Experimental Research of Green Concrete Using Fly Ash as Partial Replacement of Cement

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Abstract :*This paper presents "Research of Green Concrete using Fly Ash as Partial Replacement of Cement.Green concrete is a type of concrete which resembles the conventional concrete but the production of these concrete requires minimum amount of energy and causes least harm to the environment. So, fly ash and recycled coarse aggregates are used to reduce CO_2 emissions, cost saving, energy saving, depletion of natural materials and reduce wastes from the demolition of construction and industry. In this paper, the physical properties of local materials are tested according to ASTM procedure. After testing the materials, American (ACI-C211) method is used for calculation of mix design of concrete. Trial mix designs are considered by using 69% of max: aggregate size (20mm). By using least square method, the highest 28 days compressive strength 6200 psi of concrete is obtained at w/c ratio of 0.46 and aggregate percentage of 69%. And, by using this w/c ratio 0.46 and 69% of coarse aggregate, the field mix design is also calculated. The compressive strength of concrete with various percentages of fly ash (10% and 20%) as cement replacement is tested to know 7 days, 14 days and 28 days strength.*

Key Words: *Green concrete; recycled coarse aggregates; physical properties; cement replacement; compressive strength*

1. INTRODUCTION:

Concrete is the most widely used construction material in the world. It is used in many different structures such as dam, pavement, building frame or bridge. With the development of economy and population, concrete is the vital part of the main building of structure and it is widely used in nowadays. Its popularity gives the well-known advantages, such as low cost, good in compression, durable, good fire resistance, general availability and wide applicability. But this popularity of concrete also carries with it a great environmental cost. Concrete is a manufactured product, essentially consisting of cement, aggregates, water and admixtures. The production of cement, an essential constituent of concrete, leads to the production of carbon dioxide. Most damaging are the huge amounts of energy required to produce Portland cement as well as the large quantities of CO2 released into the atmosphere in the process. The billions tons of natural materials are mined and processed each year.

Green concrete is a type of concrete which is much like the conventional concrete but the production or usage of such concrete requires minimum amount of energy and causes least harm to the environment. Rapid industrial development causes serious problems all over the world such as depletion of natural aggregates and creates enormous amount of waste material from construction and demolition activities. The development and use of mineral admixtures for cement replacement is growing in construction industry mainly due to the consideration of cost saving, energy saving, environmental production and conservation of sources. Mineral admixtures generally used are raw fly ash, rice husk ash, silica fume and blast furnace slag. Rapid industrial development causes serious problems all over the world such as depletion of natural Supplementary cementitious materials .Fly ash and recycled coarse aggregates are used to reduce such problems.

Green Concrete capable for sustainable development is characterized by application of industrial wastes to reduce consumption of natural resources and energy and pollution of the environment. Green Concrete used in various construction fields. In order to avoid the environmental and economy affect caused by the ingredients of concrete and to obtain the strength, an attempt has been made to analyze the effect of replacement of cement by optimum amount of fly ash, partial and full replacement of coarse aggregate by recycled coarse aggregate in the research.. Recycled coarse aggregate are the concrete blocks crushed into 20mm size and made as saturated surface dry. The objectives of this research are to determine the compressive strengths with different mix proportions of fly ash as cement replacement and to evaluate experimentally the effects of partial replacement of cement with fly ash and using recycled coarse aggregate for green concrete production.

2. FLY ASH:

Fly ash is a by-product of coal combustion in electric power generating plants. Fly ash released during this combustion process is an environmental pollutant, because of which care must be taken while using as an admixture for construction purposes. The particles of fly ash are glassy, and spherical in shape. Fly ash, the

most widely used supplementary cementitious material in concrete, is a by-product of the combustion of pulverized coal in electric power generating plants. During combustion, the coal's mineral impurities (such as clay, feldspar, quartz, and shale) fuse in suspension and are carried away from the combustion chamber by the exhaust gases. In the process, the fused material cools and solidifies into spherical glassy particles called fly ash. The fly ash is then collected from the exhaust gases by electrostatic precipitators or bag filters. Fly ash is a finely divided powder resembling Portland cement. Most of the fly ash particles are solid spheres and some are hollow cenospheres.

Characteristics of Fly Ash

(1)Environmental Effect

With proper mixture proportions and quality controls, about 25% of Portland cement can be replaced by Fly Ash and at the same time contribute to reduction of CO_2 emissions and obtain concrete that is more durable than normal Portland cement concrete.

