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A Review on Investigating the experimental process for partial replacement of cement with sugarcane bagasse in the construction industry

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A Review on Investigating the experimental process for partial replacement of cement with sugarcane bagasse in the construction industry

Nadin Dawoud^a, Amany Micheal^b, Rania Rushdy Moussa^c

^{a, b & c}The British university in Egypt (BUE), Suez Desert Road El Sherouk City, 11837, Cairo Egypt

Nadin150210@bue.edu.eg

Abstract. In the last few decades there has been speedily increasing in the agriculture and industrial wastes. This causes many environmental issues and raises the potential to contaminate the natural resources of living such as water, air and soil. Recently, the amount of organic waste produced daily has been rising, while it is poorly managed. It is either burned or disposed improperly, which effect negatively the environment and public health. On the other hand, during the cement production process many wastes, and pollutants are generated which have major negative impacts on the environment. Cement is considered as a substantial constituent of building materials in the construction industry. Many research's intended to explore the potential of utilizing organic waste products in the construction industry by partially replacing cement with organic wastes such as sugarcane bagasse to create an eco-friendly brick with appropriate structure properties. Previous research's used different treatment techniques to treat the organic waste and prepare it for construction industry. It was noticed that the treatment method used in previous research's affected the structural properties of the new bricks with organic waste partially replacing. This research intends to study and analyse the process and techniques used by other researcher's experimental work to treat and replace cement with sugarcane bagasse. This research will present the best procedures for partially replacing cement with sugarcane bagasse in cement bricks without compensating the structural properties of regular cement bricks. This study will analyse and compare previous researcher's experimental work to obtain the best experimental program and to utilize sugarcane bagasse in brick industry.

Keywords: *Sugarcane bagasse; Cement; Eco-friendly block; Partial replacement; Thermal conductivity; Strength*

1. Introduction

Agriculture and industrial wastes generation are becoming a dangerous and significant problem in the world (Xu, Ji, Gao, Yang, & Wu, 2018). This problem is becoming more significant by time due to growth in population rate. The accumulation of wastes causes many environmental issues and raises the potential to contaminate natural resources of living such as water, air and soil. So, the appropriate disposal of these wastes and by products is a serious burden of every country (Moussa, 2019). The safe disposal of such industrial wastes is very expensive. Furthermore, there is a lack of disposal sites which can appropriately handle such wastes without causing harmful effects on the environment. The



understanding of waste management process requires the understanding of wastes and how can they be managed. Therefore, researchers from all over the world are focusing on ways to utilize these wastes, to reduce their harmful effects (Singh, Saxena, Bharti, & Singh, 2017).

Lately, burning the organic waste or the inappropriate disposal methods for these organic wastes became a huge international problem as shown in Figs. 1 and 2. Today, Egypt recycling only 20% of its organic wastes (Elfeki & tkadlec, 2014; Guirguis & Moussa, 2019). The wastes affect negatively the environment by creating visual pollution, the black cloud, increasing the insect population in the environment as well as it affects the human's health. Sugarcane is one of the most promising organic residues around the world and in Egypt. It produces cane trash and bagasse as wastes materials. Bagasse is a fibrous material left after cane milling. Most bagasse is burned and combusted to generate energy and electricity; however, this contribute to the emission of carbon dioxide and to the formation of black cloud. As the government and people became aware of recycling, researchers started to explore methods of incorporating bagasse in the construction industry of manufacturing bricks by replacing some of its components (Mangi, et al., 2017). The brick industry is one of the places where the beneficial use of agricultural waste could have goodfuture.''



Figure 1: sugarcane bagasse burning (afrik21, 2019)



Figure 2: Sugarcane bagasse disposal, (afrik21, 2019)

At present, brick industry is cursed with its environment pollution from cement production as shown in Fig. 3. Cement is considered one of the most important industries worldwide as it is the backbone for the development of any country. It is the world's most consumed construction material because of its excellent mechanical and durability properties. According to (Stajanča M., 2012) for every one human being in the world, 1 ton of cement is being produced every year and as a result to its significant, its production impacts need to be understood. According to the Industrial Development Authority, Egypt alone has produced 83.5 metric ton (M/T) of cement in 2016 and it is also named as the 14th country in the list of the cement producing countries as cement Industry estimates to be 5.9% of the Egyptian economy (2019). Cement production is one of the major energy consuming industries in the construction system and generates harmful emission, odours and noise thus harming the environment and its inhabitants. As demonstrated in Figs. 4 and 5, some of the emissions produced from the process are dust, carbon dioxide, nitrogen oxides and Sulphur dioxide (Stajanča M., 2012).

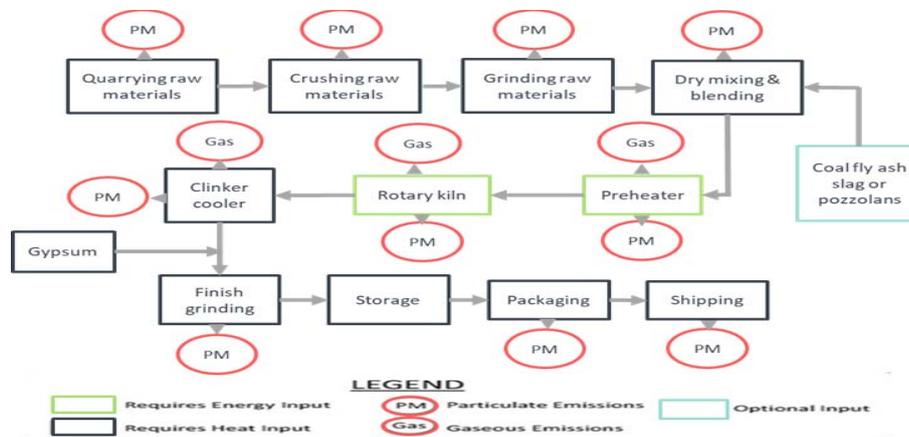


Figure 3. Cement production process and emissions, (Eřtokova, 2012)



Figure 4. Air pollution in cement production industry, (Eřtokova, 2012)



Figure 5. Dust emissions in cement production industry, (Eřtokova, 2012)

In recent years, various studies have been conducted to produce bricks having an appropriate strength and better mechanical properties with low environmental impacts with the integration of agricultural waste. Many researchers started testing the process of partially replacing cement by sugarcane bagasse to reduce waste generated from cement production industries and utilize the usage of bagasse in various areas, this is briefly explained in Fig.6.

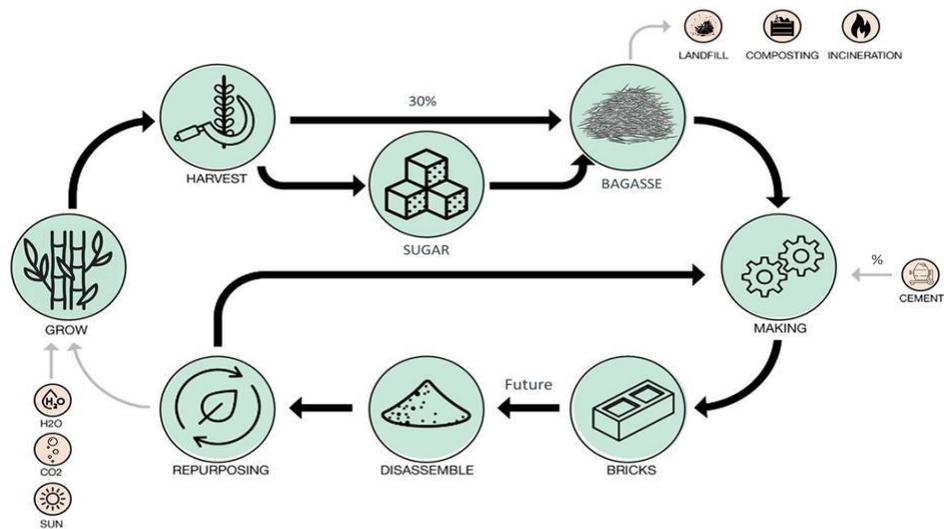


Figure 6. Utilizing sugarcane bagasse in brick industry, (developed by author, 2019)

This study aims to investigate the production of a block by using an organic waste Material; sugarcane bagasse fibres as a partial replacement of cement to improve its physio-mechanical properties.

