HIGH PERFORMANCE INDUSTRIALISED BUILDING SYSTEM MULTI-LAYERS SLIM BEAMS

SHERZAD QADIR MAJID

A dissertation submitted in partial fulfillment
of the requirements for the award of the degree
of Master of Engineering (Civil-Structure)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

February 2012

*To my beloved parents, my brothers and sisters, my wife, my beloved kids ***Zhinaz, Zhinyar and Zhiya****

Thanks for your prayers, supports & encouragement

ACKNOWLEDGEMENT

First and foremost, I would like to thank my supervisor of this research, Associate Professor Dr. Abdul Kadir Marsono for the valuable guidance and advice. He inspired me greatly to work for this research. His willingness to motivate me contributed tremendously to my master degree.

Besides, I would like to thank all staff of civil engineering faculty for providing me with a good environment and facilities in the structural laboratory to complete this research. In addition, I would also like to thank our librarian for letting me borrow some books, for the computer labs for letting me use computers and internet.

Finally, an honourable mention goes to my family, father, mother, sisters, brothers, my wife and my kids; and friends, especially my best friend Navid Ranjbar; for their helps, understandings and supports on me in completing this academic degree. Without their support I would face many difficulties while doing this research.

And it would not be successful without God who guides us in our everyday life and activities; I thank Him for the good health he has given to me, and for the success of my study. For all the people who helped me a lot, thank you very much and may God bless you all. Last but not least, I would like to express my earnest gratitude to whom that always believing in me.

ABSTRACT

The qualities and the quantities of materials are not controlled in proper way when a lot of concrete and many steel reinforcements are being wasted. Variation of the sizes of beams and columns are not simplified and generalized, which leads to the increase of cost of construction and unnecessary need. Nowadays, Industrialised Building system (IBS) has become an alternative to speed up the construction completion and to increase the flexibility. The IBS multi-layers slim beam with new type of connection is a new innovation. It is based on the concept of mobility and deployable to speed up the construction process, unification and adaptability. For this purpose, an experimental investigation into the behaviour of six IBS multi-layers slim beams made of high strength concrete and rectangular spiral shear reinforcement with new type of connection has been carried out in three different testing assemblies. These tests were carried out to determine the laboratory ultimate strength capacity of these multi-layers IBS slim beams and to assess the performance and the behaviour of connections. All specimens were connected to a column frame steel-section channel supported on a 3.4 m span. The models were subjected to two point loads. Deflections at various points, crack patterns, crack widths, strain in steel, strains on concrete surface and rotation of connection were recorded during the test. The concrete properties i.e. compressive strength and tensile strength were also recorded. It was found that the capacity of SET 2 (2 slim beams) increased by 87% with comparison to SET 1 (1 slim beam) and the capacity of SET 3 (3 slim beams) increased by 28% with comparison to SET 2 (2 slim beams). The crack patterns of all specimens were similar and the mode of ultimate failure was flexural behaviour. It was associated with crushing and spalling of the concrete at supports. The initial stiffness of connection increased with the increase of the number of slim beams in the set beam. The rotational capacity (ductility) behaved differently as the size of the combined beams increases, and the connections lose their ductility with the increasing number of slim beams. The experimental results were comparable with simulation results carried out by finite element software.

