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Review

Green Concrete mix using solid waste and nanoparticles as alternatives – A review

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HIGHLIGHTS

- Green concrete mix to minimize CO_2 emission and environmental pollution.
- Substitution of cement and aggregates with various waste materials.
- Green house gases effects resolution by implementation of nanotechnology.
- Study on use of industrial waste in cement concrete – pathway to advance studies.

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ABSTRACT

The process of manufacturing of ordinary Portland cement (OPC) is energy intensive and creates various environmental problems such as pollution and emission of CO_2. There is a need for the an alternative eco-friendly Green Concrete. The waste materials from agriculture, industries, bio-waste, marine waste and e-waste can be recycled and used as a supplementary Green Concrete materials. This will reduce environmental impact of the production of OPC and reduces energy consumption. The application of nanotechnology for a Green building in the current and future is very much significant. The production and implementation of Green Concrete is still in its infancy stage. Academicians and R & D need to step in by promoting application at the industry level. The focus of this review paper is to create awareness to utilize the discarded materials as well as to highlight the new technology to manufacture Green Concrete.

Contents

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1. Introduction

The economy of any country grows based on the infrastructure available. Infrastructure covers roads, bridges, buildings, warehouses, airports, harbors, container terminals etc. As the demand for infrastructure grows, so does the need for concrete, which leads to the demand of more cement. Cement concrete is in great demand in the construction industry and at the same time it is an environmental concern, as it produces hazardous gases in various stages of production. We generally know that any concrete mix has cement, aggregates, sand, water and additives as per design need. With growing demand to control pollution and use waste materials from different industries, this is an attempt to replace standard materials with alternative substitutes. It covers the effects on compressive strength, setting time, cost effectiveness and reduction of pollution levels. Natural resources are not perennial, so we need to find alternatives to replace them without compromising on the quality and effective parameters of the ultimate product. The cement kilns produce hazardous gases and contribute to global warming. Animals are also adversely affected by the pollution caused by cement plants. During transport of cement bags from manufacturing site to end user, it undergoes wear and tear and cement dust flies into the environment. It causes breathing diseases and effects the labor who used to transfer, dump and redistribute the stored cement bags. Solid waste management is a major concern due to increase of quantity of waste materials and industrial by-products. This is increasing the land filling problems and recycling cost of waste materials. Utilization of these materials as Green Concrete is the only option to reduce the disposal concern. The Green Concrete is made from the eco-friendly waste materials and ushers in a revolution in the concrete industries by its technology. The waste products can be reused directly as a partial substitute of cement and save the energy consumption during the production of cement. Some waste materials are having pozzolans properties. Pozzolans is a material rich in silica and alumina which itself possess little or no cementing property, but in the presence of water, it chemically reacts with calcium hydroxide at ordinary temperature to form the cementitious properties [1].

The complete process of cement manufacturing, right from crushing and transport of lime stone, heating of kilns and crushing is all polluting. The river sand is used as fine aggregate for the concrete mixes which is obtained from the river beds and erodes the valuable top soil. Since sand mining is a lucrative business does not benefit the government economically and disturbs the ecology of the rivers. Water flow is uneven and the river bed is degraded. Coarse aggregate is gravel powdered and pounded to sizes from granite and blue stones. This also makes mining and blue metal companies to chip and blast mountains. Most of the mountains are completely chipped off which influences the rainfall pattern. Pollution and ash dust flying in the air is a major disadvantage of blue metal quarrying. It is also powdered to manufacture M-sand, a cheaper alternative to river sand. Volcanic materials and thermally processed materials can be also used as lightweight aggregates as natural resources. Water is a major commodity and usually potable grade water is best suited for cement concrete mix manufacturing. Water is depleting and recycled water must be replaced in the system to have a sustainable supply of water. Concrete mix causes release of green house gases (CO_2) and pollutes the atmosphere. Concrete is the most used material in construction industry and it undergoes various types of deterioration due to environmental effects.

An enormous amount of waste materials from different surroundings, environments and industries are produced every day. The waste materials such as rice husk ash (RHA), saw dust ash (SDA), rubber crump, plastic waste, coconut husk and shell, textile waste (sludge and fiber) etc lead to waste disposal crisis. Recycle of such types of wastes can be used as an admixture to make the Green Concrete structures. This will reduce the quantity of cement used and CO_2 emission and reduce the global warming. In this paper, the explanation is about the waste materials as an admixture which provides better strength and durability of concrete than the existing one which not only solves the environmental and ecological problems but also significantly improves the microstructures and durability properties of concrete. The demolished building waste is mixed in concrete which saves the space required to dispose them and at the same time they get recycled and fresh material is not needed.