Achieving the aim of this study, there are some of integrated objectives that must be applied:

- Utilizing the usage of organic waste materials such as sugarcane bagasse in the construction industry
- Analysing previous researchers' experimental work and compare their results
- Obtain the best experimental program for cement replacement by sugarcane bagasse

The presented research suggest that the sugarcane bagasse fibres can be used as a cement replacement to produce a new model of eco-friendly bricks with lower thermal conductivity of the brick and appropriate strength as shown in Fig. 7.

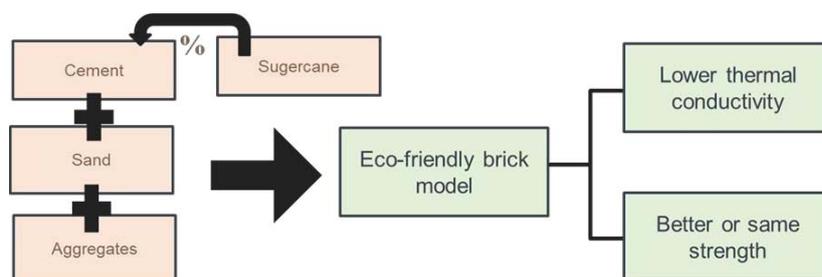


Figure 7. Research hypothesis

The results of this research are developed by two Theoretical qualitative methods (Fig. 8):

- Literature review descriptivemethod
- Analytical comparative previous experimental workmethod

The first theoretical method section will be covered through the detailed background information in the literature review. The literature review will be composed of detailed information about organic

waste, its environmental impact and its use in the construction industry. Then the sugarcane bagasse component, properties and its negative impacts on the environment will be stated. In addition, the cement production and its impacts will be explained with the properties of the ordinary Cementous brick.

The second theoretical method will be covered through analyzing and comparing previous researchers' experimental work that was done on this topic. Several case studies with several experimental alternatives will be compared to obtain the best experimental program for future research.

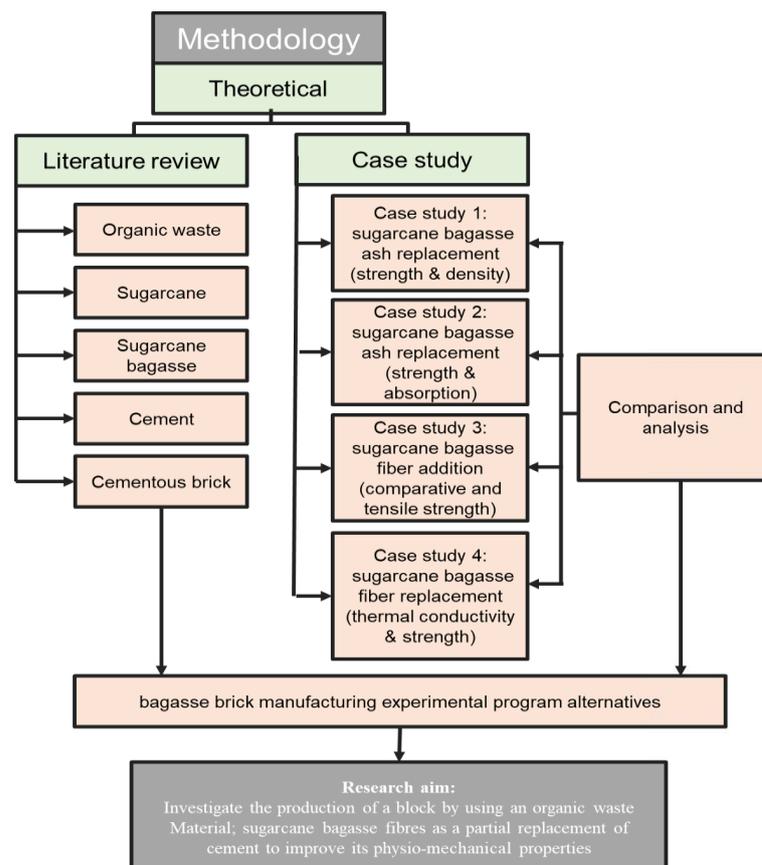


Figure 8. The research outline

2. Organic waste

In this part, the sugarcane bagasse is introduced in detail with description and analysis of its chemical, physical and mechanical properties. In addition, its negative impacts to the environment and people's health are presented to highlight its recycling and management necessity. This will assist in understanding of its importance in the utilization in other industries especially the construction industry.

2.1. Sugarcane bagasse in Egypt

Around the world, 38 billion metric tons of organic wastes approximately are produced annually. This dramatic increase is the result of numerous factors such as human actions, consumption rate, and population explosion (Kiyasudeen, et al., 2016). According to Elfeki & tkadlec 56% of the total Egyptian municipal solid wastes of 12.88×10^6 tons are organic wastes which is considered the main source of solid wastes in Egypt as shown in Fig. 9 and 83.5% is being dumped and poorly disposed.

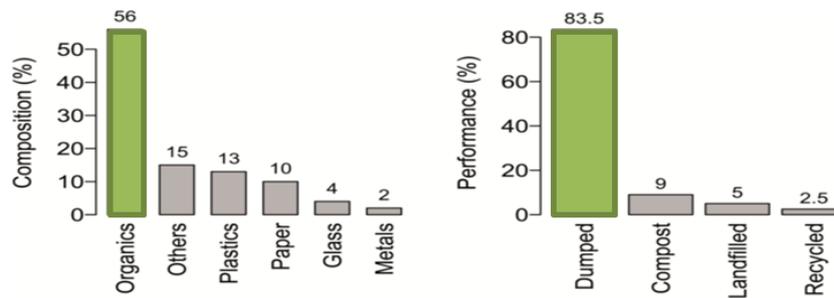


Figure 9. Composition (left) and performance (right) of MSW in Egypt as reported in 2010 (Elfeki & tkadlec, 2014)

Despite the existence of 66 composting plants in Egypt, the recycled organic waste still does not exceed the 20%, therefore managing organic waste is crucial to avoid serious environmental and public health problems (2014). By 2025, it is predicted that the annual organic waste generation will exceed 30 million tons annually. Poor disposal and combustion of organic waste have always been the result due to the poor management of these wastes which lead to numerous environmental problems. In addition, improper disposal of organic wastes in dump sites and waterways contaminated air and water supplies, this hindered the Egyptians natural resources, heritage, and population welfare.

Organic wastes have been utilized in many sectors in the construction industry. In 10 are the six main fields of applications identified are (Arub, 2017): Interior partitions and finishes such as flat boards, furniture, acoustic absorption, thermal insulation, carpets, moquette and envelope systems.

