with sand as fine aggregate in concrete without compromising on strength and durability of concrete. This study opens up a major avenue for utilization of pond ash. The use of pond ash as partial replacement of sand as fine aggregate in concrete gives higher compressive strength than conventional mix. The experiment with coarse aggregate (20 mm and 12 mm), sand, stone dust and pond ash is done. The cubes of M-20 grade concrete with varying percentage of pond ash are made as per mix design of concrete. The variation in density and compressive strength with different percentage of pond ash are shown in fig. 1 and 2 below.

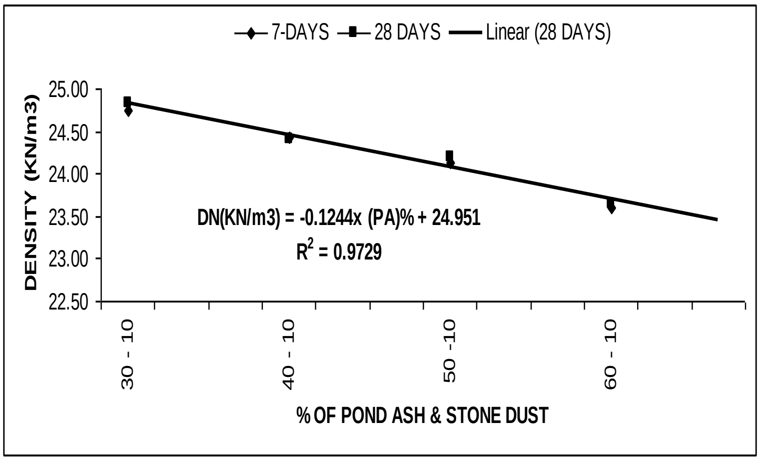

Figure. 1: Variation in density with percentage of LAS replacement with PA

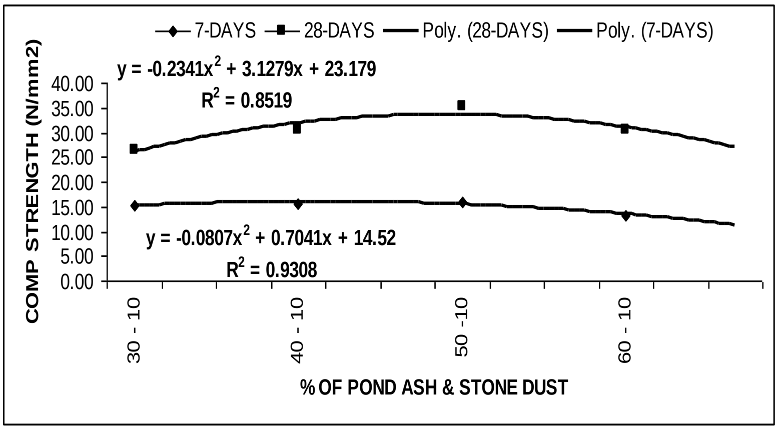

Figure. 2: Variation in compressive strength with % of LAS replacement with PA

The following conclusions may be drawn from experiment

(1) The density of the concrete mix decreases with increase in percentage of pond ash. It is evident that density decreases by 7.85% for 60% pond ash as compared to 0% pond ash.

(2) The compressive strength of concrete mix increases with addition of pond ash up to 50% and there after it decreases. It is evident that compressive strength increases by 7.08% (28 days) corresponding to pond ash 50%.

(3) It is evident from fig. 2 that the addition of pond ash results in almost constant compressive strength at early stage (7-days) and increases in later stage (28-days).

