DEFORMATION BEHAVIOUR OF SELF-COMPACTING CONCRETE CONTAINING HIGH VOLUME PALM OIL FUEL ASH

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I dedicate this work

To my parents

Nizamul Huq

And

Mrs. Sajeda Begum

Whose love, kindness, patience and prayer have brought me this far. I thank them

For their love, understanding and support throughout my endeavors

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ABSTRACT

Self-compacting concrete (SCC) is an advanced type of concrete that can be placed and compacted under its own mass without vibration. SCC is used to facilitate and ensure proper filling and good structural performance of restricted areas and heavily reinforced structural members. SCC is a flowing concrete with high workability. Although SCC can be proportioned with a wide range of aggregates, the selection of favorable aggregate characteristics can significantly enhance the economy and performance of SCC. Using supplementary cementitious materials can reduce the cost of cement. One of the potential recycle materials from palm oil industry is palm oil fuel ash (POFA). The objectives of the research project were to evaluate the effects of high volume POFA characteristics and mixture proportions on the deformation behaviour of SCC. This study outlines laboratory tests, which was conducted by the replacement levels of 0%, 50% and 70% of POFA instead of OPC by the weight, with water-binder ratio of 0.4. Target properties for SCC workability were studied as a function of the application and in terms of filling ability, passing ability, segregation resistance. These include slump flow, J-ring, and V-funnel at $T_{5minutes}$ for fresh properties and compressive strength, split tensile strength, flexural strength, creep, shrinkage, and modulus of elasticity tests for harden properties. Test specimens comprising of cube, cylinder and prism were prepared and tested at 7, 28, 56 and 90 days. Results obtained in this study reveals that high volume palm oil fuel ash used in self-compacting concrete exhibited satisfactory performance, particularly at later ages.

ABSTRAK

Konkrit tanpa mampatan (SCC) adalah sejenis konkrit terkini yang boleh ditempatkan dan dipadatkan di bawah jisim sendiri tanpa meggunakan getaran. SCC digunakan untuk membantu dan memastikan kerja mengisi ruang yang betul serta prestasi struktur yang baik di kawasan terhad dan anggota struktur yang banyak tetulang. SCC adalah konkrit yang berkebolehan untuk mengalir dengan kebolehkerjaan yang tinggi. Walaupun SCC boleh berkadaran dengan semua agregat, pemilihan ciri-ciri agregat yang bagus secara signifikan boleh meningkatkan ekonomi dan prestasi SCC. Penggunaan bahan-bahan bersimen tambahan boleh mengurangkan kos simen. Salah satu daripada bahan-bahan kitar semula daripada industri minyak sawit yang berpotensi adalah abu pembakaran kelapa sawit (POFA). Objektif projek kajian ini adalah untuk menilai kesan ciri-ciri POFA berisi padu tinggi dan perkadaran campuran ke atas perubahan perilaku SCC. Kajian ini merangka ujian makmal yang dijalankan dengan kadar penggantian 0%, 50% dan 70% POFA, bukannya OPC mengikut berat, dengan nisbah air-pengikat 0.4. Sasaran sifat kebolehkerjaan SCC dikaji mengikut fungsi aplikasi dan dari segi keupayaan mengisi ruang, keupayaan melapasi serta rintangan pengasingan. Ini termasuk ujian serakan, gegelang-J, dan corong-V di T_{5minit} untuk sifat baru dan kekuatan mampatan, kekuatan tegangan pemisahan, kekuatan lenturan, rayapan, pengecutan, dan ujian modulus keanjalan untuk sifat-sifat kekeras. Spesimen untuk pengujian terdiri daripada kiub, silinder dan prisma telah disediakan dan diuji pada umur 7, 28, 56 dan 90 hari. Keputusan yang diperolehi daripada kajian ini menunjukkan bahawa isi padu abu pembakaran kelapa sawit yang tinggi yang digunakan dalam konkrit tanpa mampatan menunjukkan prestasi yang memuaskan terutama pada umur kemudiannya.

