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USE OF ENVIRONMENT FRIENDLY RECYCLED BUILDING MATERIALS IN EGYPT

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ABSTRACT

Building materials are all over the place. They are the one which create the built environment. Choosing the appropriate material is a necessary step in the design process of the product, as the reliability of the design relies on the chosen materials.

The role of materials in architecture has a greater impact than just those to do with design and aesthetics. They have cultural, moral, social and environmental impacts. These implications are widely being ignored. The main focus is being on the performance of the building, pure aesthetics in addition to the short-term economics of used materials. Usually, Architecture and materials are only being taken into account in the terms of the user experience, with a very little or no consideration to impacts which result from the actual existence of the architecture itself. That is why the problem of where materials come from and where they finally end up has a little or no effect on how architecture is applied as a whole [1].

On the other side waste is considered a result of a dead-end scenario within a linear process. thus, countries with higher amount of waste can bs considered as the most polluters, or as countries having highest amounts of reusable resources. From this point concept of recycling started to have its own impact in life cycle of each material [2].

Recycling is the process of converting waste materials to reusable material. Recently, many countries started to depend on environmental recycled materials to achieve a better environmental performance with less energy consumption, as recycled materials save about 75% of energy in comparison with those made from scratch, and construction cost. Depending on recycling as a basic process to be applied on materials, products would be a part of a continuous reutilization and recovery process [3]. Construction industry is working on developing the ecological buildings depending on using design and technical solutions which facilitate energy saving and one of the most effective techniques is using recycled materials.

This research aims to concentrate on recycled materials and evaluating their performance to raise awareness about the benefits of using these materials in building sector despite the great challenge of introducing alternative materials to the mainstream practice as it is usually a difficult and time-consuming process, in addition to that, the construction market is conservative and the rejection of new materials or techniques is very likely to happen for fear of risk taking. Proving that, recycled building materials have the potential to offer a better environmental performance of the building with less energy consumption and less cost in comparison with using conventional building materials. In addition to that, recycled materials have the potential to close the circle in the life cycle of the building.

On the other side, Egypt has a great potential to use waste materials and develop recycling process depending on the great amounts of available waste materials that can be recycled instead of being thrown in landfills causing environment pollution.

This research will depend on a set of statistics issued by the Egyptian government regarding the quantities, classification, and types of waste materials available in Egypt. It will also depend on the analysis of a group of previous literature reviews that studied recycled materials and their impact on the environmental performance of the building. In addition to, making a comparative analysis between conventional and recycled materials to get out which have a better environmental performance. Since it will be difficult to be study all building materials, a group of commonly used materials was chosen like bricks as a construction building material, glazing as a material for facades, and plastic as a finishing material used in the interior.

KEYWORDS: Building Materials, Waste Materials, Recycled Materials, Environmental Performance, Energy Consumption, Design Process, and Construction Process.

استخدام مواد البناء المعاد تدويرها الصديقة للبيئة في مصر

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الملخص

مواد البناء عنصر أساسي في تكوين كل ما يحيط بنا في كل مكان. فهي تُعتبر من العناصر الأساسية فى خلق البيئة المبنية.

يُعد اختيار المادة المناسبة خطوة حيوية في عملية تصميم المنتج، حيث أن مدى قابلية استخدام التصميم تعتمد على المواد المُختارة.

استخدام المواد في الهندسة المعمارية له آثار أكبر من مجرد تلك المتعلقة بالتصميم والناحية الجمالية. حيث أن لها آثار ثقافية وأخلاقية و اجتماعية وبيئية. تم تجاهل هذه الآثار إلى حد كبير مع التركيز على أداء المبنى والجمال الخالص والاقتصاديات قصيرة الأجل للمواد المستخدمة.

عادةً ما يتم التعامل مع العمارة والمواد المستخدمة أخذاً فى الاعتبار تجربة المستخدم فى المبنى فقط مع إعطاء القليل من الاهتمام لتأثير العمارة في حد ذاتها بل أحيانا يتم تجاهله تماماً. ولذلك فإن مسألة من أين تأتي المواد أو إلى أين ينتهى بها الأمر في النهاية لم يكن لها تأثير يذكر على ممارسة الهندسة المعمارية ككل [1].

على الجانب الآخر ، يتم اعتبار النفايات ضمن سيناريو منتهى لعملية خطية بحيث يمكن للبلدان التي لديها الكثير من النفايات أن تكون من أكبر الملوثين للبيئة ، أو اعتبارها كدول لديها أكبر قدر من المواد التى يمكن إعادة إستخدامها. ومن هذا المُنطلق، فأصبح لإعادة التدوير دوراً مهماً فى دورة حياة كل مادة [2].

إعادة التدوير هي عملية تحويل النفايات إلى مواد قابلة لإعادة الاستخدام.

