



Shear Test Procedure for Rammed Earth

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Abstract / Summary

With growing awareness of sustainable construction, use of rammed earth and study of its mechanical parameters are proven vital. Rammed earth behaviour under lateral load and shear strength parameters plays an important role in protecting and designing new structures. Considering shear strength as a vital parameter, this paper introduces an experimental approach to study the shear strength parameters of the rammed earth wall interface. Customised wedges with different inclination are used to induce shear and normal force on the samples, and digital image correlation method was adopted to measure the displacement of samples using VIC-3D tool. Along with the shear strength of the rammed earth samples this paper presents the cohesion and angle of internal friction of the rammed earth interface under bi-directional loading. These parameters will be of helpful in understanding the behaviour of the rammed earth wall under lateral loads.

Introduction

Rammed earth technology in building construction is an ancient methodology (Jaquin 2011), which has reinstated as a locally available and sustainable construction material and researchers around the globe are investigating its mechanical parameters (Araki, Koseki, and Sato 2011; Q. Bui et al. 2014; Hall and Djerbib 2004; Maniatidis and Walker 2008) to understand and promote its usage in rapidly growing construction industry. Along with compressive characteristics, it is very important to understand the shear parameters which play a vital role in failure under lateral loading. Since rammed earth is a layered structure study of interface behaviour is critical (Bui and Morel 2009; Cheah et al. 2012; Silva et al. 2014) to understand rammed earth wall under lateral loading. In this study, the surface deformation of the material is measured using Digital image correlation (DIC) method, which is been widely accepted to measure surface deformation of materials (Pan et al. 2009; Sutton et al. 1983) (T.-T. Bui et al. 2014). This method uses the speckle pattern images captured during loading to calculate the deformation and thus eliminates the usage of extensometer or strain gauges that to be attached on the specimen surface.

Specimen Preparation & conditioning

The soil chosen for manufacturing test specimens are extracted from the construction site in cras-sur-reyssouze, Ain, France. Weighed soil (prepared) was mixed at 10% water by weight of the soil and stored in an air tight plastic bag for 24 hours to obtain moisture equilibrium. Using weigh batching, known quantity of soil per layer was manually rammed in a formwork until the layer thickness of 60mm (+2mm) is achieved. Specimens of dimension 208mmx120mmx120mm & 120mm cube (Figure 1) were manufactured for testing at 30° & 45° inclinations respectively. Specimens were stored in a climate controlled room at 25°C and 50% relative humidity for about 25 days, the average moisture present in the specimen during testing was about 2%.

Experimental procedure

Wedge Design

The shearing properties of the interface can be studied by applying the biaxial loading to the interface by varying specimen angle of inclination. In order to induce biaxial load, two set of metallic wedges (shown in Figure 2) were designed, such that the specimen layer inclination (θ) with the vertical axis of the loading press is at 30° and 45°. Each set has an

identical bottom and top wedge with width of 120mm. Wedges are designed such that, when specimen is positioned, top layer of the specimen is fixed and the incremental load is applied from bottom without blocking the layer movement.

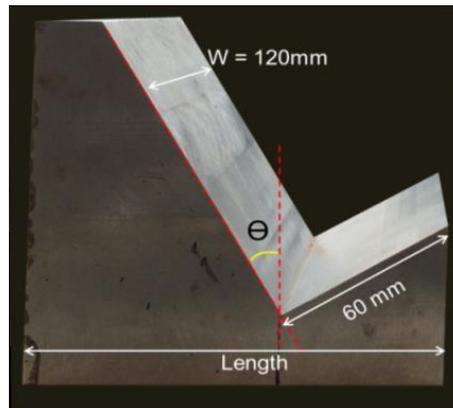


Fig.2

Experimental Procedure Specimen surface Preparation

Specimen surface undulation has to be levelled so as to establish a good contact between specimen and wedge. Before preparing speckle pattern, any dust or loose particle present on the specimen surface should be removed using a soft brush. Well distributed random speckle pattern are marked on the prepared surface by using black coloured spray. Speckle pattern should be as fine as possible without any dark spots to ensure more subset within the area of interest (AOI), which yields more accurate correlation of analysis.