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LIST OF ABBREVIATIONS

ACI	-	American Concrete Institute
ASTM	-	American Society for Testing and Materials
BS	-	British Standards
CANMET	-	Canada Centre for Mineral and Energy Technology
EASEC	-	East-Asia and Pacific Conference on Structural and Construction
EFNARC	-	European Federation of National Associations Representing producers and applicators of specialist building products for Concrete
FA	-	Fly ash
GGBFS	-	Ground granulated blast-furnace slag
HRWR	-	High range water reducers
HRWRA	-	High range water reducing admixture
HVBFS	-	High volume blast-furnace slug
HVFA	-	High volume fly ash
HVMA	-	High volume mineral aggregates
HVPOFA	-	High volume palm oil fuel ash
MOE	-	Modulus of Elasticity
MS	-	Malaysia Standards
OPC	-	Ordinary portland cement
PCE	-	Polycarboxylate ethers
PFA	-	Pulverised fuel ash
POFA	-	Palm oil fuel ash
RHA	-	Rice husk ash
RILEM	-	The International Union of Laboratories and Experts in Construction Materials, Systems and Structures

SCC	-	Self-Compacting Concrete
SCM	-	Supplementary cementitious material
SMF	-	Sulfonated condensates of melamine
SNF	-	Sulfonated condensates of naphthalene
U.S	-	United States
VMA	-	Viscosity Modifying Admixture

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Concrete is the conventional and one of the most durable building materials for most civil engineering works in the world. It provides superior fire resistance. Structures made of concrete can have a long service life. Reinforced concrete, prestressed concrete and precast concrete are the most widely used types of concrete functional extensions in modern days.

Self-Compacting Concrete (SCC) is an advanced type of highly flow able, non-segregating concrete that is able to flow under its own mass without vibration and through congested reinforcement. Apart from health and safety benefits, it offers faster construction times, increased workability and ease of flow around heavy reinforcement. Having no need for vibrating equipment spares workers from exposure to vibration. No vibration equipment also means quieter construction sites Self-compacting concrete development must ensure a good balance between deformability and stability. SCC contains large amount of fine particles such as palm oil fuel ash (POFA), pulverized fuel ash or fly ash, rice husk ash (RHA) and blast furnace slag in order to avoid gravity segregation of larger particles in the fresh mix.

The fluidity of SCC ensures a high level of workability and durability whilst the rapid rate of placement provides an enhanced surface finish. SCC's overnight strengths typically reach 30-40N/mm^2 and two-day strengths can break the 100N/mm^2 barrier which enable easier and more reliable demoulding [1].

The concept of self-compacting concrete came into being in 1980’s in Prof. Okumara’s laboratory in japan [2]. The high seismicity of this geographical region requires the use of high levels of steel reinforcement in construction. The use of self-compacting concrete appeared as a solution to improve the filling up of the zones, which are not very accessible to conventional methods of concrete compaction. This solution also has the advantage of overcoming the gradual decline in the number of workers qualified to handle and place concrete.

1.2 Background of the Study

For several years beginning in 1983, the problem of the durability of concrete structures was a major topic of interest in Japan. To make durable concrete structures, sufficient compaction by skilled workers is required. However, the gradual reduction in the number of skilled workers in Japan's construction industry has led to a similar reduction in the quality of construction work. One solution for the achievement of durable concrete structures independent of the quality of construction work is the employment of self-compacting concrete, which can be compacted into every corner of a formwork, purely by means of its own weight and without the need for vibrating compaction. The necessity of this type of concrete was proposed by Okamura in 1986. Studies to develop self-compacting concrete, including a fundamental study on the workability of concrete, were carried out by Ozawa and Maekawa at the University of Tokyo [3].

The prototype of self-compacting concrete was first completed in 1988 using materials already on the market. The prototype performed satisfactorily with regard to drying and hardening shrinkage, heat of hydration, denseness after hardening, and other properties. This concrete was named “High Performance Concrete.” and was defined as follows at the three stages of concrete. At almost the same time, “High Performance Concrete” was defined as a concrete with high durability due to low water-cement ratio by Professor Aitcin. Since then, the term high performance concrete has been used around the world to refer to high durability concrete. Therefore, Okamura has changed the term for the proposed concrete to “Self-Compacting High Performance Concrete”.

Self-compacting concrete has many advantages over conventional concrete; eliminating the need for vibration; decreasing the construction time and labor cost; reducing the noise pollution; improving the interfacial transitional zone between cement paste and aggregate or reinforcement; decreasing the permeability and improving durability of concrete, and facilitating constructability and ensuring good structural performance.

