EFFECT OF MIX RATIO AND CURING WATER ON THE COMPRESSIVE STRENGTH OF OIL PALM SHELL (OPS) AGGREGATE CONCRETE

BY

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JANUARY, 2016

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BY

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES
AHMADU BELLO UNIVERSITY,
ZARIA-NIGERIA

IN PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE (M.Sc) DEGREE IN CIVIL ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING
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AHMADU BELLO UNIVERSITY,
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JANUARY, 2016

DECLARATION

I hereby declare that this dissertation has been composed by me and that it is a record of my own research work. This has not been accepted in any previous application for a degree anywhere. However, as it is required by research laws and ethics, all sources of information are specifically acknowledged by means of references.

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Name of student	Signature	Date

CERTIFICATION

This dissertation entitled "EFFECT OF MIX RATIO AND CURING WATER ON THE COMPRESSIVE STRENGTH OF OIL PALM SHELL (OPS) AGGREGATE CONCRETE" by Abdullahi Saidu, meets the requirement governing the award of the degree of Master of Science (Civil Engineering) of the Department of Civil Engineering, Ahmadu Bello University Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to my beloved parents Alhaji Abdullahi Saidu Mai-Kada and Hajiya Rabi Iliyasu. My lovely wife; Mrs. Halima Idris, and My lovely Children (Aisha, Waheedah, Abdullahi, Khadija, Al-Ameen and Hafsat)

ACKNOWLEDGMENT

I offer my profound gratitude to Allah, the most beneficent and merciful, to whom all the praises should be upon, for sparing my life and making it possible for me to see this very important time. The presentation of this thesis has become possible due to the guidance of the following people whose assistance and direction I very much appreciate and therefore acknowledged.

Foremost is my main supervisor, the Head of Department; Engr. Dr. Y.D. Amartey, who spent hours of his valuable time going through this work and guiding me to completion time. Engr. Dr. A. Ocholi, Member Supervisory Committee, Engr. (Dr.) J.M. Kaura also contributed in no small measure particularly during the development of this research and successful completion. I will also never forget with the wonderful contribution given by Engr .A.A. Murana. May the almighty Allah (S.W.A) reward you all. My former employer: Alhaji Buba of Zukhruf Nigeria Ltd Abuja, and the present one: Urban Shelter Infrastructure Ltd Abuja, will never be forgotten for their understanding and patience during my study.

I am also indebted to Engr. (Prof) S.P. Ejeh, Engr. (Prof) K.J. Osinubi, Engr. (Dr.) O.S Abejide, Engr. (Dr) J.A. Sadeeq, Engr. (Dr.) T.S. Ijimdiya, Engr. (Dr.) A.O Eberemu, Engr. J. Ochepo. Engr. H.S Otueze, Engr. B.H. Sada, Engr. A. Lawan, Engr. O.S. David, and other members of staff of the Civil engineering department, Ahmadu Bello University, Zaria who in one way or the other contributed to the success of this thesis. Special regards is due to my Sister Khadija, and my friends Mall. Muhammad Idris, Muhammed Iskeel, Ahmad Kasim, Fadlu Sadal and Kabiru Gombe.

ABSTRACT

In this study, the compressive strengths and Modulus of elasticity of lightweight Concrete with oil palm shells as partial replacement of coarse aggregate was presented. The different types of mixing water were used, namely, clean water from Ahmadu Bello University Water Works, Salt water, obtained from Lagos Shore and Pond water obtained from Nagoye, Zaria. Also three mix ratios were adopted which include 1:2:4, 1:1.5:3 and 1:1:2 mix ratios. Five mixes were investigated; control, which contain granite coarse aggregate only; then four other mixes with 20%, 40%, 60% and 80% granite coarse aggregate replacement by oil palm Shell (OPS) aggregate. Fifteen samples where produced for each mix ratio, given a total of 135 concrete cube specimen for compressive strength tests and another 135 cylinder specimen for cylinder compressive strength tests and another 135 cylinder specimens for indirect tensile test for the determination of modulus of elasticity. In conclusion, after undertaking the laboratory practical's on the OPS using 3 types of water for curing and varying the mix ratios to conform with class M15, M20 and M25, the effect of mix ratio and curing showed a tremendous difference but the use of OPS as a lightweight aggregate material was found to be adequate when compared with other materials being used as lightweight aggregate.

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CHAPTER ONE

INTRODUCTION

1.1 Preamble

Natural resources of the world are drastically dwindling due to the increasing demand of natural aggregate for the construction industry. The frequent use of natural aggregate in some areas led to environmental degradation, and has given impetus to studies and researches for sustainable development by using different waste products in the construction industry. Lightweight aggregates from industrial waste such as fly ash, ground granulated blast furnace slag, bed ash has led to sustainable materials but due to the lack of production techniques, many of the developed and under-developed countries have not been able to use them to their advantage. If the weight of the structure is decreased by using lightweight aggregate in concrete, it will in turn reduce the foundation cost due to reduction in self-weight, which has been convincingly proved in developed countries (Alengaram, 2013). Reddy *et al.,* (2014) stated that the consumption of the primary aggregate was 110 million tonnes in the U.K. during 1960 and reached nearly 275 million tonnes in the year 2006. Similarly 2 billion tones of aggregate are produced each year in the United states and it is expected to increase to more than 2.5 billion tonnes by the year 2020 (Reddy *et al.,* 2014). It has been predicted that the demand for concrete is expected to grow to approximately 18 billion tons a year by 2050. Such heavy demands draw attention and preservation of natural aggregates, which are a matter of grave concern. Since aggregates contribute about 60–80% of the volume of the concrete, effective and efficient use of agricultural waste contributes to energy saving, conservation of natural resources and reduction of the cost of construction materials. Agricultural

wastes in the form of aggregate for concrete production can be considered as one of the environmental benefits and has shown better thermal property with the proven recognition by most of the sustainability rating systems (Shafigh *et al.*, 2014).

Concrete is the most versatile heterogeneous construction material and the impetus of infrastructural development of any nation (Olafusi and Olutoge, 2012). Concrete is a composite inert material comprising of a binder course (e.g. cement), mineral filler (body) or aggregates and water (Oyenuga, 2001). Concrete is one of the oldest manufactured construction materials used in construction of various structures around the world. The cost of concrete and other construction materials in Nigeria is currently so high that the majority of individuals find it difficult to afford, with the exception of Government, Industrial and Business Corporations. There had been calls from several government quarters on means to reduce the cost of Civil Engineering construction works by adopting cheap locally available engineering materials. The Nigerian Building and Road Research Institute (NBRRI) was established in order to fulfill this mandate.

The high demand for concrete in construction industry has resulted to a rapid decrease in natural stone deposit such as the limestone and granite. As a result of escalating environments problem which comes as a result of excessive usage of natural stone deposit, thereby causing ecological imbalance, the need to find and explore an alternative material that could be used as a replacement to the conventional aggregate has become necessary.

Structural lightweight aggregate concrete is an important and versatile material in modern construction. It has many and varied applications including multistory building frames and floors, bridges, offshore oil platforms, and prestressed or precast elements of all types. Many architects, engineers, and contractors recognize the inherent economies and

advantages offered by this material, as evidenced by the many impressive lightweight concrete structures found today throughout the world (ACI 213R-7, 1987). Structural lightweight aggregate concrete solves weight and durability problems in buildings and exposed structures. Lightweight concrete has strengths comparable to normal weight concrete, yet is typically 25% to 35% lighter. Structural lightweight concrete offers design flexibility and substantial cost savings by providing: less dead load, improved seismic structural response, longer spans, better fire ratings, and thinner sections, decreased storey height, smaller size structural members, less reinforcing steel, and lower foundation costs (Oyenuga, 2001).

Oil Palm Shells (OPS) are the crushed outer part of palm kernel nut derived after the extraction of palm oil. Oil Palm Shell (OPS) is the hard endocarp of palm kernel fruit that surround the palm seed. It is obtain as crushed pieces after threshing or crushing to remove the seed which is used in the production of palm kernel oil (Olutoge, 1995). Palm kernel shell are available in large quantities in palm oil producing areas such as Okiti-pupa, Ode-aye farm settlement, Araromi obu rubber and oil plantations, Irele oil plantations all in Ondo State, National Institute for Oil Palm research (NIFOR) and Okomu farms in Edo State and in reasonable quantities in other towns and villages especially in the southern part of Nigeria (Alagbon, 1994). Many varieties of palm exist, which include Dura, Pisifere and Tenera and they are recognized mainly by the thickness of their shell (endocarp) and fibrous oily part (mesocarp) and the fruits. Dura variety has very thick shell and thin fibrous part only. In the Pisifera variety, the shell is almost absent or very tiny, the bulk of the fruit being fibrous mainly produce little or no kernel. The Tenera variety is the hybrid of dura and pisifera. The thickness of the shell and the fibrous part are of medium size (Nwokolo, 1994).

OPS are used for the followings:

i. As a good source of fuel for domestic cooking in most area where they occur, such as Edo State, Cross River State and Anambra State.
ii. They are often dumped as waste products of the palm oil industry.
iii. OPS may be used for making terrazzo.
iv. They are used as fill materials for filling pot holes in muddy areas in some localities.

1.2 Statement of the Problem

In areas where the palm oil is produced in commercial quantities, the OPS can be found in large quantities though it may not completely compete with conventional aggregate but can reduce cost and disposal problems. 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 resulted to degradation of our environment. As a result, the emphasis on sustainable materials has been much 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. For a very long time, different types of LWA such as clinker, foamed slag, and expanded clay has been used as construction material (Chandra and Berntsson, 2003). Recently, because of growing environmental concerns, waste materials are being used as aggregates for construction (Teo *et al.,* 2007). During the last 27 years, oil palm shell (OPS), has been used by researchers as LWA to replace conventional NWA in structural elements and road construction (Okpala, 1990; Teo *et al.,* 2006; Mannan, 2006; Ndoke, 2006). Numerous articles on the physical, mechanical, structural and functional properties using OPS as LWA have been published. Eurocode 2 is based on concrete cylinder strength, BS 8110 is based on cube strength. This study compared the cylinder and cube strength of the OPS concrete, considering various mix ratios, and different types of curing water.

1.3 Justification of the Study

OPS are usually found stockpiled at open spaces in Nigeria which have negative impact on the environment such as breeding spots for mosquitoes. During major rainstorms, some of the palm kernel shells are also carried away by surface water thereby clogging local drains. Currently, there is inadequate supply of fresh high quality aggregates from quarries near metropolitan areas in Nigeria compared to the cost of OPS, which is a waste, the cost of production of crushed aggregates is high due to importation of dynamites with hard currencies. Moreover, the quarrying operations adversely affect the environment in various ways such as:

i. Pollution of water bodies with sediments and industrial oils.
ii. Excessive dusts causing air pollution which trigger respiratory system diseases in the community around.
iii. Noise pollution from blasting and crushing

iv. Increased erosion at the quarry site.

Vibration damage (cracks) to nearby buildings. The high cost of production of aggregates and the environmental concerns have motivate the investigation into the possible use of OPS as partial replacement of coarse aggregate, that is expected to produce lightweight concrete, because OPS is lightweight compared to the conventional aggregate. Lightweight concrete has numerous advantages such as savings on reinforcement, formwork, scaffolding, foundation work, better fire resistance, heat insulation, and sound absorption. Moreover, the use of concrete with a lower density permits construction on grounds with a low load bearing capacity.

1.4 Aim and Objectives

1.4.1 Aim

The aim of this study was to evaluate the cylinder and cube strength of oil palm shell concretes, considering various mix ratios, and different types of curing water.

1.4.2 Objectives

The specific objectives include the following:

i. Perform the preliminary tests on the constituent materials like sieve analysis on the aggregates as well as washing and drying of the oil palm shells (Ordinary Portland Cement, Fine Aggregate, Conventional Coarse Aggregate and the Oil Pail Shells).
ii. Establish the workability of the mixes considered in this study (1:2:4, 1:1.5:3 and 1:1:2).
iii. Perform compressive strength tests, on cylinder and cube samples.

iv. To observe the outer surface of the cylinder and cube test sample on removal of the formworks after 24hours of casting for bondage of the OPS and other aggregates present in the concrete produced.

v. To illustrate on graph the compressive strength trend using various percentage replacement of granite with OPS 20%, 40% 60%, and 80%.

vi. To observed the impact of curing water retained within the pores that exist within the sample being cured.

1.5 Scope of the Research

The study is limited to the investigation of concrete made with Oil Palm Shells as partial replacement for coarse aggregate in lightweight concrete production using clean water, salt water and pound water. It involved tests on the constituent's materials, tests on the fresh and the hardened concrete.

