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Research Article

Sustainability in Civil Engineering: Evaluating the Effectiveness of Environmentally Friendly Materials in Modern Construction Projects

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ABSTRACT

The increased growth of pollution sources that accompanying developments in various areas of life, especially in the field of civil engineering, because it represents the infrastructure industry of any country, the focus on caring for the environment has become more than ever before, since the construction of buildings, facilities, roads, bridges, and others have a bad environmental impact, whether through the work or materials used in it, the civil engineer must therefore strive to find alternative solutions, and one of those solutions is to encourage sustainability in civil engineering in general.

The most important thing is to use environmentally friendly building materials in particular. This is done by finding alternative building materials than traditional materials to reduce environmental pollution and work to preserve natural resources and improve the quality of living, while at the same time providing the basic elements, which are durability, availability and economic cost.

In this research, we will discuss making a comparison between sustainable building materials and regular (non-sustainable) building materials, by taking advantage of laboratory experiments on sustainable building materials and previous experiences to verify the efficiency of available sustainable materials and setting appropriate standards for their use in the correct ways.

Keywords: Civil engineering, sustainability materials, sustainable building, modern construction, environment friendly materials.

INTRODUCTION

The developments taking place in our lives, especially in the field of constructions development, have been accompanied by the emergence of many negatives, the most important of which is environmental pollution, which has led to global warming and a decline in the public health index. As a result of carbon emissions and the use of manufactured materials containing chemical elements that affect the health of the individual, in addition to the consumption of natural resources such as (water and forests), which threatens desertification and the abundance of industrial waste, the responsibility has been placed on the civil engineer to think of solutions to achieve environmental balance and find alternatives; such as using environmentally friendly and energy-efficient building materials that preserve natural resources and individual health. Engineers have studied the properties of natural materials or even industrial waste to create new products with suitable, renewable, diverse, and even economic properties and good quality, then they called them "sustainable materials," in addition to their long lifespan and their ability to withstand climate fluctuations and different weather conditions, besides they do not require regular maintenance because most of them are natural materials and interact with the environment [1].

THE CONCEPT OF SUSTAINABILITY IN CIVIL ENGINEERING:

It is the design and construction of structures and infrastructure in a way that preserves natural resources and reduces the environmental impact of the project through the construction method or the use of environmentally friendly building materials, which helps improve the quality of life and well-being of building users in addition to contributing to enhancing energy use.

SEARCH PROBLEM:

Finding a balance between meeting infrastructure needs and protecting the environment by determining the criteria and standards necessary for the use of sustainable building materials. This will be done by identifying the characteristics of sustainable building materials, studying their advantages and disadvantages, and comparing them with the characteristics of traditional building materials to reach a realistic and comprehensive assessment.

OBJECTIVE OF THE RESEARCH:

Presenting and evaluating environmentally friendly building materials in modern buildings, based on analyzing their impact on the environment, economy, public health, and preserving natural resources, by presenting their advantages and disadvantages and comparing them with traditional building materials.

Whether we are looking for an alternative to conventional building materials or want to do our part in reducing waste, lowering our carbon footprint and conserving natural resources when choosing sustainability building materials, the primary considerations must be taken into account, the cost, durability and availability.

What are sustainable building materials?

These are often made from recycled or natural materials but can be reused or recycled after their useful life. Therefore, here we will evaluate the use of sustainable building materials in civil engineering projects, based on an analysis of their impact on the environment, economy, and natural resources. This is done by understanding how to reduce the environmental footprint and cost and improve the quality of living compared to the traditional (non-sustainable) building materials that are chosen based on the principles and standards of durability, cost and availability only.

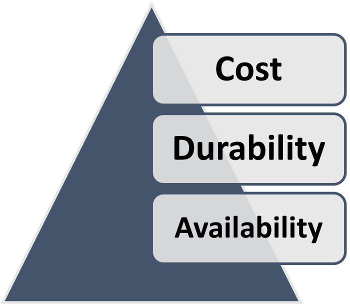


Fig.1 The principles and standards of the traditional (non-sustainable) building materials.

But thanks to sustainable construction, the criteria for selecting building materials will be more sustainable and comprehensive, so that their quality and durability are not less than traditional building materials, but may even be of higher quality, efficient, and beautiful standards [2].

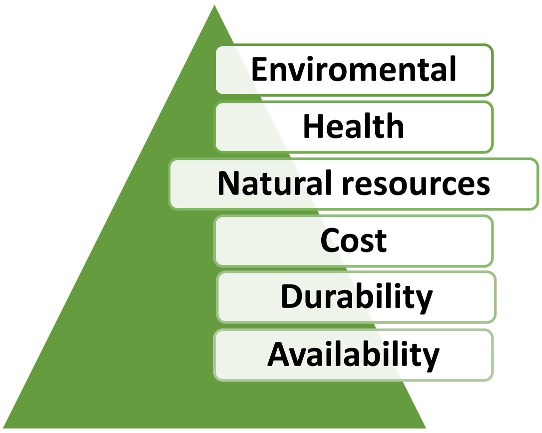


Fig.2 Sustainability standards in building materials. [3]

SUSTAINABLE BUILDING MATERIALS INCLUDE SEVERAL TYPES:

1- Sustainable recycled building materials:
This materials is economical, especially in the long term

➢ **Recycled Steel:** Steel has been used in large quantities throughout the ages, especially in constructions. This resulted a large quantities of scraps, as it is an element that can be recycled without diminishing its basic properties. Rather, the recycling process works to reduce metal waste and save energy, as it consumes much less energy than the process of extracting and manufacturing the raw material, in addition to reducing the carbon emissions associated with it where the global warming potential created during the rebar manufacturing process is 467 kgCO2 eq as taken from the environmental impact calculation report. The recycled steel is also considered more economical compared to the iron ore industry. In addition to all of the above, it helps preserve natural resources. Therefore, the use of recycled steel is considered one of the first and most important sustainable materials [4].

