STRUCTURAL BEHAVIOUR OF CIRCULAR CONCRETE FILLED STEEL TUBE COLUMN FILL WITH SELF-COMPACTING CONCRETE INCORPORATING COAL BOTTOM ASH AS FINE AGGREGATE REPLACEMENT

NORUL ERNIDA BINTI ZAINAL ABIDIN

A thesis submitted in fulfilment of the requirement for the award of the Doctor of Philosophy in Civil Engineering

Faculty of Civil and Environmental Engineering
Universiti Tun Hussein Onn Malaysia

OCTOBER 2019

DEDICATION

Especially to my beloved family, my supervisor and friends
for giving me infinite care and blessing

Thank you for your endless support to me

ACKNOWLEDGEMENT

First of all, all praises to Allah, the Almighty for giving me the courage and guidance to finish the project. The author would like to acknowledge and extend my heartfelt gratitude to my supervisor, Assoc. Prof. Dr. Norwati binti Jamaluddin for her advice, encouragement, and guidance. Without her guidance, this research would not have been possible. The author would also like to express my gratitude to my co-supervisors, Assoc. Prof. Ts. Dr. Mohd Haziman bin Wan Ibrahim and Prof. Ir. Dr. Kartini binti Kamaruddin for their guidance and support towards the completion of this research.

The author would also like to thank my beloved family especially my parents, Zainal Abidin bin Taib and Nor Ajijah binti Abdul Gani. Also, the author would like to express my gratefulness and love to my husband, Mohd Fahmy bin Sarip for his unending support and love. Moreover, the author would like to express my love and affection to my daughter, Lisa Fila Sofea binti Mohd Fahmy for being my inspiration, and pillar of strength in completing this research. Besides that, the author would like to thank my beloved friends and lab mates who had helped me during this project and for their support given.

Last but not least, the author would like to extend my gratitude to lab assistants, Mohd Afandi bin Abu Bakar, Amran bin Abd Rahman, and Suhaimi bin Harun from Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia and also lab assistants, Muhammad Tarmizi bin Ismail and Azri Syafiq bin Kamarozaman from Faculty of Civil Engineering, Universiti Teknologi Mara, Shah Alam for helping me to complete my research study. Thank you very much.

ABSTRACT

Lack of compaction may affect the interaction between the steel tube and the concrete, hence influence the behaviour of CFST column. Employing self-compacting concrete (SCC) in CFST column as an infill concrete remove the necessity for compaction. However, higher volume of fine aggregate required in SCC makes SCC less preferable. The objective of this research was to investigate the behaviour of circular CFST column filled with SCC incorporating coal bottom ash (CBA) as fine aggregate replacement. In this research work, sand was replaced with CBA at 10%, 15%, 20%, 25%, and 30% of replacement levels. Tests for compressive strength, split tensile strength, flexural strength, and water absorption were performed on specimens at 7 and 28 days curing age. The testing results show that 15% of CBA was the optimum percentage suitable used in SCC. In studying the behaviour of CFST columns, 18 CFST column specimens were tested to fail under the axial compression loading. From the experimental results, it can be concluded that the utilisation of SCC with CBA in the CFST column able to improve the behaviour of CFST column. From compression testing results, the strength of CFST column filled with SCC with CBA increased about 45-50%. The experimental results were also compared with the design standard of Eurocode 4 (EC4). From the comparison, the EC4 conservatively predicts the strength of the column specimens. For instance, EC4 conservatively predicted the column strength in series I by about 21-31%. The finite element analysis (FEA) was conducted on the long column to verify the experimental results and from the FEA result, the predicted value for specimens with 140 mm diameter is 0.005% closer to the experimental results. These discoveries are significant as they showed that the utilization of CBA in SCC as an infill in CFST column able to provide the same strength as CFST with normal SCC. Besides, the use of CBA as partially replacement to the sand will help in more sustainable SCC production by lowering energy and raw material consumption.

ABSTRAK

Kekurangan pemadatan boleh menjejaskan interaksi antara tiub keluli dan konkrit dan secara tidak langsung mempengaruhi sifat tiang CFST. Dengan menggunakan konkrit mampat sendiri (SCC) ke dalam tiang CFST sebagai konkrit pengisi membuang keperluan untuk pemadatan. Walau bagaimanapun, jumlah agregat halus yang tinggi di dalam SCC menjadikan SCC kurang diminati. Objektif penyelidikan ini adalah untuk mengkaji sifat tiang bulat CFST yang terdiri daripada SCC yang mengunakan abu arang batu (CBA) sebagai pengganti agregat halus. Dalam kajian ini, pasir telah digantikan dengan CBA pada paras penggantian 10%, 15%, 20%, 25% dan 30%. Ujian-ujian kekuatan mampatan, kekuatan tegangan pemisahan, kekuatan lenturan dan penyerapan air dijalankan ke atas spesimen-spesimen sehingga akhir tempoh pengawetan iaitu selama 7 dan 28 hari. Hasil kajian menunjukkan bahawa 15% adalah peratusan optimum yang sesuai digunakan di dalam SCC. Dalam mengkaji sifat tiang CFST, sebanyak 18 spesimen tiang telah diuji hingga gagal fungsi apabila dibebankan dengan beban mampatan. Berdasarkan kajian, penggunaan SCC dengan CBA dalam tiang CSFT dapat mempertingkatkan sifat tiang CFST. Daripada keputusan ujian mampatan, kekuatan tiang CFST diisi dengan SCC and CBA meningkat sebanyak 45-50%. Keputusan kajian juga dibandingkan dengan standard reka bentuk Eurocode 4 (EC4). Daripada perbandingan, EC4 konservatif dalam meramal kekuatan spesimen tiang. Sebagai contoh, EC4 secara konservatif meramalkan kekuatan tiang dalam Siri I kira-kira 21-31%. Analisis unsur terhingga (FEA) juga dijalankan di tiang panjang untuk mengesahkan keputusan kajian dan FEA, Nilai ramalan spesimen dengan diameter 140 mm adalah 0.005% lebih dekat dengan hasil kajian. Penemuan ini penting kerana ia menunjukkan bahawa penggunaan CBA di dalam SCC sebagai pengisi tiang CFST dapat memberikan kekuatan yang sama seperti CFST yang di isi dengan SCC biasa. Selain daripada itu, penggunaan CBA sebagai pengganti kepada pasir akan membantu

dalam pengeluaran SCC yang lebih lestari dengan menurunkan penggunaan tenaga dan juga bahan mentah.

CONTENT

LIST OF TABLES

LIST OF FIGURES

SYMBOLS AND ABBREVIATIONS

Abbreviations

SCC	Self-compacting concrete
CBA	Coal bottom ash
CFST	Concrete filled steel tube
FEM	Finite Element Modeling
FEA	Finite Element Analysis
HPC	High strength concrete
SP	Superplasticiser
HRWR	High range water reducer
VMA	Viscosity modifying admixture
ASTM	American society for testing and material
LOI	Loss in ignition
XRF	X-Ray Fluorescense
SEM	Scanning Electron Microscope
EGSCC	European guideline for self-compacting concrete
EFNARC	Specification and guideline for self-compacting concrete
SI	Strength Index
DI	Ductility Index
CCR	Concrete Contribution Ratio
SF	Slump Flow
LVDT	Linear Variable Differential Transducer
EC4	Eurocode 4
EC3	Eurocode 3
COV	Coefficient of variation