Camera positioning

Specimen is positioned in between the wedges ensuring symmetry on vertical axis with speckle pattern facing cameras. Cameras are then oriented in line with the specimen testing angle, such that the optical x-axis is parallel to specimen interface as shown in Figure 3. By illuminating additional light source on specimen surface, camera aperture is adjusted until the ideal brightness is achieved. Cameras connected to VIC-3D system are calibrated by capturing images of the calibration gird (Figure 4) at different orientation, which is positioned in front of the specimen AOI surface, a minimum of 10 images per surface are captured for calibration process.

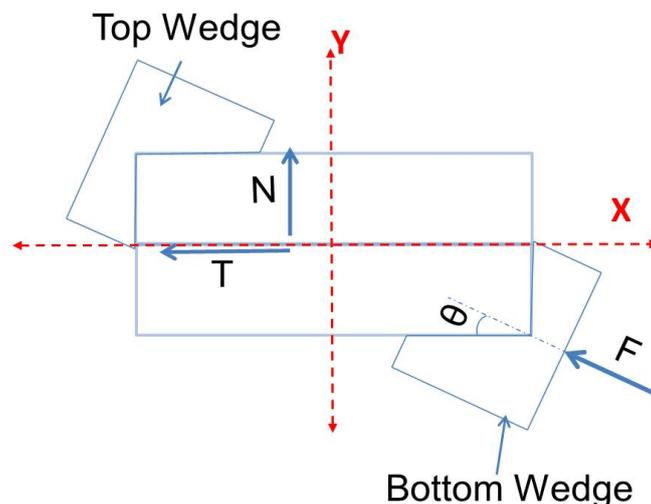


Fig. 3

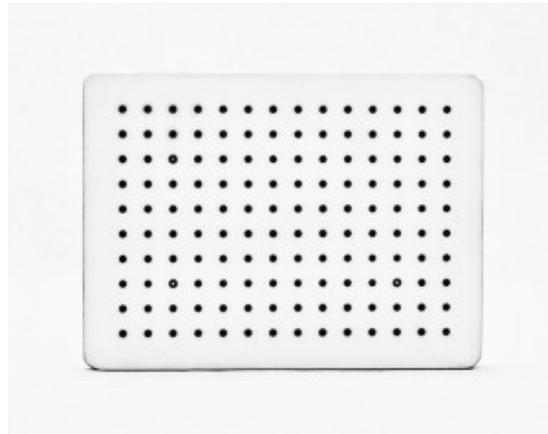


Fig. 4

Loading

Loading of specimen is initialized by defining VIC-3D software to capture an image per second until rupture. Considering low strength of unstabilised rammed earth, loading of the test is programmed at a constant displacement rate of $5\mu\text{m/s}$. Force per image is recorded in the VIC-3D system through analog data transfer.

The failure load [F] obtained from the test is resolved to calculate the maximum shear force [T] and normal force [N] acting on the specimen as shown in Figure 5: Resolution of forces on the specimen interface.

$$T = F \cos \theta, N = F \sin \theta, \tau = TA, \sigma_n = NA$$

F = Force [N], T = Shear Force [N], N = Normal Force [N], θ = Inclination angle of force with respect to interface, A = Area of Interface [mm^2], τ = Shear Stress [MPa], σ_n = Normal Stress [MPa].