Proper selection of finely ground materials can enhance the packing density of solid particles and enable the reduction of water or HRWRA demand required to achieve high deformability. It can also reduce viscosity for a given consistency; especially in the case of SCC made with relatively low water/binder ratio. Reducing the free water can decrease the VEA dosage necessary for stability. SCC can also include supplementary cementing material (SCM) mainly to improve the strength and durability of concrete [4]. However, SCM can influence the fresh properties of SCC such as filling ability, passing ability and segregation resistance [5]. Depending on the type and properties of SCM, this effect can be positive or negative for the fresh properties of SCC. The literature review revealed that several SCM’s, such as silica fume, ground granulated blast-furnace slag, fly ash and rice husk ash were used to produce SCC with good workability properties, strength and durability [4, 6-8]. Similarly, palm oil fuel ash (POFA) can be used in SCC. Previous studies have been done to produce different SCC mixtures incorporating POFA in the range of 0-15%

of cement by weight. The effects of POFA on the filling ability, passing ability and segregation resistance of SCC were examined. It was found that POFA can be used to produce SCC possessing the aforementioned fresh properties within the acceptable ranges [9]. In another study concrete was produced using a particular level of POFA replacement and same or more strength was achieved as compared to OPC concrete. About 30% of cement replacement with POFA shown no significant strength reduction [10].

1.3 Problem Statement

Considering the amount of POFA arising from oil mills in Malaysia, Thailand, Indonesia and other palm oil producing nations and the desire to address the environmental problem posed by this waste and even though there are clearly economic and environmental benefit associated with the use of POFA as cementicious material in construction works, there is relatively little or no information on the application of high volume palm oil fuel ash (HVPOFA) in production of construction materials. Researches have shown that well treated POFA will produce material with high quality comparable to other ashes. This research therefore, is intended to study the strength, durability performance of HVPOFA concrete, with the view to reduce the consumption of Portland cement and providing cost benefit form of disposal of palm oil waste generated from palm oil mills. Available literature indicates that improperly proportioned and cured concrete with POFA may be of inferior quality, particularly in the area of carbonation and durability. There are also indications that poor quality POFA concrete may be due to the quality of POFA being used. Therefore, further investigations are required to determine the factors that influence the properties of concrete with high volume POFA in other to come up with a guideline for the best practice.

1.4 Objectives of the Study

The main objectives of this research are as follows:

i. To investigate the fresh properties of self-compacting concrete containing high volume POFA.
ii. To determine the mechanical properties of SCC contain HVPOFA.
iii. To determine deformation characteristics of HVPOFA.

1.5 Scope of the Study

The study is centered on the use of High Volume Palm Oil Fuel Ash (HVPOFA) in concrete, to determine it compressive and tensile strength as well as it deformation properties, which is believed to be within the limits set by the objectives. The results of the study cannot be applied in general terms, except for POFA that possess the same index characteristics. Cost effectiveness of HVPOFA concrete will not be considered in this study. This of course does not intend to neglect the study economy to back ground, but rather it is believed that technical issues have to be understood and fixed right before the economic aspect of the study is determine.

1.6 Significance of the Study

Self-compacting concrete has many advantages over conventional concrete. The incorporation of waste as supplementary cementing material in concrete and other construction related materials are gradually gaining recognition at appreciable rate was they exist. In Malaysia one of the common wastes is palm oil fuel ash (POFA), which is a by-product of oil mills arising from the use of palm oil shall and palm oil bunch which are used to power oil mill plants for electricity generation. At present these wastes are disposed as land fill material without any economic benefit in return. Appropriately used, POFA can considerably enrich the properties of concrete and other related construction materials, which will reduce the pressure on the domestic and industrial consumption of Portland cement, "there is increase pressure to replace higher level of Portland with fly ash to help reduce the $C0_2$ emissions associated with the manufacturing of Portland cement". Fundamentally, for every production of Portland cement a considerable amount of $C0_2$ is released into the atmosphere. A total of 23 billion tons of $C0_2$ is released in to the atmosphere in the production process of Portland cement amounting to 7% of total releases of $C0_2$ worldwide [11]. But findings in available literatures as confirmed POFA to be a pozzolanic material, which can also fit into similar replacement of fly ash. Replacement of Portland cement with POFA could reduce cement production, which will in turn reduce CO emission, promote sustainability, reduce its cost of disposal and become environmental friendly material.

