EFFECTS ON LOADING CALCULATION OF REINFORCED CONCRETE STRUCTURAL DESIGN SUBJECTED TO FIRE: REVIEW ON BUILDING CODES AND STANDARDS

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DEDICATION

My dearest family, Dr Mariyana and friends"

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ABSTRACT

This study is to review the relevant building codes and standards for the design of reinforced concrete structural elements under fire condition. Detailed study of the relevant codes and standards for the reinforced concrete design under fire will be carried out. The design requirements will then be identified based on the respective codes requirement or recommendation to identify the differences between the codes in terms of prescriptive and performance design, load combination for fire condition and the design of reinforced concrete structural elements during fire condition. A simple numerical analysis of the reinforced concrete structural element will be carried out to demonstrate the difference in terms of loading calculation adopted for the element design and the reinforced concrete design. The calculation shows that the material strength reduction factor increased when the temperature rises which also affects the flexural strength of the concrete element. However, the reduced permanent and variable actions load factor for the fire condition load combination also reduced the designed moment required, corresponding to the reduction in flexural strength due to the reduced material strength exposed to fire.

ABSTRAK

Kajian ini dijalankan bagi tujuan pengulasan piawai reka bentuk struktur elemen konkrit.bertetulang semasa waktu kebakaran. Pengajian buitran piawai reka bentuk stuktur konkrit yang berlainann akan dilakukan. Perbezaan dalam segi piawai preskripsi atau prestasi, gabungan beban semasa waktu kebakaran dan reka bentuk struktur elemen konkrit bertetulang semasa kebakaran akan dikenal pasti. Pengiraan mudah bagi reka bentuk struktur akan ditunjukkan bagi menentu perbezaan dari segi gabungan beban dan reka bentuk struktur elemen konkrit bertetulang. Pengiraan tersebut menunjukkan bahawa faktor pengurangan kekuatan bahan meningkat apabila suhu kebakaran meningkat dan menjejas kapasiti beban beam. Walau sedemikian, gabungan beban yang dikurangkan semasa kebakaran juga mengurangkan kapasiti momen yang diperlukan dengan pegurangan kekuatan bahan semasa suhu kebakaran meningkat.

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INTRODUCTION

1.1 Reinforced Concrete Design Code of Practice

British Standards Institution (BSI), which is the national standards body of United Kingdom, develops the British Standards (BS) under the authority of a Royal Charter. The principle of British Standards encompass the development, publication, maintenance and application of British Standards and related standardization documents, together with the UK's participation in European and international standardization.

Efforts to develop Eurocodes started in 1975. The Commission of the European Community (presently the European commission) decided to develop an action programme for the construction field. The purpose of the programme is to harmonise the technical specifications and to eliminate the technical obstacles. The established set of harmonised technical rules for the construction works would serves as an alternative to the national rule for the member states in the European Union, and ultimately replaced them. Ten sections of the Eurocodes are published as a separate European Standards. All the Eurocodes relating to material have a Part 1-1 which covers the design of building and other civil engineering structure and Part 1-2 for fire design.

Britain, which is part of the European Union, along with the rest of its member, is obligated to adopt the Eurocode with its respective national annex, which is consistent with the other European country, rather than national level. On April 2010, BSI withdraws 57 British Standards and replaced with the 10 new Eurocodes. The old British Standards may still be used; however, they will not be maintain or updated which means that one day it will be obsolete.

In Malaysia, Uniform building By Law governs the engineering practices. The latest amendment to the Uniform Building by Law includes the replacement of British Standards with Eurocodes and adopted as Malaysian Standards. Since April 2010, United Kingdom had withdrawn all British Standards and fully adopted the use of Eurocodes in United Kingdom consultancy practice. For the construction industries and the professional engineering practices to move forward, it is imperative that Eurocodes to be adopted as referenced designed standard and for submission purposes. However, the implementation of revised Building by Law has not yet to be adopted and implemented by all the local authorities' levels (Ir. Prof. Dr.Jeffrey Chiang, 2015).

1.2 Fire Safety Engineering

One of the biggest treats to be buildings around the world is fire. Fire in a building is a destructive force which can cause millions of dollars of damages and sometimes causes deaths to people. The outbreak of fire can occur at any time to any kind of building, and often least expected. Therefore, for the safety of the occupants, the building design largely focused on the escape routes for the occupant and the access for the fire fighter. The building layout must provide safe routes for the occupants to leave the building and access for fire fighter to enter or leave the building. Part of the structure must also be designed in such a way that it will not collapse during fire and does not allow the fire to spread, which is part of fire safety engineering for building. Fire safety engineering can be defined as the engineering application to the effects of fire in order to reduce the damages to the properties and loss of life by providing preventive or protective measures.

