A LOOK AT RESOURCES AND STRATEGIES TOWARDS THE DEVELOPMENT OF A SUSTAINABLE CONSTRUCTION MATERIALS INDUSTRY IN BOTSWANA

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***Abstract*—** The economy of Botswana has increased extensively since independence. In contrast to this increase, the construction industry which is one of the key indicators of a developing nation continues to be highly dependent on imported building material products from neighbouring countries of South Africa, Namibia, Zimbabwe and Zambia. Only two companies in the country currently blend cement. Even then, the overwhelming majority of raw materials used in the blends are imported. Furthermore, there are no glass manufacturers in Botswana. The ceramic industry is limited to the manufacture of clay bricks notwithstanding a few studios on crockery and sanitary ware which nonetheless use imported clay.

This paper presents natural resources and industrial waste products in Botswana that can be used for the development of sustainable building materials. It also looks at the distribution and cost of other widely used building materials in the country. Finally the paper looks at projects and national strategies aimed at a country-wide development of a sustainable building materials industry together with their successes and hitches.

***Keywords*—** Botswana construction industry, construction materials, natural resources, sustainable materials.

I. Introduction

Botswana is one of the fastest growing economies in the world with a nominal GDP per capita that grew by about eight times in the past twenty years from BWP 8800.8 million in 1995 to BWP 66795.9 million in 2015 [1]. In contrast to this increase in GDP, the construction industry which is one of the key indicators of a developing nation continues to be highly dependent on imported ready-made building material products from neighbouring countries of South Africa, Namibia, Zimbabwe and Zambia. Figure 1 shows the import bill for cement, glass and ceramic products from 2010 to 2015 [2]-[4]. As shown in the figure, in the past five years the import bill of blended cement has ranged from BWP 566 million to BWP 628 million, of glass and glassware has ranged from BWP 140.6 million to BWP 189.2 million annually whilst that for ceramic products ranged from BWP 170 million to BWP 220 million. In 2015, the combined import bill for these materials was BWP 942 million which is about 1.4% of the GDP. Note that these are conventional materials used worldwide and their production has now become standardised.

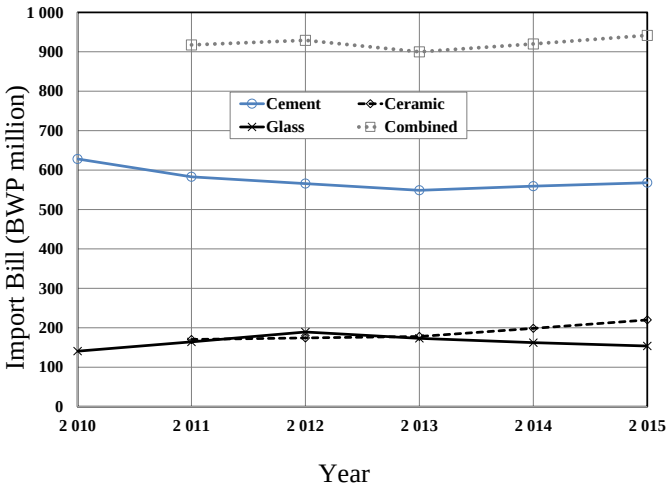

Fig. 1 Import bill for construction materials in Botswana

The approach of making materials available to the industry through import of ready-made conventional materials could be the least challenging since they don't need any processing. It is however certainly not sustainable and offers little contribution to the general welfare of the nation which already exhibits continued increase in unemployment rate and poverty incidences [5], [6]. It is therefore necessary to look at local resources that can be used in the development of a sustainable building materials industry which will, in return, enhance the welfare of the nation. A map of Botswana is placed at the appendix as reference to various locations in Botswana referred to in this paper.

