BAMBOO REINFORCEMENT for SEISMIC IMPROVEMENT

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Research Objectives

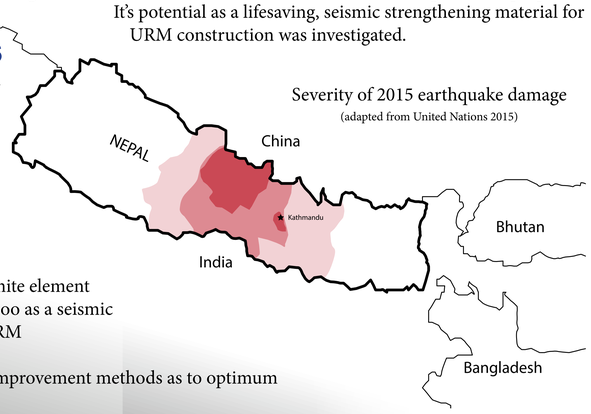
PROJECT SIGNIFICANCE

In seismic events, unreinforced masonry (URM) buildings are highly susceptible to collapse and put many peoples' lives at risk. In a country with high seismicity such as Nepal, it would be recommended that people do not construct with URM in the first place. This building typology, however, is ingrained in the region's vernacular, and economic constraints make it unviable to completely change building culture and heritage. Common strengthening techniques for URM require the use of materials which are often too expensive or difficult to access by people in developing countries. **A human-centered design solution is needed**. Bamboo is a natural, sustainable, fast-growing, and readily-available material which exhibits strong material properties. It's potential as a lifesaving, seismic strengthening material for URM construction was investigated.

RESEARCH AIMS

Relevant literature was reviewed and found:

- Lack of comprehensive investigation on the use of horizontal bamboo reinforcement in low-cost masonry structures
- Minimal implementation of finite element analysis (FEA) to model bamboo as a seismic strengthening technique in URM
- Minimal comparison within improvement methods as to optimum parameters, sizing and design

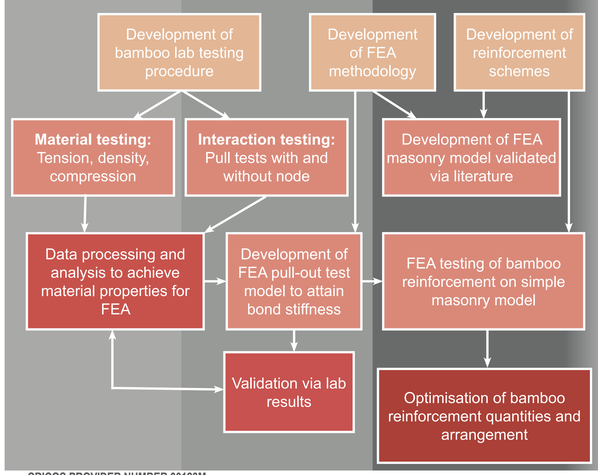


Severity of 2015 earthquake damage
(adapted from United Nations 2015)

AIM 1
Investigate bamboo material properties

AIM 2
Investigate bamboo-mortar interaction and model with FEA

AIM 3
Develop and model reinforcement solutions



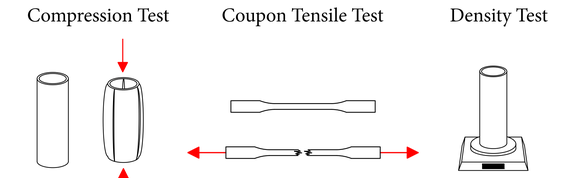
WHY BAMBOO?

- Cheaper than steel and concrete (typical materials of high seismic performance)
- Can be treated to prevent insect and weather damage
- A sustainable material that stores carbon from the atmosphere
- Rapid growing, naturally-occuring material abundant in the region
- Strong material with the potential for high seismic performance
- Locally-known construction material with precedence as scaffolding throughout the region