The loss of life and damages to the properties can be eliminated if fire outbreak can be prevented. Comprehensive strategies or preventive measures can be put in place to reduce the chances of fire, however, we can never be one hundred percent sure that it can prevent all major fires, hence the fire safety engineering design. In Malaysia, one of the most effective counter measures against the outbreak of fire is the provision of sprinkler system to control or extinguish the fire. Safe routes for the occupants and fire fighters, barriers to control the spread of fire or smoke, and the structure will not collapse at the early stage of fire while the occupants are leaving the building is also being taken into consideration during design stage. Figure 1.1 shows the EPF building in Malaysia caught on fire caused by the flammable cladding of the building.

Figure 1.1 The EPF building on February 2018 (Photo: THE STAR / ASIA NEWS NETWORK)

1.3 Statement of the Problem

Among most of the widely adopted building material, concrete material provides the highest resistance to fire. Concrete material does not contribute to the fire load. Instead, it provides the necessary fire protection, thermal insulation and barrier between compartments which provides escape routes during fire. Concrete material also provides the most cost effective options for fire protective construction. Figure 1.2 shows the case of modern high-rise building exposed to fire. The building was destroyed by the fire outbreak at level 21 floor out of 29 floors in total. The used of load bearing concrete elements such as shear wall, columns and corewalls helped to prevent the complete collapse of the building under fire which lasted for 25 hours. Based on the reinforced concrete fire resistance design, the provision of the respective concrete cover, fire resistance rating or fire resistance level helps to improve the fire resistance of the building.

Figure 1.2 Winsor Tower, Madrid

Before the publication and implementation of Eurocodes for reinforced concrete (RC) building design, British Standards is widely adopted for RC building design in Malaysia. Fire resistance of structure or structural element is given in the tabulated data under Section 4 of BS 8110 -2:1985, the fire resistance capacity of the structural element is specified in terms of concrete cover for the respective structural elements based on the respective fire resistance duration only.

Based on Eurocodes, an entire section of Eurocodes (Eurocode 2: Design of concrete structure – Part 1-2: General rules – Structural fire design) is dedicated for the design of structural element under fire. Different methods ranging from simplified method to complex finite element method are specified in the Eurocode. The reduction of material strength for the concrete and steel reinforcement is determined based on the estimated temperature, and the capacity of the structural element is re-checked based on the reduced material strength and compared with the fire design load combination designed loadings.

With such contrast of the design requirement and recommendation for fire resistance, this study will focused on the review of the different for structural fire design codes not limited to Eurocode, but also British Standards, Australia standards and New Zealand Standards.

1.4 Objectives of the Study

The objectives of the study are as follows:

a. To critically review the structural reinforced concrete design for fire based on Eurocode, but also British Standards, Australia Standards and New Zealand Standards.

b. To identify the differences in terms of prescriptive and performance based standards, load combinations, material reduction factor during elevated temperature and the design of reinforced concrete structural fire design, based on Eurocode, British Standards, Australian Standards and New Zealand Standards.

c. To carry out simple calculation for the respective load combinations, simply supported reinforced concrete beam and slab and minimum concrete cover and dimension required based on Eurocode, British Standards, Australian Standards and New Zealand Standards.

d. To compare the design procedure and flexural strength of simply supported concrete beam and slab at ambient temperature and elevated temperature.

1.5 Scope of the Study

This research will review on both prescriptive and performance based standards, design procedure, load combinations, and design and analysis method for reinforced concrete structural fire design based on Eurocode, British Standards, Australia Standards and New Zealand Standards. Design of reinforced concrete structural element procedure comparison and simple analysis for the respective code of practice load combination for fire condition will be carried out. Simplified design method such as 500°C isotherm method for beam and slab design will be adopted to demonstrate the effect of different concrete cover on the flexural strength based on the respective load combination under fire condition for a simply supported rectangular beam, continuous T-beam and simply supported slab.

1.6 Significance of the Study

This study will identify the prescriptive and performance based standards, design procedure, load combinations, and design and analysis method for reinforced concrete structural fire design based on the respective codes of practices according to the different load combination and concrete cover for particular fire resistance duration. Perhaps this study can be used to compare the flexural strength of reinforced concrete structural element concrete at ambient and elevated temperature.

1.7 Chapter Arrangement

Chapter 1: In this chapter, introduction to the research study, statement of the problems objectives, scope of the study, and the significance of the study will be elaborated.

Chapter 2: This chapter will review on the prescriptive and performance based standards, design procedure, load combinations, and design and analysis method for reinforced concrete structural fire design based on Eurocodes, British Standards, New Zealand Codes and Australian Codes.

Chapter 3: The outline and the research methodology of this study will be identified in this chapter.

Chapter 4: The respective prescriptive and performance based standards, design procedure, load combinations, and design and analysis method for reinforced concrete structural fire design based on Eurocodes, British Standards, New Zealand Codes and Australian Codes will be tabulated for comparison, and the findings of the comparison to be identified and elaborated.

Chapter 5: Summary of the research proposal above and the future works to be suggested.

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