A review on fly ash as a sustainable material to reinforce the mechanical properties of concrete

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Abstract: Fly ash is a fine powder produced by coal combustion in thermal energy plants before the release of gas into the atmosphere. This industrial by-product may be below the standard building materials, but it is advantageous to good performance because of its low cost. This study reviews the literature to investigate the properties and improvement of fly ash/fibre as a concrete substitute compared to fibre, silica fumes, cocoon fibres and other agents. Furthermore, because fly ash is widely considered as a concrete pozzolan, it will open the way for more sustainable solid waste management through industrial waste and sustainable materials combined with organically available plant materials such as cocoa and rice husk.

Keywords: concrete; coconut fibre; fly ash; moisture content; sustainable concrete.

Reference to this paper should be made as follows: Mohamed, A., Doaemo, W. and Muduli, K. (2022) 'A review on fly ash as a sustainable material to reinforce the mechanical properties of concrete', *Int. J. Materials Engineering Innovation*, Vol. 13, No. 1, pp.58–72.

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1 Introduction

Concrete, which can be made of cement, sand, or gravel, in addition to water, blends, and enhancing agents, is an essential material in construction. However, the cement industry makes a significant contribution to both air pollution and carbon dioxide emissions (Ahdaya and Imqam, 2019). Minerals (e.g., concrete or steel) and synthetic fibres are the raw materials most commonly used (e.g., glass or plastic). Increasing environmental concerns regarding pollution and greenhouse gas emissions have resulted in the encouragement of environmentally friendly alternatives; to reduce the carbon footprint of building materials (Ahmaruzzaman, 2010). Consequently, over the last several decades, concrete has become the focus of research in an attempt to find appropriate alternatives to the environmentally unfriendly cement. Research indicates that in the middle of the 20th century, fly ash was used to cut solid waste produced by coal combustion (Ali, 2011).

Fly ash is a fine powder, which is produced as a carbon gas by-product within thermal power plants. It is captured within chimneys by electrostatic precipitators and other particulate-filtering devices before CO_2 emissions are released into the atmosphere. It is estimated that thermal energy waste reaches approximately 600 million tonnes worldwide; with 75%–80% of fly ash being disposed of, or recycled on land or forests (American Coal Ash Association, 2003). Concrete fly ash improves plastic concrete workability, strength, and durability, whilst reducing hydration and CO_2 emissions (Godwin, 2018). Fly ash can be described as grey, colourful, abrasive and predominantly alkaline (Ardanuy et al., 2015). It is a fine Earth ash, made up of silica and aluminium, which can cement materials in the presence of water. The addition of lime and water to fly ash produced a compound similar to 'Portland' cement. In Portland, pozzolana cement, fly ash can be used as an alternative to pozzolan. These additions turn fly ash into a vital substitute in mixed cement, mosaic tiles, hollow buildings, and other building materials that require for Portland cement (PC) (Behera, 2010). In early research and applications, the replacement of dams using up to 70% fly ash, and advanced technology which used up to 50% fly ash has been demonstrated (Behera, 2010).

Fly ash is classified using Class F and Class C. Burning anthracite or bituminous carbon typically produces Class F fly ash, whilst burning sub-bituminous coal lignite normally produces Class C fly ash (Behera, 2010). Class F fly ash generally contains a small amount of lime, in combination with silica, alumina, and iron (over 70%), usually below 15%. Thus, Class F is more remarkable than Class C (Das and Singh, 2015). Class C fly ash is usually obtained from coal, which can produce 15%–30% fly ash. The higher lime content and the prevalence of calcium oxide make Class C fly ash more unique.

