USE OF THE KIWIRA FLY ASH IN THE MANUFACTURE OF BUILDING BLOCKS

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ABSTRACT

Research has been done on the feasibility of using fly ash as a partial replacement of Ordinary Portland Cement in the production of low cost construction blocks.

Fly ash from Kiwira Power Plant (Tanzania) was used for the study and a practical optimum cement replacement ratio was found to be 25%.

The results indicate that substantial savings could be achieved by the use of the fly ash at the same time pollution problems of the ash could be minimized.

The use of the low cost fly ash cement blocks in construction could solve the housing problems of the majority of rural and urban poor.

Other suggested possible uses of the fly ash are in concrete and in the manufacture of Lime Fly Ash Block (LFB).

INTRODUCTION.

General

Fly ash, known also as pulverised-fuel ash, is the ash precipitated electrostatically from exhaust fumes of coal-fired power stations. It is pozzolanic in nature and an extensive review has been written by Berry and Malhotra [1]. The ash is in a form of a very fine dust and is carried off in the stack gases from the boiler units and collected by air pollution control equipment.

Fly ash particles are typically spherical and are at least the same fineness as cement (although with fewer very fine particles [2]) so that silica is readily available for reaction [3]. The diameter of the particles range from 0.001mm to more than 0.150mm, the majority(prefarably more than 60%) being less than 0.045mm [4]. The range of particles size in any given fly ash is largely determined by the type of dust collection equipment used. Fly ash from the boilers where mechanical collectors alone are employed, is coarser than from plants using electrostatic precipitator

Chemical composition of ash is determined by types and amounts of incombustible matter in the coal used. Fly ash comprises chemical compounds from elements such as silicon, aluminium, calcium and magnesium. The same compounds exist in fly ash and Portland cement. Those of fly ash are armorphous (glassy) due to rapid cooling, those of cement are crystalline formed by slower cooling. The major difference between fly ash and Portland Cement is the relative quantity of each of the different compounds. Portland cement is rich in lime (CaO) while fly ash contains less lime. Fly ash is high in reactive silicates while Portland Cement has smaller amounts [5]

According to ASTM C 618 - 89, there are two types of fly ash, namely Class F and Class C. Class F fly ash is normally obtained from sub-bituminous coal (anthracite) while Class C fly ash is obtained from bituminous coal (lignite). Both Class F and Class C fly ashes are suitable for cement replacement in concrete.

However, Class F fly ash has 70% siliceous and aluminous material (SiO_2 + Al_2O_3 + Fe_2O_3) while Class C fly ash has 50%. Thus Class C fly ash has more pozzolanity (6). Other chemical and physical constituents of the two types of fly ash are shown on Tables 2 and 3.

Table 1. Chemical Composition of FlyAsh (ASTM C 618-89)

1. Sulphur trioxide (SO_3) max.%	5.0
2. Moisture content max. %	3.0
3. Loss on Ignition max. %	6.0

Table 2. Physical requirements of Class C and Class F Fly Ash (ASTM C 618-89)

Fineness: - Amount retained when wet sieved on 0.045 mm sieve Max %	34
Pozzolanic activity index - with Portland cement, at 28 days min % of control	75
Water requirement max % of control	105
Soundness: - Outoclave expansion or contraction max %	0.8
Uniformity requirements Specific gravity max variation from average %	5
Percent retained on 0.045mm (No.325) Max variation %	5

World wide Production and Utilization.

According to O. Manz [7] in his report on world wide production and use of fly ash, in 1989, the production of coal was 4,636 million tonnes.The largest producers of coal were China, USA, USSR, East Germany and Poland. In the same year, 563 million tonnes of coal ash were produced with approximately 90 million tonnes being utilized for diferent purposes. The total amount of ash used in concrete was about 27.9 million tonnes as cement raw material, 7.6 million tonnes in blended cement and 17.5 million tonnes for cement replacement.

The Chinese experience.

Despite the impressive figures on world-wide utilization of fly ash cited above, literature indicates that apart from China, very small amounts of fly ash and bottom ash are used in the manufacture of low cost construction materials such as bricks and blocks.Available literature also indicates that most research done on the manufacture of bricks and blocks aimed at fired or steam cured blocks.

In China coal is used as the major source of energy and this results in substantially high production of fly ash. To avoid excessive pollution by this ash there was a need to research on fly ash utilization.A project was introduced at Shanghai Research Institute of Building Sciences (SRIBS) with a package of technology and management of fly ash.

Between 1982 and 1989 the production of fly ash increased from 27 million tonnes to 55 million tonnes. In the cause of execution of this project the utilization of fly ash increased from 4.6 million tonnes in 1982 to 14 million tonnes in 1988[8].

Currently in China fly ash is used in concrete, road construction, bricks, tiles and blocks, silica fume super-high performance concrete, abrasion resistant concrete, cement manufacture, backfill, aerated concrete, expanded aggregate for lightweight concrete and for high temperature refractory materials etc.

