



Structural Health Monitoring: Plastic Material Assessment of Important Structures

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Abstract

Digital image processing (DIP) uses the principle of photogrammetry and is also used to track features and associate their positions with a predefined coordinate system. Measurements are made by comparing a series of images taken at regular intervals. It can be used for many tests, including compression, tension, torsion, bending, and various combined loads for static and dynamic applications. A series of quasi-static tensile tests on plastic samples with four surface-mounted fibre optic probes showed that these probes had excellent linear strain behaviour over the entire range of applied loads. A free vibration test was also performed to evaluate the dynamics based on the cantilever configuration. The sensor response results show an excellent agreement with traditional sensors. This project deals with the comparison between maximum stress generated in building and bridge structures using MATLAB® software. The comparison of the behaviour of various types of cubes such as Plain Concrete beam (28 days), 5% Plastic waste as replacement of sand (28 days), 10% Plastic waste as replacement of sand (28 days), 12.5% Plastic waste as replacement of sand (28 days) and 15% Plastic waste as replacement of sand (28 days) The results found using different methods were comparable.

1. Introduction

Currently, improvements in living conditions worldwide must focus on environmental issues in all aspects, including construction. The construction industry's goal is to contribute to the development of environmentally friendly buildings by implementing technical and design solutions to reduce the energy consumption of the building materials industry, reduce embodied energy, and minimize cost and environmental impacts (Ramana et al.). Because the quality of the environment inside buildings is a significant health factor, finding

environmentally friendly building materials is necessary (Meena and Ramana). Due to its low biodegradability and abundance, the disposal of plastic waste in the environment is regarded as a significant issue (Meena, Jethoo, and Ramana). At the time of writing, industrial and urban wastes made of polypropylene (PP) and polyethylene terephthalate (PET) were considered partial replacements for conventional concrete aggregates (Bisht, Ramana, et al. P.V. and Agnihotri Surendranath, Ramana, et al. Meena, Jethoo, and Ramana). As a result, finding alternative methods of waste disposal that are friendly is becoming a significant research prob-



lem. It reduces environmental pollution and aids in the conservation and recycling of energy production processes (Surenthranath and Ramana Bisht and Ramana). Plastic waste is a component of municipal solid waste that has recently become an important research topic to investigate the possibility of disposing of the waste in mass concrete, particularly self-compacting concrete, lightweight concrete, and pavements (Golewski). It can be used as a composite construction material, an inorganic filling material, and concrete aggregate (Shahidan Aciu et al.). Because it is widely used and has a long service life, recycling plastic waste material in concrete has many benefits and advantages because the waste is removed from the waste stream for an extended period.

Almeshal, Ibrahim, et al. (Almeshal et al.) investigated the limits and possibilities of laser speckle on samples. They concluded that a rough reflective surface is usually painted for diffuse reflectance (Alqahtani et al.). However, excessive staining of the object after displacement may result in speckle patterns that are entirely or partially decorrelated with the speckle pattern in the undeformed state of the object surface.

Ghourchian, Sadegh, et al. (Ghourchian et al.) studied the effect of partially replacing coarse aggregates with plastic and they concluded that the modified concrete mix, with the addition of plastic aggregate replacing conventional aggregate up to a certain 20% gives strength within the permissible limit (Zhao Canivell et al.).

2. Methodology

2.1. Testing of the Cube

These specimens are tested by a compression testing machine after 28 days of curing. Load should be applied gradually till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete. Compressive strength is the ability of a material or structure to carry the loads on its surface without any crack or deflection. A material under compression tends to reduce the size, while in tension, size elongates.

2.2. Statistical Method of analysis via MATLAB®

1. First, The video of whole 3-point loading test is recorded.
2. Video is converted into a large number of images using software

3. Now the whole process is done in MATLAB® using four basic commands that are used are-

- **Filelist_generator** (to select the working folder and choose the images to work upon).
- **Grid_generator** (to select a particular image on which need to generate the grid which will be analyzed).
- **Automate image** (to auto-select the images and analyse the movement of positions of grid points).

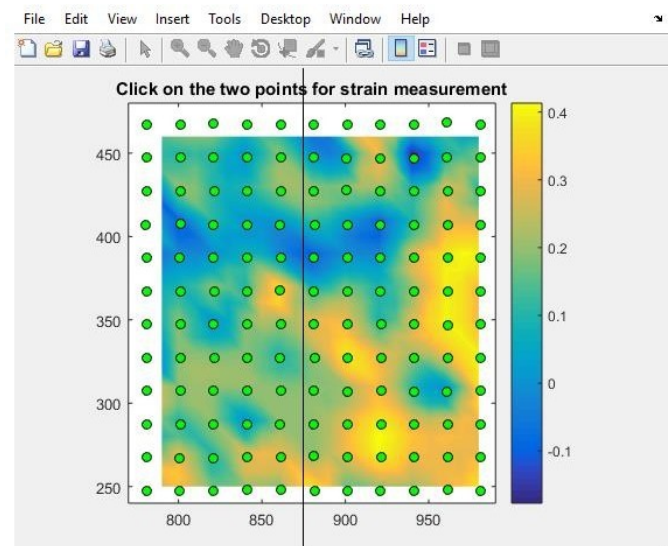


FIGURE 1. MATLAB®-Displacement - 2 Point Choose

2.3. Finite element method of analysis via MATLAB®

1. First, The video of whole 3-point loading test is recorded.
2. Video is converted into a large number of images using software
3. Now the whole process is done in MATLAB® using one basic command that is used.

