Infrastructural Development in Africa by Use of Suitable Construction Approaches

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Abstract
The construction sector generally shows a great contribution to socio-economic development in Africa, and has particularly enhanced the continent's employment sector over the last few years. The African concrete construction sector is quite different when compared to its European and/or American counterparts. Modern infrastructural development exists in many urban cities in Africa, but this is at variance with rural areas, which tend to have little or no basic amenities such as sound road networks, solid and affordable shelter, and potable water. A large percentage of the construction activities are observed through the informal construction sector which mainly constitutes of cheap labour. This paper gives a basic introduction into the necessities for infrastructural development in Africa with focus on the construction sector. The paper addresses the practised construction activities based on the informal construction sector as well as suggests sustainable construction approaches sufficient for the African rural communities to benefit from the available economy. A better understanding of this sector is required which can help improve the existing methods of construction rather than adopt the construction techniques observed from the developed countries.

Keywords: concrete construction, construction sector, infrastructural development, sustainable, informal construction sector.

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Introduction

There have been rapid advances in concrete technology during the past three decades. The improvement in strength and other structural properties in concrete materials are now being accepted as routine developments. Over the course of the twentieth century, cement has emerged as the material of choice for modern infrastructural needs. However, cement is still a complex material and with the environmental and technical developments of the last decades, especially with regard to its replacement, it has become even more sophisticated. Its production demands a high level of expertise, yet production processes offer a wide variety of opportunities for concrete production, which can be beneficial for Africa considering the continent's growing market for the product [1].

Infrastructural Development in Africa

Infrastructure is generally the bottleneck to any country's development. Infrastructural development consistently requires a strong financial and technical investment, and proper project planning. In some parts of Africa and in the developing economy, construction with cement has given rise to urbanisation and infrastructure development [2]. The task of providing infrastructural facilities for the rapidly growing population is enormous. Sustainable construction of structures is good engineering practice and involves using limited resources to achieve design objectives, balancing competing and often contradictory interests over the full life-cycle of the structure [3]. Africa constitutes a substantial percentage of the growing urbanisation without commensurate infrastructural development facilities to take care of the increasing population. In order to cater for this population increase, every year there is the need to have a framework for developing a suitable construction approach that will be able to build physical infrastructures that can be well managed within the communities in which they are located. Engineers have traditionally used their expertise to design and construct structures and structural components that are serviceable and durable in addition to strength and stability. The socio-economic realities of the African continent demands that this needs to be broadened in order to develop a synergy between employment opportunities, available skill, entrepreneurship and the use of small scale enterprises in the creation and maintenance of physical infrastructures. The construction techniques that are adopted can be used to meet socio economic needs of the people in the environment and therefore, developing manpower [4]. There are a number of operations that have contributed to the infrastructural development of an economy however, concrete, as a building material plays an important role. Concrete is a material for construction in the developing countries due to the expected protracted growth in demand for infrastructure, industrial growth, and general construction. The health of the construction sector in Africa is perhaps the best indicator of the strength of a national economy. With a few exceptions, the construction industries of most African countries successfully weathered the global financial crisis and new building projects are under way across the continent.

Cement and concrete technology, in particular, is experiencing a significant growth despite disruption to progress experienced in some African countries. This can be seen through examples of recently emerging economies such as Uganda and Rwanda, whereby a major disruption of infrastructural development occurred in the 1980s and 1990s respectively. Rwanda experienced a substantial loss during the 1990s civil war, but has recently experienced a steady economic recovery partly due to industrial development. Nevertheless, the aftermath for some countries in Africa, such as Burundi and Democratic Republic of Congo (DRC), still lack in the appropriate cement and concrete technology. The main reason for this phenomenon is due to the product's high production value that consumes a considerable amount of energy and resources. Considering the current economic state, especially in sub-Saharan Africa, financial strengths required for cement production are difficult to come by. Hence, cement produced in Burundi and DRC is priced at USD 17 and USD 22 per 50 kg bag respectively. In many cases, cement prices can show a high variation

between two cities of the same country. With Tanzania as an example, cement prices vary between USD 10 – 16 from East to Northwest regions respectively, which can be attributed from insufficient road transportation facilities. Similarly, road infrastructure in DRC is a major setback, especially in Katanga region, where currently a cement plant exists with no market for its production since cement is readily available at a cheaper price from Lusaka, Zambia. The locally established high cement prices caused by high production costs makes the product value expensive to the African market, hence cement is often imported. Additionally, most steel used for concrete construction is also imported from Europe or Asia due to unavailability of steel producing plants in many countries in Africa, therefore construction with concrete is deemed rather expensive.
The existing geological and geographical boundary conditions in Africa, demands for specific and suitable cement and concrete technology considerations regarding cement production and concrete construction [5].



