Advanced Composite Masonry Confinement Techniques and Analytical Model Comparison to Experimental Literature Database

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Course Description

The confinement of masonry columns using **advanced composites** is frequently used in order to **upgrade the column capacity**. In this study, **the efficiency of using different types of advanced composite for external confinement as a strengthening method is investigated**. A wide range of experimental database of masonry column specimens has been collected from the results that are available in scientific literature. The **data is analyzed and compared to analytical code models**.

Learning Objectives

- To understand external composite strengthening systems.
- To Investigate the efficiency of using different types of advanced composite for external confinement of masonry columns.
- To study the effect of equivalent fiber reinforcement index on strength enhancement ratio.
- To evaluate different theoretical models that used to predict confined masonry column capacity.
- To compare between the experimental results and predicted capacity using available analytical models.

Background

- The masonry unit is one of the most common construction materials that used in the construction of buildings around the world.
- In research efforts around the world, columns are receiving a great deal of attention due to their importance as a structural element since the failure of a column can lead to significant consequences to the entire building including collapse.

Background

- Historically, there are many conventional techniques that have been used for masonry wall and column retrofitting, such as cross section enlargement, steel jacketing, and ferrocement jacketing.

Background

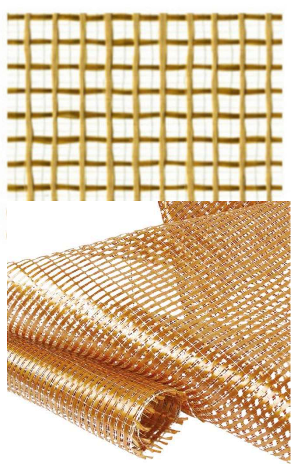
- Recently, advanced composites such as fiber reinforced polymers (FRP), fiber reinforced cementitious matrix (FRCM) and steel reinforced grout (SRG) are gaining more widespread attention for general masonry strengthening usage.

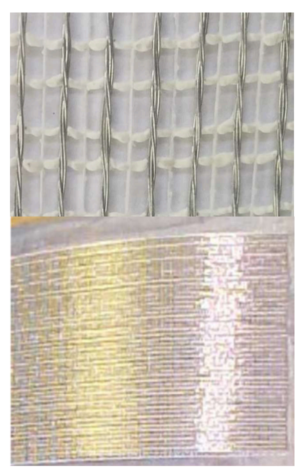
Background

- Advanced composite materials used for strengthening has many advantages due to its excellent physical and mechanical properties.

Advanced Composites

- Three types of advanced composites were investigated in this study (FRP, FRCM, and SRG).





Expected Modes of Failure

- Brittle Failure of Unconfined Column

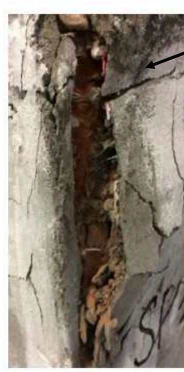


Expected Modes Of Failure

- Failure Configurations of Confined Columns

FRCM Rupture



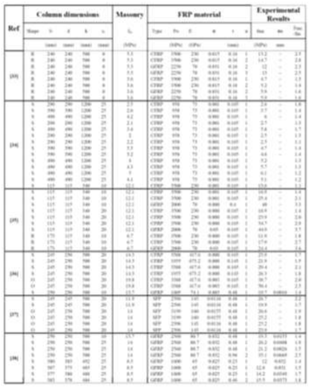



Steel cord rupture

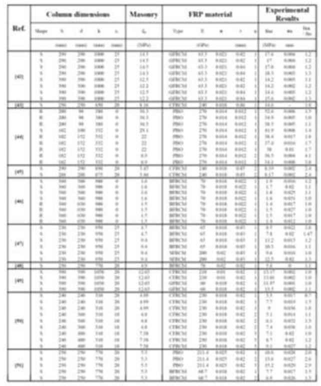
Vertical cracks (along the column corner)

Data Collection

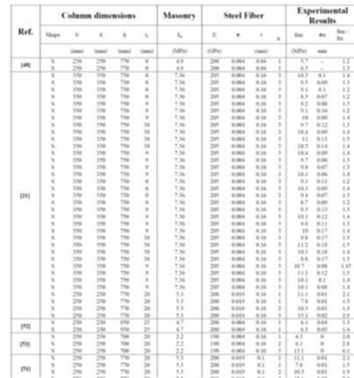
Data was collected from a wide variety of journal publications and technical reports from available sources from around the globe.



