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Significance of Waste Materials in Sustainable Concrete andSustainable Development

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Abstract. The relevance and use of waste materials, such as slag, rice husk ash (RHA), palm oil fuel ash (POFA), and fly ash (FA), as a cement additive and concrete ingredient for the creation of sustainable concrete as well as sustainable development have been reviewed critically in this study. Below are also noted the advantages of using additional waste materials in cement and concrete. The proper use of waste materials as a substitute for cement and a component of concrete, however, will be a valuable and effective way to produce sustainable concrete as well as sustainable development for the comfort and continued existence of the current and future generations on the planet. This conclusion is based on the information from published literatures.

Keywords: waste materials (slag, FA, RHA, POFA), sustainable concrete, energy, CO_2 emission

1. Introduction

It is well known that sustainable development, one of the most crucial issues facing the world today, entails designing our communities so that we can all live comfortably without using up all of our resources. We have an impact on the environment through the way we live our lives, which has an effect on the environment. Demands for clean water, clean air, waste disposal, safe and quick transportation of people and products, residential and commercial buildings, and energy sources are all rising progressively to meet the needs of human life. In fact, it is widely acknowledged by all parties involved that concrete fulfils significant roles in the development of contemporary infrastructure, industrialization, and urbanisation for the world's expanding population. In addition, it's important to note that the concrete sector currently consumes the most natural resources, including water, sand, gravel, and crushed rock. Due to these factors, sustainable concrete is one of the hottest topics in the global concrete industry. Its primary goals are to reduce the amount of polluting and carbon dioxide (CO2) gases released during the production of concrete, increase the efficiency of the use of waste materials, develop low-energy, long-lasting, flexible buildings and structures, and take advantage of concrete's thermal mass to lower energy demands. Ordinary Portland Cement (OPC), the second most used substance after water, is now a crucial component in the creation of concrete for use in contemporary infrastructure. Unsurprisingly, roughly 7% of the CO2 produced worldwide is emitted into the atmosphere as a result of OPC production alone [1]; as a result, global warming is getting worse by the day. Burning OPC clinker at a temperature of about 14000°C results in CO2 emissions, but it also uses up a lot of fossil fuels. Researchers, engineers, and all companies involved in concrete technology would have a specific responsibility and alternative approach to tackling issues. Therefore, by properly utilising waste materials (slag, RHA, POFA, FA, ash from timber, silica fume, etc.) as an ingredient of cement or constituent of concrete, as suggested by numerous researchers, all of these problems, particularly in the concrete sector, could be solved/minimized simultaneously. As a result, this study has focused on the importance and necessity of using these waste materials in the production of sustainable concrete as well as sustainable development.

Nowadays, the demands and consumptions of goods from every sector (e.g. industrial, agricultural) are increasing due to the increasing population whole over the world. As a results, huge quantity of various types of wastes are also been generated from those sectors as a by-products. Among the different types of waste in the world, only the author's interested waste (slag, RHA, POFA, FA, silica fume) generation view is presented in Table1. Slag is a by-product from still mills; fly ash (FA), the waste generated from coal operated power plant, silica fume is mainly generated from silicon industries; rice husk is the outer covering of paddy, generated from rice mills; POFA is produced from the palm oil fuel mills. These waste generation trends are increasing gradually due to the increasing demand in various industrial and agricultural sectors. Owing the technical advantages of RHA, unfortunately, only a little fraction of these RHA are being used for different purpose such as heat producing in the rice processing mills as alternative of fuel but most of them are dumped as garbage. Although, a few quantities of rice husks are being used as animal's and fish food. As seen from Table 1, there is no exact statistics of consumption of these wastes, only a small portion of these wastes is consumed for different purposes. Although these waste bears valuable and technical merits, but these are simply dumped into ponds, lagoons or as disposed as landfills. However, all of these waste are contain high percent of silica; consequently, more suggestions have been come out from various researchers to use these as supplement of cement of as ingredient of concrete. How their contribution enhanced the properties of concrete as well as in sustainable concrete that is explained in following section.

Table1: Production and consumption of various wastes

Name of wastes	Production source	Quantity (million ton)	Consumption (million ton)	Reference
Slag	Steel industries	100.00	35	[2]
FA	Coal operated power plant	900.00	*	[3]
POFA	Palm oil mills	More than thousand ton	*	[4]
Rice husk	Rice processing mills	110.00 (@ 20% from 550 million ton rice)	*	[5]
RHA		16.50 to 22.00	*	
Silica fume	Silicon industries	2.00	*	[3]

*Few portion (not exactly specified)

