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### Use of Pozzolans in Shared Shelter Settlements

Raw materials and their derivatives in Ghana are allocated according to who can most afford their purchase; the result is that developers and the government obtain the majority of these materials, making it difficult for an average Ghanaian to acquire materials for construction of permanent dwellings. Moreover, financing through homeownership mortgages is not a possible strategy for home construction, so homes must essentially be paid for in cash, in full or as a piecemeal process. Thus, in rural sectors, inexpensive materials, such as tree limbs and dirt, are used for the construction of homes (Owusu-Adade 235). This has resulted in 50% of all rural Ghanaian homes as needing demolition and replacement, and another 26.5% as needing massive upgrading and improvements (“Housing Policy in Ghana” 1).

In addressing the affordability, we identified potential alternative materials for the production of concrete. Due to the rapid industrialization occurring in Ghana, the price of cement has dramatically increased, leaving it a material that is unaffordable for most individuals. For example, the cost of concrete increased 350% from 2007-2009 (Solomon-Ayeh 1). With concrete unaffordable for most Ghanaians, we needed to identify a material that is not only plentiful, but also can result in a load-bearing capacity that is comparable to concrete. The alternative that we have discovered that is starting to be researched and used in rapidly urbanizing areas with intense demands for concrete is pozzolans. A pozzolan is a silicate that can be combined with water, sand, and concrete to create a concrete-like substance. The strength of the pozzolan concrete varies with the initial source of the pozzolan, but it can actually result in stronger and less porous concretes than traditional methods (Sutar, Mishra, Sahoo *et. al.* 266).

We identified six different potential sources of pozzolan that were commonly referenced in our literature review. The first, fly ash, is derived from the burning of coal. Rice husk ash is derived from

extracting rice from its pods, and then heating the pods up so that they ignite and leave behind an ash that can be used in the water, sand, and concrete mixture. Bamboo can be utilized in a similar process. Spent oil shale is another potential source, which is the material left behind in the extraction of oil. Natural sources, such as ash from volcanoes, is a readily available source that does not require industrial inputs for their extraction. Finally, bauxite waste, also known as “red mud,” is derived from the extraction of aluminum from bauxite, a clay-like material. The waste, which is initially a liquid after extraction, can be dried, and the dust can be used as a pozzolan in the water, sand, and concrete mixture.

Given the various sources of potential pozzolans to use in making an alternative concrete, they each have their own potential viability as a feasible alternative in Ghana. Regarding fly ash, Ghana will not have a coal power plant until 2018 (Sedzro). Consequently, there is little local sourcing of fly ash, and transporting it from another region would prove to negatively impact its cost effectiveness as an alternative to concrete. Rice husk ash could be a potential pozzolan source in the south of Ghana, but in the Ashanti region, our study area, only 1.5% of Ghana’s rice is produced there (*National Workshop 4*). Again, this could be transported, but the key to maintaining the alternative concrete’s cost-effectiveness is to have a local source to minimize the costs associated with transportation. Spent oil shale is a potential source, as its use as a source of energy is expanding and it is also produced in the Ashanti region, but its resultant alternative concrete is potentially weak (Al-Otoom 41). Regarding natural sources, there is very little volcanic activity near Ghana. Bamboo is a plentiful resource, but it can only compose 10-15% the concrete, sand, water, and pozzolan mixture (Asha, Kumar, and Salman 50), which impacts its cost-effectiveness.

Upon review of the literature, the most economically viable alternative, and the most structurally sound alternative, is the use of pozzolans derived from bauxite waste. Ghana produces a significant amount of the world’s aluminum, resulting in similarly significant volumes of bauxite waste.

In Ghana's Ashanti region, three aluminum refineries are located near Kumasi; Ghana Bauxite has a refineries in Bibiani and Anhwiaso, and the Volta Aluminum Company has a refinery in Bekwai. The proximity of these refineries indicate lower transportation costs in the evaluation of the relative economy of the use of bauxite as a pozzolan source. Moreover, the use of red mud dust can significantly reduce the cost of concrete, while maintaining a strength that is approximate to that of concrete. Using a 15% replacement of concrete in the concrete, sand, and water mixture, a pure concrete mixture 13.7% more expensive than the red mud mixture, and the difference in strength is considered to be approximately 3% less (Bishetti and Pammar 50). This could be problematic in large-scale construction, but the proposed shared-shelter design will not reach over two-stories tall due to the expense of steel rebar. Other studies have similarly indicated that red mud improves the economy of the concrete mixture by 6.43%, although this case indicates that the mixture's strength is not compromised (Rana and Sathé 410). Generally, upon review of the literature, the mixture must exceed 10% to achieve economy, but it must be less than 20% to avoid compromising the strength of the brick.