This paper explains the three different types of resources such as resources of agriculture, industries and bio-waste. By implementing nanotechnology, the properties of concrete structures can be improved.

2. Material resources

2.1. Resources of agriculture

Plant-based agricultural wastes such as rice husk, timber waste as saw dust, palm oil fuel ash and coconut shell are the sustainable resources to produce concrete.

2.1.1. Rice husk ash (RHA)

Rice husk is an agricultural waste obtained from milling of rice which is one of the largest available un-utilized biomass resources. The disposal of this natural waste is a great problem because of pollution. RHA is highly pozzolanic (siliceous materials) due to its extremely high surface area. It contains 90–95% SiO_2 which is an essential ingredient in concrete whereas OPC contains only 21% of SiO_2. The waste generated from the rice field, as RHA can be incorporated in the concrete mix (Green Concrete) to improve workability, strength, durability and decrease the cement quantity. RHA forms a calcium silicate hydrate gel (C-S-H) which can stop the cracking of the concrete and save it from any corrosion and leaching. The use of RHA in concrete showed the development of strength [2,3]. In self-compacting concrete, RHA solves the disposal problem, thus keeping the environment free from pollution [4]. Silica present in the RHA combines with the calcium hydroxide and forms a resistive on the material, under acidic conditions. Ramezanianpour et al. (2009) showed that concrete incorporating RHA modified concrete is having superior compressive, splitting tensile strength and modulus of elasticity is different compared with that of the controlled concrete [5]. Alireza et al. (2010) used RHA as pozzolanic material in mortar and concrete [6]. It improve the improve the mechanical and durability properties. Ramasamy (2012) found that addition of 20% RHA showed higher resistance against sulphate attack [7]. Krishna (2012) discussed about the effectiveness of RHA as a versatile concrete admixture and application of RHA concrete [8]. Godwin (2013) proved that by using RHA, concrete can be modified which is the proper replacement percentages and used in the form of

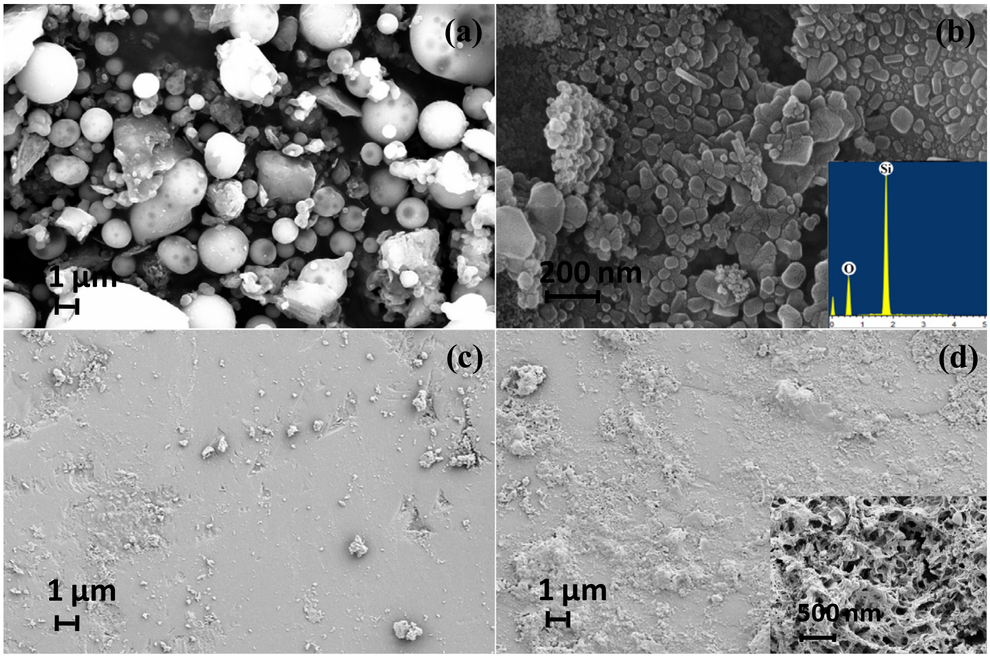

Fig. 1. Scanning electron micrograph of (a) Fly ash (b) RHA (c) Fly ash modified concrete and (d) RHA modified concrete.