- **Recycled concrete and aggregate:** Concrete is one of the most important building materials and is used in large quantities in infrastructure. By reusing demolished concrete and structures, the construction industry can reduce the demand for new raw materials. Traditional gravel can be replaced with crushed concrete in new projects, saving energy and reducing costs as recycled concrete contributes to maintaining structural integrity and reducing the carbon footprint associated with traditional concrete production. Demolition and construction waste has become one of the major problems that are difficult to get rid of, as it is estimated at about (14.7-12) million tons annually, while concrete waste is only estimated at about (7.8 tons). With the increase in the rate of construction waste, some countries have resorted to recycling it by use it in construction to preserve natural resources and get rid of waste [5] .
- **Recycled glass:** Glass products are manufactured and consumed in large quantities due to the widespread use and demand for various glass products, leading to alarming accumulations around the world. This, in turn, poses an environmental problem. As a material with distinct physical and chemical properties, it is also suitable for use in the construction sector as a raw material. These properties include its non-biodegradability, chemical resistance, low water absorption, high hydraulic conductivity, temperature-dependent tensile strength, variable particle size, and wide availability in a variety of chemical forms and compositions, making it a sustainable material with diverse uses in all types of construction [6].

Recycled glass is increasingly used in construction as decorative elements, tiles, and concrete additives. Crushed glass can enhance the aesthetic appeal of concrete and reduce reliance on natural sand. Recycling glass conserves resources and requires less energy than producing new glass, making it a valuable tool in sustainable building practices.

- **Recycled Plastic:** Recycled plastic is a widely used building material due to its availability in large quantities and has light weight. It is also considered economical and environmentally friendly, as it helps in getting rid of plastic waste that is harmful to the environment. Therefore, it is considered a sustainable building material and has the basic characteristics of durability and good elasticity where it has become possible to convert plastic waste into durable building materials that can be used in tiles, roofing and insulation Acoustic and thermal insulation by using it as a partial replacement for aggregates in concrete, as aggregates constitute the largest proportion of concrete and the heaviest in weight, representing 85% of its weight. Since plastic has a lower density than natural aggregates, as a result, the use of plastic waste significantly enhances the thermal and sound insulation efficiency of lightweight concrete. In addition, its manufacturing cost is significantly lower than that of conventional concrete, and due to its light weight, plastic can be installed and used quickly and with minimal effort. Therefore, plastic waste can be considered an ideal material for producing lightweight green concrete, which can be used as a non-structural component in building construction [7].

SUSTAINABLE BUILDING MATERIALS (INDUSTRIAL WASTE):

This materials resulting from industrial waste and therefore they are economical in addition to their advantage of being environmentally friendly by helping to get rid of waste

- **Ferrock:** is a new building material made from recycled steel dust. Its unique composition makes it more resistant to cracking than traditional concrete, which enhances its durability and reduces its need for maintenance. It is one of the environmentally friendly building materials, which has the additional advantage of having very low carbon emissions; in fact, during its drying process, it absorbs carbon dioxide, which is an environmentally friendly feature [8]. Ferrock is also an ideal material for use in places that require strength and durability, such as: foundations, and building load-bearing structures [9]. Although it is still in the experimental stage, ferric promises to be qualified to become a widely used building material:

Fig.3 Ferrock slab and brick [10]

- **Hempcrete:** It is a building material made from sawdust and concrete or the inner woody pulp of the hemp plant mixed with lime and water. It is lighter than regular concrete, making it easier to handle on construction sites, and has a lower environmental impact in transportation. Hempcrete provides better insulation than traditional concrete. To help save energy in buildings, it is also fire-resistant, which makes it one of the safety equipment in construction. Hempcrete can be used to make: bricks, building stones, and panels that combine the thermal properties of wood with the strength of concrete [11].

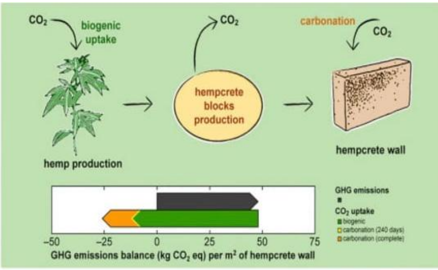


Fig.4 GHG emissions balance by using hempcrete wall. [12]

Fig.5 Hemp bricks are made from hemp fiber, limestone powder and water.

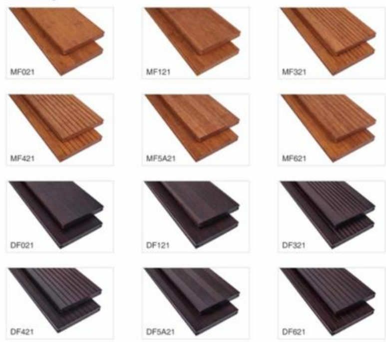
- Fly ash: While burning coal powder to generate heat a combustion residue that contains 80% fly ash and 20% residual ash at the bottom [13]. Fly ash, which is a fine powder have the same features of Portland cement so can be used instead of Portland cement which saves cement and energy consumption in addition to being an economical material, it has many advantages and is able to improve certain properties of concrete, such as durability, because it generates less heat during the reaction, so it can be used 100% instead of Portland cement. Therefore, it can be considered as a sustainable building material that meets all basic standards [8]. One of its most important applications is its use in geopolymer concrete, In addition to its use as a filler in paints, as a structural filler in road construction, and in the manufacture of bricks, ceramic tiles, and plaster [14].
- **Geopolymer concrete (GPC):** It is a new type of concrete manufactured by reacting aluminate-silicate bearing materials with a caustic activator, such as industrial waste (fly ash, ground granulated blast furnace slag (GGBFS), rice husk ash and ceramic waste) [15]. Pozzolanic materials with high silica and alumina content act as binders in the mixture and can be a suitable substitute for Ordinary Portland Cement (OPC). Where, Sustainable development can be reach to the use of geopolymers in the construction industries, because they lead to reduced carbon dioxide emissions, optimal use of natural resources, waste disposal, reduced energy consumption, and thermal stability. They are also more cost-effective in building long-lived infrastructure, on the social and economic level, and in generating job opportunities [16].