CHAPTER TWO

LITERATURE REVIEW

2.1 Preamble

In many developing and underdeveloped countries in Asia and Africa, the researches on the use of industrial waste materials such as oil palm shell (OPS) as Lightweight Aggregate (LWA) have shown that OPS can be used as potential LWA. Especially, in the agro-based developing countries such as Malaysia and Nigeria, there has been awareness on the utilization of agricultural and industrial wastes into potential construction materials. Abdullah (1984) was the first one to use OPS as LWA in Malaysia and proved that complete replacement of normal weight aggregate (NWA) with OPS is a possibility. In Nigeria, Okafor (1988) conducted further study on using OPS and found out that similar to normal weight concrete (NWC), water to cement (w/c) ratio affects the mechanical properties of palm kernel shell-aggregate concrete. Other researchers (Okpala, 1990; Olanipekun *et al.,* 2006; Mannan and Ganapathy, 2002; Alengaram *et al.,* 2008; Jumaat *et al.,* 2009) investigated physical, mechanical and structural properties of OPS and have shown its behaviour similar to that of NWC. Malaysia is the second largest oil palm exporting countries in the world. The demand for vegetable oil in the international market is on the rise. Every year, palm oil industries produce large volume of OPS as waste material after the production of palm oil. Ramli (2003) stated that nearly 5 million ha of oil palm trees is expected by the year 2020 in Malaysia alone. This will increase the production of both palm oil and its wastes. Normally, the OPS is attained by breaking the palm kernel. They are lightweight, but hard and come in different shapes and sizes. OPS are not fully utilized and it has contributed to pollution. This kind of waste material can be utilized to substitute the conventional coarse aggregate to produce the LWC. Near the

rural area where the palm oil factories are located, OPS can be used to build houses, drain segment etc. to replace the conventional normal weight concrete (NWC). This would pave way for sustainable construction as the depletion of natural resources such as granite or conventionally used coarse aggregates is on the rise. The use of LWC permits greater design flexibility and substantial cost savings, reduce dead load, improved cyclic loading structural response, longer spans, better fire ratings, thinner sections, smaller size structural members, less reinforcing steel and lower the foundation costs. OPS concrete is one of the structural lightweight concretes. From the previous studies done by the other researches, it has been found that the air-dry density of OPSC was found in the range of 1725 to 1900 kg/m^3 (Abdullah, 1984; Okafor, 1988; Mannan and Ganapathy, 2002; Olanipekun *et al.,* 2006; Alengaram *et al.,* 2008; Jumaat *et al.,* 2009).

2.2 The Oil Palm Shells (OPS)

OPS was partially a waste in the 1990s and early 2000 as more than 350,000 tons were available for sale. Prior to 2007, OPS had been a little known then for its potential usage on a large scale especially in concrete work (Mohammad, 2007). Beyond 2000, research into utilization of Palm Kernel Shell as light weight concrete and other uses had received a big boost. Oil Palm Shells (OPS) are organic waste materials obtained from crude palm oil producing factories in Asia and Africa (Alengaram, *et al.,* 2010). The Palm Oil Plant, considering its three different varieties Durà, Pesipherà and Tenerà, produces an edible fruit similar to an apricot which has a nut inside. During the crude palm oil process the fruit's flesh is melted through a steaming treatment. The chemical composition of OPS aggregate is presented in Table 2.1.

Table 2.1 Chemical Composition of OPS Aggregate (Source: Teo *et al.*, 2007)

Elements	**Results (%)**
Ash	1.53
Nitrogen (as N)	0.41
Sulphur (as S)	0.000783
Calcium (as CaO)	0.0765
Magnesium (as MgO)	0.0352
Sodium (as Na_2O)	0.00156
Potassium (as K_2O)	0.00042
Aluminium (as Al_2O_3)	0.130
Iron (as Fe_2O_3)	0.0333
Silica (as SiO_2)	0.0146
Chloride (as Cl)	0.00072
Loss on Ignition	98.5

The residual nuts are further mechanically crushed to extract the seeds or kernels. The Oil Palm Shells (OPS) is a virgin biomass with a high calorific value, typically about 3,800 Kcal/kg (ASTM, 1978). Oil Palm trees grow in the coastal belt in Nigeria which varies in depth from 100 to 150 miles and a riverine belt which follows the valleys of the Niger and Benue for a distance of about 450 miles from the sea. The main palm oil producing states include Ogun, Ondo, Oyo, Edo, Cross River, Anambra, Enugu, Imo, Abia, Ekiti, Akwa-Ibom, Delta and Rivers. Palm kernel shells in the past had been used solely as fuelling material at home and for industries. The quest for alternative civil engineering construction material which is economical and light in weight has been a major drive in carrying out this work. This study will particularly focus on the strength and stiffness of OPS concrete, considering various mix ratios and mixing water. Oil palm shell possesses hard characteristics as coarse aggregate and there have been attempts to use it as a coarse aggregate to replace conventional coarse aggregates traditionally used for concrete production (Mohammed *et al.,* 2008). Ata *et al.,* (2006) compared the mechanical properties of oil palm shell concrete with that of coconut shell concrete and reported the economy of using Oil Palm Shells as lightweight aggregate. Generally, palm kernel shell consists of 60 – 90% of particles in the range of 5 – 12.7mm (Okafor, 1988). The specific gravity of palm kernel shell varies between 1.17 and 1.37, while the maximum thickness of the shell was found to be about 4mm (Okpala, 1990). Oyejobi *et al.*, 2012. The density of palm kernel shell ranges from 1700 to 2050kg/m3 and it depends on factors such as type of sand and palm kernel shell contents (Mohammed *et al.,* 2008). Generally, when the density of concrete is lower than 2000kg/m^3, it is categorized as light weight concrete. Thus, the palm kernel shell concrete can be produced within this target density of 2000kg/m^3, hence palm kernel shell concrete is a light weight concrete. According to

(Mohammed *et al.,* 2008), the 28 days cube compressive strength obtained was 15 – 25MPa while the structural behavior of palm kernel shell is very limited. Ndoke (2006) in his work observed the performance of oil palm shells as partial replacement for coarse aggregate in asphalt cement. According to Teo *et al.,* (2006), for structural concrete using oil palm shell (OPS) as light weight aggregate, the compressive strength of OPS concrete was 28.1MPa at 28days curing which is approximately 65% higher than the minimum required strength of 17MPa for structural light weight concrete recommended by American Standard of Testing Materials (ASTM 1330). Yusuf and Jimoh (2011) worked on the appropriateness of the various nominal mixes of the 'palm kernel shell concrete' as rigid pavement. They evaluated the mixes accordingly at both fresh and matured ages with corresponding costs. They reported that Nigerian OPS satisfies the density criterion for normal concrete and lightweight concrete in all respects while the palm kernel shell concrete at nominal mixes of 1:1.5:3 and 1:1:2 satisfied the specifications for rigid pavement. In addition, the cost of producing OPS concrete/m2 for all levels of traffic and mix proportions is cheaper than those of normal concrete and asphaltic concrete. Saman and Omidreza (2011) reported the influence of oil palm shell on workability and compressive strength of high strength concrete. They noted that the general strength of oil palm shell (OPS) concrete samples produced high strength concrete with compressive strength reaching up to 52.2 N/mm^2 at 28days.

2.3 Mix Design of OPS Concrete

In well-proportioned mixtures, the cement content and strength relationship is fairly constant for a particular source or one type to another. Therefore, trial mixtures with varying cement contents are required to develop a range of compressive strengths, including the strength specified (Kosmatka *et al.,* 2002). Because Oil palm shells are

lighter than the cement matrix, the shells tend to segregate in wet concrete mixes. Abdullah (1996) suggested that trial mixes are necessary to achieve a good mix design. Lightweight concrete mix design is usually established by trial mixes. Mix design methods that apply to normal weight concrete are generally difficult to use with lightweight aggregate concrete (Shetty, 2005). A study for finding a mix design method for OPS lightweight concrete was conducted by Mannan and Ganapathy (2001). They found that the 28-day compressive strength of OPS concrete, designed according to the America concrete institute (ACI) method for conventional concrete, is not suitable for OPS lightweight concrete because the strength is very much less than the targeted design strength. Even with this method and the use of superplasticizer, the strength could not be increased. Furthermore, they followed the mix design method for lightweight aggregate such as Leca, Fumed slag, Aglite and Lytag. However, these methods were not suitable for OPS concrete. They explained that OPS aggregate is a natural organic material with a smooth texture and different shapes. Olanipekun et al. (2006) investigated the effect of crushed, granular coconut and palm kernel shells as substitutes for conventional coarse aggregate in two mix ratios of 1:1:2 and 1:2:4 with a water to cement ratio of 0.75 and 0.50 and a 28-day compressive strength of 35 and 27.5 MPa respectively. They concluded that by using these lightweight aggregates, grades 20 and 15 lightweight concrete can be obtained if the percentage replacement levels of the conventional coarse aggregate with both lightweight aggregates do not exceed 25 and 50% respectively, for both mix ratios tested. Irrespective of other mix proportions of OPS structural lightweight concrete, the OPS content in $1m^3$ for achieving the compressive strength for grades of 20 - 35, ranged from 290 - 450 kg. (Teo *et al.,* 2007; Teo *et al.,* 2006; Mannan and Ganapathy, 2004; Mannan and Ganapathy, 2002; Mannan and Ganapathy, 2001; Mannan *et al.*, 2002; Alengaram *et al.,* 2008). In these researches, the cement content was in the range of 400 -

600 kg/m3. It should be noted that, generally, the cement content in lightweight aggregate concrete varies from the same as normal weight aggregate to 70% more for the same strength of concrete (Neville and Brooks, 2008). According to ACI-213R, for structural lightweight concrete (compressive strength ranges from 17 to 41 MPa) the cement content is in the range of 240 - 500 kg/m^3 (Mehta and Monteiro, 2006).

2.4 Mixing Water

Almost any natural water that is drinkable and has no pronounced taste or odour can be used as mixing water for making concrete. However some waters that are not fit for drinking may be suitable for use in concrete. Water from any of these sources is suitable for making concrete (Rakesh *et al.,* 2014). In Nigeria various sources of water are available in different parts of the country for mixing the concrete. A popular yard-stick (criteria) to the suitability of water for mixing concrete is that, if water is fit for drinking it is fit for making concrete. This does not appear to be a true statement for all condition. Some water containing a small amount of salt would be suitable for drinking but not for mixing concrete and conversely water suitable for making concrete may not necessarily be fit for drinking. Generally water which is available easily on the site such as tap water, bore well water, well water, municipal waste water etc. are directly used for mixing the concrete. Hence in this research work an attempt is made to investigate the effects of different types of water on the compressive strength of the concrete. Three different types water are considered. These are:

i. Clean tap water (water fit for drinking)

ii. Salt water (obtained from sea at Lagos)

iii. Pond water (not fit for drinking)

CHAPTER THREE

METHODOLOGY

3.1 Materials

Procedure

The sample materials to be used include:

i. Clean sharp sand
ii. Granite chippings
iii. Ordinary Portland cement (Dangote Cement)
iv. Clean and dried oil palm shells (OPS)
v. Clean drinkable water

The batching will be made for the mix ratio 1:2:4, 1:1:5:3 and 1:1:2 the concrete produced will be casted into the cylinder mould of 150mm diameter and 300mm height as well as the cube mould of 150mmx150mmx150mm.

After the casting. The moulds will be removed after 24 hours and the sample will be immersed into curing containers in batches. The curing period will be for 7days, 14days 21days and 28 days. The crushing will be done for each of the batches accordingly to obtain the crushing strengths.

Curing Method

For the curing method, when the cylinder and cube samples were removed from the moulds, they will be immersed into the curing water,

The samples made from mix ratio 1:2:4, 1:1:5:3 and 1:1:2 will all be curred in batched for 3days, 7days, 14days, 21 days and 28 days.

The first set of samples produced will be made from 100% granite which is the control mix, followed by 20% replacement, 40% replacement, 60% replacement and 80% replacement.

3.1.1 Aggregates

Crushed granite used for the study was of size 20mm (Plate 3.1), obtained from a stone quarry at Dogarawa, along Kaduna-Kano dual carriageway in Zaria. The palm kernel shells used were sourced from a local palm oil processing factory at Abedo village via Moniya in Akinyele Local Government Area of Ibadan, Oyo State. The shells were flushed with hot water to remove dust and other impurities that could be detrimental to concrete. They were sun-dried and packed in plastic sheets to prevent contact with water.



Plate 3.1: Crushed Granite used in the Study

3.1.2 Oil palm shells (OPS)

The oil palm kernel shells (Plate 3.2) in this study were collected from a local palm oil processing factory at Abedo village via Moniya in Akinyele Local Government Area of Ibadan, Oyo State.



Plate 3.2: Oil Palm Shell Dump (Abedo Village, Oyo State)

3.1.3 Cement

Ordinary Portland cement manufactured by Dangote Cement Factory at Obajana in Kogi State, and conforming to BS 12 (1996) was used in the concrete production.

3.1.4 Mixing water

Natural river sand also obtained from Zaria, was used in producing the concrete. Three types of mixing water were used for the production of the concrete, namely:

i. Clean water from ABU water works.

ii. Salt water obtained from Lagos Sea.

iii. Pond water obtained from a pond at Nagoye, Zaria.