different types of concrete structures [9]. Jayanti et al. (2013) observed that almost 10% substitution by RHA instead of cement was found to give the optimum results for the 28 days strength [10]. Padma Rao et al. (2014) confirmed the significant increase in compressive strength from 7, 28 and then 56 days in concrete by using RHA [11]. A comparative study of partial replacement of OPC by fly ash (20%) and RHA (3%) modified concrete showed higher strength, less porosity and permeability in RHA modified concrete due to presence of nanosilica [12]. Further they also confirmed through FESEM analysis that presence of nanosilica in RHA modified concrete has polymerized layered structure and rough surface texture which helps to increases the bonding between aggregates and cement paste, therefore increases the strength (Fig. 1) Using RHA as Green Concrete, will cut down on the overall carbon emissions from the concrete industry. So far, RHA modified concrete is remains in laboratory stage, that can be further improved and industries have to come forward to adopt it.

2.1.2. Saw dust ash (SDA)

SDA is an additional amount of wood ash generated, as a by-product of burning wood waste and it is essential to solve the problems associated with their disposal. Tarun, Rudolph and Rafat (2003) reported the following elements in wood ash: carbon (5–30%), calcium (5–30%), carbon (7–33%), potassium (3%–4%), magnesium (1%–2%), phosphorus (0.3%–1.4%) and sodium (0.2%–0.5%). It also contains SiO_2 and CaO that are pozzolana materials [13]. Abdullahi (2003) has studied the behavior of wood ash/OPC concrete and chemical analysis of wood ash, consistency, setting time and slump test of the fresh paste were determined [14]. Abdullahi (2006) has found compressive strength of the concrete was increased with the 20% replacement of wood ash at 60 days [15]. Wood waste ash is an acceptable material to produce structural grade concrete with improved strength and durability [16]. Raheem et al. (2012) used SDA substitution as a pozzolan in the production of concrete which is combined SiO_2, Al_2O_3 and Fe_2O_3 [17]. This saw dust is one of the environmental threats for the society as it is not good for human health and another organism. The use of SDA as Green Concrete will solve the disposal and environmental problem and make the sustainable concrete structures. The timber industries can look this as an alternative of waste saw dust disposal.

2.1.3. Palm oil fuel ash (POFA)

POFA is an agricultural waste of palm oil residue from which palm fiber and shells are procured. They are burnt at 800 °C–1000 °C which generate the electricity thermally [18]. It is one of the environmental threats since it is disposed as landfill materials because further utilization is not possible. It was used by many researchers as a supplementary cementitious material in mortar or concrete [19–24]. POFA contains 21–22% of silica oxide which can react with calcium hydroxide ($Ca(OH)_2$) from the hydration process and produce more calcium silicate hydrate (C-S-H) [25]. 20% replacement of POFA could be the optimum level to achieve the strength of concrete which will reduce gradually beyond this replacement level [25]. Vanchai Sata (2004), analyzed 10, 20, and 30% of ground POFA concretes and found that the highest strength was in 20% substitute of POFA at the age of 28 days, the compressive strength of concretes containing POFA was tested at ages of 7, 28 and 90 days [23]. Michael Yong Jing Liu (2014) worked on utilization of palm oil fuel ash as binder in lightweight oil palm shell geopolymer concrete and found that mix of up to 20% POFA can be categorized as structural lightweight concrete [26]. Ramin Andalib (2014) highlighted that in reinforced concrete beams instead of cement, utilization of Palm Oil Fuel Ash (POFA) with fly Ash was incorporated [27]. Addition of superplasticizer is significant to achieve the workability, high filling ability, fluidity, reduce the inter-particle friction, maintain the deformation capacity, viscosity and self compact ability in concrete structures with enhanced compressive strength [28,29]. The sustainable production of Green Concrete by POFA is feasible precisely for the environment. Based on the overall review it could be concluded that POFA could be used as a successful supplementary cementing material to replace 20% of cement in concrete and mortar.

2.1.4. Coconut husk and shell

The disposal of coconut husk and shell is another environmental issue. Studies have shown that burning of agricultural wastes causes air pollution and depletes the nourishment which leads to decreased soil fertility [30]. Though the decomposition of agricultural waste in the field is not harmful and it increases the productivity of the soil but its decomposition process is very slow. The preparation of coconut shells as aggregates is air dried in the room temperature of 25–30 °C and can be broken manually into small chips and sieved to get the 12 mm size. This is used in concrete industries as partial replacement of coarse aggregates to reduce the natural consumption for the production of Green Concrete. The replacement of coconut shell as aggregates in the concrete mix enhanced the compressive strength compared to conventional concrete mixture [31]. This natural coconut shell aggregates should be replaced as 10–20% in place of normal aggregate. The performance of coconut shell aggregate mixed concrete is little lower than normal aggregate concrete [32]. Vishwas P (2013) observed that 28 days cured compressive strength of coconut shell aggregates modified concrete was 24.21, 22.81 and 21.80 for 10%, 20% and 30% which provided the promising results for lightweight concrete [33]. From the environmental and economic point of view, coconut husk and shell can be used as alternative construction material.