DIC_GUI (A new tab will open as shown in.

a) Now insert the undeformed image that is without crack cube image.

b) Next, need to insert the deformed image that is with crack cube image as shown.

c) And then click on start and go for define the region of interest i.e. region of interest selection of the area is done where the cracks develop and the by default give the grid size 10 x 10 and then a new tab will open and go for the result of the displacement in x and y direction and magnitude of the respective direction and strains in the different direction which is ξ_{xx} , ξ_{xy} , ξ_{yx} and ε_{yy}

In Figure 1. MATLAB®- Displacement - 2 Point Choose is described.

3. Results and Discussion

3.1. Control Mix (PC)

DIC tests were performed on various concrete cube samples. This phenomenon of gradual balance as the relative load increases leads to cracks in various types of wheels. The optical method (DIC Method) is used to measure 3D and 2D displacement and surface deformation. Especially in conjunction with the available math program MATLAB®. To correlate the digital image, the speckle pattern is correctly placed on the sample surface. Some sample images were taken during the test and processed using the mathematical program MATLAB®. Some good images were selected for analysis during the upload and download process. The correlation considers a square grid of 20 pixels in the X-direction and 20 pixels in the Y-direction a three-dimensional view of the surface displacement at different loading stages. In all the graphs from Figure 2, Strain Graph for Control Mix and Deflections Graph for different Loading conditions for Control Mix in Result and Discussion the cracks can be seen as the load increases. Finally, draw the figure number in the chart corresponding to the deformation of the concrete in the X-direction and the load to see the change of the deformation of the concrete under the cyclic load. The concrete measured by DIC is used to assess the damage of the concrete cube. Use a small diameter ($250\ \mu\text{m}$) multimode POF to detect matrix cracks in modern fibre composite materials. This method infers damage based on varying the stretch ratio of the optical power. It is reported that when the unidirectional sample is loaded along the axial direction, the optical performance decreases linearly with the deformation, and no damage is observed. A rolled sample, after the crack initiation in the sample, a nonlinear optical response is observed. The observations support their predicted response and hypothesize that the observed optical response nonlinearity indicates local POF deformation due to damage in the main body, thus demonstrating the feasibility of detecting lateral damage to composite materials.

3.2. P1 (5% Plastic Waste)

P1 refers to a concrete cube with 5% coarse aggregate instead of plastic. The correlation considers a

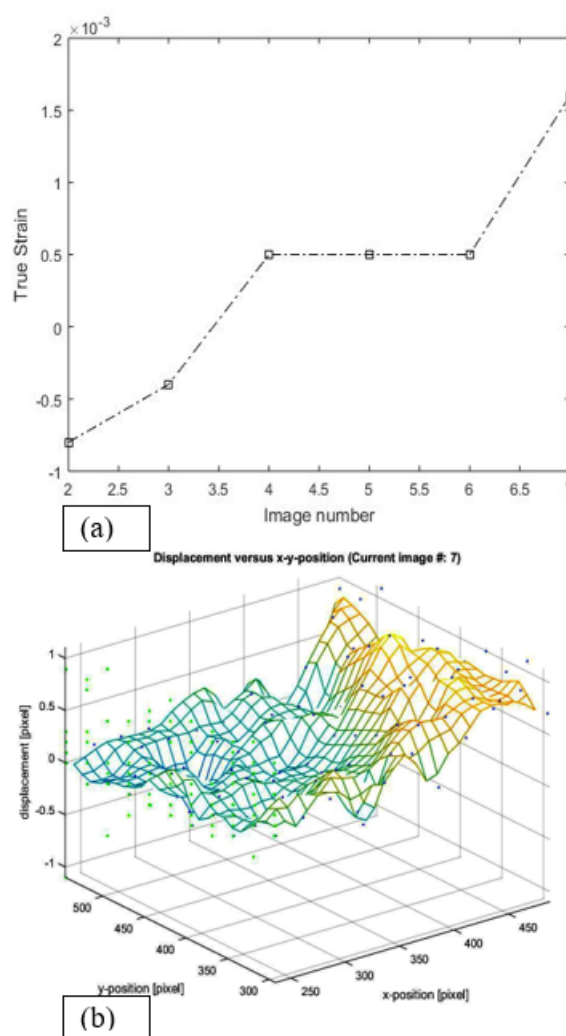


FIGURE 2. (a) Strain Graph for Control Mix (b) Deflections Graph for different Loading conditions for Control Mix

square grid of 20 pixels in the X-direction and 20 pixels in the Y-direction a three-dimensional diagram of the surface displacement at different loading stages. In Figure 2. the Strain Graph for Control Mix & Deflections Graph for different Loading conditions for Control Mix is illustrated. In Figure 3, Strain Graph for 5 % Replacement and the Deflections Graph at different Loading conditions for 5 % Replacement of Plastic where the crack growth as the load increases and compare the downward displacement obtained from the DIC with the displacement of the field centre. The rigidity of reinforced concrete beams is to create a foundation for new conditions. The baseline is an accurate measurement of the function of the process before the input variables change. These data can be compared to the effect of changing the behaviour of the evaluated

phenomenon. The baseline of the original beam was constructed using the loading conditions described above.