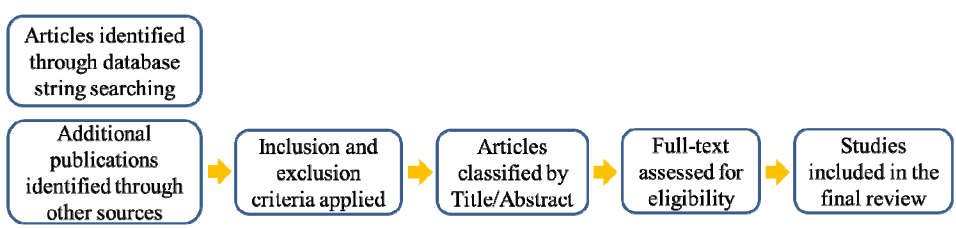
Whilst fly ash has been thoroughly examined as a cement substitute – giving both strength and unique consistency to concrete-, finding alternatives to commonly used fibre refinement materials is also crucial. The most used fibre materials are glass fibres, plastic, asbestos and steel fibres. Further, the concrete and steel-making minerals such as aluminium and copper are used together with synthetic fibres produced from glass and plastic to produce raw materials or other products.

Increasing sustainability concerns have led to investigations into alternative reinforcement materials, which are needed to provide additional refurbishment of fly ash concrete, as the physical characteristics of fly ash are limited. It has been found that organic plant-based materials, such as cocoa, rice husk and arca leashes, are appropriate reinforcing materials (Drochytka et al., 2019). These organic fibres can also come from the local sector, and are therefore more easily accessible and cost less (Ganiron et al., 2017).

This research aims to combine these waste products as commodities like coconut husk, fly ash and beetle nut in concrete production.

During the research period, more than 50 papers were reviewed. To do this, several research platforms were used, including Google Scholar, Semantic Scholar and Elsevier articles in conventional academic literature, and the newly developed AI-supported search tool (Figure 1). Additionally, the study included high-quality articles from other resource sources (Figure 1). The criteria of inclusion and exclusion according to the importance of the specific productions were applied after collection elements on fly ash and organic strengthening.

Figure 1 The illustration shows the evaluation process for review articles (see online version for colours)



This literary review is a structured way of collecting and analysing past studies; methodical, efficient, and successful reviews provide more information on a particular problem (Hoffman, 2005). This fly ash test literature was prepared, and afterwards compared to other substances such as fibres, silica, coconut fibre, etc.

A literature review of fly ash adsorption includes many studies of the individual pollutants in either in an aqueous solution or flue gas. For example, the results from industrial wastewater are satisfactory. In addition, several articles from science journals were used (Jeon, 2018; Kanojia and Jain, 2017; Kayali, 2004) to bring further knowledge of the properties of fly ash to this study. While the literature proposes a number of approaches to achieving the necessary overview of current material around fly ash, including providing context and history, highlighting the relevance of future study and making recommendations.

2 Literature review

2.1 Ash and fly ash

According to the reviewed literature (Kayali, 2004), ash is simply the total amount of the mineral content of the feed. To measure the ash content of forage or total mixed ration (TMR), the forage or TMR is burned at 500°C for two hours, after the inorganic materials, or residual materials, are determined. The minerals found within foods can be divided into two general categories, endogenous and exogenous:

a The endogenous minerals contained within plants include calcium, phosphorus, potassium and magnesium. Many endogenous minerals have the nutritional value needed to increase calcium content, and thus reduce supplementation costs of lactating milk cows.

b Exogenous minerals are external elements of the plant. Exogenous minerals are mostly soil-related minerals (for example, silica), and soil contamination of forages and rations should be minimal. This category would also be included in TMRs, the third category of ash, and additional minerals like salt and tampon.

Whether endogenous, exogenous, or supplementary minerals, the total ash produced is not readily identifiable; all of this adds to the minerals in a feed. This can be found in the following four types of ash:

a coal ash is the residual collection produced in the course of the combustion of coal

b fly ash is light carbon ash which floats into waste piles

c lower ash, which found on the bottom of a boiler and contains the heavier section of carbon ash

d charcoal ash, which is derived from the melting of boiler ash.

2.2 Applications for fly ash

There are numerous fly ash applications:

a as a replacement in the production of PC

b as a substitute for clay fly ash bricks

c fly ash pellets can substitute the average aggregate in concrete mix

d within structural banks and other fillers (usually road construction)

e soft ground stabilisation

f the building of road sub-bases

g asphalt concrete mineral filler.