2.1.5. Molasses waste

Molasses is the waste by product of sugar and paper industries, which contains lignosulphonate and acts as a dispersing reagent. They have plasticizer effect to improve the physical properties of concrete structures such as workability, durability and strength. The plasticizer (admixture) is one of the important additives that are being used for designing of concrete structures and reduce the water content in the concrete mix. The molasses-containing yeast fermentation waste was used as a plasticizer in concrete mixtures and analyzed the basic principles of the effects of organic and inorganic components of yeast fermentation waste on the properties of the bonding system of concrete [34]. Akar and Canbaz (2016) studied the addition of 0.5 and 1% of molasses decrease in water-cement rates in concrete, affected concrete durability negatively and reduced the cost of Green Concrete production [35].

Table 1
Mix details of normal concrete and fly ash modified concrete.

Concrete-Mix N/30/20/60: Normal Concrete				
Ingredients	Cement	Water	Fine agg.	Coarse agg.
In kg/m^3	(C)	(W)	(FA)	(CA)
Concrete	400	180	684	1168
Mix Preparation	C ÷ C:	W ÷ C:	FA ÷ C:	CA ÷ C
By Weight	1	0.45	1.71	2.92

Concrete-Mix N/35/20: Concrete with Fly Ash and Superplasticizer (SP)							
Ingredients	Cement	Water	Fly Ash	Binder	Sand	Coarse agg.	Superplasticizer
In kg/m^3	(C)	(W)	(FA)	(B)	(FA)	(CA)	SP
Concrete	225	143	150	375	549	1130	6.75
Mix Preparation	C ÷ C:	W ÷ C:	FA	Total B	FA ÷ C:	CA ÷ C	B ÷ SP
By Weight	0.6	0.38	0.4	1	1.46	3.01	1.8%

2.2. Resources of industries

2.2.1. Fly ash

Fly ash is the residue of burnt coal and mostly procured from thermal power plants. In India, we are still heavily dependent on thermal power plants as there is a supply of Lignite and coal. The coal when burnt leaves a residue which must be disposed. Recycle of fly ash by replacing it instead of cement provides a solution to dispose and also a cost-effective alternate Green Concrete structure. The fly ash modified concrete reacts with calcium hydroxide of cement and forms stronger and more durable compounds. It binds the toxic chemicals from contaminating natural resources and also reduce the uses of energy and CO_2 emissions. It reduced water requirement, increases workability, reduces bleeding, segregation and heat of hydration and improves resistance to sulphate and acid attack, long term strength gain. Fly ash contains SiO_2, Al_2O_3, Fe_2O_3 whereas CSH gel is the byproduct of reactions between fly ash and calcium hydroxide act as good filler, increases strength, reduces permeability and corrosion, increases sulphate resistance and reduces alkali-aggregate reaction. The mixture of normal concrete (NC) and fly ash modified concrete with superplasticizer were casted for a yearlong exposure studies in seawater (Table 1) [36].

2.2.2. Ground-granulated blast-furnace slag (GGBFS)

GGBFS is the by-product of iron and steel and ground iron slag from blast furnaces and its composition depends on the raw materials used during the iron production. It is considered to be a Green recyclable material. It is used in concrete mixture as slag cement with composition of silicates, aluminates, CaO and MgO. The concrete structures which are surviving in the high temperature (450 °C) must face dehydration, permeability, thermal expansion and cracking problems as a result, reduction in strength and increased porosity affects the concrete structures. At elevated temperature, strength of the concrete is lost of about 15–20% [37–39]. The slag cement added as a partial replacement of cement (up to 40%) had higher compressive and flexural strengths than normal concrete modified by Portland cement [40]. The GGBFS modified concrete structures using iron slag is a sustainable construction materials for pavements, pipes, foundations and for marine applications.