ABSTRAK

Kualiti dan kuantiti bahan yang tidak dikawal dengan baik akan mengakibatkan pembaziran konkrit dan tetulang keluli. Perbezaan saiz rasuk dan tiang yang tidak dipermudahkan akan meningkatkan kos pembinaan yang tidak diingini. Pada masa kini, Sistem Bangunan Perindustrian (Industrialised Building System, IBS) telah menjadi satu alternatif untuk mempercepatkan penyiapan pembinaan dan meningkatkan keupayaan serta fleksibiliti. Set rasuk nipis IBS adalah satu innovasi baru yang mengetengahkan penyambungan yang baru. Ianya adalah berdasarkan konsep mudah alih dan membolehkan proses pembinaan di singkatkan dengan penggunaan struktur yang mudah. Bagi tujuan ini, penyiasatan makmal ke atas kelakunan enam IBS dengan rasuk nipis yang diperbuat daripada konkrit kekuatan tinggi dan tetulang ricih lingkaran segi empat tepat dan sambungan jenis baru telah dijalankan dalam tiga kumpulan ujian. Ia adalah untuk menentukan kapasiti kekuatan muktamad pelbagai set rasuk IBS langsing. Ia juga menilai prestasi dan kelakunan sambungan. Semua spesimen disambungkan kepada tiang keluli dan disokong pada rentangan 3.4 meter. Model diuji dengan dua beban titik. Pesongan di pelbagai tempat, corak retak, lebar retak, terikan keluli, terikan permukaan konkrit dan putaran sambungan dicatatkan semasa ujian. Sifat-sifat konkrit iaitu kekuatan mampatan dan kekuatan tegangan juge direkodkan. Didapati bahawa kapasiti SET 2 (2 rasuk nipis) meningkat sebanyak 87% berbanding SET 1 (1 rasuk nipis) dan kapasiti SET 3 (3 rasuk nipis) meningkat sebanyak 28% berbanding SET 2 (2 rasuk nipis). Corak retak semua spesimen adalah serupa dan mod kegagalan adalah lenturan, dengan hancuran dan kopekan konkrit pada sokongan. Kekukuhan awal sambungan meningkat dengan peningkatan bilangan rasuk tipis dalam set. Kapasiti (kemuluran) berbeza apabila bilangan rasuk nipis berubah dan sambungan kehilangan kemuluran dengan bertambahnya bilangan rasuk nipis. Keputusan eksperimen adalah sepadan dengan keputusan simulasi yang dijalankan dengan perisian unsur terhingga.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

G_c	specific gravity of the cement or cementitious material
G_{ssd}	aggregate specific gravity in saturated surface dry condition
W_{abs}	absorbed water in the aggregate in per cent
W_{tot}	total water content of the aggregate in per cent
W_h	moisture content of the aggregate in per cent
G_s	specific gravity of the liquid superplasticizer
s	total solid content of the superplasticizer in per cent
M_{sol}	mass of solids in the superplasticizer
d	superplasticizer dosage as a percentage of the mass of solids in comparison to the total mass of cementitious materials
V_{liq}	volume of liquid superplasticizer
V_w	volume of water in the liquid superplasticizer
V_{sol}	volume of solids in the superplasticizer
W	mass of water in kg per cubic metre of concrete
B	mass of binder in kg per cubic metre
C	Binder Mass
As	Cross sectional area of reinforcement
$As_{,min}$	minimum cross sectional area of reinforcement
A_{sw}	Cross sectional area of shear reinforcement
Ec	Tangent modulus of elasticity of normal weight concrete

s	Height of the compression zone in equivalent stress block
E_s	Design value of modulus of elasticity of reinforcing steel
SLS	Serviceability limit state
ULS	Ultimate limit state
V	Shear force
V_{Ed}	Design value of the applied shear force
b	Overall width of a cross-section of beam
d	Effective depth of a cross-section
fcd	Design value of concrete compressive strength
fck	Characteristic compressive cylinder strength of concrete at 28 days
$f_{c'}$	Compressive cylinder strength of concrete at 28 days
fcm	Mean value of concrete cylinder compressive strength
fctm	Mean value of axial tensile strength of concrete
h	Overall depth of a cross-section
α	Angle ; ratio
β	Angle ; ratio; coefficient
γ c	Partial factor for concrete
γ s	Partial factor for reinforcing steel
λ	height of the compression zone in equivalent stress block
w	Width of the compression zone in equivalent stress block
η	Effective strength

CHAPTER 1

INTRODUCTION

1.1 Background

Structural engineers, regardless of locality, have as a part of their responsibility, the safety of lives that is a prime consideration than any other profession. It is this responsibility that accounts for their conservatism. In the field of engineering materials and methods of construction, great advances have been accomplished within the past few decades through precast and prestressed concrete, high strength steel, high performance concrete. Materials improvements have also been driven along design procedures and process of materializing the structures as evidenced by the gaining popularity of ultimate strength design, plastic design and limit state design.