SUSTAINABLE BUILDING MATERIALS (RENEWABLE NATURAL MATERIALS):

- **Straw:** Using straw bales as an alternative to traditional building materials as a renewable natural resource, and widely available. Although it is a very light material, it is highly durable when the beams are compacted well and strengthened with steel bars and because it has thermal insulation properties, so it is used in walls and ceilings. Therefore, it is a very good sustainable material, as it has an environmental impact of 0%, and even more, as it preserves natural resources, is energy-saving, and economical [8].
- **Compacted soil:** It is made from soil (loam) mixed with other materials such as straw, clay [17]. Lime or carbon (ash) can be added and then compressed into blocks to be used in instead of cement conventional where to reduce the environmental impact resulting from the cement industry, as it was found that a ton of CO_2 is released for every ton of cement manufactured, while building a house on average consumes 5-10 tons of cement. In addition to its use in thermal insulation of interior spaces in residential buildings. It is characterized by its low cost and the possibility of reuse, and it does not require workers with special skills.

- **Timber:** Wood is considered one of the oldest materials used in building works, it still is a multi-use raw material and it is a natural material that is renewable and recyclable. Wooden structures are usually characterized by a combination of different elements that together provide the best possible bearing capacity, thermal, sound and moisture insulation, fire resistance, and a long lifespan, in addition to the ease of obtaining it from trees, which makes it a fairly sustainable material.[17]
- **Bamboo:** A herbaceous plant that resembles trees and has exceptional natural properties due to its rapid growth with the least amount of energy, as bamboo can grow from 15-18 meters in 30-40 days. It is a distinctive material as it has a set of properties combined in one material (light weight, flexibility and durability). The durability of bamboo can be more than steel, and thus it is the most sustainable natural material that can be used instead of steel.[8]

Some of the common uses of bamboo is on outdoor flooring because of its high density, durability, weather resistance and stunning beauty, as shown in the figure below:[18]



- **Mycelium:** It represents the vegetative structure of fungi. Being an organic material, it is biodegradable, so it leaves little waste and has no negative impact on the environment. When dried, it becomes extremely durable and resistant to rot, water, and fire. When combined with other materials, such as wood, sawdust, and demolition waste, we can obtain bricks used in the construction of buildings and their components [8].

Fig.6 Bioterals diagram photo for new building material from Mycelium.

- **Cork:** A renewable, natural material extracted from the bark of cork trees. This material is characterized by its high thermal insulation ability, in addition to its light weight and its ability to resist mold. Therefore, it can be included in the list of sustainable building materials, as it can be used in flooring and wall covering [8].
- **Rigid polyurethane foam extracted from plants:** This foam is an eco-friendly insulation material made from natural plant materials, such as: bamboo, hemp, and seagrass. Compared to traditional materials, polyurethane foam provides better insulation, ease of handling and installation; because it is lightweight. Because they are made from plant materials, they are renewable and have less negative impact on the environment, and are often used in walls, ceilings and floors; for the excellent insulation properties it provides [8].

SOLAR PANELS:

Solar panels have gone beyond being a source of sustainable energy to being used as a sustainable building material in walls, fences and roofs. A notable example of a building that incorporates solar panels as an integral part of its design is the Solar City Tower in Rio de Janeiro, Brazil, this demonstrates the possibility of generating energy from solar panels and also using them as a sustainable building material at the same time [19].

Fig.7 using solar panels to build a wall to save energy and building materials.

To verify the effectiveness and efficiency of sustainable materials, practical experiments were conducted on them to ensure the possibility of using them as sustainable and environmentally friendly building materials instead of regular and unsustainable building materials:

- Through an experimental and analytical study of the bond behavior between recycled concrete waste aggregate and deformed and traditional steel bars, using a pull test, as the bonding strength between concrete and reinforcing bars is considered one of the basic factors that determine the performance of reinforced concrete elements.

Tensile tests were conducted on two types of steel bars (reused and regular) using a 250 kN Perrier testing machine. The results showed that: the yield strength, f y, was about 550 MPa; The ultimate strain is about 10% and the ultimate tensile strength exceeds 650 MPa, as shown in the following Fig.8, which shows the stress-strain curves for the two types of rebar [20].

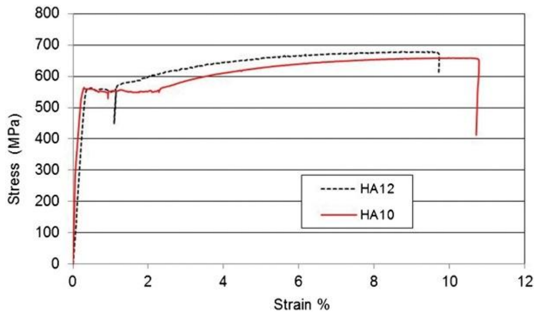


Fig.8 Stress–strain curves for the used deformed rebars. [20]

The bar specimens were fabricated from steel with a yield strength of 500 MPa which is a guaranteed yield point and are deformed steel bars with diameters Φ = 10 mm and Φ = 12 mm. The two types of rebar are named respectively HA10 and HA12 as shown in (Fig. 9). Their measured surface properties are shown in Table 1 [20].