2.2.3. Waste foundry sand (WFS)

WFS or Green sand is a by-product of ferrous and nonferrous metal casting industries with high quality silica and uniform physical properties. When used as a moulding material, WFS has good very thermal conductivity. When removed from the foundry, it is termed as waste or Green foundry sand. Many researchers reported the use of waste foundry sand in different applications such as highway [41–48] and the other concrete products such as bricks, blocks and paving stones [49–53]. The utilization of WFS in concrete not only makes it economical, but also helps in reducing disposal concerns [54]. The increase in compressive, splitting tensile and flexural strength was compared with conventional concrete by substituting the 30% as fine aggregates [55]. Eknath and Desai (2011) found WFS as a fine aggregates in making structural grade concrete with different percentages of replacements such as 0, 10, 20, & 30% by weight of fine aggregate and tests were performed for 7 and 28 days. The cured concrete of M20 grade and achieved the strength of 20 N/mm^2 after 28 days. [56]. M20 grade of concrete, is the mix ratio of cement, sand and aggregates of 1:1.5:3 in volume. Guney (2010) found concrete with 10% waste foundry sand exhibits almost similar results to that of the control one [57].

2.2.4. Silica fumes

Silica fumes is a very effective pozzolanic material because of its extreme fineness and high silica content [58,59]. It is a by-product of the smelting process of production of silicon metal and ferrosilicon alloy from the industries. It is an ultra fine powder and spherical in shape with an average size of 150 nm. Silica fumes contain more around 85–90% silica, which is 100–150 times smaller than cement particles. It acts as filler and used as a chemical admixture in the concrete. It provides additional strength to the concrete as it reacts with calcium hydroxide of fresh concrete and make additional CSH gel to reduce the permeability and refined pore structure which results in a higher resistance to sulphate attack in aggressive environments [60]. The silica fume reacts with calcium hydroxide found in the Portland cement and form the calcium silicate hydrate similar to calcium silicate hydrate found in the Portland cement.

2.2.5. Glass wool fiber

Glass wool is manufactured by mixing natural sand and recycled glass at 1450 °C. Glass wool is a lightweight and an extremely strong recycled material. Its bulk strength and weight properties are favorable compared to other metals. The addition of 0.1% of glass fibres into the concrete can develop the improved mechanical and durability properties at 28 days [61]. R. Gowri and Angeline Mary (2013) investigated at 28 days the compressive and split tensile strength of the concrete increases by addition of glass fibres [62]. The glass powder waste is which is normally land-filled should also be considered for the replacement of fine aggregates in the construction industries. The glass powder with fly ash and silica fume as partial replacements of cement added with styrene butadiene rubber (SBR) significantly improved the bond between the SBR and cement matrix. This showed the increase in the compressive and flexural strengths, reduced the alkali silica reaction (ASR) expansions, percentage of water absorption, and the rate of water absorption than those of the control mix [63].

2.2.6. Rubber waste

Rubber (Tyre) disposal is another problem for the environmentalist. Burning of tyre creates atmospheric and health problems. Moreover, land filling is also not the solution. So another alternative of Green Concrete technology has to be found for potential use of these waste materials. It can be used as aggregates which exhibited lower compressive and splitting-tensile strength than normal concrete [64]. The properties of these types of concrete can be enhanced by the additives which depends on the size and distribution of the rubber particles [65,66]. Rubber concrete also called "rubcrete" can solve the problems of uses of natural rubber. Tyre waste modified concrete is recommended for concrete structures especially in areas of severe earthquake risk, severe dynamic actions like railway sleepers and can be used for non-load bearing structures noise reduction barriers [67]. The mechanical behavior of the concrete such as compressive strength and dynamic loading can be analyzed in this rubber filled concrete.

2.2.7. Plastic waste

The Green Concrete can also be manufactured using plastic waste which will enhance the strength and durability. Use of plastic has risen so high, that plastics are a part and parcel of almost every sphere of our activity. Naturally plastic waste is non-biodegradable and takes many years to degrade. This waste can be used a replacement for fine aggregate as substitution of sand in the formulation of concrete. So far river sand is used as fine aggregates that may create problems for the shortage of river sand in the near future. So, we may always think about the substitute for this fine aggregate as the replacement. Shredded plastic waste such as polythene bags and plastic bottles with similar grain size can be used as replacement materials as light-weight concrete which reduces the waste disposal issues in nature and is cost effective in terms of transport. Zainab et al. (2008) reusing waste plastic as a sand-substitution aggregate in concrete gives a good approach to reduce the cost and problems posed to dispose plastics [68]. Youcef Ghernouti (2014) results showed that use of plastic bag waste improves the workability and density but at the same time decreases the compressive strength of concrete containing 10 and 20% of waste by 10–24% respectively. This loss of mechanical strength is acceptable for light weight materials [69].

Table 2
EDAX of OPC and CDA is showing weight percentage of different elements.

