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DESIGN A SUSTAINABLE BLAST PROTECTION WALL SYSTEM TO BE USED IN URBAN AREAS

A Thesis Submitted to Council of College of Engineering, University of Diyala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering

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بسم الله الرحمن الرحيم

"وَيَسْأَلُونَكَ عَنِ ٱلرُّوحِ قُلِ ٱلرُّوحُ مِنْ أَمْرِ رَبِّي وَمَآ أُوتِيتُم مِّنَ ٱلْعِلْمِ إِلاَّ قَلِيلاً "

صدق الله العظيم

مــن ســورة الاســراء – آيـــة 85

Certification of Supervisor

I certify that the thesis entitled **"DESIGN A SUSTAINABLE BLAST PROTACTION WALL SYSTEM TO BE USED IN URBAN AREAS"** was prepared by **"Ali Ghalib Adrees"** under my supervision at the Department of Civil Engineering-College of Engineering-Diyala University in a partial fulfillment of the Requirements for the Degree of **Master of Science in Civil Engineering.**

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Date: / / 2022

In view of the available recommendation, I forward this thesis for debate by the examining committee.

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Date: / / 2022

Dedication

To whom he strives to bless me comfort and welfare, my dearest father, and to the spring that never stops giving, my mother, their love and encouragement made me able to get a great success.

To all who teach, support and trust me, especially my wonderful supervisor "Dr. Assal" who made me enjoy my work.

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There are no words that can express my gratitude towards them

Design A Sustainable Blast Protection Wall System to be Used in Urban Areas

ABSTRACT

There have been many attacks in the current century that claimed the lives of many victims and caused economic and psychological effects on societies in a number of regions of the world. In the last years, terrorist organizations have adopted most attacks and used different strategies that made it difficult to identify these attacks by the security and intelligence services. The objective of this study: 1) the extent of the possibility of using eco-friendly available materials to design blast protection wall. 2) verify the ability of the simple blast wall to mitigate explosions. 3) Draw attention to investigate the performance of sustainable materials to mitigate blast.

In this study, simple wall system has been proposed a blast wall made of locally available sustainable materials. The structure of blast wall is composed of a parent structure of adobe brick and a core layer of recycled aggregates where the first layer is adobe and the base layer is recycled aggregate and the last layer is adobe brick (Brick-Recycle Aggregate-Brick(BRAB)) and The features of BRAB wall is the low cost of construction and maintenance and can construct with minimum effort. The response of the wall was examined by performing a numerical analysis using the 3D finite element method. The commercial software ABAQUS/Explicit version 6.14 combined with ConWep blast loading model as inbuilt blast load function was considered to represent the interactions between blast wave and the wall. Three groups of simple walls were modeled: the first group consisted of three walls with a height of 3 meters and a thickness of the core area (30,60 and 90) cm. The second group consists of three walls with a height of 4 meters and a thickness of the core area (30,60 and 90) cm. The third group consists of three walls with a height of 5

meters and a thickness of the core area (30,60,90) cm. The TNT explosive charge of 1 kg was placed at different distances from the wall. Through the results of the analysis, it was found that the efficiency of the BRAB walls increases with the increase of the height of the wall, as well as the thickness of the core layer, the group of walls with a height of 5 meters showed a higher efficiency, especially at a thickness of 90 cm for instance, for walls W1 the displacement is reduced by 23.42% when the thickness is increased to 60 cm and it is 35.55% when the thickness of the core is 90 cm. For walls W2 the displacement was reduced by 22.4% when the wall thickness was increased to 60 cm and 36.55% when the thickness of the core was 90 cm. For W3 walls the displacement reduction is 14% when the wall thickness is increased to 60 cm and 52.36% when the thickness of the core is 90 cm.

The use of BRAB walls can reduce the construction cost compared to the concrete wall of the same geometry. The cost of construction BRAB wall of thicknesses of 30, 60, and 90 cm, has been reduced by approximately 30%, 20%, and 15%, respectively. Moreover, CO_2 emission decreased by more than 98% for the same wall geometry models and the embodied energy has decreased by more than 95%.

