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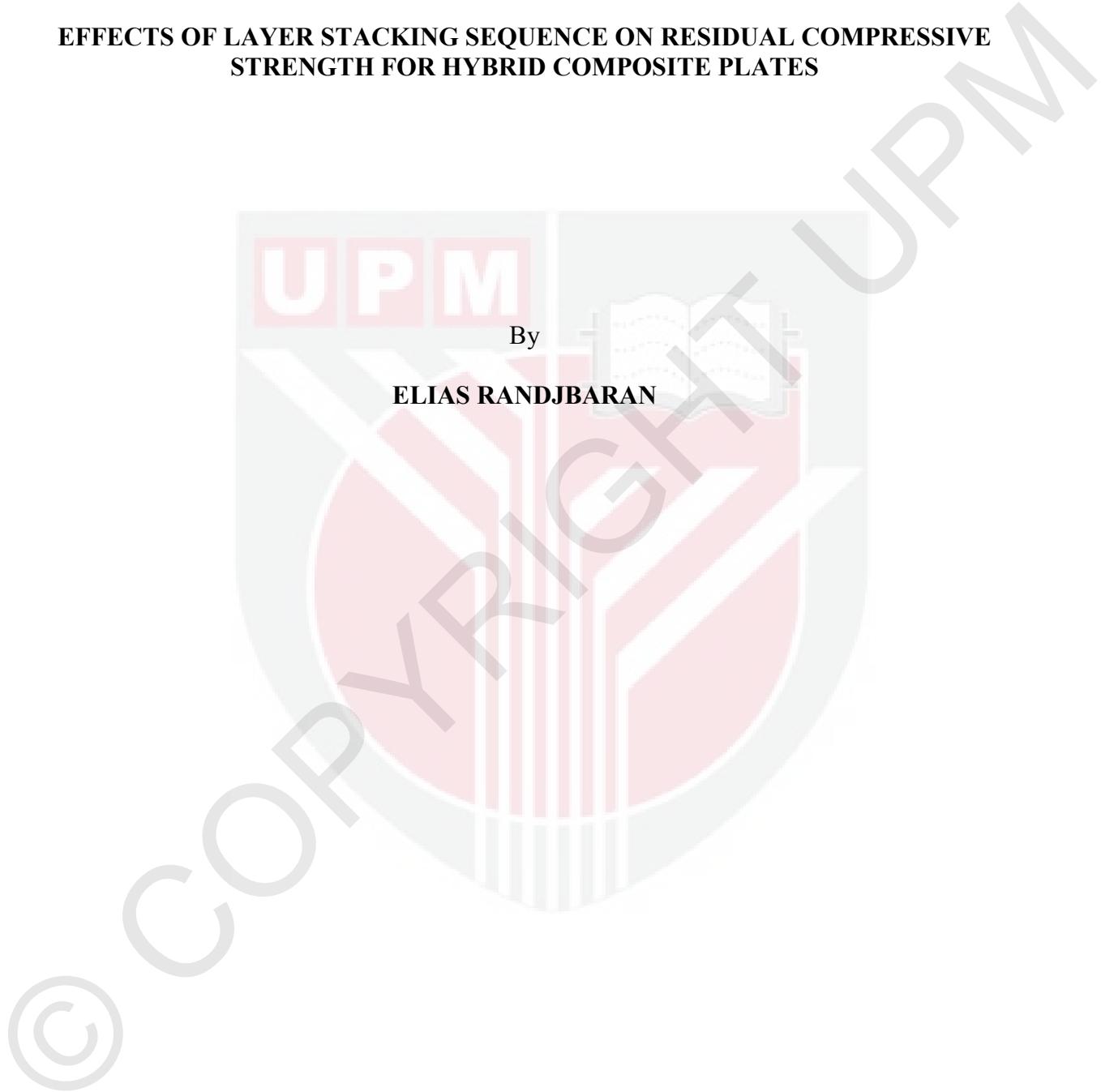
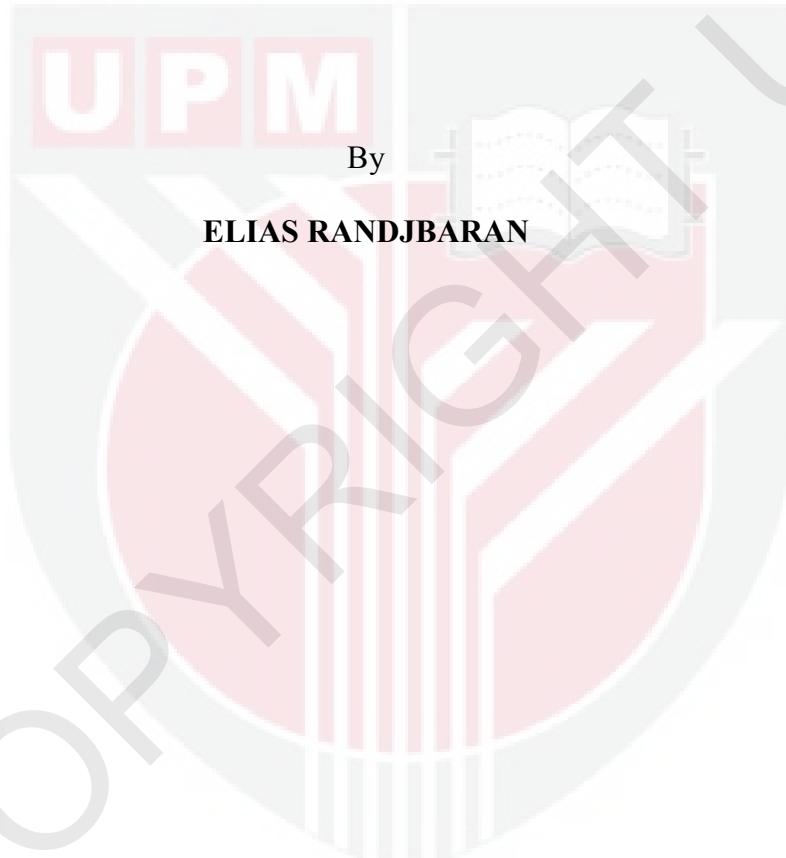
**EFFECTS OF LAYER STACKING SEQUENCE ON RESIDUAL  
COMPRESSIVE STRENGTH FOR HYBRID COMPOSITE PLATES**

