



Continental Application of Foamed Concrete Technology: Lessons for Infrastructural Development in Africa

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

The properties of foamed concrete as a variable density concrete, is now being tapped for effective application in the global construction industry. This study presents the properties and applications of this type of concrete at varying densities highlighting the advantages and circumstances for its use. Economic and Other Considerations together with its multipurpose applications were also presented. Comparative study of the involvement levels in the use of foamed concrete technology economy by the various continents was undertaken. Results indicated that Asia and Europe alone accounted for 50% and 33.3% respectively, totalling 83%. Africa's exposure level to foamed concrete technology is only 5.6% which is grossly non-commensurable to the population on the Continent compared with shares from other parts. Some research and development efforts were presented to show that there are opportunities for groundbreaking research works in this field.

Keywords: Foamed concrete; continental applications cellular technology; infrastructural development.

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1. INTRODUCTION

There many types of concrete used in many different applications. Foam concrete is a type of porous concrete. Its features and uses make it similar to aerated concrete. The synonyms are Aerated concrete, Lightweight concrete and Porous concrete. Cellular concrete was patented for use as an insulation material in 1923. The first comprehensive review on foamed concrete was presented by [1] and a detailed treatment by [2]. [3], summarised the composition, properties and uses of the cellular concrete, irrespective of the method of formation of the cell structure [4], investigated the potential of laterite as fine Aggregate in foamed concrete production. An aerated concrete produced by the addition of an air-entraining agent to the concrete (or a lightweight aggregate such as expanded clay aggregate or cork granules and vermiculite) is sometimes called cellular concrete, lightweight aerated concrete, variable density concrete, foamed concrete and lightweight or ultra-lightweight concrete [5,6]. The foam is formulated to provide stability and inhibit draining (bleeding) of water [7]. The aerated autoclaved concrete which is manufactured off-site using an entirely different method should not be compared with the foamed concrete.

Foamed concrete is applicable in various continental climates. In hot continental climates, with very hot days and cold nights with temperatures of 90°C and 10°C respectively, it is successfully used in Kazakhstan, Iran, Kyrgyzstan and Uzbekistan. In this climate, foam concrete can keep ideal temperature inside the house all day with only 40 centimetres thick walls. The same 40cm. foamed concrete wall is enough to keep warm, the cold climate countries of Canada, Russia and Ukraine. In the cold climate countries, most energy is spent on heating with houses usually built with thick walls or with 2 layers - brick and thermal insulation. It is possible to use only foam concrete for the walls, internal walls, floor and roof, thereby having very durable and solid house, [8]. Also in the tropical climates of India, Vietnam, Malaysia and South Africa, foam concrete is successfully used. The material cannot be attacked by insects and mice. The entire African community is yet to be involved in the economics of foamed concrete applications, hence the focus of this paper.

2. MATERIALS AND FOAMED CONCRETE TECHNOLOGY

The raw materials required are:

- Cement;
- Fine Sand;
- Stable Foam;
- Water

The fine sand could be ordinary quartz sand quarry dust or industrial waste and the waste resulting from extracting and processing limestone and other rocks.

A mechanized production line will consist of the following units:

- i. Sand dump site
- ii. Sand conveyor belt
- iii. Sand bin with a screw-metering device
- iv. Cement bin with a screw-metering device
- v. Foam generator
- vi. Foam production plant
- vii. Metal matrix for shaping the foamed concrete

Sand may be conveyed through a conveyor belt into the sand bin which is equipped with a metering device for measuring the amount of sand required for a particular batch production. Cement is poured into the cement bin also equipped with a metering device. Cement is mixed with sand using water forming slurry. This is further mixed with foam produced from a foam generating machine. A typical layout of a foamed concrete plant is shown in Fig. 1. Stable foam is the key ingredient in the production of foamed concrete. This foam is made by a simple foaming generator where air, water and foaming chemicals are mixed and stable foam is formed. The foam can be derived from either protein or synthetic chemicals. It consists basically 95% air and is very stable to enable it to last through the stages of mixing with the mortar slurry. The amount of foam expended can affect the cost of the concrete being produced. Generally, it takes about 400 - 500 liters of preformed foam to make 1m³ of foamed (cellular) concrete (with a density range between 900 – 1300 kg / m³). The various sizes of foam generator depend on the volume of foam concrete that is needed to be mixed. Figs. 2(a) and (b) below show sample of a foam generator and complete foamed concrete machine respectively [9].