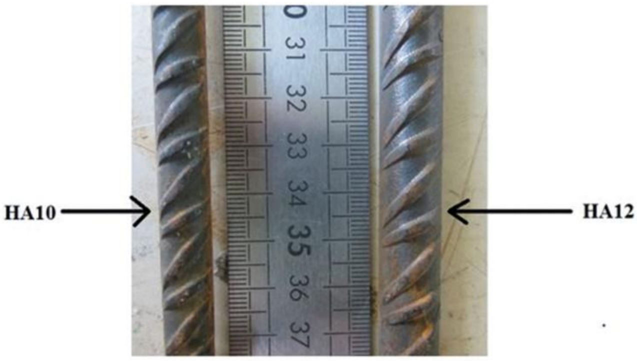


Fig.9 The bar specimens of steel rebars HA10 and HA12. [20]

Table 1. Surface characteristics of the rebars:

	HA10	HA12
Rib height (mm)	**1.5**	**1.7**
Rib width (mm)	2	2
Rib spacing (mm)	7.5	8.3
Rib face angle	45°	45°

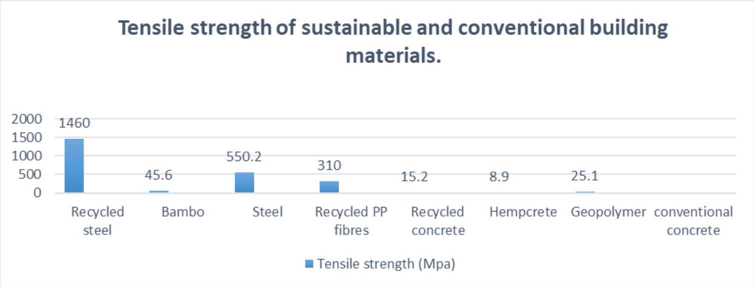


Fig.10 Tensile strength of sustainable and conventional building materials. [21][22]

- To verify the effectiveness of the rest of the recycled concrete waste and use it as an alternative material to natural aggregate its through the same experimental study and by analyzing the bond behavior of the recycled concrete aggregate between it and the plain and deformed steel bars, and using the same pull test.

By studying three different ratios of replacement of recycled coarse aggregate (20, 50, and 100%) with two types of reinforcing steel (plain and deformed) using a pull test, found that, at the same mixing ratio, the bond strength between the recycled aggregate concrete and the plain reinforcing steel decreased with increasing replacement ratio. in contrast, there is no clear relationship between the adhesion strength of recycled aggregate concrete (RAC) and deformed reinforcing steel and the replacement ratio, however, water absorption was observed to be the main difference between natural and recycled aggregates, and this difference was attributed to the presence of an old porous mortar adhering to the natural grains with a network of cracks resulting from crushing processes. The high porosity of the recycled aggregate was due to the lower density compared to the natural aggregate [20].

Table 2. Physical properties of the aggregates: [20]

	Natural aggregates			Recycled aggregates		
	NS 0/4	NG 4/10	NG 6.3/20	RS 0/4	RG 4/10	RG 10/20
Bulk density ρ_{rd} (g/cm3)	2.59 ± 0.010	2.70 ± 0.009	2.70 ± 0.004	2.17 ± 0.002	2.29 ± 0.004	2.26 ± 0.004
Water absorption, WA_{24}(%)	0.74 ± 0.05	0.55 ± 0.04	0.46 ± 0.02	7.50 ± 0.06	5.50 ± 0.27	5.1 ± 0.01

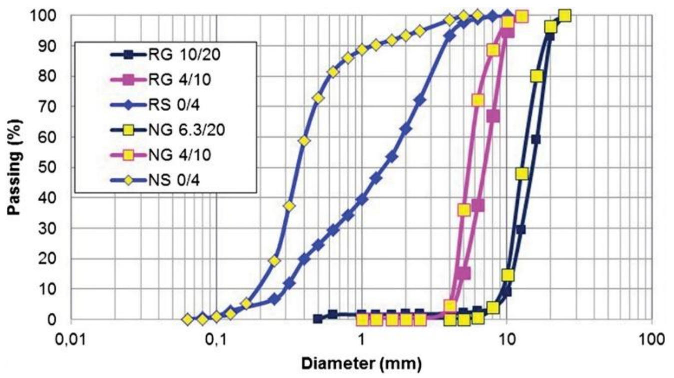


Fig.11 Particle size distribution of the aggregates. [20]

It has been observed that the recycled sand contains a higher proportion of fine materials than natural sand, as it was (the content of fine materials in the recycled sand was equal to 3.2%, while the percentage was equal to 0.3% in the natural sand), but the size distribution of its particles shows larger masses than natural masses. Therefore, the presence of fines may be the reason for the better bonding between the rebar and the recycled concrete.

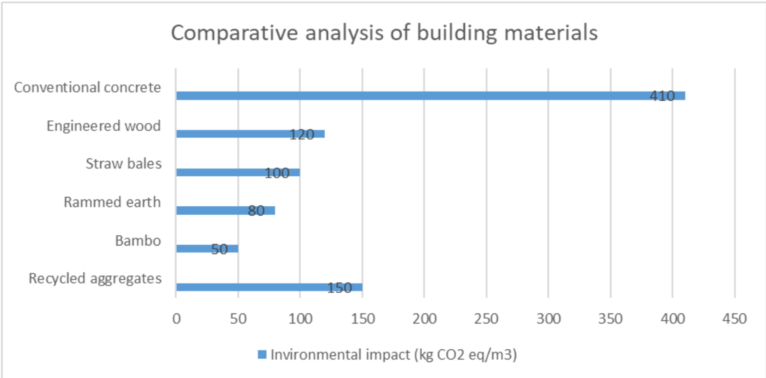


Fig.12 Comparative analysis of building materials.