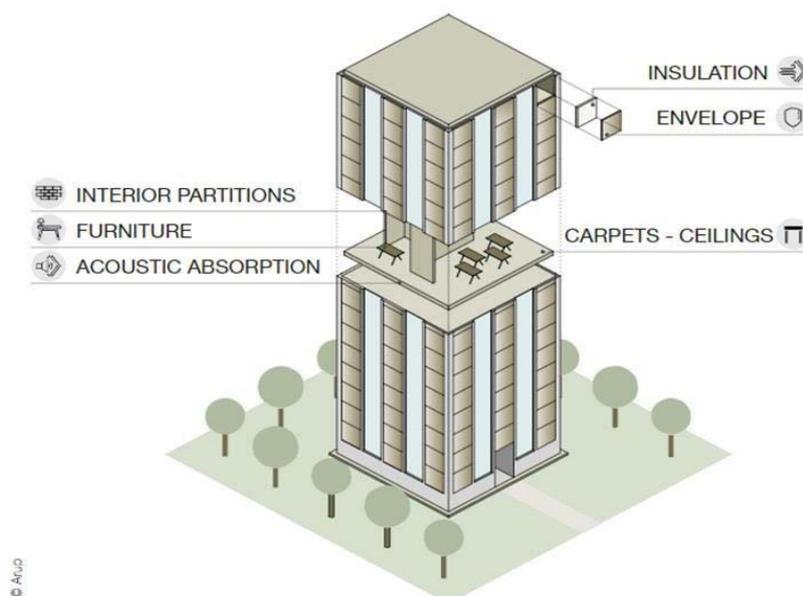


Figure 10. Fields of application for products made from organic waste (Arub, 2017)

2.2. Types of agriculture waste in Egypt

Agricultural wastes are the highest type of organic waste source in Egypt, Egyptian crops produce numerous amounts of residues every year, Table 1 lists the types of major agricultural crop residues in Egypt and its generation amounts annually. The table illustrates the sugarcane residue production is more than 16.8 million tons annually. Therefore, sugarcane bagasse recycling is a promising field in Egyptian neighbourhoods as it provides a great opportunity for creating a sustainable building material.

Table 1. Types of agricultural waste and percentage of it in Egypt. (Megeed, 2012)

Crop residues	Amount (million tons)
Cotton stalks	1.6
Rice straw	3.6
Maize residues	4.5
Sugar cane residues	16.8
Wheat straw	6.7
Barely straw	0.2
Sugar beet residues	0.32
Trees trimming residues	1.7
Vegetable residues	0.71
Banana residues	1.7
Beans straw	0.35
Lentil straw	0.012
Pea straw	0.042
Public garden residues	1.14
Sorghum residues	1.2
Sesame straw	0.56
Date palm residues	0.66
potato	0.317
tomato	1.11

2.3. Sugarcane in Egypt

Sugar is one of the main substrates of human diet. India, Brazil, Thailand, Australia and China are the world's five top sugar producing countries. Sugar production industry in Egypt started from the year 710 AD (Hassan and Nasr, 2008). Distribution percentages are shown in Fig. 11. Cane plantations are concentrated in the area of Upper Egypt in Menia, Sohag, Qena, Luxor and Aswan. Annually, about 16 million tons of cane are cultivated in Upper Egypt (Hamada, 2011). Among Arab countries, Egypt is considered the largest producer of sugarcane followed by Sudan, at 7.5 million tons annually (ESCWA, 2009). During the sugar production process in the mill, several by-products and residues are generated. These are (Fig.12):

- 30% Bagasse, which is the fibrous remaining material produced from sugarcane chopping and milling.
- 3.5% Filter mud/cake resulting from cane juice filtration.
- 0.4% Furnace ash, in case the bagasse is combustion for steam and electricity generation.

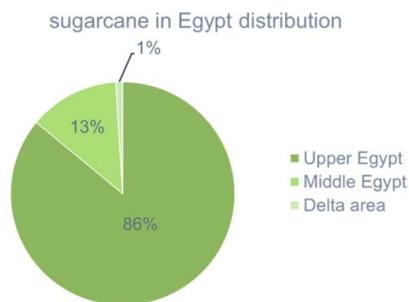


Figure 11. Percentage of sugarcane in Egypt, (Megeed, 2012)

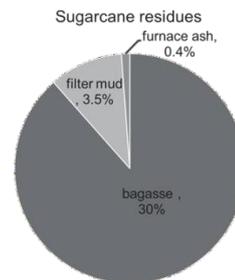


Figure 12. Percentage of sugarcane residues, (developed by author, 2019)

3. Sugarcane bagasse(SCB)

In this part, the sugarcane bagasse is introduced in detail with description and analysis of its chemical, physical and mechanical properties. In addition, its negative impacts to the environment and people's health are presented to highlight its recycling and management necessity. This will assist in understanding of its importance in the utilization in other industries especially the construction industry.

3.1. Sugarcane bagasse in Egypt

Sucrose extraction for sugar and ethanol production is the main reason sugarcane has been grown. The sugarcane culture accountable for huge bagasse generation quantities, its generation of bagasse is 140 kg bagasse for every ton of sugarcane (Faria, 2011). Nowadays, the by-product; sugarcane bagasse is valued by sugar-alcohol sector producers as it is the main raw material for bioenergy and biofuel production, this grants the use of bagasse an economic and environmental importance for the producing countries (Mulay, Vesmawala, Patil, & Gholap, 2017). Till this day, the use of bagasse for energy generation in industrial ovens is continuous, however its industries have expanded as its value is remarkably growing due to the increase in recycling awareness and it is nowadays used to produce building materials, packaging materials, and disposable tableware. In addition, the paper industry started to introduce sugarcane bagasse fibres as a replacement of wood fibres for the production of napkins, toilet paper and cardboards (Sales & Lima, 2010).

Bagasse a heterogeneous in size and particles shape with respect to its three dominant constituents, the polymers: cellulose, hemicellulose, and lignin. Their chemical ingredients and composition are listed in Table 2:

Table 2. Composition of bagasse (Rabelo, 2015)

Component	Composition (%)
Glucose	19.5
Xylose	10.5
Arabinose	1.5
Galactose	0.55
Lignin	9.91
Organo soluble	2.7
Reducing sugars	1.85
Uronic acids	1.91
Ash	1.6
Cellulose	50
Total hexoses	20.04

Table 3 presents a list of the physical properties of bagasse. The fibres with the highest aspect ratio have the highest tensile properties and provide a high surface area which is useful for reinforcement purposes.

Table 3. Physical properties of bagasse (Gupta, 2015)

Property	Value
Diameter (μm)	10-34
Length (mm)	0.8-2.8
Aspect ratio (l/d)	76
Moisture content (%)	49

Bagasse exhibits excellent mechanical properties such as high strength, flawless finish, easy manufacture, and extremely low thermal conductivity. In table 4, the mechanical properties of bagasse fibres are presented

Table 4. Mechanical properties of bagasse (Gupta, 2015)

Property	Value
Tensile strength (Mpa)	180-290
Young's Modulus (Gpa)	15-19
Failure strain (%)	1-5
Density (kg/m^3)	880-270

3.2. *Negative impact of SCB disposal*

The dramatic residue generation during sugarcane harvest mismanagement, insufficient tools and data assessment for using waste management alternatives regardless economic criteria and lack of cheap sustainable waste management alternatives to reach the optimum environmental balance results in numerous negative impacts. Sugarcane bagasse is poor disposing and burning during the harvest season cause various many detrimental impacts for example air quality degradation and harmful combustion products emission such as, carbon monoxide (CO) and volatile organic carbons (VOC). This negatively affect neighbouring communities' health and contribute to black cloud formation. This contamination is not limited to only the surrounding environment, but also the production of fly ash damages the soil microbial diversity. In addition, water stream polluted by fertilizers and waste from sugarcane harvesting are subjected to reduction of water-oxygen content which negatively impacts the aquatic animals (Kiyasudeen et al., 2016). Air and water pollution occur mainly from agricultural disposal and burning. Various harmful emissions are produced due to bagasse combustion this causes numerous health issues to the community such as lung problems and breathing issues. Moreover, fertilizers' chemicals and pesticides leaking into ground drinking water contributes to many health-related problems such as blue baby syndrome which causes death in infants (Hussein & Sawan, 2010).