FRP Studies



FRCM Studies



SRG Studies

Reference, Geometry, Material Properties, Experimental Results

Data Analysis

- EQUIVALENT FIBER REINFORCEMNT INDEX (EFRI)

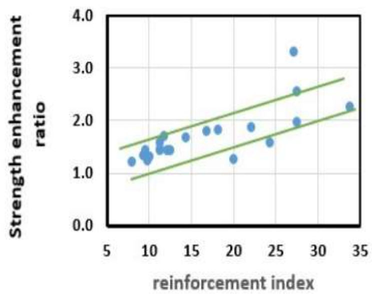
To propose an appropriate index to capture the key factors that control the behavior of confined masonry columns, the EFRI was considered. EFRI is a factor combining the geometry, masonry, and fiber properties together as represented:

$$\boldsymbol{\omega_f = \rho_f E_f / f_m\,(h/d)}$$

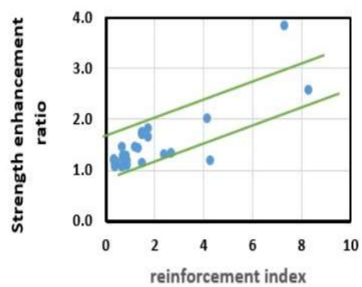
Where ρ_f is fiber reinforcement ratio, E_f is fiber tensile modulus of elasticity, f_m is compressive strength of masonry, h/d is the slenderness ratio.

Data Analysis

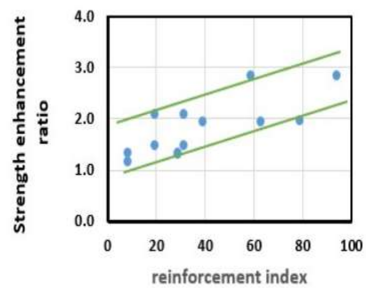
On average, the trend of improving the strength enhancement ratio is nearly linear with the EFRI. For the FRP database, the band width (**parallel green lines**) to cover a high percent of data is very narrow and less scatter compared with other systems.



FRP system



FRCM system



SRG system

Reinforcement Index vs. Strength Enhancement Ratio Relationship

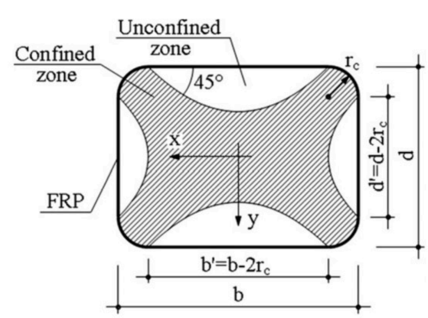
Data Analysis

EVALUATING DIFFERENT ANALYTICAL MODELS

Six analytical models have been chosen (three for the FRP system and the other three for the FRCM system) for the purpose of evaluation based on the following general expression:

$$f_{mc} = f_{mu}\left[\alpha + \grave{k}\left(\frac{\grave{f}_{eff}}{f_{mu}}\right)^{\alpha_1}\right]$$

Where f_{mc} is the masonry confined compressive strength, f_{mu} is the masonry unconfined compressive strength, f_{eff} is the effective lateral confinement pressure. $\alpha, \grave{k}$ and α_1 are non-dimensional parameters.



Confinement of Rectangular Sections Externally Wrapped with Advanced Composite

Data Analysis

EVALUATING DIFFERENT ANALYTICAL MODELS

$$f_{mc} = f_{mu}\left[\alpha + \grave{k}\left(\frac{\grave{f}_{eff}}{f_{mu}}\right)^{\alpha_1}\right]$$

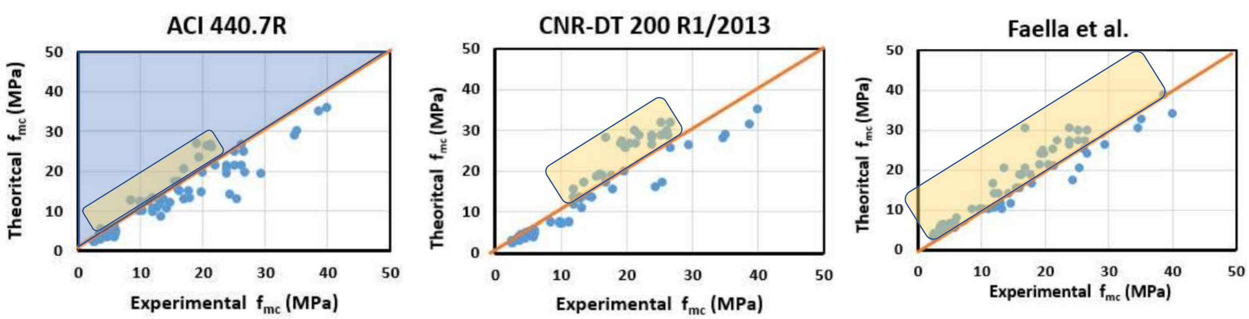
Numerical Coefficients Provided by Different Analytical Models