The cement production process causes the depletion of a large amount of non-renewable resources in addition to carbon emissions, as cement production only results in emissions ranging between 5-7% of the world's total (CO_2) emissions and t is expected to reach 10% in the near future[23]. Therefore, this will leads to a rise in global warming. The use of industrial by-products in the formation of geopolymers reduces carbon emissions and energy consumption by at least 25%.[24]

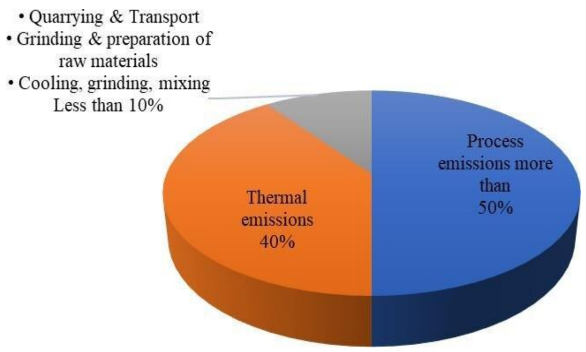


Fig.13 CO2 emissions of clinker production.[25]

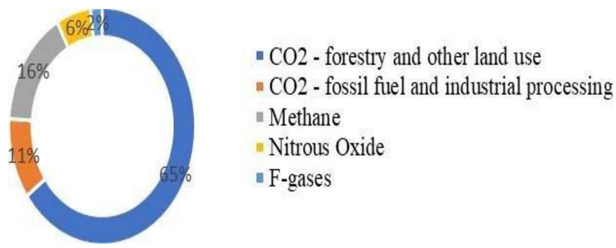


Fig.14 Percentage of total CO2 among greenhouse gases.[25]

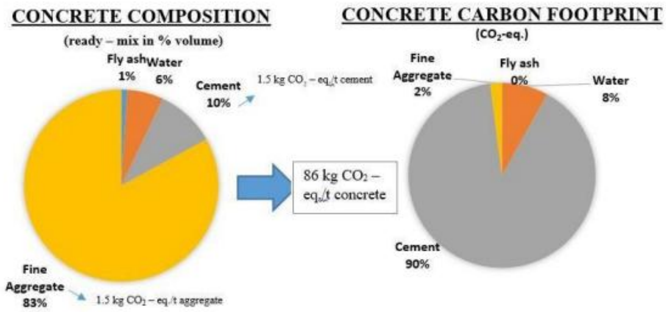


Fig.15 Cement content in concrete and its carbon footprint.[25]

Therefore, the idea of replacing it with binding materials that are less depleting of natural raw materials and have less impact on the environment began, such as geopolymer cement, which is a highly alkaline (K-Ca)-poly(siloxane-siloxane) cement, produced through an inorganic polycondensation reaction, which results in three-dimensional zeolite frameworks. One of the properties of geopolymer cement is its rapid setting at room temperature, providing compressive strengths of 20 MPa after just 4 hours at 20°C when tested according to the standards applied to hydraulic binder mortar. The ultimate compressive strength for 28 days ranges from 70 to 100 MPa.

The following figure illustrates a general concept of geopolymers, developed by Doxon et al [26]:

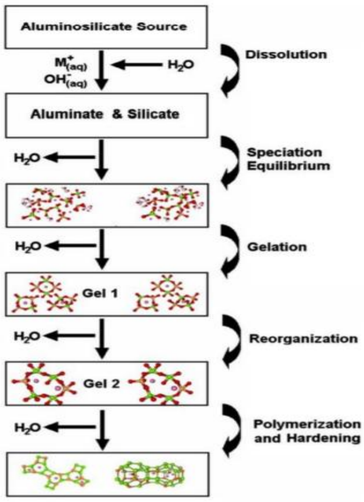


Fig.16 Conceptual model for geopolymerization. [26]

- Geopolymer concrete is produced by activating alkali aluminosilicate materials for use as a sustainable alternative to cement in concrete, but this causes to results in brittle and low-strength concrete. Therefore, glass fibers were used in geopolymer concrete mixed with fly ash and slag as binders to improve its performance, and this was done by using two types of glass fibers separatey or as a compsite mixture. Adding fiberglass to geopolymer concrete, a hybrid mixture of 1% fiberglass, has provided superior results. The glass fibers used were of different lengths but had similar properties. The workability of geopolymer concrete was evaluated based on shrinkage tests, compression factor, and bending time. Its mechanical properties are characterized by tensile and compressive strength, modulus of elasticity, bending behavior and shear behavior [27].

Performance and carbon footprint reduction were also examined
For geopolymer mortar (GM) containing eggshell powder (ESP) and
Rice husk ash (RHA) as sustainable alternatives to traditional binders.
And using the response surface methodology, using response Surface Methodology (RSM), ESP and RHA were added at volumetric percentages from 0% to 30% as partial replacements for GGBS. Experimental results revealed that the inclusion of RHA and ESP significantly enhanced pressure, especially at optimal doses, with the highest strength levels recorded, It reaches 48 MPa. An ecological assessment
indicated that using RHA and ESP can lower CO_2 emissions compared
with the traditional materials, thereby promoting more sustainable in practices of construction and building [16].

