WEST AFRICA BUILT ENVIRONMENT RESEARCH (WABER) CONFERENCE

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Abuja, Nigeria

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(Volume 1)

Editors

Dr Samuel Laryea
Dr Sena A. Agyepong
Dr Roine Leiringer
Professor Will Hughes

Proceedings of the West Africa Built Environment Research (WABER) Conference 2012
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Abuja, Nigeria, 24-26 July 2012

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Declaration

All papers in this publication have been through a review process involving initial screening of abstracts, review by at least two referees, reporting of comments to authors, modifications of papers by authors and re-evaluation of re-submitted papers to ensure quality of content.

FOREWORD

A big welcome to every participant at this WABER 2012 Conference. Our first three conferences, 2009-11, took place in Accra, Ghana. Nigeria is hosting the WABER Conference for the first time, 24-26 July 2012, and it is a delight to be in this beautiful city of Abuja. Thank you for coming and we hope you enjoy the conference.

Time really flies! I still have a vivid recollection of our first event in Accra on 2-3 June 2009. So soon we are having a 4th WABER Conference already. Every credit for the rapid development of the WABER Conference in the last four years should really go to those of you who have participated in the past as well as those attending the conference this year. In the past four years, many of us have become friends through WABER. Many young academics and researchers have also been helped to develop their research work and skills through WABER and thereby found an opportunity to move their careers and ideas forward. The story of WABER just goes to show that we are stronger when we come together and there is nothing we cannot achieve when we work together and support each other. With most of the countries in Africa pushing for development, the WABER Conference provides an essential channel for bringing built environment academics, researchers and practitioners together for the generation of knowledge, interaction and leadership on the key issues that we need to tackle in order to address our challenges and opportunities of the 21st century particularly in relation to the construction sector and built environment.

Since 2009, WABER has brought together more than 500 built environment academics, researchers and practitioners to work together towards the development of the built environment field in Africa. We strive to: support young built environment researchers in West Africa (WA) especially to develop their research work and skills through constructive face-to-face interaction with their peers and experienced international academics; supply a platform for more senior academics to network and share ideas on their current research work; and serve as a vehicle for developing the built environment field in Africa.

In addition to the 500+ people involved in WABER, we also have about 60 institutions in the WABER Conference network, comprising mainly of universities and polytechnics. This network of people has enabled us to develop a new textbook on “Construction in West Africa” which will be launched at this conference in Abuja. The WABER Book was written by ten academics of West African origin based in six different countries. This contribution is another example of what we can collectively achieve when we work together and combine our ideas. A big thank you to all authors and our partners who have supported us and helped to publish the book.

We have engaged in some outreach activities within the past year. In January 2011, some members of our team visited built environment departments in six polytechnics and two universities in Ghana to interact with lecturers and postgraduate students and deliver research workshops. We also donated textbooks to some departmental libraries as a means of supporting students and teaching and learning activities. In August 2011, visits to six universities in Nigeria enabled us to interact directly with staff and students in built environment departments. These visits continue to foster closer interaction with our friends in various institutions. I would like to express our sincere thanks to colleagues in all institutions visited for your warm hospitality.

This year’s conference proceedings consist of 125 papers. We initially received and screened 278 abstracts with the help of our Scientific Committee. 182 full papers were eventually submitted and each went through a peer review process. Thus, the papers accepted for publication represent around 68% of full papers received. We congratulate the authors of papers that made it into the proceedings for a job well done. We also thank the 56 members of our Scientific Committee and 84 members of our Review Panel for your expertise and input into the quality of this conference.

The published papers cover a wide array of topics including: Building services, Construction design and technology, Construction economics, Construction finance, Contract law, Contracting, Contract administration, Decision support systems, Economic development, Engineering, Energy, Environment, Facilities Management, Health and safety, Housing, Human resources and skills, Information technology, Materials science, Procurement, Project management, Quantity surveying, Real estate and planning, Risk management, Supply chain management, Sustainable technologies, Urban development. As such they reflect various areas of socio-economic development aspirations of countries in West Africa. With most countries in Africa pushing for development, some of the research findings here can play an important role in helping to realize the development aspirations of African economies.

An important and impressive statistic is that the 329 authors of the papers in this year's conference proceedings come from 87 different institutions and 10 different countries. This provides plenty of scope for cross-boundary learning. It also provides for a rich intellectual, international and multicultural blend and platform for networking and developing new knowledge and longer-term collaborations. We hope that all delegates at this conference will make good use of this opportunity. Going forward into the future WABER will develop strategic initiatives for helping more people to develop their work and achieve their potential. The Micheletti & Co. Ltd Prize for Best Masters Research Dissertation is a scheme to recognise and encourage younger researchers.