**ELIAS RANDJBARAN**

**FK 2013 71**



**EFFECTS OF LAYER STACKING SEQUENCE ON RESIDUAL COMPRESSIVE  
STRENGTH FOR HYBRID COMPOSITE PLATES**



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

**July 2013**

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## **DEDICATION**

To all the scientists and researchers whole around the world, no matter what the nationality, language, race, or skin colour are.



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

**EFFECTS OF LAYER STACKING SEQUENCE ON RESIDUAL COMPRESSIVE STRENGTH FOR HYBRID COMPOSITE PLATES**

By

**ELIAS RANDJBARAN**

**July 2013**

**Chairman: Associate Professor Rizal Bin Zahari, PhD**

**Faculty: Engineering**

An experimental investigation on the effects of layer stacking sequence on response of 6-layer hybrid composite plates under compression after ballistic impact has been conducted. The composite plates consist of two layers of each of Kevlar, carbon, glass fibres as well as epoxy resin and the hardener. The specimens were prepared through hand-lay-up traditional fabrication method. Five groups of hybrid composite materials were fabricated with the different stacking sequences. Stacking sequence and Orientation of them are as follows; Hybrid 1 : [0<sub>K</sub>/0<sub>C</sub>/0<sub>G</sub>/0<sub>K</sub>/0<sub>G</sub>/0<sub>C</sub>]<sub>s</sub>, Hybrid 2 : [0<sub>G</sub>/0<sub>C</sub>/0<sub>K</sub>/0<sub>C</sub>/0<sub>K</sub>/0<sub>G</sub>]<sub>s</sub>, Hybrid 3 : [0<sub>K</sub>/0<sub>G</sub>/0<sub>C</sub>/0<sub>G</sub>/0<sub>C</sub>/0<sub>K</sub>]<sub>s</sub>, Hybrid 4 : [0<sub>G</sub>/0<sub>K</sub>/0<sub>C</sub>/0<sub>C</sub>/0<sub>G</sub>/0<sub>K</sub>]<sub>s</sub>, and Hybrid 5 : [0<sub>K</sub>/0<sub>C</sub>/0<sub>G</sub>/0<sub>G</sub>/0<sub>C</sub>/0<sub>K</sub>]<sub>s</sub>. The specimens were undergone ballistic impact testing and then the residual compressive strength was measured. Finally, the best sequence of the layers for producing high resistance polymeric laminated composites was introduced. It was found that the damage characterisation of Hybrid 2 possesses better impact resistance, ability to absorb the energy and penetration compared to the rest of them. Hybrid 3 has the highest compressive energy absorption after ballistic impact. Calculating the energy absorption upon the ballistic impact defines that Hybrid 2 has the maximum amount of 95.2 J. Besides, Hybrid 3 and Hybrid 5 are showing the same close behaviour, which velocity difference of them is 0.55 m/s and the difference of energy absorption is 0.03 J. Compressive energy absorption of the intact and the clean -hole specimens illustrates that Hybrid 4 in both of them has a maximum strength against the compressive force with 2285 and 1940 J respectively. Compressive ballistic energy absorption of the specimens shows that Hybrid 4 has the highest strength in compression after ballistic impact with 1940 J.