فى الآونة الأخيرة، بدأت العديد من الدول الاعتماد على المواد البيئية المُعاد تدويرها لتحقيق أداء بيئي أفضل مُصاحب لإستهلاك أقل للطاقة حيث توفر المواد المُعاد تدويرها ٧٥٪ من الطاقة مقارنةً بالمواد التى يتم إنتاجها من نقطة الصفر، بالإضافة إلى تحقيق تكلفة بناء أقل. وبالإعتماد على إعادة التدوير كعملية أساسية يتم تطبيقها على المواد، فإن المنتجات ستصبح بالتبعية جزء من عملية إعادة إسترداد واستخدام المواد المستمرة [3]. تتمثل المهمة الرئيسية لصناعة البناء بأكملها في المساهمة في تطوير المباني البيئية من خلال تطبيق الحلول التقنية والتصميم التي تسهل توفير الطاقة. يعتبر إستخدام المواد المُعاد تدويرها واحداً من أكثر الطرق فاعلية فى تحقيق هذا التطوير.

يهدف هذا البحث إلى التركيز على المواد المُعاد تدويرها وتقييم أدائها لزيادة الوعي بفوائد استخدام هذه المواد في قطاع البناء على الرغم من التحدي الكبير المُتمثل في إدخال مواد بديلة للمواد الشائع استخدامها، لأنها عادة ما تكون عملية صعبة وتستغرق وقتًا طويلاً ، بالإضافة إلى أن سوق الإنشاءات مُحافظ ، فمن المرجح أن يَصعُب تقبُّله لاستخدام المواد أو التقنيات الجديدة خوفًا من المخاطرة.

كما يهدف إلى إثبات أن مواد البناء المُعاد تدويرها لديها القدرة على توفير أداء بيئى أفضل للمبانى من حيث تحقيق استهلاك أقل للطاقة بالإضافة إلى تقليل التكلفة مقارنةً بمواد البناء الشائع استخدامها بالإضافة إلى قدرة المواد المُعاد تدويرها على إغلاق الدائرة في دورة حياة المبنى.

على الجانب الآخر، مصر لديها القدرة على استخدام مواد المخلفات وتطوير عملية إعادة تدويرها بالإعتماد على الكميات الهائلة المتوفرة من مواد المخلفات القابلة لإعادة التدوير بدلاً من إلقائها فى مقالب النفايات مُسببة تلوث البيئة.

سيعتمد هذا البحث على مجموعة من الإحصائيات الصادرة من الحكومة المصرية المتعلقة بكميات مواد المخلفات و المواد الطبيعية المتوفرة فى مصر ، وتصنيفها، وأنواعها. كما سيعتمد على تحليل مجموعة من الأبحاث السابقة التى توصلت إلى مواد معاد تدويرها مع دراسة تأثيرها على الأداء البيئى للمبنى. بالإضافة غلى الإعتماد على التحليل بالمقارنة بين المواد

التقليدية والمواد الُعاد تدويرها لإستنتاج أيهما أفضل أداء بيئى. نظرًا لأنه سيكون من الصعب دراسة جميع مواد البناء ، فقد تم اختيار مجموعة من المواد شائعة الاستخدام مثل الطوب كمواد تأسيس للمبنى ، والزجاج كمادة للواجهات ، والبلاستيك كمادة تشطيب تستخدم داخل المبنى.

الكلمات المفتاحية : مواد البناء, مواد المخلفات, المواد المُعاد تدويرها, الأداء البيئى, استهلاك الطاقة, عملية التصميم, عملية البناء.

1. INTRODUCTION

Building materials are considered the base of the built environment. In other words, they are any material that can be used for construction. They mainly include cement, bricks, wood, steel, concrete, aggregates, metal, clay, and many more. In the past, people used wood, pure bricks, and straw. But now, engineers have started to mix and match the required materials to get a higher quality structure [4].

Through the pre-industrial societies, shelters were built using locally available materials. The only mean to test the characteristics of materials was time. Materials and building solutions which went through the test of time and passed it were spread in the community and passed from generation to another while taking participation through building activities.

Through continuous participation that made a continuous chance for improvement. Each society has its own way to treat materials, as some societies depend on making improvements in durability and strength of materials and buildings built using these materials. Other societies have made improvements on building materials durability that make structures with life span that could be measured in centuries.

On the other side, some societies depend on using materials in their rudimentary form which result in structures with life span of few years. Although there is a continuous improvements made in strength and durability of materials, but the resulting materials cannot meet all needs of societies in the whole world [5].

Using materials in architecture has greater effect than just those to do with design and aesthetics. They have cultural, social, moral and environmental effects. These factors were ignored with the focus on building performance, short-term economics and pure aesthetics of materials. Architecture and materials are considered within the terms of user experience, with little or almost no consideration to implications beyond the actual existence of the architecture itself [6].

There are a wide range of various construction materials that had been included in all Construction project since a very long old time. Ancient Egyptians and Greeks started using gypsum and limestone as base materials for their constructions. The main breakthrough in building materials came in the early 18th century as Joseph Aspdin invented Portland Cement. This step was like an introduction followed by a wide range of materials to be used as building materials.

As a result of rapid technological up-gradation within the out-Construction industry, there was a wide spread of the range of building materials. As time pass, we are going to see more and more types of building materials that will be introduced through our construction industry [5].

It is noteworthy that construction industry sectors are working on many plans with great effort to reduce pollution resulted from materials. Construction sector is considered one of the most users of material resources, energy, water, money and one of the largest pollution makers. As a result to these effects, Some industry leaders are working on actions and strategies required to make construction process more sustainable [7]. Many companies are seeking to get green building certification to reduce and track their environmental effect even if it is with little real impact [8].