2.3 Nature of fly ash

Fly ash is a by-product of pulverised carbon burning used for coal-fired power plant power generation. The unburned residual is obtained after the coal is ground at 75% or higher and removed from the thermal zone. Fly ash is determined by its source, grade, and composition; usually consisting of 10%–40.0% incinerators such as clay, shale, quartz, Feld spatula, dolomite and Calestone (Khan and Ali, 2019; Mason, 2003; Mittal et al., 2005; Pereira, 2013). Fly ash is non-fuel impurities, which are carried by the flue gas after the volatile matter and carbon, have been completely burnt in a furnace at a high temperature. Fly ash is collected from both the top and bottom of the furnace. The upper flue gas stream is managed through mechanical and electrostatic separators, collecting fly ash. Whilst simultaneously, fly ash that falls back into the furnace collects at the bottom and is known as lower fly ash.

Today, the world's total production of fly ash is estimated to be around 600 million tonnes (Das and Singh, 2015; Pereira, 2013). The physical properties of fly ash, such as its fine quality, particle size, shape, strength and colour all affect the concrete process (Mason, 2003; Mittal et al., 2005; Pereira, 2013). Whilst, the suitability of fly ash for concrete use depends on the fineness.

2.4 Sustainable concrete industry development

The cement industry is well known for its significant contribution to economic growth in developing countries. However, it also significantly contributes to greenhouse gases (Mittal et al., 2005; Pereira, 2013). As a result, levels of CO_2 are increasing at an alarming rate. Immediate steps must be taken to mitigate increases in temperatures, damage to both the natural environment and the planet. China accounts for approximately 60% of the worlds cement production; in 2014, China produced 2.48 billion tonnes of cement in 2014 (Pereira, 2013; Prusty and Patro, 2015; Public Employees for Environmental Responsibility, 2011; Rajamma, 2009; Rico et al., 2017). This mass production is due to high urban pressure, the economic recovery of industrialised countries and a GDP of 137.4 gr/US dollars.

In making these construction materials, the sustainable development of the cement industry requires the use of waste materials. However, cement substitution by fly ash is helpful because only 25% of this substitution has significant increases in strength of cement substitution by fly ash have significant increases in strength. Both coal and thermal industries face high costs of disposal, whilst fly ash does not, it can be built into the concrete, subsequently saving waste and is thus a sustainable building concrete (Prusty and Patro, 2015; Rajamma, 2009; Rico et al., 2017; Rodriguez, 2019; Roy and Krishna, 2015).

2.5 Toxic substances in fly ash

Fly ash can contain several toxic materials (Rajamma, 2009; Rico et al., 2017). The four most harmful materials are:

a Cadmium, which can also be found in batteries, tinctures and paints, can affect human health by causing cancer and reproductive problems.

b Neurotoxins, which are also found in batteries *via* lead and varnishes, can affect human health by causing reproductive problems.

c Mercury-containing ecotoxins and neurotoxins, these can also be found within batteries, paint and fluorescent lamps, again, they can cause negative reproductive affects in humans.

d Finally, vinyl chloride (PVC) is a plastic compound that has adverse effects on human health through carcinogenic and mutagenic properties.

Additionally, PVC can be used to support the volatilisation of heavy metals in a solid residue thermal process, thus creating increased harmful effects on human and environmental health through contamination by heavy metals (Rico et al., 2017; Rodriguez, 2019; Roy and Krishna, 2015).