Industrialised Building System (IBS) is a coordinated dimensioning of components for construction where all parts of the structure such as column, beam, and slab is prefabricated or precast in the factory or site factory and assemble it on site. IBS has emerged as a potential solution for modular coordinated constructions. IBS concrete structures, where the superstructure is erected from the individual elements of prefabricated components, manufactured in factory in a favourable environment and strict production and quality control, will produces units of high quality in term of performance and appearance. The designer can select from a range of finishes, be able to inspect and accept the units before they leave the factory. Public buildings such as schools, universities, hospitals, offices, car parks, residential housing and hotels can be built using IBS concrete components.

Malaysia have utilises precast concrete system but the use of IBS is still low compared to developed countries such as United States, Europe and Japan [1]. IBS shall be able to merge with any scheme of other constructions such as steel or other precast component producer. One of the early definitions of industrialised building system has been given by Esa et al [2], in which IBS is a continuum beginning from utilising craft-men for every aspect of construction to a system that use manufacturing production in order to minimise resource wastage and enhance value for end users.

In the 1970s, when the compressive strength of the concrete used in the columns of some high-rise buildings was higher than that of the usual concretes used in construction, there is no doubt that it was legitimate to call these new concretes ‘high-strength concretes HSC’. They were used only because their strength was higher than that of the usual concretes. However, when superplasticizers began to be used to decrease the water/cement (W/C) ratio, it was found that concretes with a very low w/c ratio also had other improved characteristics, such as higher flowability, higher elastic modulus, higher flexural strength, lower permeability, improved abrasion resistance and better durability. Thus the expression ‘high-strength concrete’ no longer adequately described the overall improvement in the properties of this new family of concretes. Therefore the expression ‘high-performance concrete HPC’ became more and more widely used. High performance concrete leads to achieve high performance structure.

The use of HPC in the IBS can offer several benefits such as reduce times of casting, lifting less weight and more slim members and less mobilization effort.

In this study, an experimental investigations will carried out on new IBS concrete slim (the ratio of height to width is more or equal to 1:3) beams using new type of steel-connection which is able to erect more than one slim beam as multi-layers unit to form a frame for whole structural system as one of its high performance characteristics, this study checks the behaviour of IBS slim beam during the loading until the ultimate failure.

1.2 Statement of Problem

The IBS multi-layers slim beam is a new innovation. It is based on the concept of mobility and deployable to speed up the construction process, unification and adaptability. New innovation design has to be checked and verified experimentally. The beam components beside simulation under applied loads to be check for its real behaviour and rare availability of supporting content in code of practices for design, especially beams with spiral shear reinforcement and new type of structural connection.

Relating to these purposes, an experimental investigation into the behaviour of six IBS slim beams made of high strength concrete and rectangular spiral shear reinforcement at sizes of 100 x 300mm of concrete has been designed and put into study.

1.3 Aim of the Study

The aims of this study are to develop a high performance concrete (HPC) slim beam and the effect of its assembly for an IBS from standardised cross section.

1.4 Objectives of the Study

The prime objective of this research is to investigate the behaviour of HPC multi- layers smart IBS slim beam under two points load test to the failure.

In order to achieve the aim and the prime objective of this study, the following specific objectives are proposed:

1. To determine the experimental ultimate strength capacity of these beam structures sets of multi-layers IBS slim beams.

2. To evaluate the ultimate flexural behaviour of IBS slim beam structures sets and to check the attribute of strength of the assembly.

3. To assess the performance and behaviour of connections for load transfer mechanism formation to column.

4. To study the experimental results with finite element methods.

1.5 Scope of the Work

The scope of the work study of item (a), (b) and (c) is to fabricate to precision a series of six slim beams in laboratory with size of 100 x 300 x 3400 mm long to form 3 combination of beam structure. These beams are to be tested in laboratory condition to ultimate failure. The formation of beam structure comprising:

a) Set 1: Single slim beam;
b) Set 2: Double slim beam; and
c) Set 3: Triple slim beam.