The main concept of sustainability is to enhance the quality of life which help people to get a healthy environment with improved environmental, social, economic conditions. Sustainable project is being designed, constructed, operated, renovated or reused in a resources and ecological manner [9]. Sustainable buildings should meet some requirements such as, energy

and resource efficiency, pollution prevention, CO2 and greenhouse gases emissions reduction, mitigation of noise, improved indoor air quality and to be in harmony with the environment.

The ideal building is the one that is inexpensive to be built, last for a long time with a modest maintenance and by the end of its life it returns completely to earth [10].

As there are new technologies being developed to get required sustainable structure such as Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM) and Building for Environmental and Economic Sustainability (BEES). Buildings are being designed to cut off the impact of the built environment on the natural environment and the built environment [11].

Egypt has many innovative applications of alternative recycled construction building materials. But the market share is still low despite the rapid growth [8].

2. The Need for Environment Friendly Building Materials

Global economic activity is expected to be increased fivefold by 2056, global energy consumption will be increased about threefold, global population will be increased by more than 50% and global manufacturing activity will be increased about threefold [12]. Construction sector is considered one of the most resource intensive industries in comparison with other industries.

As building industry is growing rapidly, energy use is growing rapidly as well causing exhaustion of resources in addition to harmful environmental impacts such as: carbon dioxide emissions, ozone layer depletion, climate change and global warming [13].

In addition to energy consumption and pollution caused by construction section, it is considered one of the most consumers of raw materials as it consumes up to 3 billion tons which is about 40% of global use [14]. According to The United Nations Environment Programme (UNEP), Gravel and sand are considered the most used raw materials after water and their use exceeded the natural renewal rate [15].

Sustainable buildings approach is a great step towards making sustainable development including economic, environmental and socio issues. There are various methods that lead to sustainable building which cause less harm to environment such as: reducing waste production, increasing the reuse of waste materials resulted from production materials phase or during building life cycle till it is abandoned, in addition to depending on alternative building materials which are less harmful to environment [16]. Sustainable building starts at the early stage of planning passing through selection of materials then construction and continues through its life till its deconstruction stage and recycling of resources in order to reduce the waste resulted from demolition.

As per the European Statistical Office, The Eurostat, each European citizen is responsible for about 2000 kg of waste /year (This doesn't include mining waste, if included it would be 5000 kg/person/year [17].

As per the Eurostat data, total waste generated by companies and households in Europe is about 2535 billion tons /year, and about 36% (923 billion tons) of this waste is an industrial waste generated from the construction works [18]. 90% of this generated waste that end up in landfill could be reused or recycled but the in Europe the recycling rate is just 50% [17].

The design and production of environment friendly recycled materials became a necessity to achieve requirements of circular economy as shown in Figure 1

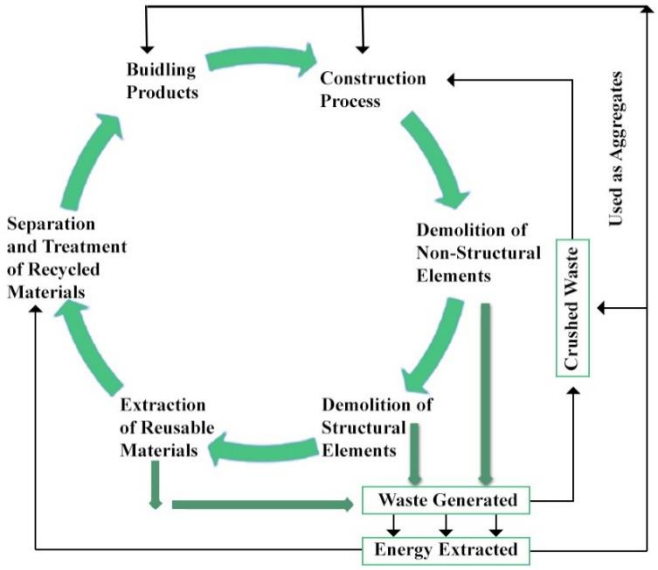

Figure 1. Circular Economy Concept with Respect to Recycled Materials in Construction Process

The main goal of circular economy is to avoid the end of life for construction and demolition waste and to be reused again in construction [19].

3. Effect of Using Environment Friendly Recycled Building Materials as Alternative to Conventional Materials in Egypt

There are many types of building materials which are commonly used in any building construction. Such as, mortar, bricks, concrete, reinforced concrete, plastic, glass, steel, paints and timber. Each of these materials has its advantages and disadvantages while using. According to each project requirements, materials are being selected. On the other side, there are various alternative recycled materials that can be used as an effective replacement for commonly used conventional building materials with a better effect on environment and health without affecting its efficiency.

3.1 Bricks as construction building material

Brick is considered one of the most commonly used materials in building construction sector in Egypt, mostly in low-cost housing sector. Till recent decades, Silt from the Nile river was the most commonly used materials in bricks production process. Nowadays, as a result of the continuous growing of population therefore there is an increasing demand for housing, the continuous need for developed construction technique and the Nile silt is considered now unsuitable materials so the Egyptian government banned its use for this purpose, it was a must to find other local sources to explore a new raw material that would be suitable for bricks production process [20].