Construction industry and of course construction activity has been made the focus area that will help reduce environmental pollution (waste) arising from industrial and domestic activity, through the concept of reuse and recycle. Wastes material, may take several forms depending on the source, the research therefore is determine to exploits the potentials of POFA to construction industry.

This research therefore, seeks to investigate the strength characteristic, durability and deformation behavior of concrete containing high volume POFA for sustainable development as well as to put POFA into economic benefit.

REFERENCES

1. http://www.concretecentre.com/technical_information/building_solutions/special_concrete/self-compacting_concrete.aspx.
2. Okamura, H., K. Ozawa, and M. Ouchi, *Self-compacting concrete.* Structural Concrete, 2000. 1(1): p. 3-17.
3. Ozawa K., Kunishima, M., Maekawa, K. and Ozawa, K.: *Development of High Performance Concrete Based on the Durability Design of Concrete Structures, Proceedings of the second East-Asia and Pacific Conference on Structural Engineering and Construction (EASEC-2)*, January 1989. Vol. 1, pp. 445-450.
4. Safiuddin, M., J. West, and K. Soudki, *Hardened properties of self-consolidating high performance concrete including rice husk ash.* Cement and Concrete Composites, 2010. 32(9): p. 708-717.
5. Safiuddin, M., J. West, and K. Soudki, *Flowing ability of the mortars formulated from self-compacting concretes incorporating rice husk ash.* Construction and Building Materials, 2011. 25(2): p. 973-978.
6. Safiuddin, M., *Development of self-consolidating high performance concrete incorporating rice husk ash*. University of Waterloo; 2008.
7. Lachemi, M., *Development of cost-effective self-consolidating concrete incorporating fly ash, slag cement, or viscosity-modifying admixtures*. ACI Materials Journal, 2003. 100(5).
8. Khayat, K., *Optimization and performance of air-entrained, self- consolidating concrete*. ACI Materials Journal, 2000. 97(5).
9. Safiuddin, M. and M. Jumaat, *Fresh properties of self-consolidating concrete incorporating palm oil fuel ash as a supplementary cementing material*. Chiang Mai Journal of Science, 2011. 38(3): p. 389-404.

10. Karim, M., *Strength of Concrete as Influenced by Palm Oil Fuel Ash.* Australian Journal of Basic & Applied Sciences, 2011. 5(5).

11. Mehta K. P., *High-performance, high-volume Fly ash Concrete for sustainable development. International workshop on sustainable development and concrete technology*. At www.intrans.iastate.edu/pubs/slrstainable/mehtasustainable, 2011.

12. Abdullahi, k and Hussin, M. W., *A potential partial cement replacement material in aerated concrete. Proceedings of the 6th Asia-Pacific Structural Engineering and Construction Conference (APSEC 2006)*, Kuala Lumpur, Malaysia. 2006.

13. Borhan, M.N, Ismail, A and Rahamt, R. A., *Evaluation of palm oil fuel ash (POFA) on I Asphalt mixtures*. *Australian journal of Basic and Applied Sciences, 2010,* 4(10), 5456-5463.

14. Trangchirapat W, Janturapitakkul C. and Chindaprasirt P., *Use of Palm Oil Fuel Ash as a supplementary cementicious material for producing high-strength concrete*. *Construction and Building Materials. Elsevier, 2009.*

15. Awal, A.S.M.A. and Hussin, M.W., *Effect of palm oil fuel ash on durability of concrete, Proceedings of the 5th International Conference on Concrete Engineering and Technology*, Kuala Lumpur, Malaysia, 1997, pp.299-306.

16. CII-CANMET-CIDA, *Use of high volume fly ash concrete for building sector.* Environmental science and technology division, central building research institute Roorket-247667, 2005.

17. Jiang, L., *The interfacial zone and bond strength between aggregate and cement paste incorporating high volume of fly ash*. Cement and concrete research, Elsevier, 1999, 21 Pp313-316.

18. Sahmaran M, Yaman O. I and Tokyay M., *Transport and mechanical properties of self-consolidating concrete with high volume fly ash*. Cement and concrete composite, Elsevier, 2009, 31 Pp99-106.