Symbols

f_{ct}	Tensile strength
d	Designated cross-sectional dimension
N_{max}	Maximum load carrying capacity of CFST column
A_s	Cross-sectional areas of the steel
A_c	Cross-sectional areas of the concrete
f_y	Strength of the steel tube
f_{ck}	Strength of the concrete
$N_{pl,Rd}$	Plastic resistance of a column
N_{cr}	Euler critical load,
EI	Effective elastic flexural stiffness
K_e	Effective length factor
L	Length of CFST column
ξ	Confinement factor
η_a	Modification factor reflect the effect of the hoop stresses on the yield stress of the steel
η_c	Modification factor reflect the effect he effect of the tri-axial state of stress to the concrete strength
χ	Reduction factor
N_{Ed}	Design value of the compression force
$N_{c,Rd}$	Design cross-sectional resistance of the section to uniform compression force
$\bar{\lambda}$	Relative slenderness
γ_{M0}	Partial safety factor
A_{eff}	Effective area
$N_{b,Rd}$	Buckling resistance of the compression member
t	Steel tube thickness
q	Body force
P	Axial force
E_s	Elastic moduli of steel
E_{cm}	Elastic moduli of concrete
E_r	Elastic moduli of reinforcement

Symbols

I_s	Second moment of area of structure steel section

I_c	Second moment of area of concrete
I_r	Second moment of area of reinforcement
N_{ue}	Load capacity from experimental results
N_{uc4}	Load capacity predicted by Eurocode 4
N_{uc3}	Load capacity predicted by Eurocode 3
	Plastic resistance of a column
N_{Num}	Load capacity predicted by MATLAB

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of research

The application of composite tubular columns or also known as concrete-filled steel tube (CFST) column is a structural system that offers advantages of both steel tube and concrete. The steel tube acts as permanent formwork while providing lateral confinement to the concrete whilst local buckling which commonly occurred on thin-wall steel tube are delayed by concrete (Dundu, 2012). Due to these characteristics, CFST columns have widely used in structural application as it offered higher strength and ductility, higher torsional resistance capacity, and also the ability to dissipate energy (Abed, AlHamaydeh, & Abdalla, 2013; Han, Li, & Bjorhovde, 2014) when compared to conventional reinforced concrete column and steel tube column.

In CFST column system, concrete plays an important roles in providing strength and stiffness. It not only delays local buckling and forces the steel to buckled inward, it also provide appropriate load capacity for CFST column when exposed to high temperature (Dai & Lam, 2012; Mohanraj, Kandasamy, & Rajaraman, 2010). In the past, there was numerous number of research studies were carried out on normal concrete filled in the CFST columns (Fam, Qie, & Rizkalla, 2004; Han, Liu, & Yang, 2008b; Dundu, 2012; Chang, *et al.*, 2013). Some of the literatures have been generally reviewed by Schneider (1998) and were completed for the purpose of "full" review on the literatures by Han (2002). However, a small number of research studies have been carried out on CFST columns with Self-Compacting Concrete (SCC) used as infill. This was also reported by Domone (2006) in his study. Domone (2006) analysed 11 years of case studies from 1993 to

2003 which related to SCC and the main interest of the study was to observe the distribution and the types of SCC application in the structure-based element. Out of 51 case studies, five cases involved with the use of SCC in a novel form of construction such as composite structure and thin section pre-cast units.

SCC can be defined as a flowing concrete that is able to consolidate fully under its self-weight without the tendency to segregate and bleeding. Its characteristic to flow within heavy reinforcement without the aid of vibration makes it favorable to the construction with complicated structures. Due to this characteristic, the use of SCC in the CFST column has begun to raise interest among researches. For instance, Han & Yao (2004), Tao, Han, & Wang(2005), Yang & Han (2011), Yu, Ding, & Cai, (2007), Han, Hou, & Wang (2014), Hou, Han, & Zhao (2013), and Mirmomeni, *et al.*, (2017) studied stub columns filled with SCC with concrete cubic strength ranged from 40 to 121 MPa. From the studies, the experimental results showed that the behaviour of CFST filled with SCC have similar behaviour as composite columns filled with normal concrete. This results implying that the strength predictions used in the existing design code developed for normal concrete filled columns is suitable used for SCC filled columns within the scope of tested concrete strength. However, the ductility for very high strength SCC filled steel tubes was found to be generally smaller than that for normal strength concrete. This probably due to the brittleness of high strength concrete as reported by Qing *et al.*, (2008) and Jamaluddin, *et al.*, (2013). The behaviour of high strength SCC filled stub columns when exposed to standard fire are also studied by Lu, Zhao, & Han, (2009). From their study, it was found out that the behaviour of CFST column fill with high strength SCC when exposed to standard fire is almost the same as the normal concrete filled columns.

The materials used in the SCC are the same as the materials used in the production of normal concrete. This includes the use of additive material from waste by-product such as fly ash, quarry dust, and silica fume. This material was added into the concrete as part of the total constituent system. The benefits of these additive materials come from its particle size distribution characteristic and pozzolanic activity. The utilisation of combustion by-products in the SCC had gained great attention among researchers lately. This is probably due to its similarity to the fine aggregate particle size. For example, Kurniawan (2008); Lachemi, (2001); Liu, (2010); Pathak & Siddique, (2012) investigated the potential used of pulverised fly ash in SCC as a replacement of cement. While for CBA, the study about its suitability to replace sand in the concrete and mortar was reported by Wongkeo & Chaipanich, (2010); Balasubramaniam & Thirugnanam (2015), Cheng (2012), Govindarajan *et al.*, (2014), Kim & Lee (2013) and Purushothaman & Nadu (2013). However, in the case of SCC, very limited research study can be found investigating its potential use as partial replacement material (Aswathy & Paul, 2015; Kadir, *et al.*, 2016; Kasemchaisiri & Tangtermsirikul, 2008; Siddique, Aggarwal, & Aggarwal, 2012).

Although the utilisation of SCC in the composite structure has begun to raise interest among the researchers, the use of SCC incorporating CBA as infill material is yet to be found. Apart from that, the use of the concrete incorporating CBA in the CFST column is seen able to reduce the potential of leachability of heavy metal such as arsenic in the concrete. This is due to the ability of the steel tube to confine the concrete. Owing to this advantage, the application of the CBA is suitable for this study. Therefore, the purpose of this research is to study the structural behaviour of CFST column containing SCC incorporating CBA as sand replacement material. Apart from that the use of Furthermore, a reliable finite element method (FEM) was developed to predict the bearing capacity of CFST column under axial load and then compared to the results obtained from the experimental works.

1.2 Problem statement

Compaction is an important process which involved expelling the entrapped air from the concrete via concrete compactor. According to Ravindrarajah, Farrokhzadi, & Lahoud (2003), lack of compaction not only influences the permeability of the concrete, it also reduce the durability of concrete structure. In the case of composite column, the lack of compaction not only affects the properties of the core concrete itself, but also may influence the interaction between the steel tube and its core concrete, and thus influences the behaviour of the composite columns. (Han & Yao, 2003)

Compaction is one of the most crucial factor that affecting bearing capacity of CFST column. In the study conducted by Han (2000) and Han & Yang (2001), it was found out that better compaction of concrete may results in higher member capacities of CFST column with circular hollow section and higher sectional capacity of CFST column for square and rectangular hollow section. However, compacting concrete mix by vibration in the concrete filled steel sections cause difficulties and may produce number of effects which impair the quality of the elements. Inserting an immersion vibrator into narrow spaces between a steel section and formwork entails the risk of vibrator coming into contact with the steel section which may leads to segregation in the bond formation area (Elzbieta & Woyciechowski, 2013). Therefore, in order to solve problem regarding compaction in composite column, the use of SCC mix is the right solution to be applied in the process of concreting composite column.