Bauxite waste is a material that has very few, if any, industrial uses; it is also a significant environmental pollutant that is usually stored in open-air facilities. It is usually pumped away from the production site, although it may be transported in containers where the infrastructure is not available. After the liquefied waste dries, a red dust is leftover, which must be contained to prevent becoming an airborne health hazard. Typically, the dried bauxite waste is re-located from the site, and it is stored in



Image 1. Red mud bricks as derived from bauxite waste. (Agyei-Tuffour, Annan, Buabeng, *et. al.*)



Image 1: Open-air storage of bauxite waste sludge.

dried stacks. When the mud is in this state, however, this is where the bauxite waste can be put to use as a pozzolan in a concrete, sand, and water mixture. The re-use of bauxite waste increases the sustainability of the aluminum industry, reducing the volume of significant hazardous industrial by-products. The potential for eliminating environmental pollutants is a positive implication of using bauxite waste in brick construction.

Despite bauxite waste's potential use as an alternative economic material to concrete, more research is required before it can be safely put to use on a large-scale, residential basis. "Bauxite waste can contain trace quantities of metals such as arsenic, beryllium, cadmium, chromium, lead, manganese, mercury, nickel and naturally-occurring radioactive materials, such as thorium and uranium" ("Bauxite Residue Management"). These elements remain in the industrial byproducts, the red mud, associated with aluminum production. This does not indicate that the resulting product, red brick, is inherently dangerous to human health, but we recommend caution in this approach. Moreover, there is a dearth of

literature regarding the use of bauxite waste pozzolans in residential construction and their safety. In the interest of public health, we conclude that, to avoid potential negative consequences for vulnerable groups like children, the safety of red brick derived from bauxite waste must be studied more thoroughly if it is to be implemented in large-scale residential projects.

Moreover, we were unable to identify where the bauxite waste sites are located in Ghana. It seems reasonable to assume that the sites would be near where aluminum is produced, but this will not necessarily be the case due to the particularities of storing bauxite waste. If the sites are located elsewhere outside of the Ashanti region, the economy of the bauxite waste red bricks will be negatively affected, due to transportation costs; the cost of transporting the waste would have to be factored, as well as the cost of transporting the dried dust or end-product, the red brick, were it to be produced near the storage facilities. Secondly, through our group's experience in Ghanaian markets, red dust could not be found in large enough quantities to comprise a significant portion of the concrete mixture in a large-scale project, like home construction.

In conclusion, despite the potential increased affordability of cutting a concrete mixture with bauxite waste pozzolan, we determined that a more prudent approach is to await further safety studies before using the material on a large scale. Bauxite waste pozzolan could be used more in areas where human exposure is not so prolonged, such as in roads, but residential uses should presently be discouraged. This is to say, in the desire to find more affordable materials for home construction, human well-being must not be sacrificed in the process.

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Sutar, Mishra, Sahoo, *et. al.* "Progress of Red Mud Utilization: An Overview." *American Chemical Science Journal* 4(3), 2014. Print.

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<sup>1</sup> URL provided because no publication date is included in the article.

## Design of the Shared Shelter Settlement

Pozolana and other local materials for construction:

The Pozolana proposal contains a clear vision but there are not enough products on the local market. A new factory initiated by the Building and Road Research Institute at the KNUST was opened at Winneba in March 2016 to produce them on a large scale. So moving forward we may use these product plus earth blocks and adobe to construct buildings.

This vision may sound ambitious at the moment but when conveyed at with more enthusiasm and precision might become more compelling and encourage more people to use them for affordable housing. There is a backlog of affordable housing in the country. This is therefore an opportunity for more designs and material choices to be used in the long term to make housing more affordable in the country especially in the rural areas.

Recommendations:

We were also able to modify the designs for the disable day care facility which is also scheduled to be constructed beginning march ending. A latrine was proposed to be constructed and shifted 40 feet from the main building to the south. After surveying the site we realized there was construction going on the south of the proposed site. We will therefore recommend that any future permit for digging a bore hole for that property should be denied on the fact that there might be contamination of water on the south side, since it slopes south and the waste might leech downhill and as such may contaminate the water in the immediate vicinity.