3.3. *Current uses of SCB*

Sugarcane bagasse as shown in Fig. 13 is currently used in various industries. Some of its uses in Egypt are steam and electricity generation as it is a free, secure and reliable fuel generated originally as a waste product, fibreboard production which positive effect on deforestation as it avoids the use of virgin wood and pulp and paperproduction.

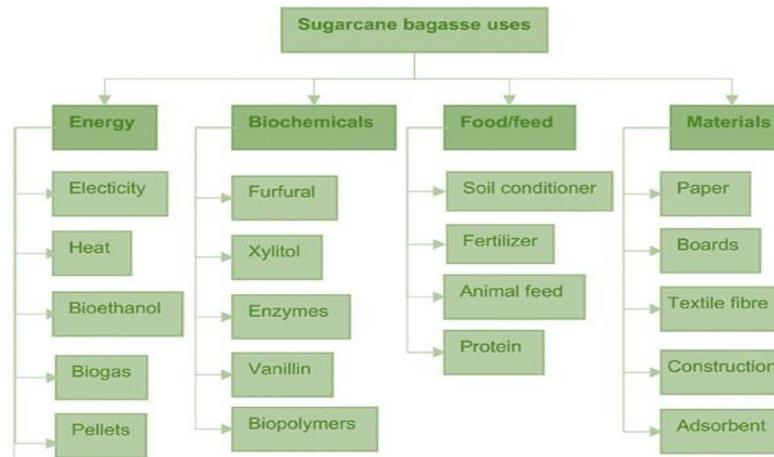


Figure 13. Sugarcane bagasse uses (WADE, 2004)

3.4. The use of SCB in the construction industry

Recent studies are made to use organic fibres in the construction industry in brick industry as shown in the table below, insulation boards, fibrous building panels and cement boards. Organic fibres are produced from various solid wastes for example bamboo, coconut, date palm, oil palm, sugar palm, sugarcane, and vegetable wastes. These fibres have inert chemical properties than either steel or glass fibres in addition to their lower cost and natural form. Table 5 demonstrate the different types and sources of solid wastes worldwide and their recycling and utilization potentials for construction materials.

Table 5. Different types and sources of solid wastes and their recycling and utilization potentials for construction materials (Pappu et al., 2007)

Type of solidwastes	Source details	Recycling and utilization potential
Agro-waste (organic)	Baggage, rice and wheat straw and husk, sawmill waste, ground nutshell, jute, sisal, cotton stalk, vegetable residues	Cement boards, particle boards, insulation boards, wall panels, roof sheets, binder, fibrous building panels, bricks, acid-proof cement, coir fibre, reinforced composites, polymer composites
Industrial waste (inorganic)	Coal combustion residues, steel slag, bauxite red mud, construction debris	Bricks, blocks, tiles, cement, paint, fine and coarse aggregates, concrete, wood substitute products, ceramic products
Mining/mineral waste	Coal washeries waste; mining waste tailing from iron, copper, zinc, gold and aluminium industries	Bricks, fine and coarse lightweight aggregates, tiles
Non-hazardous waste	Waste gypsum, lime sludge, limestone waste, broken glass and ceramics, marble processing residues, kiln dust	Blocks, bricks, cement clinker, hydraulic binder, fibrous gypsum boards, gypsum plaster, super-sulphated cement
Hazardous waste	Contaminated blasting materials, galvanizing waste, metallurgical residues, sludge from wastewater and <u>waste treatment plants, tannery waste</u>	Boards, bricks, cement, ceramics, tiles

The principle causes of environmental concerns and burdens of the continuous growth of agriculture and industrial waste generation, therefore using organic wastes in the construction industry such as brick production is highly beneficial (Xu, Ji, Gao, Yang, & Wu, 2018). Researchers from around the world started focusing and searching for ways to utilize these wastes, to reduce their harmful effects. Many studies nowadays try to approach this issue by partially replacing cement with bagasse. According to a study, one ton of sugarcane produces 280 kilo grams of bagasse waste which is also considered as an economical issue also as an environmental issue due to poor disposal and handling (Xu, Ji, Gao, Yang, & Wu, 2018). Recycling the sugarcane bagasse in the brick industry to partially replace cement is considered as inexpensive and will reduce both environmental and economic problems.

4. Cement

In this part, the cement production process will be introduced, and its negative environmental impacts will be evaluated. This will help understand the cement's properties and application in brick industry. In addition, Cements brick will be explained to help understand its properties and usage.

4.1. Cement production industry

Cement is a fine, soft, powdery-type substance, used mainly for binding sand and aggregates together for concrete mixing. Cement acts as a hydraulic binder; hardens during water addition, and it is the key ingredient in concrete and mortar to be used for building durable structures. According to the European cement association (2016) The cement-making process can be divided into two basic steps (Fig.14):

- The main constituent of cement is clinker, is manufactured in a kiln with gas at temperature of 2000 °C, this heats raw materials such as limestone and other materials for example clay to 1450°C. in this process, limestone is transformed into calcium oxide (lime) then reacts with the other components to form new minerals. This semi-molten material is then rapidly cooled to a temperature of 100 -200°C.
- Cement grey powder is produced by grounding clinker with gypsum and other materials

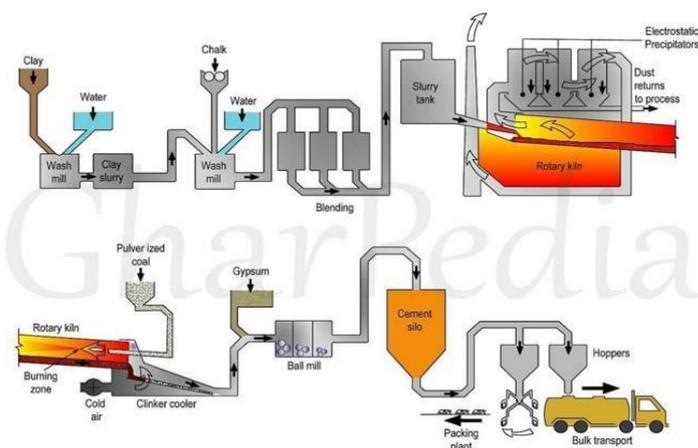


Figure 14. cement manufacturing process (gharpedia , 2018)

4.2. Impact on the environment

4.2.1. Energy consumption:

Energy consumption is the biggest environmental concern with cement and concrete production. Manufacturing process of cement is considered to be the most energy intensive industries around the world. Cement production, direct fuel use for mining and transporting raw materials consumes around 1,758 kWh per cement ton (Parga, Rocco, Christoforo, & Panzera, 2012). Fig. 15 present the percentage of energy demand during cement production process.