3.1.1 Use of Bricks in Egypt

The most commonly used brick types in Egypt are the following: the red brick comes firstly then the cement brick and the sand brick.

- **Red Brick:** (Clay Brick) is considered the most commonly used in Egypt as it is used in construction about 80% of buildings.

  - It is considered the most brick type with the worst effect on the environment, therefore it has the greatest effect on damaging human health in addition to resources depletion [21].
  - Red brick has low thermal insulation factor which leads to the necessity to use artificial cooling devices which have a harmful effect on environment that leads to global warming in addition to the sever consumption of required energy to get the required thermal comfort.
  - More specifically, most factories in Egypt in the process of red brick manufacturing depend on natural gas or diesel-burning for firing process of bricks, which is considered an exhaustion of non-renewable energy, a harmful source for air pollution in addition to the required cost which leads to an economic burden [22].
- **Cement Brick:** is considered the second commonly used building materials in Egypt. Egypt is considered one of the largest producers of cement all over the world as from 2010 till 2020, Egypt produced about 50 million tons of cement which is used in cement brick manufacturing process [23].
  - The manufacturing process of cement brick is less harmful to the environment in comparison with red brick [22].
  - Cement brick still has a negative effect on environment as it is responsible for 4 - 5% total of CO2 emissions generated worldwide [24].
- **Sand Brick:** is considered the third commonly used building materials in Egypt.
  - The process of manufacturing of sand blocks is free from any harmful process or materials to environmental, except the usual usage of energy [25].

3.1.2 The Potential to Use Bricks with Recycled Content

Cement brick in mainly consist of cement, fine aggregate and coarse aggregate. By adding recycled chopped rice straw to the mixture as aggregate resulting in a recycled brick type with a better mechanical properties and environmental effect.
Egypt is considered one of the most countries to produce which resulted in about 4.3 million tons of rice straw annually [26]. Although this great amount can be used effectively in many industrial fields, but only 20 % of rice straw is being used in other industries such as paper, ethanol, fodders and fertilizers production [27]. This is because of the shortage in baling machines, most farmers tend to burn rice straw to get rid of rice straw despite being prohibited in the Egyptian law of Environment number 4-1994 [28]. This causes a great damage to environment as a result of the toxic carbon emissions resulted from burning causing air pollution and threaten human health [29].
The main challenge is to make the best use of cost-effective technologies required to reuse and recycle rice straw into other industries to get rid of straw in a safe way in addition to improve other industries.

- **Effect on Compressive Strength of Cement Bricks:** The Egyptian Code of Practice (ECOP 204-2005) states that: The stress of bricks must be 70 kg/cm2 at least or more for solid cement bricks which is used for load bearing walls and must be 25 kg/cm2 at least or more for solid cement bricks which is used for non-load bearing walls [30]. Using recycled chopped rice straw as addition to the mixture of cement brick made the resulted cement brick with a compressive value with range (114.4-116.7) kg/cm2 [31]. Which means that the compressive strength performance of cement brick would be improved. Figure 2.

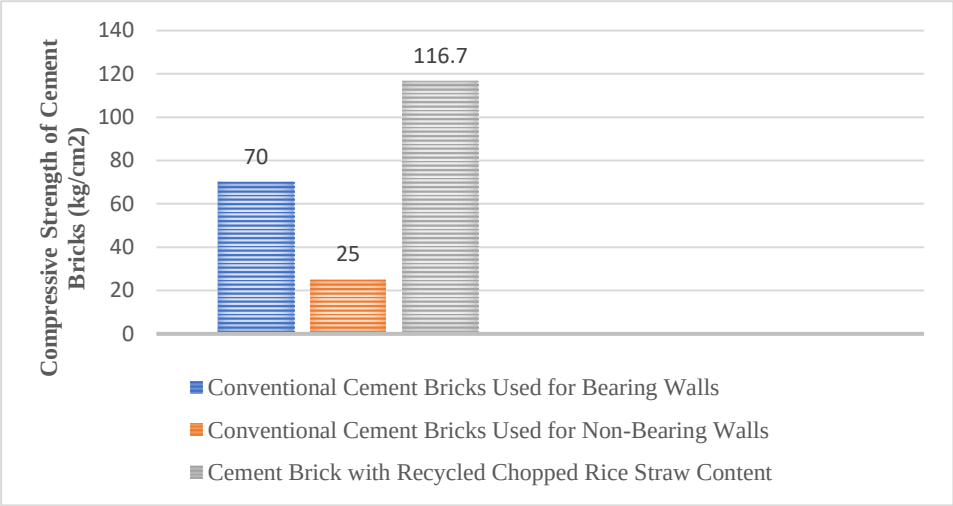

Figure 2. Compressive Strength of Cement Bricks (Comparison Between Cement Bricks for Load Bearing Walls, Non-Bearing Walls and Cement Bricks with Recycled Chopped Rice Straw Content).

Effect on Environment: By applying sustainable design support system (SDSS) factors* on recycled cement bricks-chopped rice straw in comparison with standard cement brick, it was found that, recycled cement bricks-chopped rice straw have a better sustainability ranks than standard cement bricks [31].