Table. 3A: sieve analysis of CA-I (20 mm)

Sl.No.	**IS sieves**	**Wt. retained (gms)**	**Cu. Wt. retained (gms)**	**Cu. % Wt. retained**	**Cu. % passing**
1	40 mm	0	0	0%	100%
2	20 mm	700	700	35%	65%
3	10 mm	1280	1980	99%	1%
4	4.75 mm	20	2000	100%	0%
5	2 mm	0	0	---	---

Table. 3B: Sieve analysis of CA-II (12 mm)

Sl.No.	IS sieves	Wt. retained (gms)	Cu. Wt. retained (gms)	Cu. % Wt. retained	Cu. % passing
1	20 mm	0	---	0%	100%
2	10 mm	538	538	53.80%	46.20%
3	4.75 mm	442	980	98%	2%
4	2 mm	20	1000	100%	0%

Table. 3C: Sieve analysis of LAS

Sl.No.	IS sieves	Wt. retained (gms)	Cu. Wt. retained (gms)	Cu. % Wt. retained	Cu. % passing	Remark
1	10mm	0	0	0%	100%	Confirming to grading Zone-I of Table.4 BIS:383:1970
2	4.75 mm	121	121	6.05%	93.95 %	
3	2.36 mm	267	388	19.40 %	80.60 %	
4	1 mm	709	1097	54.85 %	45.15 %	
5	600□	351	1448	72.40 %	27.60 %	
6	300□	490	1938	96.90 %	3.10%	

Table. 3D: Sieve analysis of PA

Sl.No.	IS sieves	Wt. retained (gms)	Cu. Wt. retained (gms)	Cu. % Wt. retained	Cu. % passing	Remark
1	4.75 mm	0	0	0%	100%	Confirming to grading Zone-IV of Table.4 BIS:383:1970
2	2.36 mm	2	2	0.20%	99.80%	
3	1 mm	6	8	0.80%	99.20%	
4	600□	8	16	1.60%	98.40%	
5	300□	84	100	10%	90%	
6	150□	641	741	74.10%	25.90%	
7	75□	150	891	89.10%	10.90%	
8	Pan	109	1000	100%	0	

Table. 3E: Sieve analysis of stone dust

Sl.No.	IS sieves	Wt. retained (gms)	Cu. Wt. retained (gms)	Cu. % Wt. retained	Cu. % passing	Remark
1	10 mm	6	6	0.60%	99.40%	Confirming to grading Zone-II of table. 4 BIS:383:1970
2	4.75 mm	15	21	2.10%	97.90%	
3	2.36 mm	122	143	14.30%	85.70%	
4	1 mm	275	418	41.80%	58.20%	
5	600 □	113	531	53.10%	46.90%	
6	300 □	146	677	67.70%	32.30%	

7	150 □	238	915	91.50%	8.50%	
8	75 □	74	989	98.90%	1.10%	
9	Pan	11	1000	100%	0	

Table. 3F: Grading combination of CA-I and CA- II in proportion 20:80

Sl. No.	IS sieves	Cu. % passing			Remarks
		CA-I 20%	CA-II 80%	Combined Grading	
1	20 mm	13%	80%	93%	Confirming table.2 BIS:383:1970
2	10 mm	0.20%	36.96%	36.98%	
3	4.75 mm	0%	1.60%	1.60%	
4	2 mm	0%	0%	0%	

Table. 3G: Grading combination of SD : FA (LAS :PA) for all proposed proportions

Sl. No.	**IS Sieves**	**Cu. % passing for combined grading**				**Remarks**
		Mix-I (LAS:PA:SD) (60:30:10)	Mix-II (LAS:PA:SD) (50:40:10)	Mix-III (LAS:PA:SD) (40:50:10)	Mix-IV (LAS:PA:SD) (30:60:10)	Confirming Zone-II, table.4 BIS:383:1970
1	10 mm	99.94	99.94	99.94	99.94	
2	4.75 mm	96.1	96.685	97.18	97.85	
3	2 mm	86.69	88.55	90.41	92.27	
4	1 mm	62.43	67.75	73.08	78.4	
5	600 □	48.25	54.49	60.73	66.97	
6	300 □	12.86	15.14	17.42	19.7	
7	150 □	4.96	5.93	6.86	7.81	
8	75 □	0.11	0.11	0.11	0.11	

5. References:

(1) Basu-2009, "Fly Ash Based Concrete", Journal – Civil Engineering and Construction Review, February – 2009, pp-78-87.

(2) Bera, Ghosh and Ghosh-2007, "Compaction Characteristics of Pond Ash", Journal - Materials in Civil Engineering, Volume IXX, Issue-4, April-2007, pp-349-357.