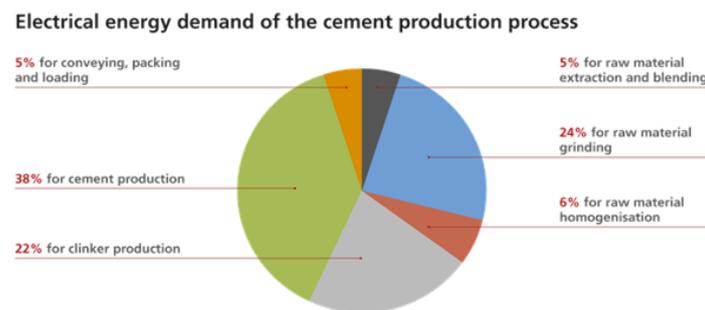


Figure 15. Energy demand of the cement production process (cembureau, 2018)

4.2.2. Air emissions:

Carbon dioxide emissions are produced from two different sources during cement production. The largest source is fossil fuels combustion for rotary kiln operation which is approximately 3/4 t of CO₂ per ton of cement followed by limestone calcining into lime chemical process in the cement kiln. Cement industry is accountable for about of 5% of global CO₂ emissions (Torrie, 2017). Fig. 16 shows emissions percentages of CO₂ comes from cement bricks production in Egypt in 2006. Cement and concrete production generate considerable quantities of air-pollutant emissions besides CO₂ such as dust and other air pollution emissions. The dust particulate emits around 360 pounds per ton of cement produced as a result of raw material handling, cement clinker grinding and packaging or loading finished cement. Air pollutants emitted during cement manufacturing are sulphur dioxide (SO₂) and nitrous oxide emissions.

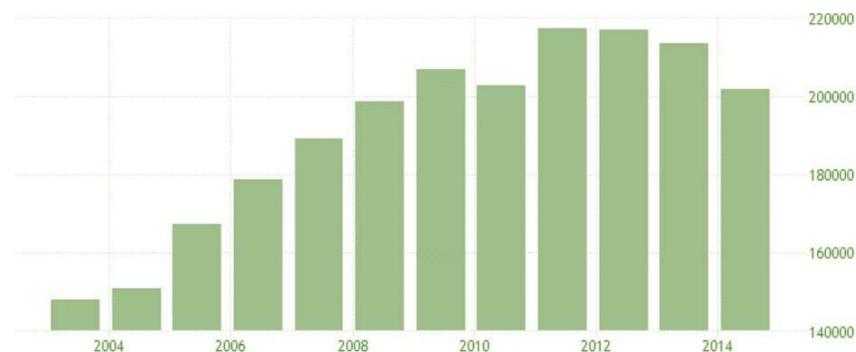


Figure 16. Percentage of CO₂ comes from cement bricks in Egypt in 2006 (Torrie, 2017)

4.2.3. Water pollution:

Water pollution is another environmental issue with cement and concrete production. At the batch plant, water used for equipment cleaning is sometimes discharged into setting ponds where the solids settle out (Hussein & Sawan, 2010).

4.3. *Cementsbrick*

Cement is used by architects and structural engineers to design structures with high structural capacity, fire resistance, water resistance and insulating and acoustical advantages. In many cases, this minimum-maintenance material provides economical advantage to building codes and clients' needs.

4.3.1. *Structuralproperties:*

Cement blocks vary by type however; its primary structural property is compressive strength. The Building Code Requirements for Structural Concrete include the structural property standards for cement bricks at 7-day and 28-day (Dlamini, 2014). According to the Egyptian standard specification 1292, for load bearing brick to be 5.6 N/m² and for non-load bearing brick to be 2 N/m².

4.3.2. *Thermalconductivity:*

The insulating properties of various concrete blocks vary depending on manufacturer and on block density. As the density of the block decreases by volume producing low weight block, the lower the thermal conductivity of the block, which enhance the insulation properties of the block (Babor, Plian, & Judele, 2010)

4.3.3. *Cost:*

Cement blocks prices in Egypt are expensive in which in 2018 for every

- 1000 brick from Cement hollow 40 × 20 × 12 cm cost 3729 Egyptianpound
- 1000 brick from Cement hollow 40 x 20 x 20 cm cost 4746 Egyptianpounds
- 1000 brick from Cement solid 25 x 12.5 x 6 cm cost 630 Egyptianpounds

4.3.4. *Waterresistance:*

Permeability and porosity vary by unit type, but generally cement blocks water absorbents. The mixture of course and fine aggregates creates a better waterproofed cement block finish. The block's permeability is affected by the amount of cement used in the manufacturing process. As the mixture gets rich in cement, the less the block's permeability (Torrie, 2017).

4.3.5. *Aestheticproperties:*

Most cement blocks come in greyish colour. Nowadays, manufactures produce blocks with variety of colours, textures and finishes for different purposes. This eases the architect's job for utilizing this type of block in various uses, design and to meet the ever-evolving constructionmarket.

5. Case studies

In this part, several case studies that experimented sugarcane bagasse as a partial cement replacement will be analysed to obtain different experimental alternative for the different experiment's components. This helps to obtain the best suitable experimental program to be adapted in this research.

5.1. *Experimental Study on Partial Replacement of Cement by Sugarcane Bagasse Ash (Kumari, 2015)*

- A. Location: India
- B. **Date:** July2015
- C. **Type of model experimented:** concrete cylindrical specimens with dimensions of 150 mm x 300 mm
- D. **Cement type:** Portland Pozzolana cement with trade name "LAFARAGE DURAGUARD" cement referring to IS code 1489-1-1991(part 1). Table 6 shows itsproperties:

Table 6. Portland Pozzolana cement physical properties (Kumari, 2015)

Tests	Results
Fineness (%)	6%
Soundness (mm)	5 mm
Specific gravity	3.057
Normal consistency (%)	34%
Initial setting time (min.)	106 min.
Final setting time(min.)	310n.



- E. **Bagasse treatment method:** Combustion; The bagasse was heated at 700 °C for one hour until it became dry and black ash as shown in Fig.17.

**Figure 17.** Combustion treatment process (Kumari, 2015)

- F. **Percentage of replacement:** 5%, 10%, 15% and 20%
 G. **Water-cement ratio:** 0.44, 0.45, 0.46
 H. **Factors tested:** Compressive strength and density of concrete
 I. **Methodology:** the concrete mix was experimented at water-cement ratio of 0.44, 0.45 and 0.46. Several samples with varied sugarcane bagasse ash percentages of 5, 10, 15 and 20%. Samples then undertake the proposed tests to obtain results (Fig.18).

**Figure 18.** Concrete blocks after curing (Kumari, 2015)

- J. **Results and findings:** the following graphs show the strength and density results obtained through this experimental program

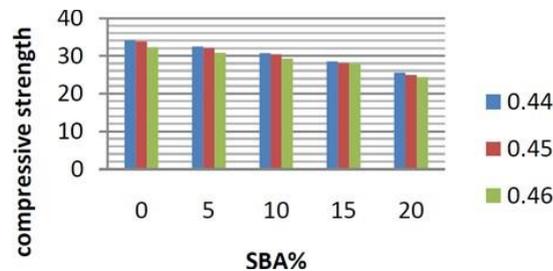


Figure 19. Compressive strength of different SBA percentages and different W-C ratio (Kumari, 2015)

Fig.19 display the compressive strength comparison between concrete and SBA samples at different W-C ratio of 0.44, 0.45 and 0.46. The graph shows that compressive strength decreases with increase in w/c ratio.

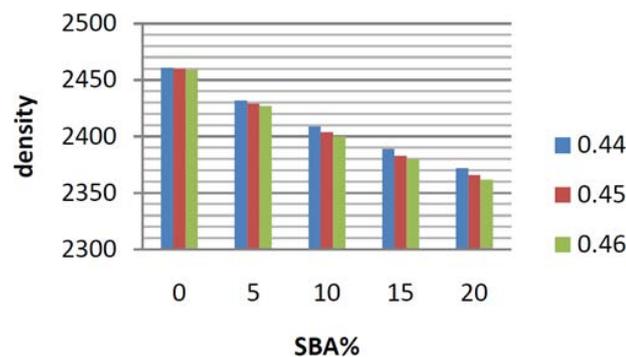


Figure 20. Density at different SBA percentages and different W-C ratio (Kumari, 2015)

Fig. 20 shows the density comparison between concrete and SBA samples at different W-C ratio of 0.44, 0.45 and 0.46. The graph shows decrease in density with the increase in w/c ratio.

