EARTHQUAKE ANALYSIS OF IBS FOR SINGLE STOREY HOUSING

SITI RADIAH BINTI YUNUS

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To my beloved father, mother, brothers and sisters.....

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ABSTRACT

An earthquake is the motion or trembling of the ground produced by sudden displacement of rock in the Earth's crust and has the potential for causing a number of actions that may be hazardous. One of the constructions methods that may be able to take into account of earthquake effects in the design considerations is Industrialised Building System (IBS) due to its flexibility at joints and lateral stiffeners at bracing that able to absorb the vibrations. IBS is a building system in which structural components are manufactured in a factory or at site factory and then transported, assembled into a structure with minimal site wet work and erected on the site properly joined to form the final units. Single storey housing was analyzed by using *Multiframe 4D* software in this study. The structural modeling consist of conventional and IBS model. The analyses were carried out with and without seismic loads. The results were interpreted in order to determine the behaviour of each construction method to withstand the design loads and seismic loads.

ABSTRAK

Gempa bumi adalah pergerakan atau gegaran yang terjadi disebabkan berlakunya anjakan pada kerak bumi yang boleh mengakibatkan kemusnahan yang teruk. Salah satu kaedah pembinaan yang boleh mengambil kira kesan daripada gempa bumi dalam rekabentuk pembinaan ialah IBS (*Industrialized Building Systems*) berdasarkan sifat kebolehlenturannya pada sambungan dan boleh menyerap getaran. IBS adalah sistem bangunan di mana komponen-komponen strukturnya dihasilkan di kilang, kemudian diangkut ke tapak pembinaan, dipasang dan disambung menjadi struktur yang lengkap. Kaedah pembinaan ini memerlukan tenaga kerja yang sedikit dan memberikan tapak pembinaan yang bersih. Di dalam kajian ini, rumah satu tingkat dianalisis dengan menggunakan perisian *Multiframe 4D*. Pemodelan terbahagi kepada dua iaitu model IBS dan model konvensional dan analisis dibuat menggunakan dua keadaan iaitu tanpa beban seismik dan apabila beban seismik dikenakan. Keputusan yang diperolehi daripada analisis dikaji bagi mendapatkan sifat kelakuan bagi setiap kaedah pembinaan dalam menanggung beban-beban yang dikenakan.

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f_y	-	Characteristic strength of steel
f_{cu}	-	Characteristic strength of concrete
f_s	-	Estimated design service stress in the tension reinforcement
Es	-	Modulus of elasticity of steel
Ec	-	Modulus of elasticity of concrete
v_c	-	Poisson's ratio of concrete
v_s	-	Poisson's ratio of steel
$?_c$	-	Density of concrete
$?_s$	-	Density of steel
?	-	Rotational at joint
b	-	Width or effective width of the section or flange in the compression zone
x	-	Depth to the neutral axis
As'	-	Area of compression reinforcement
d	-	Effective depth of the tension reinforcement
d'	-	Depth to the compression reinforcement
M	-	Design ultimate moment at the section considered
v	-	Design shear stress

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Earthquakes are one of the most devastating natural disasters on earth. A strong earthquake is a natural disaster which brings sudden fatality, great economic loss and shock to the community [1]. An earthquake is the vibratory movement of the earth's surface that follows a sudden release of energy in the crust [2]. Earthquakes may occur naturally or as a result of human activities. Figure 1.1 shows the location of earthquakes with different magnitude and depth. The point on the ground surface immediately above the initial rupture point is called the epicenter of the earthquake. The quake effects depending on the location of the epicenter. Earthquakes are very difficult to predict. Therefore, the only way to prevent structural damage against seismic loading in earthquake areas is to design and construct the structure for earthquake loading even for low storey buildings.

One of the construction methods that may be able to take into account of earthquake effects in the design considerations is Industrialised Building System (IBS) due to its flexibility at joints and lateral stiffeners at bracing that able to absorb the vibrations. In Malaysia, IBS closed system or precast construction is not a new

construction method [3]. IBS is a system where parts, members, and elements of structures are produced beforehand at the factory and transported to the site of construction [4]. The elements of structures that produced in factory or at site factory such as walls, column, slab, staircase, beam, windows, doors as shown in Figure 1.2.