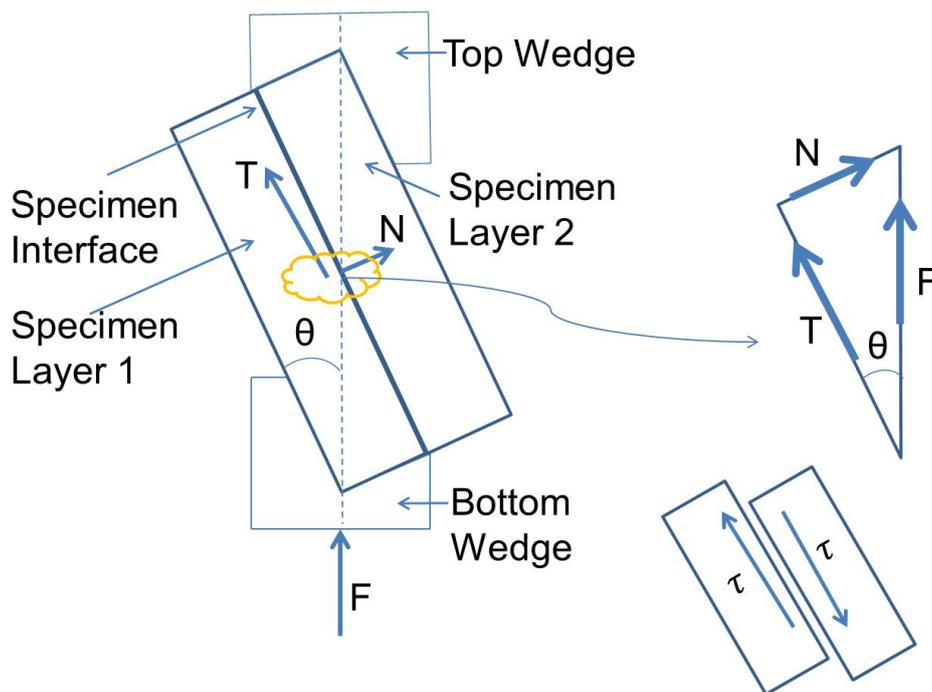


Fig. 5

Digital image correlation

Surface displacement of the specimen is calculated by correlating the speckle images captured during the test with respect to the reference image using VIC 3D tool. As default, VIC 3D considers optical view coordinate (Figure 3) as the reference for correlating speckle pattern to process displacement in 'u' and 'v' directions. In this analysis, surface displacement is calculated by defining fixed boundary condition as shown Figure 6. Within the AOI the inspection rectangles P1, P2, P3 & P4 are defined to investigate the displacement of the material within the inspection area.

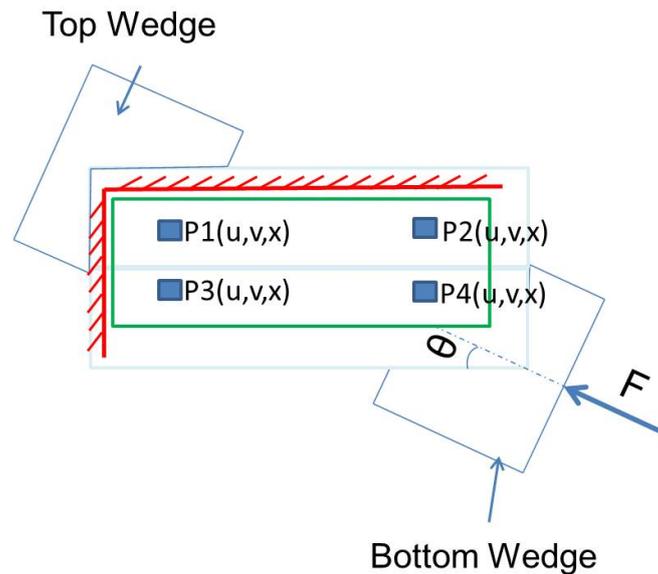


Fig. 6

Results & Discussion

Shear strength of interface

The failure load of the interface is resolved into shear force and normal force, the average failure shear stress of the specimen tested at 30° inclination was calculated to be 0.13MPa for average failure normal stress of 0.07MPa, and at 45° inclination it is 0.86MPa. The shear strength of the unstabilised rammed earth wallet tested in diagonal compression test was found to be 0.7MPa (Silva et al. 2014), the failure reported is combination of diagonal failure and interface delamination. Whereas the failure observed in this test is due to delamination of the interface under pure shear.

The shear strength of the soil tested at 45° was found to be 33% of the compressive strength (cylindrical specimen) of the soil tested with same density, whereas the shear strength found in diagonal shear test (Silva et al. 2014) was 19% of the compressive strength of similar wallet. The difference in correlation between two studies may be attributed to change in dimension of the specimen, and also it should be noted that, in this study only interface delamination is studied unlike multi-layered specimen tested by (Silva et al. 2014).

Six specimens (three in each inclination) were tested and its failure stress are plotted to draw the coulomb's failure line (shown in Figure 7), from coulomb failure line cohesion of the unstabilised rammed earth interface was found to be 55kPa with angle of internal friction as 43° . The results fall in close agreement with the investigation of (Corbin and Augarde 2015) for unstabilised rammed earth specimens using direct shear test in which

the cohesion and angle of internal friction was reported to be around 30-90kPa and 39°-68° respectively.