Table 1 List of samples study findings of concrete and fly ash

ID	*Author*	*Year*	*Reference*	*Publication type*	*Flyash type*	*Platform*
01	Ahdaya and Imqam	2019	Class C fly ash geopolymer for cementation of oil wells	Journal Articles	Class C	Elsevier
02	Ahmaruzzaman	2010	Review on the use of coconut fly ash: a polyvalent material and its engineering applications	Journal Articles	Fly ash	Elsevier
03	Ardanuy et al.	2015	Fly Ash characterization for efficient use and management	Journal Articles	Cellulosic fibe	Elsevier
4	Jeon et al.	2018	The Class F fly ash with $CaCl_2$ is enabled by rapid chlime (CaO)	Journal Articles	Class F	Elsevier
5	Kanojia and Jain	2017	Coconut shell performance as coarse concrete aggregate	Journal Articles	Coconut shell	Elsevier
6	Khan and Ali	2019	Concrete behaviour improvement with fly ash, silica and coconut fibre	Journal Articles	Fly ash, silica-fume, coconut fibres	Elsevier
7	Pereira	2013	Waste from coal combustion – Everywhere is Coal Ash	Journal Articles	Coconut Fiber	Elsevier
8	Prusty and Patro	2015	Biomass ash characterization and use of cement-based materials	Journal Articles	Agricultural waste	Elsevier
9	Rajamma et al.	2009	Fly ash for road makers	Journal Articles	Biomass fly ash	Elsevier
10	Saloma et al.	2015	Enhancing nanomaterial concrete durability	Journal Articles	Fly ash	Elsevier
11	Shen et al.	2017	China cement industry: driving force, impact on the environment and sustainable development	Journal Articles	Cement industry	Elsevier

Table 1 List of samples study findings of concrete and fly ash (continued)

ID	*Author*	*Year*	*Reference*	*Publication type*	*Flyash type*	*Platform*
12	Snyder	2019	Research methodology literature review: an overview and guidelines	Journal Articles	Cement industry	Elsevier
13	Wang et al.	2014	Mechanism of thermochemical response of plum oxide in thermal treatment with poly (vinyl chloride)'	Journal Articles	Vinyl chloride	Elsevier

During research, the eligibility of the full text was evaluated after the title and abstract were classified, based on the papers most relevant material from comprehensive research and the reliability of the results. It should be noted that some aspects from other sources are included in an advanced area because of their expertise. As shown in Table 1, the details of the literature examined can be found.

3 Methodology

3.1 Moisture content

A silica crust measures the fly ash moisture content by weighing 1 gram of a sample that is thinly powdered (–212 μ) and air. The fly ash is then stowed and heated in a heated electric furnace at 108 ± 20°C for 1.5 hours, before cooling in a dryer and weighing for 15 minutes. Weight loss is recorded as a percentage-specified dry basis humidity content, based on the following formula (Behera, 2010; Sajjala, 2017).

$$\%\text{ moisture content} = \frac{(B-C)*100\%}{(B-A)}$$

A empty crucible wt.

B crucible wt. + coal (before heating)

C crucible wt. + coal (after heating).

3.2 Composition content

Fly ash is mainly comprised of silicon, iron, calcium oxides, sodium, potassium, titanium, sulphur and low magnesium levels. Fly ash is classified mainly into two classes: Class C or Class F, which is determined by its chemical composition in the form of the mineral mix of the concrete.

Class C fly ash generally consists of sub-bituminous coals. Mainly, containing aluminium sulphate, glass of calcium, quartz, lime (calcium oxide) and tricalcium aluminium (CaO). This type of compound is also known as high calcium ash fly, as it tends to contain more than 20% CaO.

Table 2 PCC fly ash specification M295 AASHTO (ASTMC618)

Requirement	*Composition*	*Rate*	*Class F*	*Class C*
Chemical requirements	$SiO_2 + Al_2O_3 + Fe_2O_3$	Max%	70[1]	50
	SiO_3	Max%	5	5
	Moisture Content	Max%	3	3
	Loss on Ignition (LoI)	Max%	5[1]	5[1]
Optional chemical requirements	Available Alkalinity	Max%	1.5	1.5
Physical requirements	Finest (+325 Mesh)	Max%	34	34
	Pozzolanic activity/cement 7 days)	Max%	75	75
	Pozzolanic activity/cement (28 days)	Max%	75	75
	Water requirement	Max%	105	105
	Autoclave expansion	Max%	0.8	0.8
	Uniform requirements[2] : density	Max%	5	5
	Uniformrequirements[2] : Fineness	Max%	5	5
Optional physical requirements	Multiple factors (LOI x fineness)	-	255	-
	Increase in drying shrinkage	Max%	0.03	0.03
	Uniformity requirements: Air entraining agent	Max%	20	20
	Cement/Alkali Reaction: Mortar expansion (14 days)	Max%	0.020	-

