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Confinement of Brick Columns using Fiber Reinforced Geopolymer Adhesive Jackets

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\Structures

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CHAPTER ONE

INTRODUCTION

1.1 General

For many centuries, bricks have been among the most popular and essential building materials. They are without a doubt the oldest material used for construction. They were initially discovered around Jericho and in what is now known as southern Turkey. The original bricks were manufactured from mud and dried outside in the sunlight . But it was eventually discovered that bricks that had been burned by fire were more durable and could withstand more severe weather. As a result, bricks have become a more dependable and permanent structures building material. Now that clay has been exposed to water, it exhibits flexibility. Such plastic clays may be shaped into any ideal shape, and the finished brick is a leading material due to its strength, stability, durability, economy, and ease of supply. Given that the stones had to be chiseled, which required a lot of energy in the form of labor as well as taking a lot of time for the processing needed for a given unit to be carved out, the clay could be easily molded into any of the desirable shapes and sizes and has great strength properties when fire is burned. Bricks can be easily made, which is why they became an important building element. Stones had to be even polished properly because their surface and shape are not regular (Malagavelli et al, 2022).

Columns are compression structural components that can endure both axial compression and bending moment combinations. They are considered to be a critical component for the functionality and safety of structures. Currently the members need to be strengthened or modified. This may be resulted to a number of factors including a change in the structure's intended use, increased load capacity requirements as a result of design or construction failings, a review of the code's requirements, or the rehabilitation of the structure, as well as an improvement in the ductility and compressive strength of columns to better accommodate the necessary environmental and service factors (Rocca and Silvia, 2007).

The urgent need for structural retrofitting of existing unreinforced masonry (URM) structures stems in large part from these structures' susceptibility to lateral motions, such as moderate or powerful earthquakes (A.Penna et al, 2014), as well as from their insufficient energy efficiency. As a result, developing nations are prioritizing improving the built environment (Triantafillou,1998 and Krevaikas et al, 2005). When subjected to lateral loads, the unreinforced masonry is brittle and prone to rapid failure. New reinforcing techniques have been created as a result of the failures of unreinforced masonry in recent earthquakes (Madhavi et al, 2021). The confinement of the structures is one of the important applications in civil engineering. The confinement buildings give a number of benefits including greater capacity, keep the internal components, make the structures safer, more ductile, minimize the section dimensions, increase the structures earth-quick resistance, and keep it from various environmental conditions (Salman, 2015). For confining constructions, a variety of materials and methods are employed, such as jacketing concrete, steel, external steel wiring, and fiber-reinforced polymer (FRP). Fiber-reinforced polymer confinement in order to repair damaged reinforced concrete columns, one of the most popular confining techniques is to use FRP composites. While this technique is very effective and essential to improve the behavior of columns, such as their load capacity, compressive strength, and ductility for short columns, the designer still encounters challenges when attempting to use FRP in slender or long columns due to inadequate research, guidelines, and design support. FRP has several benefits, including a high strength to weight ratio, light weight, ease of installation, great durability, and high corrosion resistance. There are several types of FRP, including glass, aramid, and carbon fiber reinforced polymer (CFRP). Due to its high modulus of elasticity, which is bonded by epoxy as shown in Figure (1-1), CFRP is a new composite material with wide usage in the civil engineering industry (Jijin et al, 2015).

Figure (1-1): Jacketing of Columns by CFRP (Jijin et al, 2015).

1.2 External Confinement of Brick Column by FRP Techniques

A technique used on structural elements like columns, beams, or panels to produce advanced mechanical properties and with great effectiveness in strengthening and rehabilitating structural members is known as external insulation of concrete , can used also for brick column too. In the discipline of structural engineering, it is regarded as one of the most promising technologies. Because of their deterioration, ageing, environmental-induced degradation, lack of maintenance, or the necessity to satisfy current design criteria, existing structures have become increasingly important during the past few decades (Sachet et al, 2020). A widely used technique in many seismic event rehabilitation project includes jacketing columns with fiber reinforced composites, particularly fiber reinforced polymer (FRP) composites . Despite all of these benefits, there are a few disadvantages to using FRP for retrofitting, most of which can be attributed to the organic epoxy resins used to bind the fibers: poor fire resistance, high costs, inapplicability on wet surfaces or at low temperatures, risks for manual laborers, diffusion tightness, poor thermal compatibility with the base material, susceptibility to Ultraviolet (UV) radiation, and low reversibility (Nanni, 2012 and C. Carloni et al, 2015) this leads to thinking of an alternative material which has the same properties .

