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RESEARCH AND DEVELOPMENT

New slump test – a 21st-Century vision integrating rheology

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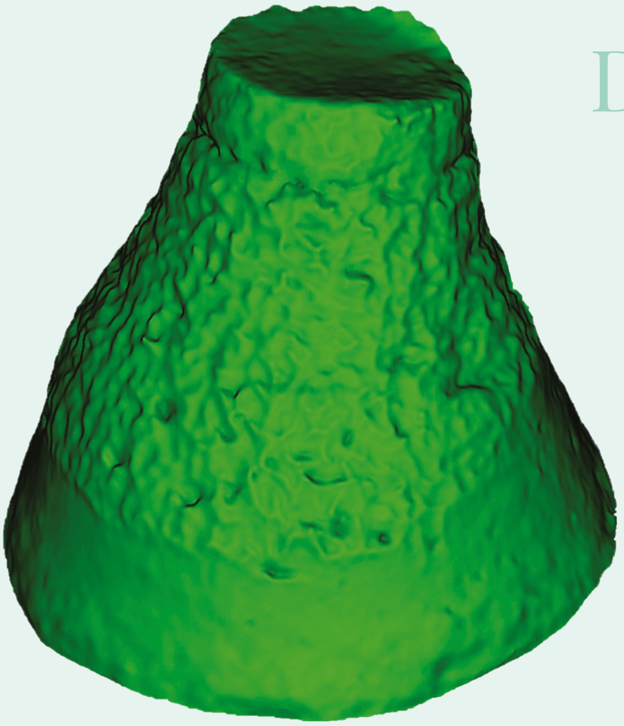


Digital Reconstruction of the Slump Test – a 21st-Century vision integrating rheology

Callum White and **Janet M Lees** of the **Concrete Infrastructure Research Group**, at the **University of Cambridge**, provide an overview of the development of a digital reconstruction of the slump test.

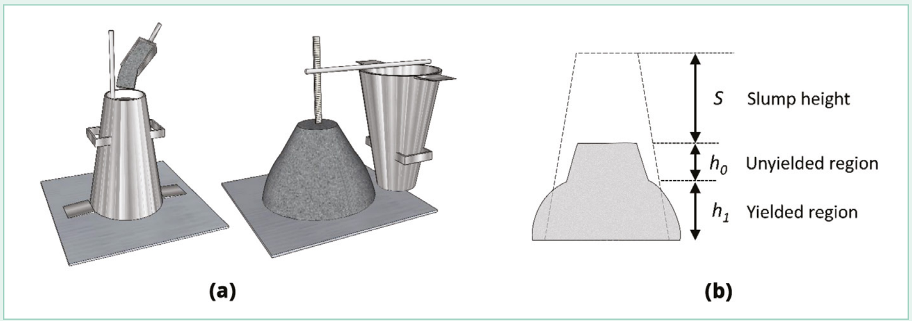
Concrete use significantly contributes to climate change, air pollution and biodiversity loss. To address these issues collectively, the concrete sector must prioritise waste reduction and focus on increasing material efficiency. This can be accomplished by adopting performance-based design strategies supported by increased confidence in mix performance. Effective data collection and curation can lead to a better understanding of material behaviour and performance. Although data collection is becoming more common in the concrete industry, it is essential to prioritise the data that has the most significant impact on decision-making leading to sustainable outcomes. The University of Cambridge Concrete Infrastructure Research Group's interests in Sustainable Digital Concrete are dedicated to enhancing data availability in crucial areas of influence. The Sustainable Digital Concrete project seeks to develop innovative techniques by combining modern technologies with traditional testing methods to gain deeper insights into concrete behaviour.

UNDERSTANDING FRESH-STATE CONCRETE

The Abrams cone slump test is a standard method used to evaluate the consistence of fresh concrete (Figure 1). The slump test primarily provides information on delivery consistency but does not currently offer much insight into material behaviour. In contrast, torque vane rheometer measurements of parameters such as concrete yield stress and plastic viscosity provide a deeper understanding of the behaviour of concrete in its fresh state (see Tattersall[1]). However, despite the value of such data, the relatively high cost of rheometers and potential impracticality for use on all but the largest projects have prevented their widespread use in concrete practice.