Figure 1: The Great Rift Valley in Africa [5]

The commonest cement produced in Africa is Ordinary Portland Cement (OPC) or cement blended with limestone, which is generally produced in large scale. Awareness of producing cement from wastes or pozzolan materials is scarce, regardless of the fact that pozzolan materials are naturally available in Africa. The Great Rift Valley (Figure 1) that runs through Eastern Africa consists of natural available cementitious materials that are sufficient for cement and concrete technological developments. Other cementitious materials can be obtained from waste materials that generally exist in the country. With proper investigations and research of such materials existing, the result could lead to a sustainable solution for eliminating the existing constraints with cement production in Eastern and Central Africa.
Currently, it is inevitable that a high amount of cement is needed for concrete construction, which largely can contribute to high financial investments. With the growing population in the African continent and insufficient supply of cement production for concrete construction, there is a need for sustainable concrete technology that can be applied for the benefit of the economy.

Concrete Construction

The concrete industry is a complex network of multiple players, which include suppliers and manufacturers of construction materials, contractors, architects and engineers, labour personnel and artisans, research and academic institutions, and the government. Coordinating structures are essential for proper functioning and advancement of the industry. Concrete construction is seen as the broad mechanism for the realisation of human settlements. This includes the beneficiation of building materials and the construction project cycle from feasibility study to the construction phase, including managing and operation of the build environment.

Concrete construction requires special regulations and procedures to conform to the national or international standards. These procedures can be optimised to provide suitable properties of concrete. Regularly the procedures and standards adopted for concrete construction in Africa are British standards and/or American standards. Nationalised standards for concrete exist in Eastern and Southern Africa, however all practised standards are developed from a background which exhibits different boundary conditions than the ones existing in the African continent, for instance the curing of concrete at 20°C whereas a majority of countries in the continent exhibit temperatures higher than 35°C. The concrete structure is designed for the ultimate limit state and checked for the service limit state. Variations in concrete strength change from one place to another, therefore applying a single factor would be inappropriate for all situations and locations. Partial safety factors would be more appropriate, for good quality concrete or acceptable level concrete if the quality of concrete is questionable.

The properties of fresh and hardened concrete depend on the relative volumes of the constituent materials. Figure 2.0 shows the breakdown of the new and advanced concrete production. This breakdown is practised in the many developed countries in Europe, North America and Asia, where concrete production has been well established, and where various options and new technologies exist for optimisation of other suitable building materials. In most African countries, concrete production can be broken down as shown in Figure 2.1. Recycled materials in concrete production are rarely used, and this technology is not a common practise in Africa. Nevertheless, addition of such materials into cement and concrete production can be considered a suitable approach for improving concrete properties, generating employment as well as utilising the necessary materials, which at the same time influence the reduction of the high end costs of concrete products.