As mentioned earlier, with the promising use of SCC, many researchers have studied the potential use of SCC in the CFST column (Alwash & Al-salih, 2013; Han, Yao, & Zhao, 2005; McCann, Gardner, & Qiu, 2015; Mirmomeni *et al.*, 2017), including utilizing waste by-product in the process of making SCC mix. For instance, mineral additive such as fly ash, silica fume, and blast furnace slag was added in the SCC as the cement replacement (Han, Liu, & Yang, 2008a; Han, *et al.*, 2006; Yang, Lam, & Gardner, 2008; Qing *et al.*, 2008). However, none was found using waste by-product as replacement to the fine aggregate in the SCC as infill in the CFST column.

Regarding the SCC composition, there is no significant difference between SCC and normal vibrated concrete except for higher volume of fine aggregate and the inclusion of chemical admixture. The use of higher volume of fine aggregate in the SCC is the main concern by many as it may cause depletion on the natural resources and eventually, may lead to the environmental issues. Therefore, there is an attempt to use waste by-product in the production of SCC as fine aggregate replacement (Jiang & Mei, 2008; Johnsirani & Kumar, 2013; Kumar, Suresh, & Naidu, (2016); Patil & Gurav, (2016) including CBA (Aswathy & Paul, (2015); Kadir, *et al.*, 2016; Kasemchaisiri & Tangtermsirikul, 2008; Siddique, Aggarwal, & Aggarwal, 2012). CBA is waste by-product generated from coal-fired power plant. Unlike fly ash, which has been well accepted as pozzolanic material and commonly used either as a component of blended Portland cement or mineral admixture in concrete (Ondova, Stevulova, & Meciarova, 2013), CBA is generally used in highway, embankment, subgrade, and subbases as reported by American Coal Ash Association (2008) or being deposited on the landfill without further use (Kadam & Patil, 2013; Kurama & Kaya, 2008; Singh & Siddique, 2014a).

In Malaysia, electricity is mainly generated from coal-fired power plant. There are seven coal-fired power plants operate daily with total capacity of 8,500 MW, which makes coal as one of Malaysia's most important sources of energy. As reported in The Star (2013), Malaysia consumes about 42 million tonnes of coal annually. The amount is devastated as it will produce tonnes of coal combustion by-products include fly ash and CBA. With future planning on the newest construction of coal-fired power plant that expected to complete in 2019 (The Star, 2017) to uphold the current demand of electricity, the amounts of coal combustion by-product are expected to increase.

As cited in Kurama & Kaya, (2008), the recycling of CBA is about 5.28% in concrete compared to fly ash with recycling rate of 47% as reported by American Coal Ash Association, with the total CBA production of about 19.8 Mtonnes in 2002. Due to the lower rate of recycling of CBA, a number of researches have investigated the potential use of CBA as partial replacement of fine aggregate in the production of concrete in terms of its strength and durability. However, the outcome from the investigation shows that the incorporation of CBA in the concrete production as a substitution of fine aggregate does not improve its compressive strength due to its porous particle structure and high water absorption (Bai, Darcy, & Basheer, (2005); Ozkan, Yuksel, & Muratoglu, (2007); Yuksel, Bilir, & Ozkan, (2007). Moreover, the waste by-product from combustion contains heavy metals within their composition and these metals are toxic to the environment as well as to human health.

According to Yahya *et al.*, (2017), the metallic element in the CBA such as copper (Cu), nickel (Ni), chromium (Cr), zinc (Zn), and lead (Pb) resulting the classification of CBA in Malaysia under the Schedule Waste (SW 104) Environment Quality Act. In the study conducted by Kadir, *et al.*, (2016), the concrete with 30% fly ash and CBA have the highest arsenic (As) leaching with 18.576 mg/L. Arsenic has gained considerable attention due to the fact that it is mobile throughout a wide

REFERENCES

Abed, F., AlHamaydeh, M., & Abdalla, S. (2013). Experimental and numerical investigations of the compressive behavior of concrete filled steel tubes (CFSTs). *Journal of Constructional Steel Research*, *80*, 429–439.

Abedi, K., Ferdousi, A., & Afshin, H. (2008). A novel steel section for concrete-filled tubular columns. *Thin-Walled Structures*, *46*(3), 310–319.

Abubakar, A. U., & Baharudin, K. S. (2012a). Potential use of malaysian thermal power plants. *International Journal of Sustainable Construction Engineering & Technology*, *3*(2), 25–37.

Abubakar, A. U., & Baharudin, K. S. (2012b). Properties of concrete using tanjung bin power. *International Journal of Sustainable Consturction Engineering & Technology*, *3*(2), 56–69.

ACAA (2008) “American Coal Ash Association”. Coal Combustion Products (CCP) Production & Use. Aurora, CO.

Aggarwal, P., Aggarwal, Y., & Gupta, S. M. (2007). Effect of Bottom Ash as Replacement of Fine Aggregate in concrete. *Asian Journal of Civil Engineering (Building and Hpusing)*, *46*(1), 93–100.

Aggarwal, Y., & Siddique, R. (2014). Microstructure and properties of concrete using bottom ash and waste foundry sand as partial replacement of fine aggregates. *Construction and Building Materials*, *54*, 210–223.

Ajel, H. A., & Abbas, A. M. (2015). Experimental and Analytical Investigations of Composite Stub Columns. *International Journal of Innovative Research in Advanced Engineering*, *4*(2), 185–200.

Alwash, N. A., & Al-salih, H. I. (2013). Experimental Investigation on Behavior of SCC Filled Steel Tubular Stub Columns Strengthened with CFRP. *Construction Engineering*, *1*(2), 37–51.

American Institute of Steel Construction (AISC 360:2010), Specification for Structural Steel Buildings, Chicago.

Andrade, L. B., Rocha, J. C., & Cheriaf, M. (2007a). Aspects of moisture kinetics of coal bottom ash in concrete. *Cement and Concrete Research*, *37*(2), 231–241.

Andrade, L. B., Rocha, J. C., & Cheriaf, M. (2007b). Evaluation of concrete incorporating bottom ash as a natural aggregates replacement. *Waste Management (New York, N.Y.)*, *27*(9), 1190–9.

Andrade, L. B., Rocha, J. C., & Cheriaf, M. (2009). Influence of coal bottom ash as fine aggregate on fresh properties of concrete. *Construction and Building Materials*, *23*(2), 609–614.

Andrawes, B., Shin, M., & Wierschem, N. (2010). Active confinement of reinforced concrete bridge columns using shape memory alloys. J*ournal of Bridge Engineering 15*(1), 81-89.

ASTM C 618. Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete.

Aswathy, P. U., & Paul, M. M. (2015). Behaviour of Self compacting concrete by partial replacement of fine aggregate with coal bottom ash, *2*(October 2015), 45–52.

Bai, Y., Darcy, F., & Basheer, P. A. M. (2005). Strength and drying shrinkage properties of concrete containing furnace bottom ash as fine aggregate. *Construction and Building Materials*, *19*(9), 691–697.

Bai, Y., Ibrahim, R., & Basheer, P. A. M. (2005). Properties of lightweight concrete manufactured with fly ash , furnace bottom ash , and lytag. *International Workshop on Sustainable Development and Concrete Technology*.

Baig, M. N., Fan, J., & Nie, J. (2006). Strength of concrete filled steel tubular columns. *Tsinghua Science and Technology*, *11*(6), 657–666.

Baig, U., & Nagai, K. (2013). Effect of self-compacting concrete and aggregate size on anchorage performance at highly congested reinforcement regions. *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering*, *7*(9), 670–678.

Bajare, D., Bumanis, G., & Upeniece, L. (2013). Coal combustion bottom ash as microfiller with pozzolanic properties for traditional concrete. *Procedia Engineering*, *57*, 149–158.

Balasubramaniam, T., & Thirugnanam, G. S. (2015). An Experimental investigation on the mechanical properties of bottom ash concrete. *Indian Journal of Science and Techology*, *8*(May), 992–997.