The Industrialised Building Systems (IBS) is a construction process that utilizes techniques, products, components, or building systems which involve prefabricated components and on-site installation. Industrialization has demonstrated to reduce the costs, improve the quality and get complex products available at high quality of finishing to the vast majority of people [5].

Many world-class Malaysian developers have chosen precast over the conventional methods for important projects such as the Petronas Twin Towers, Putrajaya, KL Sentral and KLIA. But the real component to meet IBS standardization is not available in Malaysia. Other IBS projects around the world are shown in Table 1.1. IBS application can be effectively used with modular coordination concept and standardization. Modular coordination is an international system of dimension standardization in building based on ISO Standards. IBS is the system which covers all types of structures but it is always misinterpreted as systems limited only for the construction of buildings [3].

In this study, single storey housing model is constructed using conventional construction and IBS component. The analysis is carried out by using *Multiframe 4D*. The analysis includes a static and earthquake effects. The profile behaviour between the conventional system and IBS are obtained from the analysis.

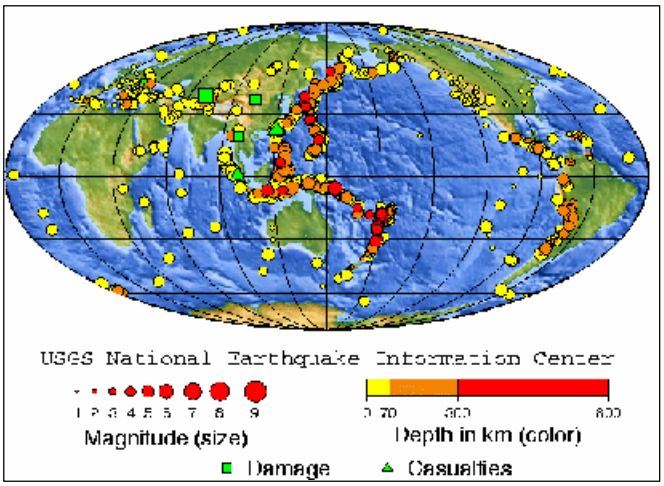

Figure 1.1: Location of Earthquakes

Beam

Staircase

Wall

Slab

Column

Figure 1.2: IBS components

Table 1.1: IBS constructions

IBS constructions	Description
 Serdang Hospital, Malaysia	• It is the first hospital in Malaysia to be built using the hybrid IBS-steel and precast concrete structures. • It is constructed at an elevated site near to the PLUS Highway-Kajang Interchange on the way to Putrajaya.
 Hong Kong Bank, Jakarta	• The first structural high-rise precast concrete building in Indonesia. • All beams, slab soffits, and exterior column claddings were constructed of precast concrete and tied together with an in-situ reinforced concrete topping to integrate all precast elements into a monolithic structural frame.
 Ramon Magsaysay Building Manila, Philippines	• An 18-storey, 15540 square meter office building with composite precast, prestressed concrete floor frame designed for Seismic Zone 3 forces.
 Dalian Xiwang Building Dalian, China	• 43-storey precast concrete office building utilizing precast concrete beams, slabs and exterior architectural cladding designed for high seismic activity.

1.2 Problem Statement

Frequent earth tremor is happening around the world. Earthquakes have the potential for causing a number of actions that may be hazardous. It is possible to damage the buildings in some cases with little warnings. The motion caused by earthquake is the speed and the cyclic nature of the motion. The stress producing forces that are exerted on a building during such motions are affected by the relative stiffness and mass of the building itself. Thus evaluation of the potential damage must include considerations of properties of the buildings, as well as the specific nature of the ground movements. The IBS is capable to inherit the earthquake design. The problem in Malaysia is even the earthquake resistant design is only in manufacturing philosophy and not even the IBS components are designed to resist the seismic loads. Civil engineering is not catering the earthquake analysis for building entirely. The objective of the earthquake analysis in IBS is to inherit the analysis and design of the components and constructions for earthquake event.