2. Benefits of Waste Materials as Cement Replacement

Waste materials when processed properly could be used as valuable engineering materials and could also be satisfy the design requirements. In this connection, the following examples are pointed out. For producing high-strength concrete, POFA can be used as a pozzolanic material; it improves the durability and reduces cost due to less use of cement. It will also be beneficial for the environment with respect to reducing the waste disposal volume of landfills. POFA contains the silica oxide that can react with calcium hydroxide ($Ca(OH)_2$) generated from the hydration process; and the pozzolanic reactions produce more secondary calcium silicate hydrate (C-S-H) gel compound as well as reducing the amount of calcium hydroxide. Thus, for the concrete production, POFA contributes to make stronger, denser and more durable concrete. POFA, RHA and fly ash (FA) can be used as pozzolans to replace part of Portland cement in making mortar with relatively high strength and good resistance to chloride penetration [6]. These wastes are abundantly available in Malaysia and have been proved as pozzolanic materials [7]. Ground POFA with high fineness can be used as a cement replacement to produce high-strength concrete with a compressive strength as high as 70 MPa at 90 days when used to replace Type I Portland cement at 20% by weight of binder [8]. Hale et al. [9] found that replacements rates of 15% for fly ash and 25% for slag cement improved long term concrete properties without much sacrifice in early age properties. RHA has been used in lime pozzolana mixes and could be a suitable partly replacement for Portland cement [10-12]. Ground POFA is a good pozzolanic material and can be used to increase both the compressive strength and the sulfate resistance of mortar [13]. Pozzolans from industrial and agricultural by-products such as FA and RHA are receiving more attention now since their uses generally improve the properties of the blended cement concrete, and reduce the cost and negative environmental effects [14]. The 28-day compressive strengths of the saw dust ash (timber ash)/OPC concretes at 5%, 10% and 15% of levels of replacement of cement are about 93%, 78% and 68% of the control mix, respectively [15]. Haque [16] suggested that the proper use of the fine FA can produce both high strength and high performance concrete. Quaternary blended cement (RPTS cement) with replacement of OPC up to 66% can be used for the production of high strength (100 MPa-120 MPa) sustainable high performance concrete [17]. Slag is commonly used in concrete because it improves durability and reduces porosity; improve the interface with the aggregate; lower cement requirement; save energy; and good performance as well as better engineering properties [18]. In addition, several other advantages of these wastes have been given below:

- RHA can be incorporated either as an admixture or as cement replacement material [19].
- Slags have been used as aggregates for road construction, about 97% of the produced steel slag have used during construction of surface layer, road base and sub base for high tracked roads in Germany in 1998 [20].
- With high fineness, POFA can be used as a cement replacement to produce high-strength concrete; it also reduces the water permeability of concrete [8].
- POFA can be used as a cement replacement to produce good resistance against sulfate attack [21-22].
- RHA Improves compressive strength [23-25], flexural strengths of concrete [26-27]; and split tensile strength of concrete [28-30].
- RHA mixed concrete shows better bond strength compare to OPC concrete [25]; [29].

3. Necessity and Possible Ways of Sustainable Construction

As we know, cement and concrete industries is the third energy consumer after aluminium and steel [2]. Besides, huge amount of natural stones, sand, and water is being consuming by the concrete construction. It could be noted that about 850 to 900 kcal/kg (in the dry process), and 1300-1600 kcal/kg (in the wet process) heat energy is required in cement production [31]. However, the global average electricity consumption is approximately 111 kWh per ton of cement production [32]. The embodied energy requirement is nearly 817,600 BTU per ton of concrete production, from which maximum (94%) is comes from cement manufacturing [33]. As a result, natural resources and energies (fuel or electrical) are depleting gradually. Thus, it is great warning for us as well as the future generation for the preservation of the natural resources and energies. Therefore, it is the optimum time to find an alternative way of concrete production or to search another sustainable binder that can be used as supplement of cement for the sustainable concrete production; more amounts of wastes consumption in cement and concrete manufacturing could be another solution. Because, consumption of wastes in cement and concrete production could be reduced the energy demand as well as reduced the CO_2 emission rate. For example, 1587kWh/ton energy is required for CEM I (without slag), but the requirement is 1206 kWh/ton, 938 kWh/ton and 602 kWh/ton for the addition of 30%, 50% and 75% slag respectively [34]. Besides, 300 million tons of CO_2 could be reduced by replacing only 18.5% of the cement with slag or fly ash per year in the world [35]. Furthermore, we all the concerns in concrete construction have the responsibilities to preserve our natural resources and prevent the CO_2 emission by utilizing more wastes in cement and concrete manufacturing to achieve the sustainable concrete as well as sustainable development. In addition, awareness regarding sustainable construction and sustainable development could spread out among the designer, developer, proprietor and the general public in the society.

4. Concluding Remarks

In fact, to survive in the global community, production would be continued from various sectors, consequently, waste must be generated from those sectors as well. Thus, searching a sustainable as well as less energy demanded production technology from different sectors, including cement and concrete construction, could be investigated. Additionally, waste consumption policy could also be applied in large scale as a part of sustainable concrete construction. The goal of sustainable construction and sustainable development could be achieved by consuming wastes in cement and as an ingredient of concrete as prescribed by several researchers, because, incorporation of wastes in cement and concrete not only reduce the CO_2 emission but also improve the strength and durability properties of concrete; production cost of concrete would also been reduced. Furthermore, proper utilization and consumption of waste is valid, logical and significant issue to reach the sustainable world for the future inhabitants.

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