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Environmental and Cost Effects of Stabilized Laterite-Tyre Composite in Buildings

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Abstract
The increasing amount of waste tyres worldwide made its disposal a significant problem. Because of this, the availability of a market for the tyres became imperative. Incidentally, this market was found in the housing sector where recycled waste tyres were used as stabilized laterite composite for alternative building material. This study evaluated the environmental effects of the recycled waste tyres as a composite of stabilized laterite for buildings. It also evaluated the cost effects of the stabilized laterite composite. The study concludes that the stabilized laterite composite is a cost-effective alternative building material and that it reduces the level of greenhouse gasses. Other relevant issues were also discussed.
Keywords: Tyre stabilized laterite; Polymers; Cement; Greenhouse gases; Rubber.

1. Introduction

Studies on the Laterite soil stabilized with cement are well-grounded, advanced and cited in housing literature (Hambirao & Rakaraddi, 2014; Al-Rawas, Taha, Nelson, Al- Shab & Al-Siyabi, 2002; Akshatha, Jain, & Ahmed, 2018). The benefits of these studies have showcased stabilized laterite as an alternative low-cost building material and recourse to affordable housing for the urban poor in developing countries (Olotuah, 2003). Laterites are clay materials composed of non-organic elements of Alumina (Al), Silica (Si) and water (H_20) in ratios: $Al_20_3.Si0_2.2H_20$. Its molecular weight is 258 and it has a density of 1600 Kg/m^3 (dry) or 1760 Kg/m^3 (wet). It is malleable and ductile when mixed with water but shrinks and becomes brittle when it is dry. Its particles are usually less than 0.004 mm hence it easily mixes with stabilizing hydraulic binders (cement) to form stabilized laterites with each new combination of cement and laterite introducing new potential of strength, stiffness and other stabilizing enhanced properties.
Despite these, further improvements and advances in the properties and quality of stabilized laterite is realizable. These improvements can come by up-grading the stabilized composite by addition of granulated tyres which is essentially a rubber polymer, to the stabilized laterite and tested at different laterite, cement, and polymer ratios. The tests employ field and laboratory analysis, to understudy parameters such as optimum moisture content, and to determine the structural strengths and durability of the stabilized laterites and its granulated rubber additive. The results are cross-referenced to determine structural improvements, relative advantages in terms of sustainability and the construction industry.
In view of these, this study reviews existing work on stabilized laterite and investigates the environmental and cost effects of tyre as composite of stabilized laterite in buildings. The study also examines the environmental benefits of this approach and posits that this will enhance improved environmental sustainability. This study is examined in four different sections. Section 1 introduces the research while 2 examines the nature of polymers and rubber elastomers underscoring the fact that rubber occur as natural and synthetic polymer. Section 3 discusses the nature of laterites, polymer and hydraulic stabilized laterites while the paper was concluded in section 4.

2. Polymers

2.1. The Nature of Polymers and Rubber Elastomers

A polymer is a large organic molecule of thermoplastics or thermosets consisting of many repeated and interlinking sub-units of atoms of monomers joined by covalent bonds and interlinking chains. Consequently, it is a substance of large molecular mass relative to small molecular in-organic compounds. As a result, it manifests unique physical properties, including toughness, visco-elasticity and possessing the tendency to form glasses and semi-chrystaline structures rather than chrystals. Polymers range from synthetic plastics such as polystyrene to natural bio-polymers. Rubbers are a group of thermoplastics or themoset elastomeric polymer materials having large elastic properties and are solids at room temperatures. In addition, it can be stretched twice its length and still return to the original lengths when released. In this way, it is an unusual thermoplastic because its monomers are not cross-linked at room temperature making it particularly useful when materials that need to be elastic as well as cast mouldable are required. It occurs in natural and synthetic forms.

2.1.1. Natural and Synthetic Rubber

Natural rubber is obtained by a suspension of latex (a non-soluble organic component) in water. Synthetic rubber however, consist of Poly-styrene-butadiene-styrene (SBS)- a hard elastomer which enhances durability. SBS is often renamed co-polymer or a block co-polymer because it is composed of three segments which are: the first, a long chain of polystyrene; the middle: a long chain of poly-butadiene; and the last is another long chain of polystyrene. The Polystyrene is a tough hard durable plastic while Poly-butadiene is a rubber-like material, which gives it its elastic properties. Therefore, rubber and plastic are conjoined in SBS, to form an unusual material possessing the characteristic of each of the two and are called thermoplastic elastomer. This material behaves like rubber at room temperature, retaining its shape after being stretched but when heated can be processed like plastics and molded into shapes.