1.6 Arrangement of the Thesis

This thesis is divided into seven chapters in addition to the present one as an introduction to this thesis. In Chapter 2, a literature review is presented to give more understanding to the need of industrialised building system. It reviews theoretical and experimental studies of previous work in similar fields. Moreover, different conceptual models of steel connections are also reviewed.

In Chapter 3, the design of high strength concrete mix was illustrated and an Excel spread sheet has been developed for this purpose. Moreover, a design of high strength concrete beam in flexure as well as to shear design with spiral links has been stepwise according to Eurocode 2.

In order to better understand the formation of structures experimental work of IBS slim beams, the components and test setups of six IBS slim beams are explained in Chapter 4. The details of beam specimens, material properties, instrumentation and the testing procedure used are described.

The results obtained from the experimental work carried out at the Structural and Material Laboratory of the Universiti Technologi Malaysia (UTM) are presented and discussed in Chapter 5. The influence of each design parameter is studied separately, and test results are compared with Eurocode 2 [3], Eurocode 3 [4-5] and Eurocode 4 [6].

The comparisons of all specimen results have been represented in Chapter 6.

Chapter 7 presents general and specific conclusions, together with recommendations for future research. A list of references cited in the thesis and appendices are also presented.

References

[1] L. P. CHUNG, "IMPLEMENTATION STRATEGY FOR INDUSTRIALISED BUILDING SYSTEM," Faculty of Civil Engineering, Universiti Teknologi Malaysia; Thesis, 2006.

[2] H. Esa, and Nuruddin, M.M (1998) Policy on industrialised building system. Report on Colloquim on Industrialised Construction System, Kuala Lumpur.

[3] Eurocode-2, "Design of concrete structures," in *part 1-1: General rules and rules for buildings*, ed, 1992-1-1:2004.

[4] Eurocode3, "BS EN 1993-1-1:2005; Design of steel structure- Part 1-1: General rules and rules for building."

[5] Eurocode3, "BS EN 1993-1-8:2005 : Design of steel structure- Part 1-8: Design of joints."

[6] Eurocode4, "BS EN 1994-1-1:2004: Design of composite steel and concrete structures ".

[7] Abdul Kadir M.R. , M. S. Jaafar, S. M. Sapuan and A.A. Ali, "Performance Comparison between Structural Element of Building Systems in Malaysia," *American Journal of Applied Sciences*, vol. 2 (5), 2005.

[8] Mohd Rofdzi Abdullah1 , Mohd Nasrun Mohd Nawi, Ahmad Tarmizi Haron, Mohammed Arif, "INDUSTRIALISED BUILDING SYSTEM: A DEFINITION AND CONCEPT," in *ARCOM Conference*, Nottingham, United Kingdom, 2009.

[9] Rahman ABA and Omar. W., " Issues and challenges in the implementation of IBS in Malaysia," in *6th Asia-Pacific Structural Engineering and Construction Conference (ASPEC 2006)*, Kuala Lumpur, Malaysia, 2006.

[10] K. K. Hamid. ZA, Zain. MZM, Ghani. MK and Rahim. AHA. Industrialized Building System (IBS) in Malaysia: the current state and R&D initiatives. Malaysian Construction Research Journal (MCRJ). 2(1): 1-11, 2008.

[11] CIB report.. CIB Publication 329, "New perspective in industrialization in construction – a state of the art report," Zurich2010.

[12] CIDB, "Industrialised Building System (IBS) Roadmap 2003-2010," Construction Industry Development Board (CIDB), Kuala Lumpur (2003).

[13] Kamarul Anuar Mohd Kamar, Mohamed Nor Azhari Azman and Mohd Sanusi S. Ahamad, "Industrialized Building System (IBS): Revisiting Issues of Definition and Classification," *Int. J. Emerg. Sci*, pp. PP. 120-132, 2011.