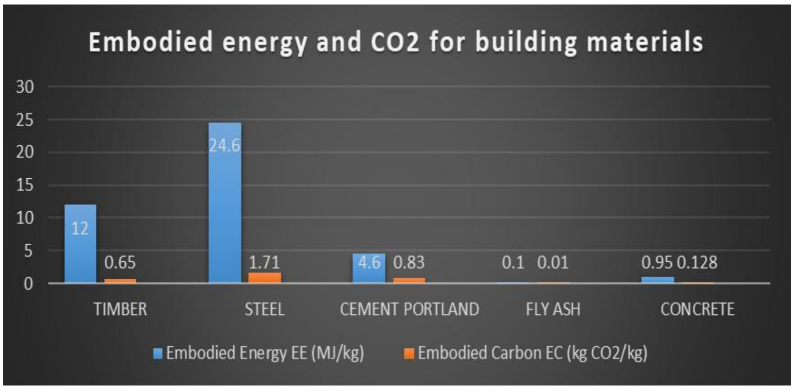


Fig.17 Embodied energy and CO2 for building materials.[28]

- Ferrock concrete it is a material that has recently appeared in the field of construction and has unique environmental benefits that have attracted researchers' interest in it. Ferrock is a better alternative to traditional concrete. It represents a waste management tool, as iron powder is the main component of Ferrock and other industrial wastes such as fly ash, unlike traditional concrete, which is made from cement, also Ferrock gains its strength through the consumption of carbon dioxide, which reacts with the iron to form iron carbonate. It has been discovered that treating it with carbon for four days and treating it with air for three days yielded the best test results. Water is used only to transport and mix the raw materials, contrary with cement, which requires it throughout its entire strength acquisition period, the curing phase, and found that the ideal composition of Ferrock is 60% iron powder, 20% flyash, 10% metakaolin, 8% limestone, and 2% oxalic acid.

Then Ferrock concrete has the ability to reduce carbon emissions and utilize industrial waste, as it is a sustainable alternative to traditional concrete. To prove the efficiency of ferrock practically, a practical experiment was conducted between cement and ferrock material, cement, coarse aggregate, and fine aggregate were used and Ferrock composition were (Iron dust 60%, fly ash 20%, metakaolin 10%, lime stone 8%, oxalic acid 2%).[25]

Table 3: Proposed experimental concrete mix: [29]

MIX 1	Cement 80%+ fly ash 20% + M sand 85% + glass powder 15% + coarse aggregate + water + super plasticizer (control concrete)
MIX 2	Cement 70% + fly ash 20% + ferrock 10% + M sand 85% +glass powder 15% + coarse aggregate + water + super plasticizer.
MIX 3	Cement 60% + fly ash 20% + ferrock 20% + M sand 85% +glass powder 15% + coarse aggregate + water + super Plasticizer.
MIX 4	Cement 50% + fly ash 20% + ferrock 30% + M sand 85% +glass powder 15% + coarse aggregate + water + super Plasticizer.
M40	Ordinary Portland cement refers from IS 269-2015, concrete mix proportion used for M40

Compressive strength tests were performed for the concrete specimens after 7 and 28 days of curing, respectively. It was found that the compressive strength of Ferrock at 10%, 20% and 30% was approximately 44%, 53% and 31% higher than that of normal concrete (M40 F0%) at 28 days, as shown in Figure 16. It was also found specifically that the concrete sample containing 20% Ferrock gave good mechanical strength to the concrete compared to other Ferrock ratios (0%, 10%, 30%).[29]

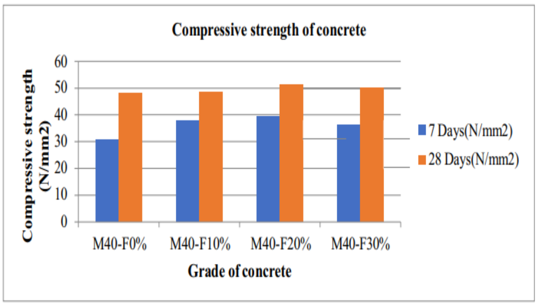


Fig.18 The graph shows that the compressive strength of M40 grade concrete.[29]

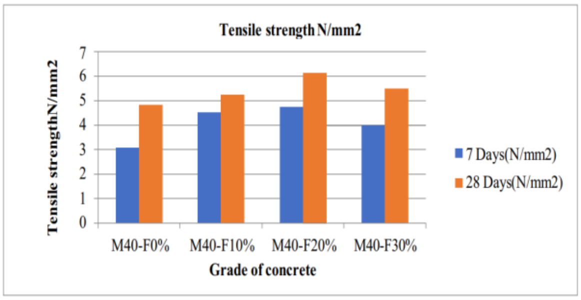


Fig 19. The graph shows the split tensile strength of M40 grade concrete.[29]

It was found from the above that the best sample is the one containing 20% iron, as it provided good mechanical strength compared to the iron percentages in other concrete.

- Hemp concrete has the ability to sequester up to −16 kg of carbon dioxide/m2 (U = 0.27 W/m2 K) throughout its life cycle. Thus, long-term biocarbon storage can be achieved through the use of hemp material, and additional carbon storage can also be obtained by carbonizing the binder.

The evaluation was based on 36 hemp concrete compositions over their life cycle with different contents and densities using an equivalent functional unit (FU) for a 1 m2 wall assembly with a U value of 0.27 W/(m2K), and the percentage of CO2 emissions from manufacturing that could be recovered through in situ carbonization of the binder was estimated.

We expect the total life cycle CO2 emissions of hemp concrete to be negative, with a minimum of −16.0 kg CO2eq/FU for the hemp concrete mixture formulations studied. But some hemp concrete formulations can exhibit net positive emissions, especially high-density mixes (>300 kg/m3) containing Portland cement, so it is essential to select and fit materials into the design of carbon-storing hemp concrete [30].

Hempcrete is used in the construction of non-load bearing parts of buildings and is applied in construction work together with the frame made of wood or steel. Therefore, experiments were conducted on it to improve its properties in terms of compression and load capacity by making different mixing ratios to find out the optimal mixing ratio for the binder to make hempcrete using hemp fibers. Add lime for improvements of the hemp compressive strength to a greater extent, to enhance it's the potential [31].