3.2 Preparation of Test Specimens

3.2.1 Mix Ratio and percentage replacement

The proportioning by volume was used in this research. The study utilized three types of cement-aggregate ratios of 1:2:4, 1:1.5:3 and 1:1:2. Water cement ratio of 0.5 was used in all mixes. OPS were used to replace Coarse Aggregate at dosage levels of 0%, 20%, 40% 60% and 80% replacement by total volume of the aggregate.

3.2.2 Preparation of the oil palm shells (OPS)

Oil coating and mud particles normally stick to the surface of fresh OPS. Pretreatment is therefore necessary to remove the impurities. This can be achieved by various methods, including natural weathering, boiling in water and washing with detergent. In this investigation, washing with detergent was adopted. After washing, thorough rinsing was k2done in order to ensure that all particles of detergent were removed as these can lower the cement performance. The OPS was air-dried and then stock piled. Due to the high water absorption of OPS, pre-soaking of the aggregate for about 45min to 1 hour is necessary. Before the OPS was used as aggregate, it was sieved and only aggregates passing through 20mm sieve and retained on the 5mm were used. Particles outside this range have large relative surface areas and high absorption rate.

3.2.3 Production of the concrete test cubes

The concrete test cube were cast at the concrete laboratory of the department of Civil Engineering, Ahmadu Bello University, Zaria. 150mmx150mmx150mm steel moulds were used the specimen are in accordance with BS 1881 (1996). The cubes are shown in Plate 3.3 for each of the three mixing water used (clean water from Ahmadu Bello University, Zaria water works, salt water from Lagos and pond water from Nagoye, Zaria), for each of the three adopted mix ratios (1:2:4, 1:5:3 and 1:1:2), corresponding to M15, M20 and M25 concrete grades respectively. Fifteen (15) test cubes were cast and crushed, for both the control specimen (containing crushed granite aggregate only), and for crushed granite particularly replaced with 20%, 40%, 60% and 80% giving a total of 135 cubes.

All freshly cast specimen were left in the moulds for 24 hours before demoulding and curing. The demoulded cube were then placed in cursing tanks (Plate 3.4) until it was time for crushing test, at the ages of 3,7,14,21 and 212 days.



Plate 3.3: Casting of the Concrete Test Cubes



Plate 3.4: Curing of the Concrete Test Cubes

3.2.4 Production of concrete test cylinders

150mm diameter and 300mm high cast iron moulds were used for casting the cylindrical specimen. The cylinders were cast at the concrete laboratory of Ahmadu Bello University, Zaria based on BS 1881 (1996). Two set sample were produced; for the compressive strength (crushing test) and for the modulus of elasticity tests. (Indirect tensile test).

For each of the three mixing water, and for each of the three adopted mix ratios, fifteen (15) test cylinder each for crushing and modulus of elasticity tests were cast and tested, for both the control specimen and the specimens containing 20%, 40%, 60% and 80% OPS replacement of the crushed granite, given 270 cylinders (135 cylinders for crushing test and 135 cylinders for modulus of elasticity tests).

The specimens were demoulded after 24hours and cured until testing dates of 3, 7, 14, 21 and 28 days (Plate 3.5).



Plate 3.5: Curing of the Concrete Test Cylinders

3.3 Laboratory Tests on the Oil Palm Shells (OPS)

The following tests were performed on the Oil Palm Shells. The tests were conducted at the concrete laboratory of the Department of Civil Engineering, Ahmadu Bello University, Zaria.k2

i. Sieve Analysis
ii. Water Absorption
iii. Aggregate Impact Value k2
iv. Aggregate Abrasion Value
v. Aggregate Crushing
vi. Chemical Analysis

3.3.1 Sieve analysis

The gradation of OPS done using sieve analysis. This was done by passing OPS through a set of standard sieves and cumulative passing percentages were calculated. The total of about 96% of the OPS used as coarse aggregate passed through sieve 16 mm but retained on 5mm. This conformed to the literature, hence OPS are classified as coarse aggregate (BS 882, 2002). Grading of coarse aggregate is necessary in order to get a cohesive and light weight concretek2.

3.3.2 Water absorption

This test assist in the determination of the water absorption of the OPS. For this test 2000g was used. The apparatus used for this test are: Wire basket – performed, electroplated or plastic coated with the wire hangers for suspending it from the balance, Water-tight container, for suspending the basket, dry soft absorbent cloth – 7 5cm x 45cm (2nos.), Shallow tray, of minimum 650 sq.cm area, Air-tight container of a capacity similar to the basket and Oven.

3.3.3 Aggregate impact value

This test was performed on the OPS in order to determine its impact value. The apparatus used for determining aggregate impact value of coarse aggregates is Impact testing machine, BS Sieves of sizes – 12.5mm, 10mm and 2.36mm, A cylindrical metal measure of 75 mm dia, and 50mm depth, a tamping rod of 10mm circular cross section and 230mm length, rounded at one end and Oven.

3.3.4 Aggregate crushing value

This test helps to determine the aggregate crushing value of the OPS. The apparatus used is Cylindrical measure and plunger, Compression testing machine, BS Sieves of sizes – 12.5mm, 10mm and 2.36mm

3.4 Laboratory Tests on the Ordinary Portland Cement (OPS)

Dangote Ordinary Portland Cement, produced at Obajana, in Benue state were used. The cement was subjected to the following laboratory tests in order determine its suitability

i. Consistency.
ii. Initial setting time test

iii. Final setting time test on the Dangote cement (Obajana) to establish its suitability for the mix.

iv. Soundness Test.

3.5 Laboratory Tests on the Fine Aggregate

The following tests were conducted on the fine aggregate used in this study

i. Specific gravity of sand

ii. Silt content of sand

iii. Bulk density of sand.

3.6 Workability Test on the Fresh Concrete

3.6.1 Slump test

The slump test is the most commonly used method. Consistency is a term very closely related to workability. It is a term which describes the state of fresh concrete. It is used for the determination of the consistency of freshly mixed concrete, where the maximum size of the aggregate does not exceed 38 mm. The slump test is suitable for slumps of medium to high workability, slump in the range of 25 – 125 mm; the test fails to determine the difference in workability in stiff mixes which have zero slumps, or for wet mixes that give a collapk2se slump. It refers to the ease with which the concrete flows. It is used to indicate the degree of wetness. Workability of concrete is mainly affected by consistency i.e. wetter mixes will be more workable than drier mixes, but concrete of the same consistency may vary in workability. It is also used to determine consistency

between individual batches. The apparatus used for conducting the slump test consists of slump cone or Abrams cone with handles and foot pieces Plate 3.6. The size of the slump cone is 20-cm diameter base, 10 cm diameter top and 30 cm height. Foot pieces can be fixed to the clamps on the base plate. The base plate has lifting handle for easy transportation. One graduated steel tamping rod 16 mm diameter x 600 mm long rounded at one end graduated in mm. The internal surface of the mould is thoroughly cleaned and free from moisture and adherence of any old set concrete before commencing the test. The mould should be placed on smooth surface. Oil is applying on internal surface of the mould and applies the smooth surface where the mould is placed. The types of slump are as follows.

Collapse: In a collapse slumps the concrete collapses completely.

Shear: In a shear slump the top portion of the concrete shears off and slips sideways.

True: In a true slump the concrete simply subsides, keeping more or less to shape



Plate 3.6: The Slump Test

3.6.2 Compacting factor test

The compacting factor test gives behaviour of the concrete under the action of external forces. If measures the compactability of concrete, by measuring the amount of compaction. This test is suitable for mixes having medium and low workabilities i.e. compaction factor in between 0.91 to 0.81, but is not suitable for concretes with very low workabilities, the compaction factor below 0.71. The apparatus is shown



Plate 3.7: Compacting Factor Test

3.7 Laboratory Tests on the Hardened Concrete

3.7.1 Compressive strength of concrete cubes and cylinders

To obtain the compressive strength of concrete cubes and cylinders Avery Danison universal testing machine (UTM) having capacity of 2500KN was used in the Concrete laboratory, Department of Civil Engineering, Ahmadu Bello University, Zaria, as shown in Plate 3.8. In this test the strength was obtained in KN The measured compressive strength of the specimens shall be calculated by dividing the maximum load applied to the specimen during the test by the cross sectional area calculated from mean dimensions of the section and shall be expressed to the nearest N/mm^2. Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. The specimens were tested by compression testing machine after 7 days curing, 14 days curing 21 days curing and 28 days curing. Load should be applied gradually till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.



Plate 3.8: Compression Strength Test (Avery Denison UTM)

3.7.2 Modulus of elasticity

Modulus of elasticity of concrete is a very important property required tor the determination of the deflection of the structural elements. Deflection of concrete beams and slabs is a common structural movement. It also mentioned that the deflection is the result of the flexural strains that develop under dead and live loads and this may result to cracking in the tensile zone. The modulus of elasticity testing was used to determine the deflection of the concrete specimens that are having different percentage of OPS as partial replacement for crushed granite, for each of the three defined mix-ratios. The testing was carried out after 56 days of casting. The testing specimen was 150mm diameter and 300 mm height. The Modulus of Elasticity can be calculated by the difference of the measured stresses and strains on an upper level (that is. 1/3 of the value of compressive strength) and a lower level (that is 0.5 N/mm^2). Plate 3.9 shows the setup of Modulus of Elasticity. The experiment was conducted at the Department of Civil Technology, Nuhu Bamalli Polytechnic, Zaria.



Plate 3.9: Test Setup for the Modulus of Elasticity.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Tests on the Ordinary Portland Cement

The results of the consistency, setting time and soundness test results are presented in Tables 4.1, 4.2 and 4.3 respectively.

Table 4.1: Result of consistency test

Mass of OPC (g)	Water Cement Ratio (Consistency for Sample 1)	Water Cement Ratio (Consistency for Sample 2)
400	0.31	0.31

Table 4.2: Setting time

Setting Time Type	Sample 1	Sample 2

Initial	6.5 Min	7 Min
Final	145 Min	149 Min

Table 4.3: Result of soundness test

Test	Soundness	
	Sample 1	**Sample 2**
Initial Exp.	6.0	4.5
Final Exp.k2	10.0	9.0
Soundness	4.0	4.5

4.2 Tests on Fine Aggregate

Particle size analysis, specific gravity, silt content and bulk density tests were performed with the view to establish the suitability of the aggregate for use in the mix. The results are presented in Tables 4.4 to 4.7.

Table 4.4: Particle size analysis (fine aggregate)

Sieve Size	Weight Retained (g)	% Retained	Cumulative % Passing	Cumulative % Retained
5	21	2.1	97.9	2.1
2.36	52	5.2	92.7	7.1
1.18	209	20.9	71.8	28.2
600um	488	48.8	23.0	77.0
300	164	16.4	6.6	93.4
150	40	4.0	2.6	97.4

75	9	0.9	1.9	98.3
Pan	17	1.7	-	100.0

Table 4.5: Specific gravity of sand

	Sample 1	**Sample 2**	**Average**
Mass of dry (B)	0.500	0.500	0.500
Mass of pycnometer + water(P)	1.500	1.450	1.475
Mass of pycnmeter + water + sand (PS)	1.800	1.750	1.775
Specific Gravity = B (P+B-Ps)	2.500	2.500	2.500

Table 4.6: Silt content of sand

Samples	**Sand Layer**	**Silt Layer**	**Silt Content**
Sample 1	100ml	3ml	3%
Sample 2	100ml	2.5ml	2.5%

Table 4.7: Bulk density of sand

	Sample 1	Sample 2	Average
Weight of cylinder	1.25	1.25	1.25
Weight of cylinder + water (kg)	4.00	4.00	4.00
Weight of cylinder + sand (kg)	5.20	5.24	5.22
Weight of sand kg	3.95	3.99	3.97
Weight of water (kg)	2.75	2.75	2.75
Volume of cylinder (m^3)	$2.75\ 10^{-3}$	$2.75\ 10^{-3}$	$2.75\ 10^{-3}$

Bulk Density (kg/m^3)	1436.36	1450.91	1443.64

4.3 Chemical Analysis

The Obtained OPS were subjected to chemical analysis. The results are presented in Table 4.8.

Table 4.8: Chemical composition of the OPS

Constituent	**Percentage Composition**
Fe_2O_3	4.89
SiO_2	63.56
CaO	8.40
Al_2O_3	3.78
MgO	3.90
K_2O	4.01

Na_2O	0.37
MnO_3	0.01
L.O.I	10.51

The chemical parameters of the sea water obtained from the coastal water at Lagos was also established and presented in Table 4.9.

Table 4.9: Chemical Parameters of salt water used for curing

Chemical Parameter	**Content (%)**
Alkalinity	3.4
Total Hardness	7.2
NaCl	51.3
Calcium	1.3
Iron	2.4
Potassium	0.3

Chromium	8.9
Chloride	25.2

4.4 Workability Test Results

The results obtained from the compaction factor and slump tests are presented in Table 4.10. It can be seen that, for both mixes workability reduces as the oil palm shell (OPS) percentage increases.

