



Faculty of Engineering

**FINITE ELEMENT ANALYSIS  
ON PEPPER BRICK STRENGTH**

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**FINITE ELEMENT ANALYSIS ON PEPPER BRICK STRENGTH**

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This thesis is submitted to

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Dedicated to,

My beloved family and friends

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## ABSTRAK

Tesis ini membentangkan aplikasi bagi Simulia Abaqus/CAE untuk permodelan tiga dimensi bata bercampur lada dan melakukan analisis dengan tujuan mencari kesan peratusan liang-liang terhadap taburan tegasan dalaman. Bata ini akan dimodel sebagai bahan isotropi homogen elastik dengan taburan rawak 0, 2, 5 dan 10 Wt. % kekosongan bagi mewakili liang-liang. Data dikumpul menggunakan dua kaedah; tiga set untuk nodus mengufuk dan dua set untuk nodus tegak. Data yang dikumpul untuk setiap jenis peratusan liang akan dibandingkan kepada tegasan von Mises yang sepadan daripada 0 Wt. % bata sebagai tegasan maksimum rujukan. Kebarangkalian kegagalan akan dianalisiskan untuk setiap set data dan disusun dalam satu jadual. Cara analisa ini akan digunakan untuk menetapkan nilai peratusan liang yang terbaik untuk kebarangkalian kegagalan minimum dengan keporosan yang sebanyak mungkin.

## **ABSTRACT**

This thesis presents the application of Simulia Abaqus/CAE to model three dimensional pepper waste mixed brick and to do finite element analysis in order to find the effect of pores percentage on the internal stress distribution. This brick will be modeled as elastic homogeneous isotropic material with random distribution of 0, 2, 5 and 10 Wt. % voids to represent the pores. Data are gathered using two methods; three sets of horizontal nodes and another two sets for vertical nodes. Data gathered for each type of pore composition will be compared to von Mises stress of corresponding node from 0 Wt. % brick as the reference maximum stress. Failure probability will be analyzed for each set of data and arranged in a table. This analysis method will be used to determine the best pore composition for minimum failure probability with most porosity as possible. Result is consistent with actual experimental data which suggest 5 Wt. % brick as the best choice.

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## NOMENCLATURE

kg	kilogram
kPa	kilopascal
$\mu\text{m}$	micrometer
3D	Three dimensional
Wt. %	Weight percent

# CHAPTER 1

## Introduction

### 1.1 Overview of Water-Penetrable Bricks

The oldest bricks found in the Middle East by archeologists dated 10000 years ago [10]. Scientists had suggested that these bricks were made from mud collected after the flooded river cleared. This mud will be hand-molded into rectangular bar and left in the sun to dry. Bricks will be layered with mud and tar as mortar, to create structures. Most of these structures still standing today, as proved by Great Wall of China and Coliseum in Rome.

Bricks are divided into various types and for different purposes [11]. The commonly used bricks are shown in Figure 1.1. The most known brick is the common brick which is used in building structure. These red colored brick does not contain special materials and does not have special marks, color or texture. Another type of brick is face brick. Face brick is normally applied at the side of stacked brick or on top of brick due to its aesthetic value and

durability. Face brick has variety of colors option, uniform surface texture and color and able to withstand freezing temperature and moisture.

Refractory bricks are made from fireclays which are heat resistant and therefore commonly used in building furnaces, kilns and fireplaces. Fireclays are clays with high alumina, silica content or non-clay minerals such as bauxite or silicon carbide. Glazed brick are high quality and durable brick with smooth surface and therefore easy to clean [12]. This type of brick normally being used in building where easy cleaning is necessary; for example, hospitals and laboratories.

Thin brick is almost the same as common brick except for their dimension [13]. Their thickness is reduced to just half inch which is  $1/6^{\text{th}}$  the thickness of common brick. This brick is more economical than common brick because of lower production cost and easier installation. Paving brick are used to lay pavement, either indoor or outdoor [26]. Paving brick has aesthetic value and normally have various texture and color. Their durability is also higher compare to common brick.



Figure 1.1 Various types of bricks normally available. From left to right; common brick, glazed brick <sup>[27]</sup>, refractory brick <sup>[31]</sup> and thin brick <sup>[32]</sup>

Another type of brick is water-penetrable brick. It is also known as porous brick, osmosis brick and water-permeable brick. This type of bricks is porous and has lower density compare to common brick. Any fluids located on this brick will be transferred to the bottom sides of the brick by the effect of gravity (Refer Figure 1.2). This special characteristic enables water-penetrable brick to be used outdoor and normally associated with pavement brick.

There are many versions of water-penetrable brick but mainly being categorized into two types, depending on their way to transfer the water. First type involved external water transfer around the brick. This involved specially designed brick and being arranged in such a way that water can sweep down to earth easily. Another type involved internal water transfer inside the brick and this function does not affected by the way the brick being arranged. Water can be transferred with pores or micro tunnels arranged inside the brick.



