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PRECAST CONCRETE SANDWICH PANEL AS A BUILDING SYSTEM

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Precast Concrete Sandwich Panels (PCSP) that act as load bearing elements are structurally and thermally efficient building elements with potential for use as an Industrialised Building System (IBS).

The study aims to investigate all issues related to structural performance of PCSP. The strength characteristics of PCSP under imposed loads with both wythes being structural wythes were established and the condition for achieving composite behaviour was examined. Although it is possible to use any conventional flooring system with the use of PCSP as walling elements, the structural behaviour of PCSP under lateral load was also studied so that PCSP can be adopted as flooring elements. This helps to reduce the number of different types of elements necessary in a building. A study on typical connections between PCSP elements was also undertaken.

Under axial and eccentric loads, an experimental program consisting of twelve specimens with different heights was carried out. The theoretical investigation consists of two theoretical formulations namely, classical expressions and Finite

Element Method (FEM). Comparison between non-linear FEM proposed models and experimental data was made in order to validate the models.

An FEM parametric study was carried out by varying two important parameters i.e. the effect of slenderness (height-to-thickness ratio, H/t) and the stiffness of the shear connectors as measured by the bar diameter. The ultimate strength of the PCSP was found comparable to the strength expected for full composite panels. It achieved a high composite behaviour at service and acted in partially composite manner at ultimate stage. A study on the effect of opening in the form of doors and windows in the sandwich panels was also undertaken. It was found that the ultimate load of the PCSP decreases with increase in slenderness ratio (H/t). Simplified design formulae to determine the ultimate strength of PCSP under axial and eccentric loads were proposed to closely match the strength values.

The FEM investigation was extended to explore the feasibility of usage of PCSP as slab. Two non-linear FEM models (2-D and 3-D models) were used to simulate the behaviour of PCSP as one-way and two-way acting slabs respectively. The non-linear FEM models were validated by experimental data. Parameters such as shear connector numbers and applied loading influencing the ultimate strength and the compositeness of the PCSP working as slab were investigated. A method for the determination of the interface shear force and the design of shear connectors was proposed. The results as obtained experimentally indicated that the classical elastic theory assuming fully composite action and non-linear FEM models were reasonably accurate in predicting ultimate loads and lateral deflections.

The behaviour of typical vertical connections between two precast concrete sandwich panels under shear and bending using FEM was carried out. FEM results were found to be in good correlation with experimental values. Ultimate strength,

ductility of the connection, strain in anchor steel bars, strains variations across the critical zone together with cracking patterns and mode of failure were studied. The proposed FEM model predicted with an acceptable accuracy the general behaviour of the connections under moment and shear forces. On the basis of this investigation, connection reinforcement details were recommended.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PANEL SANDWIC KONKRIT PASANG DAHULU SEBAGAI SISTEM BINAAN

Oleh

BENAYOUNE ABDELGHANI

Mac 2003

Pengerusi: **Profesor Abang Abdullah Abang Ali**

Fakulti: **Kejuruteraan**

Panel Dinding Sandwic Konkrit Pasang Dahulu (PCSP) galas beban adalah elemen yang mempunyai ciri-ciri struktur yang kukuh dan penebat haba yang berkesan. Panel PCSP juga berpotensi untuk di jadikan sebagai salah satu Sistem Binaan Industri (IBS) yang ekonomi.

Objective utama penyelidikan ini adalah bertujuan untuk mewujudkan panel sandwic galas beban yang berpotensi sebagai salah sebuah sistem binaan yang terunggul. Penyelidikan bertujuan untuk mengenalpasti segala isu yang berkaitan dengan sifat-sifat kejuruteraan struktur PCSP. Dengan itu, ciri-ciri kekuatan PCSP akibat beban kenaan terhadap dinding tersebut dapat di kenalpasti dan sifat rencam dinding sandwic panel dapat di selidiki dengan lanjut. Untuk mengurangkan bilangan elemen yang di perlukan dalam sistem binaan tersebut, panel PCSP juga telah di uji sebagai sistem papak. Dengan itu, ujian terhadap panel PCSP dengan di kenakan beban sisi telah di jalankan. Penyelidikan terhadap sistem sambungan antara elemen-elemen PCSP juga telah di kaji.

Program ujikaji terhadap dua belas panel yang di kenakan beban paksi dan beban sipi serta ketinggian panel yang berbeza di jalan kan. Sifat kelangsingan dan kesipian beban terhadap kekuatan panel telah di kaji. Kajian melalui teori secara lazim dan secara kaedah unsur terhingga (FEM) telah di laksanakan. Untuk mengesahkan model tak lelurus FEM yang di cadangkan, perbandingan antara data-data ujikaji telah di lakukan.

Kajian berparameter melalui FEM telah di jalankan dengan mengubahsuai dua parameter penting iaitu kesan kelangsingan (nisbah tinggi ke tebal, H/t) dan keukuhan penyambung ricihan melalui perubahan garispusat bar. Melalui kajian ini, di dapati bahawa kekuatan muktamad PCSP mempunyai nilai yang menghampiri kepada panel yang bercirikan rencam penuh. Kajian terhadap panel dengan pembukaan saperti tingkap dan pintu juga telah di jalankan. Dalam kajian itu, di dapati bahawa kekuatan mukatamad panel menurun dengan bertambahnya nisbah kelangsingan (H/t). Dari itu, persamaan rekabentuk dapat dihasilkan untuk memberikan nilai kekuatan muktamad PCSP akibat beban paksi dan beban sipi.

Kajian FEM telah di perluaskan terhadap PCSP sebagai sistem papak. Dua FEM model tak lelurus (model 2-D dan 3-D) telah di cadangkan untuk mengkaji sifat-sifat papak satu-hala dan dua hala. Model FEM tak lelurus tersebut telah di perbandingkan dan di sahkan dengan data-data ujikaji. Parameter saperti bilangan penyambung ricihan dan beban kenaan yang mempengaruhi kekuatan muktamad dan kerencaman PCSP sebagai papak telah di kaji. Satu kaedah untuk menentukan daya ricih di antara muka papak dan rekabentuk penyambung ricihan telah dapat di cadangkan. Keputusan kajian menunjukkan bahawa teori kenyal secara lazim dan model FEM tak lelurus adalah memuaskan dalam meramal beban muktamad dan pesongan sisi.

Kajian terhadap sambungan menegak antara dua panel sandwic konkrit pasang dahulu terhadap daya ricih dan momen lentur telah di jalankan dengan menggunakan model FEM. Keputusan model FEM menunjukkan nilai yang setanding dengan ujikaji. Kekuatan muktamad, kemuluran sambungan, keterikan pada bar pengikat, perubahan keterikan pada zon kritikal serta corak retakan dan ragam kegagalan telah di bentangkan. Model FEM yang dicadangkan telah memberi ramalan keputusan yang memuaskan terhadap sambungan yang di kenakan daya ricih dan momen lentur. Hasil dari kajian ini, tetulang untuk sambungan tersebut dapat di syorkan.

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