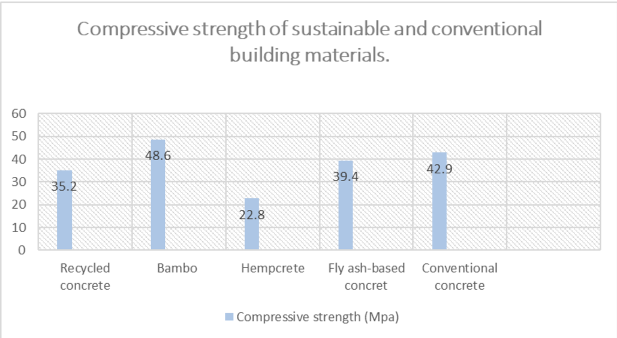


Fig.20 Compressive strength of sustainable and conventional building materials.

Hemp concrete is characterized by its resistance to high temperatures due to the cellular structure of hemp concrete, which leads to the presence of large air gaps within the cured mixture, as it shows remarkable resistance to heat, thus enhancing energy efficiency. Based on the study conducted by Carney and Carney, the compressive strength of unbound gypsum was found to be 12.0 MPa. Therefore, adding it to hemp produces a stronger material, thereby improving the mechanical properties of hemp concrete. Using a gypsum-hemp mixture can create a building material with higher compressive strength than using lime with hemp in concrete. Therefore, a combination of hemp and gypsum is preferable, as they are both sustainable building materials. [32].

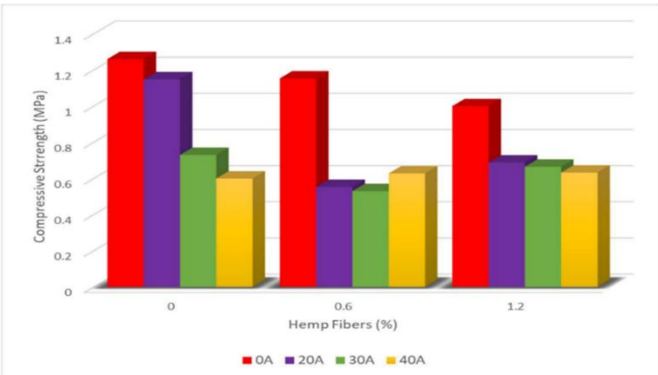


Fig.21 An examination of the effects of clayey soil and fibers on compressive strength after 7 days.[33][34]

Table 4. Comparison table between traditional building materials and sustainable building materials:

Factor	Traditional Building Materials	Sustainable Building Materials
Environmental Impact	Often have a high carbon footprint due to the energy-intensive production processes (e.g., cement, steel). May deplete natural resources and generate significant waste.	Lower carbon footprint, often made from renewable or recycled resources and emphasis on minimizing waste and pollution.
Energy Efficiency	Can contribute to energy inefficiency in buildings, leading to higher heating and cooling costs.	Designed to improve energy efficiency through insulation, thermal mass, and natural ventilation.
Resource use	They may depend on non-renewable resources and contribute to deforestation or destruction of natural resources.	Prioritize the use of renewable, recycled, and locally sourced materials.
Durability and Maintenance	Some traditional materials are durable, but others require frequent maintenance or replacement.	Often durable and long-lasting, with low maintenance requirements.
cost	Initial costs can be lower, but long-term costs (energy, maintenance, replacement) may be higher.	The initial cost of materials is higher, but the long-term savings in energy and maintenance can offset the initial investment.

RESULTS EXTRACTED FROM THE RESEARCH:

After arriving at an assessment of the impact of using sustainable building materials on the fields of public health, environment and energy, and analyze the economic impacts of adopting their use in buildings, whether currently or in the long term, compared to traditional building materials; It is wise to make the decision to choose sustainable building materials to achieve long-term cost savings related to energy efficient buildings, as choosing these materials does not require significant maintenance and has a long lifespan, which leads to a significant reduction in construction and maintenance expenses over the years. Using sustainable building materials is also a great way to reduce the environmental impact of construction projects and improve the quality of living.

As for the factor related to durability, sustainable buildings can withstand bad weather conditions and natural disasters, ensuring longevity and reducing the frequency of necessary repairs or replacements.

We only have to take the basic considerations (cost of materials, durability, and availability) in the process of selecting sustainable building materials.

We must also encourage the provision of sustainable materials locally, as it not only saves transportation costs, but also contributes to supporting the community and reduces the carbon impact associated with transportation.

CONCLUSION:

The most important question that any civil engineer must ask, based on his construction role in all areas of infrastructure, before starting any work, which is:

What should be consider when choosing building materials for the next project?

We must take into account factors such as:

1- The impact of materials on the environment, reducing carbon emissions.
2- Preserving natural resource.
3- Should be used building materials that consume less energy.
4- Be available locally.
5- Use building materials that are close or similar in their durability to reduce the energy consumed in maintenance operations over the long life of the building.
6- Specify materials and products with reuse potential.
7- Chose materials that low water use and that low-water-pollution.
8- Chose materials or products that assist with sustainable site design strategy.
9- Can use some materials or products are not green or sustainable in themselves but can help in the sustainability purpose of the project such as white Portland concrete is a highly reflective material and although it is not a green material but helps reduce urban heat over the life of the pavement.

10- Focus on materials that have a long- life maintenance.

In addition to our interest in the basic factors (durability, cost, and availability) to the same extent. It is also important to consider how these materials will be installed and maintained over the long term.

The strategy of choosing sustainable building materials for any facility is not an easy process, despite the existence of several practical techniques such as:

- Analytical Hierarchy Process (AHP): This is a structured technique for organizing and analyzing complex decisions. It breaks down a decision problem into a hierarchy of criteria, sub-criteria, and alternatives, allowing you to compare them systematically [3].
- Fuzzy: In real-world decisions, we often deal with information that is imprecise or uncertain. Fuzzy logic allows us to work with this kind of "fuzzy" information, where things aren't simply true or false, but can have degrees of truth.
- (FEAHP) stands for Fuzzy Extended Analytical Hierarchy Process. It's a decision-making tool that helps you choose the best option when faced with complex situations involving many factors that are difficult to measure precisely.