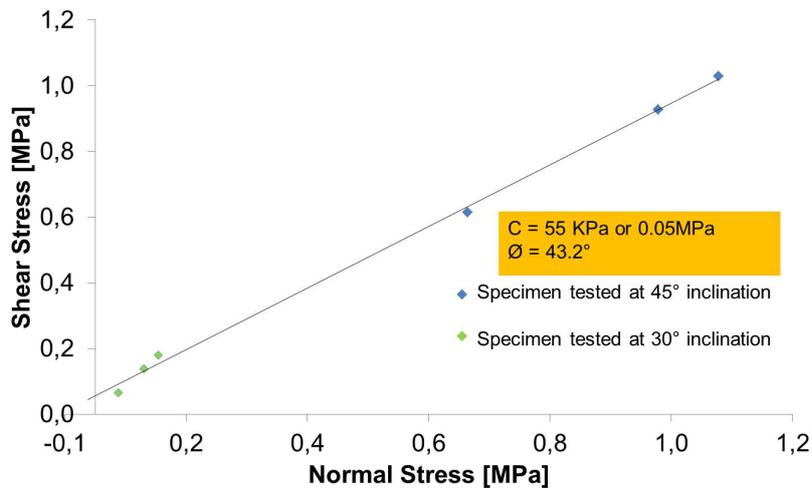


Fig. 7

Shear modulus of interface

Shear strain calculated from the displacements extracted using VIC 3D software are plotted against the respective shear stress. An example of the shear stress stain graph is shown in the Figure 8. The shear strain on each surface is calculated and the average shear strain of both the surface is considered as the interface shear strain. The slope of the best fit linear line is taken as the shear modulus of the material. The average shear modulus of the material at 30° & 45° inclination is found to be 205MPa & 292MPa.

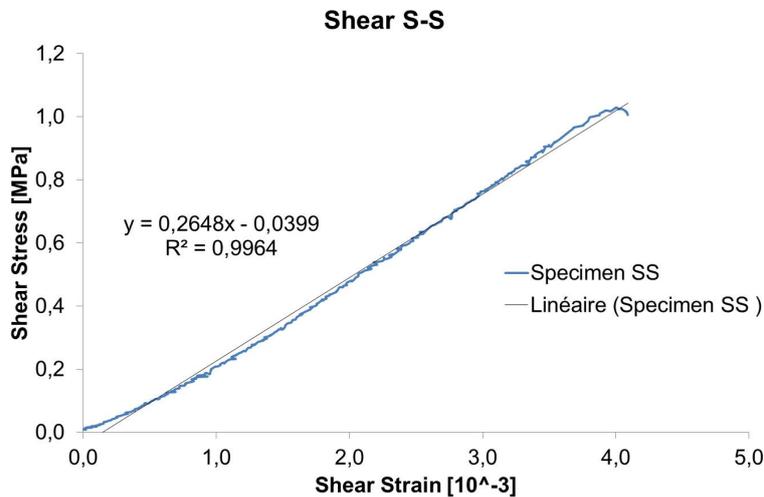


Fig. 8

Conclusion

Shear strength of the rammed earth structures is vital, considering the layered structure, interface shear strength parameters plays crucial role in understanding the behaviour of unstabilised rammed structure under lateral loads. In this paper, an experimental approach using inclined wedges to subject specimens under bi-directional loading is presented. From experiment, it was also found that the interface shear strength is 33% of the compressive strength. The advantage of this approach is that, it reduces the specimen size and uses a classical device in simple axial compressive press to induce both shear

and normal load. In this study, DIC is adopted to study the strain fields of the specimen to calculate the shear modulus. Along with the shear strength of the interface, this approach enables to calculate cohesion and angle of internal friction of the interface, which are found to be 55kPa and 43° for the soil tested. This experimental procedure would be extended to test specimens with different moisture content, to observe the influence of moisture content and also at more inclinations to plot coulomb's failure envelope.

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Biography

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Abhilash H N is currently pursuing PhD in Doctoral school of ENTPE, Lyon, has completed his post graduate programme in advance construction management from NICMAR, Pune (INDIA). He is interested in continuing research work on sustainable building materials.

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