In conclusion, the present study aims to draw the attention of researchers to consider sustainable blast protection wall systems to reduce injuries and protect property.

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R	distance from the origin of a detonation to a measuring
W	charge mass of TNT in kilograms
TNT_E	equivalent TNT mass
H_{EXP}	heat detonation of an explosive
W_{EXP},	mass of an explosive
H_{TNT},	heat detonation of TNT
σ1, σ3	the principal stresses
T and C	tension and compression
W1	A model of the wall high is 3m
W2	A model of the wall high is 4m
W3	A model of the wall high is 5m

LIST OF ABBREVIATION

ASTM	American Society for Testing and Materials
BRAB	Brick-Recycle Aggregate-Brick
CO_2	Di oxide Carbon
EE	Embedded Energy
CW	concrete wall
tc	thickness of core reign
AB	Adobe Brick

CHAPTER ONE
INTRODUCTION

1.1 General

Increased in terrorist attacks in the past twenty years, in particular, the increase in the attacks on buildings using high explosive materials that lead to the collapse of the building and damage to its residents. Iraq is one of the countries that suffer the most from terrorist attacks that have claimed the lives of many innocent citizens (see Figure (1-1). as a result of these attacks, the focus has increased greatly on scientific research that concerned how to protect against explosives by strengthening the building and constructing barriers **(Lutz, 2019).**

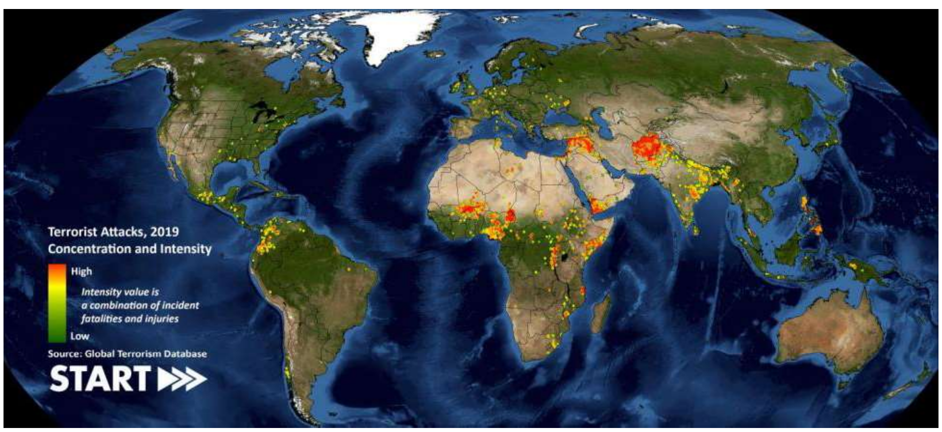

Figure (1-1) Worldwide number of attacks in 2013 (Global Terrorism Database, 2019)

Explosions are divided into three main parts: nuclear, physical and chemical explosions. An example of a physical explosion is the eruption of a volcano or the explosion of a gas cylinder. A nuclear explosion occurs when a large amount of energy is released due to the fission or fusion of the nucleus of an atom. A chemical explosion takes place through a rapid reaction or rapid oxidation of explosive materials, which produces a large amount of energy that leads to the generation of a high-Density shock wave, this type is the most used in terrorist attacks. Explosives are classified according to their susceptibility to ignition and are divided into two types: primary and secondary **(HUSSEIN, 2020).**

1.2 Research Hypothesis

Explosions have become an international phenomenon that requires global cooperation to confront this difficulty. Terrorist bombings impede the development of society and threaten its existence, where such bombings can be carried out anywhere depending on the target of the attack **(Makhutov et al 2009; Cernak 2010).** Terrorist attacks have targeted public buildings and facilities in the past years leading to massive damage to property, an increased number of victims due to the shock wave and shrapnel, which are the most responsible for injuries and losses **(Badshah et al 2017; Ahmad et al 2013).** Therefore, requires protecting citizens from terrorist bombings and minimizing property damage. Among the methods of protection is to Stop or prevent explosion incidents. However, it is not guaranteed to detect attack plans before the implementation. **(Mays and Smith, 2011**).

