Experimental Study on Partial Replacement of Cement with Fly Ash in Cement Concrete Pavement

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Abstract: Large amount of fly ash are generate from various thermal power station and their disposal is becoming one of the vital environmental challenges. Few years ago, fly ash generated by the burning of coal fired power plants was considered as material of very low value, useful only for landfill. But its usefulness as pozzolanic additive to cement is an important discovery. Therefore, studies have been taken out to reuse high volume fly ash as cement replacement in building materials and pavement construction. In present day, the industrialization and urbanization are the two phenomena that are extend all over the world. Apart from the necessity of these phenomena, there should also be analysis into their negative impacts on the worldwide environment and common life. Most important bad effect of these international processes has been the production of large amount of industrial wastes. Therefore, the problems related with their safe management and dumping has turned into a major test to environmentalists and scientists. Another issue is the stress on land, materials and resources to assist the developmental activities, including infrastructure, pavement etc. The thermal power plants produce considerably large quantities of solid byproduct namely fly ash.

In this experimental program was carried out to partial replacement of fly ash as cement, for enhancement in properties of materials and technology. Cement content is replaced by fly ash according to the range of 0%, 10%, 20%, 30%, 40% and 50% by weight of cement for M35 Grade design mix Concrete with 0.43 water cement ratio and analyzed on different parameters. The exploratory results show that the use of 30% fly ash and 70% of cement gives a excellent performance in terms of compressive strength at 7,14 and 28 days when compared with the cement having no fly ash content.

Keywords: Rigid Pavement, Compressive Strength, Fly Ash, Waste Material, Eco-friendly, CTM

1.0 INTRODUCTION

Concrete is the secondary most widely used material after water and over six milliard tons of concrete is produced each year. Concrete is specific to separate approach like new construction, repair, rehabilitation and retrofitting. Concrete building components in separate sizes and shapes include wall panels, doorsills, beams, pillars and more. Post-tensioned slabs are a select method for industrial, commercial and residential floor slab construction. It makes sense to order the uses of concrete on the basis of where and how it is manufacture, together with its techniques of application, since these have different requirements and properties.

Concrete's versatility, durability, supportable, and economy have made it the world's most widely used construction material. About four tons of concrete are manufacture per person per year worldwide and about 1.7tons per person in the United States. The term concrete mentioned to a mixture of aggregates, usually sand, and either gravel or crushed stone, held together by a binder of cementitious paste. The paste is typically made up of Portland cement and water and may also contain additional cementing materials (SCMs), such as fly ash or slag cement, and chemical admixtures (Figure 1.0).

Figure 1.0 Concrete components: cement, water, coarse aggregate, fine aggregate, supplementary cementing materials, and chemical admixtures

1.1 FLY ASH

Fly ash additionally known as pulverized fuel ash in the United Kingdom is a coal burning product that is composed of the particulates (fine particles of burned fuel) that are induced out of coal-fired boilers together with the flue gases. The ash that falls to the bottom of the boiler's combustion chamber is called bottom ash. (Managing Coal combustion Residues in Mines, committee on Mine placement of coal combustion wastes, National Research council of the National Academies, 2006)

Fly ash is generally considered as a waste material, that is generate as a byproduct of coal combustion process. Fly ash production has increased up to 900 million tonnes per year by 2008 and it is anticipated to increase up to about 2000 million tonnes in year 2020. The amount of fly ash generated by electric power plant in Malaysia is increasing year by year in Malaysia. According to the statistic reported for years 1987 – 1989, 415 million tons of fly ash was produced all over the world. Only 16 % of the totals were utilized in construction sector .The combustion of coal at high temperatures and pressures in power stations produces different types of ash.