2.1.2. Tyre

Tyres are produced industrially using, fabric, wire, carbon black synthetic rubber and natural rubber. Rubber in the raw form has the tendency to soften and creep at elevated temperatures. Because to this behaviour, its use is limited unless it is cured by the addition of sulphur in a ratio of 1-5% of the rubber. Industrially, this process is referred to as vulcanisation and it results to cross-linking the elastomeric molecules of the rubber to remove this limitation. Thereafter it can be used in the industrial production of tyres. The tyre industry manufactures over one billion tyres annually (making it a major consumer of rubber globally) most of which tends to become waste at the end of its useful life. (European Commission, 1999; European Commission, 2000; Tyre Technology International, 2004). Indeed, within the past three years, the European Union alone reported over three million tonnes of waste tyres (European Commission, 2000).

With umpteen waste tyres now used as landfills, which in itself was generating another problem, the Union through its landfill directive sought to mitigate this by curtailing the landfill disposal of waste tyres. Faced with this situation, it became germane to find a market for the waste tyres; and this interestingly became available in the housing sector where it can be re-used as alternative building material.

3. Laterite Composites

3.1. Laterites and Stabilized Laterite Composite.

Laterites are rusty-red soil types rich in iron and aluminium, and formed in hot and wet tropical areas. Laterite is mined while it is below the water table; as such it is wet and soft and can then be cut into regular sizes. Upon exposure to air, it gradually hardens because the moisture between the flat clay particles evaporates and the larger iron-salt lock into a rigid lattice structure and become resistant to atmospheric conditions. Laterites are stabilized cements.

Cements however, cures through a series of hydration chemical reactions when mixed with water. The curring occur as constituents of the cement hydrates, crystallize and interlock. Stabilized laterites (figure 1) employ cements (which solidify with water) such as Portland cement. Thus, it is made up of cement and laterite mix in prescribed ratios, cured under regulated temperature and have been used extensively in wall constuctions. Research has shown that by varying the mix, stabilized laterite composites of various strength, permeability and ductility can be realized and more importantly that, stabilized laterite composite perfom optimally with 7% cement proportion.

Figure 1. Curing process

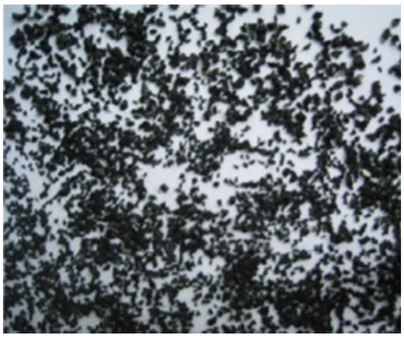

Figure 2. Laterite wall construction

3.2. Tyre Stabilized Laterite

The addition of granulated tyres (figure 2) to stabilized laterites has also been documented in literature (Zare, 2006; Otoko, Ephraim, & Ikegboma, 2014; Marandi, Bagheripour, Rahgozar & Zare, 2008; Loher, Axtell, & Bowers, 2000; Sivakumar, Vasudevan & Sayida, 2008; Puppala & Musenda 2000).

It was shown that a mix of 4% cement and 4% granulated tyre in laterite produces a composite of similar strength and durability as ordinary stabilised laterite of 7% cement mixture (Chee-Ming, 2007). Owing to this improvement in performance, the role of the granulated tyres as the stabilizer and the cement /laterite composite as the matrix become clearer. In this way, the tyre impacts its special mechanical and physical properties to enhance the synergy and produce material properties unavailable in the individual constituent materials. Aside, the production processes involving the granulation of the tyres and all the secondary industrial processes involved have been observed to be environment friendly (Otoko, Ephraim, & Ikegboma 2014; Cairns, Kew, & Kenny, 2004) and cost effective because they are processed from waste tyres (Pacheco-Torgal, Yining, Said, 2014; Oikonomou & Mavridou, 2009; World Bussiness Council for Sustainable Development – WBCSD, 2009).