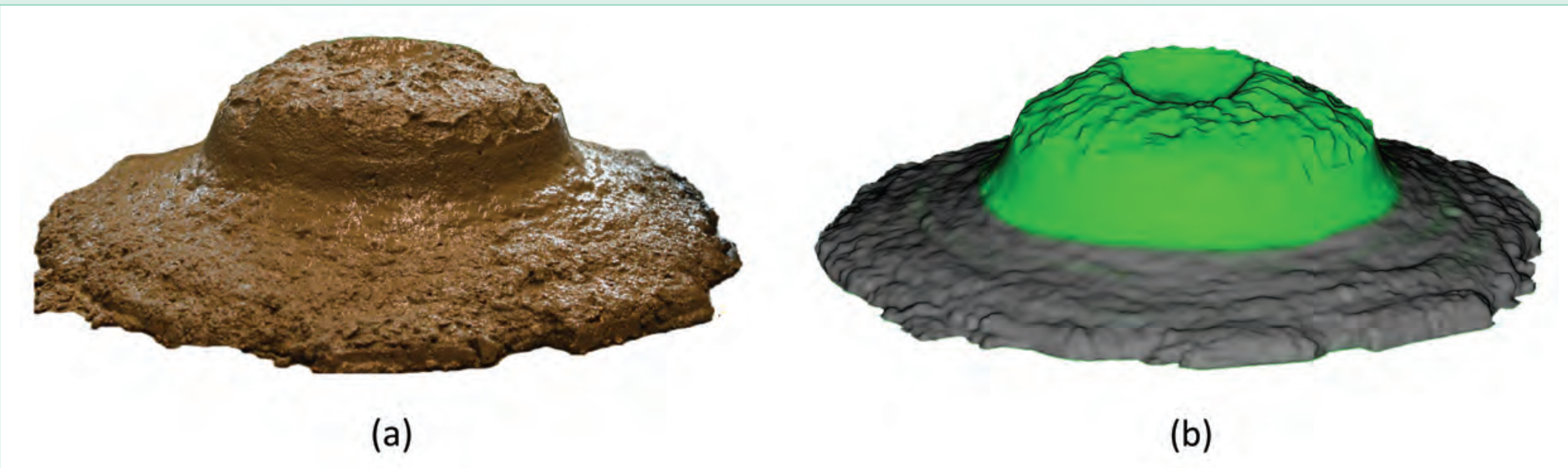
Currently, the 'slump height' *S* is measured as the distance between the deformed shape and the original height of the cone. However, in a more nuanced approach, the slumped concrete structure can be divided into two main parts: the yielded and unyielded sections (Figure 1). In this way, the observed slump can be related to the concrete yield stress using the force balance deformation approach, where the yield stress is proportional to the weight of the concrete acting above the yielded region (see Tanigawa *et al*[2]). However, a barrier to adoption has been the difficulty in measuring the height of the unyielded region. Previous studies have used total slump height as a substitute measurement, but this introduces significant inaccuracies in yield stress prediction (see White and Lees[3]). The Cambridge Digital Slump Reconstruction provides a novel method to measure the height of the unyielded region, allowing for yield stress predictions with increased accuracy and for more useful information to be derived from the quick and straightforward slump test.

