

FINITE ELEMENT MODELING AND
PROBABILISTIC ANALYSIS OF PRESTRESSED
INVERTED T-BEAM WITH WEB OPENINGS

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MASTER OF ENGINEERING (CIVIL)

UNIVERSITI MALAYSIA PAHANG

FINITE ELEMENT MODELING AND PROBABILISTIC ANALYSIS OF
PRESTRESSED INVERTED T-BEAM WITH WEB OPENINGS

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SUPERVISORS' DECLARATION

I hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Civil Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for the quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for the award of any other degree.

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ABSTRACT

Recent trends of structural mechanics applications in finite element analysis demonstrate an increasing demand for efficient analysis tools. This thesis presents a probabilistic analysis approach applied in finite element analysis for modelling prestressed inverted T-beams with web openings structure used in building service system (mechanical, electrical, communications, and plumbing). Prestressed concrete structures are commonly designed to satisfy criteria of serviceability and safety. In order to ensure the serviceability requirement it is necessary to predict the response of these structures under service loads. However, calculation of deflections of prestressed concrete structures is complicated by several factors, including shrinkage and creep of concrete, relaxation of prestressing reinforcement and cracking. Due to the inherent uncertainties in nature, it is difficult to determine the related parameters precisely. Material and geometric properties of the cracked prestressed concrete structure and load systems possess different degrees of uncertainties. Uncertainties of material properties could arise because of limited site investigations and limited material laboratory test and in accurate formula for correlating various material parameters. Uncertainties of geometric properties could be due to variations during fabrication and erection of the structure. The experimental program reported in this study was in the literature review about four prestressed inverted T-beams with circular web openings tested to failure to evaluate the openings' effect on various beam behaviours. Using ANSYS, finite element models were developed to simulate beam deflection behaviour. Comparison of analytical results with the available experimental results for load-deflection relationships showed good agreement between both results. Probabilistic analysis methodology could predict the response (i.e. deflection, stress, strain etc) due to various combination of input variables (i.e. opening radius, Poisson's ratio, modulus of elasticity, etc). Probabilistic methodology applied in finite element analysis provides an alternative ways to structural analysis of prestressed inverted T-beams with web openings to achieve a robust and reliable design in a more efficient way. In this thesis, Monte Carlo simulation and Latin Hypercube simulation (LHS) was used to analyze the effect of parameter uncertainty for the prestressed inverted T-beams with web openings. From the analysis results, it was observed that the changes in prestressing force, ultimate tensile strength of prestressing steel, elastic modulus of prestressing steel and beam width tend to be the most influencing parameters, which need to be tightly controlled. As a result, from deterministic analysis and probabilistic analysis, it was found that probabilistic analysis tends to be closer to reality than deterministic methods and gives a way of designing for quality.

ABSTRAK

Trend terkini aplikasi mekanik struktur dalam analisis unsur terhingga menunjukkan peningkatan permintaan terhadap peralatan analisis yang cekap. Tesis ini membentangkan pendekatan analisis kebarangkalian yang digunakan dalam analisis unsur terhingga bagi pemodelan prategasan T-rasuk terbalik dengan struktur pembukaan web yang digunakan dalam pembinaan sistem perkhidmatan (mekanikal, elektrik, komunikasi, dan paip). Struktur konkrit prategasan biasanya direka untuk memenuhi kriteria kebolehhidmatan dan keselamatan. Dalam usaha untuk memastikan keperluan kebolehhidmatan adalah perlu untuk meramalkan sambutan ini struktur di bawah beban khidmat. Walau bagaimanapun, pengiraan pesongan struktur konkrit prategasan adalah rumit oleh beberapa faktor, termasuk pengecutan dan rayapan konkrit, kelonggaran prategasan tetulang dan keretakan. Disebabkan ketidaktentuan yang wujud dalam alam, ia adalah sukar untuk menentukan parameter yang berkaitan dengan tepat. Sifat bahan dan geometri struktur retak konkrit prategasan dan beban sistem mempunyai darjah berbeza ketidaktentuan. Ketidaktentuan sifat bahan boleh timbul kerana siasatan tapak terhad dan ujian makmal bahan terhad dan dalam formula yang tepat untuk menghubungkan pelbagai parameter bahan. Ketidaktentuan sifat geometri mungkin disebabkan kepada variasi semasa fabrikasi dan pendirian struktur. Menggunakan program pemodelan ANSYS, model unsur terhingga telah dibangunkan untuk mensimulasikan tingkah laku pesongan rasuk. Perbandingan keputusan analisis dengan keputusan ujian makmal dalam kajian ilmiah untuk hubungan beban-pesongan menunjukkan perjanjian yang baik antara kedua-dua keputusan. Metodologi analisis kebarangkalian yang dapat meramalkan tindak balas (iaitu pesongan, tegasan, terikan dan lain-lain) disebabkan oleh kombinasi pelbagai pemboleh ubah (iaitu pembukaan jejari, nisbah Poisson, modulus keanjalan, dan lain-lain). Kaedah kebarangkalian yang digunakan dalam analisis unsur terhingga menyediakan satu lagi cara alternatif analisis struktur pra-tegasan T-rasuk terbalik dengan bukaan web untuk mencapai reka bentuk tegap dan boleh dipercayai dengan cara yang lebih cekap. Dalam karya ini, simulasi Monte Carlo dan Latin Simulasi Hypercube telah digunakan untuk menganalisis kesan yang tidak menentu parameter bagi prategasan T-rasuk terbalik dengan bukaan web. Daripada keputusan analisis, dapat diperhatikan bahawa perubahan daya prategasan, kekuatan tegangan muktamad keluli prategasan, modulus elastik keluli prategasan dan lebar rasuk cenderung menjadi faktor yang paling mempengaruhi parameter, yang perlu dikawal ketat. Hasil daripada kajian ini, perbandingan antara analisis berketentuan dan analisis kebarangkalian, didapati bahawa analisis kebarangkalian cenderung untuk menjadi lebih dekat dengan keadaan sebenar berbanding kaedah berketentuan dan memberikan cara mereka- bentuk untuk kualiti.

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