Fly ash is a fine gray powder include mostly of spherical, glassy particles that are produced as a byproduct in coal-fired power stations. Fly ash acts with lime to form cementitious compounds. It is commonly known as additional cementitious material. Fly ash is a residue generated in combustion and comprises the fine particles that rise with the flue gases. Ash that does not rise is called bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is a heterogeneous material. The main chemical components present in fly ash are:

Table 1.4.1 Chemical Compositions of Fly Ash

S. No.	Compound	Percentage
1.	Silicon Oxide	59.94
2.	Aluminum Oxide	22.87
3.	Iron Oxide	4.67
4.	Calcium Oxide	3.08
5.	Magnesium Oxide	1.55
6.	Sulfur Oxide	0.35
7.	Potassium Oxide	2.19
8.	Sodium Oxide	0.62
9.	Loss of ignition	3.34

1.2 Scanning Electron Microscope (SEM)

Cambridge Stereoscan 200 was used to study the morphology of the fly ash molecule. Examination under the scanning electron microscope showed that the samples had the usual fly ash morphology and were controlled of mostly small, spherical particles. Fig. 1.2 shows SEM micrograph of the cenospheses particle. It can be observed that the fly ash sample consists of almost regular spherical (cenospheres) particles ranging 2 um to 14 um in diameter. Fig. 2 shows micrograph of cenospheres particle. Usually, fly ash composed of mostly small and spherical particles (Swamy and Lambert,1981)

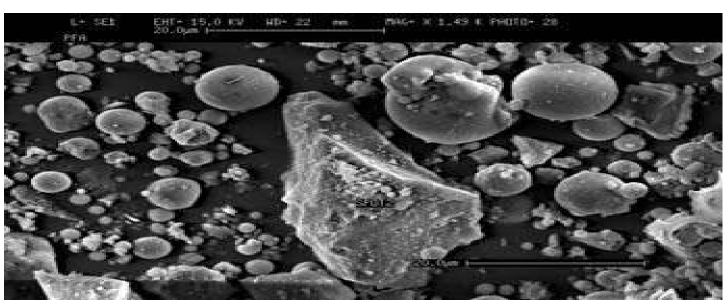

Fig 1.2: SEM micrograph for the cenospheres particle (2.20kx)

1.3 FLY ASH AS A FILLING MATERIAL

Fly Ash has been used for many years as an alternative to maiden aggregates for embankments, especially in road construction projects (UKQAA b, 2007). Fly Ash is used for fill applications because:

- It is lightweight when compared to most materials, having a particle density of 2.10 to 2.3 and a dry bulk density ranging from 1100kg/m^3 to 1450kg/m^3. This leads to savings in material, transport costs and reduces settlement in underlying soils.
- The self-hardening properties of some Pulverized Fuel Ash offer considerable strength advantages over natural clay and granular materials. As Pulverized Fuel Ash is pozzolanic, the small quantity of free lime normally present will enhance the strength of the resulting embankment. This reaction can be increased by mixing lime with the PFA when being placed. It is the pozzolanic reaction that is principally used in soil stabilization and hydraulically bound sub-bases as the binder.
- The immediate strength of Pulverized Fuel Ash means simple shallow trenches have a reduced need for shoring.
- With proper profiling Pulverized Fuel Ash fill can be trafficked in all weathers. (UKQAA a, 2007)

1.4 ADVANTAGES OF USING FLY ASH FOR RIGID PAVEMENT CONSTRUCTION

- Fly ash is a lightweight material, as compared to commonly used fill Material (local soils), therefore, causes minor settlements. It is especially attractive for embankment construction over weak sub grade such as alluvial clay or silt where excessive weight could Cause failure.
- Flexible to stabilization with lime and cement.
- Can replace a part of cement and sand in concrete pavements thus making them more economical than roads constructed using usual materials.
- Fly ash admixed concrete can be prepared with zero slump making it amenable for use as roller compacted concrete.
- Reasonable low compressibility results in negligible subsequent settlement within the fill.
- Preserve good earth, which is precious topsoil, thereby protecting the environment.
- Higher value of California Bearing Ratio as compared to soil provides for a more efficient design of road pavement.
- Pozzolanic hardening property imparts additional strength to the road pavements/ embankments and decreases the post construction horizontal pressure on retaining walls.