On that note, we wish to record our thanks and gratitude to a number of individuals and organizations who have supported us in various ways: Vector Morrison Ghana Ltd; A-Kon Consults Limited (Ghana); Oladele Construction Ltd (Nigeria); K+H Limited (Ghana); HLB Ltd (Ghana); Laurus Development Partners; PPMC Ltd (Ghana); Micheletti and Co. Ltd; Mr. Michael Kwadwo Frimpong (President of the Africa Association of Quantity Surveyors (AAQS)); Mr. Afolabi Abdulsalam Dania (University of Reading, UK); Professor Kabir Bala (Ahmadu Bello University, Nigeria); Professor Stella Zubairu and a number of our colleagues in Nigeria.

A common tradition at academic conferences is to have keynote speakers. We are blessed this year to have some really experienced international academics who will be speaking to us: Professor Roger Flanagan (University of Reading, UK); Dr Roine Leiringer (University of Hong Kong, Hong Kong); Dr Chris Harty (University of Reading, UK); Professor Stella Zubairu (Federal University of Technology, Minna, Nigeria) and Professor Will Hughes (University of Reading, UK). It is great to have these academics contributing a keynote to the conference.

I wish to express appreciation to Dr Sena Agyepong, our Regional Organising Director, and members of our LOC particularly Mr Oladele Ishaq for your hard work and capable management of local organising arrangements. Above all, many thanks to all those of you who have come to take part in this conference. Enjoy Abuja and have a safe journey back home.

Dr Samuel Laryea
School of Construction Management and Engineering
University of Reading, UK
July 2012

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The peer review process for an international conference of this nature requires the expertise and contribution of a number of international academics. We wish to thank the following people who carried out the review of abstracts and papers for the WABER 2012 conference in addition to the members of our Scientific Committee. Thank you for your contribution.

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CONTENTS

SECTION 1: KEYNOTES

The business of construction procurement: selecting, defining and managing procurement - Will Hughes 1
The importance of evaluation and sustainability in the built environment - Stella Zubairu 9

SECTION 2: CONFERENCE PAPERS

Effects of curing conditions on compressive strength development of high strength concrete - A.E. Abalaka and O. G. Okoli 17
Assessing the structural integrity of existing building structures - A. D. Abdul'Azeez; I. K. Zubairu; D. Dahiru and U. A. Ahmed 25
Perception of educators and practitioners on the relevance of architectural curriculum of Nigerian universities to the building industry - Abdullahi Abubakar 35
Investigating the Practice of Cash flow forecasting by Contractors in Nigeria - Mustapha AbdulRazaq, Yahaya Makarfi Ibrahim and Ahmed Doko Ibrahim 47
Assessment of development of technicians/technologists in the built environment disciplines in Nigeria - Emmanuel Achuenu, Bulus Gwom Pam and Stella Ache Achuenu 55
Multi-skilling barriers in the construction industry in North-Western Nigeria - Nasiru Adamu, Mohammed Hassan Nensok and Adefemi Aka 67
Evaluation of involvement of built environment professionals in housing transformation processes in three government housing estates in South- Western, Nigeria - Victor Olufemi Adegbehingbe 83
Slum development in 3rd world countries: causes, effect and way out. 91
Examining the effect of quality management practices used on construction project performance - Ademeso Olatunji, Windapo Abimbola and Fasina Nureni 99
Analysis of spatial types and social space in Ile-Ife domestic architecture - C O Adeokun 109
Assessment of contractors' cost control practices in Metropolitan Lagos - Afeez Olalekan Sanni and Olufemi Daniel Durodola 125
Client perspective for the implementation of lean construction in Nigerian construction industry - Ograbe Ahiakwo, David Oloke, Subashini Suresh and Jamal Khatib 133
An exploration of the use of Delphi methodology in housing satisfaction studies -Clinton Aigbavboa and Wellington Thwala 147
Morphing the rules: advanced adaptations of mud in Nigerian buildings - Stephen Babatunde Ajadi 163
Effect of crude oil impacted sand on the properties of concrete - Wasiu Olabamiji Ajagbe, O A Agbede and B I O Dahunsi 177
Sustainable housing development and communal provision of infrastructures in Asuwamo residential estate Akure, Nigeria - Mary Adebola Ajayi and Felix Kayode Omole 191
Impact of risk on performance of design and build projects in Lagos State, Nigeria - O M Ajayi, O E Ogunsanmi, O A Salako and B A Mafimidiwo 203
Durability characteristics of concrete produced with date seed as light weight aggregate - A Aka, N Adamu and M H Nensok 217
Impact of total quality management (TQM) on Nigerian construction firms - J. A. Akinola, O. F. Akinradewo and S. O. Olatunji 225
Relevance of Hernando De Soto's principle of land titling to Lagos Metropolis - Emmanuel Adesina Aladeloba 237
Rational design of concrete mixes using uncrushed aggregates - T. O Alao 251
Causes of financial loss to contractors in the Uganda construction industry - Christopher Semyalo, Henry Alinaitwe and Anthony Kerali 263