3.2 Glass as a building material

Glass is a material that became a part of everyday life as it is being used in many fields and shapes. Experts suppose that Egypt was the place where glass was first discovered, used and manipulated, others suppose that it was discovered and used in Mesopotamia and then this process was shortly taken to Egypt after its discovery [32].
Since last years, glass is being widely used in architectural fields because of its special features such as, translucency, high tensile strength, high compressive strength, resistance to environmental factors and durability [33]. As a result of the great development in architectural technologies, there is a rapid increasing demand for new different transparent elements to be used in modern buildings such as facades and roof structure [34].
In 2007, As per the Green Rhino Energy, 138 million tons of glass were produced. Using glass has a great effect on energy efficiency, so choosing the appropriate glass type has a great effect on improving the energy efficiency of the buildings [35].

3.2.1 Use of Glass in Egypt

Egypt glass manufacturing, has seen a rapid increase from 2005 till 2015. The total annual production is more than 3.34 million tons per year [36]. Egypt continued to import glass till 2010, in 2012 the production rate was enough to satisfy the demand and started to export about 30% its glass production as per Mohamed Khattab, the Head of Glass Division at Federation of Egyptian Industries [37]. The consumption of glass increased as a result of the increasing demand for glass to be used in construction and facades [38]. As glass production process depends on heating sand to high temperature till being melted then cooled rapidly to keep some of its liquid properties like transparency. During manufacturing process of glass, there are many resulted impacts that harm the environment, such as:

- **Energy consumption:** The heating process consumes a lot of energy to reach the required temperature which is about 1425 °C. It is required to use from 3.7 to 6.0 kilojoules of energy to produce a metric ton of glass [39].
- **Water consumption:** The cooling process consumes a lot of water as well to cut its temperature down [40].
- **Air Pollution:** During the melting process, Nitrogen oxides (NOx) and Sulphur oxides (SO2) are released as a result to burning fuels in heating process which can contribute to formation and acidification of SMOG*
- **Carbon Emissions:** Burning fuels during heating process in addition to decomposition of the raw materials lead to CO2 emissions which cause greenhouse gas effect. 20% of released CO2 are due to decomposition of the raw materials and the other 80% are due to used energy [41].

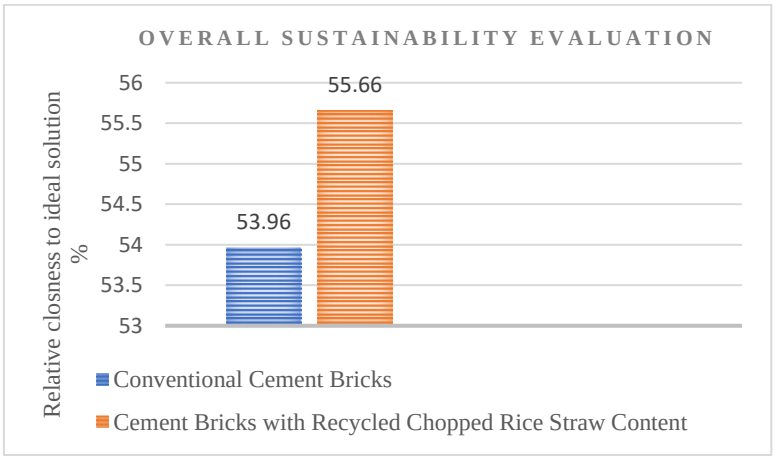

Figure 3. Sustainability ranks considering all SDSS [31].

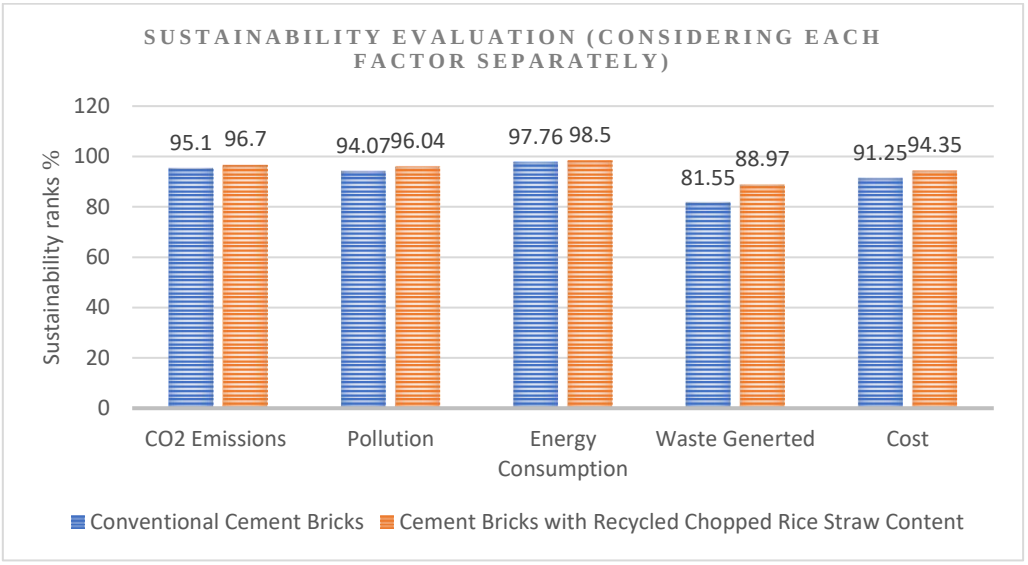

Figure 4. Sustainability ranks considering each factor from the first group of SDSS factors [31].