(2)Fly Ash as a Water Reducer

Too much of mixing water is probably the most important cause for many problems that are encountered with concrete mixtures. There are two reasons why typical concrete mixtures contain too much of mixing water. Firstly the water demand and workability are influencing greatly by particle size distribution, particle packing effect and voids present in the solid system. Generally fly ash in mortar or concrete mixture reduces that water requirement for obtaining given consistency.

3. RECYCLED COARSE AGGREGATE:

Recycling is the act of processing the used material for use in creating new product. The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement materials. Recycled aggregate are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. There are many advantages through using the recycled aggregate. The advantages that occur through usage of recycled aggregate are: environmental gain, cost, job opportunities, and sustainability.

Recycled coarse aggregate generally has a higher absorption and a lower specific gravity than conventional aggregate. This results from the high absorption of porous mortar and hardened cement paste within recycled coarse aggregate. Absorption values typically range from 3% to 10% depending on the concrete being recycled. The values increase as coarse particle size decreases. The high absorption of the recycled aggregate makes it necessary to add more water to achieve the same workability and slump than for concrete with conventional aggregates. The particle shape of recycled coarse aggregate is similar to crushed rock. New concrete made from recycled coarse aggregate generally has good durability. Carbonation, permeability and resistance to freeze-thaw action have been found to be the same or even better than concrete with conventional aggregates.

4. TESTING OF MATERIALS USED IN THIS RESEARCH:

In this research, Local product Double Rhino cement is used and fly ash is considered to partially replace for cement. Fly ash is taken from Tigyit Coal Fired Power Plant between Loikaw and Pinlouk. Recycled coarse aggregates are also taken from the demolition site of Mandalay Industrial zone. Detailed chemical analysis of cement is conducted. The chemical composition test of Double Rhino Cement is tested at Ar Thit Man Company. The chemical composition of fly ash is tested at Geology Department of Mandalay University. The chemical composition of Double Rhino cement and fly ash are shown in Table 1 and Table 2 respectively.

Table 1: Chemical Composition of Double Rhino Cement

Chemical constituents	Composition in Percentage (%)	Approximate Composition Limits of Cement (%)
Silica (SiO_2)	20.03	17-25
Alumina (Al_2O_3)	5.74	3-8
Ferric Oxide (Fe_2O_3)	3.07	0.5-6
Calcium Oxide (CaO)	63.37	60-67
Manganese Oxide (MgO)	1.56	0.1-4
Sulphur Trioxide (SO_3)	1.75	1-3
Others	0.64	1
Loss	3.84	2
Total	100	

Table 2: Chemical Composition of Fly Ash

Oxide	Content (%)		ASTM Class F Requirement
Silica (SiO_2)	52.7	82.89	Min 70
Alumina (Al_2O_3)	22.7		
Iron Oxide (Fe_2O_3)	7.49		
Calcium Oxide (Ca O)	8.75		-
Sulphur Trioxide (SO_3)	1.11		Max 5
Others	7.25		-
Total	100		-

According to the ASTM requirement, the limitation of Fly Ash Class F are the combination of silica, alumina and iron oxide is minimum 70 and the amount of Sulphur trioxide is 5 maximum. The amount of the combination of silica, alumina and iron oxide in selected fly ash is 82.9 which is greater than minimum 70 and Sulphur trioxide is 1.11 which is lesser the maximum 5 value. So, the fly ash used in this study is a Class F fly ash.

Physical properties of cement and cement with various replacement percentage of fly ash are tested. And, the physical properties of fine and recycled coarse aggregates are also tested. The physical properties of local materials used in this research are determined according to ASTM procedure. Test results are shown in Table 3 to Table 6. The properties of the materials are within the standard limit.

Table 3: Physical properties of local Double Rhino cement

Sr No.	Properties		Result Value	ASTM Standard range
1	Specific gravity		3.14	3.1 to 3.25
2	Finess Modulus		1.0%	<10%
3	Normal Consistency		31%	26% to33%
4	Setting time (min)	initial	95 min	>45 min
		final	145 min	<375 min
5	Soundness		0.6 mm	<10 mm

Table 4: Physical properties of local Double Rhino cement with various % of fly ash

% replacement of fly ash	0%	10%	20%
Normal consistency(%)	31	31	30.5
Fineness(%)	1.0	1.5	2.5
Initial Setting Time (min)	95	160	135
Final Setting Time (min)	145	250	230
Soundness (mm)	0.6	0.9	0.95