Minimization of heat gains in buildings: the case of domestic buildings in cape coast metropolis – Ghana - Samuel K. Ansah and Emmanuel Bamfo-Agyei 275

Strength performance of laterized concrete at elevated temperatures - J. A. Apeh and E.B Ogunbode 289

Effect of packing densities of aggregates on the workability and compressive strength of concrete - Chinwuba Arum 299

A need to re-define the status of professional valuation: The Nigerian perspective - Thomas A Ashaolu 313

Evaluation of public private partnership (PPP) as alternative procurement route for infrastructure development: Case of Nigeria mega city - Oluwaseyi A. Awodele, Stephen O. Ogunlana and Olusola F. Akinradewo 329

Sustained beautification of Nigerian cities through landscaping: The case of Akure - Dorcas A Ayeni and Charles A Olalusi 345

Success factors for implementation of private public partnerships in the construction industry in Uganda - Henry Alinaitwe, Robert Ayesiga and Albert Rugumayo 355

Assessment and management of stormwater drainage facilities in residential areas of Enugu city - Kevin Ejike Chukwu and B. O. Uwadiegwu 367

An assessment of housing sanitation and waste management practices in the residential core areas of Osogbo, Osun State Nigeria - Hezekiah A. Ayoola, A. F. Lawal and M.L. Akinluyi 377

Benefit of conducting energy calculations in the built environment of Nigeria - Amina Batagarawa 389

Effect of climate change on construction project planning in Nigeria - Wasiu A. Bello, R. A. Adekunle and O. E. Ogunsanmi 399

Estimating cost contingency for construction projects: The challenge of systemic and project specific risk - Joseph Ignatius Teye Buertey, Emmanuel Abeere-Inga and Theophilus Adjei Kumi 413

Assessment of the rental values of residential properties in urban slums: The case of Osogbo, Osun state Nigeria – I.D. Dabara, A.S. Okunola, A.G. Odewande and A. Okorie 427

Evaluation of the pozzolanic activity of Kajuru pumice tuff as sustainable Cementitious materials for cement blending - D W Dadu, A M Stanley, K S N Gora and P E Ehoche 441

Assessment of Public-Private-Partnership Regulatory Framework for Infrastructure Development in Nigeria - Alhassan Dahiru 451

An evaluation of the concrete production in typical construction sites in Nigeria - Dauda Dahiru and Nasiru Shehu 463

Quantity and quality assessment of artificial lighting system of buildings in Nigeria - Dalhatu Abdulsalam, Yunusa M Saleh, Abdullahi A Mati and Aliyu Suleiman Shika 473

The preference of Ghanaian contractors in providing occupational health and safety items; an exploratory study - Frederick Owusu Danso, Edward Badu and Divine Kwaku Ahadzie 483

The reach and limits of architectural theory in practice: Interpretations from a Nigerian perspective - Elizabeth T Dassah, Erepitan O. Ola-Adisa and Michael C. Odoala 495

Using indoor climatic measurements for occupancy monitoring - Tobore Ekwevugbe, Neil Brown and Denis Fan 507

Urban open spaces; luxury or necessity - Augusta Ifeoma Emenike 521

A case for the construction of green buildings in Lesotho - F.A. Emuze, W.M. Shakantu and K. Ntsihlele 523

Efforts in Rural Development by African Governments; Focus on Nigeria's Niger Delta - Prince E. England and A A Yakub 535

Determinants of vacancy rate in shopping centres in Akure, Nigeria - N B Ezeokoli, V A Bello and O S Adebisi 551

Assessment of bid evaluation strategies for construction projects in Lagos State, Nigeria - I. O. Famakin, I. O. Aje. and O. Olajide 563

Contributing factors of delay in the Nigerian construction industry: A comparative analysis with other selected countries - Emmanuel O Fatoye 575

The kitchen in domestic space: A comparative study of kitchens cooking and culinary practice in Ile-Ife, Nigeria - Folake Isaacs-Sodeye 589

Mass housing in Nigeria, customize the brief: Provide a desired house - Folaranmi Adedayo Olatunde 607

The Use of Laterite-Cement-Enhanced Bricks in the Provision of Public Infrastructure: A Case Study of Osun State University Bukateria Complex, Osogbo, Osun State, Nigeria - M.B Gasu ; A. O. Ajayi and E Ogunjumo 619