COAL AND FLY ASH PRODUCTION IN TANZANIA.

Reserves and Occurrence of Coal in Tanzania.

Important coal reserves in Tanzania occur in the Karoo fields of south western Tanzania. Reserves are estimated at 1900 million tonnes of which 304 million tonnes may be considered proven.

There are ten known potential coal fields in Tanzania. These are Songwe Kiwira, Kelewaka Mchuchuma, Ngaka, Njuga Mhukuru, Mbamba Bay Galula, Ufipa, Liweta and Lumecha. Of these, only Songwe-Kiwira and Kelewaka Mchuchuma are considered significant.

At present coal is mined at Ilima and Kiwira only. The Ilima mine has a production capacity of 10,000 tonnes per year and the Kiwira mines produces 150,000 tonnes per year.

Fly Ash Production in Tanzania.

Two major sources of fly ash in Tanzania are the Southern Paper Mill (SPM) and Kiwira Power Plant. The combined production of these sources is estimated at 10,000 tonnes per year.

It is estimated that by the year 2000 the demand for coal inTanzania will reach 2.67 million tonnes. Of these 1.2 million tonnes will be used in power production giving an estimated fly ash output of 120,000 tonnes annually

PROPERTIES OF THE KIWIRA FLY ASH.

Chemical and physical tests on the Kiwira Fly Ash have revealed the properties summarised in Tables 3 and 4 below.

Table 3: Chemical Composition of Kiwira FlyAsh.

CHEMICAL	PERCENTAGE
SiO_2	44.3
Al_2O_3	22.3
Fe_2O_3	3.802
CaO	2.577
MgO	0.481
K_2O	0.883
SO_3	2.29
Cl	0.005
LoI	2.55

Source: Materials Testing Laboratory, Tanzania Portland Cement Company, Dar es Salaam (1991).

Table 4 : Physical Properties

Sieve Test

SAMPLE	Percentage passing through sieve sizes.			
Sieve (mm)	0.060	0.090	0.100	0.200
Fly ash	76.26	80.06	81.32	83.98

Source: Materials Testing Laboratory, Tanzania Portland Cement Company, Dar es Salaam (1991).

Other Physical Properties include the following:

- Specific gravity, 2.11
- Moisture content, 2.7 %
- Pozzollanic activity index, 88%
- Fineness 1811.5 cm^2/g

From the above test results and according to ASTM requirements, the Kiwira Fly Ash falls under Class F (See Tables 2 and 3).

UTILIZATION OF THE KIWIRA AND SOUTHERN PAPER MILL (SPM) FLY ASH

A pilot project for the production and utilization of the fly ash has been proposed by the National Construction Council of Tanzania.

The main objectives of the project will be

- To utilize fly ash by setting up mini fly ash/cement block factories near the plants.
- To reduce environmental pollution.
- To introduce an alternative building material using this industrial 'waste'.

A feasibility study will be carried out in collaboration with the Kiwira Power Plant and the SPM on the economic benefits of improving the fly ash collection and setting up mini block factories.

TEST PROCEDURES AND PROGRAMME.

Tests were performed at the Building Materials Laboratory, University of Dar es Salaam on full size sand cement fly ash blocks of nominal size 30 x 14 x 14 cm. The blocks were produced by a hand operated cinva ram press.

The ratio of binder to sand was maintained at a ratio of 1:9 by weight. The amount of water added for each mix was calculated as outlined in ASTM C 311 (9) so as to ensure the same consistency. Curing was done under water and parallel samples were cured using wet sack craft.

Table 5 shows the proportions by weight of binder used in the study

The sand used was clean common sand free of deleterious substances. The grading of the sand used is shown on Table 6. Strength tests were performed on the bricks at 12 hrs, 24 hrs, 48 hrs, 7 days, 28 days, 90 days and 180 days. At each age, three bricks were tested and the average strength determined.

Table 5. Mix Proportions of Cement/Fly Ash by Weight

Cement %	Fly ash %
100	0
75	25
50	50
40	60

Table 6 : Grading of Sand.

Percentage Passing on sieve size							
Sieve size (mm)	0.075	0.150	0.300	0.600	1.18	2.36	4.75
Passage %	1.2	4.7	18	41	76.4	97.1	100

TEST RESULTS

The results of the tests are shown on Table 7 and plotted on Figures 1 and 2.

The results shown are an average of tests on three bricks. The results indicate as expected that with an increase in percentage of fly ash in the binder the strength decreases and that there is an increase in strength with age.

At 28 days the strength of the brick with 25% ash replacement is about 96% of that with 100% cement as binder while at 6 months it is 86%.

Samples cured under water showed higher strength values than those cured parallel using wet sack craft but the difference is not significant.