(3) BIS-10262-1982, "Indian Standard Recommended Guidelines for Concrete Mix Design", Bureau of Indian Standard, Manak Bhavan, Bahadur Shah Zafar Marg, New Delhi 110002.

(4) BIS-383-1970, "Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete – II Revision", Bureau of Indian Standard, Manak Bhavan, Bahadur Shah Zafar Marg, New Delhi 110002.

(5) BIS-2386-1963, "Indian Standard Methods of Test for Aggregates for Concrete -Part III Specific gravity, Density, Voids, Absorption and Bulking", Bureau of Indian Standard, Manak Bhavan, Bahadur Shah Zafar Marg, New Delhi 110002.

(6) CIDA-2005, "Fly Ash Status Summary Report in India", A report prepared by Canadian International Development Agency (CIDA) under HVFAC project, Copyright Confederation of Indian Industry – 2005.

(7) Datta and Chaubey-2009, "Optimization of Fly ash in Concrete", Journal – Civil Engineering and Construction Review, February – 2009, pp-56-61.

(8) ENVIS - 2006, "FLY ASH – Problem and Management Aspects", ENVIS NEWSLETTER, A publication of Centre of Environmental Studies under Forest and Environment Department, Government of Orissa, Issue Volume-3, No.1, November-05-January 06.

(9) FAUP-2005, "Fly Ash Management in India : An Integrated, Approach", Fly Ash India 2005, International Congress, organized under Fly Ash Utilisation Programme (FAUP), Technology

(10) Information, Forecasting and Assessment Council, Department of Science and Technology, Government of India at New Delhi, India, December 2 – 5, 2005.

(11) HWB-2003, "Fly Ash Utilization", e-Magazine – ENVIRONMENT – Technologies for Better Quality of Life, Heavy Water Board, VS Bhavan, Mumbai.

(12) Juneja-2009, “High Volume Fly Ash Concrete for the Reduction of Green House Gases”, Journal – Civil Engineering and Construction Review, February – 2009, pp-34-43.

(13) Kalgal, Pranesh and Ravishankar-2007, “Strength and Durability of Concrete with Pond Ash as Fine Aggregate”, the Indian Concrete Journal, Volume-81, March 2007, pp-7-12.

(14) Mangaraj and Krishnamoorthy-1994, “Use of Ponded Flyash as part Replacement of fine Aggregate in Mortar and Concrete”, The Indian Concrete Journal, May-1994, pp-279-282.

(15) NCB-2003, “Flyash Based Portland Pozzolona Cement for Strong and Durable Concrete”, A bulletin published by National Thermal Power Corporation (A GoI Enterprises), R and D Division, Noida (UP) and National Council for Cement and Building Materials, Ballabhgarh (Haryana), 2003.

(16) NTPC-2005, “Ash A Resource”, A bulletin published by National Thermal Power Corporation (A GoI Enterprises), R and D Division, Noida (UP), 2005.

(17) Pandey and Agrawal–2002, Piyush Kant Pandey and Raj Kumar Agrawal, “Utilization of Mixed Pond Ash in Integrated Steel Plant for Manufacturing Superior Quality Bricks”, Bulletin - Material Science, © Indian Academy of Sciences Vol. 25, No. 5, October 2002, pp- 443–447.

(18) Ritwik, Singh and Das-2001, “Effect of Addition of Pond Ash and Fly ash on properties of Ash-Clay Burnt Bricks”, Journal - Waste Management and Research, ISSN 0734–242X, 2007: 25: pp- 566–571.

(19) Sinha-2008, “TECHNOLOGY – Fly Ash Disposal and Utlization : The Indian Scenario”, Rajiv Sinha, Department of Civil Engineering, Indian Institute of Technology, Kanpur (UP).

(20) Sofi et al 2009, “Experimental Investigation on the Utilization of Pond Ash for Pavement Blocks”, Journal – Civil Engineering and Construction Review, April – 2009, pp-72-79.

(21) Virendra Kumar-2004, “Compaction and Permeability Study of Pond Ash amended with Locally Available Soil and Hardening Agent”, Journal of Institution of Engineers (India), IE(I) Journal, CV, Volume-85, May – 2004, pp-31-35.