Ingredients	C	O	Na	Mg	Al	Si	P	S	K	Cl	Ca	Ti	Fe
OPC	6.56	43.01	–	0.27	1.02	6.21	–	1.08	0.63	–	39.28	0.26	1.69
CDA	6.47	49.81	1.70	3.05	1.45	25.85	1.49	–	1.62	0.63	7.30	–	0.63

2.2.8. E waste

There are also some efforts in the concrete industry to utilize the non-biodegradable e-waste as a partial replacement of coarse or fine aggregates. The usage of e-waste to make Green Concrete can reduce the land-filled or disposal problems of the E-waste materials. E-waste particles are used as coarse aggregates in concrete. With 0%–30% replacement it exhibits a good strength gain [70]. Its properties can be compared with sand as it contains silica materials. The crushed e-waste which was pulverized by friction rolling machine showed increased strength when replaced up to 4% of fine aggregates. Subsequent reduction in strength was observed because of the decrease in the packing density [71]. Krishna and Rao (2014) found that compressive strength of concrete was optimum when coarse aggregate is replaced by 15% with E-Waste [72]. The uses of non-metallic portions of E-waste in concrete to increase its mechanical properties exhibit a good strength gain than the controlled mix concrete [73].

2.2.9. Recycled coarse aggregate

Construction and demolished waste is one of the major solid waste used in landfills. The usage of recycled coarse aggregates from demolished construction can be used as 100% replacement of coarse aggregates [74]. These recycled coarse aggregates can be used for road beds, pavements, boundaries and preserve the natural resources [75]. There is another important study on the Green Concrete made with recycled concrete aggregates (RCA), fiber reinforced polymer (FRP) and fiber scrap aggregate (FSA) which indicated both fresh and hardened RCA concrete properties were similar to control concrete containing only natural aggregates [76].

2.2.10. Effluents water and sludge

The waste generated from the effluent treatment plant are waste water and sludge. The disposal of waste water leads to environmental problems and on the other side treatment and discharge is very much expensive. Due to lack of proper disposal of waste water, it is contaminating the ground water and effects on the environment. The consumption of potable water for the production of Green Concrete is increasing day by day. Waste water from textile industries were used for the concrete casting and compared with the specimens casted with potable water [77,78]. K. Chandrasekaran (2001) reported the brick manufactured by 10–20% sludge from hosiery knitwear dyeing wastewater treatment plants provide ideal strength [79].

2.3. Bio-waste materials

2.3.1. Cow dung ash (CDA)

Bio waste such as CDA is one of the upcoming supplementary materials to make green sustainable concrete. It is non-polluting admixture, contains SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O, SO_3, and replacement of cement can be done by 5–30%. The weight percentage of OPC and CDA was compared for different elements by Energy-dispersive X-ray spectroscopy (EDS) and found that basic nature of CDA had more silica content than OPC (Table 2) [80]. Literature says that dung may improve workability and durability or may act as additional binder [81]. Pam Billy Fom et al. (2011) studied the compressive strength of cement cow dung stabilized bricks and investigated the lateritic soil blocks treated with cow-dung and found it has higher compressive strength than ordinary lateritic blocks [82]. Peter and Dorothy (2013) investigated the strength and the durability properties of earth brick stabilized with cow dung and a better compressive strength was observed in dry state than wet condition [83]. Bricks stabilised with 20% Cow dung contents by weight of earth has a dry and wet compressive strength of 6.64 and 2.27 MPa respectively. They suggested to prevent cow dung stabilised earth bricks from prolonged direct contact with rainwater. Silica was synthesized by using CDA and confirmed the results by X- ray diffractogram and EDS analysis. There was not much difference found in the crystallite structure and chemical composition of OPC and CDA [84]. Sahin Sirri et al. (2006) studied by replacing cattle manure ash instead of cement in concrete and found the 56-day compressive strengths of samples with 5, 10 and 15% cattle waste ash provided the best results and determined 96, 95 and 94% of the control's value, respectively [85]. CDA performs well in when a limited percentage (up to 10%) can be used for floor applications or as building component but not subjected to high structural stresses [86]. CDA modified concrete, reduces CO_2 emission, resistant to sulphate attack, additional tensile strength, less cracks, improves durability and cost-effective.