[14] E. Hognestad, and Hanson, N. W. and McHenry, D., "Concrete stress distribution in ultimate strength design," *ACI Journal*, vol. V. 52, No.6, pp. pp. 455-480, 1955.

[15] Ibrahim M.H. and MacGregor, J. G., "Modification of the ACI Rectangular Stress Block for High-Strength Concrete," *ACI Structural Journal*, vol. Vol. 94, No. 1, pp. pp. 40-48, 1997.

[16] Attard, M. M. and Stewart, M. G., "A Two Parameter Stress Block for High Strength Concrete," *ACI Structural Journal*, vol. Vol. 95, No. 3, pp. pp. 305-317, 1998.

[17] D. Marinucci, and Patnaikuni, I., "Stress Blocks for High Strength High Performance Concrete Columns and Beams," in *Proc. Sixth International Conference on Structural Failure, Durability and Retrofitting*, Singapore, 14-15 September 2000, pp. pp. 106-115.

[18] E. Oztekin, Pul, S., and Husem, M., "Determination of rectangular stress block parameters for high performance concrete," *Engineering Structures*, vol. Vol. 25, pp. pp. 371-376, 2003.

[19] Ozbakkaloglu M. S., "Rectangular stress block for high strength concrete," *ACI Structural Journal*, vol. Vol. 101, No.4, pp. pp. 475-483, 2004.

[20] Bae S. and Bayrak O., "Stress Block Parameters for High-Strength Concrete Members," *ACI Structural Journal*, vol. Vol. 100, No. 5, pp. pp 626-636, Sept-Oct 2003.

[21] P. A. Mendis, and Pendayala, R. S., "Structural design with high-strength/high-performance concrete – beams and columns," *Concrete in Australia*, vol. Vol. 23, No. 2, pp. pp. 26-28, 1997.

[22] T. H. Wee, Chin, N. S. and Mansur, M. A., "Stress-strain relationship of high strength concrete in compression," *Journal of Materials in Civil Engineering*, vol. Vol. 8, No. 2, pp. pp. 70-76, 1996.

[23] K. Azizinamini A, S. S. B., Brungardt P, Hatfield E., "Seismic Behavior of Square High-Strength Concrete Columns," *ACI Structural Journal*, vol. Vol. 91, No.3, pp. pp 336-345, 1994.

[24] S. E. Swartz, Narayan Babu, H. D., Periyakarupan, N. and Refai, T. M. E., "Structural bending properties of higher strength concrete," *High Strength Concrete. ACI SP-87*, pp. pp.147-178, 1985.

[25] P. H. Kaar, Hanson, N. W and Capell, H. T., "Stress-strain characteristics of high strength concrete," *Farmington Hills, Detroit. American Concrete Institute*, vol. SP-55, pp. pp.161-186, 1978.

[26] ACI, "Building Code Requirements for Structural Concrete (ACI 318M-08) and Commentary," vol. First printing, June 2008, ed: American Concrete Institute, 318M-08.

[27] D. D. Arthur H. Nilson, Charles W. Dolan, *Design of Concrete Structure*, Fourteenth ed.: Mc Graw Hill, 2010.

[28] K. E. Leslie, Rajagopalan, K. S. and Everard, N. J. “Flexural behavior of high-strength concrete beams." ACI Journal. Vol. 73, No. 9, 1976, pp. 571-521.

[29] G. U. Tognon, P.; and Coppetti, G., "Design and Properties of Concretes with Strength over 1500 kgf/cm2," ACI JOURNAL, Proceedings V. 77, No. 3, May-June 1980, pp. 171-178.

[30] Okada, K. and Azimi M. A., ” Memoirs of the Faculty of Engineering, Kyoto University, Japan. Vol.43, No2. pp. 304-318.

[31] J. A. Pastor, Nilson, A. H. and Slate, F. O. “Behaviour of High-strength Concrete Beams,” Research Report 84-3. Department of Structural Engineering, Cornell University, Ithaca, New York, 1984, 311pp.