CRICOS PROVIDER NUMBER 00123M

Material and Interactions

BAMBOO PROPERTY TESTS

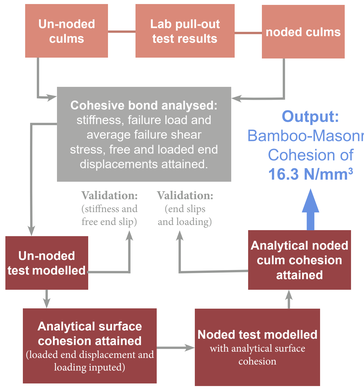


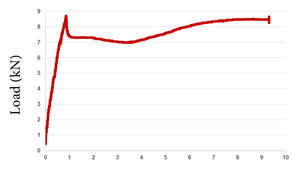
Compression Results: strength: 84 MPa

Tension Results: strength: 134 MPa, Young's modulus: 14700 MPa

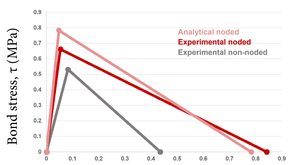
Density Results: density: 1859 kg/m^3

BAMBOO INTERACTION TESTS AND FEA

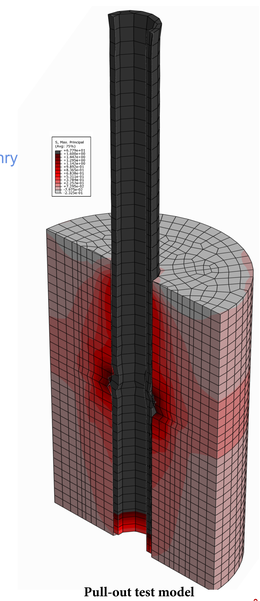




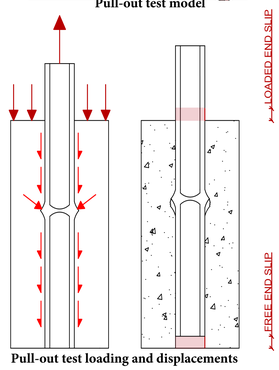
Example graph of loading to displace bamboo sample from mortar



Local bond stress-slip relationship for bamboo in mortar



Pull-out test model



Pull-out test loading and displacements

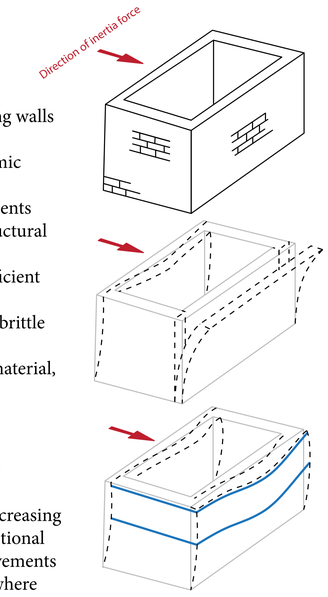
Seismic Reinforcement

FEA MODEL OF SEISMIC BANDS

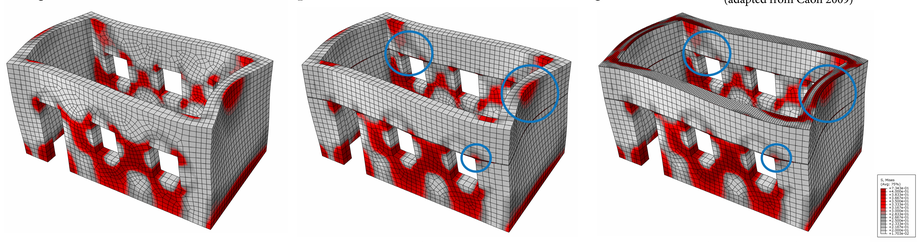
- Seismic bands act to support a building under earthquake loading by tying walls together
- Bamboo can potentially replace conventional steel for reinforcing of seismic bands
- A computer model of a simple masonry building with different arrangements of bamboo seismic bands was generated to analyse their influence on structural strength under earthquake loading
- Macro modelling (applying smear properties to a wall) was used as an efficient and easy way to model and change different reinforcement arrangements
- Concrete damage plasticity effects were incorporated to model the quasi-brittle behaviour of masonry
- Finite Element Analysis allowed analysis of bamboo as a reinforcement material, using material properties investigated in the laboratory

FINDINGS

- Addition of bands was found to reduce displacement and stress at critical locations (such as the top of weak walls)
- Increasing the volume of bamboo in each band was effective at further increasing strength however had diminishing returns – using bands with a cross-sectional area equivalent to six pieces of bamboo had negligible cumulative improvements
- Moderate reduction in displacement of up to 3.5% found at top of walls where maximum displacement occurs
- Significant reduction in stresses of up to 14% between windows at 1.5m height



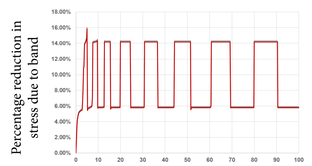
Structure under loading without and with seismic bands
(adapted from Caon 2009)



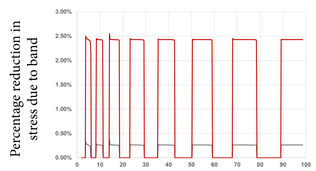
House with no seismic reinforcement

Addition of lintel band only
(stresses redistributed to seismic band)

Addition of lintel and roof band
(stresses redistributed to seismic bands)



Maximum principle stress 1.5m above ground between windows



Maximum principal stress at exterior top of southern wall

FUTURE RESEARCH

It is recommended that future research should:

- Develop and carry out additional material testing procedures to refine model input parameters
- Implement local bond stress-slip model incorporating a residual friction component
- Continue investigation into the impact of seismic bands against specific failure mechanisms
- Further develop FEA model in terms of complexity and overarching application in varying contexts

REFERENCES

- Caon, E 2009, *Progettazione sismica edifice in muratura*, Casa Innovativa, viewed 10 October 2018, <http://www.casainnovativa.com/strutture/antisismica/progettazione-sismica-edifici-in-muratura>.
- United Nations 2015, *Nepal – severity of districts in term of the earthquake intensity area*, no scale, United Nations, New York.