Greening Accra: The use of landscape architecture to enhance the city's environment - Karen Evans Halm 627

Mitigating construction project risk using Building Information Modeling (BIM) - D.B. Hammad; A. G. Rishi and M. B. Yahaya 643

Public-Private Partnerships (PPPs) in Housing Provision in Ogun State, Nigeria: Opportunities and Challenges - Eziyi O. Ibem and Egidario B. Aduwo 653

Foundation for a decision support framework for optimal sequencing of emissions savings refurbishment options in non-domestic buildings - Taofeeq Ibn-Mohammed , R.Greenough; S.Taylor; L. Ozawa-Meida and A. Acquaye 663

Improving Labour Productivity in Masonry Work in Nigeria: The Application of Lean Management Techniques - John Ebhohimen Idiake and Kabir Bala 677

An analysis of contractors' approaches to risk management practices in Lagos state, Nigeria - Irewolede Ijaola 687

Bridging the cultural gap between traditional and modern building designs - Oluwatosin Olufunto Ijatuyi and Abraham Adeniyi Taiwo 697

Effect of used oil on the strength and compressibility behavior of lateritic soil - Ijimdiya, T S and Igboro, T 709

INDEX OF AUTHORS 719

INDEX OF KEYWORDS 721

STRENGTH PERFORMANCE OF LATERIZED CONCRETE AT ELEVATED TEMPERATURES

J. A. Apeh[1] and E. B. Ogunbode[2]
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The study presents the results of an experimental program to investigate the strength performance of Laterized concrete at elevated temperature. Four concrete mixes incorporating 0, 10, 20 and 30% laterite as a replacement by weight of sand was prepared. A concrete mix ratio of 1:2:4(Cement: laterite/sand: granite) with water/cement ratio of 0.65 was used for the study. The laterite content in the fine aggregate was varied from 0 – 30% at 10% interval. Specimens cured for 7, 14, 21 and 28days were subjected to uniaxial compressive loading tests at room and elevated temperatures of 200, 400 and 600^{o}C. Results showed that for the varying percentage replacement of sand with laterite, compressive strength of laterized concrete decreases; and with increase in temperature, the strength decreases. It was also observed that an air-cooled lateritic concrete specimen has higher residual strength values than water- cooled specimens. A maximum compressive strength value of 24.10N/mm^2 was obtained for the mix with 30% laterite – 70% sand at 400^{o}C which indicates the strength of laterized concrete that is sufficient for use at elevated temperature not exceeding 400^{o}C.

Keywords: compressive strength, elevated temperature, laterite, residual strength

INTRODUCTION

The three basic necessities of life are air, food and shelter. The earth as one of the major materials was used for Man's shelter since time immemorial (Adakole, 1992). The continuous usage of the material for affordable housing leads to its depletion hence the need to seek alternatives or develop new materials to solve the problem of housing for ever – increasing population. Basically, the use of latcon as a material in building construction involves the modification of lateritic soils in its raw form. Laterite has been used in building construction for thousands of years and presently used for shelter for approximately 30 % of the world population (confirman et al, 1990). It is formed by the weathering of rocks under humid tropical conditions and is mainly made of Iron and Aluminium hydroxides (Philip, 1993). Laterite is found extensively all over Nigeria and equally in all tropical regions of the world.

When fine aggregate is wholly or partially substituted with laterite soil in its natural form, it is known as laterized concrete or LATCON. In Nigeria, it is one of the under-utilized building materials due to the uncertainty of its strength and other properties (Ikponmwosa and Salau 2010; osadebe and Nwakonobi 2007). Lasisi and Osunade (1984) in their study on the effect of grain size on the strength of laterite cubes found that the finer the grain sizes, the higher the compressive strength. Falade (1994) took the study further when he examined the influence of water/cement ratios and mix

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Apeh, J.A. and Ogunbode, E.O. (2012) Strength performance of laterized concrete at elevated temperatures *In:* Laryea, S., Agyepong, S.A., Leiringer, R. and Hughes, W. (Eds) *Procs 4th West Africa Built Environment Research (WABER) Conference*, 24-26 July 2012, Abuja, Nigeria, 289-298.

proportions on workability and characteristic strength of concrete containing laterite as fine aggregate and found that water requirement increases as laterite/ cement ratio increases, for a given mix proportion.

Udoeyo et al, (2006) carried out an experimental investigation on some characteristics of concrete containing laterite as partial or full replacement of fine aggregate. Test results showed that concrete with 40% replacement of sand with laterite could attain design strength of $20N/mm^2$. This fact is reinforced in the comparative study of strength properties of unreinforced and fibre reinforced normal and laterized concrete by Ikponmwosa and Falade (2006). Test results showed that strength increases with age of the test specimens. Also, laterite replacing sharp sand in concrete up to 45% produced the highest compressive strength.