2.1 Mixing Procedure and Mix-ratios Required

The materials required are sand (or quarry dust), cement, water and foam. Ratio of sand to cement to water (Sand: Cement: Water) for different dry densities required ranges from 0:1:0.55 to 3:1:0.6. The steps to follow are stated below:

1. Dry mix sand (and or quarry dust) and cement in a concrete mixer for 2 minutes.
2. Add water incrementally to obtain a reasonable mix for 1 minute.
3. Measure a volume of the required foam.
4. Add the measured foam to the wet mix in step 2 and mix for 30secs.

Any mixing more than 30 sec after adding foam will cause the foam to disintegrate.

Standard Engineering Waterproofing Ltd presented the mix designs for EABASSOC Lightweight Foamed Concrete for a range of dry densities [10]. This included the amounts of cement, sand, water and foam shown for each mix design required to make 1m³ of EABASSOC Lightweight Foamed Concrete.

3. PROPERTIES OF FOAMED CONCRETE AND APPLICATIONS FOR INFRASTRUCTURAL DEVELOPMENT

Foamed Concrete is a lightweight, free flowing concrete material, ideal for a wide range of applications. Its production incorporates small-enclosed air bubbles within the mortar thereby making it lighter and possessing special properties such as low thermal conductivity and high fire resistance. [11], indicated that by

appropriate method of production, aerated concrete with a wide range of densities (300 - 1800 kg/m³) can be obtained thereby offering flexibility in manufacturing products for specific applications (structural, partition and insulation grades). Density of foamed concrete ranges from as low as 300kg/m³ [12] to as high as 1600kg/m³ and hence can be used in a wide range of applications from pre-cast wall blocks and panels, void filling, floor and roof screeds, roof insulation, trench reinstatement, road foundations, and bridge abutment work.

Density of regular concrete is 2400 kg/m³. Although at a very low density of 300 kg/m³, this material can be considered to have no structural integrity at all, it will only function as a filler or insulation use. The variable density reduces strength [13] to increase thermal, [14] and acoustical insulation by replacing the dense heavy concrete with air or a light material such as clay, cork granules and vermiculite. There are many competing products that use a foaming agent that resembles shaving cream to mix air bubbles in with the concrete. All accomplish the same outcome: to displace concrete with air. [15], determined properties of foamed concrete at different dry densities.

[16] indicated that a foamed concrete of M20 grade could be obtained by using a cement of 468 kg/m³; sand 234 kg/m³; quarry dust 234 kg/m³; fly ash 468 kg/m³; water 327 litres/m³ and 14 kg/m³ of foam. It is possible to attain the above strength at 90 days. The reason could be that the addition of fly ash of equal amount of cement; makes it possible to gain the strength with age. They have also shown that foam concrete exhibits good resistance to sulphate attack and that the compressive strength of the

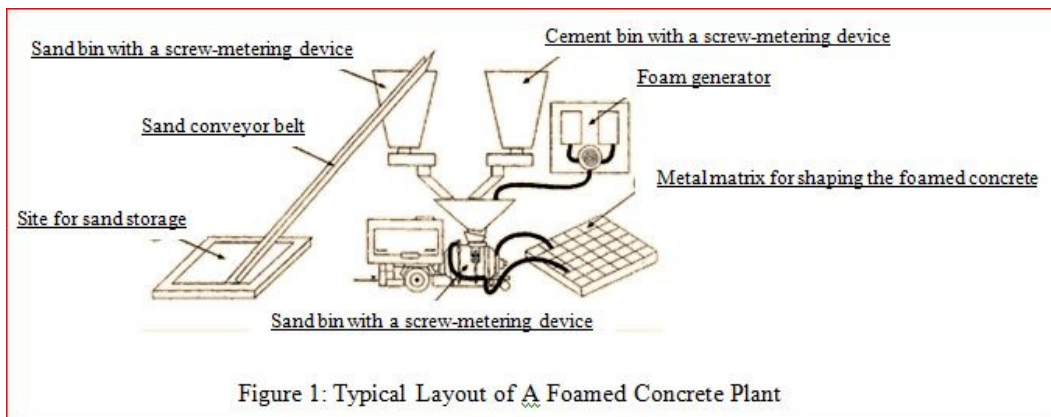


Figure 1: Typical Layout of A Foamed Concrete Plant

Fig. 1. Typical layout of a foamed concrete plant



Fig. 2(a). Foam generator

[9]: LithoPore® - German advanced cellular lightweight concrete technologies



Fig. 2(b). Complete foamed concrete machine

sulphate attacked specimens used more or less followed the same pattern as that of normal specimens.

Foam concrete flows very well and is highly workable with no requirement for compaction. It is quick setting and can be accelerated to allow for black-topping within 4hrs. The lower density concrete with superior insulation properties has an overall lower maintenance costs. There is no sagging in any trench re-instatement activity. There is time saving with backfilling and cost effective solution.