Table 4.10: Result of workability, compacting factor and slump test

	OPS Replacement of Coarse Aggregate (%)				
	0	**20**	**40**	**60**	**80**
Partial Compacting weight (kg)	17.7	17.2	15.5	12.5	11.2

Fully Compacting weight (kg)	20	18.5	17.5	15	12.8
Compacting Factor	0.89	0.93	0.89	0.83	0.87
Slump (mm)	40	40	40	40	40

The workability of both mixes decreases with increase in the percentage replacement of granite by OPS. This is due to the increase in the specific surface as a result of the increase in the quantity of OPS, thus requiring more water to make the specimens workable. The workability of the volume-batched concrete produced by volume replacement of granite by palm kernel shells is higher than that produced by weight replacement. The rate at which workability reduces per unit percentage increase in OPS is lower for the volume-batched concrete than for weight-batched concrete. Since granite is denser than palm kernel shells, replacement by an equal mass of palm kernel shells leads to a larger increase in volume than replacement by an equal volume of granite. Increase in the quantity of shells increase the specific surface area, thereby more water would be

required. However, since the water cement ratio remains the same, the workability of the mix reduces.

4.5 Density Test Results

The minimum 28-day densities of weight-batched OPS concrete and volume batched OPS concrete are 1292kgm^{-3} and 1710kgm^{-3} respectively according to ASTM C567. For the volume replaced concrete, POS concrete with 50% replacement of granite can be regarded as normal weight (density>2000kgm^{-3}), while for weight-batched concrete, 25% replacement of granite can be regarded as normal weight concrete. It is seen that the rate at which densities decrease with increase in the percentage replacement is higher for the weight-batched POS concrete than for volume-batched concrete. The density test results are presented in Table 4.11

Table 4.11: Density of OPS concrete (kgm^{-3}) cured in clean tap water. 1:1:2 mix ratio

	Palm kernel shell replacement (%) of Coarse Aggregate			
Age at Testing (days)	0	20	40	80
3	2319	1925	1635	1343
7	2328	2101	1680	1366
14	2370	2109	1713	1392
21	2378	2122	1786	1465
28	2392	2177	1835	1519

This is attributed to the larger increase in the quantity of palm kernel shells in weight-batched OPS concrete than in volume-batched OPS concrete. Replacement of granite by equal weight of OPS leads to the introduction of more palm kernel shells in the mix since granite is heavier than palm kernel shell. This leads to an increase in volume without increase in weight which reduces the density. The density of volume-batched concrete on the average reduces by about 7kgm^{-3} per unit percentage increase in replacement whereas density of weight-batched concrete on the average reduces by about 11kgm^{-3} per unit percentage increase in oil palm shells.

4.6 Produced Specimens

As mentioned in chapter three that, a total of two hundred and twenty five concrete test cubes and concrete test cylinders are to be produced. 15 specimens for each of the three adopted mix ratios, in turn, for the control specimen (0% OPS) and for the specimens with 20%, 40%, 60% and 80% OPS. The Aggregate ration between the crushed granite and the OPS are presented in Table 4.12.

4.7 Compressive Strengths Test Results

Compressive strength of concrete is a lifeline property used in concrete technology. All other mechanical parameters such as modulus of rupture, splitting tensile strength and modulus of elasticity directly depend on the compressive strength of the concrete. Compressive strength depends on the strength of matrix, particle strength of aggregate, cement content and W/C ratio. The compressive strength of volume-batched concrete at various OPS content are shown in Tables A1 to A18 in the Appendix. The results were plotted in Figs 4.1 to 4.18.

The figures displayed the effects of replacement of crushed granite with OPS as partial replacement, on the compressive strengths of the specimens. It is clear from all the plots that the compressive strength decreases as OPS content increases.

The lower compressive strength for the OPS concrete can be explained as follows, as Ok2PS content increases, the specific area increases, thus requiring more cement paste to bond effectively with the shells. Since the cement content remains the same, the bonding is therefore inadequate. Strength depends to a large extent on good bonding between the cement paste and the aggregates. The compressive strength reduces as a consequence of the increase in percentage replacement of granite.

28 days after casting, the compressive strength drop from 39.11N/mm^2 (for control specimen) to 13.99N/mm^2 (Corresponding to 20% OPS replacement of coarse aggregate); about 60% decrease in compressive strength.

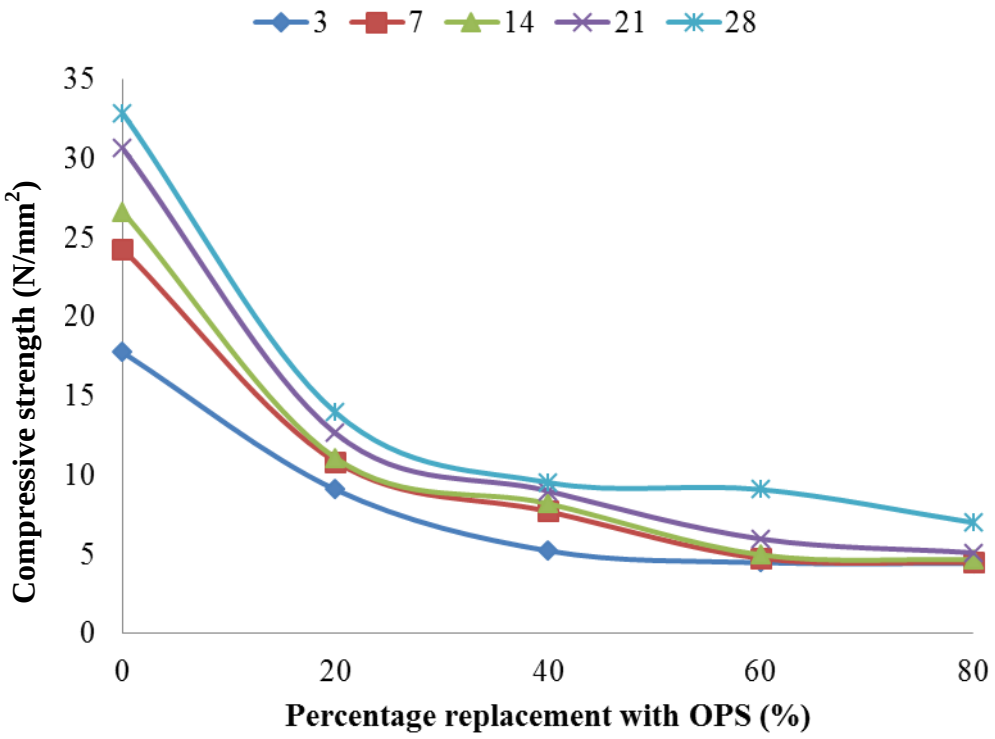


Figure 4.1: Variation of Compressive strength with OPS content (cubes cured in salt water – 1:2:4 Mix ratios)

Fig. 4.1 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with salt water, considering 1:2:4 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cubes are respectively 9.11N/mm^2, 10.88N/mm^2, 11.11N/mm^2, 12.67N/mm^2 and 13.99N/mm^2.

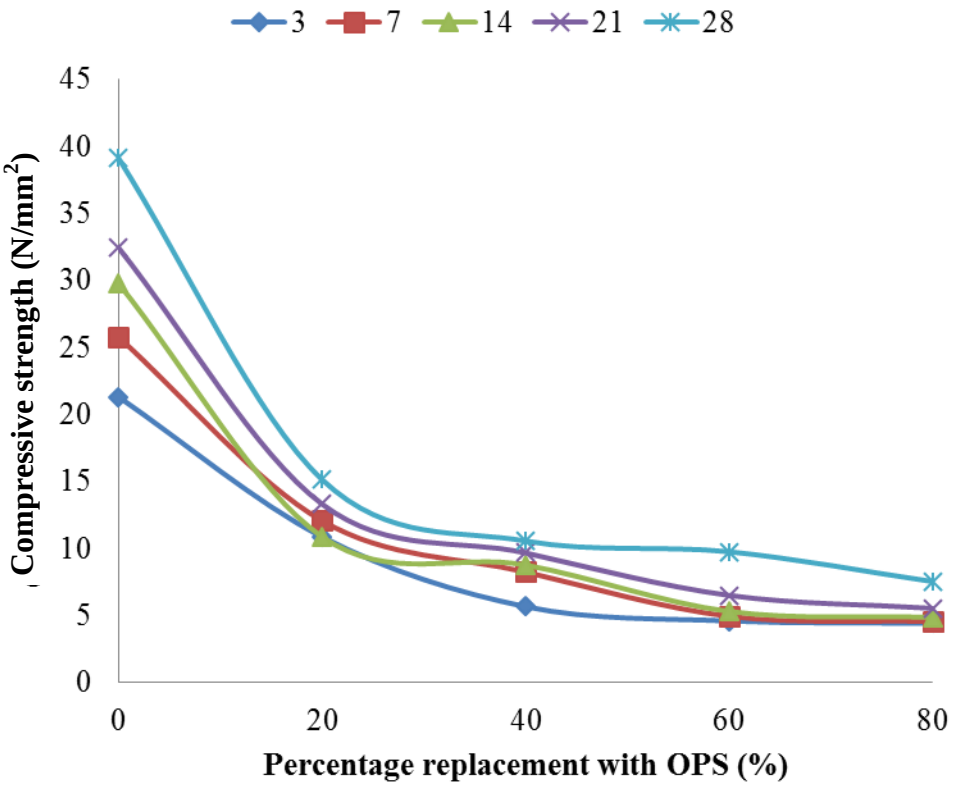


Figure 4.2: Variation of Compressive strengths with OPS content (Cubes cured in clean tap water – 1:2:4 Mix ratio)

Fig. 4.2 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with clean tap water, considering 1:2:4 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cubes are respectively 10.89N/mm^2, 12.09N/mm^2, 10.89N/mm^2, 13.337N/mm^2 and 15.16N/mm^2.

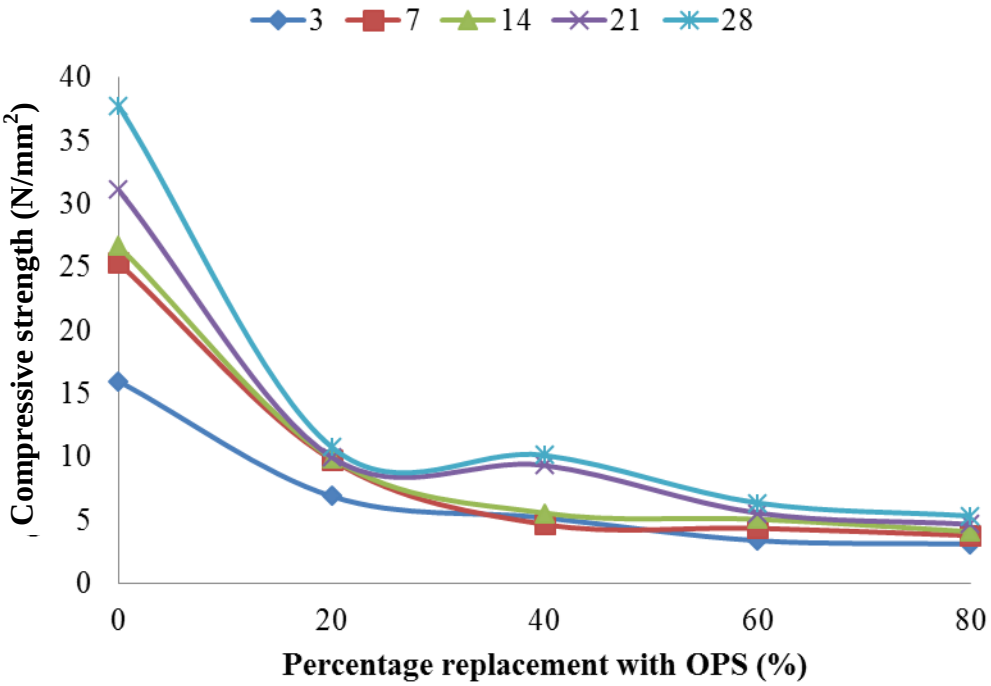


Figure 4.3: Variation of compressive strength with OPS content (Cubes cured in pond water 1:2:4 Mix ratios)

Fig. 4.3 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with pond water, considering 1:2:4 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cubes are respectively 6..89N/mm^2, 9.78N/mm^2, 9.91N/mm^2, 9.99N/mm^2 and 10.79N/mm^2.