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II. Cement Industry

The overall requirement of cement by the Botswana construction industry in 2015 was 0.89 million tonnes of which 0.58 million tonnes was imported as ready-made cement and the remaining 0.31 million tonnes was blended by two companies in Botswana [2], [7], [8]. Unfortunately, one of the companies which blended 0.28 million tonnes, imports all its raw materials readily processed. The only processing it does in Botswana is blending, packaging and distribution. The second company, which blended 0.03 million tonnes, imports clinker and gypsum but at least uses limestone and fly-ash from Botswana. The proportion of local raw materials used by this company constitutes only 33% of material used which translates to about 1.1% of the total cement consumed by the construction industry [8]. The approach used by this company is much more beneficial to the nation. Their production rate, however, is very low to make a significant impact in the construction industry. Significantly, the most expensive process in cement manufacturing which is the production of clinker is done outside the country.

Table 1 shows the cost of 50 kg bag of, arguably, most commonly used cement that is blended locally. As shown in the table, the cost of cement in some areas is near double that in Gaborone. This variation is primarily due to high transportation costs. Note also that the south-east to the eastern region of the country holds major entry points for imported building materials. This price variation therefore cuts across various other imported cements further buttressing the need to set-up local cement production plants.

TABLE 1 COST OF A TYPICAL 50 KG CEMENT BAG IN BOTSWANA

Location	**Cost of 50 kg cement bag (BWP)**
Gaborone	49.95
Lobatse	52.75
Francistown	55.96
Tsabong	64.95
Gantsi	69.9
Hukuntsi	74.95
Kasane	79.3
Maun	80
Shakawe	87.5
Charles Hill	95

A desk study of resources for limestone and marble in Botswana which are the primary raw materials in the production of cement showed that potential reserves for these minerals are heavily contaminated with Magnesium Carbonate or Magnesium Oxide [9] - [17]. The few that can be used in the cement industry have insufficient reserves to support the construction industry. For example, the largest reserves for calcitic limestone and marble are Matsiloje limestone at 0.67 million tonnes [14], Mmadinare marbles at 0.68 million tonnes [17] and Makoro marbles at 0.27 million tonnes [16]. These resources are not only widely spaced, their combined reserves cannot support the industry. Limestone in Matsiloje is currently used as an extender in the production of blended cement [8].

Availability of other raw materials used in cement production such as slag, fly-ash, clay and gypsum was also looked into. Fly-ash is produced at Morupule Power Station and at Sowa Plant. Morupule Power Station produces 0.75 million tonnes of fly-ash annually whilst Sowa Plant produces 0.04 million tonnes of fly-ash annually [18], [19]. Regrettably, less than 0.6% of Morupule fly-ash is currently used in cement production with the rest of the fly-ash dumped in fly-ash ponds. This process is not only overly expensive, it is also a potential hazard to the environment primarily through contamination of underground water resources.

Slag is produced by Bamangwato Concession Limited (BCL) at a rate of one million tonnes per year [20]. The current stockpile for the slag at BCL mine is in excess of 20 million tonnes. Similar to fly-ash, this slag is not consumed by the industry.

The chemical composition of fly-ash from Morupule B, fly-ash from Sowa and that of slag from BCL is shown in Table 2 [21]. These materials meet the minimum requirements for use in concrete as stipulated in ASTM C618 and ASTM C989 standards [22], [23]. Fly-ash from Morupule B with a sum of Silicon Dioxide, Aluminium Oxide and Iron Oxide of 53.61% is Class C fly-ash and therefore in addition to having pozzolanic properties, it also has a potential for self-cementitiousness. Fly-ash from Sowa with a sum of Silicon Dioxide, Aluminium Oxide and Iron Oxide of 76.59% is Class F and therefore only has pozzolanic properties.

TABLE 2 CHEMICAL COMPOSITION OF FLY-ASH AND SLAG IN BOTSWANA

Raw material	**Elements (% by mass)**					
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3
Morupule Ash	29.06	18.89	5.66	17.89	1.58	3.39
Sowa Ash	40.70	29.76	6.13	6.66	1.77	0.98
BCL Slag	34.44	6.55	57.56	2.14	1.70	1.66

Large reserves of high quality gypsum are found in Bojanamane at 1.8 million tonnes [24] and in Lebung at 2.4 million tonnes [25]. It can be shown that these reserves are able to support the cement industry for over 150 years. Clay, which is another resource needed in the production of clinker is abundant in many areas of the country. Further discussion on the availability of clay is under the ceramics section.

