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A study on suitability of pond ash and Fly ash in Concrete as a replacement to fine Aggregate and Cement for Sustainable Development

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ABSTRACT

River sand is expensive due to the depletion of natural resources. Large scale depletion of these sources creates environmental problems In such a situation pond ash can be used as an alternative to the river sand. Enormous amount of production of cement increases the temperature of earth. So it is advisable to use Flyash as replacement material for cement.We have attempted to use Pond ash and flysh as a replacement material for fine aggregate and cement by replacing sand in various percentages. We have taken pond ash and flyash from four thermal power plants namely Neyveli, Mettur, Ennore, Tuticurin and carried out tests to find out the optimum percentage replacement of fine aggregate by pond ash and cement by flyash.

Key words : *Pondash, Flyash, Optimum percentage replacement, Thermal power plant, Best power plant*

Introduction

Pond ash can be defined as a residue and by-product of Thermal power plants. Pond ash utilization helps to reduce the consumption of natural resources Natural sand is depleted nowadays and it is inevitable to look for a alternative material and we have planned to use pondash as a alternate for River sand. Moreover we have also utilised flyash as a replacement for cement. In our study Pondash and flyash are taken from four thermal power plants in tamilnadu (Mettur, Ennore, Neyveli, Tuticurin). Chemical and physical properties of pondash, flyash, coarse aggregate and fine aggregate are analysed. Initially cement and fine aggregate are replaced with 25 %, 50% and 75 % of flyash and pondash of four thermal power plant and mix design is done as per IS10262 – 2009, specimens are casted for M30 grade and tested for its Compressive, tensile and flexural strength to determine the maximum replacement percentage. Once the maximum replacement percentage is identified, specimens are casted and tested for 7,28,56 and 90 days compressive, flexural, split tensile strength at replacement percentage of every 10% until it reaches the maximum replacement percentage by using four thermal power plant pondash and flyash. Best thermal powerplant pondash and flyash is identified along with optimum grade and optimum replacement percentages. Initially physical and chemical properties of constitutent materials are analysed.

Materials Used and Their Properties

Pondash sample were collected from power plants namely Mettur, Neyveli, Tuticurin, Ennore. Their

physical and chemical properties are analysed and tabulated in Table 1 and Table 2. Ash is the residue after combustion of coal in thermal power plants. Particle sizes of the ash can vary from approximately 1 to approximately 600 ìm. Unused fly ash and bottom ash (residue collected from the bottom of the furnace) are mixed in slurry form and deposited in pond.

Table 1. Chemical Composition of Pondash

Characteristics	Mettur	Neyveli	Tuticorin	Ennore
Loss on Ignition, in %	4.85	1.38	5.23	10.81
Silica (as SiO_2) in %	64.36	81.38	56.35	38.07
Aluminium Oxide (Al_2O_2) in %	16.34	3.86	24.87	34.58
Iron Oxide (Fe_2O_3) in %	5.23	7.42	5.06	4.22
Titanium Oxide (TiO_2) in %	NIL	NIL	NIL	NIL
Magnesium Oxide (MgO) in %	2	1.43	1.68	2.98
Calcium Oxide (CaO) in %	1.95	1.01	2.64	3.56
Sodium (Na_2O) in %	2.27	1.35	1.97	1.68
Potassium (K_2O) in %	3	2.17	2.20	4.10

Table 2. Physical Properties of Pondash

S.No	Property	Mettur	Neyveli	Tuticurin	Ennore
1.	Specific gravity	2.24	2.52	2.31	2.38
2.	Bulk Modulus	841	1050	910	990
3	Fineness Modulus	2.50	2.75	2.62	2.66

Flyash samples are taken from Thermal power plants namely Mettur, Neyveli, Tuticurin, Ennore. Their physical and chemical properties are also analysed and values are tabulated in Table 3 and 4.