19. P. Van den Heede and N. De Belie, *Durability Related Functional Units for Life Assessment of High-Volume Fly Ash Concrete*, 2010.

20. Bentz D. P and Ferraries C. F., Rheology and setting of high volume fly ash mixture. Cement and concrete composite, Elsevier, 2010, 32Pp 265-270.

21. Namagga, C and Atadero, R. A., *Optimization of Fly Ash in Concrete: High Lime Fly Ash as a Replacement for Cement and Filler Material*. World of coal ash (WOCA) Conference. Lexington KY, USA, 2009.

22. Sivasundaram V. Caratte G. G and Malhotra V.M., *Long-term strength development of high volume fly ash concrete*. Cement and concrete research, 1990, 12 Pp 263-270.

23. Dinakar P. Babu K.G and Manu S., *Durability property of high volume fly ash self-compacting concretes*. Cement and concrete research, Elsevier, 2008, 30 Pp 880-886.

24. Malhotra V.M and Painter K. E., *Early-age strength properties and freezing and thawing resistance of concrete incorporating high volumes of ASTM class F fly ash*. The international journal of cement composites and light weight concrete, 1989, Vol-11 Pp 37-46.

25. Rafat Siddique, *Performance characteristic of high volume class f fly ash concrete*. Science direct. Cement and concrete research, 2003, 34 pp487-493.

26. Neville A. M., *Properties of Concrete*, 3rd pitman publishing limited, 1981.

27. Gambhir M. L., *Concrete Technology*, 3rd edition. Tata McGraw- Hill publishing company limited, New Delhi, 2004.

28. Hussin M. W, Kang L. S and Zakaria F., *Engineering properties of high volume slag cement grout in tropical climate*. Malaysian journal of civil engineering, 2007, 19 (1) Pp42-54.

29. S. J. Barnett, M. N. Soutsos, S. G. Millard, and J. H. Bungey, *Strength development of mortars containing ground granulated blast-furnace slag: Effect of curing temperature and determination of apparent activation energies,* Cem. Concr. Res., 2006, vol. 36, no. 3, pp. 434–440.

30. Md. Moinul Islam, Md. Saiful Islam, Mondal B. C and Das A., *Strength behaviour of mortar using slag with cement in sea water environment*. Journal of civil engineering (IEB), 2009, 37 (2) Pp 111-112.

31. Arreshvhina N. Fadhadli Z. warid M. H, Zuhairy A. H and Roswadi, *Microstructural behaviour of aerated concrete containing high volume of GGBFS. Proceeding of the 6th Asia- pacific structural engineering and construction conference,* 2006.

32. Sobolev Konstantin, *Mechano-chemical modification of cement with high volume of blast furnace slag*. Science direct. Cement and concrete composite, 2005, 27 Pp848-853.

33. Choi, YW; Moon, DJ; Chung, JS; Cho, SK., *Effects of waste PET bottles aggregate on the properties of concrete*. Cement Concrete Res., 2005, 35, 776-781.

34. Malhotra S. K and Tehir S. P., *Development of bircks from granulated blast furnace slag*. Construction and building materials, 1996, 10 Pp 191-193.

35. Awal, A. S. M and Hussin, M. W., *Influence of palm oil fuel ash in reducing heat of hydration of concrete*. *Journal of civil engineering (IFB), 2010,* 38(2), ppl53-157.

36. Hussin, M.W and Awal, A.S.M.A., *Palm Oil Fuel Ash-a potential Pozzolanic Material in Concrete Construction. Proceedings of the International Conference on Urban Engineering in Asian cities in the 21" century, Bangkok, Thailand. 1996,* pp. D361-D366.

37. Awal, A. S. M and Nguong, *A short-term investigation on High Volume Palm Oil Fuel Ash (POFA) concrete*. A Final year Master project report, UTM, 2010.

38. Ouchi M., *History of Development and Applications of Self-Compacting Concrete in Japan. Proceedings of the First International Workshop on Self-Compacting Concrete*, 1998.

39. Concrete, *S.-C., The European Guidelines for Self-Compacting Concrete*. 2005.

40. http://www.theconcreteportal.com/scc.html.

41. K. H. Khayat and A. Yahia, *Effect of Welan Gum–High Range Water Reducer Combinations on Rheology of Cement Grout*, ACI Materials Journal, 1997, Vol. 94, No. 5, pp. 365 – 372.