3.1 Economic and Other Considerations for Foamed Concrete

Foamed concrete is the most popular of all low-density concretes in developing countries [17]. The reasons given for this are the low capital expenditure on equipment and the ready availability of the principal materials. Foamed concrete can be produced on a small scale, even at site level, and it is relatively easy to place and finish without heavy or expensive equipment. Foamed concrete is self-compacting, free flowing and pumpable and, therefore, easy to place in inaccessible places. It has good thermal and acoustic properties and is also frost resistant. It is however too weak for direct exposure to traffic and hail and should be protected by a wearing layer (asphalt can be used for roads).

The development of protein-hydrolysis-based foaming agents and specialized foam generating equipment has improved the stability of the foam, making it possible to manufacture foamed concrete for structural applications.

Foam concrete is extremely fire resistant and well suited to applications where fire is a risk. [8], carried out test to show that in addition to prolonged fire protection, the application of intense heat, such as a high energy flame held close to the surface, does not cause the concrete to spall or explode as is the case with normal dense weight concrete.

Global experience has shown that the special technological feature of foamed concrete allows it to be used for multipurpose applications which include:

- Thermal and soundproofing insulation of floors;
- Thermal insulation of flat, mono-pitch and double-pitch roofs;
- Cavity filling, well backfilling, masonry grouting;
- Setting up pipeline monolithic thermal insulation;
- Production of building blocks and wall panels (of different designations);
- Monolithic low-rise and individual house building.
- Leveling Floors
- Road Sub-Bases and maintenance
- Bridge Abutments and repairs
- Ground Stabilization

Siram, [18] studying foamed concrete and present generation's building solution had concluded that foam concrete, having gained importance because of its wide range of applications which include Thermal insulation, Fire resistance, Workability, Flow-ability, Sound absorption, Self-compacting, Density, Energy absorption etc., is a problem solver for wide

variety of challenges in construction, mining and manufacturing applications. Figs. 3 and 4 are examples of foamed concrete applications for infrastructural developmental works as presented in [19].



Fig. 3. Foamed concrete used as underlayment and slab thickening for air port



Fig. 4. Peacehaven treatment works. Courtesy propump engineering ltd

4. AFRICA AND GLOBAL INVOLVEMENT IN FOAMED CONCRETE TECHNOLOGY ECONOMY

Foam concrete, being an effective thermal insulation and constructional-thermal insulation material, is nowadays widely used in more than 50 countries. It has been used as a structural material in schools, apartments and housing developments in countries such as Brazil, Singapore, Kuwait, Nigeria, Botswana, Mexico, Indonesia, Libya, Saudi Arabia, Algeria, Iraq and Egypt. [20], presented the use for development in Third World while [21] considered foam concrete for Developing Countries.

In the Netherlands foamed concrete are being used not only for level corrections in housing developments, but also as a fill material where ground subsidence has taken place and as a founding layer for road works on very weak soils. Messrs. Lafarge Industries South Africa (Pty) Ltd [22] in their presentation of Industrial Foam Concrete has shown that they are well rooted in South Africa and Europe.

Messrs. LLC Stroy-Beton who has worked with hundreds of Clients in over 12 Countries, has presented a representative list of a few Stroy-Beton equipment's Clients and their Countries [8]. Table 1 has prepared the list to indicate the Continents that are being represented.

Summary from the above, presented in Fig. 5 indicates involvements of 5.6%, for Africa, for North America and for Australia. Asia and Europe alone accounted for 50% and 33.3% respectively. This indicates that Asia and Europe share more than 83% of the exposure to the use of foamed concrete. The other three Continents, Africa, North America and Australia together can only account for 17% share of exposure to the foamed concrete technology. Africa's 5.6% exposure level for foamed concrete technology is grossly non-commensurable to the population on the Continent compared with shares from other parts.

Africans therefore need to also take the advantage of the technology for infrastructural developmental programmes like their counterparts in Europe and Asia.

5. PPORTUNITIES FOR RESEARCH AND DEVELOPMENT

In response to the need for a larger capacity aggregate bins for higher volumes of low density materials (for example - recycled product), which are used in the production of expanding foamed concrete, [23] has specifically designed Reimer R12 and named it "The Utility". The 9-11m³ capacity utility vehicle is shown in Fig. 6. It has a production rate up to 60m³/hour and is equipped with the following:

- i. 225mm diameter auger
- ii. 3-tonne capacity cement hopper
- iii. Cement metering
- iv. 2,300L capacity Water tank
- v. Hydraulic pump
- vi. Wireless remote controls
- vii. Vibrator system

- viii. Delivery measurement digital computer
- ix. Low noise batch plant power
- x. Additional options include Foam generator

hours at a temperature of up to 12,000 degrees Celsius.