Whilst reports on industrial minerals indicate that Botswana does not have sufficient quality carbonates to run a cement manufacturing industry, it undoubtedly has abundant other raw materials needed in the production of cement which are currently not being used. For sustainability of the industry as well as to create employment, it is recommended that import of raw materials be limited only to deficient carbonates but in an unprocessed form. All other processes for cement manufacturing from production of clinker to blending using

local resources and packaging cement should be done in the country. Fortunately Botswana has one of the world largest reserves for coal to supply fuel for the production of clinker [26]. This approach will greatly reduce the import bill and current cost of disposing fly-ash and slag. Most importantly, it will create employment and curb adverse environmental impacts likely to result from these industrial waste.

III. GLASS MANUFACTURING INDUSTRY

As already mentioned, the annual import bill for glass and glassware in Botswana is above BWP 140 million [3]. Unlike in the cement industry where primary resources are limited, Botswana has vast quality raw materials for the glass manufacturing industry as summarised in Table 3 [10] – [13]. Additionally, Sowa Mine produces 0.2 million tonnes of soda ash annually and has the capacity to increase this production to 0.3 million tonnes [19]. Currently this soda ash is exported to South Africa for use in manufacturing glass. According to [27] the rate of returns from the export of soda ash are very low due to high transport costs coupled by that soda ash is a low value commodity. For sustainability of the industry, it is essential that glass manufacturing be done in Botswana. As will be indicated later under Government initiatives, an attempt towards developing a glass manufacturing industry was once made.

TABLE 3 SILICA RESERVES IN BOTSWANA

Source	% SiO_2	Reserves
Makuta Hills	99.2	Fairly large reserves
Jakalasi No 1	98,2	Over a million tonnes
Mmajojo Hill	98.4	Over a million tonnes
Shale Hill	97.6	Considerable reserves
Tswapong Hills	97.8	Enormous resources
Suselela Hill	98.64	Fairly large resources
Mmasegomana Hills	98.28	Unlimited resources
Maape village	96.89	Fairly large reserves
Ditsotswane Hill	98.65	Over a million tonnes
Marapoatshwene Hill	97.8	Enormous reserves
Lobatse	97.9	Over a million tonnes
Mmamabula	96.3	Over a million tonnes

IV. CERAMIC INDUSTRY

Botswana has sizable ceramic raw materials spread countrywide which can be used to produce high quality ceramic products [10] – [13]. Table 4 shows a summary of sources of clay with sufficient resources for use at industrial scale. It is worth noting that only three of the possible sources of ceramic raw materials shown in Table 4 are known to be used by the ceramic industry to produce clay bricks and, occasionally, pottery. Note that silica sand presented in Table 3 is also a major raw material for the ceramic industry. The import bill for ceramic products against the available resources clearly suggest that development of a sustainable ceramic industry in Botswana is feasible. This industry would go a long way in job creation in the form of formal employment and engagement in the small, medium and micro enterprises.

TABLE 4 SOURCES OF CLAY IN BOTSWANA

Sources of clay	Composition	Quantity
Mokgopeetsane River	48.2% sand, 16.6% silt and 35.2% clay	Fairly large reserves
Pilane	53.2% sand, 20.5% silt and 26.3% clay	Considerable reserves
Moshaneng	43 to 54% sand, 21% silt and 24-34% clay	Fairly large reserves
Kgwakgwe Hill Kanye	29% sand, 43% silt, 28% clay	Fairly large reserves
Taung River	34.9% sand, 23.9% silt, 41.2% clay	Fairly large reserves
Gaborone Dam	48% sand, 25.2% silt, 26.8% clay	Fairly large reserves
Metsemotlhaba River	12.7% sand, 32.3% silt, 55% clay	Fairly large reserves
Mokatse	56.7% sand, 12.45 silt, 30.9% clay	Fairly large reserves
Lobatse	44.8% sand, 29.8% silt, 25.4% clay	Considerable reserves
Lekobolo Pan	31.3% sand, 18.1% silt, 50.5% clay	Enormous reserves
Makoro	9.3% sand, 55.7% silt, 35% clay	Considerable reserves
Bonwapitse River	21.4% sand, 20.4% silt and 58.2% caly	Considerable reserves
Shoshong River	14.8% sand, 22.7% silt, 62.5% clay	Considerable reserves
Serule siding	17.8% sand, 31.6% silt, and 50.6% clay	Considerable reserves
Woodhall	16.2% sand, 53.8% silt, and 30% clay	Considerable reserves
Dukwe	1.8% sand, 46.7% silt, and 51.5% clay	Considerable