Source: Shen et al. (2017) and Snyder (2019)

Class F fly ash usually consist of quartz, mullite and magnetic alumino-silicate carbons and anthracite carbons. Class F is less than 10% calcium oxide; thus, it is known as low volume ash (CaO) (Saloma et al., 2015; Zhang et al., 2021; Shen et al., 2017; Snyder, 2019).

3.3 Concrete with coconut fibre and silica-fumes

The literature on coconut fibre obtained from the husk of the coconut is rather limited. The husk consists of a soft, complex and embedded matrix (Wang et al., 2014; Wang, 2019; Yadav, 2017; Zeb et al., 2019; Nancy, 2010; Lessard, 2016). The fibrous parts are both mechanically and chemically complex, therefore they are widely applied (Mason, 2003; Zeb et al., 2019; Nancy, 2010; Lessard, 2016). In addition, their tensile strength is greater than that of other natural fibres, and their flexibility is excellent, making the material a potential supplement to inorganic cement reinforcement fibres (Wang et al,, 2014; Wang, 2019; Yadav, 2017; Zeb et al., 2019; Nancy, 2010).

In a study performed with coconut shell aggregate (CSAC), the three mixtures used were mixed accordingly and subjected to durability testing:

Mix 1 (M1) CSAC 18.5% coarse aggregate weight replacement

Mix 2 (M2) CSAC replaces 30% cement with fly ash

Mix 3 (M3) CSAC replace 15% cement with blast furnace slag.

The results of tests demonstrated that in comparison to M2 and M3, the M1 mix had the same slowdown, compaction factor, tensile strength divided and compression force as the control mixture.

Another study was conducted based on these findings (Kayali, 2004; Lessard, 2016). The quality of different percentages of cocoa shells was studied in CSAC, and its development showed that the strength of the concrete mix decreased as the cocoa shell rate increased. The study of Mason (2003), Zeb et al. (2019), Nancy (2010) and Lessard (2016), however, found that concrete strength decreased as water absorption increased.

Godwin (2018) talked about the use of a combination of agricultural waste. The 10% arecanut shell ash and 5% cocoon shell, and 5% oil palm shell were the most resistant compared to other combinations, showing comparable strength to standard concrete. The concrete has proven to be reinforced by fly ash and steel in agricultural waste. This study suggests that agriturismo can be used as a possible replacement for various concrete components.

Snyder (2019) found that the toughness of coconut fibres is the highest among the natural fibres. In the design blend consisted of cement, sand, coarse aggregate and water, in a 1:1:2:0.48 ratios. The compression strength was recorded in the design mixture as the cocoon fibre was 20% higher with a 10% increase in split tension.

A further study on the effect of silica and fly ash in reinforced cocoa fibres was performed (CFRC). Four mixtures were produced: PC, CFRC, CFRDSF, and cocoa fibre fly ash horn (CFRFAC). The CFRDSF mixture substituted 10% cement mass with silica fume, and the CFRFAC mixture substituted 10% cement mass with fly ash. The cubes and beams were cast and tested according to the UK standards. The CFRDSF declined by 3.8%; the CFRFAC declined by 8% when compared to the PC decline. CFRDSF and CFRFAC have respectively been improved by 7% and 23%, followed by PC. The mixtures experienced cycles of 14 days in alternate air and seawater environments (ten days of drying and four days of wetting), continuous water dives, and tropical air. The strength was measured by compression and flexicurity parameters, while the durability properties were analysed by the inherent permeability (Wang, 2019), carbonation depth, and chloride penetration tests. In order to determine the workability of the concrete, the gross aggregate must be tested by ASTM Standard C143 and ACI Committee 544.2R. In addition, the ASTM Standard C39 was used to implement elasticity modules, compression strength and crack compression behaviour. For flexure testing, ASTM Standards C1609 and C78 have been adopted. Following experiments (Lessard, 2016), the elastic modulus, compressive strength, and compressive compression of crack behaviour increased with the inclusion of different fly ash levels, i.e., 0%, 5%, 10% and 15% with cemented mass. Also, there is an increase in total energy absorbed by split stress force, 5%, 95% and 26% flexure strength.