Bashkin, V. N., & Wongyai., K. (2002). Environmental fluxes of arsenic from lignite mining and power generation in northern Thailand. *Environmtal Geology 41*(8):883–888.

Boukendakdji, O., Kadri, E.-H., & Kenai, S. (2011). Effects of granulated blast furnace slag and superplasticizer type on the fresh properties and compressive strength of self-compacting concrete. *Cement and Concrete Composites*, *34*(4), 583–590.

Bouzoubaa, N., & Lachemi, M. (2001). Self Compacting Concrete Incorporating High-Volumes of Class F Fly Ash□: Preliminary Results. *Cement and Concrete Research*, *31*(3), 413–420.

Bradford, M. A., Loh, H. Y., & Uy, B. (2002). Slenderness limits for filled circular steel tubes. *Journal of Constructional Steel Research*, *58*(2), 243–252.

Bridge R. Q., & O'Shea M. D. (1998). Behaviour of thin-walled steel box sections with or without internal restraint. *Journal of Constructional Steel Research*, *47*(1-2), 73-91.

Brouwers, H. J. H., & Radix, H. J. (2005). Self-Compacting Concrete: Theoretical and experimental study. *Cement and Concrete Research*, *35*(11), 2116–2136.

BS 1377-3:1990. Methods of test for soils for civil engineering purposes. Chemical and electro-chemical tests

BS 1881-122:2011. Testing concrete. Method for determination of water absorption

BS 3797:1990. Specification for lightweight aggregates for masonry units and structural concrete.

BS EN 933-1:2012. Test for geometrical properteis of aggregates. Determinatioan of particle size distribution. Seieving method.

BS EN 1993-1-1: 2005. Eurocode 3: Design of stree structure.

BS EN 12390-4:2000. Testing hardened concrete. Compressive strength. Specification for testing machines.

BS EN 10002-1:1990. Tensile testing of metallic materials. Method of test at ambient temperature.

BS EN 12390-6:2000. Testing hardened concrete. Tensile splitting strength of test specimens.

BS EN 12390-5:2000. Testing hardened concrete. Flexural strength of test specimens

BS EN 10255:2004. Non-alloy steel tubes suitable for welding and threading. Technical delivery conditions.

BS EN 12620:2002+A1:2008. Aggregates for concrete.

BS EN 933-1:2012. Tests for geometrical properties of aggregates. Determination of particle size distribution. Sieving method.

BS EN 12350-11:2010. Testing fresh concrete. Self-compacting concrete. Sieve segregation test.

BS EN 12350-10:2010. Testing fresh concrete. Self-compacting concrete. L box test.

BS EN 12350-8:2010. Testing fresh concrete. Self-compacting concrete. Slump-flow test.

BS EN 1994-1-1:2004. Eurocode 4. Design of composite steel and concrete structures. General rules and rules for buildings.

Bukovská, P., & Karmazínová, M. (2012). Behaviour of the tubular columns filled by concrete subjected to buckling compression. *Procedia Engineering*, *40*, 68–73.

Cadersa, A. S., Rana, J., & Ramjeawon, T. (2014). Assessing the durability of coal bottom ash as aggregate replacement in low strength concrete. *Journal of Emerging Trends in Engineering and Applied Sciences*, *5*(5), 344–349.

Campione G., Scibilia N., & Zingone G. (1999). Strength and ductility of hollow circular steel columns filled with fiber reinforced concrete. *Department of Engineering Structure Universiti Palermo*, 1-90128.

Canpolat, F. (2011). The role of coal combustion products in sustainable construction materials. *The Indian Concrete Journal*, *1990*(June), 26–38.

Carpenter, A. C. (2007). Life cycle based risk assessment of recycled materials in roadway construction, *27*, 1458–1464.

Chacón, R. (2015). Circular Concrete-Filled Tubular Columns : State of the Art Oriented to the Vulnerability Assessment, 249–259.

Chakraborty, R., & Anita, M. (2009). Ecotoxicology and Environmental Safety Mutagenicity and genotoxicity of coal fly ash water leachate. *Ecotoxicology and Environmental Safety*, *72*, 838–842.

Chang, X., Liang Ru, Z., Zhou, W., & Zhang, Y.-B. (2013). Study on concrete-filled stainless steel–carbon steel tubular (CFSCT) stub columns under compression. *Thin-Walled Structures*, *63*, 125–133.

Cheng, A. (2012). Effect of incinerator bottom ash properties on mechanical and pore size of blended cement mortars. *Materials & Design*, *36*, 859–864.

Cheriaf, M., Rocha, J. C., & Péra, J. (1999). Pozzolanic properties of pulverized coal combustion bottom ash, *29*, 1387–1391.

Ching, J., & Ho, M. (2011). Improved behaviour of concrete-filled- Steel-tube columns with external confinement. *Australian Earthquake Engineering Society 2011 Concference*.

Chitawadagi, M. V., Narasimhan, M. C., & Kulkarni, S. M. (2010). Axial strength of circular concrete-filled steel tube columns — DOE approach. *Journal of Constructional Steel Research*, *66*(10), 1248–1260.

Chithira, K., & Baskar, K. (2012). Experimental and Numerical Investigation on Circular CFT Columns under Eccentric Load Condition with and without Shear Connectors. *International Journal of Earth Sciences and Engineering*, *5*(1), 169–179.

Dai, X. H., & Lam, D. (2012). Shape effect on the behaviour of axially loaded concrete filled steel tubular stub columns at elevated temperature. *Journal of Constructional Steel Research*, *73*, 117–127.

Damtoft J. S., Lukasik J., Herfort D., Sorrentino D., & Gartner E. M. (2008). Sustainable development and climate change initiatives. *Cement and Concrete Research 38*(2), 115–127.

David Rich, Jacqui Glass, Alistair F. F. Gibb, C. G. (2012). Institutional Repository UK contractors â€™ views on self-compacting concrete in construction This item was submitted to Loughborough ’ s Institutional Repository (https://dspace.lboro.ac.uk/) by the author and is made available under the. *Proceeding of the ICE - Construction Materials*.

De Oliveira, W. L. A., De Nardin, S., de Cresce El Debs, A. L. H., & El Debs, M. K. (2009). Influence of concrete strength and length/diameter on the axial capacity of CFT columns. *Journal of Constructional Steel Research*, *65*(12), 2103–2110.

De Oliveira, W. L. A., De Nardin, S., El Debs, A. L. H. de C., & El Debs, M. K. (2010). Evaluation of passive confinement in CFT columns. *Journal of Constructional Steel Research*, *66*(4), 487–495.

Dehn, F., Holschemacher, K., & Wei ße, D. (2000). Self-Compacting Concrete (SCC) Time Development of the Material Properties and the Bond Behaviour. *LACER*, *5*, 115–124.

Ding, F., Yu, Z., Bai, Y., & Gong, Y. (2011). Elasto-plastic analysis of circular concrete-filled steel tube stub columns. *Journal of Constructional Steel Research*, *67*(10), 1567–1577.

Domone, P. L. (2006). Self-compacting concrete: An analysis of 11 years of case studies. *Cement and Concrete Composites*, *28*(2), 197–208.

Druta, C., Wang, L., & Stephen Lane, D. (2014). Tensile strength and paste–aggregate bonding characteristics of self-consolidating concrete. *Construction and Building Materials*, *55*, 89–96.

Dundu, M. (2012). Compressive strength of circular concrete filled steel tube columns. *Thin-Walled Structures*, *56*, 62–70.

Edamatsu Y., Nishida N., & Ouchi M. (1999). A rational mix-design method for self-compacting concrete considering interaction between coarse aggregate and mortar particles. I*n: Proceedings of the 1st international RILEM symposium on SCC. Sweden*, 309–20.