V. MASONRY UNITS

In Botswana almost all buildings are built from masonry works. These can either be clay or concrete masonry units. Quality of these units is certified by the Botswana Bureau of Standards (BOBS) under the BOS 27 for concrete masonry units and BOS 28 for clay units [28], [29]. Table 5 gives all masonry products that are currently certified by BOBS [30]. It is unexpected that only five manufacturers have masonry units certified by BOBS whilst each village or town in the country has multiple manufacturers of masonry units. Additionally, the Department of Industrial Affairs has 17 companies registered with them that actively supply masonry units [31], [32]. Note that the Department of Industrial Affairs registers manufacturers with an annual turnover of above BWP 10 million. This therefore indicates that there are many units that are uncertified and yet find use in construction. The safety, reliability and durability of structures built from these are questionable. Work by [32] has pointed to a number of structures in Botswana where premature repairs had to be made and attributed them to masonry units that were not fit-for-purpose.

TABLE 5: CERTIFIED MASONRY UNITS IN BOTSWANA

Manufacturer	Location	Scope of Certification
Brickbuild (Pty) Ltd,t/a Panda (Francistown)	Farm NQ 26, Monarch, Francistown, Botswana	7MPa concrete masonry units
		14MPa concrete masonry units.
		10MPa concrete masonry units.
Brick Build (Pty) Ltd t/a Panda (Gaborone)	Plot 20605, Block 3, Broadhurst Industrial, Gaborone, Botswana	10MPa concrete masonry units.
		14MPa concrete masonry units.
	Dipotsana, Village	10MPa – Non Face Plastered (NFP) burnt clay masonry units.
Kwena Concrete Products (Pty) Ltd	Plot 14404/5 Maakgadigau Road, Gaborone West Industrial, Gaborone, Botswana	10 MPa concrete stock bricks
		14 MPa concrete stock bricks
Makoro Brick & Tile (Pty) Ltd	Makoro Village, Botswana	Burnt clay masonry units of classes: face brick extra(FBX), face brick standard (FBS)
		Burnt clay masonry units class: Non Face Brick Extra (NFX)
Lobatse Clay Works (Pty) Ltd	Plot 4821, Woodhall Industrial, Lobatse, Botswana	Burnt clay masonry units of class: Face bricks extra(FBX)
		Burnt clay masonry units of class: Face bricks standard (FBS)
		Burnt clay masonry units of class: NFX

It is important to note that not only are licenced units scarce, they are also limited to a few locations in the south-east to the eastern part of the country. This implies that for major construction projects in the rest of areas around the country, certified units have to be hauled to those areas. This obviously is at a high cost especially for the furthest areas which can be up to 1800 km away. Table 6 shows typical country-wide transport cost of a commonly used clay unit that is certified by BOBS. The nominal cost of this unit without transport is One Pula Thirty Four Thebe (BWP 1.34). It follows then that for some regions such as Shakawe in the north western part of the country, transport cost of this unit can be about 1.6 times more than its nominal cost. This process is certainly not affordable or sustainable.

TABLE 6 UNIT COST OF TRANSPORTING TYPICAL LICENCED MASONRY UNIT IN BOTSWANA

Location	Transport cost of 1000 units (BWP)
Lobatse	116
Gaborone	199
Tsabong	803
Hukuntsi	924.99
Francistown	982.55
Gantsi	1202
Charles Hill	1387
Maun	1805
Kasane	1836
Shakawe	2111

The scarcity of certified units in Botswana can be attributed to distribution of developments in the country, availability of raw materials for brick production and Botswana strategies for quality control. The Greater Gaborone area and the Greater Francistown area combined holds over 50% of the Botswana population [33]. This, understandably, are areas where the largest construction takes place and therefore have a higher demand for certified products. It is therefore understandable that they have a greater percentage of certified units. Other probable reasons for the scarcity of certified products are discussed in later sections of this paper.

