Study on displacement and strain of concrete cubes using
digital image correlation (DIC)

Nadia Putri Wijanarko*, Essy Arijoeni and Bastian Okto Bangkit Sentosa
Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia,
Depok, West Java, 16424, Indonesia

*Email: nadia.wijanarko@gmail.com

Abstract. Digital Image Correlation (DIC) is a new, cutting edge technology employed the
study full-field displacement of materials; concrete included. DIC uses the help of digital
images that was recorded sequentially during testing period. There had never been a research
conducted using the method in Universitas Indonesia using conventional tools. This research
proves that such thing is possible. The component and steps to DIC are extensively discussed
in the research; speckle pattern, method of record, images produced, and data computation.
Through this research, the behavior of how displacement and strain were developed when
concrete is subjected to compressive testing can be studied. The results of the research were
analyzed quantitatively using the digital images and its computation based on computer
software used. Additionally, provided that this was a preliminary research, there are many
aspects and suggestions found from this research that will be applicable for future researches.

1. Introduction
A method of digital image processing named Digital Image Correlation (DIC) is a method that has been
developed to analyze displacement and strain of a material after testing is conducted upon the material
[1]. The principle of DIC is to track the difference between two digital images; for instance, prior and
after testing, and developed correlation coefficient between the two. Correlation coefficient is then
applied to find the position of a point in the region of interest (ROI). By doing so, analysis on
displacement and strain can be conducted [2].

It is understood that DIC is now vastly applicable and easy to be done. In addition, DIC is also known
to be compatible for many types of materials as long as it possesses grey scale coloring on its surface
to ease the analysis part [3]. Grey level is essential as the difference between the color spectrum of
black and white is easier to be distinguished from one another compare if other colors is used. As it is
vastly applicable on many materials, concrete testing using DIC is also deemed possible.

In the case of concrete, DIC can be applied to analyze its displacement and strain after compression
test is conducted. It is important to do such testing and analysis of concrete as concrete is a material
that is very common used in construction. Knowing its displacement and strain will help determine
many of its other properties and the crack pattern that will appear on the surface of the concrete.
Distribution of cracks can also be detected and analyzed using DIC analysis [4]. As it is commonly
assumed, brittleness of a concrete will increase as its strength. Brittleness of a concrete will directly
influence its quality [5]. That knowledge will be useful for the future application of the concrete itself.

2. Method
The research was conducted using the following flow of research: specimen preparation, speckle
patterning, apparatus setup, compression testing, application of DIC (analysis on displacement and
strain. For specimen preparation, there will be 9 different strength values used in this particular
experiment. The 9 of them are classified into 3 grades of concrete grades which are low, moderate, and
high strength concrete. The range of each strength are: Low: 20 – 30 MPa, Moderate: 30 – 40 MPa,
Speckle patterning was conducted using the same method and tools of application. The pattern was imposed directly using marker pen with a round tip. The pattern was imposed manually by hand to gain control over the spacing and size of the pattern. Images are to be taken simultaneously with the compression test. Camera need to be set up on a tripod so that the images taken could all be uniformly still and steady. It is also important to make sure that camera stay in focus during the course of which the images are taken. In order to do so, optimum distance for camera to be set up needs to be investigated.

The configuration of the apparatus is attached below:

![Apparatus configuration](image-url)

**Figure 1.** Apparatus configuration.

Concrete cubes were then subjected to mechanical testing; compressive strength test. The test was conducted in accordance to SNI 03-1974-1990. After the test and picture recording is completed, the data can be analysed using NCORR.

3. Results and discussions

3.1. Displacement using DIC

![V-displacement](image-url)

**Figure 2.** V-displacement on low strength concrete
It is important to note that the value on the v-displacement graph had been multiplied by -1. From the v-displacement graph, it is known that the displacement value is negative. This indicates that during the compression, the specimen decreased in size. From the u-displacement graph, it is known that point 1 displaced to the right-hand side, while point 5 displaced to the left-hand side. This indicates that during compression, the specimen expanded to two sides.