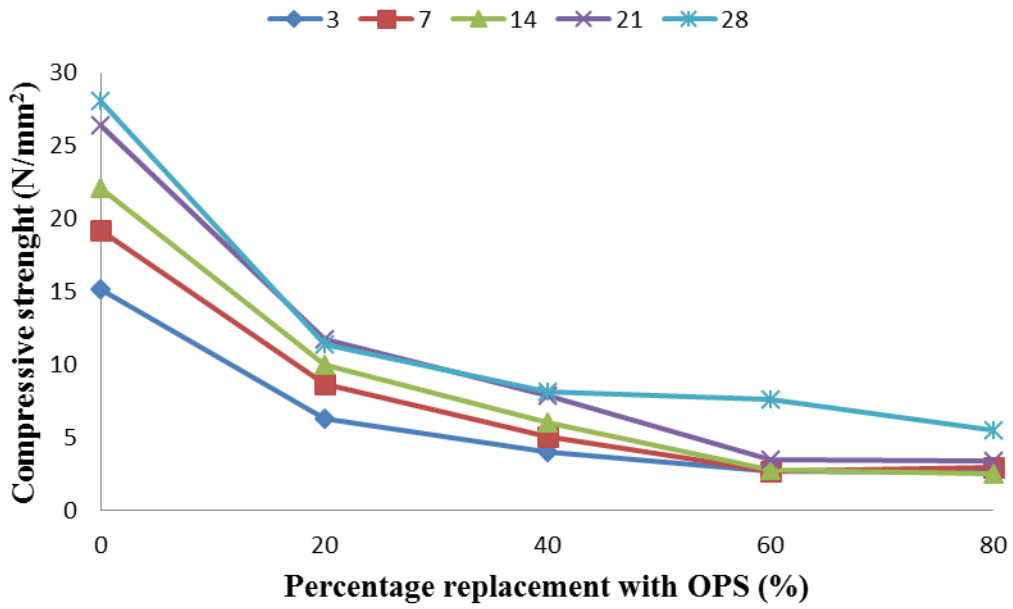


Figure 4.4: Variation of Compressive strength with OPS content (Cylinder cured in salt water 1:2:4 Mix ratios)

Fig. 4.4 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with salt water, considering 1:2:4 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cylinder are respectively 6.32N/mm^2, 8.62N/mm^2, 9.96N/mm^2, 11.77N/mm^2 and 11.41N/mm^2.

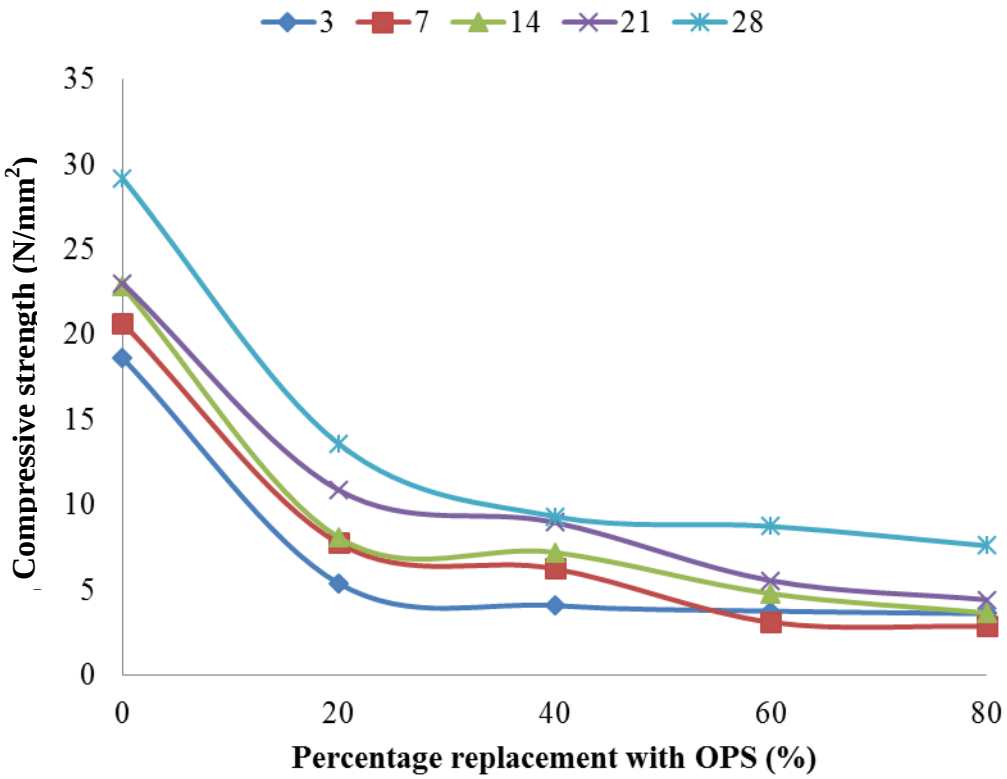


Figure 4.5: Variation of Compressive strengths with OPS content (Cylinder cured in clean tap water – 1:2:4 Mix ratios)

Fig. 4.5 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with clean tap water, considering 1:2:4 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old

concrete cylinder are respectively 5.41N/mm^2, 7.77N/mm^2, 8.11N/mm^2, 10.89N/mm^2 and 13.61N/mm^2.

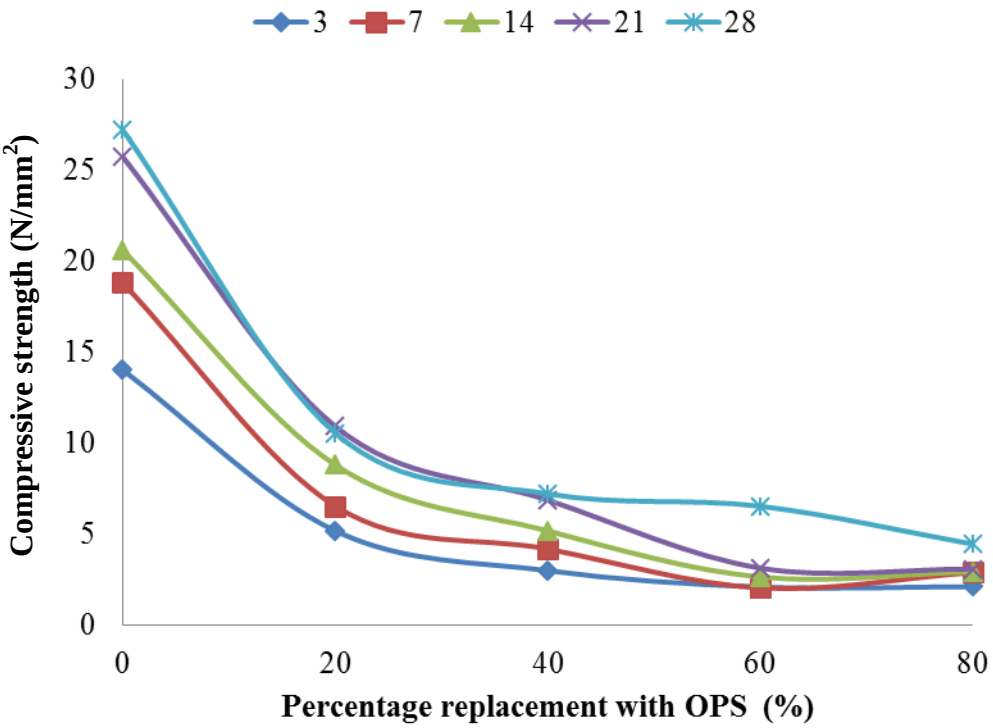


Figure 4.6: Variation of Compressive strengths with OPS content (Cylinder cured in pond water – 1:2:4 Mix ratios)

Fig. 4.6 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with pond water, considering 1:2:4 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cylinder are respectively 5.20N/mm^2, 6.56N/mm^2, 8.82N/mm^2, 10.94N/mm^2 and 10.57N/mm^2.

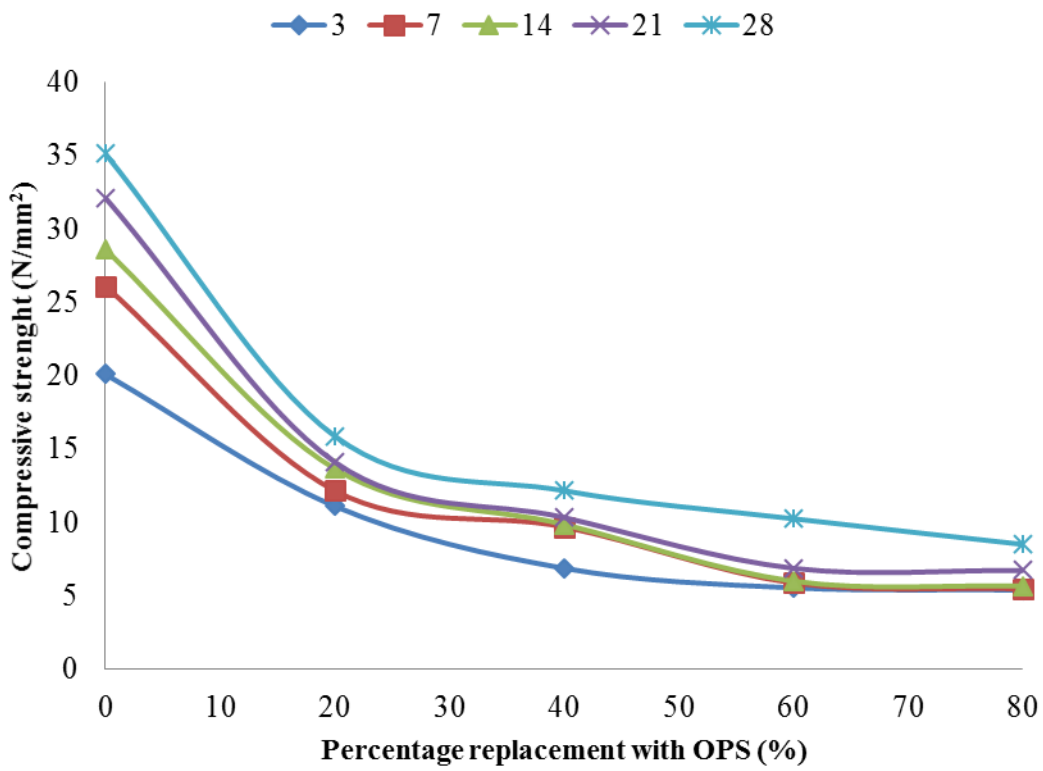


Figure 4.7: Variation of Compressive strengths with OPS content (Cubes cured in salt water – 1:1.5:3 Mix ratios)

Fig. 4.7 shows the relationship between compressive strength and percentage aggregate rek2placement by OPS. The plot is for concrete cube, produced with salt water, considering 1:1.5:3 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cylinder are respectively 11.12N/mm^2, 12.18N/mm^2, 13.67N/mm^2, 14.13N/mm^2 and 15.89N/mm^2.

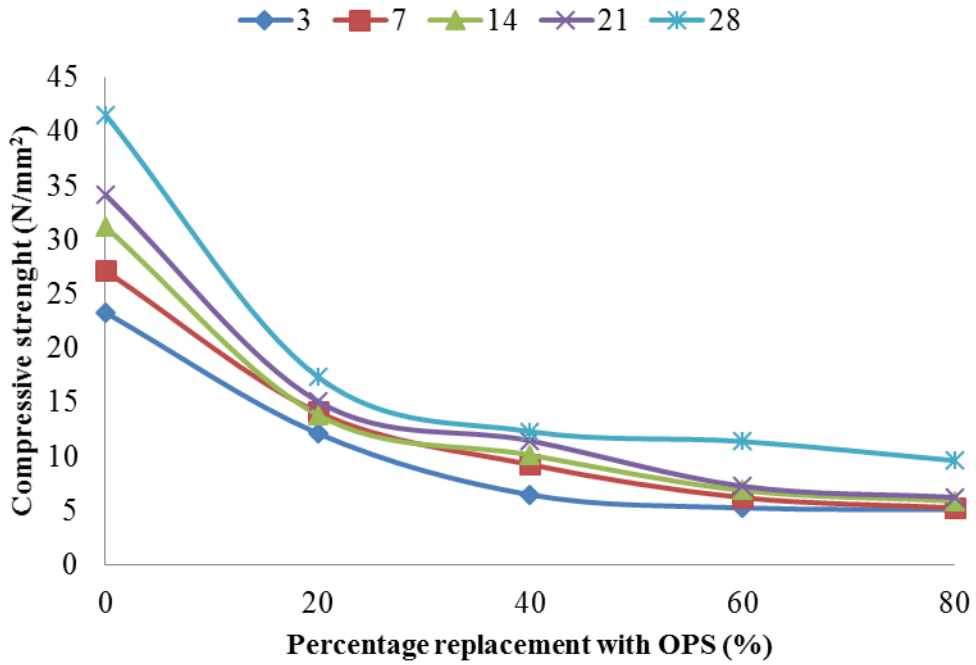


Figure 4.8: Variation of Compressive strengths with OPS content (Cubes cured in clean tap water – 1:1.5:3)

Fig. 4.8 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with clean tap water, considering 1:1.5:3 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cubes are respectively 12.16N/mm^2, 14.12N/mm^2, 13.86N/mm^2, 15.12N/mm^2 and 17.38N/mm^2.

