DYNAMIC BEHAVIOUR OF LONG SPAN CANTILEVER STEEL-CONCRETE COMPOSITE FLOOR

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DEDICATION

To my lovely parents, who gave me endless love, trust, constant encouragement over the years, and for their prayers.
To my spouse, for being very understanding and supportive in keeping me going, enduring the ups and downs during the completion of this project report.
To my only daughter and son, for them who sacrifice so much for me not being in their important events during my project report completion.
To my family, for their patience, support, love and prayers
This project report is dedicated to them.

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ABSTRACT

Vibration and deflection are two main parameters that always govern the constructability of long span cantilever slab. This paper present the dynamic behavior of a 12.5m long span cantilever steel-concrete composite floor of an actual new proposed construction project. STAAD PRO software was used to analyze the structure subjected to both static and the dynamic loading. From the preliminary analysis using static loading, it was found that the original proposed structural configuration does not pass the deflection limit and is not constructable due to requirement for too big steel section not readily available in market. Consequently, modification to shorten the cantilever length to 6m is introduced and finally makes the structure possible to be build using a ready size of steel beams that are available in Malaysian market. In the detail dynamic analysis, excitation of dynamic loadings similar to human activity at a few random locations is applied to produced various mode shape. Results from the dynamic analysis gives acceleration on adjacent panels. The acceleration vs time graph is then used to calculate the critical natural frequency of the adjacent panels. This value of natural frequency then used to determine the range of recommended peak acceleration using the graph introduced by AISC Design Guide No. 11. It is found that the natural frequencies of the adjacent floor are in the range of 4 – 7 Hz, which is considered a low frequency floors. With the combination of low acceleration and low natural frequencies, it makes the modified floor which the new length is 6m still not comfortable to be used. Therefore, recommendation to thicken the concrete slab is proposed to increase the natural frequency of the floor, so that a comfortable construction is obtained.

ABSTRAK

Gegaran dan pesongan merupakan dua perkara penting yang mempengaruhi pembinaan lantai komposit julur yang sangat panjang. Kertas kerja ini menerangkan kelakuan dinamik lantai komposit keluli-konkrit julur sepanjang 12.5m, yang merupakan sebahagian daripada cadangan pembinaan projek baru yang sebenar. Perisian STAAD PRO digunakan untuk menganalisis struktur yang dikenakan beban statik dan juga beban dinamik. Daripada analisis awalan menggunakan beban statik, didapati bahawa konfigurasi asal struktur yang dicadangkan menunjukkan kegagalan pematuhan had pesongan dan tidak membolehkan untuk dibina kerana memerlukan saiz rasuk keluli yang terlalu besar dan memerlukan tempahan khas. Dengan sebab itu, ubahsuai memendekkan panjang julur rasuk kepada 6m dibuat dan akhirnya membuatkan struktur boleh dibina menggunakan saiz rasuk keluli yang sedia ada dalam pasaran Malaysia. Dalam analisis terperinci, pengenaan beban dinamik yang menyerupai aktiviti manusia di beberapa lokasi yang dipilih secara rawak menghasilkan pelbagai bentuk mod. Keputusan daripada analisis dinamik memberikan pecutan di lantai berdekatan. Graf pecutan melawan masa yang diperolehi daripada output perisian digunakan untuk mengira frekuensi semulajadi lantai kritikal yang berdekatan. Nilai frekuensi semulajadi pula akan digunakan untuk menentukan had pecutan puncak yang paling ideal, yang diperkenalkan oleh AISC Design Guide No.11. Adalah didapati bahawa frekuensi semulajadi lantai berdekatan berada antara 4 – 7 Hz, yang mana ianya adalah rendah. Kombinasi pecutan dan frekuensi semulajadi yang rendah membuatkan lantai masih tidak selesa untuk digunakan. Oleh itu, pengesyoran dibuat untuk menebalkan lantai konkrit bagi meningkatkan frekuensi semulajadi lantai supaya struktur yang lebih selesa dapat dibina.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

CHAPTER 1

INTRODUCTION

A steel-concrete composite structure is becoming a popular selection of structural system nowadays. This kind of structures is increasingly used to build modern landmarks of urban areas. The selection of this composite combination normally is due to its fast construction and lightweight. It is also obviously chosen due to its tensile-compression ideal combined capacity, where the steel has a very good tensile strength capacity, and the concrete is very good in compression strength capacity.