Table 3. Physical properties of Flyash

S.no	Property	Mettur	Neyveli	Tutucurin	Ennore
1.	Specific gravity	2.17	2.45	2.3	2.35
2	Bulk modulus	740	995	810	835
3	Fineness Modulus	2.25	2.67	2.42	2.49

Table 4. Chemical Composition of Flyash

Characteristics	Mettur	Neyveli	Tuticurin	Ennore
Loss on Ignition in %	9.85	6.38	11.23	13.81
Silica (as SiO_2) in %	44.36	59.38	38.35	32.07
Aluminium oxide (asAl_2O_2) in %	14.00	9.12	14.87	18.58
Iron Oxide (as Fe_2O_3) in %	20.23	15.42	23.57	21.67
Calcium Oxide (as CaO) in %	5.95	6.01	6.64	6.56
Sodium (as Na_2O) in %	2.54	1.35	1.97	3.12
Potassium (as K_2O) in %	3	2.17	3.20	4.10
Magnesium oxide (as MgO) in %	0.07	0.17	0.17	0.09

Locally available river sand is used as Fine aggregate. Coarse aggregate of size 20mm are used and they was taken from quarry localby. Their properties are given below.

Cement we have used in this study is OPC 53 grade.

Portable water is used in this study. Superplasticizer Cerroplast is used in this project inorder to improve the workability and to reduce the water requirement.

Mix Design

Mix design for M30 grade is done as per IS 10262 2009.

Table 5. Properties of Fine Aggregate & Coarse aggregate

S. No.	Property	Fine Aggregate	Course Aggregate
1	Specific gravity	2.65	2.78
2	Bulk density in kg/m^3	1460	1530
3	Fineness Modulus	2.50	4.33
4	Water absorption	0.98	NA

Table 6. Properties of Cement

S.No	Property	Value
1	Normal consistency	28.75
2	Specific gravity	3.14
3	Initial setting time, (minutes)	45
4	Final setting time, (minutes)	235

Table 7. Mix proportions of concrete

S.No	Description	Value
1	Cement grade	OPC53 Grade
2	Coarse aggregate size	20 mm
3	Cement (kg /m^3)	380
4	Fine aggregate (kg/m^3)	709
5	Coarse aggregate (kg /m^3)	1290
6	W/C ratio (%)	0.35

Experimental Investigation

Initially the pond ash and flyash was replaced with 25 %, 50% and 75 % of sand as fine aggregate and cement. Specimens were casted and tested for Compressive strength , Split tensile strength and flexural strength in M30 grade. The results are expressed in N/mm^2.

Compresive strength

We cannot infer the maximum compressive strength from the above table. So it is decided to continue the above tests in every 10% replacement from 0 to 50%.

Split tensile strength

From the above results it is evident that replacement fine aggregate and cement by pondash and flyash above 50 % does not provide fruitful results. Optimum results can be find out by replacing every 10%.

Flexural Strength

As we can interpret from the above table that , replacement of pondash and flyash above 50% in concrete doesn't prove to be fruitful. So inorder to find the optimim replacement percentage it is decided to replace pond ash and flyash (collected from the four thermal plants) as fine aggregate and cement in percentages of 10%,20%,30%,40% and 50%.

Mechanical Properties of Concrete with Pondash and Flyash

Compressive Strength

Compressive strength of the specimens are tested at 7,28,56 and 90 days with increase in replacement percentage of 10% from 0 – 50. Strength values are expressed in N/mm^2

While looking at the compressive strength results, replacement by Ennore plant pondash and flyash shows higher strength of 41.21N/mm^2 in 90

Table 8. Comparison of Compressive Strength (25% Replacement)

Pond Ash and Flyash	Comp strength (7 days)	Comp strength (28 days)	Comp strength (56 days)	Comp Strength (90 days)
Neyveli	30.45	43.50	45.87	46.91
Mettur	27.46	41.57	43.16	44.05
Tuticurin	26.10	38.16	40.55	42.40
Ennore	24.05	36.50	38.87	39.23

Table 9. Comparison of Compressive Strength (50% Replacement)

Pond Ash and Flyash	Comp strength (7 days)	Comp strength (28 days)	Comp strength (56 days)	Comp Strength (90 days)
Neyveli	30.22	33.56	38.11	43.26
Mettur	27.87	30.63	34.56	41.64
Tuticurin	24.48	29.87	32	36.50
Ennore	22.63	27.19	30.12	34.12