Table 5: Physical properties of fine aggregates

Sr No.	Properties	Result Value	ASTM Standard range
1	Specific gravity	2.66	2.5 to 2.9
2	Finess Modulus	2.05	2 to 3.1
3	Water Absorption	1.01	<3%

Table 6: Physical properties of recycled coarse aggregates

Sr No.	Properties	Result Value	ASTM Standard range
1	Specific gravity	2.72	2.5 to 2.9
2	Finess Modulus	7.75	6 to 8
3	Water Absorption	2.2%	<3%

5. TRIAL MIX DESIGN FOR CONCRETE:

In order to obtain a satisfactory mix, the estimated proportions of the mix must be checked by making trial mixes and, if necessary, appropriate adjustments must be made to the proportions until a satisfactory mix has been obtained. American (ACI-C211) method of mix design is used for normal weight aggregate concrete. In this study, trial mix designs are considered by using 69% of max: aggregate size (20mm). In this study, target strength of trial mix design is 5000 psi. The water-cement ratio is considered such as 0.4 and 0.5 for the comparison of the compressive strength of concrete. The mix designs are calculated by using various water to cement ratio. The trial mix designs are summarized in Table 7and the batch weight per cubic yard of fresh concrete are described in Table 8 and Table 9.

Table 7: Trial Mix Design of Case 1 and 2

Case No.		Fly Ash (%)	w/c	Coarse Agg: (%)
Case 1	A	10	0.4	69
	B	20	0.4	
Case 2	A	10	0.5	69
	B	20	0.5	

Table 8: Batch Weight per Cubic Yard of Fresh Concrete(case 1)

Replacment % of Fly Ash	Wt: of Unit (lb/yd^3)					Water-cement ratio
	Cement (lb)	Fly Ash (lb)	Sand (lb)	Aggregates (lb)	Water (lb)	
0%	680	-	958	1863	388	0.4
10%	612	68	958	1863		
20%	544	136	958	1863		

Table 9: Batch Weight per Cubic Yard of Fresh Concrete (case 2)

Replacement % of Fly Ash	Wt: of Unit (lb/yd^3)					Water-cement ratio
	Cement (lb)	Fly Ash (lb)	Sand (lb)	Aggregates (lb)	Water (lb)	
0%	680	-	1069	1863	387	0.5
10%	612	68	1069	1863		
20%	544	136	1069	1863		

Compressive strength is a measure of the maximum resistance that a concrete specimen can maintain against axial loading. It is one of the primary parameters for concrete quality control testing. In this research, the cube test is used. The test results are shown in Table 10 and compared in Figure 1 and Figure 2..

Table10: Compressive strength of concrete with various % of fly ash

% of fly ash	Water-cement ratio	Compressive strength (psi)	
		7 days	28 days
10%	0.4	5106	6922
	0.5	4221	5741
20%	0.4	4482	6422
	0.5	3756	5537

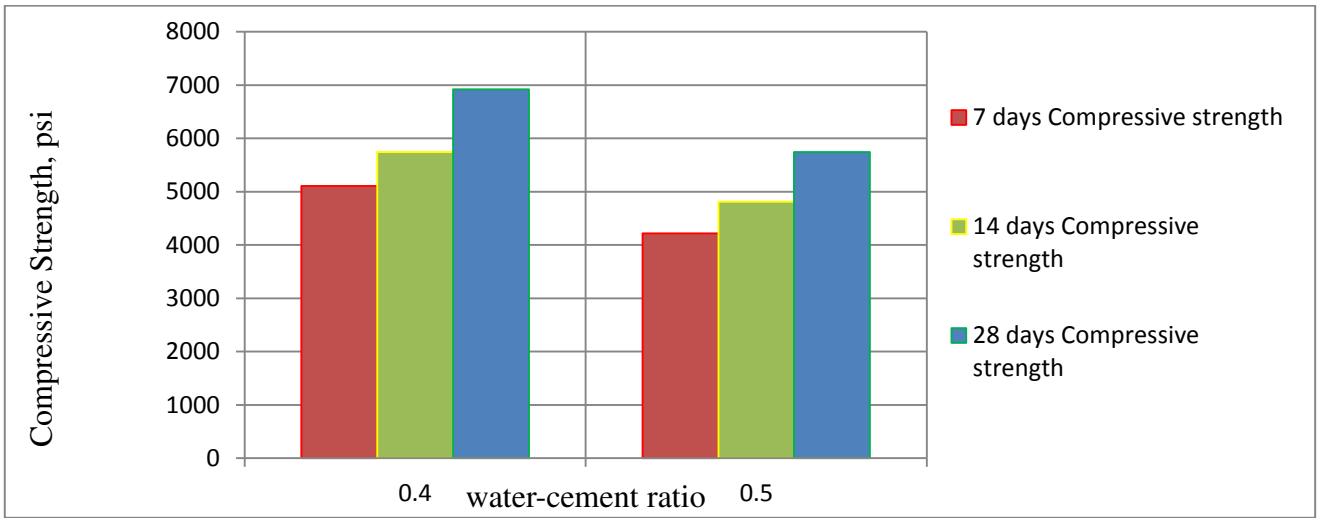

Figure 1.Compressive Strength of Concrete (Fly Ash 10%)