42. M. Sari, E. Prat and J. –F. Labastire, *High Strength Self-Compacting Concrete: Original Solutions Associating Organic and Inorganic Admixtures*. Cement and Concrete Research. 1999, Vol. 29, No. 6, pp. 813 – 818.

43. M. Lachemi, K. M. A. Hossain, V. Lambros, P. –C. Nkinamubanzi, and N. Bouzoubaa, *Performance of New Viscosity Modifying Admixtures in Enhancing the Rheological Properties of Cement Paste*. Cement and Concrete Research, In Press, 2003.

44. S. D. Hwang, D. Mayen-Reyna, O. Bonneau and K. H. Khayat, *Performance of Self-Consolidating Concrete Made With Various Admixture Combinations, Proceedings of the 3rd International RILEM Symposium on Self-Compacting Concrete*, O. Wallevik and I. Nielsson, Ed., RILEM Publications, 2003, pp. 467 – 478.

45. M. Lachemi, K. M. A. Hossain, V. Lambros, and N. Bouzoubaa, *Development of Cost-Effective Self-Consolidating Concrete Incorporating Fly-Ash, Slag Cement, or Viscosity-Modifying Admixtures*. ACI Materials Journal, V. 100, No. 5, Sep-Oct 2003.

46. K. H. Khayat, *Viscosity-Enhancing Admixtures for Cement-Based Materials: An Overview*. Cement and Concrete Composites, Vol. 20, 1998, pp. 171 – 188.

47. J. Ambroise, S. Rols and J. Pera, *Self–Leveling Concrete–Design and Properties*. Concrete Science and Engineering, Vol. 1, 1999, pp. 140-147.

48. V. Rajayogan. M. Santhanam, and B. S. Sarma, *Evaluation of Hydroxy Propyl Starch as a Viscosity Modifying Agent for Self-Compacting Concrete*. *Proceedings of the 3rd International RILEM Symposium on Self-Compacting Concrete*. O. Wallevik and I. Nielsson, Ed., RILEM Publications, 2003, pp. 386 – 394.

49. Shehu, I. and A. Awal, *Mechanical properties of concrete incorporating high volume palm oil fuel ash.* Advanced Materials Research, 2012. 599: p. 537540.

50. De Schutter, G., et al., *Self-compacting concrete.* Whittles Publishing, 2008.

51. Grauers, M., *Rational production and improved working environment through using self-compacting concrete.* EC Brite-EuRam Contract No. BRPR-CT96-0366, 1997.

52. Gibbs, J. and W. Zhu, *Strength of hardened self-compacting concrete. Proceedings of the First international RILEM Symposium on Self-Compacting Concrete (PRO 7),* Stockholm, Suede. 1999.

53. Klug, Y., *Comparison of the hardened properties of self-compacting and normal vibrated concrete*. *Proceedings of the 3rd RILEM Symposium on Self-Compacting Concrete*, Reykjavik. 2003.

54. Sonebi, M. and P. Bartos, Hardened SCC and its bond with reinforcement. *Proceeding of First International RILEM Symposium on Self-Compacting Concrete (PRO 7),* Stockholm, Sweden. 1999.

55. Parra, C., Mechanical properties of self-compacting concretes. *Proceeding of the 5th International RILEM symposium on self-compacting concrete*. RILEM Publications SARL, 2007.

56. Hodgkinson J.M., *Mechanical Testing of Advanced Fiber Composite*. Cambridge: Wood head publishing. Ltd. 2000, pp 132-133.

57. B. Standard, British Standard Testing hardened concrete D Part 5 : *Flexural strength of test specimens,*" Eurocode Stand., no. August, 2003.

58. Domone, P., *A review of the hardened mechanical properties of self--compacting concrete*. Cement and Concrete Composites, 2007. 29(1): p. 112.

59. Lane, R. O., and Best, J. F., *Properties and Use of Fly Ash in Portland Cement Concrete*. Concrete International, V. 4, No. 7, 1982, pages 81 to 92.

60. Yuan, R.L. and Cook, R.E., *Study of a Class C Fly Ash Concrete. Proceeding of the First International Conference on the Use of Fly Ash, Silica Fume, Slag, and Other By-Products in Concrete*. ACI SP-79, Vol. 1, American Concrete Institute, Detroit, MI. 1983, pages 307 to 319.