2.3.2. Oil palm trunk fiber

Ahmad et al. (2010) reported the potential of oil palm trunk fiber as a bio-waste resource for concrete reinforcement with improved mechanical and durability properties [87]. The oil trunk should be dried in the sunlight for 3–4 days to remove the moisture content and by using the crusher machine the optimum size of the fiber can be achieved [88]. By increasing the fiber content, there was reduction in drying shrinkage as well as controlling the cracking [89]. The cement mortar mixes containing 1–4% fiber of oil palm stem showed decreased workability of cement mortar with the increase of oil palm stem fiber [90]. The compressive strength of the concrete depends on the quantity of oil palm trunk fiber. An excessive quantity decreases the compressive strength and require more water hence decreases the density. It was suggested that 2 wt% of fiber content was the optimum to give the highest compressive strength [91].

2.3.3. Marine waste

The oyster shell waste is an outcome from the marine environment and is a great landfill problem. It is also non-biodegradable and pollutes the land and water when discarded indiscriminately. They are mechanically or manually crushed and then sieved to optimum size for the use as aggregates. Some articles depict that pavements using oyster shell waste cannot crack. Extreme heat or cold will not affect the pavement and thereby prevents formation of pothole. Yang et al. (2005) found that using crushed oyster shell can give better compressive strength but reduce the workability with fineness modulus decrease and substitution rate of oyster shell increase [92]. Chou-Fu Liang and Hung-Yu Wang (2013) worked on cementing potential of pulverized oyster shell which has calcium. After mixing with fly ash and soil, that mixture did not have any pozzolanic properties, hence exhibited inferior quality [93].