![U displacement graph](image-url)

**Figure 3.** U-displacement in low strength concrete.

![V-displacement graph](image-url)

**Figure 4.** V-displacement in horizontal line - low strength concrete.

The value of displacement had been multiplied by -1. From the figure above, it is known that displacement along all the line during stress of 0 – 10 MPa is more or less uniform. As the stress increase to 20 MPa, the left-hand side experience slightly more displacement than the right-hand side, this trend continues on up until ultimate stress at 25.21 MPa is reached. Afterwards, the displacement increased significantly with point 1 experience most displacement and point 2 the least and it climbs back up until point 5. The DIC analysis of this occurrence is attached below:
On U displacement, the value of displacement had been multiplied by -1. It can be seen that displacement up until 10 MPa is relatively uniform along the line. At displacement of 11 MPa up to ultimate stress of 25.21 MPa, it is known that the value of displacement is a mirror from one end to the other with the least amount of displacement on point 3; middle of line. Pass ultimate stress, the value of displacement increased significantly. The DIC analysis of this occurrence is attached below:

![Figure 7. U-displacement in horizontal line - low strength concrete.](image)

**Figure 5.** V-displacement at stress at (a) 0 - 10 MPa and (b) 10 - 20 MPa.

**Figure 6.** V-displacement at (a) ultimate stress and (b) end of test.
3.2. Strain using DIC

It is important to mention that the strain value on the normal strain graphs above have been multiplied by -1. On strain on v direction table, it is found that the stress-strain relationship lacks linear portion and the values continually converges. However, there were still great value of stress occurring after the maximum stress is reach. The stress – strain relationship of u direction has the same characteristic with theoretical stress-strain relationship; having an almost linear line and strain significantly increase after ultimate stress at 25.2 MPa is reached.
Figure 11. U-strain of low strength concrete.

It is important to mention that the strain value on the normal strain graphs above have been multiplied by -1. On strain on v direction table, it is found that the stress-strain relationship lacks linear portion and the values continually converges. However, there were still great value of stress occurring after the maximum stress is reach. The stress – strain relationship of u direction has the same characteristic with theoretical stress-strain relationship; having an almost linear line and strain significantly increase after ultimate stress at 25.2 MPa is reached.

Figure 12. XX strain of low strength concrete at (a) ultimate stress and (b) end of test.

Figure 13. XY strain of low strength concrete at (a) ultimate stress and (b) end of test.

Figure 14. YY strain of low strength concrete at (a) ultimate stress and (b) end of test.
It is clear that as opposed to displacement map only showing movement of speckle, the strain map provides clear distinction between areas that experiences different exposure of deformation. The area with crack and deformation, shows different coloration. The result of the specimen at the end of test is attached below:

![Specimen condition at end of test.](image)

**Figure 15.** Specimen condition at end of test.

4. **Conclusions**

It is apparent from the research that the loading is not centric. A new procedure and method should be employed to ensure that the loading conducted in the lab to be centric and the stress is uniformly distributed. It is also important to check neatly whether or not the loading is placed exactly in the center prior to the testing.

Speckle pattern that is imposed has to be bold and the color difference between the pattern and the surface has to be prominent. Specimen should be tested immediately after the pattern was imposed to avoid the pattern fading away or absorbed in the specimen. The side that is to be imposed with pattern should be the one that poses the most uniform color. Additionally, during recording of the images, it is important to keep the picture steady and free from any disturbance; movement, vibration, or changes in light as it can lead to error in reading. It is important to take the picture straight to eliminate error when choosing ROI and eventually will affect the interpretation of data. As this is a preliminary study using DIC in the lab, more researches are encouraged to study further about DIC and its application for strain and displacement study.

**Acknowledgments**

Author 1 is immensely grateful and acknowledge the expertise, help, and support offered by author 2 and 3 during the research and writing of the paper. Furthermore, this research is funded and supported by Universitas Indonesia through Hibah PITTA 2019.

**References**

[1] Vacher P, Dumoulin S, Morestin N and Mguil-Touchal S 2013 *Proc. of the Institution Mechanical Engineers Part C* **213** p 811.

[2] Salmanpour A H and Mojsilović N 2013 *APCOM & ISCM (Singapore).*

[3] Blaber J, Adair B and Antoniou A 2015 *Experimental Mechanics.*

[4] Belrhiti Y, Pop O, Germaneau A, Doumalin P, Dupré J C, Huger M and Chortard, T 2016 *IOP Conf. Series: Materials Science and Engineering* **119** p 012010.

[5] American Society for Testing and Materials *Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory* No. ASTM c 192/c 192M-05 Annual Book of ASTM standards **4** p 2.