* SMOG is a type of air pollution which reduce visibility. It is produced as a result of reaction between sunlight and nitrogen oxides. It is one of the most polluters to the environment.

3.2.2 The Potential to Use Recycled Glass

As Egypt glass manufacturing, has seen a rapid increase and the total annual production is more than 3.34 million tons per year [36]. In 2017, as well, about 15000 tons of glass trash was being produced in Cairo [42]. Only 27% of manufactured glass, which is resulted from construction, demolition waste and municipal solid waste, is being recycled. On the same time, glass waste is about 4% of total solid waste generated in Egypt [38]. Nowadays, there is a growing demand to increase glass recycling process rate to be used as a new construction building material which would have a great effect on the surrounding environment.
Glass is a totally recyclable material that can be infinitely recycled with no reduction in quality. This save more natural resources to be consumed.
Recycling glass has a great effect on environment in each step during production process. By recycling 1000 tons of glass, many savings can be done, such as [40]:

- 1000 tons of waste saved from going to landfill.
- 1200 tons of raw materials are being saved as each 1 ton of cullet (recycled glass) replaces 1.2 tons of virgin raw materials.
- 314 tons of CO2 emissions are being reduced as by using glass cullet, the rate of using carbonated raw materials would be reduced. Carbon emissions are reduced by about 50% as shown in Figure 5.
- 345000 kWh of energy are being saved as using glass cullet require less energy during glass manufacturing process. Required energy is reduced by about 30%.

Recycled glass helps to reduce generated air pollution by about 20% and related water pollution by about 50% [43].

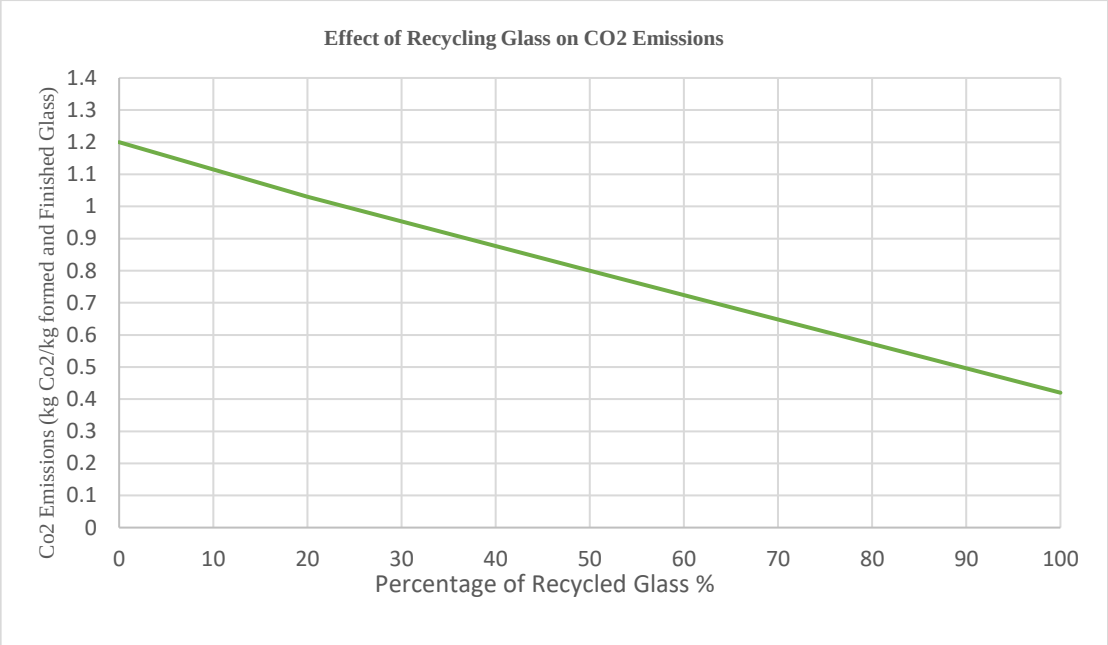

Figure 5. Effect of Recycling Glass on CO2 Emissions [43].

3.3 Plastic as a building material

As concrete is considered one of the main used materials in the industrial built environment, plastic is considered one of the main iconic symbols of the modern industrial innovation. So, Plastics consequently are considered major elements in the modern building industry [44].
Plastics are durable, flexible, versatile and low-cost materials. They have high corrosion resistance, high strength-to-weight ratio, low thermal conductivity, high chemical resistance and some types are translucent as well which are used vastly in modern economies. Starting from the 1950s, plastics production has risen globally in a significant way, reaching about 320 million tons in 2015 and nowadays increasing by about 10 million tons per year [45].

The building and construction sector is considered the second largest consumer of Plastics as about one fifth of plastics are used in building construction. Plastics help to achieve many essential functional and technical properties that are important for modern buildings.