EFNARC (2002). Specifications and guideline for self-compacting concrete.

Ekmekyapar, T., & Al-Eliwi, B. J. M. (2016). Experimental behaviour of circular concrete filled steel tube columns and design specifications. *Thin-Walled Structures*, *105*, 220–230. https://doi.org/10.1016/j.tws.2016.04.004

Ellobody, E., & Young, B. (2006). Nonlinear analysis of concrete-filled steel SHS and RHS columns, *44*, 919–930.

Elzbieta, S., & Woyciechowski, P. (2013). Influence of the compaction method on the bond between steel and concrete in composite columns. *Research Article in Periodica Polytechnica Civil Engineering*, *57*(2), 129–137.

Evirgen, B., Tuncan, A., & Taskin, K. (2014). Structural behavior of concrete filled steel tubular sections (CFT/CFSt) under axial compression. *Thin-Walled Structures*, *80*, 46–56.

Faizul, C. P, Abdullah, C., & Fazlul, B. (2014). Extraction of silica from palm ash using organic acid leaching treatment. *Key Engineering Materials.* 594, 329–333.

Fam, A., Qie, F. S., & Rizkalla, S. (2004). Concrete-filled steel tubes subjected to axial compression and lateral cyclic loads. *Journal of Structural Engineering ASCE*, *120*(April), 631–640.

Filipponi, P., Polettini, A., Pomi, R., & Sirini, P. (2003). Physical and mechanical properties of cement-based products containing incineration bottom ash. *Waste Management (New York, N.Y.)*, *23*(2), 145–56.

Fujimoto, T., Mukai, A., Nishiyama, I., & Sakino, K. (2004). Behavior of Eccentrically Loaded Concrete-Filled Steel Tubular Columns, (February), 203–212.

Gaimster, R., and Foord, C. (2000). Self-Compacting Concrete. *Concrete*, *34*(4), 23-25.

Geetha, S., & Ramamurthy, K. (2013). Properties of geopolymerised low-calcium bottom ash aggregate cured at ambient temperature. *Cement. Concrete Composition*, *43*, 20–30.

Ghannam, S. (2016). Buckling of Concrete-Filled Steel Tubular Slender Columns, (February 2004), 41–47.

Gharahsir, N., Gholamhoseini, A., MacRae, G. A., & Clifton, G. C. (2015). Stiffness of composite cfst columns. *Steel Innovations Conference 2015*, (September), 1–10.

Giakoumelis, G., & Lam, D. (2004). Axial capacity of circular concrete-filled tube columns. *Journal of Constructional Steel Research*, *60*(7), 1049–1068.

Goodier C. I. (2003). Development of self-compacting concrete. *In: Proceedings of the institution of civil engineers, structures & buildings 156*, 405-14.

Govindarajan, D., Keerthana, M., Kumara Raja, G., & Prasanna Kumar, R. (2014). Experimental Investigation on Replacement of Fine Aggregate with Bottom Ash in Concrete. *International Journal of ChemTech Research*, *6*(14), 5570–5574.

Grimes, P. (2005). Self-compacting concrete at Millennium Point. *Concrete*, *34*(4), 26–27.

Gunakala, S. R., Comissiong, D. M. G., Jordan, K., & Sankar, A. (2012). A Finite Element Solution of the Beam Equation via MATLAB, *2*(8), 80–88.

Han, L. (2002). Tests on stub columns of concrete-filled RHS sections. *Journal of Constructional Steel Research*, *58*, 353–372.

Han L., & Lin X. (2004). Tests on cyclic behavior of concrete-filled hollow structural steel columns after exposure to the ISO-834 standard fire. *Journal Structure Engineering*, *130*(11), 1807–19.

Han, L.-H., Hou, C.-C., & Wang, Q.-L. (2014). Behavior of circular CFST stub columns under sustained load and chloride corrosion. *Journal of Constructional Steel Research*, *103,* 23–36.

Han, L.-H., Li, W., & Bjorhovde, R. (2014). Developments and advanced applications of concrete-filled steel tubular (CFST) structures: Members. *Journal of Constructional Steel Research*, *100*, 211–228.

Han, L.-H., Liu, W., & Yang, Y.-F. (2008a). Behavior of thin walled steel tube confined concrete stub columns subjected to axial local compression. *Thin-Walled Structures*, *46*(2), 155–164.

Han, L.-H., Liu, W., & Yang, Y.-F. (2008b). Behaviour of concrete-filled steel tubular stub columns subjected to axially local compression. *Journal of Constructional Steel Research*, *64*(4), 377–387.

Han, L.-H., Lu, H., Yao, G.-H., & Liao, F.-Y. (2006). Further study on the flexural behaviour of concrete-filled steel tubes. *Journal of Constructional Steel Research*, *62*(6), 554–565.

Han, L.-H., & Yao, G.-H. (2004). Experimental behaviour of thin-walled hollow structural steel (HSS) columns filled with self-consolidating concrete (SCC). *Thin-Walled Structures*, *42*(9), 1357–1377.

Han, L.-H., Yao, G.-H., & Zhao, X.-L. (2005). Tests and calculations for hollow structural steel (HSS) stub columns filled with self-consolidating concrete (SCC). *Journal of Constructional Steel Research*, *61*(9), 1241–1269.

Han, L.-H., Zheng, L.-Q., He, S.-H., & Tao, Z. (2011). Tests on curved concrete filled steel tubular members subjected to axial compression. *Journal of Constructional Steel Research*, *67*(6), 965–976.

Han, L., & Yao, G. (2003). Influence of concrete compaction on the strength of concrete-filled steel RHS columns, *59*, 751–767. https://doi.org/10.1016/S0143-974X(02)00076-7

Han, S. G., & Min, O. S. (2009) Environmental contaminations near Tae-an thermal power plant: Massive death of gray mullets."*Daejeon City Journal.*

Han, L. H. (2000). The influence of concrete compaction on the strength of concrete filled steel tubes. Advances in Structural Engineering. *An International Journal (2)*:131–7.

Han, L. H., & Yang. Y. F. (2001). Influence of concrete compaction on the behavior of concrete filled steel tubes with rectangular sections. *Advances in Structural Engineering—An International Journal 2(2)*:93–100

Hardjito, D., & Fung, S. S. (2012). Parametric study on the properties of geopolymer mortar incorporating bottom ash. *Concrete Research Letters*, *1*(September 2010), 115–124.

Hardjito, D., & Why, S. W. (2011). On the use of quarry dust and bottom ash as controlled low strength materials (CLSM). *Concrete 2011: Building A Sustainable Future*, (October).

Hou, C., Han, L.-H., & Zhao, X.-L. (2013). Concrete-filled circular steel tubes subjected to local bearing force: Experiments. *Journal of Constructional Steel Research*, *83*, 90–104.

Hu, H., Huang, C., Wu, M., & Wu, Y. (2003). Nonlinear analysis of axially loaded concrete-filled tube columns with confinement effect. *Journal of Structural Engineering*, (October), 1322–1329.

Hu Y. M., Yu T., & Teng J. G. (2011). FRP-confined circular concrete-filled thin steel tubes under axial compression. *Journal Composite Construction, 15*(5), 850–60.

Huang C., Yeh K., Liu G., Hu H., Tsai K., & Weng Y. (2002). Axial load behaviour of stiffened concrete-filled steel columns. *Journal Structure Engineering, 128*(9), 1222–30.

Hull, B. K., & Bradford, K. (1998). filled tube columns . Behavior of high . strength concrete filled tube columns.