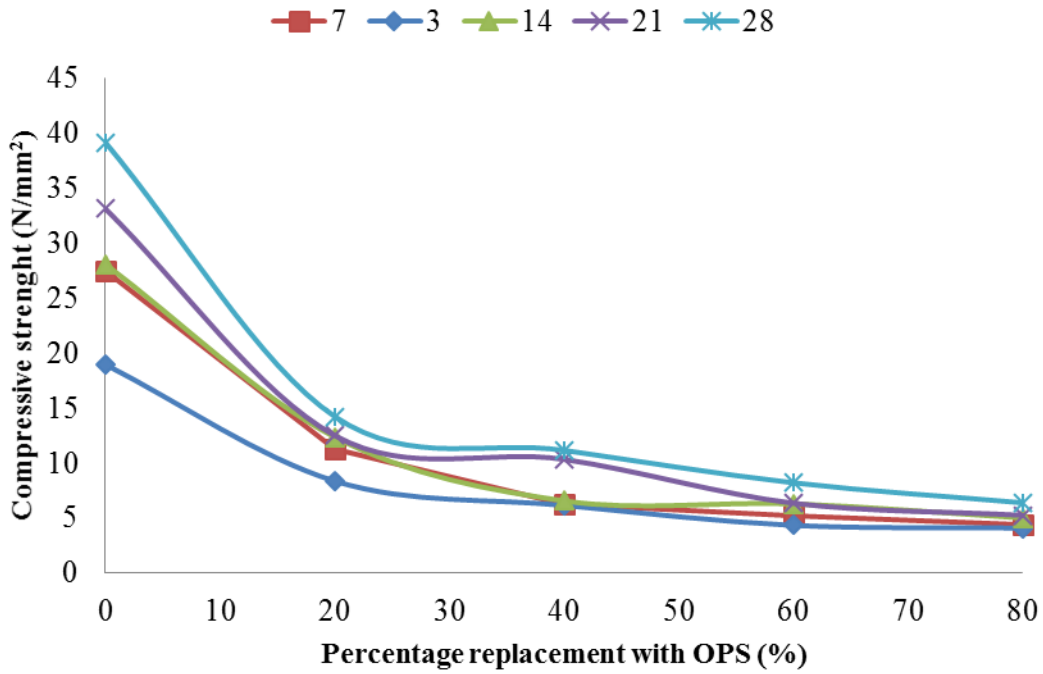


Figure 4.9: Variation of Compressive strengths with OPS content (Cubes cured in pond water – 1:1.5:3)

Fig. 4.9 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with pont water, considering 1:1.5:3 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cubes are respectively 8.39N/mm^2, 11.25N/mm^2, 12.39N/mm^2, 12.52N/mm^2 and 14.2k25N/mm^2.

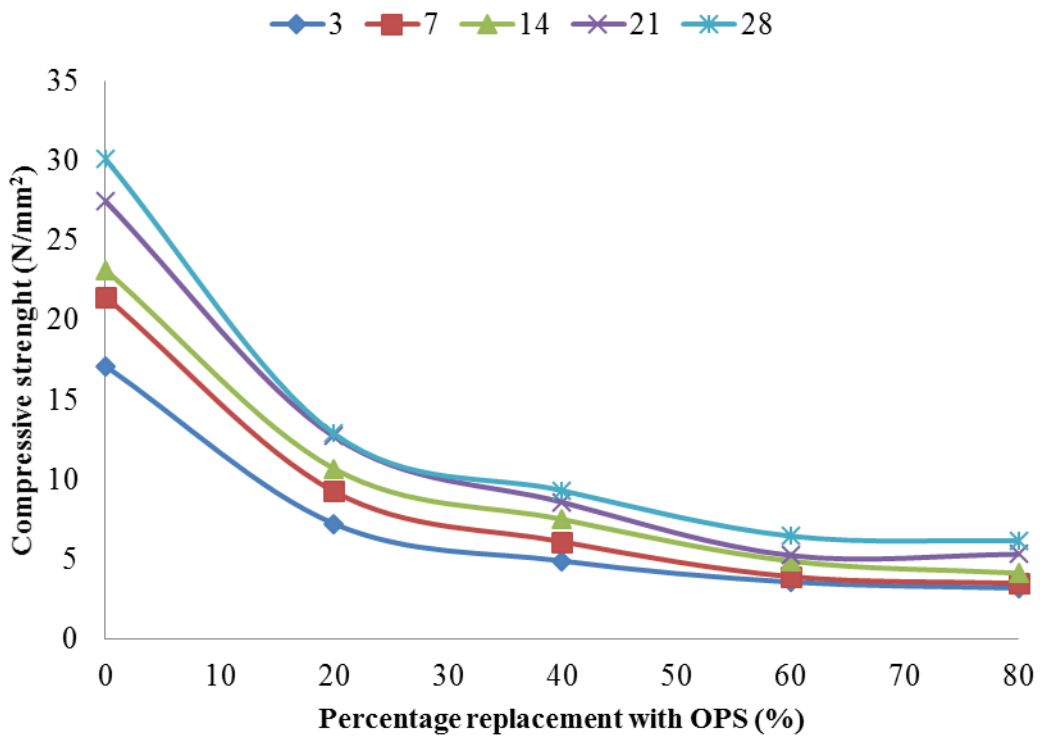


Figure 4.10: Variation of Compressive strengths with OPS content (Cylinder cured in salt water – 1:1.5:3)

Fig. 4.10 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with salt water, considering 1:1.5:3 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cylinder are respectively 7.23N/mm^2, 9.26N/mm^2, 10.69N/mm^2, 12.71N/mm^2 and 12.89N/mm^2.

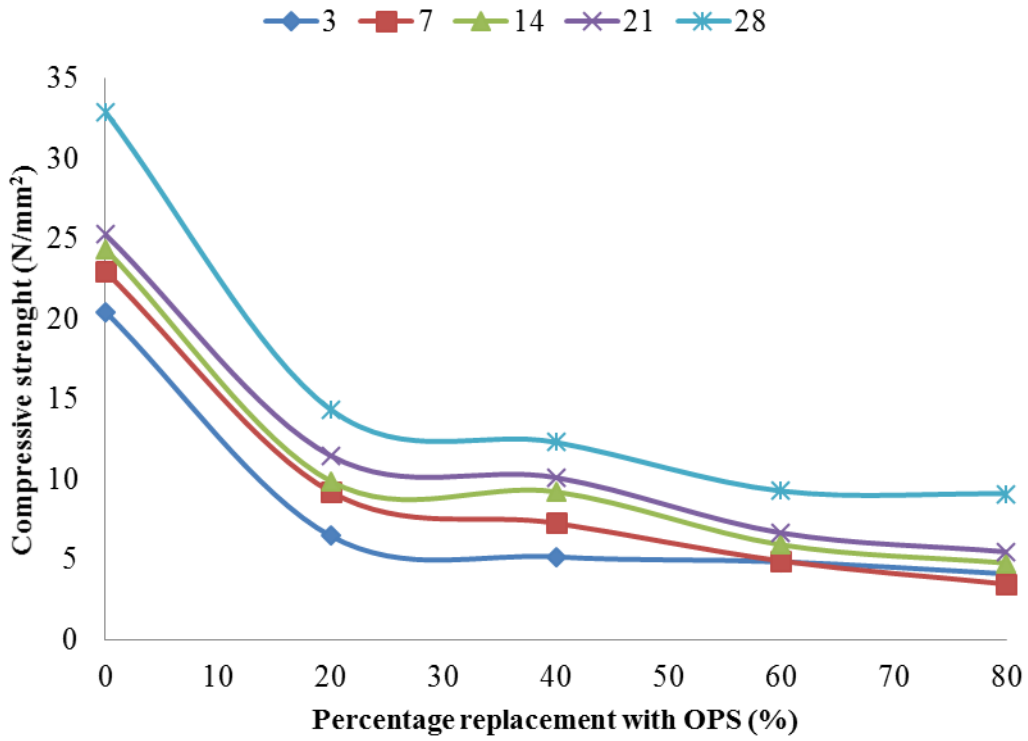


Figure 4.11: Variation of Compressive strengths with OPS content (Cylinder cured in clean tap water 1:1.5:3 Mix ratios)

Fig. 4.11 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with clean tap water, considering 1:1.5:3 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cylinder are respectively 6.48N/mm^2, 9.23N/mm^2, 9.89N/mm^2, 11.48N/mm^2 and 14.36N/mm^2.

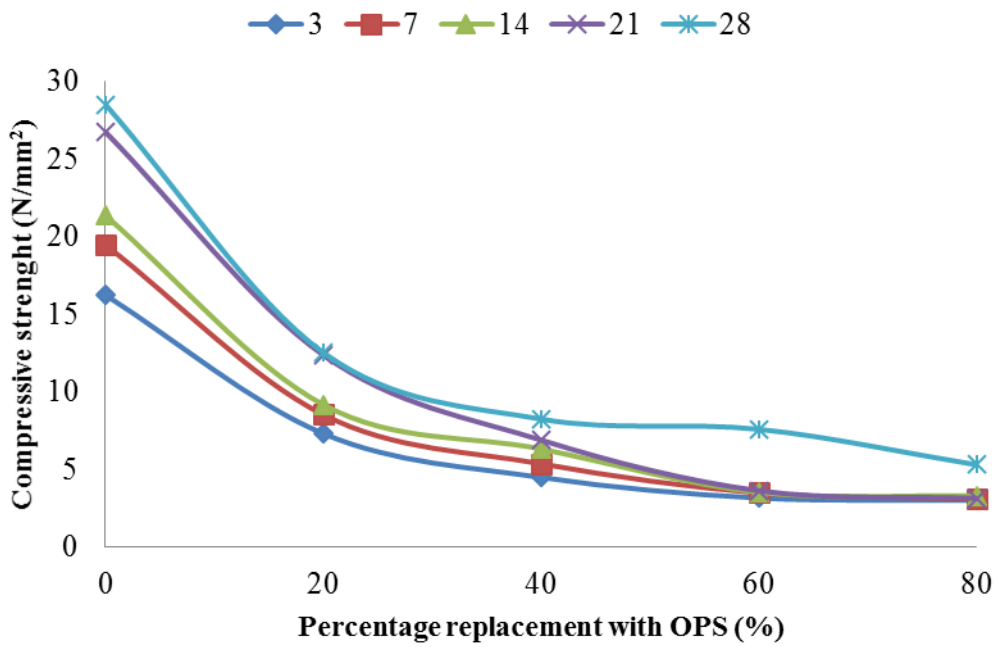


Figure 4.12: Variation of Compressive strengths with OPS content (Cylinder cured in pond water – 1:1.5:3 Mix ratios)

Fig. 4.12 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with pond water, considering 1:1.5:3 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cylinder are respectively 7.30N/mm^2, 8.52N/mm^2, 9.16N/mm^2, 12.36N/mm^2 and 12.52N/mm^2.

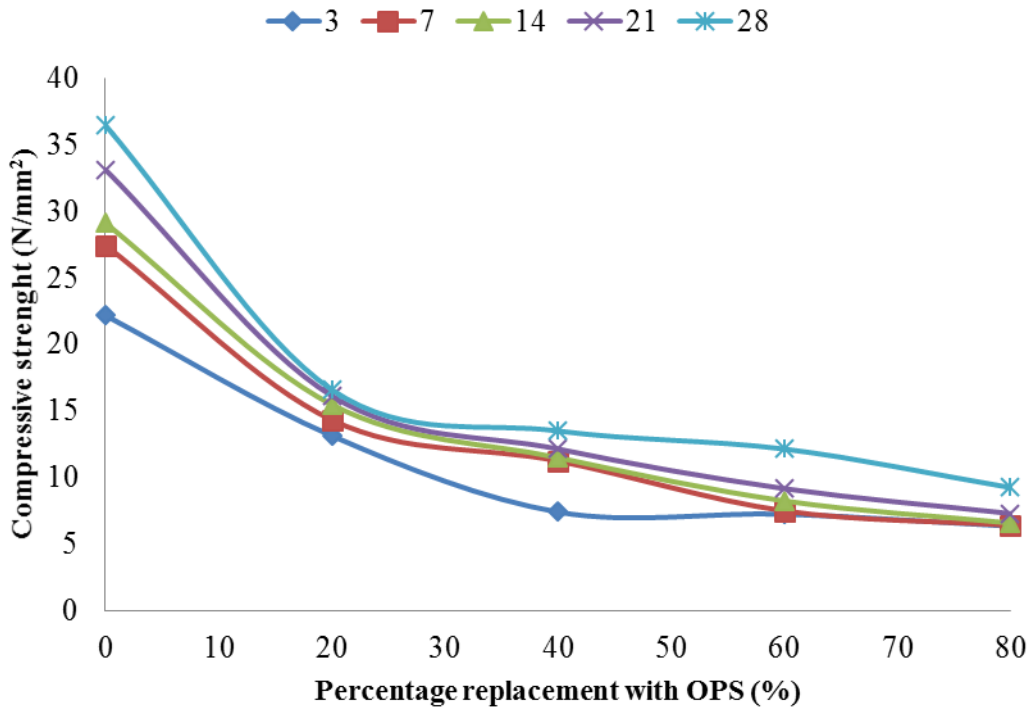


Figure 4.13: Variation of Compressive strengths with OPS content (Cubes cured in salt water 1:1:2 Mix ratios)

Fig. 4.13 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with salt water, considering 1:1:2 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cubes are respectively 13.13N/mm^2, 14.32N/mm^2, 15.48N/mm^2, 16.13N/mm^2 and 16.59N/mm^2.

