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ANALYSIS OF POUNDING BETWEEN TWO BUILDINGS DURING AN EARTHQUAKE

By

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CONTENTS

CHAPTER 3: PARAMETRIC STUDY ON POUNDING PROBLEM

CHAPTER 4: EFFECT OF GAP SIZE ON STRUCTURAL POUNDING

CHAPTER 5: EVALUATION OF CODES PROVISIONS TO AVOID STRUCTURAL POUNDING

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ABSTRACT

Structural pounding refers to the lateral collisions of adjacent buildings. Pounding occurs when building separations are insufficient to accommodate the relative motion of adjacent buildings. Review of past earthquake damage shows that pounding of adjacent buildings during earthquakes is a frequent phenomenon and an important cause of damage and in some cases it has led to collapse .

A formation and solution of the multi-degree-of-freedom equation of motion for pounding between two multistory buildings is presented. A numerical study of the parameters affecting the pounding between adjacent reinforced concrete multistory buildings has been carried out. A dynamic analysis has been utilized to investigate the pounding behavior of various combinations of adjacent reinforced concrete building structures subjected to ground accelerograms. Five examples of pounding problem have been considered in this study. Each example consists of a couple of two reinforced concrete buildings of different heights. These examples included seven different reinforced concrete building structures modeled as Ductile Moment-Resisting Frames, Dual System, Shear Wall System and Coupled Shear Wall system. The parameters studied have included variation of building heights, masses and stiffnesses and contact elastic spring stiffness. The effect of gap size on the pounding between adjacent reinforced concrete buildings during strong earthquakes has been also studied. The requirements for gap size of the Uniform Building Code (UBC-94), the Eurocode 8 (EC-8) and the Egyptian code for loads (ECL- 93) have been evaluated.

An artificial earthquake time history suitable for Egypt was generated and used to evaluate the requirements of ECL-93 for gap size. This artificial earthquake has a peak ground acceleration of 0.3g and a duration of 20 seconds and was chosen to represent the "probable design level" earthquakes for zone 3 in Egypt. This artificial earthquake can be considered "Moderate Earthquake" as required by the ECL-93.

The results of this study showed that pounding can be more severe load condition than the case of vibration without pounding. Therefore, neglecting the effects of possible pounding may lead to unsafe building design. The gap size of 2.0 cm required by the ECL-93 is seriously insufficient for the five examples analyzed in this study. Providing the gap size depending on the absolute sum (ABS) or the square root of sum of squares (SRSS) combinations of the peak displacements of the two buildings at the possible pounding level showed to be very conservative.

New simple empirical equations for calculating the minimum gap size between two adjacent buildings for the different seismic zones in Egypt have been proposed.

CHAPTER 1

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INTRODUCTION

1.1 GENERAL

In most cities of the world, specially in their centers, buildings are often constructed next to each other with no or small separation between them to minimize the waste of the high price land. When such closely spaced buildings have different dynamic characteristics as a result of a difference in height, mass, stiffness of structural elements and geometric properties, they will usually move out of phase during an earthquake. If the gap between such buildings is not adequate, they are likely to collide during an earthquake. Such collision is commonly referred to as "structural pounding". For each collision occurs, the buildings are subjected to short lateral impact forces not specifically accounted for in the conventional design process. These impact forces produce high amplitude, short-duration local accelerations, which could induce damage to structural members or mechanical and electrical components of the buildings. Furthermore, the overall dynamic response of the buildings can be amplified by earthquake pounding.

Many incidents of seismic pounding have been reported in past earthquakes [5,15,26,28,29,32]. Pounding of adjacent buildings has made damage worse, and may have caused total collapse of the buildings. The earthquake that struck Mexico City in 1985 has revealed the fact that pounding was present in more than 40% of 330 collapsed or severely damaged buildings surveyed, and in 15% of all cases it led to collapse [5]. This illustrates the significant seismic hazard of pounding by the large number of buildings damaged by pounding effect during a single earthquake. The 1989 Loma Prieta earthquake caused pounding between buildings over a wide geographical area including the cities of San Francisco, Oakland, Santa Cruz and Watsonville, where more than 200 cases of pounding were reported. Significant pounding was observed at sites over 90 Km from the epicenter thus indicating the possible catastrophic damage that may occur during future earthquakes having closer epicenters [26].