Ibrahim, M. H. W., Hamzah, A. F., Jamaluddin, N., Ramadhansyah, P. J., & Fadzil, A. M. (2015). Split tensile strength on self-compacting concrete containing coal bottom ash. *Procedia - Social and Behavioral Sciences*, *195*, 2280–2289.

Jamaluddin, N., Hamzah, A. F., Haziman, M., & Ibrahim, W. (2015). Fresh properties and flexural strength of self-compacting concrete integrating coal bottom ash. *MATEC Web of Conferences*, *47*(1010), 1–6.

Jamaluddin, N., Lam, D., Dai, X. H., & Ye, J. (2013). An experimental study on elliptical concrete filled columns under axial compression. *Journal of Constructional Steel Research*, *87*, 6–16.

Jaturapitakkul, C., & Cheerarot, R. (2003). Development of bottom ash as Pozzolanic material. *Journal of Materials in Civil Engineering*, *15*(February), 48–53.

Jiang, A., Chen, J., & Jin, W. (2013). Experimental investigation and design of thin-walled concrete-filled steel tubes subject to bending. *Thin-Walled Structures*, *63*, 44–50.

Jiang, Z., & Mei, S. (2008). Properties of self-compacting concrete with machine-made sand and high-volume mineral admixtures. *The Open Construction and Building Technology Journal*, *2*, 96–102.

Johansson, M., & Gylltoft, K. (2002). Mechanical behavior of circular steel – concrete composite stub columns, *128*(August), 1073–1081.

Johnsirani, K. S., & Kumar, R. D. (2013). Experimental investigation on self compacting concrete using quarry dust. *International Journal of Scientific and Research Publications*, *3*(6), 1–5.

Jorat, M. E., Marto, A., Namazi, E., For, M., & Amin, M. (2011). Engineering characteristics of kaolin mixed with various percentages of bottom ash. *Electronic Journal of Geotechnical Engineering*, *16*, 841–850.

Kadam, M. P., & Patil, Y. D. (2013). Effect of coal bottom ash as sand replacement on the properties of concrete with different w / c ratio. *International Journal of Advanced Technology in Civil Engineering*, *2*(1), 45–50.

Kadir, A. A., Hassan, M. I. H., & Abdullah, M. M. A. B. (2016). Investigation on leaching behaviour of fly ash and bottom ash replacement in self-compacting concrete. *IOP Conference Series: Materials Science and Engineering*, *133*(1).

Kadir, A. A., Hassan, M. I. H., Jamaluddin, N., & Abdullah, M. M. A. B. (2016). properties and leachability of self-compacting concrete incorporated with fly ash and bottom ash. *IOP Conference Series: Materials Science and Engineering*, *133*(1).

Kamarudin, R. A., Matlob, A. S., Jubri, Z., & Ramli, Z. (2009). Extraction of silica and alumina from coal fly ash for the synthesis of zeolites, Proc. 3rd Int. Conf. on Energy and Environment: Advancement Towards Global Sustainability, Malacca, Malaysia 456- 461.

Kasemchaisiri, R., & Tangtermsirikul, S. (2008). Properties of self-compacting concrete in corporating bottom ash as a partial replacement of fine aggregate. *ScienceAsia*, *34*(November), 87–95.

Kibriya, T. (2006). Performance of Short CFST Columns using SCC with Blended Cement, 1–4.

Kim, H.-K. (2015). Utilization of sieved and ground coal bottom ash powders as a coarse binder in high-strength mortar to improve workability. *Construction and Building Materials*, *91*, 57–64.

Kim, H. K., Jeon, J. H., & Lee, H. K. (2012). Flow, water absorption, and mechanical characteristics of normal- and high-strength mortar incorporating fine bottom ash aggregates. *Construction and Building Materials*, *26*(1), 249–256.

Kim, H. K., & Lee, H. K. (2011). Use of power plant bottom ash as fine and coarse aggregates in high-strength concrete. *Construction and Building Materials*, *25*(2), 1115–1122.

Kim, H. K., & Lee, H. K. (2013). Effects of High Volumes of Fly Ash , Blast Furnace Slag , and Bottom Ash on Flow Characteristics , Density , and Compressive Strength of High-Strength Mortar. *Journal of Materials in Civil Engineering*, (May), 662–665.

Kim, H. K., & Lee, H. K. (2015). Coal bottom ash in field of civil engineering: A review of advanced applications and environmental considerations. *KSCE Journal of Civil Engineering*, *0*(0), 1–17.

Kim, Y., & Do, T. (2012). Effect of bottom ash particle size on strength development in composite geomaterial. *Engineering Geology*, *139–140*(40), 85–91.

Knowles, R. B., & Park R. (1969) Strength of concrete-filled steel tubular columns. *Journal of Structural Division ASCE* 1969;95:2565–87

Kodur, V. (1998). Design equations for evaluating fire resistance of SFRC-filled HSS columns. *Journal of structural engineering, 124(6),* 671-7.

Kou, S.-C., & Poon, C.-S. (2009). Properties of concrete prepared with crushed fine stone, furnace bottom ash and fine recycled aggregate as fine aggregates. *Construction and Building Materials*, *23*(8), 2877–2886.

Krishna, A. V., Rao, K., & Rajagopal, A. (2010). Effect of different sizes of coarse aggregate on the properties of NCC and SCC. *International Journal of Engineering Science and Technology*, *2*(10), 5959–5965.

Kumar, H Ravi, Muthu, K. U., Kumar, N. S. (2013). Experimental behavior of circular hsscfrc filled steel tubular columns under axial compression. *International Journal of Research in Engineering and Technology*, (Nov 2013), 111–115.

Kumar, D., Gupta, A., & Ram, S. (2014). Uses of bottom ash in the replacement of fine aggregate for making concrete. *international Journal of Current Engineering and Technology*, *4*(6), 3891–3895.

Kumar, M. P., Suresh, R., & Naidu, G. T. (2016). Experimental Investigation on self compacting concrete by partial replacement of fine aggregate with quarry dust and cement with fly ash. *International Journal of Innovative Research in Science, Engineering and Technology*, *5*(5), 8030–8036.

Kurama, H., & Kaya, M. (2008). Usage of coal combustion bottom ash in concrete mixture. *Construction and Building Materials*, *22*(9), 1922–1928.

Kurama, H., Topçu, İ. B., & Karakurt, C. (2009). Properties of the autoclaved aerated concrete produced from coal bottom ash. *Journal of Materials Processing Technology*, *209*(2), 767–773.

Kuranovas, A., Goode, D., & Kvedaras, A. K. (2015). Load - bearing capacity of concrete - filled steel columns. *Journal of Civil Engineering and Management*, *3730*(December), 20–33.

Kurniawan, A. (2008). Static and Strength Performance of Self Compacting Concrete Containing PFA, *International Conference on Construction and Building, (30)*, 333–342.

Lachemi, M., Hossain, K. M. A., & Lambros V. B. (2006). Axial load behavior of self-consolidating concrete-filled steel tube columns in construction and service stages. *ACI Structure Journal*, *103*(1), 38–47.

Lai, M. H., & Ho, J. C. M. (2016). A theoretical axial stress-strain model for circular concrete-filled-steel-tube columns. *Engineering Structures*, *125*, 124–143.

Lee, H. K., Kim, H. K., & Hwang, E. A. (2010). Utilization of power plant bottom ash as aggregates in fiber-reinforced cellular concrete. *Waste Management (New York, N.Y.)*, *30*(2), 274–84.

Liang, Q. Q., & Fragomeni, S. (2009). Nonlinear analysis of circular concrete-filled steel tubular short columns under axial loading. *Journal of Constructional Steel Research*, *65*(12), 2186–2196.