Table 10. Comparison of Compressive Strength (75% Replacement)

Pond Ash and Flyash	Comp strength (7 days)	Comp strength (28 days)	Comp strength (56 days)	Comp Strength (90 days)
Neyveli	27.46	31.0	36.10	40.48
Mettur	24.46	36.57	38.10	39.47
Tuticurin	21.10	26.16	30.00	32.15
Ennore	20.05	24.50	29	32.19

Table 11. Comparison of Split Tensile Strength – M 30 (25% Replacement)

Pond Ash and Flyash	Split tensile strength (7 days)	Split tensile strength (28 days)	Split tensile strength (56 days)	Split tensile strength (90 days)
Neyveli	3.10	3.87	4.26	4.69
Mettur	3.08	3.30	3.45	3.69
Tuticurin	2.92	3.05	3.19	3.43
Ennore	2.75	2.88	3.12	3.30

Table 12. Comparison of Split Tensile Strength –M 30 (50% Replacement)

Pond Ash and Flyash	Split tensile strength (7 days)	Split tensile strength (28 days)	Split tensile strength (56 days)	Split tensile strength (90 days)
Neyveli	4.03	4.727	4.82	4.93
Mettur	3.71	4.36	4.62	4.75
Tuticurin	3.64	4.27	4.44	4.56
Ennore	2.8	3.78	4.0	4.16

Table 13. Comparison of Split Tensile Strength – M 30 (75% Replacement)

Pond Ash and Flyash	Split tensile strength (7 days)	Split tensile strength (28 days)	Split tensile strength (56 days)	Split tensile strength (90 days)
Neyveli	3.10	3.78	4	4.12
Mettur	3	3.19	3.29	3.41
Tuticurin	2.86	3.13	3.32	3.40
Ennore	2.60	3.0	3.14	3.27

Table 14. Comparison of Flexural Strength-M 30 (25% Replacement)

Pond Ash and Flyash	Flexural strength (7 days)	Flexural strength (28 days)	Flexural strength (56 days)	Flexural strength (90 days)
Neyveli	3.10	3.65	4	4.12
Mettur	3	3.14	3.29	3.53
Tuticurin	2.86	3.1	3.32	3.40
Ennore	2.60	2.92	3.14	3.27

Table 15. Comparison of Flexural Strength-M 30 (50% Replacement)

Pond Ash and Flyash	Flexural strength (7 days)	Flexural strength (28 days)	Flexural strength (56 days)	Flexural strength (90 days)
Neyveli	5.4	6.60	7.12	7.86
Mettur	4.2	4.86	5.29	6.20
Tuticurin	4	4.89	5.23	5.98
Ennore	3.87	4.24	4.87	5.34

Table 16. Comparison of Flexural Strength-M30 (75% Replacement)

Pond Ash and Flyash	Flexural strength (7 days)	Flexural strength (28 days)	Flexural strength (56 days)	Flexural strength (90 days)
Neyveli	5	5.76	6.23	6.85
Mettur	3.8	4.12	4.75	5.14
Tuticurin	3.4	3.8	4. 35	4.60
Ennore	3.21	3.97	4.10	4.18

Table 17. Comparison of Compressive Strength (10% Replacement)

Pond Ash and Flyash	Comp strength (7 days)	Comp strength (28 days)	Comp strength (56 days)	Comp Strength (90 days)
Neyveli	33.57	40.98	46.4	48.25
Mettur	30.54	35.05	40.88	46.20
Tuticurin	27.89	33.98	35.74	40.33
Ennore	26.65	32.67	34.10	38.65

Table 18. Comparison of Compressive Strength (20% Replacement)

Pond Ash and Flyash	Comp strength (7 days)	Comp strength (28 days)	Comp strength (56 days)	Comp Strength (90 days)
Neyveli	34.43	42.08	48.33	50.33
Mettur	26.54	33.12	40.10	45.33
Tuticurin	22.89	30	34.25	42.20
Ennore	20.14	30.67	34	39.86

Table 19. Comparison of Compressive Strength (30% Replacement)