The need for foamed concrete technology had led to this development.

Foaming agents, LithoFoam®, are especially developed for the production of foamed concrete through a worldwide unique biotechnological process.

Arab News [24], reported the development of a new foam concrete by Researchers at King Abdulaziz City for Science and Technology (KACST) using micro carbon material increasing its resistance to breakage and reducing its thermal conductivity. And that the buildings using the new foam concrete are also less subjected to the spread of fire. They have proved that buildings of foam concrete with a thickness of 150 millimeters can withstand flames for four

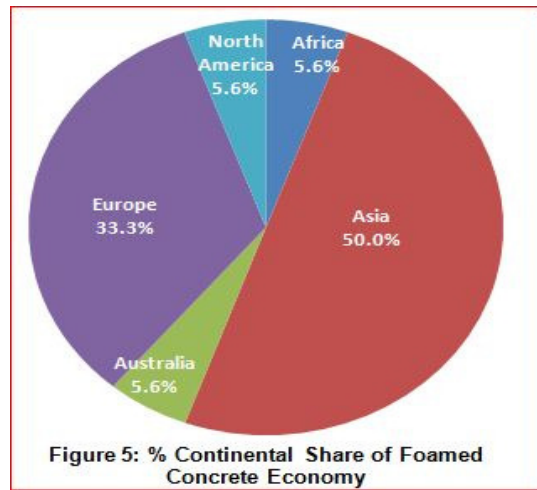


Figure 5. % continental share of foamed concrete economy

Table 1. Continental distribution of clients involved in the foamed concrete technology

| S/N | Client | Country | Continent | No. in continent | Remarks |
|-----|------------------------------|-------------------|------------|------------------|--|
| 1 | Daniel Charlton | Canada | N. America | 1 | Northern part of North America |
| 2 | Ultralite Private Blocks LTD | India | Asia | 1 | South Asia |
| 3 | Anpha Technical Group | Vietnam | Asia | 2 | Southeast Asia |
| 4 | Supracoat | Malaysia | Asia | 3 | Southeast Asia |
| 5 | Lukas Kvetoun | Czech Republic | Europe | 1 | Central Europe |
| 6 | Glen Phillips | Australia | Australia | 1 | Smallest Continent |
| 7 | Justin Vianello | South Africa | Africa | 1 | Southern Africa |
| 8 | Ganiev Ahad | Tadjikistan | Asia | 4 | Southeastern Central Asia |
| 9 | Bantsevich Andrey | Belorussia | Europe | 2 | Eastern Europe |
| 10 | Westron | Gzech Republic | Europe | 3 | Central Europe |
| 11 | ASK. | Ukraine | Europe | 4 | Eastern Europe |
| 12 | New Technologies Salam | Kyrgyzstan | Asia | 5 | Eastern part of Central Asia |
| 13 | Titov A.N. | Kazachstan | Asia | 6 | Central Asia, with its smaller part west of the Ural River in Eastern Europe |
| 14 | Tandur Cements | India | Asia | 7 | South Asia |
| 15 | Mr. Abdorrasoul Akkafzadeh | Iran | Asia | 8 | Southwest Asia |
| 16 | "Smart Group" | Uzbekistan | Asia | 9 | Central Asia |
| 17 | Vintus | Litva (Lithuania) | Europe | 5 | North Central Europe |
| 18 | OOO TPZ | Ukraine | Europe | 6 | Eastern Europe |

* Column 5 is defined as the counter for continental occurrences



Fig. 6. Reimer R12 utility vehicle for foamed concrete production

The above are just being referenced to highlight that there are opportunities for groundbreaking research and development works. Africa also needs to take advantage of this development.

6. CONCLUSION AND RECOMMENDATIONS

This paper has indicated that two of all the Continents, Asia and Europe, alone accounted for 83% of global involvement in foamed concrete technology economy. Africa and Australia each has a share of 5.6%. This stresses that Africa's exposure level to foamed concrete technology of 5.6% only is grossly non-commensurable to the population on the Continent compared with shares from other parts of the globe. The world experience has shown that the special technological feature of foamed concrete allows it to be used for multipurpose applications in the building and other infrastructural developments industries as highlighted in the text. Thus implying that Africa needs to rise up to tap opportunities that abound in this context to improve her infrastructural development rates. There are also opportunities for new ventures on the platform of foamed concrete applications and equipment.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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