The capacity of resisting higher tension force gives an extra mile for the engineer to use the steel as a beam for designing longer span of a steel beam. While for the concrete, it is suitable to be paired with the steel beam to construct an economical composite concrete slab to resist the compression force at the top middle of the slab span. This steel-concrete composite combination makes an engineer's life easier to take the challenge of architecture's innovative and award winning designs these days.

1.1 Background of Problem

A cantilever floor is an attractive and more popular in an architect's modern design nowadays, including the Malaysian architects recently. The designs were often impressive and eye-catching to the people surroundings. To make the design possible to be build, engineers will normally choose a composite steel-concrete structures system to build the cantilever floor.

A direct consequence of this design trend is the floor become too slender and that their design is usually not controlled by ultimate limit states but by serviceability criteria, such as a considerable increase in problems related to unwanted composite floor vibration. A vibration is usually even more critical in a long span slab or long span cantilever slab. The longer the cantilever floor, the more sensitive the floor to a vibration problem.

1.2 Problem Statement

Floor vibration has become a high-profile research chosen by many researchers (Brownjohn and Middleton, 2008). The research topics were so wide that covers almost everything that related to a floor vibration from the procedure for predicting the floor vibrations, experimental work and computer modelling to study dynamic vibration behavior and control of vibrations. Many studies on vibrations of long span composite floor decks were reported (Varela and Battista, 2011; Mohamed Fahmy and Sidky, 2012; Silva et.al, 2014; An et.al, 2016). However, none of them studied or even discuss the vibration on a long span cantilever composite floor. This lead to this research objectives that will focus on the dynamic behavior of the long span cantilever steel-concrete composite floor.

1.3 Objectives

The objectives of this study are:

a. To model, analyze and design a 12.5m long cantilever steel-concrete composite floor of an actual proposed new office building subjected to static loading.

b. To reanalyze the structure considering human excitation/activities to obtain dynamic behavior of the floor, namely natural frequency and maximum acceleration.

c. To determine whether the present design of cantilever floor is meeting the acceleration limit due to vibration as specified by guideline.

d. To propose a strengthening method to the floor slabs so that it meets the recommendation peak vibration acceleration limit as specified in the guideline.

1.4 Scope of Work

This study is to investigate the vibration of a floor of a real steel-concrete composite cantilever floor spanning at 12.5m length as proposed by design architect. In this investigation, STAAD PRO software was used to perform the finite element analysis to get the structure's vibration acceleration and to calculate the natural frequency of the structure due to human activity. From the vibration acceleration, level of vibration will be determined and compared with the acceptable limit. Acceleration due to vibration might also be reduced by introducing various tie members for strengthening the slab system so that the cantilever floor possible to be build.

A few assumptions were made in this study to limit the component size of the structures, location of the dynamic loading excitations and the maximum deflection allowed. As for the steel beam size, it is limited to the size of UB914x419, which the maximum readily size available at most Malaysian steel supplier. As for the reinforced concrete column, it is limited to size of 1000mm x 500mm, which normally considered among biggest column in reinforced concrete building industries. As for the vertical deflection limit, Table 8 in the document of BS5950-1:2000 were used as a guidance to limit the allowable displacement.

As for the dynamic loading, a time history from Brownjohn et.al (2008) was adopted. The chosen time history is almost equals to the mean body weight of Malaysian aged 18-59 years, 62.65kg (Azmi et.al, 2009). The location of the dynamic loading excitation randomly chooses at 3 locations 4m interval starting from the last beam that supported by the last column to the end of the cantilever floor. At every location, five (5) points at intervals of 2.5m were selected as the excitation points.

1.5 Significance of Research

Since this is a real project, it is expected to get the most economic universal steel beam size that is constructable using available size of universal steel beam in Malaysia. If the size of the beam is too huge, a tie members is expected to be introduced, so that the floor maintained its cantilever effect at a shorter span. So, this study will be use as a reference for engineers to advise their architects for future projects in estimating the economical span of cantilever floor.

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