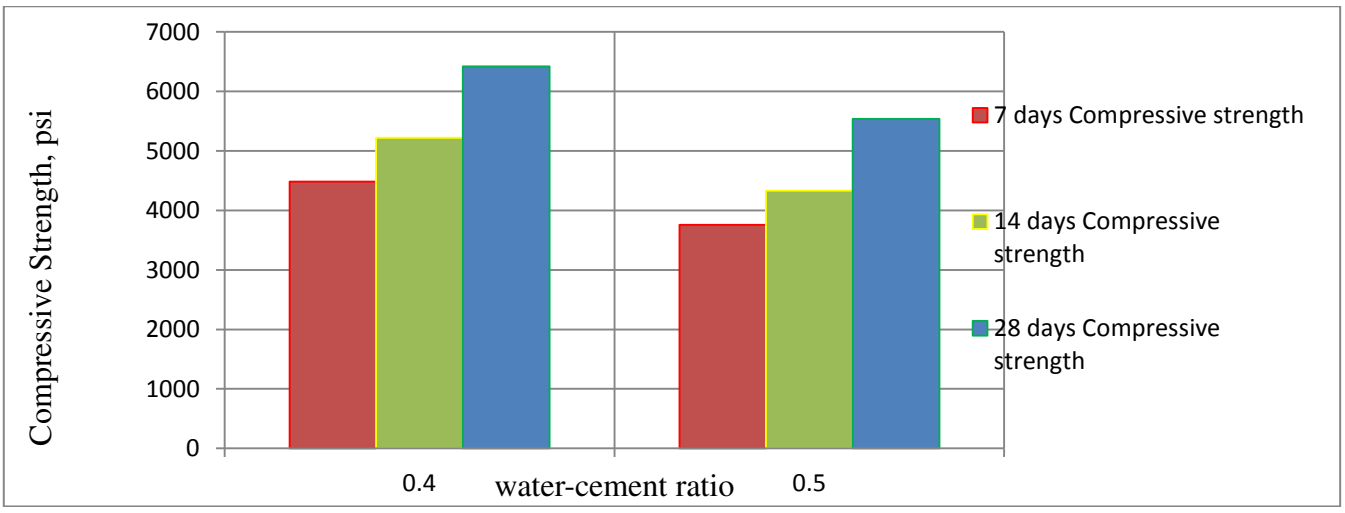

Figure 2.Compressive Strength of Concrete (Fly Ash 20%)

The relation between compressive strength and water to cement ratio is calculated by using least square method and shown in Figure 3. From the trial mix design results, it is found that the 28 days concrete strength with10% fly ash is the highest. From the figure 3, the optimize w/c for 28 days mix design strength of 6200 psi is 0.46.