Figure 1.2 Example of water-penetrable brick <sup>[33]</sup>

This report will concentrate on brick with pores that are capable of transferring water internally. Water-penetrable brick has many advantages, especially in facilitating draining floods and controlling temperature. Storm water management issues can be reduced by implementing water-penetrable paving system [14]. There will be less catch basins, storm water ponds, curbs and storm drains as water can be drained directly into the soil underneath the brick. This leads to another advantage, which is the ability to cool down surrounding area.

Normally hardened, low porosity surface are made from concretes and tars but these surfaces trap water on top of it. This is not desirable for application in pedestrian walkways, motorcycles lanes, car parks, playgrounds and this also prevent the earth to retain and absorbs water. The usage of water-penetrable bricks enables any liquid on top of the bricks to be channeled down to soil underneath it. This usage prevents river flooding during heavy downpour and dry riverbeds during drought.

## 1.2 Overview of Pepper

Black pepper (*Piper nigrum*), or more commonly known as pepper, is a spice originated from India since at least 4000 years ago [15]. This plant is native to Western Ghats of Kerala State, India and being considered as one of the most ancient commodities of spice trade. It spread from India to Southeast Asia by migrating Hindu colonists. In Southeast Asia, pepper together with ginger has the longest history of export.

This bushy flowering vine is planted for its fruit, known as peppercorn. The fruit can only be harvested from plants of at least 2 years old and may continue to produce for as long as 40 years [16]. The fruit can be harvested anytime of the year, regardless of the time of the day. Traditionally the fruit being harvested manually using hand.

Pepper plant consists of four main parts; fruits, flowers, leaf and stem (Refer Figure 1.3). The fruits are the peppercorns, developed from the flowers. Flowers grow in clusters on flowering stalks known as spikes. There are around 50-60 fruits on each spike [17]. Spike is connected to stems, region where leaves grow. Pepper leaves have diamond shape and taper towards the tip. Peppers will be harvested by cutting off the spikes and spread out to dry under the sun. After dried, pepper will be stripped off from the spikes.

Peppercorn can be processed into four different types; black, green, white and red pepper (Refer Figure 1.4). The differences occur due to different ways of processing the fruits and their flavor varies with the color. Black pepper are produced from half ripe fruit which just about to turn red. Drying process will cause it to wither and turning dark in color. Green pepper is produced by harvesting unripe fruit which is green in color. Harvesting ripe fruit will produce red pepper. White pepper is produced by harvesting very ripe fruit and soaking it in brine to remove their dark outer skin, leaving white peppercorn.

Pepper plantation mostly found in Vietnam, Brazil, India, Indonesia, Malaysia, Sri Lanka and Thailand. Vietnam has become the world's main producer and exporter of pepper starting year 2001 (Refer Table 1.1). In Malaysia, pepper plantations mostly concentrated in Sarawak. Black peppers are the main type of pepper produced here and there also small amount of white peppers produced. Sarawak white peppers, known as Sarawak Cream Label, are of very high quality and also an important source of white peppers in the world. Two of the highest grade of peppers comes from India's Malabar Coast; Malabar pepper and Tellicherry pepper [18]. Tellicherry is a higher-grade pepper, picking the largest and ripest 10% of berries from Malabar plants, are grown on Mount Tellicherry.

Although peppers are mostly used as spice, it is also used as both traditional and western medicine. In South India, black peppercorns are used in remedies for Ayurveda, Siddha and Unani medicine. These traditional medicines valued the peppercorns' hot, light and anti-flatulent effects. It is most frequently used to cure digestive problems, cough, cold, breathing and heart problems, diabetes, as an appetizer and etc.

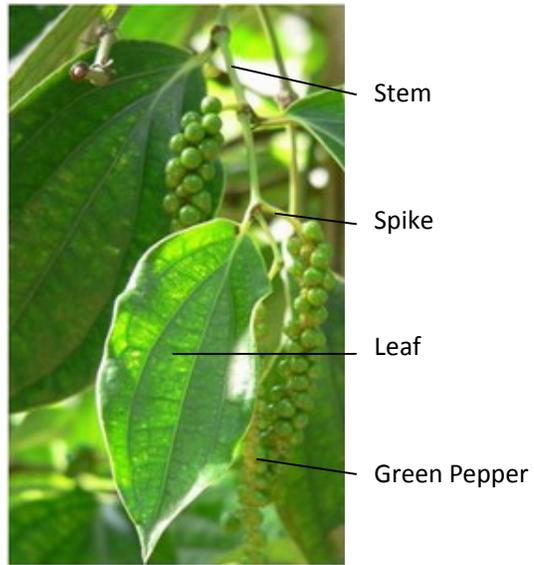


Figure 1.3 Pepper plant consist of four main parts; stem, spike, leaf and peppercorn [18]



Figure 1.4 The four different types of pepper; green, black, red and white pepper [34]