Construction and Building Materials 38 (2013) 161–172

Contents lists available at SciVerse ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Review

Utilization of oil palm kernel shell as lightweight aggregate in concrete – A review

U. Johnson Alengaram *, Baig Abdullah Al Muhit, Mohd Zamin bin Jumaat

Department of Civil Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

HIGHLIGHTS

- Seventy-four recent and past papers have been reviewed on oil palm kernel shell concrete (OPKSC).
- Physical, mechanical, durability, functional and structural behaviors of OPKSC reviewed.
- Data of past 28 years on OPKSC are tabulated for reference.
- Properties of lightweight concrete (LWC) compared with OPKSC.
- Discussion on very recent paper on foam concrete with OPKS included.

ARTICLE INFO

Article history:
Received 16 October 2011
Received in revised form 25 July 2012
Accepted 11 August 2012
Available online 21 September 2012

Keywords:
Oil palm kernel shell
Lightweight aggregate
Mechanical properties
Structural behavior
Functional properties

ABSTRACT

This paper reviews previous research carried out on the use of oil palm kernel shell (OPKS) as lightweight aggregate (LWA). OPKS is a waste material obtained during the extraction of palm oil by crushing of the palm nut in the palm oil mills. It is one of the most abundantly produced waste materials in South East Asia and Africa; OPKS has been experimented in research as lightweight aggregates (LWAs) to produce lightweight concrete (LWC) since 1984 and today there are many researchers working in this area. In this paper the physical and mechanical properties of OPKS are summarized along with mechanical, durability and functional properties and structural behavior of OPKS concrete (OPKSC). Recent papers on foamed and fiber reinforced OPKSC are also included. It is seen from the results that OPKSC has comparable mechanical properties and structural behavior to normal weight concrete (NWC). Recent investigation on the use of crushed OPKS shows that OPKSC can be produced to medium and high strength concrete. Sustainability issues combined with higher ductility and aggregate interlock characteristics of OPKSC compared to NCW has resulted in many researchers conducting further investigation on the use of OPKS as LWA.

Contents

* Corresponding author. Tel.: +60 379677632.
E-mail address: ujohnrose@yahoo.com (U.J. Alengaram).

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http://dx.doi.org/10.1016/j.conbuildmat.2012.08.026

1. Introduction

The high demand for concrete in construction using normal weight aggregates (NWAs), such as gravel and granite, has drastically reduced natural stone deposits and this has caused irreparable damage to our environment. As a result, the emphasis on sustainable materials has intensified recently. The growing need for sustainable development has motivated researchers to focus their investigation on the use of waste or recycled materials into potential construction material. Lightweight aggregates (LWAs) from industrial waste materials such as fly ash, expanded slag cinder, and bed ash has led for sustainable materials. However, the lack of production techniques in developing and underdeveloped countries has not brought much advantage to them. A substantial amount of cost can be reduced if the weight of the structure is decreased. LWA had been in use for a long period of time in developed countries and it proved cost effective. It served the purpose of both the structural stability and economic viability. The lower the weight, the more versatile are the structures. Since 2nd A.D. different types of LWA such as clinker, foamed slag, and expanded clay has been used as construction material [1]. Recently, because of growing environmental concerns, waste materials are being used as aggregates for construction [2]. During the last 27 years, oil palm shell (OPS) or palm kernel shell (PKS), has been used by researchers as LWA to replace conventional NWA in structural elements and road construction [3–6] in Africa and Southeast Asia. For simplicity, oil palm kernel shell, abbreviated as OPKS is used to represent OPS or PKS in this paper. OPKS is one kind of organic aggregate with better impact resistance compared to NWA. Numerous articles on the physical, mechanical, structural and functional properties using OPKS as LWA have been published.

OPKS is a waste product at the time of extracting oil from oil palm tree [3,7]. Oil palm tree, being as in the same genera as Coconut palm tree, shares many features with it. Its scientific name is Elaeis guineensis and is found mainly in East Africa [8]. Previously, cultivation of oil palm tree was remained secluded in the East Africa because trace of oil palm tree have been found in the era of Pharaohs some 5000 years ago but now-a-days, its cultivation is focused in South East Asia, in countries such as Malaysia and Indonesia. Olanipekun et al. [9] reported that oil palm trees can be found in large quantities in America, Asia and Africa, especially in Nigeria. Malaysia alone produces 52.8% of the total production of palm oil and Malaysia and Indonesia produce about 80% of the total palm oil of the world. Furthermore, these two countries export about 90% of the total palm oil produced altogether. There are two kinds of oil in palm nut; one is palm oil, which remain in outer core of the nut and the other is palm kernel oil which is extracted from the inner core, known as palm kernel. Palm kernel is covered by a hard endocarp which is called palm kernel shell and is alternatively known as oil palm shell [8,9]. However, the term oil palm kernel shell is also adopted by the researchers to avoid confusion and unnecessary debate.

Malaysia produces 4 million tons of OPKS annually [3,4,10–14] and according to Ramli [11] nearly 5 million hectare (ha) of palm oil trees are expected by the year 2020. Being the second largest palm oil producing country in the world, Malaysia is also responsible for producing a large amount of palm oil wastes. To preserve the environment, researchers have taken initiative to utilize OPKS as LWA [2,13,15]. Proposals were made to substitute OPKS as road based materials instead of asphalt on various occasions [6,7,9,15,16]. Teo et al. [4,15] used OPKS as LWA to build a one-storey building and a foot bridge which are being monitored for their structural behavior. OPKS is also used as granular filter material for water treatment [9,17], floor roofing and road based material [15]. Okpala [3] reported the thermal conductivity of 0.19 $W\,m^{-1}\,K^{-1}$ for OPKS which is much lower than the value of 1.4 $W\,m^{-1}\,K^{-1}$ for conventional stone aggregate. Thus the lightweight concrete (LWC) made with OPKS having low thermal conductivity and high insulation capacity may result in low energy consumption and greener environment. Recently, attempts have been made to incorporate OPKS as a substitute for poor lateritic soil. But the result shows that the composite mix of OPKS