61. Ghosh, R.S. and Timusk, J., *Creep of Fly Ash Concrete*. ACI Journals. Vol. 78, No. 5, Sep-Oct. 1981, pages 351 to 357.

62. Sivasundaram, V., Carette, G.G., and Malhotra, V.M., *Mechanical Properties, Creep, and Resistance to Diffusion of Chloride Ions of Concretes Incorporating High Volumes of ASTM Class F Fly Ashes From Seven Different Sources*. ACI Materials Journal. Vol. 88, No. 4, 1991, pages 407 to 416.

63. Malhotra, V.M. and Mehta, P.K., *High-Performance, High-Volume Fly Ash Concrete*. Supplementary Cementing Materials for Sustainable Development Inc., Ottawa, Canada, 2005, 124 pages.

64. Atis, C.D., *High-Volume Fly Ash Concrete with High-Strength and Low Drying Shrinkage*. Journal of Materials in Civil Engineering. ASCE, Vol. 15, No. 2, 2003, pages 153 to 156.

65. http://www.selfconsolidatingconcrete.org/mixdesign.html.

66. Concrete, S.-C., *The European Guidelines for Self-Compacting Concrete*. 2005.

67. EFNARC, *Specifications and Guidelines for Self-Consolidating Concrete.* European Federation of Suppliers of Specialist Construction Chemicals (EFNARC): Surrey, UK, 2002.

68. Ouchi, M., *Applications of self-compacting concrete in Japan, Europe and the United States*. . *Proceeding of the International Symposium on High Performance Computing (ISHPC)*. 2003.

69. Nakamura. S. Ouclii. M., Osterberg. T., Hallberg. S. Lwin, M., *Applications of Self-Compacting Concrete in Japan, Europe and United State*. Proceedings of die 2003 ISHPC. 1-20.

70. Aggarwal, V, Gupta, S, M and Sachideva, S. N., *Concrete Durability Through High Volume Fly Ash Concrete (HVFC). A Literature review of International Journal of Engineering Science and Technology. 2010*, Vol.2 (9), pp4473-4477.

71. Safiuddin, Md, Jumaat, Z.M, Salam, M.A, Islam, M.S and Hashim, R., *Utilization of solid waste in construction materials*. International journal of the physical science. 2010, vol. 5(13). Pp. 1952-1963.

72. Rashid, M. H. A, Molla, B.K.A and Ahmed, C.T.U., *Long-term effect of rice husk ash on strength of mortar*. World academy of science engineering and technology, 2010.

73. Attwir N. M and Kabir S., *Reduced environmental impacts through green concrete technology. The 3rd technology and innovative for sustainable development international conference,* faculty of engineering khon kaen university, Thailand, 2010.

74. Teo, D. C. L, Mannan, M.A and Kurian, V. J., *Structural Concrete Using Oil Palm Shell (OPC) as Lightweight Aggregate*. Turkish journal of engineering science. 2006, Vol 30 ppl-7.

75. Neville, M., *Property of Concrete.* Fourth Edition. Longman, 1995.

76. Neville, A.M. and Brooks, J. j., *Concrete Technology*. Produced by Longman Singapore publishers (pte) Ltd. 1994.

77. Mindess S., Young J.F. and Darwin D., *Concrete 2nd Edition*, Pearson Education, Inc., Upper Saddle River, NJ. USA, 2002.

78. MS29, *Specification for Aggregate from Natural Sources for Concrete (first revision)*. 1995.

79. BS-1881:116, *Method for determination of compressive strength of concrete cubes*. British Standards Institution, 1983.

80. ASTMC496/C496M, *Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens.* American Society for Testing and Materials: Philadelphia, USA, 2011.

81. ASTMC469-02, *Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete Specimens.* American Society for Testing and Materials: Philadelphia, USA, 2011.

82. ASTMC512/C512M-10, *Standard Test Method for Creep of Concrete in compression.* American Society for Testing and Materials: Philadelphia, USA, 2011.

83. ASTM-C157M, *Standard test method for the length change of hardened hydraulic cement mortar concrete*. American Society for Testing and Materials: Philadelphia, USA. 1999.

84. ASTMC192/C192M, *Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory*. American Society for Testing and Materials: Philadelphia, USA, 2013.