3. Nanoparticles in building materials

Recently many articles have been reported on application of nanotechnology in building materials. Nanoparticles control the matter at atomic level that deals with particle which is less than 100 nm in size. Nanoparticles with 4 nm diameter have more than 50% of its atoms at the surface and are thus very reactive [94]. The use of nanoparticles in the concrete structures alters the physical, mechanical and microstructure because of high surface area to volume ratio. Now a days, researchers are looking for addition of engineered nanoparticles which perform as Green Concrete. The production of Green Concrete should reduce the environmental impacts during fabrication of concrete structures with enhanced life cycle. The nanoparticles in the concrete structures act as a filler and activator to promote hydration process and thus develop the microstructures of concrete [95]. Silica is naturally found in conventional concrete. Addition of nanosilica in the concrete can improve the particle packing structure, reduces the permeability problems in concrete and enhanced mechanical properties. Some concrete structures are exposed to aquatic environments where calcium leaching problems occur. Addition of nanosilica in cement can control these degradation problems by C-S-H (calcium-silicate-hydrate). Nanoparticles of SiO_2 acts as a nano-filler because of formation of C–S–H gel and higher densification of the matrix improves the strength and durability of the material. The uniform distribution of nanoparticles increased the compressive strength in cement mortar [96]. Saloma et al. (2013) presents the influence of nanosilica as a partial substitution of cement in concrete and at the age of 3 days, the compressive strength of concrete that contained nanosilica increased between 3.82 and 11.84%; whereas, at the age of 7 and 28 days, the compressive strength of concrete with nanosilica increased by 3.87–17.24% and 4.93–24.59% respectively [97]. It has been also found that the modulus of elasticity and split tensile strength are likely to be increased with the increase of concrete compressive strength and recommended further the long term durability studies of nanomaterials in concrete. Titanium dioxide (TiO_2) is having hydrophilic and self-cleaning properties which have the ability to break down organic pollutants and bacterial membranes because of powerful catalytic reactions. TiO_2 nanoparticles accelerate the rate of hydration of cement and thus enhance the strength of the concrete because of its filler effects [98]. There are several reports of TiO_2 particles blended concrete having significantly higher compressive strength when compared to that of the concrete without nano-TiO_2 particles. The replacement of cement with nano-TiO_2 particles up to (0.5%, 1%, 1.5%, and 2%) of particle sizes of around 15–20 nm enhance the durability of the concrete. However, it was also found that partial replacement of cement by nano-TiO_2 particles decreased workability of fresh concrete; therefore, use of super plasticizer or water reducing agents or some mineral admixtures is substantial. Addition of TiO_2 nanoparticles by replacing the cement in concrete structures could achieve additional antibacterial and self-cleaning properties and durability. The major application of TiO_2 in building materials is due to its photocatalytic action to reduce the pollution level, self-cleaning to maintain the aesthetic appearance and self-disinfection properties to achieve a microorganism free environment in concrete structures [99]. The usage of nano-$CaCO_3$ in the concrete structures acts as a filler and provides additional strength and acceleration of hydration rate. Xiaoyan Liu et al. (2012) effect of nano-$CaCO_3$ on properties of cement paste was studied [100] as addition of nano-$CaCO_3$ decreased the ability to flow and the setting time was shortened. However, nano-$CaCO_3$ had no effect on water requirement of normal consistency of cement. Adding 1% nano-$CaCO_3$ could obviously decrease the early age shrinkage of cement paste. Some recent studies also suggested the seeding effect of the nano-$CaCO_3$ particles and the nucleation of C-S-H caused enhanced strength development. However further study is needed to confirm this. Addition of nano-$CaCO_3$ in concrete mixture may decrease the calcium leaching problem and improve hydration time, filler with improved rate of hydration, compressive strength, better physical and chemical properties. A study on the addition of large quantity of $CaCO_3$ confirmed the acceleration of hydration of C_3S [101]. The accelerating effect of the finely ground $CaCO_3$ in the hydration of cement paste was leads to the precipitation of some calcium carbosilicate hydrate. The hydration of tricalcium silicate (C_3S) in presence of more than 30% $CaCO_3$, produce some calcium carbosilicate hydrate with good mechanical performance [102]. ZnO nanoparticles are having similar properties like TiO_2 nanoparticles. It is also antibacterial, antifungal and anti-corrosive. Mohammad and Saeed (2012) investigated that ZnO nanoparticles reduce the pore of concrete structures and increased the mechanical and flexural strengths [103]. The partial replacement cement by 4% ZnO_2 nanoparticles could accelerate C–S–H gel formation at beginning of hydration [104]. It has been also found that ZnO_2 nanoparticles act as nanofillers and reduce the pore structure of the specimens by decreasing harmful pores [105]. Nazari and Riahi (2011) found that when the content of ZnO_2 nanoparticles is increased up to 3 wt (%), the flexural strength of the specimens is increased which was confirmed by rapid formation of hydrated products by XRD analysis [105]. Like other nanoparticles, 2% replacement of cement by Fe_2O_3 nanoparticles in concrete also showed improved strength whereas the ultimate strength of concrete was gained at 1.0% of cement replacement [106]. He concluded nanoparticles improves the split tensile and flexural strength of concrete but decreases its setting time. Abdoli et al. (2011) found that micro structure of cement mortar containing Fe_2O_3 nanoparticles showed the less pores, dense and compact structures [107]. He also explained the increasing Fe_2O_3 nanoparticles up to 5% reduce the mechanical properties. The addition of 4.0% of Fe_2O_3 nanoparticles increased the strength and water permeability of the concrete specimens and decreased the harmful pores to improve the water permeability and considered as nanofillers [108]. The formation of C—F—H gel because of addition of Fe_2O_3 nanoparticles can gives better filler effect with high pozzolanic action [109]. Ali Nazari et al. (2011), limewater cured concrete with the addition of 2% of Al_2O_3 nanoparticles results in more strengthening gel formation, acts as nanofillers and recovered the pore structure of the specimens [110]. Ali Nazari et al. (2010) and Agarkar and Joshi (2012) concluded that partial replacement of cement with nanophase Al_2O_3 particles enhances the compressive strength of concrete however declines its workability [110,111]. M.R. Arefi et al. (2011) found the effect of Al_2O_3 nanoparticles to enhance the mechanical as well as microstructural properties of cement mortar [112]. The addition of colloidal Al_2O_3 nanoparticles into the concrete structures improves its strength [113]. Carbon nanotubes (CNT's) are cylindrical in shape with high thermal conduction [114]. The addition of small amounts (1% wt) of CNT's can improve the mechanical properties of concrete and water. Oxidized multi-walled nanotubes (MWNT's) showed progress in compressive strength and flexural strength compared to the normal concrete.

4. Conclusion

The concrete structures prepared from the waste materials have lower environmental impact through reduced CO_2 emission and maintain all the specification of "Green Concrete". The significance of this study is to encourage the usage of solid waste to minimize the disposal cost of waste materials, decrease the environmental risk of pollution and save the landfill space. The solid waste which are generated from agricultural, industries and bio-waste, that can reduce the usage of cement in concrete structures. It has been suggested that these waste materials as a substitute to be added in concrete structures as admixture to get the better workability, strength and durability. The another findings of this paper is to utilize the nanoparticles to make Green Concrete and achieve the high performance concrete by reducing the usage of natural resources and green house emission gas (CO_2). For this inexpensive and environmental friendly building materials, the scrap merchants should be educated and trained to segregate different types of waste to be used for the construction industries. Cement manufacturing industries can buy the waste materials from these vendors which they want to incorporate and substitute in their manufacture process. The individuals can generate the revenue by selling these waste materials for construction industries and save the global warming.

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