VI. CONCRETE AGGREGATES

Aggregates needed for concrete and masonry works are mainly crushed rock and river sand. Table 7 shows major operational quarries for crushing rocks. Similar to certified units, the majority of quarries are in the south-east to the eastern part of the country. Absence of crushed aggregates in other areas of the country, particularly the Kgalagadi Region, is primarily because they don't have rocks. These areas are mainly covered with vast kgalagadi sand. Unfortunately those in areas covered with kgalagadi sand have to haul crushed aggregates at a high costs. For example, a cubic meter of crushed aggregates costs BWP 275 in Gaborone compared to BWP 975 in Tsabong.

TABLE 7 QUARRIES FOR CONCRETE AGGREGATES IN BOTSWANA

Name	Location	Aggregate
Belabela Quarry	Mma Mashia/Belabela Farms	Granite
Conduit Investment (Pty) Ltd	Moshaneng	Crushed Stone
Tamarron Trading One Hundred And Seven	Lobatse	Crushed stone
Quarries of Botswana Radisele Quarry	Radisele	Stone
Quarries of Botswana S/Phikwe Quarry	Selibe Phikwe	Stone
Mmokolodi Quarry	Mmokolodi	Granite
Pioneer Quarries	Moshaneng	Aggregates
Quarries of Botswana Lose Quarry	Lose	Stone
PM Pitlo & Sons	Kuke	Quartz/Feldspar
Nambo Projects	Ghanzi	Stone
Maun Quarries & Brickfield	Maun, Toteng	Crushed Stone
PPC/Kgale Quarries	Gaborone	Stone
Quarries of Botswana. Francistown Quarry	Francistown	Concrete & Road Stone
SA Shippers	Serowe	Aggregates

River sand which is another important raw material for concrete works has been depleted in the Greater Gaborone area to an extent that in 2013 the Botswana Cabinet ordered for the ban of river sand mining in the area. Construction in this area since then has shifted to manufactured sand from crushed rocks. River sand is however still abundant in the central to the eastern region of the country.

One major aggregate resource in Botswana is kgalagadi sand which covers more than 75% of the country. Unfortunately,

unlike river sand and manufactured sand, kgalagadi sand is very fine with little silt and coarse materials as shown in Figure 2. The characteristics of kgalagadi sand make it exhibit behaviour of low cohesion and poor compactibility. These are both undesirable properties of a material for concrete works and for brick moulding. It is not surprising that amongst the list of certified brick products in the country presented in Table 5, there are no masonry product that uses kgalagadi sand. This further explains the scarcity of certified units in some areas of Botswana. In the absence of affordable conventional materials, communities in these area that are underprivileged use the kgalagadi sand as is in their day-to-day construction works and bear the consequences that are associated with the use of a poor construction material such as excessive cracking and in some instances complete structural failure. Preliminary tests conducted at the Botswana Institute for Technology Research and Innovation (BITRI) indicated that some masonry units made from kgalagadi sand that find use in the industry have compressive strengths as low as 0.8 MPa [34].

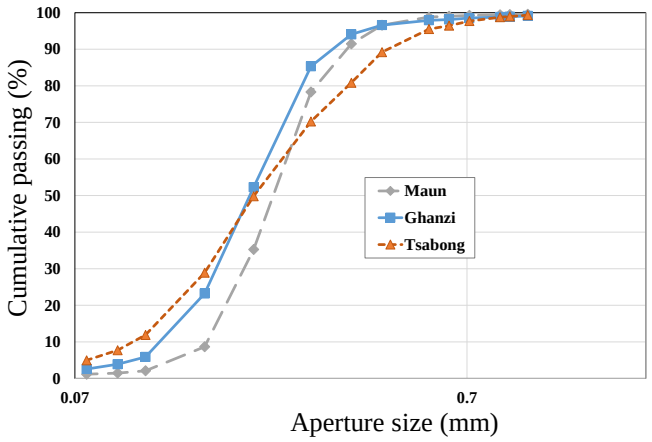

Fig. 2 Sieve analysis of typical kgalagadi sand

Kgalagadi sand is not only being used by locals in the manufacture of bricks. Almost all construction projects irrespective of the magnitude, use it in concrete works and for mortar. Little research has however been carried out to confirm the quality of works from its use given its unconventional characteristics. The safety and reliability of these structures is therefore questionable.

