BEHAVIOUR OF COMPOSITE I-BEAMS UNDER CRUSHING AND BENDING MODES

By

FARAG ABDUSSALM ALI

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

March 2004

بسم الله الرحمن الرحيم

وقل اعملو فسيرى الله عملكم ورسوله والمومنين

صدق الله العظيم

To my exemplary parents, wife and lovely son

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in partial fulfillment of the requirements for the degree of Master of Science

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Chairman: Associate Professor Yousif A. Khalid, Ph. D.

Faculty: Engineering

Experimental and finite-element analyses for glass/epoxy composite I-beams were carried out to determine the effect of number of layers on load-carrying capacity and specific energy absorption. The loading modes used throughout this investigation were the axial compression, three and four point bending. The beams were fabricated from woven roving glass fibre and epoxy. The composite I-beams fabricated for axial compression tests were of 250 mm gauge length, 76 mm flange width and 125 mm web height, while the composite I-beams fabricated for three and four point bending tests were of 500 mm gauge length, 76 mm flange width and 125 mm web height. The matrix used was made of an epoxy resin (LECO 811-563-103) and a hardener (LECO 811-563-104) which were mixed at 8:1 ratio. Loading arrangements were also built to facilitate the experimental tests needed. The composite I-beams fabricated and tested were of 4, 6, 8 and 10 layers. Three samples were tested for each type and each load case. In addition, tensile samples were prepared and tested for the composite material used to evaluate the

mechanical properties needed in the theoretical analysis stage of this project. Load-displacement results were first obtained directly for each type of samples and for each loading mode. An average, for each three similar tests, were then tabulated for the next phase of results and calculations. Experimental results obtained from this study included the first crushing load, the energy absorption and the failure modes. The first crushing load values of composite I-beams with four, six, eight and ten layers under axial compression, three and four point bending are (41.67, 69.46, 133.1 and 222.89 kN), (5.94, 11.24, 16.57 and 23.86 kN) and (8.00, 16.39, 25.08 and 35.01 kN) respectively. The specific energy absorption values of composite I-beams with four, six, eight and ten layers under axial compression are 9.79, 14.70, 33.18 and 35.88 (kJ/kg), respectively. Whereas, the energy absorption capability values of composite I-beams with four, six, eight and ten layers under three and four point bending are (235.785, 485.791, 829.500 and 1163.771 (J)) and (201.425, 422.107, 803.622 and 1006.986 (J)), respectively. Moreover, the initial crushing bending moment values of composite I-beams with four, six, eight and ten layers under three and four point bending are (0.66, 1.26, 1.86 and 2.68 (kN.m)) and (0.6, 1.23, 1.88 and 2.62 (kN.m)) respectively. On the other hand, all composite I-beams tested under axial compression fail by local buckling followed progressive crushing failure modes. Whereas, those tested under three and four point bending fail by matrix cracking followed local buckling under the loading points.

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

KELAKUAN KOMPOSIT I-BEAM MOD MENGHANCUR DAN MELENTUR

Oleh

FARAG ABDUSSALM ALI

March 2004

Pengerusi: Profesor Madya Yousif A. Khalid, Ph.D.

Fakulti: Kejuruteraan

Uji kaji dan analisis unsur terhingga bagi kaca/epoksi rasuk-I komposit telah dijalankan bagi menentukan kesan bilangan lapisan pada kapasiti membawa-beban dan penyerapan tenaga tentu. Mod beban yang digunakan sepanjang penyelidikan ini merupakan ujian mampatan paksi, tiga dan empat lentur titik. Rasuk tersebut distmktur daripada eksposi dan gentian kaca mengarah. Komposit yang distmktur untuk ujian rasuk-I ini ialah 250 mm panjang tolok, 76 lebar bebibir dan 125 mm tinggi web, manakala komposit rasuk-I dibuat untuk tiga dan empat titik ujian lentur daripada 500 mm panjang tolok, 76 lebar bebibir dan 125 mm tinggi web. Matriks yang digunakan dibuat daripada damar eksposi (LECO 811-563-103) dan pengeras (LECO 811-563-104) dan dicampur pada kadar 8:1. Susunan beban juga dibina bagi memudahkan ujian uji kaji yang diperlukan rasuk-I komposit yang distruktur dan diuji adalah 4, 6, 8 dan 10 lapisan. Tiga specimen telah diuji bagi setiapjems dan setiap kes beban. Di samping itu, spesimen tegangan juga disediakan dan diuji bagi bahan komposit yang digunakan untuk menilai sifat-sifat mekanik yang diperlukan pada peringkat analisis toeri projek ini. Keputusan anjakan

beban pertama kali diperoleh bagi setiap jenis spesimen dan setiap mod beban- purata bagi tiga ujian yang sama kemudiannya dijadualkan bagi perkiraan dan keputusan fasa seterusnya. Keputusan uji kaji yang diperoleh daripada kajian ini meliputi beban hancur yang pertama, penyerapan tenaga dan mod kegagalan. Nilai beban penhancuran pertama rasuk-I komposit bagi empat, enam, lapan dan sepuluh lapis di bawah paksi mampatan, tiga dan empat titik lenturan masing-masing adalah (41.67, 69.46, 133.1 dan 222.89 kN), (5.94, 11.24, 16.57 dan 23.86 kN) dan (8.00, 16.39, 25.08 dan 35.01 kN). Nilai penyerapan tenaga tentu rasuk-I komposit bagi empat, enam, lapan dan sepuluh lapis di bawah beban mampatan adalah 9.79, 14.70, 33.18 dan 35.88 (kJ/kg). Sebaliknya nilai keupayaan penyerapan tenaga rasuk-I komposit bagi empat, enam, lapan dan sepuluh lapis dibawah tiga dan empat titik lenturan masing-masing adalah (235.785, 485.791, 829.500 dan 1163.771 J) dan (201.425,422.107, 803.622 dan 1006.986 J). Lagipun, nilai momen lenturan penhancuran pertama rasuk-I komposit bagi empat, enam, lapan dan sepuluh lapis dibawah tiga dan empat titik lenturan masing-masing adalah (0.66, 1.26, 1.86 dan 2.68 (kN.m)) dan (0.6, 1.23, 1.88 dan 2.62 (kN.m)). Dengan erti kata lain, semua ujian rasuk-I komposit di bawah paksi mampatan adalah gagal dengan lengkokan asal diikuti peningkatan mode kerosakan penghancuran. Sebaliknya ujian yang dilakukan dibawah tiga dan empat titik lenturan adalah gagal dengan pemecahan matrik diikuti lengkokan asal dibawah titik bebanan.

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I certify that an Examination Committee met on 4th March 2004 to conduct the final examination of Farag Abdussalm Ali on his Master of Science thesis entitled "Behavior of Composite I-Beams Under Crushing and Bending Modes" in accordance Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that this thesis is based on my original work except for quotation and citation 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.

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