Liew, J. Y. R., Xiong, M., & Xiong, D. (2016). Design of Concrete Filled Tubular Beam-columns with High Strength Steel and Concrete. *Structures*, *8*, 213–226.

Lin, K. L., Chang, W. C., & Lin, D. F. (2008). Pozzolanic characteristics of pulverized incinerator bottom ash slag. *Construction and Building Materials*, *22*(3), 324–329.

Liu, D., & Gho, W.-M. (2005). Axial load behaviour of high-strength rectangular concrete-filled steel tubular stub columns. *Thin-Walled Structures*, *43*(8), 1131–1142.

Liu, M. (2010). Self-compacting concrete with different levels of pulverized fuel ash. *Construction and Building Materials*, *24*(7), 1245–1252.

Lu, H., Han, L.-H., & Zhao, X.-L. (2009). Analytical behavior of circular concrete-filled thin-walled steel tubes subjected to bending. *Thin-Walled Structures*, *47*(3), 346–358.

Lu, H., Zhao, X.-L., & Han, L.-H. (2009). Fire behaviour of high strength self-consolidating concrete filled steel tubular stub columns. *Journal of Constructional Steel Research*, *65*(10–11), 1995–2010.

Lu, H., Zhao, X.-L., & Han, L.-H. (2010). Testing of self-consolidating concrete-filled double skin tubular stub columns exposed to fire. *Journal of Constructional Steel Research*, *66*(8–9), 1069–1080.

Lu, Z. H., & Zhao, Y. G. (2008). Mechanical behavior and ultimate strength of circular cft columns subjected to axial compression loads. *The 14th World Confenrence on Earthquake Engineering*, (1999).

Mahgub, M., Ashour, A., Lam, D., & Dai, X. (2017). Tests of self-compacting concrete filled elliptical steel tube columns. *Thin-Walled Structures*, *110*(October 2016), 27–34.

Malhotra, V. M., & Bilodeau, A. (1999). High-volume fly ash system: the concrete solution for sustainable development, concrete technology for sustainable development in the twenty-first century. *Cement Manufacturers' Association , New Delhi, India*, 43-64.

Mander J. B., Priestley M. J. N., & Park R. (1988). Theoretical stress–strain model for confined concrete. *Journal of Structural Engineering 114*(8), 1804–26.

McCann, F., Gardner, L., & Qiu, W. (2015). Experimental study of slender concrete-filled elliptical hollow section beam-columns. *Journal of Constructional Steel Research*, *113*, 185–194.

Mirmomeni, M., Heidarpour, A., Zhao, X.-L., Al-Mahaidi, R., & Packer, J. A. (2017). Size-dependency of concrete-filled steel tubes subject to impact loading. *International Journal of Impact Engineering*, *100*, 90–101.

Mohanraj, E. K., Kandasamy, S., & Rajaraman, A. (2010). Seismic behaviour of concrete filled steel tubular beams. *35th Conference on Our World In Concrete & Structures:* 25 – 27 August 2010, Singapore.

Muciaccia, G., Giussani, F., Rosati, G., & Mola, F. (2011). Response of self-compacting concrete filled tubes under eccentric compression. *Journal of Constructional Steel Research*, *67*(5), 904–916.

Muhardi, Marto, A., Kassim, K. A., Makhtar, A. M., Lee F. W., & Yap, S, L. (2010). Engineering characteristics of tanjung bin coal ash. *Engineering Geology*, *15*, 1117-1129.

Nepomuceno, M., Oliveira, L., & Lopes, S. M. R. (2012). Methodology for mix design of the mortar phase of self-compacting concrete using different mineral additions in binary blends of powders. *Construction and Building Materials*, *26*(1), 317–326.

O'shea, M. D., & Bridge, R. Q. (2000). Design of circular thin-walled concrete filled steel tubes. *Journal of St*, *126*(November), 1295–1303.

Okamura, H. (1997). Self-compacting high-performance concrete. *Concrete International*, *19*(7), 50-54.

Okamura, H., & Ouchi, M. (2003). Self-Compacting Concrete. *Journal of Advance Concrete Technology*, *1*(4), 5-15.

Okrajnov-Bajic, R., & Vasovic, D. (2009). Self-compacting concrete and its application in contemporary architectural. *SPATIUM International Review*, (20), 28–34.

Ondova, M., Stevulova, N., & Meciarova, L. (2013). The potential of higher share of fly ash as cement replacement in the concrete pavement. *Procedia Engineering*, *65*, 45–50.

Ouchi, M., & Morizane, J. (2000). Reduction in interaction between coarse aggregate and mortar in self-compacting concrete at fresh stage Relative funnel speed.

Ozkan, O., Yüksel, I., & Muratoğlu, O. (2007). Strength properties of concrete incorporating coal bottom ash and granulated blast furnace slag. *Waste Management New York NY*, *27*(2), 161–167.

Park, S. B., Jang, Y. Il, Lee, J., & Lee, B. J. (2009). An experimental study on the hazard assessment and mechanical properties of porous concrete utilizing coal bottom ash coarse aggregate in Korea. *Journal of Hazardous Materials*, *166*(1), 348–55.

Patel, V. I., Liang, Q. Q., & Hadi, M. N. S. (2017). Nonlinear analysis of circular high strength concrete-filled stainless steel tubular slender beam-columns. *Engineering Structures*, *130*, 1–13.

Pathak, N., & Siddique, R. (2012). Properties of self-compacting-concrete containing fly ash subjected to elevated temperatures. *Construction and Building Materials*, *30*(3), 274–280.

Patil, V., & Gurav, R. S. (2016). Behaviour of Self-Compacting Concrete at Various Levels of Replacement to Fine Aggregate by Pond Ash and Quarry Dust. *International Journal of Science and Research*, *5*(8), 954–959.

Purushothaman, M., & Nadu, T. (2013). Strength properties of high performance concrete using bottom ash, *2*(3), 35–40. *International Journal of Civil Engineering*. *2*(3), 35–40.

Qing, Y., Tao, Z., & Wu, Y. X. (2008). Experimental behaviour of high performance concrete-filled steel tubular columns. *Thin-Walled Structures*, *46*(4), 362–370.

Qu, X., Chen, Z., & Sun, G. (2013). Experimental study of rectangular CFST columns subjected to eccentric loading. *Thin-Walled Structures*, *64*, 83–93.

Rafieizonooz, M., Razman, M., & Warid, M. (2017). Workability , compressive strength and leachability of coal ash concrete. *Chemical Engineering Transactions*, *56*, 439–444.

Raju, R., Paul, M. M., & Aboobacker, K. A. (2014). Strength performance of concrete using bottom ash as fine. *International Journal of Research in Engineering and Technology*, *2*(9), 111–122.

Ravindrarajah, R. S., Farrokhzadi, F., & Lahoud, A. (2003). Properties of flowing concrete and self-compacting concrete with high-performance superplasticier, (August), 17–20.

Roeder, C. W., Lehman, D. E., & Bishop, E. (2010). Strength and stiffness of circular concrete-filled tubes, *Journal of structural Engineering*, *136*, 1545-1553.

Romero, M. L., Ibañez, C., Espinos, A., Portolés, J. M., & Hospitaler, A. (2017). Influence of Ultra-high Strength Concrete on Circular Concrete-filled Dual Steel Columns. *Structures*, *9*, 13–20.

Santa, A. B., Bernardin, A. M., Riella, N.C., & Kuhnen. (2013). Geopolymer synthesized from bottom coal ash and calcined paper sludge, *Journal Clean. Prod.*, *57*, 302–307.

Sathonsaowaphak, A., Chindaprasirt, P., & Pimraksa, K. (2009). Workability and strength of lignite bottom ash geopolymer mortar. *Journal of Hazardous Materials*, *168*(1), 44–50.