2.0 Mix Proportion: The mix proportion for the controlled concrete of M35 (1:0.5:1) grade was Used.

2.1Materials Mixing Proportion: Mix proportion for M35 grade concrete (1:0.5:1) is given in the table below

Table 2.1: Mix proportion for concrete (M35)

S. No.	Fly Ash Content (%)	Cement (kg)	Sand (kg)	Aggregate (kg)	Fly Ash (kg)	Water (kg)
1.	0%	9.000	4.500	9.000	0.000	4.000
2.	10%	8.100	4.500	9.000	0.900	4.000
3.	20%	7.200	4.500	9.000	1.800	4.000
4.	30%	6.300	4.500	9.000	2.700	4.000
5.	40%	5.400	4.500	9.000	3.600	4.000
6.	50%	4.500	4.500	9.000	4.500	4.000

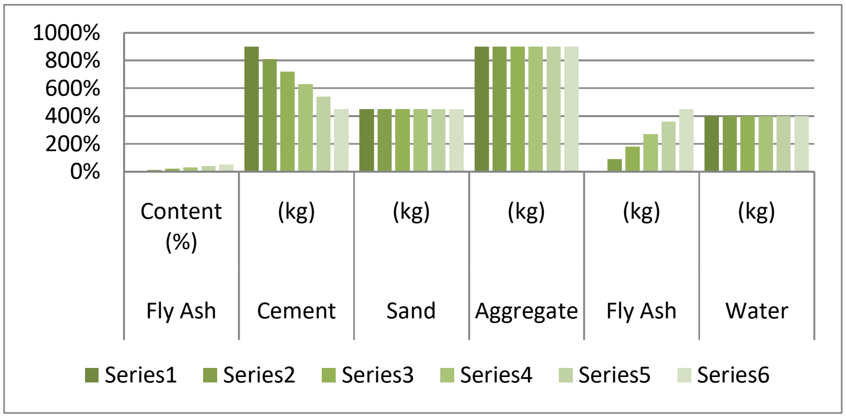

Figure 2.1: Mix proportion for concrete

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3.0 Result and Discussion

3.1 Testing Process.

Concrete cubes are tested in the laboratory after the removing of moulds. Various testes are performed, for finding the physical property of material, initial setting time moisture content specific gravity of cement, fly ash, sand etc., was determined. For workability of concrete, slump test and compaction factor test are conducted before placing of concrete in cubes and for the strength of concrete compressive strength is conducted by the compressive strength testing machine.

3.2Analysis of result

Table 3.2.1: Various tests are conducted on Materials and concrete

S No	Physical Property of Cement	
1	Specific Gravity	3.19
2	Initial Setting Time	50-55 Minutes
3	Moisture Content	5%
4	Color	Greenish Grey
	Properties of Fly Ash	
1	Specific Gravity	2.38
2	Moisture Content	19.56%
3	Color	Grey Whites
	Properties of Fine Aggregates	
1	Specific Gravity	2.9

2	Moisture Content	4.9
3	Color	Grey

Table 3.2.2: Standard Consistency of Fly Ash and Cement concrete Mix

S. No.	Content	Weight of Cement(gms)	Weight of Fly Ash (gms)	Consistency (%) P
1.	0%	300	0	34.0
2.	10%	270	30	33.0
3.	20%	240	60	32.0
4.	30%	210	90	31.0
5.	40%	180	120	30.0
6.	50%	150	150	30.0

Table 3.2.3: Initial Setting Time of Fly Ash and cement concrete mix

S. No.	Content	Weight of Cement(grams)	Weight of Fly Ash(grams)	Initial Setting Time(minutes)
1.	0%	300	0	33
2.	10%	270	30	39
3.	20%	240	60	45
4.	30%	210	90	50
5.	40%	180	120	60
6.	50%	150	150	87