The review up until now has shown that Botswana has mixed natural resources for the construction industry. Most are in abundance and of required quality for use in the industry and yet are not being used whilst others are a challenge to use in their natural form. The next section of the paper looks at Government initiatives that attempt to address the issue of sustainable building materials in Botswana.

VII. Government Initiatives

The following is a summary of Government initiatives that have been put forth to ensure sustainability of the construction industry.

i) Establishment of Botswana Geoscience Institute [26]

This institute was established in 2014 to undertake research in the field of geosciences and providing specialised geoscientific services. It replaced the Department of Geological Surveys which is mostly cited in this report.

ii) Establishment of Botswana Bureau of Standards [30]

BOBS was formed in 1997 with the primary objectives of formulating Botswana standards and co-ordinating quality assurance activities in Botswana with mission to improve the quality of life of the citizens of Botswana. By offering technical services in the areas of standardization, testing of goods and certification of products BOBS plays an important role in the construction industry. Unfortunately the only mandatory product/standard that they have related to the construction industry is cement. All other products are not mandatory leaving it to the manufacturer to certify their product or to a contractor to use a certified or non-certified product. To minimise the supply of low strength products, licencing of manufacturers to produce and supply units should be provided only to those manufacturers that meet the BOBS requirements.

iii) Establishment of Research Institutions [35] – [37]

The three major research institutions in Botswana that carryout research related to the construction industry are Botswana International University of Science and Technology (BIUST), Botswana Institute for Technology Research and Innovation (BITRI) and University of Botswana (UB). BITRI has developed a technology that uses kgalagadi sand with a cement blend made from Morupule B fly-ash and Ordinary Portland Cement to produce quality masonry units. Standards for this technology have been developed by BOBS [38], [39]. Currently BITRI, in collaboration with the Government, is rolling out the technology to areas mentioned in the paper where there are no conventional building materials besides the kgalagadi sand. Research work by BITRI in collaboration with Botswana Geoscience Institute on manufactured sand and kgalagadi sand for use in mortar is ongoing.

iv) *Establishment of Botswana Development Corporation [40]*

Botswana Development Corporation (BDC) was founded by the Botswana Government in 1970 as a development finance Institution to promote and facilitate the development of industrial, commercial and agricultural enterprises. Kwena Concrete Products (Pty) Ltd and Lobatse Clay Works (Pty) Ltd listed in Table 5 amongst the four companies that manufacture BOBS certified masonry units were founded through BDC.

In 2008, BDC formed a joint venture with a glass manufacturing company to set-up a 450 tonne float glass manufacturing plant in Palapye. Unfortunately the project failed during construction stage to meet its target and consequently it was liquidated in 2013. The project has been suspended since then.

VIII. CONCLUSIONS

The following is a summary of findings from this review;

1. The import bill for conventional building materials in Botswana is very high and unsustainable.
2. Botswana does not have adequate quality limestone to support a cement manufacturing industry. However, it has abundant other quality cement raw materials that are currently barely used. It is recommended that only limestone be imported but in its raw form with all other processes carried out locally.
3. Botswana has abundant raw materials for ceramic and glass manufacturing industries. It is recommended that these industries be developed to reduce the import bill for building materials and create employment.
4. Despite having adequate quality resources for the production of masonry units only a limited manufactures supply BOBS certified units. It is recommended that BOBS should work closely with the Department of Industrial Affairs to ensure that large suppliers of units mould certified units.
5. Research institutions set-up by Government make a great contribution towards development of a sustainable construction industry in Botswana. The uptake of their work by the construction industry is however very slow.

APPENDIX

Fig. 3 Map of Botswana

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