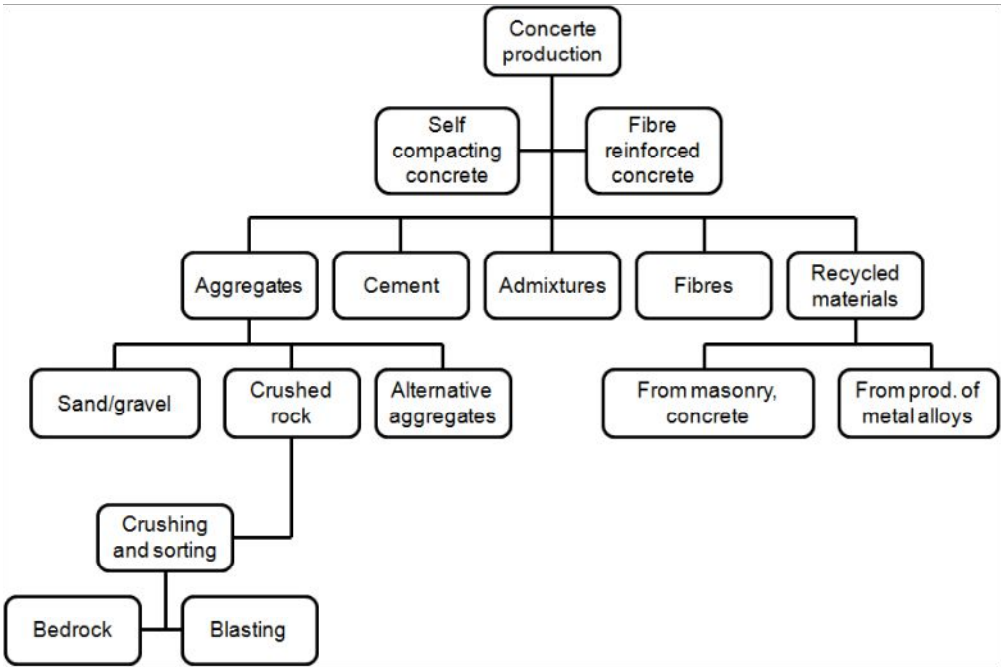


Figure 2.0: Breakdown of concrete production in developed countries

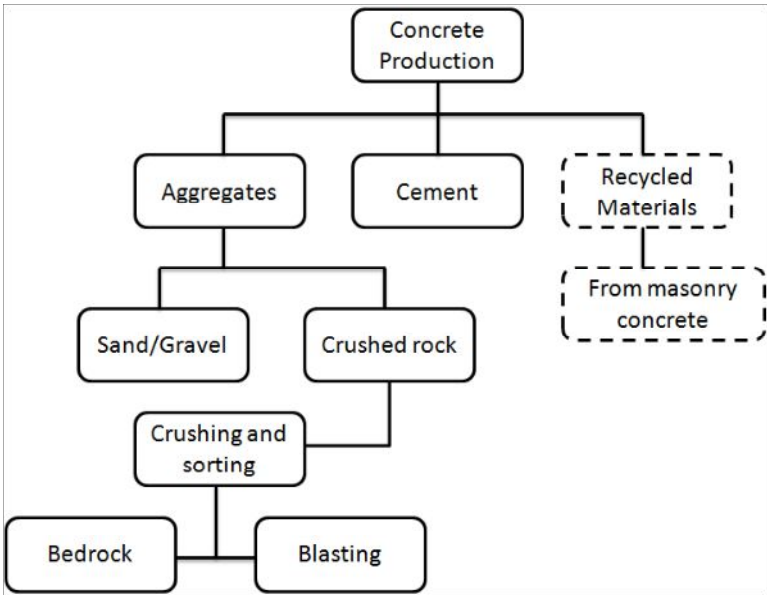


Figure 2.1: Breakdown of concrete production in developing countries

Suitable Construction Approaches in Africa

The concrete industry has great potential for generating employment, through its backward linkages with other industries, notably those involved with the production and distribution of building materials and equipment and in the provision of financial services to the industry [6]. Majority of construction works in many countries in Africa, for instance Tanzania, is dominated by the informal construction sector however their average contribution to output is relatively low. The informal construction sector is generally characterised as unregistered and unprotected individuals and/or enterprises that supply labour and contribute in various other ways to the output of the construction sector [7, 8]. Generally the formal construction sector much depends on the informal sector through availability of cheap labour. With this consideration, design and construction practices adapted in developed countries which aim to minimise costs of labour at the expense of using more materials may not yield economical designs in the developing African countries [9]. Concrete technology development for Africa should therefore be focused on the informal construction sector.

Although cheap labour may be deemed an advantage, there is a need for quality control and safety precautions. Safety with concrete is merely neglected or not heavily enforced in many countries in Africa. Majority of the concrete structures in the continent are cast-in-situ. Concrete making ingredients are manually mixed on site by labourers then transported to the designed elements/members by use of wheel barrows or buckets, as shown in Figure 3.0. In many cases, these labourers carry the buckets from the ground floor to any higher floor without considerable protection. The safety regulatory body should ensure the safety requirements for such activities. This can be done by having a safety officer present on each construction site to enforce the rules and in addition regular safety courses should be implemented for workers on the construction site [10].

Mixing of the concrete constituents should also be done with care, since cement is especially an unsafe building material, hence can cause burns due to its alkalinity, which can result in an allergic reaction that causes cement dermatitis. Limiting exposure of wet cement to the skin is easily achieved through the use of protective garments. As a further measure in EU countries, cement dermatitis is being effectively avoided by the addition of iron II (Fe-II) sulphates or zinc II (Zn-II) sulphates as chromate-reducing agents, which transform the easily soluble Chromium (VI) to insoluble and thus harmless Chromium (III) [1].



Figure 3.0: Mixing and transporting concrete in a construction site in Dar es Salaam, Tanzania

Such measures can be introduced and practiced for the African boundary conditions, considering many workers on the construction sites fail to have on-site protective garments such as overalls and gloves due to adverse weather conditions, hence such a reducing agent is necessary to be introduced in the African concrete. However, various experiments need to be undertaken to conclude the suitable percentage additive for the right mixture.