3.4 Rice husk ash, reinforced with green coconut fibre in cement matrix

The literature suggests they studied appropriate levels of the effect of using rice husk ash (RHA) rather than PC for the reinforcement of cementitious matrix with green coconut husk fibre (Yadav, 2017; Lessard, 2016). Ash is manufactured by combining the rice husk below 700°C, which is carefully done to make it a primarily amorphous pozzolan that reacts with a Ca^{2+} and an OH^{-} ion soluble alkaline medium in aqueous solutions. The top moisture product of ordinary Portland cement (OPC) is calcium silicate hydrate (CSH). However, highly reactive ash and active silica are mainly non-crystalline silica.

Therefore, a differential thermal analysis (DTA) and thermal gravimetry (TG), for example, are used.

Green cocoa fibres were manually extracted from the scallop and dried at 65°C before being stored at 25°C with a relative moisture content of 30%–90% in a controlled climate chamber, according to the literature. The literature also used the cellulose pulp, and the OPC CEM I 52.5R, as a dewatering agent, due to the retention of the slurry. To determine any mixtures physical and mechanical properties to be evaluated, the author has developed eight specimens (Prusty and Patro, 2015; Lessard, 2016).

Table 3 Proportion of material binding and material strengthening

Materials	*Mix proportions (by mass)*				
	1	*2*	*3*	*4*	*5*
Cement of Portland	1.00	1.00	0.70	0.60	0.50
Husk of rice ash	0.00	0.00	0.30	0.40	0.50
Pulp of cellulose	0.05	0.05	0.05	0.05	0.05
Green fibre of coconut	0.00	0.05	0.05	0.05	0.05
Ratio of water/binding (w/b)	0.40	0.42	0.57	0.61	0.63

Source: Public Employees for Environmental Responsibility (2011), Prusty and Patro (2015) and Lessard (2016)

Universal bending test Instron Model 3382 was carried out on 5 kN Instron cell machine Model 2714-010. In this test, four-point bending test, the mean distances between slabs. The transverse head speed was 1.5 mm/min, and the mechanical characteristics were determined following the fraction modulus and specific energy. After a 70% decrease of the maximum load was observed, the tests were completed. The authors also used Mettler Toledo mode to identify the RHA effects, and the amount of calcium attached to the concrete pasta with a pozzolanic response for the thermogravimetric simultaneous analyser 850 TGA. The author has a cycle of 28 wet days and others for 28 wet days and 28 hot bath days for assessment at 65°C (Prusty and Patro, 2015; Nancy, 2020).

Table 4 Physical characteristics of composite specimens at various ages

Formulations	*Water absorption %*	*Bulk Density (g/cm^3)*	*Apparent porosity %*
	28 days		
1	05.9 ± 2.2	2.0 ± 0.1	11.8 ± 4.7
2	21.2 ± 2.5	1.7 ± 0.1	36.9 ± 2.5
3	22.9 ± 1.1	1.6 ± 0.1	35.6 ± 1.3
4	25.1 ± 1.4	1.5 ± 0.1	37.2 ± 3.1
5	30.5 ± 4.7	1.5 ± 0.1	43.0 ± 3.6
	28 days wet cure and 28 days bath at 65°C		
1	07.8 ± 2.9	1.8 ± 0.1	14.2 ± 4.8
2	11.8 ± 1.5	1.9 ± 0.1	29.9 ± 3.3
3	18.7 ± 2.6	1.8 ± 0.1	32.5 ± 1.9
4	20.1 ± 1.4	1.7 ± 0.1	33.4 ± 1.5
5	19.8 ± 1.8	1.7 ± 0.1	33.1 ± 2.0

Source: Public Employees for Environmental Responsibility (2011), Prusty and Patro (2015) and Lessard (2016)

Following the 28 days of evaluation, the author concluded that the mechanical properties of specimen use of fibre in strengthening cement-fibre concrete production could be promising. The author also concluded that the high and low density of bulk results in higher absorption and porosity.