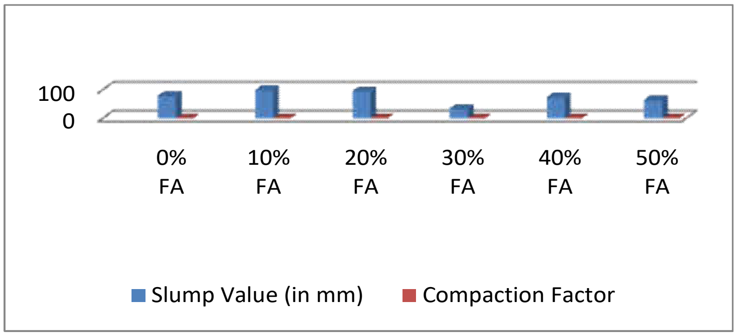

Figure 3.2: Slump Test and Compaction Factor Test of Fly ash Concrete

3.3 Water Absorption Test

It is the ability of a material to absorb and retain water is known as water absorption. Cubes are dried in the oven for 24 hours at 110 degree Celsius and after that, remove these cubes from the oven and weighed (W_1). Now immerse these cubes into the clean water for 24 hours again. Next day remove these cubes from water and soak it with the dry cloth and weighed (W_2) and note the reading.

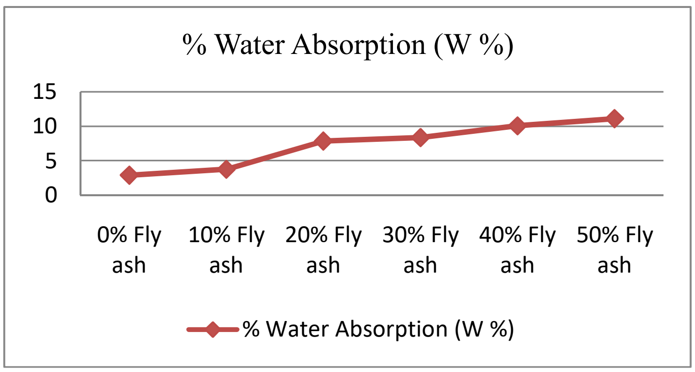

Figure 3.3: Water Absorption value of different concrete cubes

From the table, it has been observed that as the fly ash content increases, the weight of the concrete decreases and water absorption percentage also increases.

3.4 Compressive strength of cubes specimen

To study the compressive strength of Fly ash concrete in comparison to Control concrete, the compressive strength tests were conducted at the ages of 7,14 and 28 days.

Figure 3.4: Concrete Cubes under Compressive Testing Machine

3.4.1 Compressive Strength of M35 grade Control Mix Concrete:

The Compressive strength achieved at different ages namely 7, 14 and 28 days for Control concrete are given in the table below:

Table 3.4.1: Compressive Strength of M35 grade Control Mix Concrete N/mm^2

Grade of Concrete	Compressive Strength at 7 days	Compressive Strength at 14 days	Compressive Strength at 28 days
M35	26.45	32.59	38.89

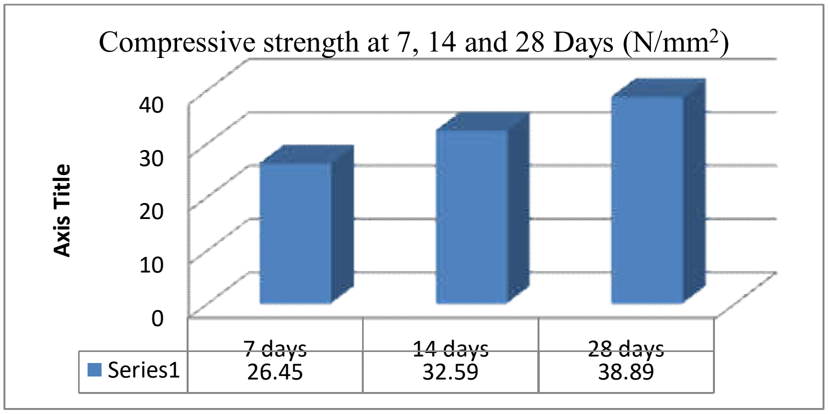

Figure 3.4.1: Compressive Strength of M35 grade Control Mix Concrete N/mm^2

3.4.2 Compressive Strength of FA Concrete:

The Compressive Strength test was carried out by obtaining compressive strength of concrete at the ages of 7, 14 and 28 days. The cubes of dimension 150×150×150mm are tested using Compression Testing Machine of 2000KN capacity.

