UNIVERSITI PUTRA MALAYSIA

MECHANICAL PROPERTIES OF TIN MINE TAILING SAND FOR GREENSAND CASTING MOULD

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

TO WHOM THEIR TRUE LOVE AND SUPPORT WERE BEHIND MY SUCCESS; MY FATHER, MOTHER, WIFE, SON, DAUGHTERS, BROTHERS, SISTERS AND TO THE SOUL OF MY GRANDFATHER, HJ KASIM, THE PERSON WHO ENCOURAGED ME TO PURSUE THIS STUDY. MAY ALLAH BLESS HIM AND GRANT HIM PEACE.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

MECHANICAL PROPERTIES OF TIN MINE TAILING SAND FOR GREENSAND CASTING MOULD

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OCTOBER 2012

Chair: **Professor Shamsuddin bin Sulaiman, PhD**

Faculty: **Engineering**

Tailing sand is the residue from tin extraction, containing between 94% to 99.5% silica. It is abundant especially in Kinta Valley of state of Perak, Klang Valley of state of Selangor and certain areas in Johor, Negeri Sembilan and Pahang in Peninsular Malaysia. Many abandon tailing sand dump areas are easily to access due to the reason of transportation of tin and at present most of them have been covered by bushes even though there are efforts to convert the land for agriculture, industrial and housing estate. The worst scenario is issue of illegal activities of tailing sand mining including sand stealing. The purpose of this research is to investigate the mechanical properties of tailing sand as aggregate for making greensand casting mould. Five samples from Tronoh and Tanjung Tualang in Perak state; Batang Berjuntai in Selangor; Jemaluang in Johor and Gambang in Pahang were gathered.

The experiments for this investigation are strictly obeying the American Foundrymen Society (AFS) standard of procedures. The investigation involved the process of; identifying locations for sampling of tailing sand with high content of silica in Peninsular Malaysia, conducting the mechanical sieve grading to identify the size spread, plotting the grain size distribution and calculating the average grain size. Further on with classifying the grain shape, the clay grade, the effects of controlled additions of clay (bentonite) and water and determining the working range on the mechanical moulding properties of tailing sand. The investigation involved comparing the mechanical properties of the tailing sand to mould sand taken from RCS Manufacturing Sdn. Bhd., the company supplying mould sand to the Proton Casting Plant, manufacturer of engine components in Malaysia and the requirement for foundry sand applications listed by Foseco Ferrous Foundryman's Handbook (Foseco).

The size spread, grain size distribution, average grain size and grain shape of tailing sand matched the Foseco requirement and RCS, which are well sorted and uniform, within the required size (217 to 281 µm) and has sub angular with compound sphericity shape. Test on the clay grade showed that clay grade is between 0.47% -2.07%, which resembles the true clay value in the sand.

Cylindrical test piece specimens dimensioning of Ø50 mm×50 mm in height from various sand–clay-water ratios, were produced by applying three ramming blows of 6.666 kg each using Ridsdale-Dietert metric standard rammer. The specimens were tested for green compression strength using Ridsdale-Dietert universal sand strength machine and permeability number with Ridsdale-Dietert permeability meter. Before the

tests were conducted, the moisture content was measured using AND MX50 moisture analyser.

The working range for samples with 2.9% by weight (wt) of water addition were at allowable clay content ranged from 2.5-5.0wt% where green compression strength ranged from 25 kN/m^2 to 43 kN/m^2 and permeability number from 63 to 225. The samples with 4.8wt% of water addition have the working range at the allowable clay content ranged from 4.0-6.5wt% where the green compression strength ranged from 35 kN/m^2 to 52 kN/m^2 and permeability number from 76 to 252.

The working range for samples bonded with 3.8wt% of clay were at allowable moisture content ranged from 3.0-4.0wt% where the green compression strength ranged from 20 kN/m^2 to 48 kN/m^2 and permeability number from 90 to 255. If bonded with 7.4wt% clay, the allowable moisture content ranged from 3.5-6wt% where the green compression strength ranged from 33 kN/m^2 to 70 kN/m^2 and permeability number from 70 to 220.

Finally, the investigation indicated that tailing sand is suitable as foundry sand for making greensand casting mould where the allowable clay and moisture content of tailing sand samples are within the range in application for making greensand casting mould for ferrous and non-ferrous metal.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah.

SIFAT-SIFAT MEKANIKAL PASIR BEKAS LOMBONG TIMAH UNTUK ACUAN TUANGAN PASIR LEMBAP

Oleh

AZHAR BIN ABDULLAH

Oktober 2012

Penyelia: **Professor Shamsuddin bin Sulaiman, PhD**

Fakulti: **Kejuruteraan**

Pasir bekas lombong adalah sisa tinggalan dari pengambilan timah yang kandungan silikanya adalah di antara 94% hingga 99.5%. Ianya banyak terdapat terutamanya di Lembah Kinta di negeri Perak, Lembah Klang di negeri Selangor dan kawasan tertentu di negeri Johor, Negeri Sembilan dan Pahang di Semenanjung Malaysia. Kebanyakan longgokan pasir bekas lombong mudah untuk dijejaki disebabkan kemudahan untuk mengangkutkan timah dan sekarang kebanyakan telah dilitupi semak samun walaupun ada usaha untuk mengubahnya sebagai tapak pertanian, industri dan perumahan. Tujuan kajian ini adalah untuk menyiasat sifat-sifat mekanikal pasir bekas lombong sebagai aggregat untuk pembuatan acuan tuangan pasir lembap. Lima sampel dari Tronoh dan Tanjung Tualang di negeri Perak; Batang Berjuntai di negeri Selangor; Jemaluang di negeri Johor dan Gambang di negeri Pahang dikumpulkan