Pond Ash and Flyash	Comp strength (7 days)	Comp strength (28 days)	Comp strength (56 days)	Comp Strength (90 days)
Neyveli	36.54	44.21	50.21	52.97
Mettur	29.54	35.05	41.88	46.34
Tuticurin	25.31	33.98	36.37	44.21
Ennore	21.65	32.67	35.10	41.21

Table 20. Comparison of Compressive Strength (40% Replacement)

Pond Ash and Flyash	Comp strength (7 days)	Comp strength (28 days)	Comp strength (56 days)	Comp Strength (90 days)
Neyveli	32.54	38.21	41.21	45.97
Mettur	29.54	35.05	40.88	43.34
Tuticurin	25.31	33.98	36.37	42.21
Ennore	23.65	32.67	35.10	41.21

days at 30% replacement. Neyveli plant shows higher strength of 52.97N /mm^2 in 90 days at 30% replacement. Mettur plant shows higher strength of 46.34N/mm^2 in 90 days at 30% replacement. Tuticurin plant shows higher strength of 44.21N/mm^2 at 30% replacement.

Split Tensile Strength

Split tensile strength results shows Neyveli plant pond ash and Flyash gives the maximum strength of 6.85N/mm^2 at 90 days in 30% replacement. Ennore plant gives higher strength as 4.97N/mm^2 at

Table 21. Comparison of Compressive Strength (50% Replacement)

Pond Ash and Flyash	Comp strength (7 days)	Comp strength (28 days)	Comp strength (56 days)	Comp Strength (90 days)
Neyveli	30.22	33.56	38.11	43.26
Mettur	27.87	30.63	34.56	41.64
Tuticurin	24.48	29.87	32.00	36.50
Ennore	22.63	27.19	30.12	34.12

Table 22. Comparison of Split Tensile Strength (10% Replacement)

Pond Ash and Flyash	Split tensile strength (7 days)	Split tensile strength (28days)	Split tensile strength (56 days)	Split tensile strength (90 days)
Neyveli	3.57	4.1	4.65	5.0
Mettur	2.76	3.23	3.87	4.29
Tuticurin	2.67	3.398	3.77	4.03
Ennore	2.37	3.26	3.61	3.84

Table 23. Comparison of Split Tensile Strength (20% Replacement)

Pond Ash and Flyash	Split tensile strength (7 days)	Split tensile strength (28 days)	Split tensile strength (56 days)	Split tensile strengt (90 days)
Neyveli	3.62	4.02	4.57	5.02
Mettur	3.17	3.73	4.23	4.56
Tuticurin	2.78	3.28	3.52	4.0
Ennore	2.68	2.99	3.3	3.99

Table 24. Comparison of Split Tensile Strength (30% Replacement)

Pond Ash and Flyash	Split tensile strength (7 days)	Split tensile strength (28 days)	Split tensile strength (56 days)	Split tensile strength (90 days)
Neyveli	4.01	5.16	5.47	5.95
Mettur	2.95	3.64	4.41	5.31
Tuticurin	2.74	3.73	4.05	4.22
Ennore	2.48	3.32	3.75	4.10

Table 25. Comparison of Split Tensile Strength (40% Replacement)

Pond Ash and Flyash	Split tensile strength (7 days)	Split tensile strength (28 days)	Split tensile strength (56 days)	Split tensile strength (90 days)
Neyveli	4.19	4.94	6.26	6.85
Mettur	3.28	4.50	5.78	6.34
Tuticurin	3.13	4.27	5.12	5.78
Ennore	2.80	3.7	4.25	4.97

90 days in 30% replacement. Mettur plant gives maximum strength of 6.34/mm^2 at 90 days in 30% replacement. Tuticurin plant gives the higher strength in 30% replacement of 5.78N/mm^2 at 90 days.

Flexural Strength

In M30 grade, Neyveli plant pond ash gives higher strength of 10.45N/mm^2 at 90 days in 30% replacement. Ennore plant pond ash with 30% replacement shows higher strength of 7.24 N/mm^2 in 90 days. Mettur plant pond ash gives higher strength of 9.54N/mm^2 at 90 days in 30% replacement. Tuticurin plant pond ash gives the higher strength in 30% replacement of 8.12N/mm^2 at 90 days.