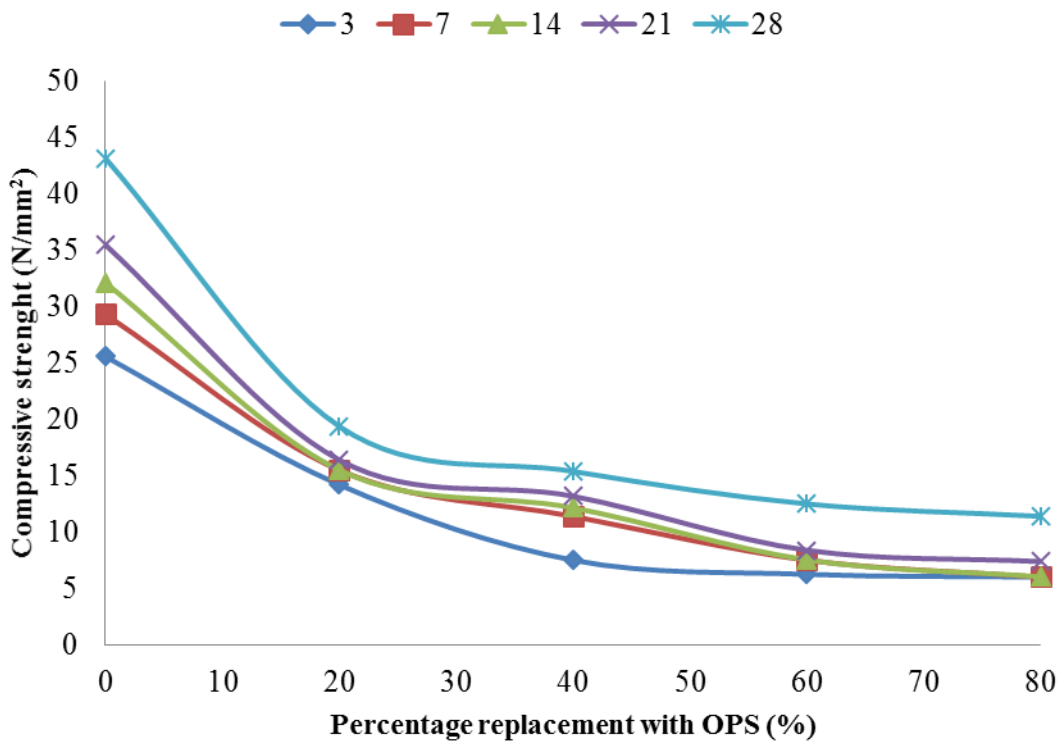


Figure 4.14: Variation of Compressive strengths with OPS content (Cubes cured in clean tap water – 1:1:2 Mix ratios)

Fig. 4.14 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with clean tap water, considering 1:1:2 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cubes are respectively 14.18N/mm^2, 15.48N/mm^2, 15.49N/mm^2, 16.38N/mm^2 and 19.36N/mm^2.

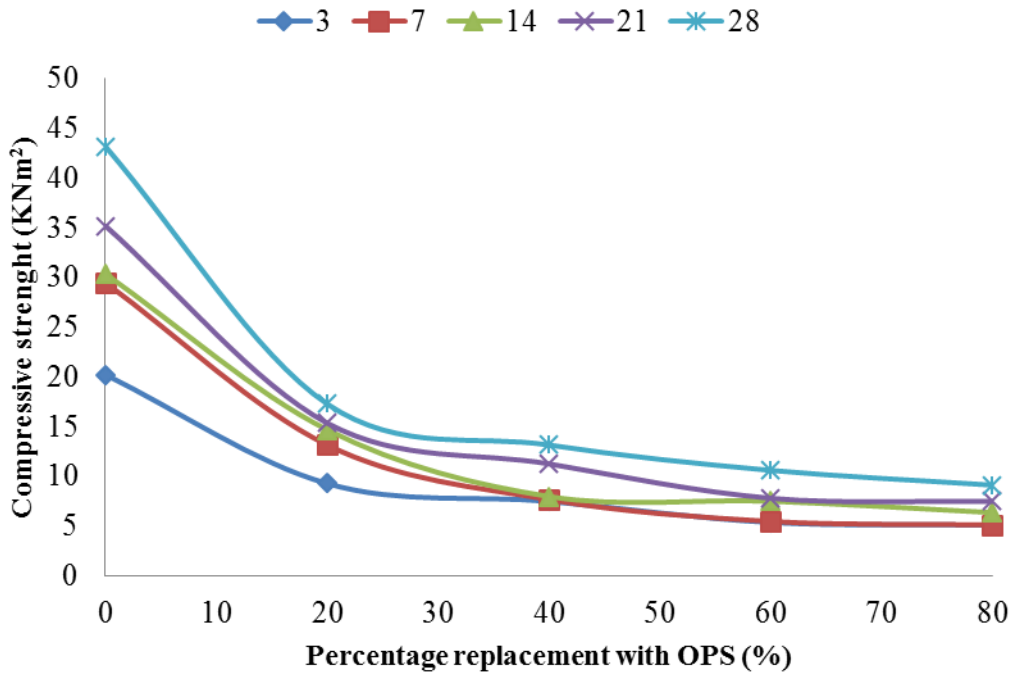


Figure k24.15: Variation of Compressive strengths with OPS content (Cubes cured in pond water – 1:1:2 Mix ratios)

Fig. 4.15 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with pond water, considering 1:1:2 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cubes are respectively 9.28N/mm^2, 13.16N/mm^2, 14.69N/mm^2, 15.36N/mm^2 and 17.28N/mm^2.

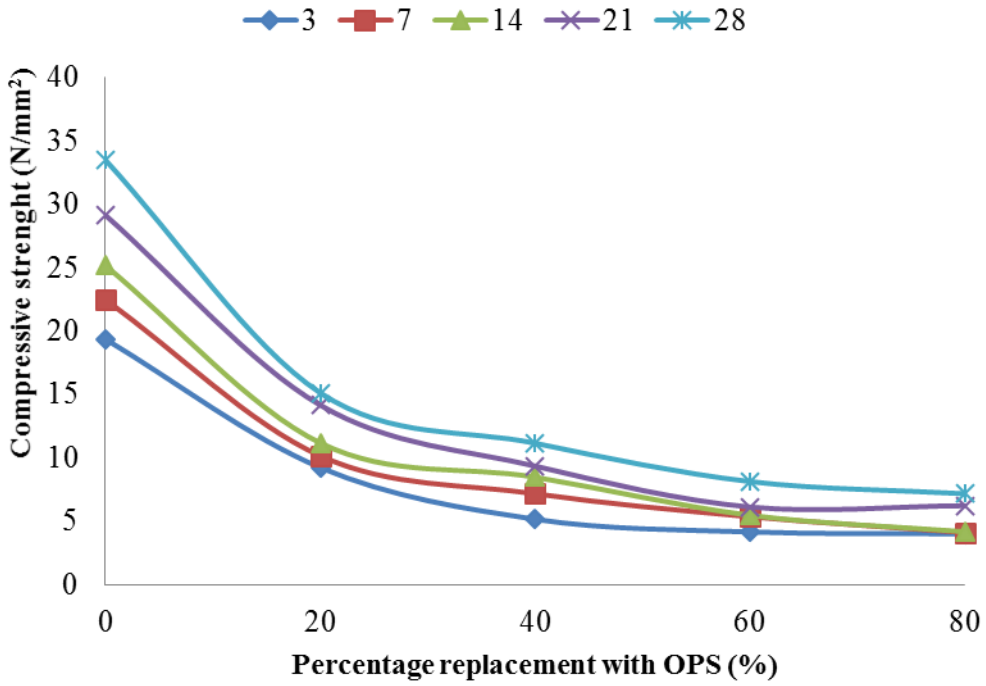


Figure 4.16: Variation of Compressive strengths with OPS content (Cylinder cured in salt water – 1:1:2 Mix ratios)

Fig. 4.16 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with salt water, considering 1:1:2 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cylinder are respectively 9.24N/mm^2, 10.16N/mm^2, 11.18N/mm^2, 14.16N/mm^2 and 15.13N/mm^2.

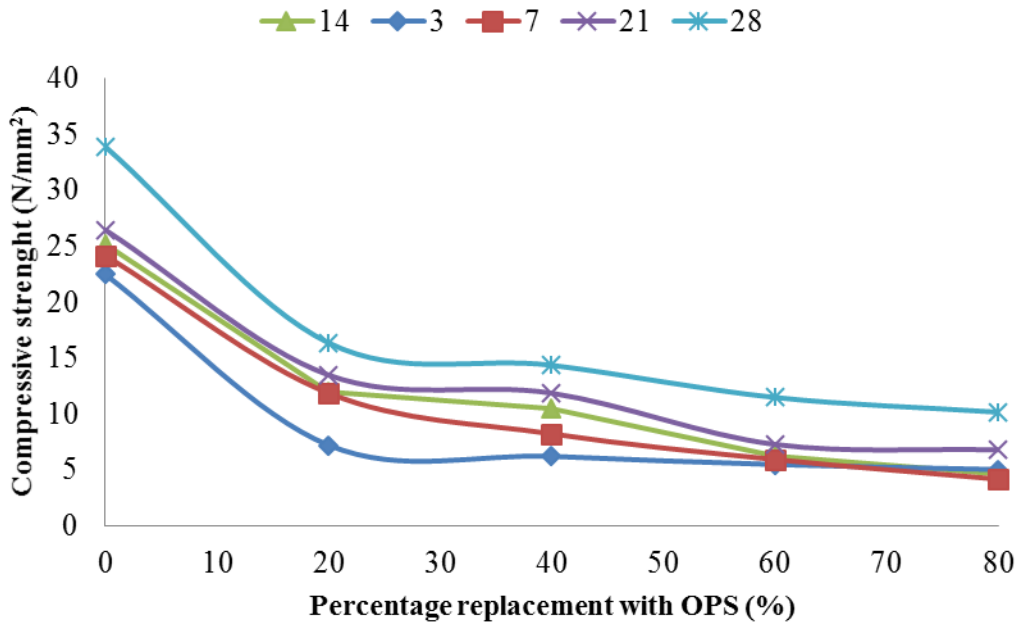


Figure 4.17: Variation of Compressive strengths with OPS content (Cylinder cured in clean tap water – 1:1:2 Mix ratios)

Fig. 4.17 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with clean tap water, considering 1:1:2 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cylinder are respectively 7.21N/mm^2, 11.86N/mm^2, 11.95N/mm^2, 13.48N/mm^2 and 16.36N/mm^2.

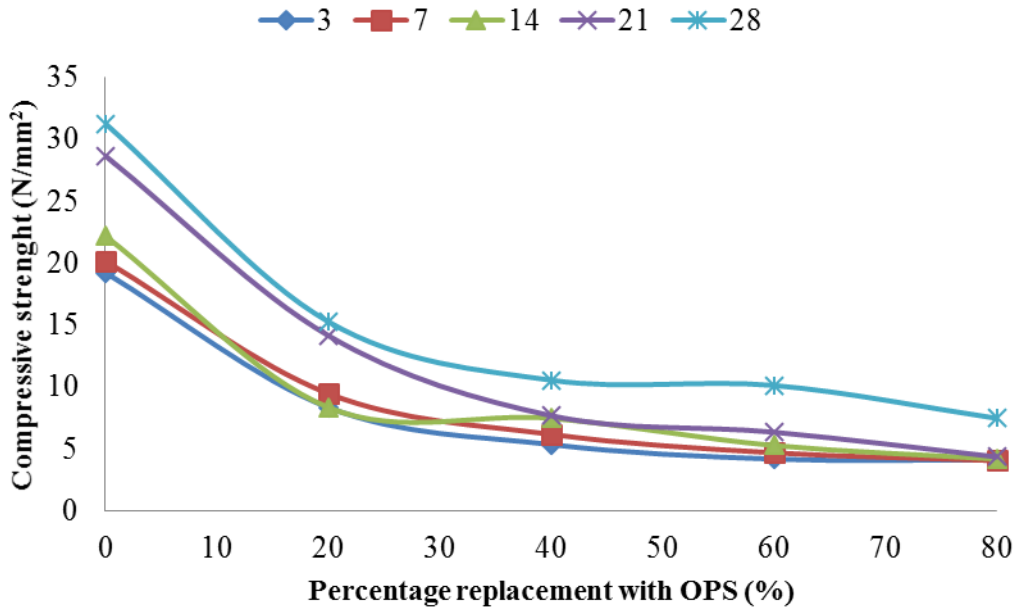


Figure 4.18: Variation of Compressive strengths with OPS content (Cylinder cured in pond water – 1:1:2 Mix ratios)

Fig. 4.18 shows the relationship between compressive strength and percentage aggregate replacement by OPS. The plot is for concrete cube, produced with pond water, considering 1:1:2 Mix-ratio. It is clear from the plot that, for all the OPS replacement considered, sharp drop of compressive strength were notice up to 20% replacement, the compressive strength then gradually decreased up to 80% OPS replacement of aggregate. 20% OPS is therefore considered here for comparison with subsequent result. The values of compressive strength at 20% OPS replacement for 3, 7, 14, 21 and 28 days old concrete cylinder are respectively 8.36N/mm^2, 9.48N/mm^2, 8.36N/mm^2, 14.16N/mm^2 and 15.28N/mm^2.

