Proceedings of the 3rd International Conference on Chemical Engineering (ICCE2021), Mehran University of Engineering and Technology, Jamshoro, September 22-23, 2021, 197-204

Utilization of Fly ash and Indus River Sand in Autoclaved Aerated Concrete

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ABSTRACT

Concrete is one of the most used construction materials in the world today with production rate of 4.4 billion tons per annum. This amount of concrete requires huge amount of cement which is made by the clinker process. This process does not only require significant amount of energy, but also large amount of carbon dioxide (CO_2) is released in the atmosphere that has become a reason of global warming. In such scenario, Fly ash as a cement replacement and Indus river sand as Quartz Sand replacement material can play a major role in solving the problem of carbon dioxide gas emissions. This technique may also save the environment from pollution that is caused due to the dumping of fly ash into the rivers. This Research study is focused on a move towards Sustainable Civil Engineering by introducing an eco-friendly concrete in the construction industry. So, fly ash and Indus river sand both were utilized in the Autoclaved aerated concrete (AAC) a light weight concrete. These materials were used at different percentages as Cement and Sand Replacement in the AAC. After replacement, Aerated Concrete were be cured in Autoclave Machine for 9h duration. Finally different tests were be performed to check the effect of both replacements.

Keywords:

Fly ash
Indus river sand
Autoclave aerated concrete

1. Introduction

Civil Engineering has major environmental impacts such as CO_2 emission, depletion of natural resources, energy consumption, noise and water pollution, reduction in the available land size etc .[1]. Hence the society is in dire need to move towards sustainable development. Pakistan along with the world is facing such problems, and a move towards sustainable civil engineering is imminently required. A solution that addresses to the some of those problems is to use the green-material or eco-friendly material. Fly ash is one of such material is being produced in abundant amount (for Lakhra coal plant production is about 2 million tons/ year) and is being deposited as backfill causing Environmental and Human health hazards [2]. Another major factor which also contributes in the increase of environmental hazards is thinning of the earth surface, which is mostly due to the excessive use of fine aggregates in the construction industry. Researchers all over the world has utilized Fly ash as a replacement of Quartz Sand in Autoclave aerated concrete. Previously the research has been done where the properties of aerated concrete are examined by partially replacing cement with class F fly ash (15%, 20%, 25% and 30%) and by using the different dosages of Aluminum Powder (0.1%, 0.25%, 0.5%,

0.75%) at cement to fine aggregate ratio of 1:2, water to cement ratio of 0.45 at the 7 and 28 days of water curing. In order to save to environment, this harmful product is put to good use by using it as a replacement of Cement and Quartz Sand in the Autoclave Aerated concrete (AAC)[3][4][5] . Along with the Fly ash as the partial replacement, Indus river sand will also be used as a replacement of Quartz Sand in the aerated concrete [6].

1.1. Aerated concrete

It is a light weight concrete composed of a binder, Fine aggregate, and an air entraining agent. It is formed by either a chemical or a physical process in which air or gas is entrapped into the slurry by the mixing of stabilized foam or an aerating agent (such as aluminum powder). Aerating agent (Aluminum Powder) reacts with Lime and generates hydrogen bubbles in the slurry, resulting in the macroscopic voids in the mix thus increasing the volume and reducing the weight and ultimately the density of the concrete. The binder composition and the method of curing influence the microstructure and thus the physical and mechanical properties of aerated concrete when used as a structural material it is cured in high pressure steam in the factory [6].

Classification of Aerated Concrete

Aerated Concrete is classified based on method of curing

Autoclaved aerated concrete.

Non Autoclaved aerated concrete.

2. Materials and Methodology

2.1. Materials used in Mix Design

Following materials were used in the research process their source and availability are given in table 01.

Table 01: Materials used in Mix Design

Material	Source
Binder (Cement)	Lucky cement factory (OPC)
Binder (Fly Ash)	Trade worth karachi
Fine Aggregate	Indus River Sand
Gypsum	Hyderabad Saddar market
Lime	Hyderabad Saddar Market
Aerating agent (Aluminium)	Sandwick company
Water	Portable water

Cement

Cement is used as a binding in the AAC. The cement used in this research to produce AAC is as per specifications of ASTM C150 and is locally available ordinary Portland cement (OPC) of Lucky Cement Company. Following tests were performed before using it in the Concrete.