Table 26. Comparison of Split Tensile Strength (50% Replacement)

Pond Ash and Flyash	Split tensile strength (7 days)	Split tensile strength (28days)	Split tensile strength (56days)	Split tensile strengt (90days)
Neyveli	3.84	4.48	4.91	5.35
Mettur	3.54	3.90	4.46	4.75
Tuticurin	2.95	3.31	3.81	4.55
Ennore	2.76	3.12	3.67	4.30

Table 27. Comparison of Flexural Strength (10% Replacement**)**

Pond Ash and Flyash	Flexural strength (7 days)	Flexural strength (28 days)	Flexural strength (56 days)	Flexural strength (90 days)
Neyveli	5.4	6.60	7.12	7.86
Mettur	4.9	5.86	6.29	6.90
Tuticurin	4.6	5.49	6.13	6.18

Table 28. Comparison of Flexural Strength (20% Replacement**)**

Pond Ash and Flyash	Flexural strength (7 days)	Flexural strength (28 days)	Flexural strength (56 days)	Flexural strength (90 days)
Neyveli	7.54	8.25	8.95	9.78
Mettur	5.26	5.96	6.84	7.5
Tuticurin	4.12	6.54	6.96	7.25
Ennore	5.33	5.88	6.47	6.90

Table 29. Comparison of Flexural Strength (30% Replacement**)**

Pond Ash and Flyash	Flexural strength (7 days)	Flexural strength (28 days)	Flexural strength (56 days)	Flexural strength (90 days)
Neyveli	7.67	8.76	9.85	10.45
Mettur	6.90	7.98	8.89	9.54
Tuticurin	5.84	6.68	7.5	8.12
Ennore	4.78	5.75	6.65	7.25

Table 30. Comparison of Flexural Strength (40% Replacement)

Pond Ash and Flyash	Flural strength (7 days)	Flexural strength (28 days)	Flexural strength (56 days)	Flexural strength (90 days)
Neyveli	7	7.60	8.38	8.78
Mettur	5	5.6	6.29	7.1
Tuticurin	4.44	5.11	5.8	6.21
Ennore	4.08	4.54	5.25	6

Table 31. Comparison of Flexural Strength (50% Replacement)

Pond Ash and Flyash	Flural strength (7 days)	Flexural strength (28 days)	Flexural strength (56 days)	Flexural strength (90 days)
Neyveli	5.4	6.40	7.12	7.86
Mettur	4.2	4.86	5.29	6.00
Tuticurin	4	4.89	5.23	5.98
Ennore	3.87	4.24	4.87	5.34

Selection of Best Powerplant Pondash, Flyash and Optimum Replacement Percentage

Best powerplant, pondash, flyash and optimum replacement percentage can be determined by comparing the results obtained from all replacement percentages with the result obtained from conventional specimen.

Table 32. Conventional specimen results

Strength in N/mm^2	7 days	28 days	56 days	90 days
Compressive strength	18.4	30.5	35.12	36.10
Flexural strength	5.13	6.55	6.82	7
Split tensile strength	2.95	3.57	4.15	4.30

By analyzing the results obtained from Compressive strength test, Split tensile strength test, Flexural strength test we can conclude that 30% replacement of pond ash and fly ash obtained from Neyveli thermal power plant provides best strength when compared with other power plant pondash, flyash. When compared with the conventional specimens, 30% replaced neyveli plant pondash and flyash specimens shows increase in 69 % of compressive strength at 90 days, 62% increase in split tensile strength at 90 days. 66.9% increase in flexural strength at 90 days.

Conclusion

Chemical and Physical characteristics of pondash and flyash samples are analysed. Compressive strength, Split tensile and flexural strength tests are conducted for M30 grade concrete using pondash and flyash. Test results shows that optimum replacement percentage of cement and fine aggregate by flyash and pondash is 30% and Neyveli Power plant pondash and flyash provide better results when compared to other powerplant pondash and flyash.

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