Penyelidikan dijalankan adalah mematuhi prosedur piawai dari American Foundrymen's Society (AFS). Penyelidikan ini melibatkan penentuan lokasi untuk pengambilan sampel pasir bekas lombong yang mengandungi kandungan silika yang tinggi di Semenanjung Malaysia, menjalankan pengredan ayakan mekanikal untuk menentukan sebaran saiz, agihan saiz bijian dan pengiraan purata saiz bijian. Seterusnya ialah pengkelasan bentuk bijian, gred tanah liat dan kesan-kesan bahan kawalan iaitu tanah liat (bentonite) dan air ke atas sifat-sifat mekanikal acuan pasir bekas lombong. Penyiasatan juga melibatkan perbandingan sifat-sifat mekanikal acuan pasir bekas lombong dengan pasir acuan yang diambil dari RCS Manufacturing Sdn. Bhd., syarikat yang membekalkan pasir acuan untuk Proton Casting Plant, pengeluar komponen injin kereta di Malaysia dan kehendak bagi applikasi pasir foundri yang disenaraikan oleh Foseco Ferrous Foundryman's Handbook (Foseco).

Sebaran saiz, agihan saiz bijian, purata saiz bijian dan bentuk bijian adalah menepati kehendak Foseco dan RCS, dimana teragih seragam dengan baik, berada dalam saiz yang dikehendaki (217 µm ke 281 µm) dan mempunyai bentuk separa bersudut yang agak bulat. Ujian gred tanah liat menunjukkan mereka mempunyai peratus gred tanah liat yang boleh diterima iaitu antara 0.47% -2.07%.

Spesimen ujian berbentuk selinder yang berukuran Ø50 mm×50 mm tinggi dari pelbagai nisbah pasir-tanah liat-air dihasilkan melalui hentaman 6.666 kg menggunakan 'Ridsdale-Dietert metric standard rammer'. Spesimen kemudian diuji kekuatan mampatan lembap menggunakan 'Ridsdale-Dietert universal sand strength machine' dan nombor ketelapan menggunakan 'Ridsdale-Dietert permeability meter'. Sebelum ujian

dilaksanakan, kandungan kelembapan diukur menggunakan penganalisa kelembapan model AND MX50.

Julat kerja bagi sampel yang ditambah air sebanyak 2.9% berdasarkan berat (wt) adalah pada kandungan tanah liat dibenarkan dari julat 2.5wt% ke 5.0wt% di mana kekuatan mampatan lembap berada pada julat 25 kN/m^2 ke 43 kN/m^2 dan nombor ketelapannya dari 63 ke 225. Jika sampel ditambah 4.8wt% air, julat kerjanya adalah pada kandungan tanah liat dibenarkan pada 4.0wt% ke 6.5wt% di mana kekuatan mampatan lembapnya berada pada 35 kN/m^2 ke 52 kN/m^2 dan nombor ketelapannya dari 76 ke 252.

Julat kerja bagi sampel yang diikat dengan 3.8wt% tanah liat adalah pada kandungan kelembapan dibenarkan dari 3.0wt% ke 4.0wt% dimana kekuatan mampatan lembapnya dari 20 kN/m^2 ke 48 kN/m^2 dan nombor ketelapan adalah dari 90 ke 255. Jika diikat dengan 7.4wt% tanah liat, julat kerjanya berada pada kandungan kelembapan dibenarkan dari 3.5wt% ke 6wt% di mana kekuatan mampatan lembapnya dari 33 kN/m^2 ke 70 kN/m^2 dan nombor ketelapannya dari 70 ke 220.

Akhir sekali, penyelidikan menunjukkan pasir bekas lombong adalah sesuai dijadikan pasir acuan bagi pembuatan acuan tuangan pasir lembap dengan kandungan tanah liat dan kelembapan yang dibenarkan adalah dalam julat yang biasa diamalkan dalam applikasi pembuatan acuan pasir tuangan lembap untuk logam ferus dan bukan ferus.

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Last but not the least; very thanks to all the technicians especially Mr. Saifuddin for their meaningful help during the experiments in the laboratories and also to Mr Ng Hwa Kian, Executive Director of RCS Manufacturing Sdn. Bhd., the company supplying mould sand to Proton Casting Plant for his kind contribution of RCS mould sand.

I certify that a Thesis Examination Committee has met on 29th October 2012 to conduct the final examination of Azhar Bin Abdullah on his thesis entitled "Mechanical Properties of Tin Mine Tailing Sand for Greensand Casting Mould" and the in accordance with the Universities and University College 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 Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the supervisory committee were as follows:

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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, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or other institutions.

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AZHAR BIN ABDULLAH

Date: 29 October 2012

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