1.3 Geopolymer Paste Adhesive

Geopolymer is a pozzolanic and "green" product , because it includes silicates and aluminates such as fly ash (FA), blast-furnace slag (BFS), rice husk ash (RHA), and metakoline as a binder rather than cement binder,. Davidovits (1978) first introduced the term "geopolymer" and created inorganic polymeric materials (1990). The typical Portland cement can actually be replaced with geopolymer. In order to considerably reduce its carbon footprint, it relies on industrially produced or little processed natural resources. It is also highly resistant to many of the durability issues that can occur with ordinary concretes (Davidovits, 2008). A technique known as polymerization is used to produce the geopolymer by blending an aluminum silicate waste product (such as fly ash and blast furnace slag) with an alkaline activator, such as sodium hydroxide (NaOH) and sodium silicate (Na_2SiO3) solution (Shihab et al, 2018) as shown in Figure (1-2).

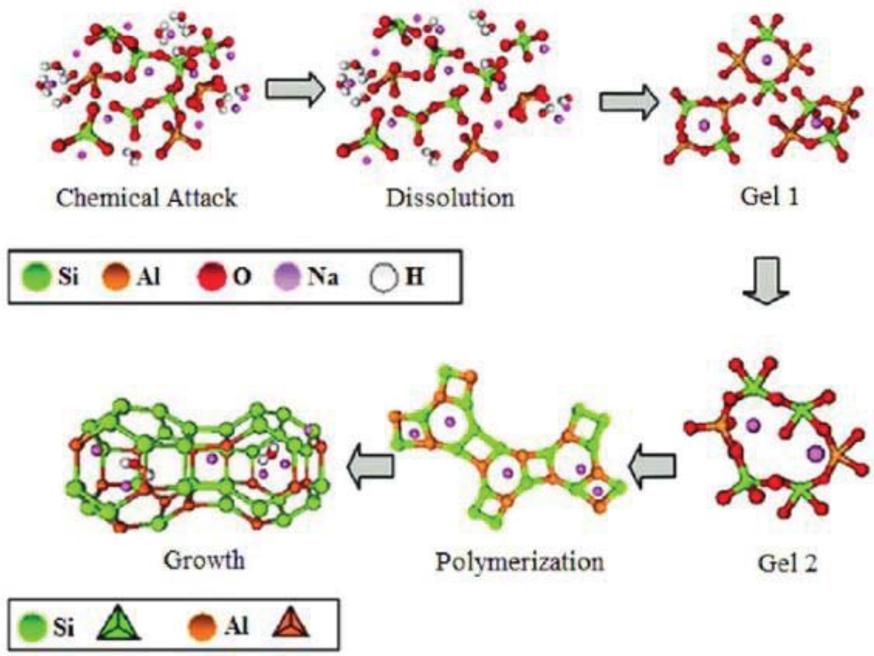

Figure (1-2) Graphic model of alkali activation of geopolymer (Shihab et al, 2018)

In addition to calcium-silicate-hydrate (C-S-H) gel, sodium-aluminum-silicate-hydrate (N-A-S-H) gel is essential for the geopolymer to gain strength (Davidovits, 2008). The early curing stage requires the high temperature for geopolymer to provide sufficient increases in strength to achieve higher mechanical characteristics (El-Hassan and Ismail, 2018). Several methods are being developed by the researchers to quicken the polymerization process so that it can cure at room temperature. Ground granulated blast furnace slag is a pozzolanic materials has a large effect on the microstructural and mechanical properties, also quicken the polymerization process at roomtemperature and enhance the binding capabilities of geopolymer paste (Saha and Rajasekaran, 2017, El-Hassan and Ismail, 2018, Sachet et al, 2020 and Salman et al, 2015), therefore, it was used in specific proportions in preparation of geopolymer paste .

1.4 Problem Statement

Epoxy was used as an adhesive material in many researches to confined brick columns, but due to the disadvantages of epoxy, it led to the need to find an alternative material with the same properties. When polymers are exposed to high temperatures (55°C and above), they quickly deteriorate and lose their mechanical capabilities. They are also dangerous since they emit toxic gases and fumes when they are being utilized. It poses a risk to the lives of manual laborers. Due to how the global warming is developing, a new adhesive substance that can withstand high temperatures is now required.