Ayangade et al (2009) took the study to a new dimension when they evaluated the effects of different curing methods on the compressive strength of terracrete (Granite and laterite). Sixty cubes of 100 x 100 x 100mm using a mix of 1:1½:3, water/cement ratio of 0.62 were cast and cured using four different methods of curing for up to 35 days. Test results of the various compressive strengths of the cubes showed that out of the four curing methods, open method produced cubes with the highest compressive strength of $10.3N/mm^2$ by the 35th day. Still, in the same vein to ascertain the strength properties of laterized concrete, Udoeyo et al, (2010) studied early prediction of laterized concrete strength by accelerated testing using the boiling water of accelerated strength testing to predict the 28-day compressive strength of laterized concrete; results showed that the accelerated strength of the concrete was between 72 and 84% of its twenty- eight days strength.

Lanre and Mnse (2007) advanced the investigation further when they studied the influence of weather on the performance of laterized concrete. This was achieved by conditioning laterized concrete cubes to varying temperatures and alternate wetting and drying. After curing for 28 days, the specimens were tested to determine the compressive strength. The results showed that the compressive strength of the treated laterized concrete decreases when subjected to alternate wetting and drying. The specimens conditioned to a temperature range of 75 – 125^oC attained compressive strength as high as $22.52N/mm^2$. However, the study could not ascertain the critical failure temperatures.

When concrete is subjected to high temperatures, it is transformed due to reactions which causes progressive breakdown of its internal structure and thus experience loss in its load – bearing capacity (Bazant and Kaplan, 1996; khoury, 2000; kalifa et al, 2000; Phan et al, 2001). However, the extent of loss in LATCON load – bearing capacity was not determined and need to be ascertained. Ikponmwosa and Salau (2010) studied the effect of heat on laterized concrete. Cube specimens were cast, cured and subjected to elevated temperatures of 250, 500 and 750^oC. The laterite content in the fine aggregate was varied from 0 – 100% at 25% interval. Specimens cured at 7 and 28 days were subjected to uniaxial compressive loading tests at room and elevated temperatures. Tests results showed that normal concrete cannot withstand large load above 250^oC while laterized concrete with 25% laterite in the fine aggregate is able to resist higher load with increase in strength at higher temperatures. The peak compressive strength value of 30.44N/mm2 is recorded for the mix with 25% laterite – 75% sand at 500^oC.

A structural component exposed to devastating fires accidentally for long periods (exceeding fire resistance duration) resulting in high rise of temperature and reduction in strength, the reduced strength of the component is called residual strength (Kumar, 2003). The data on the residual strength of laterized concrete needs to be determined. Other changes due to high temperatures include chemical and microstructural changes, such as water migration (diffusion, drying), increased dehydration, interfacial thermal incompatibility and chemical decomposition of hardened cement paste and aggregates. These changes decrease the strength and stiffness of concrete and increase irrecoverable deformation (Zhang et al, 2000).

Many researchers have carried out investigations on the strength of plain concrete at elevated temperatures (Phan and Carino, 2000; Abramowicz and Kowalski, 2005; Chan et al, 1999; Mohamedbhai, 1983; Poon et al, 2001). The suitability of laterized concrete in the construction of structural members has been studied. However, there is dearth in research on the effect of heat on this type of concrete. Due to the plasticity and fineness of laterite fines compared to sand, the effect of temperature variation will certainly influence the strength properties of laterized concrete. It is therefore very essential that the strength performance of this concrete at elevated temperatures be understood, and that is the focus of this study.

MATERIALS AND METHOD S

The study was performed at Department of building, Federal University of technology, Minna, Nigeria. Four concrete mixtures containing 0, 10, 20 and 30% replacement levels of sand by laterite were prepared with w/c ratio of 0.65 as shown in table 1.

Table 1: Mix Proportions for laterized concrete.

Mix	w/c ratio	unit weight kg/m^3				
		Water	cement	sand	laterite	granite
Mix_0	0.65	190	292	514	-	1432
Mix_{10}	0.65	190	292	462.6	51.4	1432
Mix_{20}	0.65	190	292	411.2	102.8	1432
Mix_{30}	0.65	190	292	359.8	154.2	1432

Type 1 ordinary Portland cement was used for the study with properties conforming to British standard Bs 12; 1978 with average bulk density ranging from 3050 – 3150Kg/m^3. The water used was clean, portable water, free from impurities. Two types of fine aggregates were used for the study – sand and laterite which conforms to BS 1377- 1 and 2. The sand is river sand with a specific gravity of 2.60, obtained from a deposit site at Maitumbi, Bosso local Government area, Minna, Nigeria. Laterite fines with specific gravity of 2.67, reddish- brown, absorbent and non- granular was obtained from Meikunkele, Minna, Nigeria. The coarse aggregate was crushed granite of maximum size 25mm obtained from a quarry site, Maitumbi, Minna, Nigeria. Both aggregates complied with the requirements of Bs 882. The materials including 50Kg bags of cement were transported and stored in the laboratory before use.