3.3. Environmental Importance

From the foregoing, it is obvious that evaluation of the building constuction processes with the intent of appraising environmental performance have become imperative. This evaluation is approached using the following parameters:

3.3.1. Dematerialisation of the Building.

Brown & Lutz-Carillo (2009) highlights the need for the dematerialisation of the building pointing out the challenges in not doing so and the environmental benefits in doing so. Along this line, Eleazer, Barlaz, Whittle (1992) and Swiatek (2013) pointed out that evaluation of the building industry has shown major challenges that accompany mineral extraction which is that mineral extraction per capita intended for building amounts 4.8 tonnes per inhabitant per year and this is 64 times the average weight of a person. They asserted that this should draw attention to the need for building's dematerialization. In effect, Brown & Lutz-Carillo observed that global constuction consumes 60% of the raw materials extracted from the lithosphere. From this, the building industry consumes 40% indicating 24% of the global extractions. Moreover, Life Cycle Assessment of the buildings reveal that 50% of embodied energy in buildings is represented in the materials used in construction (Vieira, Soares, Pinheiro, Paiva, Eleutério, & Vasconcelos, 2010). Intrestingly, the stabilized laterite-tyre composite alternative building material abate this energy imbalance because it reinforces the dematerialization of the building owing to the density of rubber. The density of rubber (Isoprene or 2- methyl-1, 3-butadiene) is far much lower than clay. The density of Isoprene to clay is: 681 Kg/m3 to 1760 Kg/m3 which foreshadows that a block of rubber and clay of the same volume and surface area is much lighter in rubber than clay.

3.3.2. Greenhouse Effects

The greenhouse gases are a type of gases in the atmosphere that retains sun's heat (Mandal & Byrd, 2017, Fashuyi, 2019). These gases include carbon-dioxide (CO_2), water vapour (H_2O) and nitous oxide. The production of cements from raw materials creates enormous amount of carbon-dioxide which increases the greenhouse gasses and the retention of sun's heat. In view of this, the alternative of granulated rubber stabilizers, which though require a secondary industry for re-cycling is more environment friendly because its CO_2 emission is comparably low. Adeola & Alfa (2018) went further toshow that re-cycled materials in other building composites especially as steel and Aluminium, prevents emission of CO_2. Indeed, every kilogram of secondary steel produced reduces emission by 1.2 Kg of CO_2 while re-cycled Aluminium represents a reduction of 11.3 Kg of CO_2. Figure 3-4 below gives a graphical representation of materials and the energy effects of their extractions in the lithosphere.

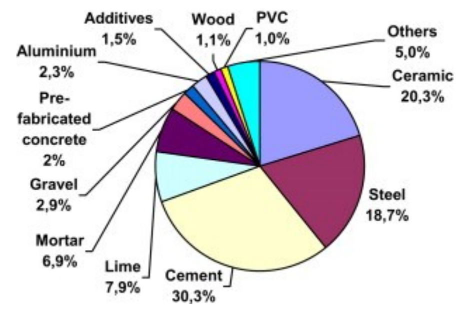

Figure 3. Embodied Energy

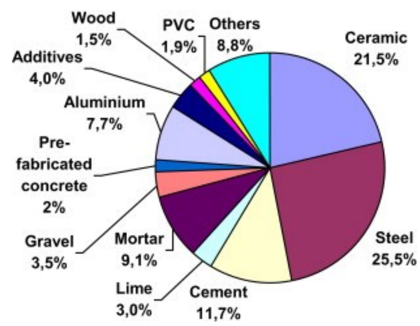

Figure 4. CO_2 manufacturing emission index

4. Conclusion

This study shows that the addition of granulated tyres to stabilized laterite composites improves its efficiency for building. The study further show that the method is cost effective because the tyres were sourced from waste and because the raw materials for the cement that would produce an equivalent durability and strength as the composite will require more labour and capital than the tyres. The study intensifies that the production of cement gives so much carbon dioxide to the air and in doing so, add to the greenhouse gasses and concludes that the tyre alternative is a more environment friendly solution. Overall, this study showed that stabilized laterite-tyre composite building material is important to sustainability and to providing cost effective solution for building and construction.

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Conflict of Interests
The authors declare no conflict of interest.

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