UNIVERSITI PUTRA MALAYSIA

POUNDING BETWEEN ADJACENT BUILDINGS IN CONSIDERATION OF SOIL STRUCTURE INTERACTION

SADEGH NASERKHAKI

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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POUNDING BETWEEN ADJACENT BUILDINGS IN CONSIDERATION OF SOIL STRUCTURE INTERACTION

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Chair: Farah Nora Aznieta Binti Abdul Aziz, PhD

Faculty: Engineering

Earthquake is known as one of the most devastating natural disasters to human and their environment that causes catastrophic failure of their life and belongings particularly buildings. The main cause of numerous building failures is collision of adjacent buildings during the earthquake which is called building pounding. It occurs when the separation gap between adjacent buildings is less than minimum distant required for them to vibrate freely. As consequence of building pounding, seismic responses of buildings are altered and in some occasions it produces larger forces and displacements than the design limits which causes building damage.

The aim of this research project is to numerically investigate seismic responses of two adjacent buildings due to earthquake induced building pounding. As the buildings are usually constructed on the soil; interaction between building and soil and further interaction between two buildings through the soil are considered in this

research project. Other parameters affecting building pounding such as separation gap, dynamic property of building and earthquake excitation are studied too.

In order to achieve the aim of this research project, a new analytical model of building pounding considering soil effect is developed. The proposed model consists of two adjacent shear buildings connected with linear visco-elastic contact force model during pounding constructed on a homogenous half-space soil. This model is then implemented into a computer program and calibrated and validated. It is found that the proposed model is efficient and accurate to evaluate seismic responses of buildings with soil effect considerations due to building pounding.

A comprehensive number of analyses are then performed and results are explained and interpreted graphically in terms of building displacement and story shear. When a tall and flexible building is pounded to an adjacent short and stiff building, displacements of tall and flexible building are reduced but displacements of short and stiff building are increased. Considering soil effect (structure-soil-structure interaction, SSSI), produced displacements in both buildings due to pounding are greater than fixed-based (FB) buildings. On the other hand, building pounding causes increment of story shears of both buildings and this increment is pronounced if SSSI condition is considered. In conclusion, building pounding worsens buildings conditions and underlying soil amplifies this detrimental effect.

Further analyses are performed to clarify effects of separation gap, dynamic property of building and earthquake excitation in building pounding. Separation gap between two adjacent buildings is found to be very critical. Number of collisions and intensity

of pounding forces are increased due to reduction of separation gap. Therefore, wider separation gap is necessary to prevent building pounding when the soil is considered, particularly if the soil is soft. In addition, evaluation of variation of buildings dynamic properties (building height) indicates more intense building pounding for tall and flexible building when the period ratio of the buildings is about half. While for short and stiff building, the most critical condition is referred to the least period ratio. Finally, the results show that each earthquake produces unique effect for different buildings and underlying soils. Thus seismic responses of adjacent buildings due to earthquake induced pounding should be analyzed in case by case basis and soil effects, particularly soft soils must be taken into consideration.

Abstract tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

GETARAN DIANTARA BANGUNAN BERSEBELAHAN DENGAN MENGAMBILKIRA KESAN INTERAKSI STRUKTUR DAN TANAH

Oleh

SADEGH NASERKHAKI

November 2011

Pengerusi: Farah Nora Aznieta Binti Abdul Aziz, PhD

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Gempa bumi merupakan salah satu kejadian yang paling dahsyat kepada manusia dan alam sekitar yang boleh mengakibatkan kesan kegagalan katastopik keatas kehidupan dan harta benda manusia terutamanya bangunan. Punca utama kerosakan bangunan semasa gempa bumi adalah disebabkan oleh pelanggaran diantara dua bangunan yang bersebelahan, ini dinamakan getaran bangunan. Ianya berlaku apabila jurang pemisahan antara bangunan bersebelahan adalah kurang daripada jarak minimum yang diperlukan bagi bangunan bergegar bebas.Akibat dari getaran bangunan, tindakbalas seismik bangunan akan berubah dan dalam sesetengah keadaaniaakanmenghasilkan daya dan anjakan yang melebihi had reka bentuk yang dibenarkan dan mengakibatkan kerosakan bangunan.