The coefficient of uniformity (C_u), which are used to standardize gradation criteria for the sand, laterite and granite are obtained from the relationships: $C_u = (D_{60} /D10)$ and $C_c = (D_{30})^2/D_{60} * D_{10})$ where D_{60} = diameter(mm) of the 60%, 30% and 10% passing sieve sizes respectively (Das, 2008). The liquid limit (LL) of a soil sample, which is a measure of the level of water content at which the soil changes from plastic to liquid was determined by the cone penetrometer method (Garg, 2008) based on the measurement of penetration of a standardized cone of specific mass into the soil from which material retained on a 425- µm test sieve has been removed. Also, the plastic limit (PL) which shows the level of water content at which the soil whose material retained on a 425-µm test sieve has been removed starts to exhibit plastic behavior, was determined by the soil snake test (Garg, 2008).The plasticity index (PI), a measure of the plasticity of the soil samples, was determined for the laterite sample. This Index indicates the water content at which the soil specimens exhibit plastic properties. The plasticity index is the difference between the liquid limit and the plastic limit; i.e PI = LL - PL.

The slump test of fresh laterized concrete mix was to determine consistency according to Bs EN 12350: Part 2 : 2000. The mould for the slump test measures 305mm in height, base diameter is 203mm, while the smaller opening at the top is 102mm. the slump cone is filled in three layers with tamping between each filling to remove voids. The concrete is leveled off at the top of the cone. With the cone removed, the height of the slump is then measured. Slump of laterized concrete against laterite content is shown in figure 3 respectively.

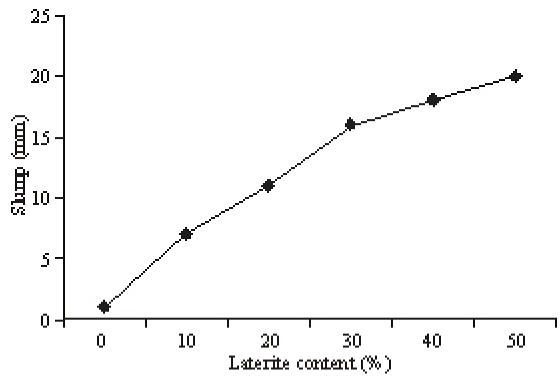

Figure 1: Slump of laterized concrete vs laterite .

The laterite content in the fine aggregate of the concrete mixtures (table 1) was varied from 0 - 30% at 10% interval. The normal concrete specimens (0% laterite) served as control for the experiment. After batching and thorough mixing of the constituents to homogeneity with a pre- calculated amount of water, the fresh mixes were cast into metallic 100mm moulds. Twenty – four test cubes were prepared from each mix. The test cubes were stripped from the moulds after 24hr, cured in a water tank for 28 days, wiped clean and then ready for testing. They were then subjected to heat pretreatment for one hour at 200, 400 and 600°C in a carbolite furnace with regulated temperature up to 700°C. After removal from oven, Twelve cubes from each batch were left in the laboratory to cool down naturally and another set was cooled rapidly by immersion in a water tank. These specimens were then tested for their compressive strength on a 600KN Avery Denison Universal testing machine using a loading rate of 120KN/min. Control (unheated) cubes were also crushed at room temperature (table 4 and 5).

The test used to investigate the effect of elevated temperatures on the compressive strength of laterized concrete was the residual unstressed test, where the specimens are heated without any load, cooled down to room temperature and then loaded to failure.

Table 4: Average compressive strength (N/mm^2) of concrete specimens (Air – Cooled)

% laterite in Fine Aggregate	$21^o \pm 0.5^oC$ (28 days)	200^oC (28 days)	400^oC (28days)	600^oC (28days)
0	19.67	17.60	16.60	15.15
10	17.80	16.20	15.49	14.60
20	13.67	12.58	11.56	10.39
30	12.67	10.90	10.14	9.25

Table 5: Average compressive strength (N/mm^2) of concrete specimens (water – Cooled)

% laterite in Fine Aggregate	$21^o \pm 0.5^oC$ (28 days)	200^oC (28 days)	400^oC (28days)	600^oC (28days)
0	28.76	23.58	22.15	20.11
10	29.57	23.60	21.88	20.70
20	19.67	14.75	13.97	13.38
30	18.93	13.63	13.06	12.49

This test method is shown graphically in figure 2 below.