Majority of the residential and commercial buildings in the East African countries are built with concrete. The typical building type is the column - beam construction, with concrete floor slabs, masonry wall partitions and cladding. At city suburbs and the countryside, semi-permanent single and double storey residential buildings are the dominant form of housing. These are slowly replacing houses built using traditional materials that are still prevalent in the rural areas. Concrete is also used on major government infrastructure projects involving construction of pavements, bridges and dams. Precast concrete is limited to masonry, concrete pipes, roofing tiles and similar products however, large-scale pre-casting of structural concrete is uncommon. Ready-mix concrete operations, which play a dominant part in Europe and North America, are relatively new in the majority of the sub-Saharan African countries, excluding South Africa [11]. It is difficult to adhere to ready-mix concrete culture due to the existing geographical conditions, which are long transportation distances and lack of developed infrastructure. The cheap labour in Africa that is readily available makes on-site concrete mixing rather cheaper and more appropriate than ready-mix concrete. Nevertheless, increasing technology for on-site concrete mixing is unavoidable to achieve the suitable concrete.

Varieties of options exist for other types of construction and are currently under practice. In sub-Saharan Africa, especially in the rural areas, there is an abundance of clay soil, which if properly treated with cement and/or lime can exhibit properties that are sufficient for construction. Such materials with the proper mix ratios are called stabilised soil bricks, generally used for construction of low-storey buildings. This practice is useful, since it requires a minimum amount of cement, available man power and a compaction machine. The dimensions of the cement-soil block can vary depending on the compaction machine used. High density cement-soil blocks, approximately 2000 kg/m^3 can be locally produced on-site from soil and cement mix of 5% cement, laid with 10 mm of cement mortar with 20% cement and no plaster. Low density cement-soil blocks, approximately 1700 kg/m^3 generally will require a high soil and cement mix of ca. 10% cement and plaster. The latter is suitably the best option for on-site production [12]. This approach is considered cost effective since

the production can be done on-site, and can effectively reduce the cost of using traditional bricks by 50%. Generally, one may use one 50 kg bag of cement for production of 100 bricks or blocks. Considering there is availability of cheap labour, higher costs may result from transportation of soil, if such soil is not available at the site. The use of fly ash in cement production or construction blocks is also another approach. This case-study is not fully developed in Eastern Africa, however it is deemed to be a suitable solution since such materials are merely used as landfill. Such wastes and other materials are optimum for use as supplementary cementitious materials (SCMs).

The concrete industry in Eastern African countries is fragmented. Although there are some professional and industry-based associations the concrete industry still needs an appropriate coordinating framework. In some other countries, frameworks such as the Concrete Society of Southern Africa play a significant role in protecting the industry from mere transplanting of technologies from other countries and support development of specifications and design codes for durable concrete, along with parallel systems for quality assurance. A similar approach might be needed in the Eastern African countries' concrete industry to advance concrete technology in regions and contribute towards sustainable development.

Conclusion

Africa's demand for cement keeps rising due to the growing of a strong rural development. However, Africa still needs a sustainable approach for a reduced cost of cement production and suitable construction procedures for the existing environment. Generally the cement production costs depend on the adopted production process. The improvement of a cement plant, however, needs large investment due to the African culture of large-scale production. The timing of the investment of process improvement must be carefully determined taking into consideration the budgetary condition of enterprises and the outlook of the cement market. Investment in new and existing infrastructure in Africa must be well resourced. Developing reliable and functional infrastructure to support the manufacturing sector and improve productivity and competitiveness in international markets is of utmost importance for Africa's development. However, many African governments face challenges formulating and implementing effective policies to build, strengthen, and manage the sectors. Infrastructural planning will have to incorporate the concerns of the existing boundary conditions.

The use of SCMs in cement production is relatively a promising solution for increase in economic growth in sub-Saharan Africa. Reducing environmental pollution and alleviating poverty in the developing countries are important goals for sustainable development. The challenge that poses to civil engineering profession is to execute projects in harmony with nature using the concept of sustainable development involving the use of high performance economic friendly materials such as SCMs produced at reasonable cost with the lowest possible environmental impact.

This requires a significant amount of knowledge transfer through education and research. In addition, initial investments are also seen as the key component for a strong starting point, which in return can eradicate the infrastructural deficiency existing in many sub-Saharan African countries.

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