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

**KESAN LAPISAN TERSUSUN SECARA BERURUTAN TERHADAP KEUATAN SISA MAMPATAN UNTUK PLAT KOMPOSIT HYBRID**

Oleh

**ELIAS RANDJBARAN**

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Suatu kajian ujikaji mengenai kesan terhadap lapisan yang disusun mengikut turutan iaitu tindak balas 6-lapisan hibrid plat komposit di bawah mampatan selepas kesan balistik telah dijalankan. Plat komposit tersebut terdiri daripada dua lapisan bagi setiap Kevlar, karbon, gentian kaca serta resin epoksi dan pengeras. Spesimen ini telah disediakan melalui kaedah fabrikasi yang disusun sendiri secara manual. Lima kumpulan bahan komposit hibrid telah direka dengan pelbagai susunan mengikut turutan. Susunan mengikut turutan dan Orientasi adalah ; Hibrid 1 :  $[0_K/0_C/0_G/0_K/0_G/0_C]_S$  , Hibrid 2 :  $[0_G/0_C/0_K/0_C/0_K/0_G]_S$  , Hibrid 3 :  $[0_K/0_G/0_C/0_G/0_C/0_K]_S$ , Hibrid 4 :  $[0_G/0_K/0_C/0_C/0_G/0_K]_S$  , and Hibrid 5 :  $[0_K/0_C/0_G/0_G/0_C/0_K]_S$ . Selepas spesimen tersebut menjalani ujian kesan balistik, kekuatan mampatan sisa kemudian diukur. Akhirnya, lapisan turutan terbaik diperolehi untuk menghasilkan rintangan polimer komposit berlapisan tinggi . Adalah didapati bahawa, pencirian kerosakan Hibrid 2 mempunyai kesan yang lebih baik dari segi rintangan, keupayaan untuk menyerap tenaga dan penembusan, berbanding dengan yang lain. Hibrid 3 mempunyai penyerapan tenaga mampatan tertinggi selepas kesan balistik. Ukuran penyerapan tenaga selepas kesan balistik menunjukkan bahawa Hibrid 2 mempunyai jumlah maksimum 95.2 J. Selain itu, Hibrid 3 dan hibrid 5 menunjukkan tingkah laku yang lebih kurang sama, di mana perbezaan halaju adalah 0.55 m/s dan perbezaan penyerapan tenaga adalah 0.03 J. Penyerapan tenaga mampatan yang utuh dan spesimen yang ‘bersih-lubang’ menunjukkan bahawa Hibrid 4 dalam kedua-dua daripada mereka mempunyai kekuatan maksimum terhadap daya mampatan dengan masing-masing 2285 dan 1940 J . Penyerapan tenaga balistik mampatan spesimen menunjukkan bahawa Hibrid 4 mempunyai kekuatan tertinggi dalam mampatan selepas kesan balistik dengan 1940 J.

## **AKNOWLEDGEMENT**

Alhamdulillah, all praise to Allah S.W.T, Lord of the Universe, and May peace and blessings are upon His beloved Prophet Muhammad S.A.W, on the household of the prophet, and on his faithful companions. Amen.



I certify that a Thesis Examination Committee has met on 23 July 2013 to conduct the final examination of Elias Randjbaran thesis entitled "Effects of Layer Stacking Sequence on Residual Compressive Strength for Hybrid Composite Plates" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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## **DECLARATION**

I declare that the thesis is 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 Universiti Putra Malaysia or any other institutions.

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**ELIAS RANDJBARAN**

Date: 23 July 2013



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