1.3 Objective

The objectives of the study focus on achieving a better understanding of the IBS constructions. Specific objectives include:

i. To model a single storey housing constructed by IBS component and conventional construction method and analyzed by using *Multiframe 4D*.
ii. To evaluate the response of the building system under various types of loads (with and without earthquake loads).
iii. To compare the joints rotation between IBS model and conventional model in order to assess the joint stiffeners / flexibility.

iv. To determine capacity of member in order to meet the design standardization.

1.4 Scope of Study

The study includes a review of Industrialized Building Systems and earthquakes process in order to have an understanding of the systems and behaviour of the ground motions. IBS model and conventional model were analyzed by using *Multiframe 4D*. Various natural civil engineering loads were used to define the deformation of each structural component. The behaviour of the components were identified and classified according to their performance.

1.5 Importance of Study

The study is to develop an understanding of the IBS system to ensure a successful upgrading of our construction industry toward the standard of IBS in Malaysia. In other words, to produce the structures that has an adequate earthquake resistant ability. The dependency on foreign workers by the Malaysian construction industry could be reduced by using Industrialised Building Systems (IBS) which does not require much wet trades, and hence, minimal usage of skilled labour is needed [6]. Beside that, IBS also have potential in earthquake damage reduction built-in property for housing. Therefore, Malaysian construction industry is to be persuaded to embed the earthquake design on IBS projects implementation to inherit earthquake design.

CHAPTER 2

LITERATURE REVIEW - IBS

2.1 Industrialized building system (IBS)

Building systems in which structural components such as floors, walls, columns, beams, and roofs are manufactured in a factory or at site factory. They are then transported and assembled into a structure with minimal site wet work and erected on the site properly joined to form the final units [7]. It joints behaviour as semi rigid type of connection and the associated panels may contribute as dampers absorbing vibration and earthquake movement. The system produced under the stringent factory quality control.

The industrialization of building is most effective when as many possible of the building components are prefabricated in a plant with appropriate equipment and efficient technological and managerial methods. Comprehensive prefabricated elements that are produced in the plant considerably reduce both the amount of work onsite and dependence on the skill of available labour, on the weather, and on various local constraints. In order to realize these benefits, it is necessary to educate architects and engineers in a system approach that integrates design, technology, management, economics and marketing of industrialized building. The main

attributes to industrialization are centralization of production, large volume, standardization of products, specialization of workers, efficient organization of production and distribution, and unified authority over all stages of the process.

2.2 Types of IBS

There are five main groups identified as being used in Malaysia [3], which are:

Type 1: Precast Concrete Framing, Panel and Box Systems – includes precast concrete columns, beams, slabs, walls, "3-D" components, permanent concrete formworks, etc. (Figure 2.1)

Figure 2.1: Precast Concrete Framing, Panel and Box Systems

Type 2: Steel Formwork Systems – includes tunnel forms, tilt-up systems, beams and columns moulding forms, and permanent steel formworks. (Figure 2.2)

Figure 2.2: Steel Formwork Systems

Type 3: Steel Framing Systems – steel beams and columns, portal frame systems, roof trusses, etc. (Figure 2.3)

Figure 2.3: Steel Framing Systems

Type 4: Prefabricated Timber Framing Systems – prefabricated timber trusses, beam and columns, roof trusses, etc. (Figure 2.4)

Figure 2.4: Prefabricated Timber Framing Systems

Type 5: Block work Systems – includes interlocking concrete masonry units and lightweight concrete blocks. (Figure 2.5)


Figure 2.5: Block work Systems

2.3 Characteristic of IBS

There are several characteristics of IBS as below [3]. The characteristics are important to ensure the achievement of the proven benefit of IBS.

1. Industrial production of components through prefabrication or highly mechanized in-situ process.
2. Reduced labour during prefabrication of components and site works.
3. Modern design and manufacturing methods involving Information Technology.
4. Systematic Quality Control.
5. Open Building Concept.
6. Follow exactly the IBS Malaysian Standard.