If continuous curing for say 6 months can be ensured we can achieve compressive strength of at least 3.5 N/mm^2 with 50 % fly ash replacement. This strength compares very favourably with block strengths obtained from road side local manufactures of sand cement blocks in Dar es Salaam. The use of cement fly ash blocks can therefore considerably reduce building costs for low cost housing schemes.

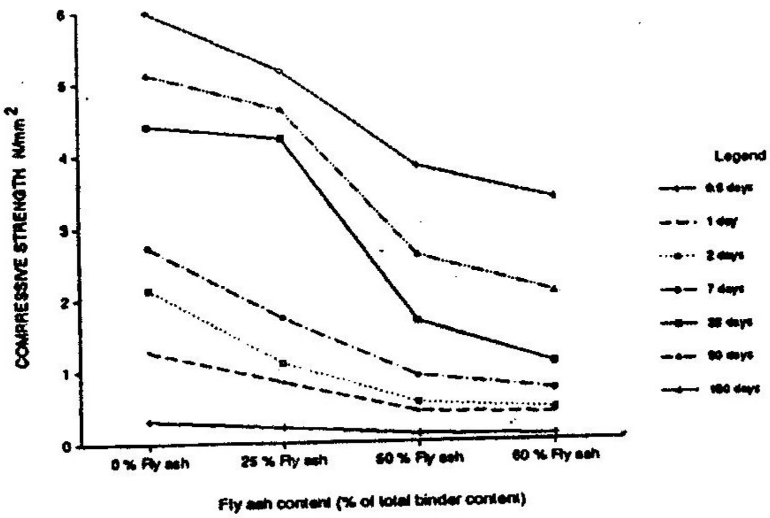

Fig. 1. Compressive Strength vs Fly Ash Content

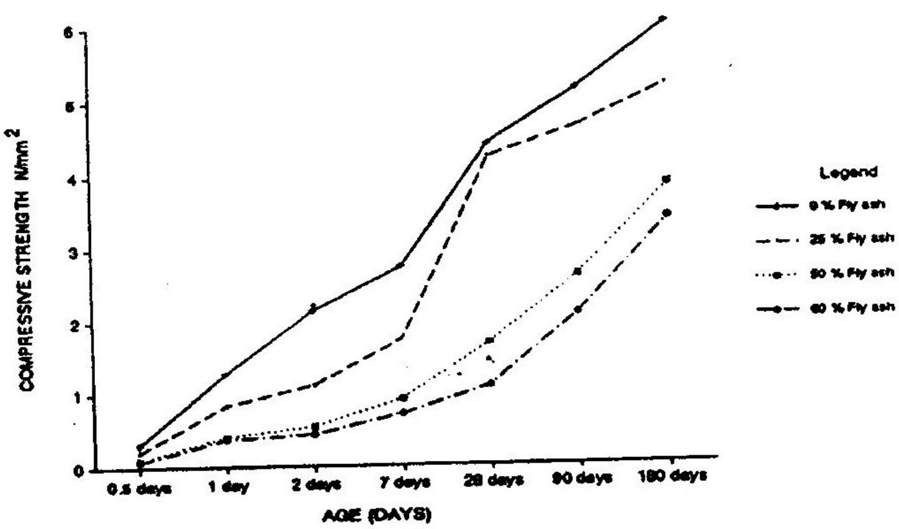

Fig. 2. Compressive Strength vs Age (Days)

A practical optimum replacement ratio suggested is 25 % fly ash so that the bricks or blocks can be used after 28 days of manufacture.

CONCLUSIONS.

Fly ash is a proven pozzolanic material. The test results in this study show that the Kiwira fly ash can be used for partial replacement of cement in sand cement blocks.

Table 7: Compressive strength of Bricks (N/mm^2) - Average of 3 Bricks

AGE AT TEST	0% Fly ash 100% Cement	25% Fly ash 75%Cement	50%Fly ash 50 %Cement	60%Fly ash 40 %Cement
12 hrs (0.5 days)	0.3	0.20	0.10	0.07
24 hrs (1day)	1.27	0.83	0.40	0.37
48 hrs (2 days)	2.14	1.10	0.53	0.43
7 days	2.73	1.73	0.90	0.70
28 days	4.40	4.23	1.60* 1.67	1.03* 1.07
90 days	5.13	4.63	2.13* 2.60	1.07* 1.57
180 days	6.00	5.17	3.63* 3.83	3.10* 3.37

* Curing on open wet sack.

With the expected increase in fly ash production inTanzania the utilization of fly ash in construction will take care of the potential future pollution problems at the same time low cost building materials could be achieved.

Power plants must be encouraged to improve their fly ash collection facilities and efforts should be made to set up block making factories utilizing this ash.

Other potential areas which need feasibility studies are the use of the Kiwira fly ash in lime fly ash blocks (LFB) and as a partial replacement of cement in concrete.

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