K. Conclusion:

- Concrete containing SBA showed a decrease in workability as SBA increases due to the higher water absorption of bagasseash.
- The concrete's compressive strength decreases with the increase of SBApercentage
- Density and compressive strength of concrete showed slight reduction as water to cement ratioincreased
- Sugarcane bagasse ash concrete is more economical and have lowerdensity.
- The burning of bagasse altered the mechanical, chemical and physical properties of the bagasse thus reducing itsproperties.

5.2. Utilization of sugarcane bagasse ash in concrete as partial replacement of cement (Mangi,2017)

A. **Location:**Pakistan

B. **Date:**2017

C. **Type of model experimented:** concrete cylindrical specimens with dimensions of 150 mm x 300 mm with 2 different mixes M20 (1:1.5:3) and M15(1:2:4).

- D. **Cement type:** The ordinary Portland cement (ASTM C150 Type-I). Table 7 shows its properties

Table 7. Ordinary Portland cement physical properties (Mangi, 2017)

Tests	Results
Fineness (kg/m ²)	330 kg/m ²
Soundness (mm)	2.5 mm
Specific gravity	3.12
Normal consistency (%)	29%
Initial setting time (min.)	65 min.
<u>Final setting time(min.)</u>	<u>275 min.</u>



- E. **Bagasse treatment method:** Combustion; The bagasse was heated and burned in a close drum for non-controllable burning until fully turning into blackish grey ash as shown in Fig.



Figure 21. Bagasse ash after being burned in a close drum (Mangi, 2017)

21.

- F. **Percentage of replacement:** 5%, and 10%
- G. **Water-cement ratio:** 0.4
- H. **Factors tested:** Compressive strength
- I. **Methodology:** the 2 concrete mixes are prepared and poured then cured for the period of 7, 14 and 28 days. Cement is then partially replaced by bagasse ash by 5%, and 10% and cured for the same period then all specimen was tested for compressive strength after the completion of the curing period. The steps are shown in Fig.22.



Figure 22. steps of concrete specimen from curing to testing and its final shape (Mangi, 2017)

- J. **Results and findings:** the following graphs show the compressive results obtained from the 2 mixes M20 and M15 through this experimental program



Figure 23. Compressive strength of concrete M20 mix with different SCBA percentages and different curing periods (Mangi,2017)

The compressive strength in M20 mix results are presented in Fig. 23. It is observed that at 5% replacement the strength is at the highest strength of 28.5 N/mm² then it decreases to 26.4 N/mm² at 10% replacement of SCBA. It is 12% higher than the normal concrete sample.



Figure 24. Compressive strength of concrete M15 mix with different SCBA percentages at different curing periods (Mangi, 2017)

Fig. 24 shows the concrete sample of M15. The compressive strength showed at 5% replacement the strength was recorded the highest at 26.7 N/mm² which results of an increase of about 11.5% compared to the normal concrete strength.

K. Conclusion:

- Concrete with SCBA shows higher compressive strength compared to normal concrete and the optimum replacement is 5%.
- Usage of SCBA reduces cement and reduce wastes by its production
- Cement replacement decreases the workability of concrete.

5.3. Utilization of sugarcane bagasse ash in concrete as partial replacement of cement (Mangi,2017)

A. **Location:**Malaysia

B. **Date:**2017

C. **Type of model experimented:** cube with size of 100 mm x 100 mm x 100mm

D. **Cement type:** normal concrete and light weight concrete

- E. **Bagasse treatment method:** Sodium Hydroxide NaOH treatment; after drying bagasse completely under the sun for 7 days it is cut into small pieces 5cm until 10cm, then it is immersed in 50% dilute NaOH for 3 days. This is done to remove the impurities and withstand longer to use in concrete. After this, it is completely dried under the sun as presented in Fig.25.



Figure 25. Sodium Hydroxide NaOH bagasse treatment method steps (Khalid, 2017)

- F. **Percentage of addition:** 0.5%, 1.0% and 1.5%
 G. **Water-cement ratio:** 0.4
 H. **Factors tested:** Compressive strength and tensile strength
 I. **Methodology:** the concrete curing in water at room temperature 7 and 28 days in order to harden to achieve maximum strength. For each sample of normal concrete and light weight concrete, 32 samples were prepared then compressive and tensile tests were conducted.
 J. **Results and findings:** the following graphs show the compressive results obtained from both of normal concrete and light weight concrete samples

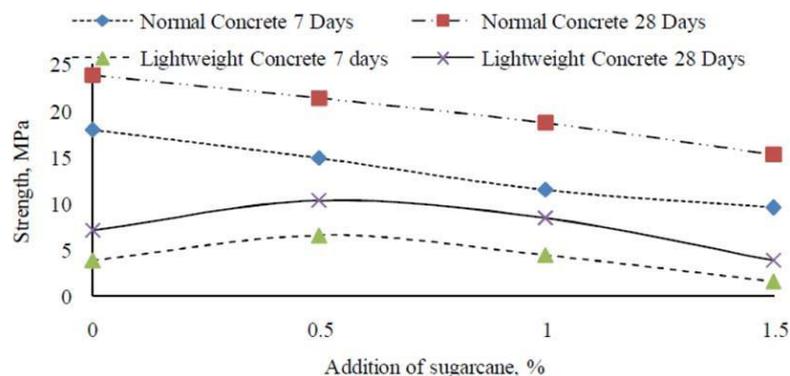


Figure 26. Compressive strength of concrete with sugarcane bagasse (Khalid, 2017)

The compressive strength results are presented in Fig. 26. The sample with 0.5% sugarcane bagasse had the highest strength of 10.3 MPa, while the sample with 1.5% addition of bagasse showed the lowest value of 3.8 MPa.

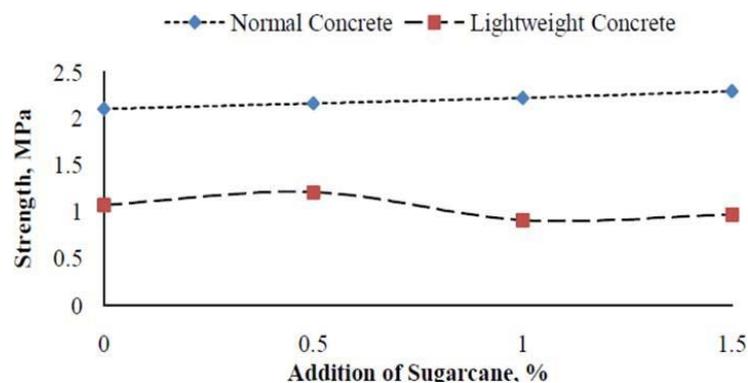


Figure 27. tensile strength of concrete after 28 days (Khalid, 2017)

Fig. 27 present the tensile strength of normal concrete and light weight concrete samples. In normal concrete, the sample with 1.5% sugarcane represented the highest tensile strength for 28 days curing of 2.29 MPa. While in light weight concrete, the addition of 0.5% bagasse showed the maximum tensile strength of 1.21 MPa in relation with 1% and 1.5% bagasse addition. The addition of bagasse results in lowering the tensile strength.

K. Conclusion:

- The optimum bagasse addition for the higher compressive strength is 0.5% addition for both normal and light weightconcrete.
- In normal concrete, the tensile strength increase as bagasse addition increases and the optimum percentage is 1.5%, while in light weight concrete the tensile strength decreases as the bagasse percentage increases and the optimum addition is0.5%.