4.8 Cost Implications

The results presented have indicated that it is possible to use palm kernel shells concrete to replace granite in concrete. Since palm kernel shells are acquired at virtually no cost, about 8% of the cost of granite in volume batched aggregate and 13% of the cost of granite in volume batched concrete can be saved. Therefore, cost of producing concrete would be reduced as granite is replaced by palm kernel shells.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

a. Preliminary tests were conducted on the ordinary Portland cement, and the OPS and the results obtained can be found on Tables 4.4 - 4.7, and 4.8 respectively.

b. To establish the workability, the slump test was conducted as follows:

   i. Collapse slump: In the slump, the concrete collapsed completely

   ii. Shear slump: In the shear slump, the top portion of the concrete shears off and slips sideways.

   iii. True slump: In a true slump, the concrete simply subsides, keeping more or less to shape the workability results can be seen on table 4.10.

c. In conclusion, after undertaking the laboratory practical's on the OPS using 3 types of water for curing and varying the mix ratios to conform with class M15, M20 and M25, the effect of mix ratio and curing were as follows:

   i. The density of OPSC (weight-batched) (kgm^{-3}) for 80% OPS lightweight aggregate at 28 days was found to be 1519kgm^{-3} which is greater than 1292kgm^{-3}. This means the OPS can therefore be used as lightweight aggregate.

   ii. The effect of mix ratio is clear considering the crushing strength obtained. The crushing strength obtained from the control mix ratio 1;2:4, 1:1:5:3 and 1:1:2 at 28days was found to be far greater than the OPS partially replaced granite mix ratio 1:2:4, 1:1:5:3 and 1:1:2, at 28days. But

considering the value 13.49N/mm^2 obtained from mix ratio 1:1:2 at 40% replacement and cured for 28days, OPS can be used to partially replace granite and be taken as a lightweight aggregate to produce lightweight concrete.

iii. The effect of curing water was also evaluated after curing the samples in clean water, salt water and pond water. It was observed out the sample cured in salt water have higher crushing strength than the sample cured in clean water. The sample cured in clean water were found to have higher crushing strength than the samples cured in pond water.

d. The modulus of elasticity test was performed and the stiffness of the concrete made with OPS was determined see table 4.1 to 4.9.

e. On the removal of the cube and cylinder form works after 7 days, disintegration (wearing) of the surface in contact with FW was observed on the 60% and 80% OPS replacement test samples. The disintegration (wearing) of the surface was higher on the 80% OPS replacement test samples. This shows that the higher the percentage of the OPS the lower the bonding as well as the crushing strength.

f. The illustrations of the compressive strength on graphs shows that the higher the OPS percentage the lower the strength. And the 40% OPS, and mix ratio of 1:1:2, cube samples cured in salt water attain the highest compressive strength at 28 days of 15.37Nmm^{-2}, while 14.36Nmm^{-2} was obtained from 40% OPS cylinder samples cured in salt water.

g. Simple cost analysis.

Table 4.12: simple cost analysis

S/No	Type of Conc.	Volume	Cost
1	Pure granite concrete	$1M^3$	₦25000.00
2	40% OPS concrete	$1\ M^3$	₦18000.00

5.2 Recommendations

From the results obtained in this thesis work, the contribution to knowledge highlights the following recommendations:

a) 40% of OPS can replace the conventional granite adequately using the mix ratio of 1:1:2 cured in clean water for 28days.

b) Due to its shape and texture, when used from 60% upward to replace granite, disintegration of the set samples during the removal of the formwork, therefore it is recommended that OPS percentage should not be more than 40%.

c) Though the results indicated the possible use of oil palm shell as a structural material, it is recommended that its long term behavior should be investigated to evaluate this possibility.

d) Plasticizers should be used in works involving palm kernel shell concrete due to its shape and texture.

e) Higher performance concrete is design to limit permeability and reduce chloride ingress, but these properties also limit the ability of externally applied curing

water typically placed on top of the concrete to reach the interior. But in the case of OPS when used as LWA, due to its shape, it will create internal curing which provides additional water throughout the concrete, more of the pores remain water filled, minimizing stress and strain development. This reduces or eliminates early age cracking of the LWC and promotes maximum hydration, which can contribute to increase strength.

f) Further research should be conducted to qualify to use of OPS as lightweight aggregate to produce lightweight concrete as a structural material.

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APPENDIX

Table A1: Compressive strength of OPSC Cubes (N/mm^2) cured in salt water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	17.78	9.11	5.24	4.49	4.44
7	24.31	10.88	7.73	4.76	4.49
14	26.67	11.11	8.22	4.98	4.67
21	30.67	12.67	9.02	5.99	5.11
28	32.89	13.99	9.56	9.11	7.02

MIX ratio; 1:2:4 Class; M15

Table A2: Compressive strengths of OPSC Cubes cured in clean tap water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	21.33	10.89	5.69	4.62	4.44
7	25.78	12.09	8.27	4.97	4.58
14	29.78	10.89	8.79	5.33	4.89
21	32.44	13.33	9.69	6.53	5.56
28	39.11	15.16	10.58	9.78	7.56

MIX ratio; 1:2:4 Class; M15

Table A3: Compressive strengths of OPSC Cubes cured in stagnant pond water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	15.99	6.89	5.19	3.38	3.11
7	25.33	9.78	4.67	4.36	3.78
14	26.67	9.91	5.56	5.07	4.09
21	31.11	9.99	9.33	5.56	4.67
28	37.78	10.79	10.13	6.36	5.33

MIX ratio; 1:2:4 Class; M15

Table A4: Compressive strength of OPSC Cylinder (N/mm^2) Cured in salt water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	15.12	6.32	3.98	2.65	2.55
7	19.24	8.62	5.01	2.71	2.92
14	22.13	9.96	6.05	2.74	2.52
21	26.41	11.77	7.85	3.45	3.38
28	28.11	11.41	8.13	7.62	5.53

MIX ratio; 1:2:4 Class; M15

Table A5: Compressive strength of OPSC Cylinders (N/mm^2) Cured in clean tap water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	18.64	5.41	4.1	3.78	3.63
7	20.69	7.77	6.27	3.13	2.89
14	22.83	8.11	7.23	4.81	3.68
21	23.04	10.89	8.99	5.57	4.45
28	29.19	13.61	9.34	8.76	7.62

MIX ratio; 1:2:4 Class; M15

Table A6: Compressive strength of OPSC Cylinders (N/mm^2) Cured in stagnant pond water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	14.05	5.2	3.01	2.11	2.13
7	18.83	6.56	4.2	2.06	2.91
14	20.62	8.82	5.2	2.66	2.95
21	25.76	10.94	6.89	3.15	3.1
28	27.24	10.57	7.23	6.55	4.47

MIX ratio; 1:2:4 Class; M15

Table A7: Compressive strength of OPSC Cubes (N/mm^2) Cured in salt water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	20.11	11.12	6.89	5.56	5.41
7	26.12	12.18	9.71	5.89	5.49
14	28.61	13.67	9.88	6.01	5.68
21	32.12	14.13	10.35	6.89	6.75
28	35.13	15.89	12.18	10.27	8.52

MIX ratio; 1:1.5:3 Class; M20

Table A8: Compressive strength of OPSC Cubes (N/mm^2) Cured in clean tap water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	23.31	12.16	6.49	5.28	5.13
7	27.16	14.12	9.28	6.23	5.28
14	31.21	13.86	10.16	6.89	5.92
21	34.18	15.12	11.48	7.28	6.25
28	41.55	17.38	12.33	11.41	9.65

MIX ratio; 1:1.5:3 Class; M20

Table A9: Compressive strength of OPSC Cubes (N/mm^2) Cured in pond water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	18.98	8.39	6.18	4.36	4.12
7	27.46	11.25	6.27	5.25	4.38
14	28.1	12.39	6.59	6.32	5.03
21	33.14	12.52	10.36	6.38	5.28
28	39.16	14.25	11.18	8.23	6.41

MIX ratio; 1:1.5:3 Class; M20

Table A10: Compressive strength of OPSC Cylinders (N/mm^2) Cured in salt water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	17.13	7.23	4.89	3.56	3.18
7	21.48	9.26	6.1	3.91	3.48
14	23.16	10.69	7.5	4.88	4.12
21	27.48	12.71	8.58	5.23	5.31
28	30.13	12.89	9.31	6.45	6.15

MIX ratio; 1:1.5:3 Class; M20

Table A11: Compressive strength of OPSC Cylinders (N/mm^2) Cured in clean tap water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	20.46	6.48	5.18	4.87	4.12
7	22.96	9.23	7.28	4.92	3.48
14	24.36	9.89	9.23	5.93	4.79
21	25.27	11.48	10.12	6.67	5.49
28	32.91	14.36	12.32	9.28	9.11

MIX ratio; 1:1.5:3 Class; M20

Table A12: Compressive strength of OPSC Cylinders (N/mm^2) Cured in pond water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	16.23	7.3	4.48	3.15	3.01
7	19.48	8.52	5.36	3.48	3.09
14	21.36	9.16	6.31	3.52	3.29
21	26.74	12.36	6.89	3.62	3.13
28	28.51	12.52	8.24	7.58	5.29

MIX ratio; 1:1.5:3 Class; M20

Table A13: Compressive strength of OPSC Cubes (N/mm^2) Cured in salt water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	22.18	13.13	7.39	7.23	6.33
7	27.46	14.32	11.23	7.48	6.39
14	29.13	15.48	11.48	8.23	6.56
21	33.14	16.13	12.13	9.15	7.28
28	36.48	16.59	13.49	12.13	9.23

MIX ratio; 1:1:2 Class; M25

Table A14: Compressive strength of OPSC Cubes (N/mm^2) Cured in clean tap water

K	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	25.56	14.18	7.48	6.23	5.98
7	29.31	15.48	11.38	7.49	5.99
K214	32.11	15.49	12.13	7.51	6.01
21	35.48	16.38	13.16	8.36	7.36
28	43.16	19.36	15.37	12.48	11.38

MIX ratio; 1:1:2 Class; M25

Table A15: Compressive strength of OPSC Cubes (N/mm^2) Cured in pond water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	20.23	9.28	7.49	5.37	5.11
7	29.48	13.16	7.68	548	5.12
14	30.36	14.69	7.98	7.51	6.36
21	35.18	15.36	11.26	7.81	7.48
28	43.16	17.28	13.16	10.61	9.13

MIX ratio; 1:1:2 Class; M25

Table A16: Compressive strength of OPSC Cylinders (N/mm^2) Cured in salt water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	19.36	9.24	5.16	4.16	4.01
7	22.48	10.16	7.18	5.36	4.12
14	25.16	11.18	8.48	5.48	4.18
21	29.13	14.16	9.36	6.13	6.23
28	33.48	15.13	11.16	8.14	7.18

MIX ratio; 1:1:2 Class; M25

Table A17: Compressive strength of OPSC Cylinders (N/mm^2) Cured in clean tap water

	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
Age at testing (days)	**Compressive Strength (N/mm^2)**				
3	22.47	7.21	6.21	5.48	5.03
7	24.18	11.86	8.23	5.93	4.18
14	25.13	11.95	10.52	6.23	4.68
21	26.46	13.48	11.86	7.28	6.79
28	33.89	16.36	14.36	11.48	10.16

MIX ratio; 1:1:2 Class; M25

Table A18: Compressive strength of OPSC Cylinders (N/mm^2) Cured in pond water

Age at testing (days)	OPS replacement (%)				
	0	**20**	**40**	**60**	**80**
	Compressive Strength (N/mm^2)				
3	19.24	8.36	5.36	4.18	4.11
7	20.18	9.48	6.18	4.69	4.06
14	22.19	8.36	7.48	5.28	4.19
21	28.67	14.16	7.69	6.36	4.36
28	31.28	15.28	10.56	10.13	7.48

MIX ratio; 1:1:2 Class; M25