Determination of Static Modulus of Elasticity of Concrete in Compression using Digital Image Correlation (DIC) Method

TB Loh[1a], Yutong Wu[1], SH Goh[2], KH Kong[3], KL Goh[4] and JJ Chong[5]

[1a,4,5] Newcastle University in Singapore, SIT Building @ Nanyang Polytechnic, 172A Ang Mo Kio Avenue 8 #05-01, Singapore 567739

[1,2,3] National University of Singapore, 21 Lower Kent Ridge Road, Singapore 119077

[1a]T.B.Loh2@newcastle.ac.uk

Abstract

The modulus of elasticity of concrete is a fundamental mechanical property that indicates the stiffness of the material. Uniaxial compression test (UCT) is a common method for determining the modulus of elasticity of the concrete. This is done by attaching a compressometer to the cylindrical concrete sample to measure the deformation of the concrete sample while the compressive load is applied. This paper presents the displacement measurement technique using Digital Image Correlation (DIC), a non-contact-based method as an alternative method to determine the modulus of elasticity of concrete.

Introduction of Experimental Setup

Digital image correlation (DIC) is a non-contact optical technique that processes digital images to measure the displacements of an object's surface [1, 2]. To validate the proposed methodology, a normal weight cylindrical concrete sample with a height of 300 mm and a diameter of 100 mm was loaded by a Universal Testing Machine (UTM). The displacement was measured using both conventional contact-based and non-contact-based methods.

For the contact-based method, a compressometer with four Linear Variable Displacement Transducers (LVDT) was mounted around the sample to measure the deformation. The time and applied load were recorded by a data logger connected to the machine.

A commercial DIC system developed by Imetrum was used for the non-contact-based method. The hardware consists of a computer processing unit connected to a monochrome camera (IM-Cam-033-UVX) with 25 mm lenses. Video Gauge software tool was used to manage the controlling, capturing, processing, and analysing of the non-contact measurements. The camera was positioned at a distance of 1 m from the targets set at the surface of the sample as shown in Fig. 1.

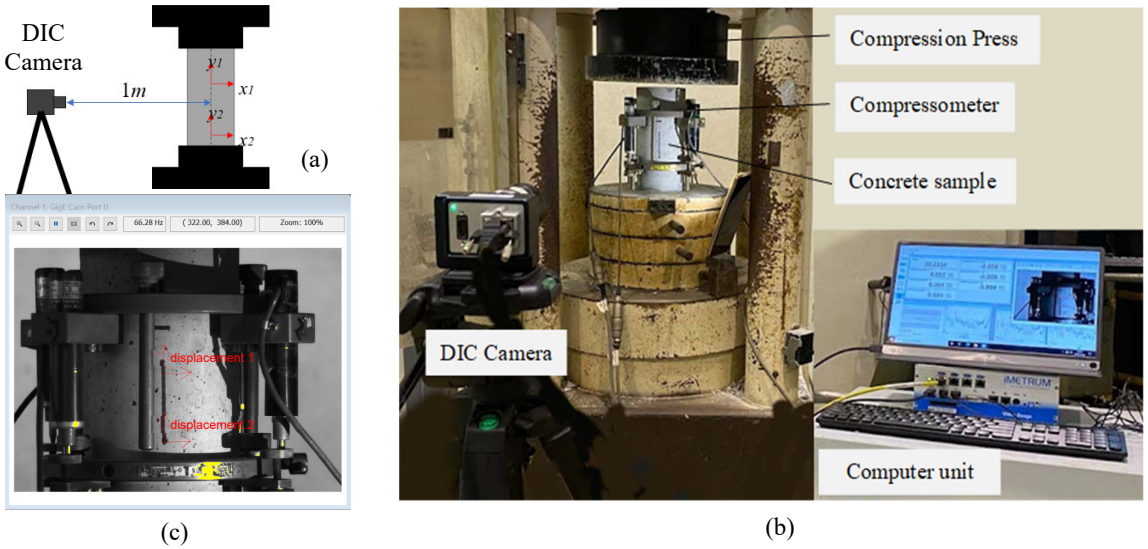

Fig. 1. (a) Schematic and (b) photo of equipment setup showing the position of the DIC camera, (c) field of view of natural targets captured by Video Gauge software

