BLAST LOADING CHARACTERISTICS OF SHALLOWLY BURIED EXPLOSIVE IN IN-SITU RESIDUAL SOIL

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DOCTOR OF PHILOSOPHY
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ZULKIFLI ABU HASSAN

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ABSTRACT

Detonated landmine transfers blast load upwards above ground. However, the transmitted blast load magnitude depends on the type and condition of the soil where the detonation occurred. Although many studies have been carried out to investigate soil effects and quantify blast data regarding landmine detonation, no data on the effect of soils in natural conditions are available. Most of the previous shallow-buried blast experimental works were laboratory-based, involved large testing facilities and were mainly carried out in remoulded soil beds. In this study, a 1/10th scale test apparatus consisting of a 0.5 m x 0.5 m square steel jig and a five mm-thick steel target plate was used to quantify blast loading in in-situ residual soil. A high-speed video camera and a piezoelectric shock accelerometer were used to measure the blast loading parameter. The landmine explosion simulation was replicated using a 20-gram high-explosive charge detonated at a constant depth of burial (DOB). By using small-scale test setups, this study aims to measure blast loading intensities and the effect of ejecta on amplifying the velocity of translated above-ground-structure during blast events on in-situ soil. Test results showed that the average energy transfer in detonation in in-situ 'Bentong' residual soil was four times higher than silica sand. The second upsurge in plate acceleration was also detected during detonation in soils which emanated from the impact of ejecta. The upsurge amplified plate velocity to about 18% and 20% in in-situ soil and silica sand test, respectively. Correlation of test results observation and 'detonation phases in soils' with post-test crater profiles showed that unique crater properties and profiles in silica sand bed and in-situ 'Bentong' soil delivered distinct blast waves. Unique crater's profile transmitted distinct ejecta characteristics that consequently amplify the magnitude of blast load.

ABSTRAK

Periuk api yang diletupkan memindahkan beban letupan ke arah atas permukaan tanah. Walau bagaimanapun, magnitud beban letupan yang dihantar bergantung kepada jenis dan keadaan tanah di mana letupan berlaku. Walaupun banyak kajian telah dijalankan untuk menyiasat kesan tanah dan mengukur data letupan mengenai letupan periuk api, tiada data tersedia tentang kesan tanah dalam keadaan semulajadi. Kebanyakan kerja-kerja eksperimen letupan tertimbus cetek sebelum ini adalah berasaskan makmal, melibatkan kemudahan ujian yang besar dan kebanyakannya dijalankan di atas tanah yang dibentuk semula. Dalam kajian ini, radas ujian skala 1/10 yang terdiri daripada jig keluli persegi 0.5 m x 0.5 m dan plat sasaran keluli setebal lima mm digunakan untuk mengukur bebanan letupan dalam tanah in-situ. Kamera video berkelajuan tinggi dan peranti pecutan piezoelektrik digunakan untuk mengukur parameter pemuatan letupan. Simulasi letupan periuk api telah direplikasi menggunakan cas letupan tinggi seberat 20 gram yang diletupkan di dalam tanah pada kedalaman yang konsisten. Menggunakan persediaan ujian berskala kecil, kajian ini adalah bertujuan untuk mengukur keamatan bebanan letupan dan kesan letupan yang menyebabkan perubahan halaju struktur-atas-tanah semasa ia bergerak ke atas sewaktu kejadian letupan. Keputusan ujian menunjukkan purata pemindahan tenaga dalam letupan dalam tanah 'Bentong' in-situ adalah empat kali lebih tinggi daripada pasir silika. Peningkatan kedua dalam pecutan plat juga dikesan semasa letupan dalam tanah yang datang daripada kesan ejecta. Kenaikan itu masing-masing meningkatkan halaju plat kepada kira-kira 18% dan 20% dalam ujian tanah in-situ dan pasir silika. Korelasi pemerhatian hasil ujian dan ‘fasa letupan dalam tanah’ dengan profil kawah pasca letupan menunjukkan bahawa sifat dan profil kawah adalah unik dalam dasar pasir silika dan tanah 'Bentong' in-situ. Keadaan tersebut merupakan faktor yang mempengaruhi hasil gelombang letupan dan ciri-ciri hamburan ejekta yang boleh mempertingkatkan magnitud beban letupan.

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APPROVAL

The Examination Committee has met on **17 May 2022** to conduct the final examination of **Zulkifli bin Abu Hassan** on his degree thesis entitled **'Blast Loading Characteristics of Shallowly Buried Explosive in In-Situ Residual Soil'.**

The committee recommends that the student be awarded the of Doctor of Philosophy (Civil Engineering).

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This thesis was submitted to the Senate of Universiti Pertahanan Nasional Malaysia and has been accepted as fulfilment of the requirements for the degree of **Doctor of Philosophy (Civil Engineering)**. The members of the Supervisory Committee were as follows.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

FIGURE NO. TITLE PAGE

LIST OF ABBREVIATIONS

AEP	-	Allied Engineering Publication
AN	-	Ammonium Nitrate
AP	-	Anti-Personnel
APC	-	Armoured Personnel Carrier
APM	-	Anti-Personnel Mines
ASTM	-	American Society for Testing and Materials
AT	-	Anti-Tank
AT	-	Air-Blast Test
AV	-	Anti-Vehicles
AVM	-	Anti-Vehicles Mines
CFAS	-	Concrete Fine Aggregate Sand
CSIR	-	Council for Scientific and Industrial Research, South Africa
DAQ	-	Data Acquisition System
DIC	-	Digital Image Correlation
DOB	-	Depth of Burial
DRDC	-	Defence Research and Development Canada
ERDC	-	US Army Engineering Research and Development Centre
ERW	-	Explosive Remnants of War
FAA	-	Free Accelerated Approach
FPA	-	Fixed Plate Approach
HE	-	High Explosive
HMAV	-	High Mobility Armoured Vehicles
HPB	-	Hopkinson Pressure Bar
IED	-	Improvised Explosive Devices
IFOR	-	Implementation Force (A NATO-led multinational force)
IHL	-	International Humanitarian Law
IMD	-	Impulse Measurement Device
LAV	-	Light Armoured Vehicles
LVDT	-	Linear Variable Differential Transformer
MALBATT	-	Malaysia Battalion

MOTAPM	-	Mines Other Than Anti-Personnel Mines
MRAP	-	Mine-Resistance Ambush Protected
NATO	-	The North Atlantic Treaty Organisation
NEC	-	Net Explosive Content
PETN	-	Pentaerythritol Tetranitrate
PPE	-	Personnel Protective Equipment
RDX	-	Royal Demolition Explosive
RHA	-	Rolled Homogeneous Armour
RMS	-	Root Mean Square
RSA-MIL-STD	-	South Africa Military Standards
RST	-	Buried in Residual Soil Blast Test
SIIMA	-	Scientifically Instrumented Impulse Measuring Apparatus
SOD	-	Stand-off Distance
ST	-	Buried in Silica Sand Blast Test
STANAG	-	NATO Standardization Agreement
TNT	-	Trinitrotoluene
UFC	-	Unified Facilities Criteria
UN	-	United Nations
UNOSOM	-	United Nations Operation in Somalia
UPNM	-	Universiti Pertahanan Nasional Malaysia
VIMF	-	Vertical Impulse Measurement Facility
VLIP	-	Vertical Launched Impulse Plate
VOD	-	Velocity of Detonation