3.3.1 Use of Plastics in Egypt

For Egypt, in 2010, 5.4 million tons of plastics were produces annually [46]. As per Egyptian trade and Industrial government, Plastic is used in construction sector as thermoplastics, insulation material, Coating compounds, Adhesives and glues, Paint resins, Fillers, reinforcing fibers and materials, Starting materials, intermediate polymerization auxiliaries and for doors and windows frames [47].
Plastic production process causes many harmful effects to the environment which should be taken into consideration especially with the increasing demand for plastics use globally.

- **Consumption of fossil oil:** Nowadays, each ton of plastics requires about 1.1 ton of fossil oil [48]. Taking into consideration the increasing production rates of plastics, the consumption of fossil oil to produce plastics would be about 903 million metric tons by 2050. Which would be more than 23% of the expected oil production unless recycling or alternative raw materials are widely used [49].
- **Carbon Dioxide (CO2) emissions:** About 2.5 tons of CO2 emissions are generated for each ton of produced plastics.

  In addition to about 2.7 tons of embedded carbon which is released in various ranges according to how the plastics are being treated at end of life [50]. As a result for the continues growing rate of plastics production, emissions from the production process and waste management process of plastics could range from about 226 to 287 billion metric tons of CO2 by 2100 [45].

- **Green House Gases (GHG) emissions:** According to the used type of plastics, production process of plastics resulted in greenhouse gases emissions ranging from 1.6 metric tons per ton of plastics to 4.8 tons [51].
- **Decomposition:** plastics take a very long time to decompose with average about 500 years. This period is affected by various factors, such as the type of used plastic, acids in the landfill and the climate [52].
- **The Increasing rate of plastic production:** As per Material Economics [45], the consumption of plastics nowadays is increasing at the rate of 10 million metric tons per year. By 2050, the estimated global consumption may reach 800 million tons per year. On the other side, recycling rates of plastics are still very low (with estimated range of 10& to 30% only). By 2050, Recycling and reuse of plastics can supply about 60% of the demand for plastics. Which could help to reduce CO2 and GHG emissions [53].
- **Missing data on construction plastics:** Studies on the types and quantities of plastics used in buildings is very rare. Without this information, it would be complicated to manage this material stock in a sustainable way [54].

Egypt is considered (as per a recent report of the Arab World by the WWF “World Wide Fund for Nature”) the biggest plastic polluter in the Arab World, in addition to being one of the biggest sources of plastic polluting the Mediterranean Sea, pouring in 250,000 tons annually. Egypt ranks second in the Middle East after Turkey with 5.6 million tons annually [46]. Globally, Egypt ranks seventh in the biggest polluters of water due to plastic dumping in the ocean [55]. On the other side, Egypt ranks second in Africa after Nigeria with 5.6 million tons annually [46].

Egypt's annual waste output, is more than 16.2 million tons. Plastics waste is considered six percent of this amount produced waste which is equivalent to 970 thousand tons. 45% is recycled, only 5% reused, and 50% of plastic garbage is not being sorted but it is incinerated instead, which cause harm to the environment [56].

3.3.2 The Potential to Use Recycled Plastic

Most plastic types are recyclable, recycling of plastic saves about 90% of the resulted CO2 emissions which is produced during manufacturing process of new plastics. By 2050, recycling and re-use of plastic could provide 60% of plastics demand, reducing CO2 emissions to half of its current generated amount [45].
Recycling plastic consumes 88% less energy than manufacturing plastics from new raw materials. By recycling just one plastic bottle, the energy saved could power a 100-watt light bulb for about an hour. Actually, more than 100 million tons of plastics are produced globally every year but on the other side, about 50% of used plastics are thrown away after just a single use thus plastics are responsible for 10% of total global generated waste [57]. Plastic waste is not managed properly in many countries globally. There are four countries in North Africa are considered from the top 20 countries that mismanage plastic waste.
North Africa in general and in Egypt especially which is ranked one of the highest countries in plastic waste mismanagement [58]. Currently, Egypt ranks the 7th in mismanagement plastic waste globally as shown in Figure 6 [59].

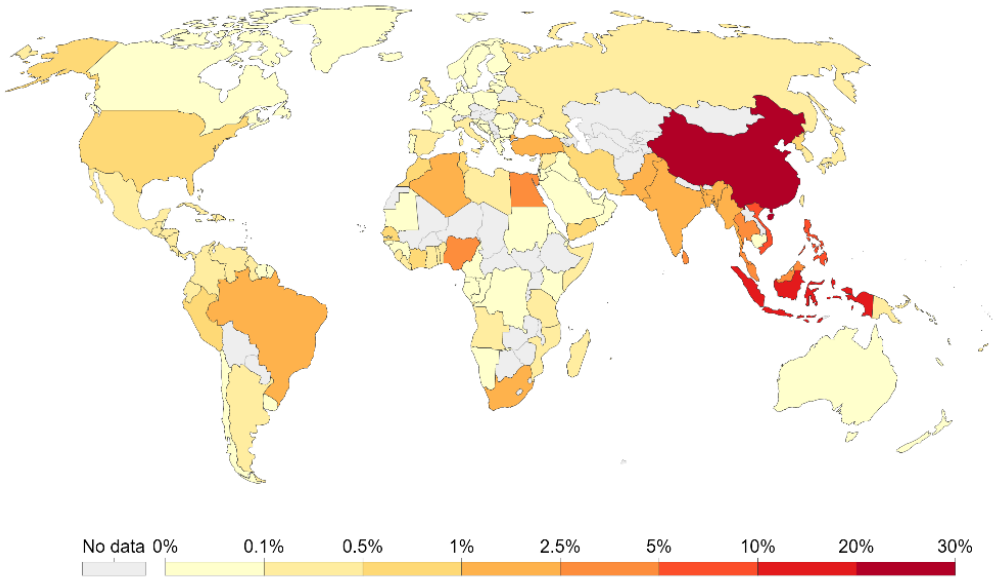

Figure 6. Share of Global Mismanaged Plastic Waste, 2010 [59].