The difference between AHP and FEAHP:
While AHP relies on pairwise comparisons using exact numbers to represent preferences, FEAHP uses “fuzzy logic” to represent these preferences. Fuzzy logic allows imprecise or incomplete information to be represented using "fuzzy sets" rather than exact numbers. This allows the FEAHP to deal with situations where it is difficult to determine preferences precisely [35].

- Product Life Cycle Analysis (LCA): Give a comprehensive assessment of the environmental impacts of a material throughout its life cycle, from raw material extraction to manufacturing, transportation, use and disposal.
- Building for Environmental and Economic Sustainability (BEES): It is a building evaluation and classification system developed by the National Institute of Standards and Technology (NIST) in the United States. The BEES system aims to evaluate the environmental and economic performance of products and materials used in construction, with the aim of supporting sustainable decision-making in the construction industry. Benefits of using the BEES system is make informed decisions, BEES provides detailed and reliable information on the environmental and economic performance of products and materials, helping Engineers and designers make informed decisions when selecting materials. BEES does not have a formal certification system, but it does provide a free software tool that can be used to evaluate products and materials. Architects and designers can use this tool to evaluate the materials used in their projects, and they can use the evaluation results to make sustainable decisions. In short, BEES is a valuable tool for engineers and designers seeking to build sustainable and environmentally friendly buildings [36].

In addition, there are many standards and certifications that can be used to evaluate sustainable building materials, e.g. (LEED) Leadership in Energy and Environmental Design, (BREEAM) Building Research Establishment for Environmental Assessment (Green Globes) [37].

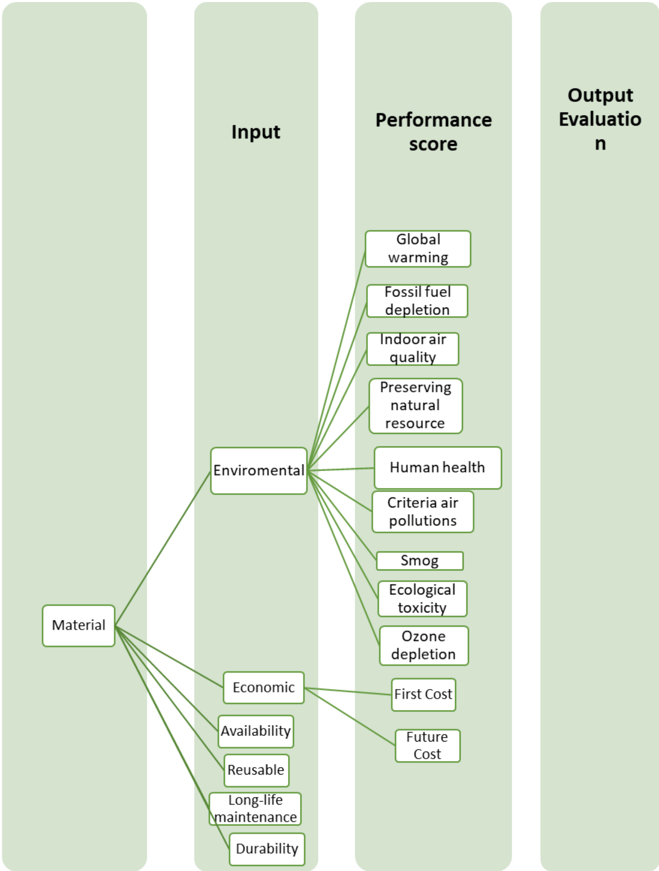


Fig.22 Simulating the (BEES) method for evaluating the sustainability of building materials. [36]

Taking advantage of the previous techniques, it is possible to propose a new method for extracting the results using (Fig. 22) by entering the values of the test results for the material to be examined using the Excel program as in (Fig.23) and by converting the different results extracted into a percentage from 0-100 and thus they can be collected on one of the axis, while the second axis will be to evaluate the percentage Sustainability of the material. The FEAHP approach can also be followed in estimating some values for some unknown or ambiguous tests.

It is possible to determine the sustainability index in materials when they are:

0-30 indicates that they are sustainable materials

31-50 average sustainability materials

51-70 low sustainability

71 -100 unsustainable materials.

As a practical application can use Portland cement for example we can use the environmental indicators of Portland cement by percentage.

The highest environmental impact values per 1 kg of Portland cement were 9.93 × 10−1 kg CO_2-eq (global warming potential), 1.04 kg 1,4-DCB (terrestrial ecotoxicity)[38].

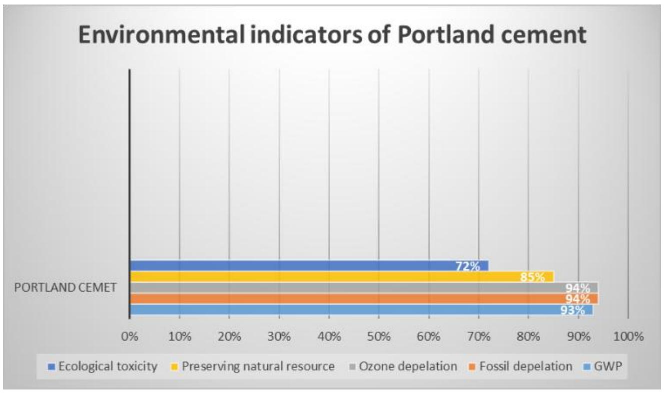


Fig.23 Environmental indicators of Portland cement [39]

From Figure 23, it becomes clear and very easy to estimate the sustainability of Portland cement, given that it is an unsustainable material, as the percentage of environmental impact was very high and exceeded 70%, and therefore it affects human health. It is also a material that depletes natural resources and fuel, and therefore it is also uneconomical.

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