Theoretical formulation	α	$\acute{k}$	$\acute{\alpha}_1$
FRP models			
CNR-DT 200-13 [59]	1	$g_m/1000$	0.5
Faella et al. [57]	1.618	$0.013(g_m/1000)^{6.324}$	1
ACI 440.7R-10 [60]	See equations from 5 to 8		
FRCM models			
CNR-DT 215-19 [61]	1	$g_m/1000$	0.5
Balsamo et al. [58]	1	$(g_m/1000)^{0.662}$	1
ACI 549.4R-20 [62]	See equations from 9 to 12		

g_m= nominal density of the masonry (kg/m^3)

Data Analysis (FRP)

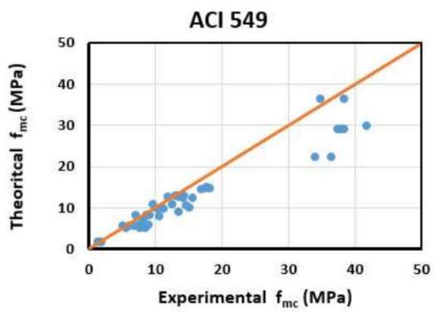
EVALUATING DIFFERENT ANALYTICAL MODELS

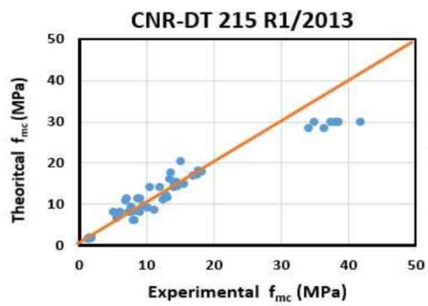


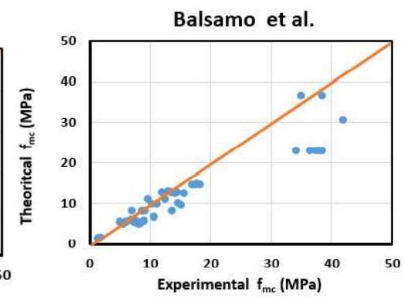
Theoretical Models for FRP

Data Analysis (FRCM)

EVALUATING DIFFERENT ANALYTICAL MODELS



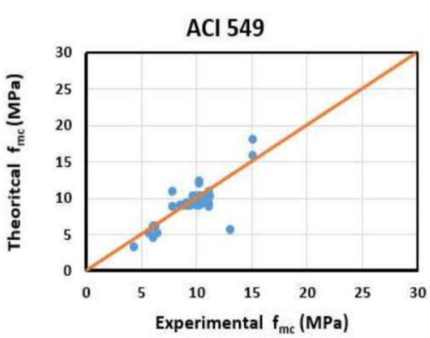


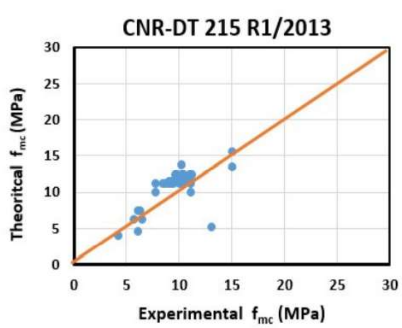


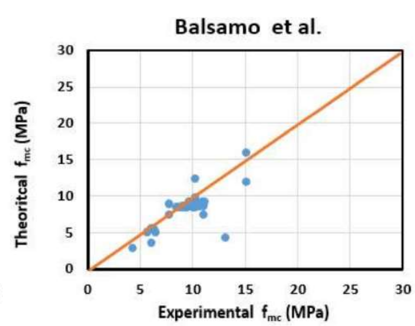
Theoretical Models for FRCM

Data Analysis (SRG)

EVALUATING DIFFERENT ANALYTICAL MODELS







Theoretical Models for SRG

CONCLUSIONS

Different modes of failure were reported such as:

- **Crushing of masonry** due to weak tensile behavior of masonry units.
- **Rupture of fiber** due to dilation of masonry unit or stress concentration developed at sharp corners, and **local buckling of fiber sheets** due to fiber excessive axial strain developed in hoop direction.
- The **combination of fiber rupture and partial slippage of the fibers** through the matrix of FRCM or SRG system.
- **Opening of the SRG jacket** is the other possible mode of failure that happened due to cracks developed on column surface.

CONCLUSIONS

Most of the selected models predicted the confined capacity conservatively.

- The models in **ACI 440** and **ACI 549** showed very good predictions for the **capacity of confined masonry columns** strengthened using FRP, FRCM and SRG respectively.
- The **trend of improving the strength enhancement ratio** is nearly linear with the Equivalent Fiber Reinforcement Index (EFRI).
- For the **FRP database assembled**, the band width to cover a high percentage of data is very narrow with less scatter compared with other systems.

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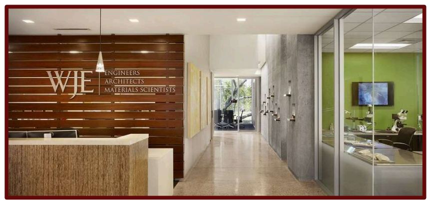

This concludes The American Institute of Architects Continuing Education Systems Course

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