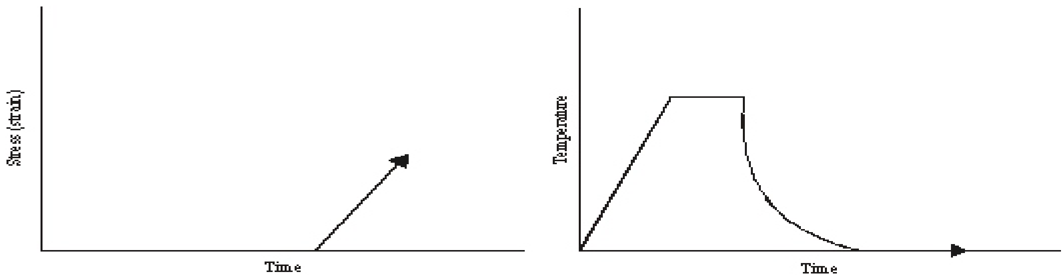

Figure 2: Residual property test method.

RESULTS AND DISCUSSION

Preliminary test results

Preliminary test results of the laterized concrete constituents are shown in table 2.

Table 2: Test results of variables for the laterized constituents.

Variable	laterized concrete constituent.		
	Sand	laterite	coarse Agg (Granite)
Sp. Gr.	2.60	2.67	2.69
Fm	4.03	2.72	2.64
C_u	1.67	7.5	1.8
C_c	1.07	1.0	1.20
Impact value			13%
Crushed value			22.10%
Atterberg limits			
LL		20.79%	
PL		09.18%	
PI		11.61%	

The particle – size distribution of laterite and sand is shown in figure 3.

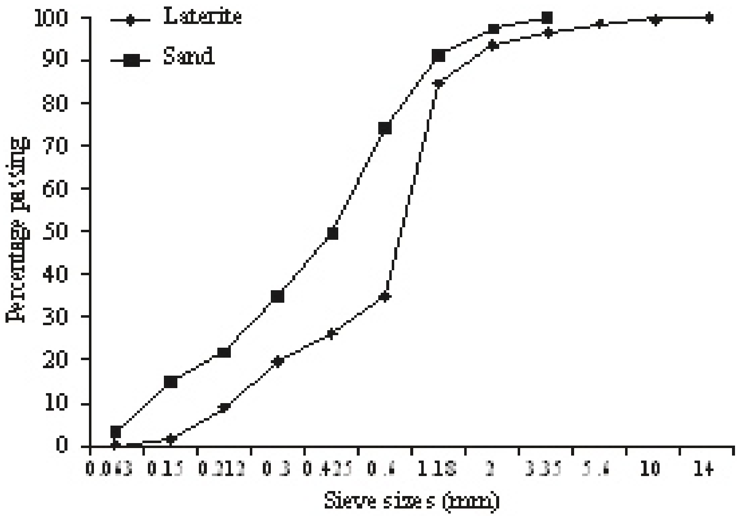

Figure 3: Grading curve for sand and laterite.

Workability

The results of the workability of fresh laterized concrete mixtures measured in terms of slump are shown in table 2 and figure 3 respectively. The workability of the concrete increases with laterite content.

Effect of elevated temperature on residual compressive strength

The test results of the residual compressive strength of plain (0% laterite content) and laterized concrete subjected to high temperatures, cooled in the laboratory freely by air (Air – cooled) and by submerging in a water-tank (water – cooled) are in tables 4 and 5 and figures 4 and 5 respectively. Figures 4 and 5 showed a common trend observed for both air – cooled and water – cooled, a decreasing residual strength with increasing temperature. The strength reduction of the tested specimens for the mixes was between 8 and 13% for air – cooled and between 18 and 28% for water- cooled, respectively at 200°C. At 400°C, the concrete mixes sustain greater strength losses of between 13 and 20% for air- cooled and between 23 and 31% for water- cooled.

A more severe loss in strength was observed for all the mixes at 600°C. At this temperature level, the strength loss of the mixes was between 18 and 27% for the air – cooled and between 28 and 34% for water cooled.

Effect of cooling regime on residual compressive strength:

From figures 4 and 5, it is a common trend that greater strength losses were sustained by specimens cooled with water than those cooled slowly by exposure to air in the laboratory. This is in agreement with findings of other researchers who have observed that cooling concrete rapidly by immersion in water after heat pretreatment results in a thermal shock which in turn leads to lower strength values than concrete cooled freely by exposure to air after heat pretreatment (Peng et al, 2008; Yuzer et al, 2004; Chan et al, 2000).