[32] Swamy, R. N, ” High Strength Concrete", ACI SP-87, Detroit, 1985, pp. 119-146.

[33] S. M. Uzumeri, and Basset, R. “Behaviors of High Strength Concrete Members,” International Symposium on Utilization of High Strength Concrete, Stavanger, June 1987, Norway, pp. 237-248.

[34] S. W. Shin, Ghosh, S. K., and Moreno, J. “Flexural ductility of ultra-high-strength concrete members." ACI Journal Proceedings, Vol. 86, No.4, 1989, pp.394-400.

[35] H. Lambotte, and Taerwe, L. R., “Deflection and cracking of high-strength concrete beams and slabs.” SP127-7, Proceedings, High-Strength Concrete, 2nd Int. Symp. Berkeley, Calif., W.T. Hester, ed., ACI Farmington Hills, Mich., 1990, pp. 108-128.

[36] C.-H. Lin, Ling, F. –S., and Hwang, C. –L. “ Flexural Behaviour of High Strength Fly Ash Concrete Beams,” Journal of the Chinese Institute of Engineers, Taiwan, Vol. 15, No. 1, 1992, pp. 85-92.

[37] Shehata, I. A. E. M. and L. C. D. Shehata, " Proceedings, 4th Int. Symp. on Utilization of High-Strength/High-Performance Concrete. Paris. 1996, pp. 945-953.

[38] R. Pendyala, Mendis, P.A. and Patnaikuni, I., "Full-range Behaviour of High-Strength Flexural Members: Comparision of Ductility Parameters of High and Normal Strength Concrete Members," ACI Structural Journal, Vol. 93, No. 1, January - February 1996, pp 30-35.

[39] S. Sarkar, Adwan, O., Munday, J. G. L., "High strength concrete: an investigation of the flexural behavior of high strength RC beams," The Structural Engineer, Vol. 75, No.7, April, 1997, pp 115-121.

[40] M. A. Mansur, Chin, M. S. and Wee, T. H. "Flexural behavior of high-strength concrete beams," ACI Structural Journal, Vol.94, No. 6, November 1997, pp. 663-674.

[41] S. A. Ashour, "Effect of compressive strength and tensile reinforcement ratio on flexural behavior of high-strength concrete beams," Engineering Structures, Vol. 22, 2000, pp. 413- 423.

[42] L. F. A. Bernardo, Lopes, S. M. R., "Neutral Axis Depth versus Flexural Ductility in High-Strength Concrete Beams," ASCE Journal of Structural Engineering, Vol. 130, No.3, March, 2004, pp 425-459.

[43] M. A. a. M. A. M. Rashid, M. A. "Reinforced High-Strength Concrete Beams in Flexure," ACI Structural Journal, Vol. 102, No. 3, May 2005, pp. 462-471.

[44] S. Ashour, Khalid Mahmood, and Faisal W. Wafa., "Influence of Steel Fibers and Compression Reinforcement on Deflection of High-Strength Concrete Beams," ACI Structural Journal. Vol. 94, No. 6, Nov-Dec 1997. pp. 611-624.

[45] M.-H. K. Keun-Hyeok Yang, Ho-Chan Lee and Myoung-Ho Oh, "Flexural behavior of hybrid precast concrete beams with H-steel beamsat both ends," *Engineering Structures*, vol. 32, pp. PP. 2940-2949, 2010.

[46] H. J. Pam, Kwan, A. K. H and Islam, M. S., "Flexural strength and ductility of reinforced normal- and high-strength concrete beams." Structures & Buildings. Vol. 146, No. 4, 2001, 381-389.

[47] D. D. a. M. Starnes, "Strength and Ductility of Concrete Beams Reinforced with Carbon FRP and Steel," *NISTIR 6830*, 2001.

[48] Hsu;Mo, "UNIFIED THEORY OF CONCRETE STRUCTURES", Second Edition 2010: 2010 John Wiley & Sons, Ltd, 2010.