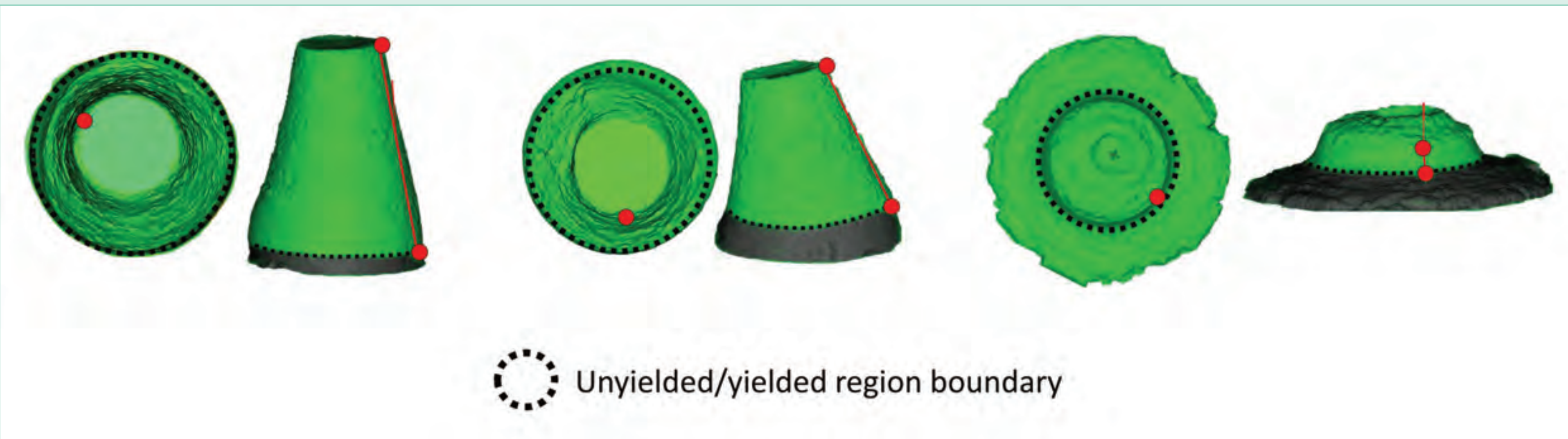
BELOW:
Figure 1 – standard slump test: (a) measurement of the difference between the deformed and original height; (b) schematic demarcation of yielded and unyielded regions within the slumped profile.



CAMBRIDGE DIGITAL SLUMP RECONSTRUCTION

The Cambridge Digital Slump Reconstruction was developed based on the adoption of 3D reconstruction technology. In this field, surfaces and profiles are captured through point cloud data and textural information, which enables the creation of models





TOP:
Figure 2 – concrete slump profile: (a) 2D camera image; (b) 3D reconstruction demonstrating the unyielded region.

ABOVE:
Figure 3 – examples of measurements of unyielded height taken for a range of slump profiles.

for scanned objects. In the case of the developed Digital Slump Reconstruction, these methods are used to accurately measure the height of the unyielded region for the first time. Tests across a range of concretes were undertaken in the UK Collaboratorium for Research on Infrastructure & Cities (UKCRIC) National Research Facility for Infrastructure Sensing (NRFIS) at the University of Cambridge. The slumped profile was captured for different concretes via an Artec Leo 3D scanner. The example shown in Figure 2 demonstrates that the 3D reconstruction approach can clearly capture the slump profile. As shown in Figure 3, the scanning techniques proved to be applicable across a range of consistencies and the developed methodology was successfully used to find the unyielded height of concrete. The unyielded height was then combined with the application of the von Mises yield criterion to predict the concrete yield stress. The accuracy of the yield stress predictions obtained via the Digital Slump Reconstruction was verified through a comparison with torque vane rheometer measurements. The predicted and measured yield stress was found, on average, to deviate by less than 5% (White and Lees[3]).

CONCLUDING REMARKS

The proposed Cambridge Digital Slump Reconstruction allows for the accurate derivation of the yield stress value from an existing slump test for the first time. Compared with alternative approaches, the system has several practical advantages. For instance, it requires minimal intervention in the current construction process. The 3D scan is taken once a slump test is complete and additional test material is unnecessary. As a widely adopted technology in other fields, 3D reconstruction systems are becoming more affordable. This will make system implementation over time more accessible, particularly when compared with rheometer options. The Digital Slump Reconstruction has the potential to provide more useful information from the current slump test, enhancing fresh state behavioural understanding. From this, better predictability of mix performance can be achieved, driving down waste and increasing material efficiency.

Acknowledgements/further information:

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The University of Cambridge Concrete Infrastructure Research Group (CIRG) focuses on the lifetime extension of existing infrastructure assets, the use of new materials in construction, more sustainable concrete and creating innovative structural solutions. Visit: *www.cirg.eng.cam.ac.uk*.

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