Effect of laterite content on residual compressive strength

Figures 4 and 5 show the influence of laterite content on the residual compressive strength of specimens. At 200^{o}C heat pretreatment cooled in water Latcon specimens with 10% replacement level of sand by laterite, the compressive strength loss was about 20%; while the loss for those with 30% replacement level of sand was about 28%. Plain concrete specimens (0% laterite content) subjected to corresponding temperature had a strength loss of 18%. At 400^{o}C the strength loss of latcon with 10% replacement of sand was 13% for air – cooled and 26% for water – cooled specimens and for concrete with 30% replacement level of sand by laterite the strength loss was 31% for water – cooled and 20% for air – cooled specimen. At 600Oc the loss in the compressive strength of Latcon was observed to be severe, especially for specimen with higher laterite content. The loss in strength was between 12% for air – cooled Latcon specimens with a 10% replacement level of sand and 27% for Latcon with a 30% replacement level of sand. Plain concrete (0% laterite) subjected to 600Oc heat pretreatment had a strength loss of about 23% for air- cooled and 28% for water – cooled.

The explanation for the losses in strength by latcon with higher laterite content is similar to that given by Poon et al, (2003), for Metakaolin concrete. Possible thermal dilations in the concrete due to elevated temperatures may have resulted in large internal stresses, and ultimately, led to internal micro cracking and fracture. Besides, the dense pore structure of latcon with greater laterite clay fines could increase vapour pressure upon heating, resulting in increased cracking and severe losses in compressive strength.

CONCLUSION

The following conclusions could be drawn based on the results of this study:

When subjected to elevated temperatures between 200 and 600^{o}C the compressive strength of laterized concrete decreased in a similar manner to that of plain concrete. Though deterioration in strength for both types of concrete was severe at 600^{o}C, however, laterized concrete maintained lesser proportion of its relative residual strength than Plain concrete.

From the results of the study, the mode of cooling significantly influenced the residual compressive strength of laterized concrete. Laterized concrete specimens cooled freely by exposure to the surrounding air after heat pretreatment maintained relatively higher residual strength values than those cooled rapidly by immersing them in water.

Since findings from other studies with that contained in this study show that rapid cooling of heat pretreated specimens by immersion in water leads to severe loss in strength, other less negative alternative method(s) of rapid cooling should be investigated.

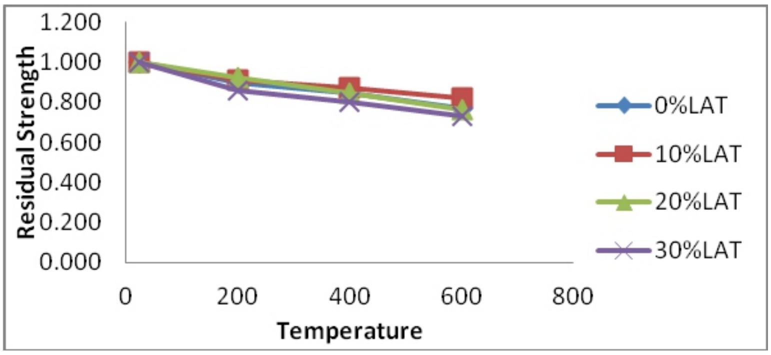

Figure 4 – Residual strength vs Temperature for Air Cooled specimens.

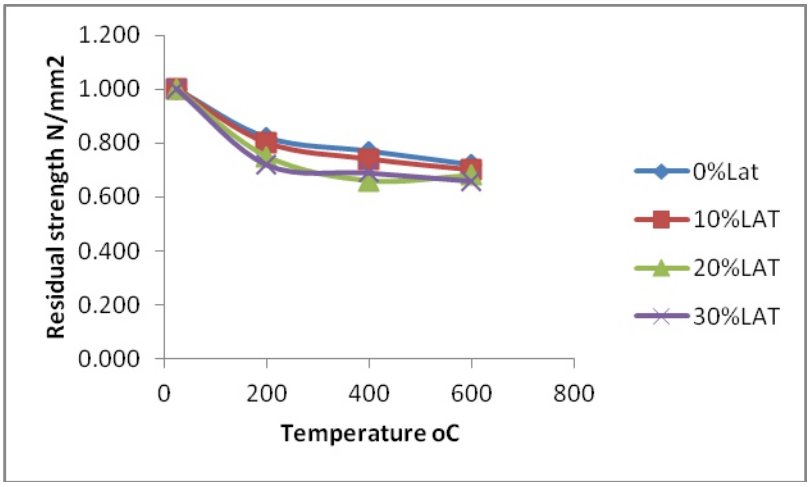

Figure 5: Residual strength vs Temperature for water – cooled samples.

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