5.4. Utilization of bagasse waste-based materials as improvement for thermal insulation of cement brick (Aminudin,2017))

- Location:**Malaysia
- Date:**2017
- Type of model experimented:** samples are with two different dimensions of 50 mm x 50 mm x 50 mm and 215mm x 102.5mm x65mm
- Cement type:** The ordinary Portland cement (ASTM C150 Type-I). Table 8 present its chemicalcompounds

Table 8. physical properties of ordinary Portland cement (Aminudin, 2017)



Tests	Results
Fineness (kg/m ²)	330 kg/m ²
Soundness (mm)	2.5 mm
Specific gravity	3.12
Normal consistency (%)	29%
Initial setting time (min.)	65 min.
Final setting time(min.)	275 min.

- E. **Bagasse treatment method:** hot water treatment; as displayed in Fig. 28, the bagasse is soaked in hot water for 4-6 days to remove excess sugar and impurities then it is washed thoroughly and placed dry in the sun. after drying the bagasse is cut into small pieces.

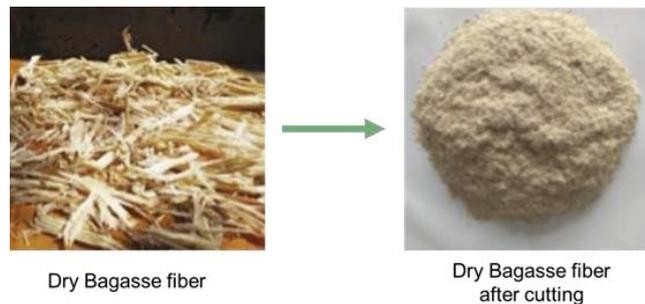


Figure 28. Hot water bagasse treatment method after cut into small pieces (Aminudin, 2017)

- F. **Percentage of replacement:** 2%, 4%, 6%, 8% and 10%
- G. **Water-cement ratio:** 0.45
- H. **Factors tested:** Compressive strength and thermal conductivity
- I. **Methodology:** the samples presented used cement to sand ratio of 1:3 and cement-water ratio of 0.45 for cement brick production. The bagasse was introduced by 2%, 4%, 6%, 8% and 10%. A control sample with 0% bagasse was introduced for comparison. This is to ensure the optimum results based on the most favourable. 50mm × 50mm × 50mm samples were produced for compressive strength test, while 102.5mm × 215mm × 65mm samples tested thermal conductivity.
- J. **Results and findings:** the following graphs show the compressive results and the thermal conductivity- compressive strength correlation obtained from the 2 dimensions samples of 50mm × 50mm × 50mm and 102.5mm × 215mm × 65mm bricks

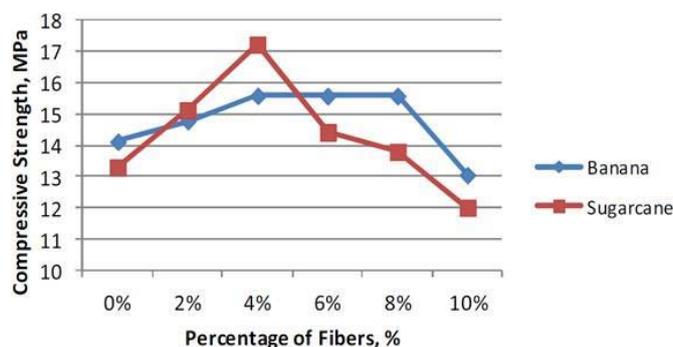


Figure 29. Compressive strength against percentage in comparison with banana trunk fiber and sugarcane bagasse (Aminudin, 2017)

The compressive strength of 50mm × 50mm × 50mm brick results are presented in Fig. 29. More than 4% replacement results in a decrease of strength of the brick. This happens due to poor workability and poor bonding between bagasse and mortar.

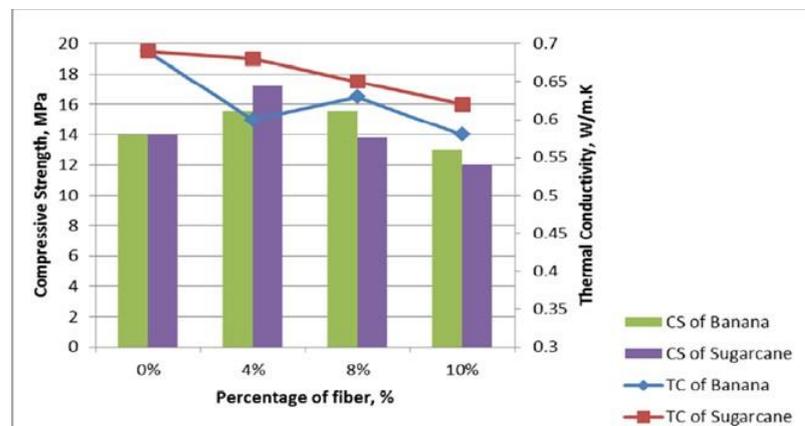


Figure 30. Compressive strength and thermal conductivity relationship of sugarcane bagasse and banana trunk fiber (Aminudin, 2017)

Fig. 30 shows that the 102.5mm × 215mm × 65mm cement brick sample compressive strength and thermal conductivity correlation. The thermal conductivity decreases as the percentage of sugarcane bagasse increases. At 0% bagasse the strength was lower, but the thermal conductivity was higher compared to 4% and 8%. Although 10% replacement shows the best result for reduction of thermal conductivity, the compressive strength decreases lower than the required strength, so it is not favourable for permeantstructure.

K. Conclusion:

- Sugarcane bagasse has a potential of partially replacing cement in cement brick industry.
- Sugarcane bagasse can lower the thermal conductivity of the brick if the strength was maintained
- 4%- 8% replacement is the optimum result before the strength drops below the standardstrength

4.6. Case studies conclusion

After analysing the previous four case studies, Table 9 summarizes all the results. Analysing Table 9, it was deduced that cement replacement with sugarcane bagasse is not limited to any specimen dimensions and most case studies used ordinary Portland cement. For bagasse treatment 3 methods were used combustion, NaOH treatment and hot water treatment, both combustion and NaoH treatment alter the properties of the bagasse, whereas the hot water treatment does not affect the bagasse's properties and it is a cheap method. Preferably the replacement should begin at 4% and does not exceed 10% to maintain standard strength with W-C ratio of 0.4 and 0.45 since as W-C ratio increase strength decrease.

Table 9. Comparison between case studies (developed by author, 2019)

Case study name	Experimental Study on Partial Replacement of Cement by Sugarcane Ash (Kumari, 2015)	Utilization of bagasse materials as improvement for thermal insulation of cement brick (Aminudin,2017)	Properties of sugarcane fibre on the strength of normal and lightweight concrete (Khalid, 2017)	Utilization of bagasse materials as improvement for thermal insulation of cement brick (Aminudin,2017)
Location	India	Pakistan	Malaysia	Malaysia