1.5 The aim of Study

The main goal of this study is to use an alternative, environmentally friendly ,sustainable and safe material in the confinement process of short square brick columns which is geopolymers adhesive material, and to develop a compressive strength of brick columns under axial load.

1.6 Study Methodology and Variables

To investigate the performance of brick column (BC) confined by fiber reinforced geopolymer adhesive and to get the above-mentioned goals , the study was done by constructing and testing thirteen square brick column, two unconfined BC and the remaining eleven are confined by geopolymer adhesive jackets and epoxy adhesive jackets to make a comparative study between them ,with cross-section 23cm*23cm and 60cm height. The experimental program includes an examination of parameters that might have a significant impact on the confinement. These parameters were:

1) Number of carbon fiber reinforced jackets layers were (1 and 2 layers).
2) Material of jackets which is (carbon fiber, glass mesh, jute, and steel mesh).

3) The confinement ratio (40%, 60%, and 100%) of the column high.

1.7 Thesis Layout :

The thesis divided into five chapters:

1. Chapter one includes the introduction, external confinement of Brick Column (BC) by FRP techniques, , geopolymer paste adhesive, problem statement, the aim of study, Study Methodology and variables.
2. Chapter two includes the literature review about the technique of confinement brick columns , epoxy adhesive, and geopolymer adhesive.
3. Chapter three includes the experimental program and the procedure used to construct the research specimens, including a detailed explanation of the mechanical testing performed on the material used in this study.
4. Chapter four includes the experimental results, discussions and explication.
5. Chapter fives includes summarizing the test results, highlighting the conclusions, and making important recommendations for future researches.

Abstract

When subjected to lateral loads, unreinforced masonry is brittle and susceptible to sudden failure. In recent times, earthquakes have increased significantly in a number of countries such as Iraq, Turkey, Lebanon, Iran, and others, changing in the natural of loads, weather conditions, which have led to an increase in the need to strengthen brick columns to withstand the impact of these factors. Especially the archaeological brick buildings that have an ancient cultural value and need to be strengthened to preserve them through the generations

Many techniques for strengthening are used, including the use of fiber reinforced polymers such as epoxy adhesive, but the undesirable properties of polymers, such as heavy cost, carbon dioxide, toxic fumes, and global warming, caused researchers to find alternative materials with high efficiency and the ability to withstand high temperatures. Geopolymer adhesive is a sustainable, environmentally friendly material, economical and gave amazing results similar to epoxy result, geopolymer adhesive is a mixture of ground granulated blast furnace slag with alkaline solution (sodium hydroxide with sodium silicate) .

The experimental program included the manufacture of brick columns confined with fiber reinforced geopolymer adhesive GA and epoxy adhesive EA jackets and their treatment in the room temperature. The study was done by constructing and testing thirteen Brick Columns(BC), two unconfined BC (with two 10cm rings one at upper edge and the other at the bottom edge) and the remaining eleven are confined by geopolymer adhesive jackets and epoxy adhesive jackets to make a comparative study between them ,with cross-section 230mm*230mm and 600mm height. The eleven confined brick columns were divided into three groups: the first group deals with the number of jackets layers (1 and 2)layers, the second group deals

with the confinement ratio of brick column (40%,60%, and 100%) from the column hight, and the third group deals with the type of jacket material (carbon fiber, glass fiber mesh, jute mesh, steel mesh).

Through the test results, it was found that the axial load capacity of brick column has increased significantly as the number of jacket layers has increased. Whereas columns confined by two layers of carbon fiber with (epoxy adhesive and geopolymer adhesive) show load enhancement ratios of (2.695 and 2.179) respectively, and deformation capacity of (2.195 and 1.369) respectivily compared with the unconfined columns. The increase in load capacity of confined BC with increase the confinement ratio by (40% , 60%, and 100%) the column with confinement 60% was the best confined column. The geopolymer adhesive was proved to be effective as an adhesive with various types of jacket material through the failure (rupture) pattern of all confined BC, where the geopolymer adhesive with jacket acted as a matrix for absorbing the stresses imparted from the core BC. During testing, the steel mesh and jute fiber were the best jackets in performance compared with it's costs.

Finally, the results show that the geopolymer adhesive is a sustainable, safe and environmentally friendly material that gives results are close to epoxy, so it is considered alternative to epoxy as an adhesive in confinement columns.