THE EFFECT OF THIN-LAYER ELEMENTS IN STRUCTURAL MODELING OF RAIL-TRACK SUPPORTING SYSTEM

By

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

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Chairman: Associate Professor Jamaloddin Noorzaei, PhD

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A conventional track system consists of rails, sleepers, ballast, sub-ballast and sub-grade. A track foundation on the basis of live load response and permanent settlement, it is necessary to use an analytical model that will realistically represent the actual behaviour of this track system subjected to actual load. This study deals with the development of numerical modeling of Malaysian railway track along with the supporting system. The model is capable to simulate the sleeper, ballast, sub-ballast, soil layers and their interaction as a single compatible unit. Under plane strain condition, the coupled finite-infinite elements were implemented to represent the near field and far field behaviour of media. Thin-layer elements have been used to represent the interfacial behaviour between sleepers and ballast. The following constitutive relationships were adopted in this study:

(i)-Linear Elastic

(ii)-Elasto-plastic

Based on the above physical and material modeling, an existing two dimensional finite element program has been extensively modified in view of including the new elements as well as the new constitutive law. After verification of the modified

version of the program, the applicability of the program was shown in analysis of railway track supporting system. The response of the railway track supporting system has been presented under static and dynamic loading. The behavior of the railway track supporting media has been discussed with respect to displacements, accelerations and rate of plastic flow.

This analysis shows that the thin layer element is reliable to be used as an interface element to represent the contact surface between two different materials.

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

KESAN BAGI ELEMENT LAPISAN NIPIS DALAM PEMODELAN SISTEM SOKONGAN RANGKAIAN KERETAPI

Oleh

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Secara umumnya, sistem landasan keretapi terdiri daripada rel, penidur, ballast, sub-ballast dan bahagian tanah. Model yang bersifat analitik dimama dapat mempersembahkan kelakuan sebenar bagi asas landasan keretapi yang menanggung beban hidup dan mengalami pemindahan yang kekal adalah amat diperlukan. Kajian ini merangkumi pemodelan sistem sokongan yang direkabentuk untuk landasan keretapi di Malaysia. Model ini berupaya mempersembahkan kelakuan rel, penidur, ballast, sub-ballast, lapisan tanah dan juga keadaan lapisan antara dua jenis bahan pembinaan yang berbeza. Hubungan yang dikaji dalam pemodelan ini adalah::

(i) Elastic linear

(ii) Elasto-plastic

Dalam proses memodel sistem sokongan landasan keretapi secara fizikal dan bahan pembinaan, satu program analisis unsure terhingga yang sedia ada telah diubahsuai dari segi penggunaan unsure yang baru dimana merupakan suatu constitutive bahan yang baru. Pengesahan telah dilakukan ke atas program yang telah diubahsuai bagi memastikan bahawa program tersebut dapat menganalisis sistem sokongan landasan keretapi di Malaysia. Kelakuan ke atas sistem rangkaian keretapi Malaysia telah

dibentang dan dibincangkan di bawah beban static dan dinamik. Di samping itu, perubahan bentuk ke atas sistem sokongan landasan keretapi juga dibincangkan.

Kajian ini telah membuktikan bahawa pemodelan suatu lapisan dapat mempersembahkan kelakuan sebenar di antara dua jenis bahan pembinaan yang berlainan.

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To my family, who, I believe, is inquisitive and questioning in the space beyond, which is congruent to that of mine.

To those giants of mechanics, physics and philosophy, on whose contributions I stand and extend.

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

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

YEAT CHOOI FONG

Date: 13 FEBRUARY 2007

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$[a] =$	Flow vector
$[a_1, a_2, a_3] =$	Co-efficient used in material modal parameters
$[\alpha] =$	Factor of end of elasticity
$[\mathrm{B}] =$	Strain-displacement transformation matrix
$[\beta] =$	A parameter
$[C] =$	Constitutive matrix in global coordinate
$[\overline{C}^{e}] =$	Elastic constitutive matrix in local coordinates
$[\overline{C}^{ep}] =$	Elasto-plastic constitutive matrix in local coordinates
$[C_i] =$	Constant parameter
$[c] =$	Co-efficient value material
$[D] =$	Elasticity matrix in global coordinates
$[\Delta] =$	Displacement in global coordinates
$[\Delta t] =$	Incremental of time
$[\delta] =$	Displacement in local coordinates
$[\partial\delta] =$	Virtual displacement vector
$[\phi] =$	Friction angle
$[\mathrm{E}] =$	Young's modulus / Modulus of Elasticity
$[\varepsilon] =$	Strains
$[\varepsilon_0] =$	Initial Strains
$[\varepsilon_x, \varepsilon_y, \varepsilon_z] =$	Nodal strains in global coordinates

$[\bar{\varepsilon}_x, \bar{\varepsilon}_y, \bar{\varepsilon}_z] =$	Nodal strains in local coordinates
$[\xi, \eta] =$	Local coordinates of gauss point
$[\zeta] =$	Mass / unit volume
$[F_x, F_Y, F_Z] =$	Concentrate load
$[F_x, F_Y, F_Z]_b =$	Body force
$[F_x, F_Y, F_Z]_s =$	Traction force / pressure
$[F(\sigma_{ij}) / f / g] =$	Failure function
$[f_{n+1}] =$	Internal force vector
$[G] =$	Modulus rigidity
$[\gamma] =$	A parameter
$[J_2, J_3] =$	Second and third invariant of deviatoric stress tensor
$[J_2^{'}] =$	Second invariant of deviatoric strain tensor
$[\psi] =$	Interface dilatancy angle
$[\mathrm{K}] =$	Stiffness matrix
$[\mathrm{K}_{nn}] =$	Normal stiffness matrix
$[\mathrm{K}_{ss}] =$	Shear stiffness matrix
$[k] =$	Hardening parameter
$[\mathrm{M}] =$	Mass matrix
$[\mathrm{N}] =$	Shape functions matrix
$[\mathrm{N}_i] =$	Nodal shape function
$[\sigma] =$	Stress
$[\sigma_0] =$	Initial Stress

$[\sigma_1] =$	Maximum Principle Stress
$[\sigma_3] =$	Minimum Principle Stress
$[\sigma_x, \sigma_y, \sigma_z] =$	Nodal stress in global coordinates
$[\overline{\sigma}_x, \overline{\sigma}_y, \overline{\sigma}_z] =$	Nodal stress in local coordinates
$[\mathrm{P}_{nel}] =$	Acceleration vector
$[Q(k)] =$	Yield stress / plastic potential
$[\mathrm{T}] =$	Transformation matrix from local to global coordinate
$[t] =$	Thickness of thin layer element
$[\tau_{xy}, \tau_{yz}, \tau_{zx}] =$	Nodal shear in global coordinates
$[\overline{\tau}_{xy}, \overline{\tau}_{yz}, \overline{\tau}_{zx}] =$	Nodal shear in local coordinates
$[u, v, w] =$	Nodal displacements in global coordinates
$[\overline{u}, \overline{v}, \overline{w}] =$	Nodal displacements in local coordinates
$[u, \dot{u}, \ddot{u}] =$	Displacement, velocity and acceleration
$[\mu] =$	Damping co-efficient
$[\nu] =$	Poisson's ration
$[x, y] =$	Global coordinates of a point