The table below represents the variation of compressive strength with age for M35 grade Fly Ash Concrete. The variation of compressive strength with the age is shown for each replacement level of fly ash namely 10%, 20%, 30%, 40% and 50%.

In each of these variations, it can be seen that, as the advances, the compressive strength also increases.

Table 3.4.2: Compressive Strength obtained at different ages with different replacement levels.

Ages in days	Compressive Strength at 7 Days(N/mm^2)	Compressive Strength at 14 Days(N/mm^2)	Compressive Strength at 28 Days(N/mm^2)
0% FA	26.45	32.59	38.89
10% FA	33.57	33.68	36.87
20% FA	26.37	34.89	38.13
30% FA	28.80	34.16	39.69
40% FA	25.79	31.79	37.82

50% FA	20.68	25.97	33.20

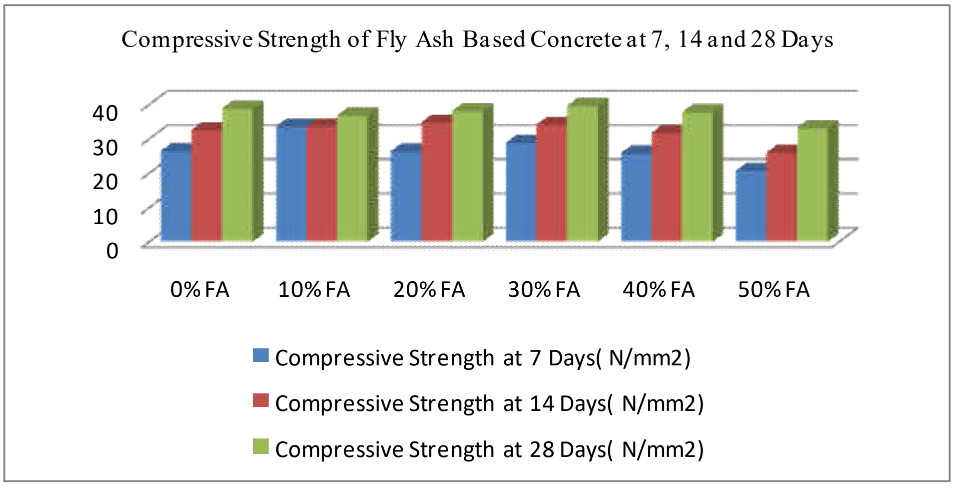

Figure 3.4.2: Compressive Strength of Fly Ash Based Concrete at 7, 14 and 28 Days

4.0 Conclusion

The experimental work on the partial replacement of cement with fly ash in the M35 grade of concrete in the order of 0%, 10%, 20% 30%, 40% and 50%, leads the choice of replacement of 20-30 % fly ash in concrete because of better results. The compressive strength graph shows that as the fly ash content increases the compressive strength also increases up to 20 to 30% and above 30%, it decreases.

It is notified that the use of 20-30% fly ash in cement is sufficient and safe to use in M35 grade of concrete in rigid pavement.

The experimental work is based on the tests results obtained from the conclusions are as follows:

- Fly ash in the concrete mix as the replacement of cement, increases compressive strength of concrete due to the pozzolanic activity of the ash.
- Fly ash is a fine, waste product produced in thermal power plants. The safe disposal is the major problem for fly ash. It can be easily used for replacing the cement up to 30%.
- The heat of hydration in fly ash concrete is low as compared to control concrete as it gains more and more strength.
- The compressive strength increases with the increments of fly ash due to the pozzolanic activity of the ash and the fineness of the particles which makes the structure hardened due to the packing and filling effect.
- In my research work, investigation or analysis, M35 grade concrete with the maximum replacement of 20-30% fly ash may be recommended.

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