Theoretical Background

The elastic modulus of concrete or secant modulus (E_c) is the slope of a line drawn from the origin to a point on the stress-strain curve corresponding to 40% stress [3] of the failure load ($f'c$) and its corresponding strain. Strain (ε) is defined as the displacement (Δl) between particles in the body relative to a reference length. In the DIC method, the strain of the concrete is computed by dividing the deformation (δ) ("displacement 2" minus "displacement 1") by the reference length (L) Eq 1:

$$\varepsilon = \frac{\Delta l}{L} = \frac{\delta}{L} \tag{1}$$

hence the secant modulus (E_c) becomes Eq 2:

$$E_c = \frac{0.4f'c}{\varepsilon} \quad \text{(MPa)} \tag{2}$$

Results and Discussion

The strain computed using the values measured by DIC and LVDT is shown in Fig. 2. The sample was pre-loaded to a compressive stress of 36 MPa and held for 50 seconds before unloading. It was held for another 50 seconds before loading to fracture at the ultimate compressive stress ($f'c$) of 51 MPa. Table 1 shows the comparison of strain measurement using DIC and LVDT at the stress point of 0.4 $f'c$ (20.4 MPa). DIC result has a 2.4% deviation from LVDT. Table 2 shows the comparison of modulus of elasticity (E_c) calculated from DIC and LVDT measurements. The comparison shows that the DIC result has a 2.8% deviation from the LVDT result.

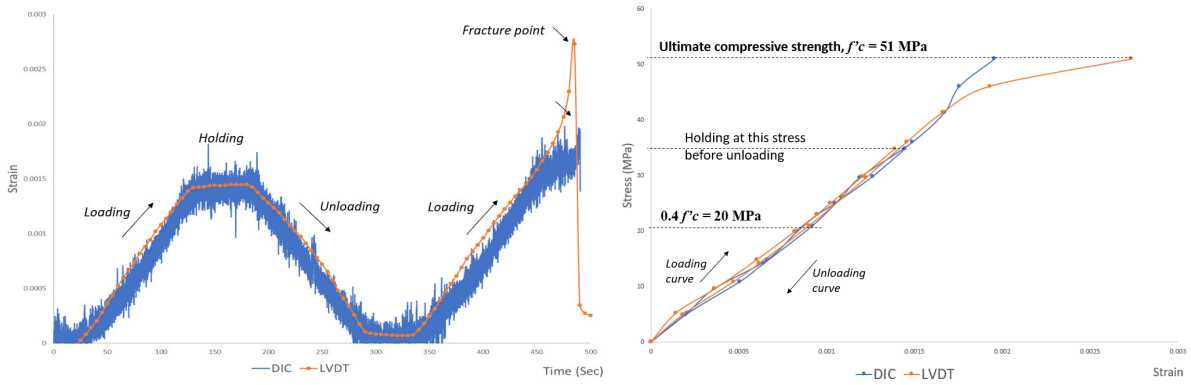

Fig 2. (a) Comparison of deformation measurement using DIC and LVDT (b) Comparison of the stress-strain curve using DIC and LVDT

Strain (ε) at 0.4 f'_c ($1x10^{-3}$)		Deviation
DIC	**LVDT**	
0.83	0.81	2.4%

Table 1. Comparison of strain measurement using DIC and LVDT

Modulus of elasticity *Ec* (GPa)		Deviation
DIC	**LVDT**	
24.1	24.8	2.8%

Table 2. Comparison of modulus of elasticity calculated from DIC and LVDT measurement

Conclusion

This study has shown that Digital Image Correlation (DIC) method can be used to obtain the static modulus of elasticity of concrete accurately. The results show good agreement with LVDT measured values. Compared with the conventional contact-based method, DIC has the advantage of being non-contact and being able to directly measure the deformation on the surface of the concrete sample.

References:

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3. Mehta, P.K. and P.J. Monteiro, *Concrete microstructure, properties and materials*. 2017.