4. Constrains of Using Alternative Environment Friendly Recycled Building Materials in Egypt

Although alternative recycled materials have dominant effects but on the other side there are many issues that could constrain using the environment friendly recycled materials.
These issues include:

- **Cost:** including the cost of material itself in addition to the cost spent on finding the appropriate alternative environment friendly recycled material and working on it. Although the initial cost of recycled materials could be more than conventional ones but taking into consideration the life cycle performance and effect of recycled materials on environment and health, we would recognize that conventional materials will far exceed the cost of environmental recycled materials [1].

- **Availability:** As conventional materials are commonly known so there is a stock standard supply for them and if any kind of conventional materials is not available from a specific supplier there would be many other suppliers and if not available today it would be available tomorrow. On the other side, recycled materials are not commonly known so it is not easy to get a stock standard supply for available recycled ones [60].
- **Effect on the design process:** The availability of recycled materials has an impact on the design process as design can't be done without knowing the availability of certain recycled materials, but on the other side, without having initial design we could not know what materials to get. Which means that the design process would become more iterative and complex [1].
- **Suitability:** As a result of lack of availability of recycled materials it is difficult to find a specific recycled material that meet the requirements of a specific design.
- **Lack of knowledge:** about which materials can be recycled or what available recycling opportunities within the region. In addition to lack of knowledge from architects about available recycled materials and their properties and effects on environment and health. It is also lack of knowledge about recycling industry infrastructure and through industry that require training [61].
- **Lack of desire by the government and society:** to take an active step in encouraging sustainable architecture due to lack of knowledge and it is possible that they will not accept products which is based on environmental considerations only as these products will need to be cost-effective and perform to be competitive to meet the same standards for durability and safety in the building industry [62].

5. Conclusion

Based on the above analysis, the following conclusions can be concluded:

- There is a continuous need to find alternative building materials with better environmental performance to reduce energy consumption, pollution and harm caused to the environment, raw materials consumption, generated waste and required cost in building industry.
- Egypt has a great potential to use recycled materials which would make a great impact on the environment and the building industry.
- Egypt has a great potential to use recycled chopped rice straw as an alternative to aggregates in bricks which would make them with better environmental impacts.
- Egypt has a great potential to use recycled glass as an alternative to conventional glass which would make it with better environmental impacts.
- Egypt has a great potential to use recycled plastics as an alternative to conventional plastics which would make it with better environmental impacts as shown in Table 1.
- There are many constrains that may obstruct using recycled materials in Egypt which should be studied carefully to enhance using recycled materials to improve the building industry and its impacts on the environment.

Table 1.Comparative analysis between Conventional and Alternative Recycled Materials.

		Conventional Building Materials	Alternative Building Materials
	Comparison Factors		
		Conventional Cement Bricks	**Cement Bricks with Recycled Chopped Rice Straw Content**
Bricks	Sustainability ranks considering all SDSS	Less Sustainable	Better performance with 1.7% higher rate
	Raw Materials	Consume more Raw Materials	Save More Raw Materials
	CO2 Emissions	Higher Carbon Emissions Rate	Better performance with 1.6% higher rate
	Pollution	Higher Pollution Rate	Better performance to reduce pollution by 1.97% better rate
	Energy Consumption	Higher Energy Consumption Rate	Better energy saving with 0.74% rate
	Waste Generated	Cause more generated waste	Less generated waste with 7.42% rate
	Cost	Higher Cost	Less cost with 3.1% rate
	Compressive Strength	Less Compressive Strength	Increased to 1.6 ratio
Glass	Raw Materials	Consume more Raw Materials	Save More Raw Materials with 20% rate
	CO2 Emissions	Higher Carbon Emissions Rate	Carbon emissions are reduced by about 50%
	Pollution	Higher Pollution Rate	Reduce generated air pollution by 20% and related water pollution by 50%
	Energy Consumption	Higher Energy Consumption Rate	Energy consumption is reduced by 30%.
	Waste Generated	Cause more generated waste	Totally recyclable - No waste
	Cost	Higher Cost	Cut required cost down
Plastics	Raw Materials	Consume more Raw Materials	Save more Raw Materials which could provide 60% of plastics demand
	CO2 Emissions	Higher Carbon Emissions Rate	Saves 90% of generated CO2 emissions
	Pollution	Higher Pollution Rate	Reducing pollution rate to half of its current amount
	Energy Consumption	Higher Energy Consumption Rate	Consumes 88% less energy
	Waste Generated	Responsible for 10% of total global generated waste	Reducing generated waste to half of its current amount
	Cost	Higher Cost	Cut required cost down

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