Schmidt, W., Brouwers, H. J. H., Kühne, H.-C., & Meng, B. (2014). Influences of superplasticizer modification and mixture composition on the performance of self-compacting concrete at varied ambient temperatures. *Cement and Concrete Composites*, *49*, 111–126.

Schneider, B. S. P. (1998). Axially loaded concrete-filled steel tubes. *Journal of Structural Engineering*, (October), 1125–1138.

Sedran T., & De Larrard F. (1999). Optimization of self-compacting concrete thanks to packing model. First international RILEM symposium on self-compacting concrete, *Rilem Publications*, 321–332.

Siddique, R. (2013). Compressive strength, water absorption, sorptivity, abrasion resistance and permeability of self-compacting concrete containing coal bottom ash. *Construction and Building Materials*, *47*, 1444–1450.

Siddique, R., Aggarwal, P., & Aggarwal, Y. (2012). Influence of water/powder ratio on strength properties of self-compacting concrete containing coal fly ash and bottom ash. *Construction and Building Materials*, *29*, 73–81.

Singh, M., & Siddique, R. (2013). Effect of coal bottom ash as partial replacement of sand on properties of concrete. *Resources, Conservation and Recycling*, *72*, 20–32.

Singh, M., & Siddique, R. (2014a). Compressive strength, drying shrinkage and chemical resistance of concrete incorporating coal bottom ash as partial or total replacement of sand. *Construction and Building Materials*, *68*, 39–48.

Singh, M., & Siddique, R. (2014b). Strength properties and micro-structural properties of concrete containing coal bottom ash as partial replacement of fine aggregate. *Construction and Building Materials*, *50*, 246–256.

Singh, M., & Siddique, R. (2015). Properties of concrete containing high volumes of coal bottom ash as fine aggregate. *Journal of Cleaner Production*, *91*, 269–278.

Soman, K., Sasi, D., & Abubaker, K. A. (2014). Strength properties of concrete with partial replacement of sand by bottom ash. *International Journal of Innovative Research in Advanced Engineering*, *1*(7), 223–227.

Su, N., Hsu, K.-C., & Chai, H.-W. (2001). A simple mix design method for self-compacting concrete. *Cement and Concrete Research*, *31*(12), 1799–1807.

Susantha K., Ge H., & Usami T. (2001). Uniaxial stress–strain relationship of concrete confined by various shaped steel tubes. *Engineering Structure, 23,* 1331–47.

Syahrul, M., Sani, M., Muftah, F., & Muda, Z. (2010). The properties of special concrete using washed bottom ash (wba) as partial sand replacement. *International Journal of Sustainable Construction Engineering & Technology*, *1*(2), 65–76.

Tao, Z., Han, L., & Wang, Z. (2005). Experimental behaviour of stiffened concrete-filled thin-walled hollow steel structural (HSS) stub columns. *Journal of Constructional Steel Research*, *61*, 962–983.

Targan, Ş., Olgun, a, Erdogan, Y., & Sevinc, V. (2003). Influence of natural pozzolan, colemanite ore waste, bottom ash, and fly ash on the properties of Portland cement. *Cement and Concrete Research*, *33*(8), 1175–1182.

The European Guideline for Self-compacting Concrete, EGSCC, (2005). Specifications, productions and use.

The Star (2013). Retrieved on Mac, 27 2014 from https://www.thestar.com.my/business/business-news/2014/03/27/tnbs-jimah-project-on-track-for-completion-by-december-2019/

United States Environmental Protection Agency (USEPA), 1996. Health Effects Tests Guidelines: OPPTS 870526. The Salmonella typhimurium Reverse Mutation Assay. EPA712-C-96-219. United States Environmental Protection Agency, Washington.

Uy, B., Tao, Z., & Han, L.-H. (2011). Behaviour of short and slender concrete-filled stainless steel tubular columns. *Journal of Constructional Steel Research*, *67*(3), 360–378.

Uysal, M., Yilmaz, K., & Ipek, M. (2012). Properties and behavior of self-compacting concrete produced with GBFS and FA additives subjected to high temperatures. *Construction and Building Materials*, *28*(1), 321–326.

Wang Y., & Kodur V. (2000). Research toward use of unprotected steel structures. *Journal Structure Engineering*, *126*(12), 1442–50.

Wongkeo, W., & Chaipanich, A. (2010). Compressive strength, microstructure and thermal analysis of autoclaved and air cured structural lightweight concrete made with coal bottom ash and silica fume. *Materials Science and Engineering: A*, *527*(16–17), 3676–3684.

Wongkeo, W., Thongsanitgarn, P., Pimraksa, K., & Chaipanich, A. (2012). Compressive strength, flexural strength and thermal conductivity of autoclaved concrete block made using bottom ash as cement replacement materials. *Materials & Design*, *35*, 434–439.

Xie, T., & Ozbakkaloglu, T. (2015). Behavior of low-calcium fly and bottom ash-based geopolymer concrete cured at ambient temperature. *Ceramics International*, *41*(4), 5945–5958.

Xiong, M.-X., Xiong, D.-X., & Liew, J. Y. R. (2017). Axial performance of short concrete filled steel tubes with high- and ultra-high- strength materials. *Engineering Structures*, *136*, 494–510.

Yahya, A. A., Ali, N., Mohd Kamal, N. L., Shahidan, S., Beddu, S., Nuruddin, M. F., & Shafiq, N. (2017). Reducing Heavy Metal Element from Coal Bottom Ash by Using Citric Acid Leaching Treatment. *MATEC Web of Conferences*, *103*, 1004.

Yang, H., Lam, D., & Gardner, L. (2008). Testing and analysis of concrete-filled elliptical hollow sections, *30*(12), 3771–3781.

Yang, Y.-F., & Han, L.-H. (2011). Behaviour of concrete filled steel tubular (CFST) stub columns under eccentric partial compression. *Thin-Walled Structures*, *49*(2), 379–395.

Yazici, H. (2008). The effect of silica fume and high-volume Class C fly ash on mechanical properties, chloride penetration and freeze–thaw resistance of self-compacting concrete. *Construction and Building Materials*, *22*(4), 456–462.

Yu, M., Zha, X., Ye, J., & Li, Y. (2013). A unified formulation for circle and polygon concrete-filled steel tube columns under axial compression. *Engineering Structures*, *49*, 1–10.

Yu, M., Zha, X., Ye, J., & She, C. (2010). A unified formulation for hollow and solid concrete-filled steel tube columns under axial compression. *Engineering Structures*, *32*(4), 1046–1053.

Yu, Z., Ding, F., & Cai, C. S. (2007a). Experimental behavior of circular concrete-filled steel tube stub columns. *Journal of Constructional Steel Research*, *63*(2), 165–174.

Yu, Z., Ding, F., & Cai, C. S. (2007b). Experimental behavior of circular concrete-filled steel tube stub columns. *Journal of Constructional Steel Research*, *63*, 165–174.

Yüksel, İ., Bilir, T., & Özkan, Ö. (2007). Durability of concrete incorporating non-ground blast furnace slag and bottom ash as fine aggregate. *Building and Environment*, *42*(7), 2651–2659.

Zeghiche, J., & Chaoui, K. (2005). An experimental behaviour of concrete-filled steel tubular columns. *Journal of Constructional Steel Research*, *61*(1), 53–66.

Zha, X., Gong, G., & Liu, X. (2013). Study on behavior of concrete filled elliptical steel tube members part I□: short and long columns under. *Advance Steel Construction*, *9*(2), 90–107.

Zhang, B., & Poon, C. S. (2015). Use of furnace bottom ash for producing lightweight aggregate concrete with thermal insulation properties. *Journal of Cleaner Production*, (Article in Press).