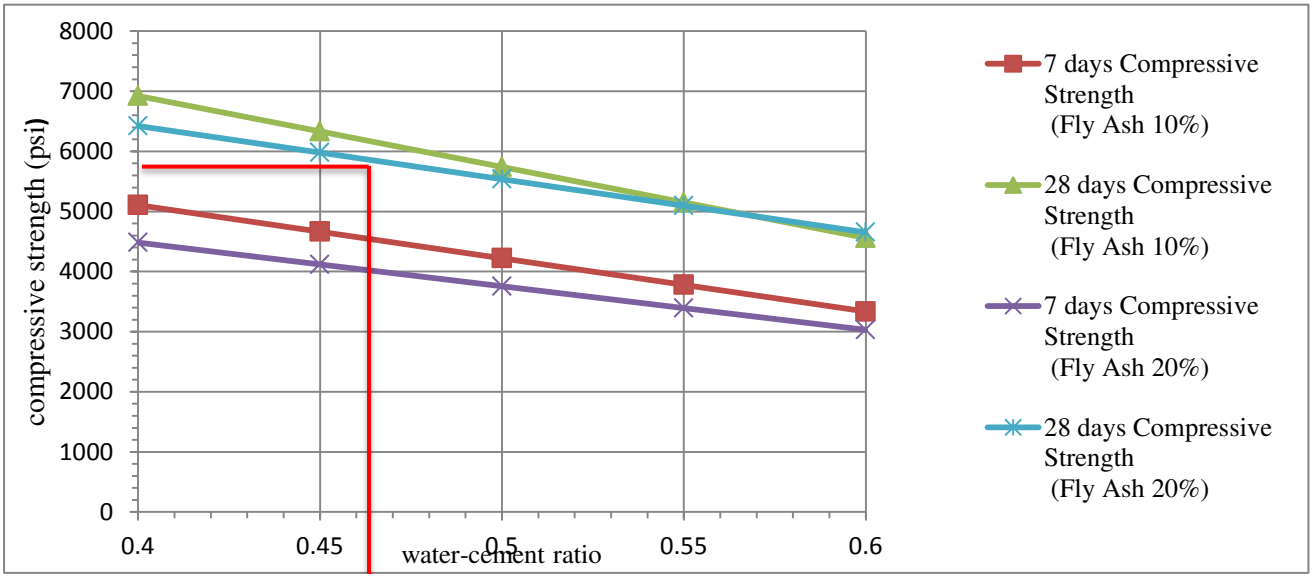

Figure 3.Compressive Strength of Concrete with different W/C ratio by using Least Square Method

6. FIELD MIX DESIGN AND COMPRESSIVE STRENGTH OF CONCRETE:

Field mix design is considered with target compressive strength (6200 psi), optimum value of w/c (0.46) and 69% of maximum recycled aggregate size (20mm). Batch weight per cubic yard of fresh concrete are the followings and the strength test results are described in Table 11. It is found that the strength of green concrete with pure cement does not reach the target strength.

cement = 739 lb/yd^3
Coarse aggregate = 1900 lb/yd^3
Fine aggregate = 981 lb
water = 340 lb

Table11: Compressive strength of concrete with cement alone

Number of Sample	Days	Strength of Each Sample (Psi)	Average Strength (Psi)
3	7	3080	3112
		3080	
		3175	
3	14	3520	3558
		3540	
		3615	
3	28	3980	4000
		4010	
		4009	

Slump and air content of concrete with pure cement and cement with various % of fly ash are compared in Table 12

Table12: Slump and air content value of concrete

% of fly ash	0%	10%	20%
Slump (cm)	7.5	8.5	9.0
Air content %	1.9	2.0	2.2

7. DISCUSSION:

From the test results, it is found that the compressive strength for 7 days, 14 days and 28 days are decreased with increasing water-cement ratio. According to figure 1and figure 2, to get 5000 psi of required compressive strength of concrete at 28 days, fly ash can be replaced about 10% and 20%. The more percentage of fly ash as cement replacement, the more values of slump. And, the slump of concrete with various replacement percentage of fly ash is within the allowable limit. The air content of concrete is within the allowable limit and the amount of air content is greater with various replacement percentage of fly ash. From Table 4, the more percentage of fly ash as cement replacement, the value of percentage retained on sieve greater. The normal consistency of Double Rhino cement is 31% and the result is within the limit. And, the normal consistencies of cement with various replacement of fly ash are decreased and all are within the standard limit. So the amount of water needed is reduced as replacement percentage increased. The more percentage of fly ash as cement replacement, the initial and final setting time is slower than the cement alone. The initial and final settings of cement and cement with various replacement of fly ash are within the standard limit. It is clear that, the more percentage of fly ash are replaced, the more value of soundness.

8. CONCLUSIONS:

The following conclusions may be drawn from the research.

- Fly ash percentage 10% is chosen for concrete mix proportions because the compressive strength of concrete at 28 days strength of 10% fly ash is higher than that of 20% fly ash.
- To get the required compressive strength (5000 psi), fly ash can be used up to 10% and 20% as cement replacement.
- The values of air content and slump are increased with more percentage of fly ash, the workability of concrete is better.
- One must not forget to achieve the sustainable construction. There are various means to achieve sustainable construction and one of the means is through green concrete.
- With Green concrete Technology we can save the natural materials for future use .With the time, the natural resources will deplete and so the cost for the material will increase. If we use waste materials for construction, the natural resources will become a sustainable material and as well the cost will be reduced.

- With waste material as alternative we can help reduce the environmental problems and protect the naturally available materials for future generations as well.
- 7.Green concrete may be produced by using fly ash and recycled aggregates to be sustainable constructions.

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