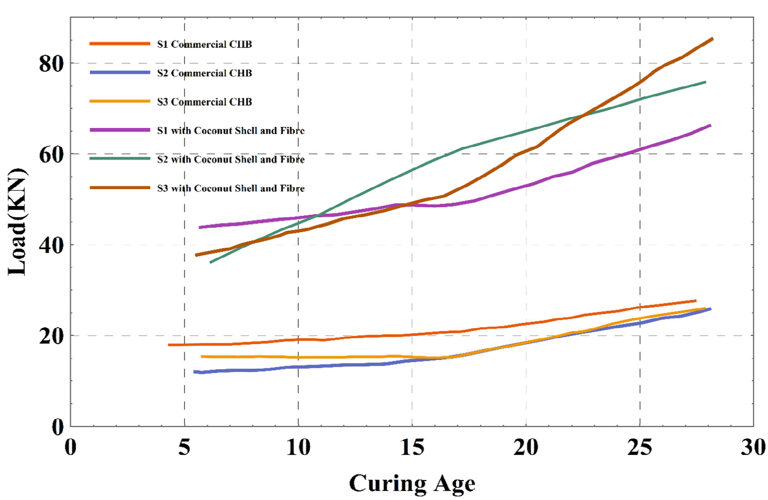
3.5 *Waste coconut shells for concrete mixture recycling*

Coconut is a multifunctional plant; it can use every part of the tree to make it environmentally friendly, right from the fruit to the tree roots. Many types of research are therefore underway on the use of coconut trees for sustainable living. For example, it is estimated that the substitution of synthetic polyester fibres for coconut husk, known as coir, reduces petroleum consumption by two to four million barrels and emissions of CO_2 of 450,000 tons per annum.

The authors presented the algorithm diagram for product development from the cocoon shell in this article. "Here, the material gathered is wet; it will undergo a drying process, which is in a controlled environment. Shells are crushed, and fibers are stripped from coconut husk. After crushing and taking out fibers, there will be an inspection of the material so that it does not get adulterate with other material." The physical property can be observed using sieve analysis if a standard is confirmed. A hollow sample of concrete block was made by blending crushed cocoa shells and fibre, sand and cement. The blend is filled in 4 inches of hollow concrete blocks.

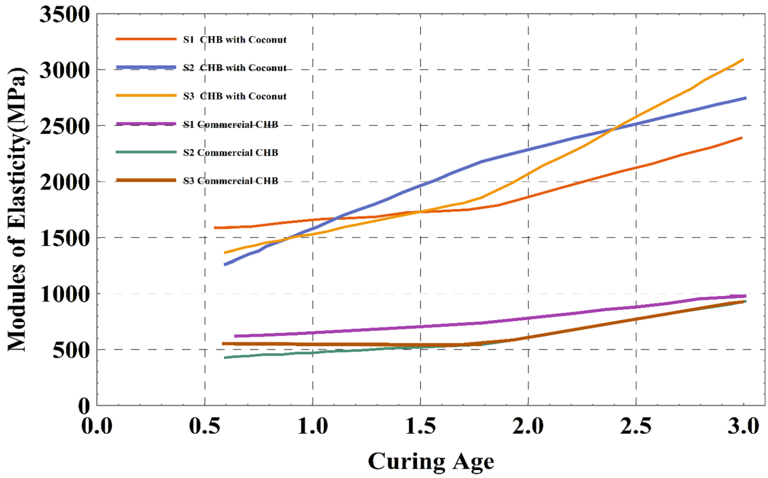
The next phase will be the curing age are 5, 15 and 30-day at treatment of the specimen. The load of 20 N and 40 N is desired at that speed at different sliding distances because the experiment shows that the cocoon shell specimen's average charge capacity is at least 2.5 times higher and further improved by the age of curing at these two load capacities. The sample will then be tested for compressive strength, humidity, and absorption in laboratories (Nancy, 2010; Lessard, 2016).

