DYNAMIC RESPONSES OF PLATES AND SLABS DUE TO IMPACT LOADS

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ABSTRACT

Impact phenomenon is a multidisciplinary subject and is of interest for all engineering, physics, aerospace, space, defense, building and auto industries. The present study involves analysis, experimentation using LabVIEW and Finite Element Method (FEM) simulation using Abaqus software for structural members such as beams and slabs. During the service life of the structure, the structural members might be subjected to impact loads. In order to develop a protective structure that is capable of withstanding the potential percussion, the relevant impact engineering studies are stimulated. Plates and slabs are the major elements of most of the structures. Steel plates are commonly used in manufacturing and have high potential to competently resist the impact load. Also reinforced concrete (RC) slab is widely used in the construction industry. Thus, the dynamic responses of the steel plates and RC slabs due to impact load were investigated in this study. The conventional analytical method, Hertz's contact theory, Navier's solution and Levy's solution were reviewed and formulated for analysing the impact responses of steel plates and RC slabs. Hammer drop test is the usual approach that is conducted to examine the impact responses of steel plates and RC slabs. The finite element professional software package Abaqus version 6.12 was used to model and simulate the response of the steel plate and RC slab in the aforementioned experiments. Since the response of plates and slabs depends on the material properties, mode of impact, the transmitted impact forces, aspect ratio of the specimens, span and boundary conditions, experiments were conducted on 58 steel plate models and 24 RC slab models with various hammer heights, specimen aspect ratios, support spans and support conditions. The experimental responses of the steel plates and RC slabs in the hammer drop test were evaluated with a data acquisition system that consists of data acquisition and analysis hardware (National Instruments USB-6281 multifunction DAQ card), two units of 4-channel ICP @ sensor signal conditioner, six numbers of model 350303 PCB piezoelectric accelerometers and an application software (National Instrument LabVIEW software). These responses were also computed using Levy's solution and modelled with Abaqus simulation. The results of the experimental studies agree well with the analytical values as well as the FEM responses obtained using Abaqus simulation, thus validating the results. Using this validation and appropriate calibration, the virtual hammer drop test is developed using Abaqus software. It is highly potent to predict the impact responses of plates and slabs accurately. Thus, the concept of this virtual impact test can be further extended for general studies involving structures of general shape, size, impact energy, direction and mode of impact. This can be particularly useful to conduct virtual tests in situations where experimental tests are either not feasible or not economical to be carried out.

ABSTRAK

DYNAMIC RESPONSES OF PLATES AND SLABS DUE TO IMPACT LOADS

Fenomena impak adalah multidisiplin subjek dan penting dalam semua bidang kejuruteraan, fizik, aeroangkasa, ruang, pertahanan, industri pembinaan dan auto. Kajian ini melibatkan analisis, eksperimen menggunakan kaedah LabVIEW dan Kaedah Unsur Terhingga (FEM) menggunakan perisian Abaqus terhadap anggota struktur seperti rasuk dan papak. Sepanjang hayat perkhidmatan struktur, anggota struktur mungkin tertakluk kepada beban impak. Dalam usaha untuk membangunkan struktur pelindung yang mampu untuk menahankan perkusi, kajian kejuruteraan impak dipergiatkan lagi. Plat dan papak adalah elemen utama dalam struktur. Plat keluli yang biasanya digunakan dalam industri pembuatan mempunyai potensi yang tinggi untuk menahani beban impak. Manakala konkrit bertetulang (RC) papak digunakan secara meluas dalam industri pembinaan. Oleh itu, tindakbalas dinamik plat keluli dan RC papak terhadap impak telah dikaji dalam kajian ini. Kaedah analisis konvensional, iaitu "Hertz Contact Theory", "Navier's Solution" dan "Levy's Solution" diulas dan dirumus untuk mendapat tindakbalas plat keluli dan papak RC. Ujian tukul jatuh adalah pendekatan utama yang boleh dijalankan untuk menganalisis tindakbalas plat keluli dan RC papak terhadap impak. Pakej perisian profesional Unsur Terhingga – Abaqus versi 6.12 dilaksanakan untuk model dan simulasi sambutan plat keluli dan RC papak dalam eksperimen di atas. Oleh kerana sambutan plat dan papak adalah berbeza mengikut sifat bahan, mod and nilai beban impak, nisbah aspek spesimen, span dan keadaan sempadan, eksperimen dijalankan terhadap 58 model plat keluli dan 24 model papak RC dengan pelbagai ketinggian tukul, nisbah aspek spesimen, span sokongan dan syarat sokongan. Tidakbalas eksperimen plat keluli dan papak RC dalam ujian tukul jatuh telah dinilai dengan sistem perolehan data yang terdiri daripada pemerolehan data dan perkakasan analisis (National Instruments USB-6281 kad pelbagai fungsi DAQ), dua unit 4-saluran ICP @ sensor penghawa isyarat, enam unit model 350303 pecutan PCB piezoelektrik dan perisian aplikasi (perisian Instrumen Nasional LabVIEW). Tindakbalas ini juga dikira menggunakan "Levy's Solution" dan dimodelkan dengan simulasi Abaqus. Keputusan eksperimen bersetuju baik dengan nilai analitikal dan nilai FEM yang diperolehi daripada simulasi Abaqus, oleh itu, mengesahkan keputusan yang didapati. Dengan pengesahan dan penetukuran tersebut, ujian tukul jatuh maya yang dibangunkan menggunakan perisian Abaqus berpotensi untuk meramalkan tindakbalas impak plat dan papak dengan tepat. Oleh yang demikian, konsep ujian impak maya ini adalah suai dan boleh diperluaskan lagi untuk kajian umum yang melibatkan struktur pelbagai bentuk, saiz, tenaga, arah dan mod impak. Ujian maya ini amat berguna apabila ujian eksperimen adalah sukar, mahal dan mustahil dilakukan .

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LIST OF ABBREVIATIONS

2D	Two-Dimensional
3D	Three-Dimensional
A/D	Analog-to-Digital
ACC	Accelerometer
ACI	American Concrete Institutes
ASTM	American Society for Testing and Materials
BEM	Boundary Element Method
C3D8R	Continuum Element (C) that has Three (3D) Degree of Freedom, Eight (8) Number of Nodes which Along The Corners as a Linear Element and Adopt The Reduced (R) Integration
DAQ	Data Acquisition
DEM	Discrete Element Method
DWTT	Drop-Weight Tear Tests
FDM	Finite Difference Method
FEM	Finite Element Method
FESS	Four Edges Simply Supported Boundary Condition
FESSP	Four Edges Simply Supported Steel Plate
FESSRC	Four Edges Simply Supported Reinforced Concrete Slab
FLD Damage	Forming Limit Diagram Damage
FLSD Damage	Forming Limit Stress Diagram Damage
FVM	Finite Volume Method
GPIO	General Purpose Input/Output
HSRPS	High-Strain-Rate Pressure Shear
LabVIEW	Laboratory Virtual Instrument Engineering Workbench

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