[49] A. Ghali, “Deflection of Reinforced Concrete Members,” ACI Structural Journal, Vol. 90, No. 4, July-August 1993, pp.368-373.

[50] D. Galeota, and Giammatteo, M. M., “High-Strength Concrete Beams Subjected to Shear,” High Strength Concrete. First International Conference held in Kona, Hawaii, Sponsored by the United Engineering Foundation, ASCE, 0-7844-0419- 4, 1997, 670 pp.

[51] R. S. Pendyala, “The Behaviour of High-Strength Concrete Beams,” PhD thesis, The University of Melbourne, 1997.

[52] A. H. N. Elzanaty, A. H.; and Slate, F. O., “Shear Capacity of Reinforced Concrete Beams Using High-Strength Concrete,” ACI JOURNAL, Proceedings V. 83, No. 2, Mar.-Apr. 1986, pp. 290-296.

[53] G. G. Konig, R.; and Remmel, G., “Shear Behaviour of Longitudinally Reinforced Concrete Members of HSC,” Darmstadt Concrete, V. 8, 1993, pp. 27-42.

[54] R. S. Mendis, "Experimental Study on Shear Strength of High-Strength Concrete Beams," *ACI STRUCTURAL JOURNAL*, vol. 97, pp. PP. 554-571, 2000.

[55] M. M. Attard, “Ductility of High-Strength Concrete Columns,” Australian Civil Engineering Transactions, V. 35, No. 4, 1993, pp. 295-306.

[56] M. K. Johnson, and. Ramirez, J. A., “Minimum Shear Reinforcement in Beams with Higher Strength Concrete,” ACI Structural Journal, V. 86, No.4, 1989, pp. 376-382.

[57] S.W. Shin, “Flexural Behaviour including Ductility of Ultra-high-strength Concrete Members", PhD thesis,University of Illinois, Chicago, 1986, 232pp.

[58] Cladera A. R., “Experimental study on high-strength concrete beams failing in shear,” Engineering Structures, Vol. 27 No.10, 2005, pp1519-1527.

[59] Rahal K.S. “Minimum Transverse Reinforcement in 65 MPa Concrete Beams,” ACI Structural Journal. Vol. 101, No.6, November 2004, pp.872-878.

[60] C. Faella, Piluso, V., Rizzano, G, Structural Steel Semirigid Connections: Theory, Design and Software, United States:CRL Press LLC. 2000.

[61] Ryan.J.C., "Evaluation of Extended End-Plate Moment Connections Under Seismic Loading," Master Thesis, Virginia Polytechnic Institute and State University, 1999.

[62] R. Bjorhovde, Brazetti, J., Colson, A. (1990), “ A Classification System for Beam–to-Column Connection”, Journal of Structural Engineering, ASCE: Vol. 1116, No. ST11, pg 059-3076.

[63] W. F. Chen, Goto, Y., Liew, J.Y.R (1996), “Stability Design of Semi-rigid Frame”, New York:Wiley-IEEE, pg 18-19.

[64] K. S. Elliot, G. Davies, H. Gorgun and M.R. Adlparvar, 1998. The stability of precast concrete skeletal structure. PCI Journal., pg 42-57.

[65] K. S. Elliott, *Precast Concrete Structures*: Butterworth-Heinemann, 2002.

[66] Ahmad Baharuddin Abd. Rahman, A. Aziz Saim and Mohd. Hanim Osman, "HYBRID BEAM-TO-COLUMN CONNECTIONS FOR PRECAST CONCRETE FRAMES " in *6th Asia-Pacific Structural Engineering and Construction Conference*, Kuala Lumpur, Malaysia, 2006.

[67] AISC, *Manual of steel construction-load and resistance factor design*, Seconed ed.: American Institute of Steel Construction, 1994.

[68] P.-C.Aïtcin, *High Performance Concrete*. London and New York: Taylor & Francis e-Library, 2004.

[69] A. M. Neville, *Properties of concrete*, Fourth and Final ed. England: Pearson Education, Reprented 2004.

[70] ACI211.1-91, "*Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete"*, ed, 2002.