Table 02: Tests Performed on Cement

Tests Performed	**Results**
Specific Gravity	3.0
Fineness	94 %
Normal Consistency	0.33
Soundness	2.44mm
Initial Setting time	75 minutes
Final Setting time	182 minutes
Compressive strength at 28 days	41 Mpa

Indus River Sand (Fine Aggregate)

According to ASTM C1693 -11 (Reapproved 2017) Sand used as a raw material for the production of AAC should be quartz sand. It is also used as fine aggregate in the production of AAC. Quartz Sand is also known as Silica Sand that is the most common type of sand. The Indus river sand used this research was the sand that retained on 425-micron sieve when sieved from 600-micron sieve because the size of quartz sand is between 4 mm to 8mm[7].

Fly Ash

Fly ash also called as flue ash is a waste product obtained from the combustion of coal in thermal plants. It is lighter in weight and has pozzolanic properties hence it can be used to replace partially cement or fine aggregate in concrete. In addition to that it produces less heat of hydration and does not emit carbon during reaction with alkaline solutions hence regarded as environmentally friendly material. The fly ash used is in this research as the replacement of Fine aggregates is of **Class C** according to ASTM C618-19 [8].

Gypsum

Gypsum is soft naturally occurring mineral of sulphate having chemical formula Ca2SO4.2H2O. It regulates the setting of the mixture of AAC. Gypsum used in this research in the production of AAC is locally available gypsum was bought from Hyderabad.

Quick Lime

When Lime CaCO3 is dissociated it produces quick lime CaO, is easily available and is widely used. Quick Lime used in this research is locally available gypsum and was bought from Hyderabad[9].

Aluminum Powder

Aluminum powder is actually the aluminum in powder form. It is gray in color. Aluminum powder besides other uses is used as an aerating agent in the production of AAC. Aluminum powder used in this research is of coarser type with average particle size of 0.2mm. By hit and trial method the quantity of aluminum powder in this research that was found to be 0.1% of cement. Aeration in sample was increased with the increasing of water content in mix[10].

Water

Water is an essential component that starts the reaction between the components of the NAAC. Water used in this research is portable water available at Concrete lab Civil Engineering Department MUET Jamshoro.

2.1. Methodology

Major steps followed in our study are depicted in fig. 01. To check the effect on compressive strength of Autoclaved aerated concrete after the utilization of fly ash and Indus river sand as a cement and fine aggregate replacement. Initially trials were made for a suitable Aluminum and Water binder ratio for the Mix design. Trials with Aluminum (0.1, 0.12, and 0.13) and water binder ratio (0.5, 0.6, and 0.7) were made. After Trials a suitable percentage of aluminum powder 0.1 % and water binder ratio of 0.75 was chosen. An additional water to fly ash ratio of 0.6 was also used. The ratio of the quantities of materials used in this research such as Binder: Fine Aggregate: Gypsum: Lime ratio is taken as 40%:50%:03%:07% i.e. 1:1.25:0.175:0.075 [2]. A total number of 64 Cubes of size $200 \times 100 \times 100$ cm were made at curing period of 9 hours in Autoclaving machine.

Fig. 01: General methodology of the research

A brief description of methodology steps are illustrated in fig. 02.

Fig 02: Detailed research methodology

After the selection of proper percentage of Aluminum as an aerating agent and water binder ratio. The next stage will be replacement of Cement with Fly ash in the AAC at different values of 15%, 20%, 25% and 30%. The optimum Percentage at which the fly ash replacement gives maximum value of compressive strength in AAC will be selected. The optimum percentage of Fly ash will be fixed and indus river sand will be replaced with quartz sand in the AAC. Finally the optimum percentage of both the Fly ash replacement and indus river sand will be chosen.

3. Results and Discussion

3.1. Compressive strength of Autoclave aerated concrete when fly ash is replaced with cement.

The results obtained after by testing of the prisms in the UTM (Universal testing machine) for compressive strength suggest that the replacement of 20 % of fly ash in the autoclave aerated concrete showed the maximum value of Compressive strength which was 8.652 Mpa and further increase in the Fly ash Percentage decreased the compressive strength (Fig. 03). It indicated that a 20% replacement of fly ash with the cement in the autoclave aerated concrete could give us an optimum condition.