Figure 2 Average load 20 and 40 kN of commercial concrete hollow blocks (CHB) with coconut and fibre after 5, 15 and 25 days (see online version for colours)



Source: Ganiron et al. (2017)

Figure 3 Average modulus of elasticity after 5th 15th and 30th days of curing age average elasticity modulus (see online version for colours)



Source: Ganiron et al. (2017)

As can be seen in Figure 2 shows that the cocoon shell specimen's average charge capacity is at least 2.5 times higher and further improved by the age of curing.

The elasticity modulus has a similar trend (Figure 3). Furthermore, the literature reveals that the amount of extra concrete and coconut shell, as well as the quality of the fibre, are improved as a potential replacement for inorganic fibres.

3.6 Cementitious material of areca nut ash

The seed of the areca palm fruit is the areca nut (betel nut). The common names, preparations, and ingredients of the areca nut depend on its use and the culture. The authors also processed, cleaned, and dried out the husks with water in the furnace of 10°C/min, up to 700°C six hours to remove volatile waste. The authors also have used ash in cement making. The ash cooled down to room temperature after the burning process and is held in a tight chamber for a halt to pre-hydration after cooling. Areca nut husk ash (ANHA) and OPC have been tested in five samples, gives that relation as illustrated in Table 5 (Das and Singh, 2015; University of Dundee, 2015).

Table 5 Mortar mixed ratio

Sample ID	*Blending Ratio (wt. %)*
A00	100% OPC + 0% ANA
A10	100% OPC + 10% ANA
A15	100% OPC + 15% ANA
A20	100% OPC + 20% ANA
A25	100% OPC + 25% ANA

Source: Das and Singh (2015) and University of Dundee (2015)

It can be concluded that the mechanical and sustainable properties of areca nut ash (ANA) are an outstanding alternative and reduce production costs. When the settling time is increased, the literature generally shows that the setting time increases as well, which can be helpful in some situations (Lessard, 2016; University of Dundee, 2019; Rajabipour, 2019; Roshani et al., 2021).

Fly ash is a rich resource that has to be researched to make it easier to apply it to new and inventive areas of commercial interest.

This review was created to serve as a stepping stone for aspiring researchers interested in the exciting field of fly ash.

4 Conclusions

This review study examines the use of fly ash and its qualities compared to ordinary concrete, based on recent studies emphasising the benefits of fly ash over conventional concrete. The study found that cement fly ash is a good substitute to the standard PC due to its binding properties. In addition, the use of cocoa fibres and cocoa covers in cement or concrete production increased the strength of the cement mixture and made the mortar more durable. In experiments with PC, there can be some disadvantages since the right equipment is needed to achieve the desired result, and this equipment can be too costly most of the time. The equipment requires specific operational skills and which also thus increases the overall cost of cement.

Natural resources such as coconut shells and betel nut ash, which do not require much equipment or expertise, can be used as reinforcement fibre. Therefore, we can use cocoa shells to improve cement quality that enhances their elasticity and fibre, improves the cement mix's compressive strength, and boosts the cost of flying ash. With these three different proportions of ingredients, with test and error, the recycling of waste materials makes cementitious concrete possible at a low cost.

This review paper will assist researchers, in the beginning, in investigating sustainable ash to enhance properties of concrete without compromising national concrete standards, paving the path for a new revolution in fly ash utilisation that will result in a greener society and long-term development. Further, these study routes would lead to more excellent knowledge of the concrete materials sectors' potential benefits. The authors plan to expand this work into an experimental research study based on this present review.

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