Year	2015	2017	2017	2017
Model type	150 mm x 300 mm concrete cylindrical specimens	150 mm x 300 mm concrete cylindrical specimens 2 different mixes M20 (1:1.5:3) and M15(1:2:4).	cube with size of 100 mm x 100 mm x 100 mm	50 mm x 50 mm x 50 mm for compressive strength 215mm x 102.5mm x 65mm for thermal conductivity
Cement	Portland Pozzolana cement	Ordinary Portland cement	normal concrete and light weight concrete	Ordinary Portland cement
Bagasse treatment	Combustion	Combustion	Sodium Hydroxide NaOH	Hot water
Hazardous waste	5%, 10%, 15% and 20% replacement	5%, and 10% replacement	0.5%, 1.0% and 1.5% addition	2%, 4%, 6%, 8% and 10% replacement
Water-cement ratio	0.44, 0.45, 0.46	0.4	0.4	0.45
Factors tested	Compressive strength and density of concrete	Compressive strength	Compressive strength and tensile strength	Compressive strength and thermal conductivity
Curing period	7 and 28 days	7, 14 and 28 days	7 and 28 days	28 days
Results	compressive strength decreases with increase in w/cratio. decrease in density with the increase in w/c ratio	M20 mix: at 5% replacement the strength is at the highest strength then it decreases slightly at 10%replacement. M15 mix: at 5% replacement the strength was the highest and decreased slightly at 10%.	Compressive strength: 0.5% sugarcane bagasse had the highest strength Tensile strength in normal concrete: the 1.5% sugarcane sample had the highest tensile strength Tensile strength in light weight: 0.5% bagasse had the highest tensile strength	Compressive strength: More than 4% replacement decreases the bricks' strength Thermal conductivity: The thermal conductivity decreases as the percentage of sugarcane bagasse increases. At 10% replacement thermal conductivity is the lowest
Conclusion	Workability of concrete decreases with the increase in bagassepercentage As the W-C ratio increases the strength and density decrease slightly	Concrete with SCBA shows higher compressive strength compared to normal concrete the optimum replacement is 5%. Cement replacement decreases the	The addition of bagasse results in lowering the tensile strength. The optimum bagasse addition for the higher compressive strength is 0.5% addition for both normal and	Brick strength decreases after 4% replacement due to poor workability and poor bonding between bagasse and mortar. 4%- 8% preplacement is the optimum result before the strength

	Optimum strength and density are at 10% bagasse replacement	workability of concrete.	of light concrete.	weight drops below the standard strength
Comments	Low density concrete isn't used for all building types	Usage of SCBA reduces cement and reduce wastes by its production	Using bagasse fibre NaOH treatment alters chemical properties but does not affect the environment	Brick with low thermal conductivity and low strength is not favourable for permeant structure
	Bagasse combustion alters its mechanical, chemical and physical properties	Bagasse combustion alters its mechanical, chemical and physical properties	Handling NaOH can be risky Expensive treatment process and takes time	Hot water treatment is favourable as it does not alter the bagasse properties Hot water treatment is easy and cheap but <u>take time</u>

6. Conclusion

As a result, to the negative environmental impacts from cement production industry, the government with the aid of scientist, engineers and researchers are searching for alternatives to decrease cement production and usage in the construction industry. The huge production of agricultural waste provided these parties with an alternative to utilize them in the construction industry. sugarcane bagasse is highly produced in Egypt; therefore, it is a good candidate for cement replacement in the brick industry. As a conclusion, sugarcane bagasse is a great candidate to be used as cement replacement to reduce the environmental impacts of cement production industry and poor disposal and burning of bagasse and to develop cheap alternative for cement brick despite its strength and durability. Sustainability will be achieved through reusing sugarcane bagasse to produce useful products like cement bricks. These proposed utilizing techniques are simple, available, cheap and can be by small-scale workers. This approach has a significant impact on achieving environmental sustainability factors, socially and economically. This type of bricks can be used for temporary and non-bearing structures. The results of previous experiments have been encouraging as in most of them strength increases and thermal conductivity and density decreases. Adding fibre to concrete bricks has reduced the density of cement bricks, which can be attributed to low fibre density this lowers the total structure weight. Although past certain percentage results drop, more research and development in this sector may alter these results in the future. As a conclusion, the use of sugarcane made cement bricks a great future in the field of construction in Egypt because it is able to achieve the three factors environmentally, socially and economically. As a result, from the previous analysis of the literature review and case studies, the following SWOT analysis (Fig. 31) shows the strengths, weakness, opportunities, and threats of the brick with cement replacement, then experimental program alternatives are shown in Table10.

Table 10. Experimental program alternatives matrix (developed by author,2019)

CEMENT	Cement type	Ordinary Portland cement
		Portland Pozzolana Cement
		Rapid Hardening Cement
		Quick Setting Cement
		Ordinary Portland cement
		Sulphates resisting cement
		High Alumina Cement
		White and coloured Cement
		Air Entraining Cement
	Cement: Sand: Aggregates	M15- 1:2:4
		M20- 1:1.5:3
	Cement: Water ratio	1: 0.4
1: 0.45		
1: 46		
1: 0.5		
Sugarcane bagasse	Bagasse treatment method	Combustion
		Sodium Hydroxide NaOH
		Hot water (preferably)
	Bagasse piece dimension	$3 < D < 5$ mm (best)
		$D < 1$ cm (preferable)
		$1 < D$ cm
	Bagasse status	Fibre
		Ash
Bagasse replacement percentage (%)	$R < 5\%$	
	$5 < R < 10\%$ (preferable) $10 < R\%$	
Mould	Mould type	Cube
		Cuboid
		Cylindrical
		Hexagon
		Interlocking
		Customized
	Mould material	Iron
		Stainless steel
		Wood
		Plastic
	Mould dimension (mm)	150 mm x 300 mm cylindrical
		100 mm x 100 mm x 100 mm
		50 mm x 50 mm x 50 mm
		215mm x 102.5mm x 65mm
		250mm x 125mm x 60mm
		Concrete mix
	Mould numbering/ pouring (unit)	Diesel oil
		Rubber lubricant
		6
		9
		12
N > 12		

Aggregate size (mm)	9.5 < A mm (not in bricks)
	4.75 < A < 9.5 mm (preferable)
	A < 4.75 mm
Curing period	7 days
	14 days
	28 days (preferable)
Tests	Compressive strength (must)
	Tensile strength
	Density
	Absorption
	Slump test
	Thermal conductivity
	Durability

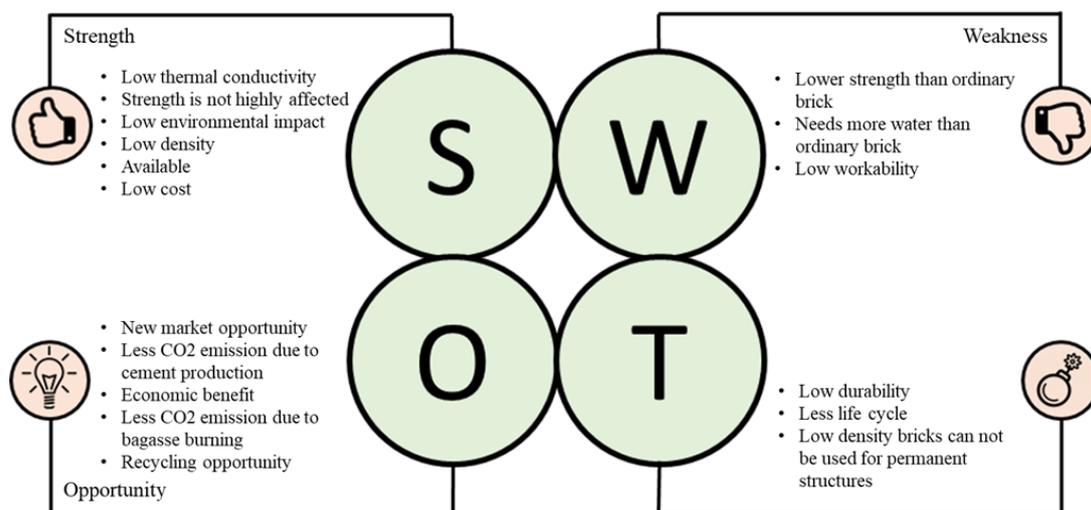


Figure 31. SWOT analysis of brick with bagasse replacement (developed by author, 2019)

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