Table 03: Compressive Strength when Fly Ash is replaced with Cement

Mix ID	Fly ash Replacement percentage	Compressive strength Mpa
FA15	15	8.244
FA20	20	8.652
FA25	25	8.521
FA30	30	8.412

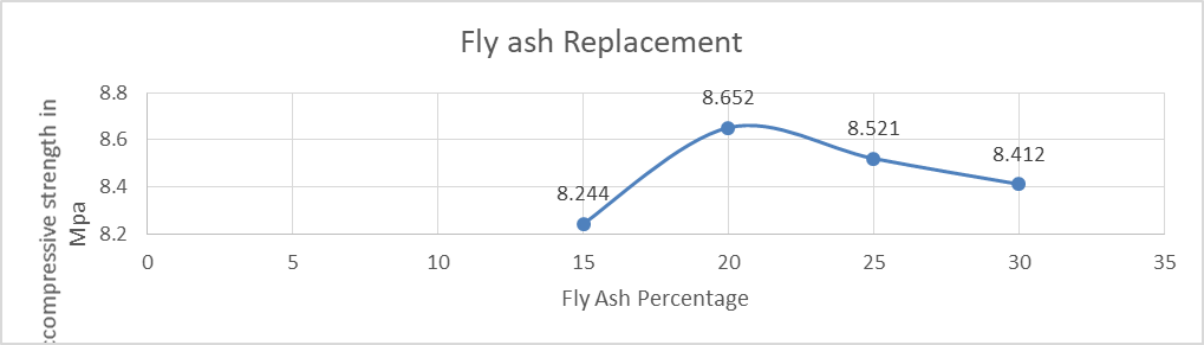

Fig 03: Compressive Strength when Fly Ash is replaced with Cement

3.2. Effect of replacement of Indus River Sand (IRS) with Quartz sand

It is already mentioned that optimum replacement of fly ash with cement in the autoclave aerated concrete was 20%. Considering this, further replacement was done in the fine aggregate, *i.e.*, Indus River sand was replaced with Quartz sand. As depicted in fig. 04, a maximum of compressive strength was obtained when replacement was achieved at 20%. The similar results are tabulated in table 04.

Table 04: Compressive Strength when Indus river sand is replaced with Quartz sand

Mix ID	Indus River Sand Replacement percentage	Compressive strength Mpa
FA20IRS25	15	8.432
FA20IRS50	20	7.852
FA20IRS75	25	7.621
FA20IRS50	30	7.412

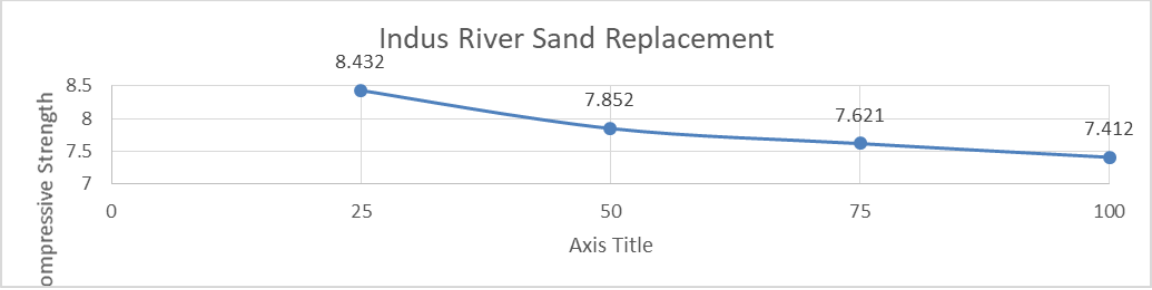

Fig. 04: Compressive Strength when Indus River Sand is replaced with Quartz Sand

4. Conclusion

The following conclusions were drawn from present work,

- ✓ Optimum percentage of fly ash was found at 20% replacement of cement with fly ash.
- ✓ The maximum compressive strength achieved after replacement of fly ash with cement was 8.652 MPa.
- ✓ When Quartz sand was replaced with Indus river sand the compressive strength of concrete decreased by increasing replacement percentage of Indus river sand.

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