Matlamat projek penyelidikan ini adalah untuk menjalankan penyiasatan berangka kesan seismik terhadap dua bangunan bersebelahan yang disebabkan oleh gempa bumi yang mengakibatkan getaran bangunan. Oleh kerana kebiasaannya bangunan dibina di atas tanah; interaksi antara bangunan dan tanah dan seterusnya interaksi di

antara dua bangunan dan tanah dipertimbangkan dalam projek penyelidikan ini. Parameter lain yang mempengaruhi getaran bangunan adalah seperti jurang pemisahan, keadaan dinamik bangunan dan ujaan gempa bumi turut dikaji.

Bagi mencapai matlamat projek penyelidikan ini, satu model analitikbaru bagi bangunan bergetar dengan mengambil kira kesantanah telah dibangunkan. Model yang dicadangkan terdiri daripada dua bangunan ricih bersebelahan yang disambungkan dengan model kontekdaya linear visco-anjal semasa getaran yang dibina diatas tanah ruang-separa yang homogeneus. Model ini kemudiannya dilaksanakan melalui program komputer dan ditentukur dan disahkan. Didapati model yang dicadangkan adalah model yang cekap dan tepat untuk menilai kesan seismik pada bangunan dengan mengambilkira kesan tanah akibat dari getaran bangunan.

Beberapa analisis yang komprehensif telah dilaksanakan dan keputusannya dijelaskan dan ditafsirkan secara grafik dari segi anjakan bangunan dan tingkat ricih. Apabila bangunan tinggi dan flexibel digetarkan bersebelahan dengan bangunan rendah dan kaku, anjakan bangunan tinggi dan flexibel berkurangan tetapi anjakan bangunan rendah dan kaku akan meningkat. Apabila kesan tanah (struktur-tanah-struktur interaksi, SSSI) dipertimbangkan, anjakan yang dihasilkan oleh kedua-dua jenis bangunan akibat getaran bangunan adalah lebih besar daripada bangunan berasaskan tetap (FB). Sebaliknya, getaran bangunan menyebabkan peningkatan tingkat ricih bagi kedua-dua bangunan dan ia sangat ketara apabila SSSI diambil kira. Sebagai kesimpulannya, getaran bangunan menyebabkan keadaan bangunan

menjadi lebih teruk dan apabila dasar tanah diambilkira, ia meningkatkan lagi kesan bahaya ini.

Analisis selanjutnya telah dilaksanakan untuk mengenalpasti kesan jurang pemisahan, keadaan dinamik bangunan dan ujaan gempa bumi terhadap getaran bangunan. Jurang pemisahan di antara dua bangunan bersebelahan merupakan faktor yang sangat kritikal. Bilangan pelanggaran dan intensiti daya getaran meningkat dengan pengurangan jurang pemisahan. Oleh yang demikian, jurang pemisahan yang lebih luas adalah diperlukan untuk mencegah getaran bangunan apabila tanah diambil kira, terutamanya jika tanah lembut. Tambahan pula, penilaian perubahan sifat dinamik bangunan (ketinggian bangunan) menunjukkan getaran bangunan lebih hebat bagi bangunan tinggi dan fleksibelapabila nisbah tempoh bangunan adalah kira-kira setengah.Manakala, bagi bangunan yang rendah dan kaku, keadaan paling kritikal dirujuk kepada nisbah tempoh terkecil. Selain itu, keputusan menunjukkan bahawa setiap gempa bumi menghasilkan kesan yang unik bagi konfigurasi bangunan dan tanah yang berbeza-beza. Oleh kerana itu, kesan seismik bagi bangunan bersebelahan disebabkan oleh gempa bumi, bangunan perlu dianalisis secara kes demi kes dan kesan tanah, khususnya tanah lembut, mesti diambil kira.

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I certify that a Thesis Examination Committee has met on 10 November 2011 to conduct the final examination of Sadegh Naserkhaki on his thesis entitled "Pounding between Adjacent Buildings in Consideration of Soil Structure Interaction" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of Supervisory Committee were as follows:

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DECLARATION

I declare that this thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not currently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

SADEGH NASERKHAKI

Date: 10.11.2011

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