[71] British Standard 1995, "Testing Aggregates," in *Part 2. Methods of determination of density*, ed: BSI, 1999.

[72] R. 1100, "High range, water-reducing, superplasticising admixture for the production of Rheoplastic concrete," ed: BASF, The chemical Company, 1999.

[73] J. A. Purkiss, *Concrete Design to EN 1992*, Second ed.: Butterworth-Heinemann, An imprint of Elsevier, 2006.

[74] Eurocode1990, "BS EN1990:2002+A1:2005-Basis of structural design," ed: BSI, p. 120.

[75] Eurocode-2, "Design of concrete structures," in *Part 2: Concrete bridges — Design and detailing rules*, ed, 1992-2:2005.

[76] ACI363R-10, "Report on High-Strength Concrete," ed: Reported by ACI Committee 363, 2010.

[77] BS1881-102:1983, "Testing concrete: Paret 102: Method for determination of slump ", ed: Cement, Gypsum, Aggregates and Quarry Products Standards Committee.

[78] BS1881-110:1983, "Testing concrete: Part 110: Method for making test cylinders from fresh concrete," ed: Cement, Gypsum, Aggregates and Quarry Products Standards Committee.

[79] BS1881-116:1983, "Testing concrete: Part 116: Method for determination of compressive strength of concrete cubes," ed: Cement, Gypsum, Aggregates and Quarry Products Standards Committee.

[80] BS1881-117:1983, "Testing concrete: Part 117: Method for determination of tensile splitting strength," ed: Cement, Gypsum, Aggregates and Quarry Products Standards Committee.

[81] BS1881-125:1983, "Testing concrete: Part 125: Methods for mixing and sampling fresh concrete in the laboratory," ed: Cement, Gypsum, Aggregates and Quarry Products Standards Committee.

[82] BS1881-108:1983, "Testing concrete: Part 108: Method for making test cubes from fresh concrete," ed: Cement, Gypsum, Aggregates and Quarry Products Standards Committee.

[83] BS1881-111:1993, "Testing concrete: Part 111: Method of normal curing of test specimens (20 °C method)," ed: Cement, Gypsum, Aggregates and Quarry Products Standards Committee.

[84] BS812-102:1995, "Testing aggregates: Part 2: Methods of determination of density," ed: BSi.

[85] C. H. Marzouk, Fracture energy and tension properties of high-strength concrete, J. Mater. Civ. Eng., ASCE 7 (2) (1995) 108-116 (May).

[86] M. K. Wiegrink, S.P. Shah, "Shrinkage cracking of high- strength concrete", ACI Mater. J. 93 (5) (1996) 409– 415 (September– October).

[87] James M. Gere, *Mechanics of Materials*, Seventh ed. Toronto , Canada: Cengage Learning, 2009.

[88] A. W. S. Beeby, R. H. 2006. Mechanisms of long-term decay of tension stiffening, Magazine of Concrete Research 58(5): 255–266.

[89] A. P. F. Fantilli, D.; Rosati, G. 2005. Effect of bar diameter on the behavior of lightly reinforced concrete beams, ASCE Journal of Materials in Civil Engineering 17(1): 10–18.

[90] D. K. Salys, G.; Gribniak, V. 2009. Modelling deformation behaviour of RC beams attributing tension-stiffening to tensile reinforcement, Engineering Structures and Technologies, in press (in Lithuanian). ISSN 2029-2317 (print), ISSN 2029-2325 (online).

[91] H. Q. G. Wu, R. I. 2008. "An Experimental Study of Tension Stiffening in Reinforced Concrete Members under Short-Term and Long-Term Loads", UNICIV Report No. R-449. Sydney: The University of South Wales. 32 p.

[92] M. Md.Tahir, Sulaiman,A., Mohammad,S., Saggaff,A,. Standardisation of Partial Strength Connections of Flush End-Plate Connection for Trapezoid Web Profiled Steel Sections. Journal-The Institution of Engineers, Malaysia. Vol. 67, No. 2, June 2006.