One method is to use explosion-proof barriers as they are a suitable option to protect against explosives and reduce their damage. Most blast barriers are multi-layer composite systems composed of high-ductile materials for the parent structure, and low-density materials for the core structure. From an economic point of view, these barriers are expensive to manufacture and install **(HUSSEIN, 2020)**.

1.3 High-Tech Blast Wall System.

Blast-resistant systems have been designed considering high-tech materials. The current research trend is to design composite sandwich panel to resist blast loading. The need to use lightweight materials and strengthening existing structures is the current concerns of most studies. The composite sandwich blast-resistant systems composed of two face-sheets made of highly ductile materials such as high strength steel to resist/reflect incident blast shock wave. The core structure is made of highly compressible (low density) materials such as foams to absorb the blast shock wave. Fig. 1 shows typical components of the composite sandwich system. Several studies have been conducted to examine different types of hightech blast wall systems to mitigate blast loading. Most studies have focused on using sophisticated systems, and advanced materials. The studies have evaluated blast wall systems, which can be part of structures as a structural element to resist blast loading **(HUSSEIN, 2020).**

1.3.1 Advantages of High-Tech Blast Wall System

The advantages of high-tech explosion-proof wall systems are summarized from the literature:

• The walls are efficient in resisting the blast load, but the cost is pricy.

• The wall consists of two main parts: the first part is called the parent structure and is made of high ductile materials. While the second part called the core structure and it is made of high compressible and low-density materials.

• The mechanism of blast mitigating is based on the reflection of the wave from the front face of the wall and the core reign absorbs the energy of the passing wave.

1.3.2 Advantages of High-Tech Blast Wall System

The disadvantages of high-tech blast wall systems include the fact that they require advanced materials that can be manufactured in developing countries, and this is what most developing countries exposed to terrorist attacks miss, in addition to the high cost of their manufacture and need skilled labor to install and maintain and importing them is very expensive.

The published literature had not discussed using recycled materials to design blast-resistant systems. The current study suggests eco-friendly blast wall systems, which can be constructed using cheap materials with minimum cost and effort. It was proposed to build an explosion-proof barrier made of mud bricks and recycled aggregates

1.4 Research Approach

Suicide bombings were carried out with new, innovative and unconventional plans to make the explosion more politically, economically, and socially impactful. there are often no buildings designed to resist the explosion, and barriers are often economically costly. Therefore, the threat of explosions requires the design of walls that are inexpensive and can be built easily that reduce damage and provide safety from blast shrapnel. **(Hrvoje and Vladimir 2013; Badshah et al 2020**)

This study suggests a simple blast wall has the capability to minimize damage and losses caused by explosions. The suggested wall is economically feasible made of sustainable materials, namely recycled aggregate and adobe and easy to construct. The wall can be setup inside urban areas when security forces facing challenges to prevent explosions.

1.5 Objective of the Study

The objective of this study is to verify the performance of a wall made of sustainable materials available, such as Waste Aggregate, and Adobe Bricks using ABAQUS software. The scenario of an Explosive belt attack was adopted as a type of attack is the most common type and the most used type of explosion that causes many victims. The geometry and dimensions of the wall were adopted according to the existing residential buildings locally.

1.6 Thesis Outline

This thesis includes five chapters in order to support the research objectives:

The first chapter explains the increase in attacks and types of explosions, as well as clarifying the methodology, hypothesis and objectives of the research

The second chapter explains the impact of terrorist bombings on people's lives, and some events that happened in Iraq were mentioned. Moreover, mentioned a number of studies that dealt with expensive and high-tech walls and barriers, and touched on some innovative walls. Sustainability and its basics and some sustainable buildings were clarified.

Chapter Three provides a historical overview of the uses and applications of explosives. The types of the confined and unconfined blast. Moreover, an explanation of the blast wave properties in free air is given. And methods of measuring the force of the blast.

Chapter four provides numerical analysis and blast wall modeling by ABAQUS. The numerical analysis results include out-of-plane displacement, acceleration, and blast pressure load of three different wall models. The cost and environmental impacts of BRAB and ordinary concrete were compared.

Chapter five includes a summary and conclusions of the current research and recommendations for future work.