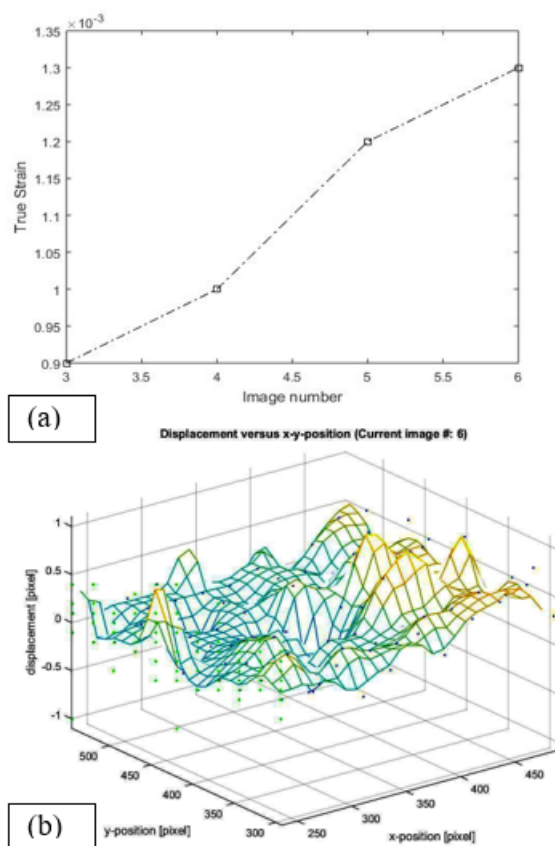


FIGURE 3. (a) Strain Graph for 5 % Replacement (b) Deflections Graph at different Loading conditions for 5 % Replacement of Plastic

3.3. P2 (10% Plastic Waste)

P2 refers to concrete cubes, and a 10% coarse surcharge is used instead of plastic. The correlation considers a square grid of 20 pixels in the X-direction and 20 pixels in the Y-direction. A three-dimensional diagram of the surface displacement at different loading stages. The crack growth with increasing load. The downward offset obtained from the DIC is compared with the midspan offset. Here, also shows the deformation curves under different load levels. The closer the clusters are, the more CNTs are contained in the contact, resulting in higher conductivity. Figure 4. shows the Strain Graph for 10% Replacement and Deflections Graph at different Loading conditions for 10 % Replacement of Plastic.

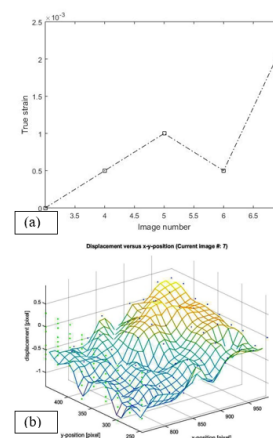


FIGURE 4. (a) Strain Graph for 10% Replacement (b) Deflections Graph at different Loading conditions for 10 % Replacement of Plastic

3.4. P3 (12.5% Plastic Waste)

P3 refers to a concrete cube with 10% coarse aggregate instead of plastic. The correlation considers a square grid of 20 pixels in the X-direction and 20 pixels in the Y-direction. A three-dimensional diagram of the surface displacement at different loading stages. The crack growth with increasing load Strain Graph for 12.5% Replacement is shown in Figure 5(a) illustrates the Strain Graph for 12.5% Replacement where the downward offset obtained from the DIC is compared with the midspan offset. Figure 5 (b) shows the Deflections Graph at different Loading conditions for 12.5 % Replacement of Plastic. Measure with direct current. Compared with BDC measurement, this is due to the influence of the electrode on the resistance of the material when using DC.

3.5. P4 (15% Plastic Waste)

P15 refers to a concrete cube with 15% coarse aggregate instead of plastic. The correlation considers a square grid of 20 pixels in the X-direction and 20 pixels in the Y-direction. A three-dimensional diagram of the surface displacement at different loading stages. It can be seen in Figure 6 (a) that the Strain Graph for 15% Replacement cracks grow as the load increases. The downward offset obtained from the DIC is compared with the midspan offset. Here, Figure 6 (b) also shows the Deflections Graph at different Loading conditions for 15 % Replacement of Plastic. The changing trend of the damaged state from the original state. This change can be explained as the change in the overall stiffness of the beam due to the occurrence of damage. This result

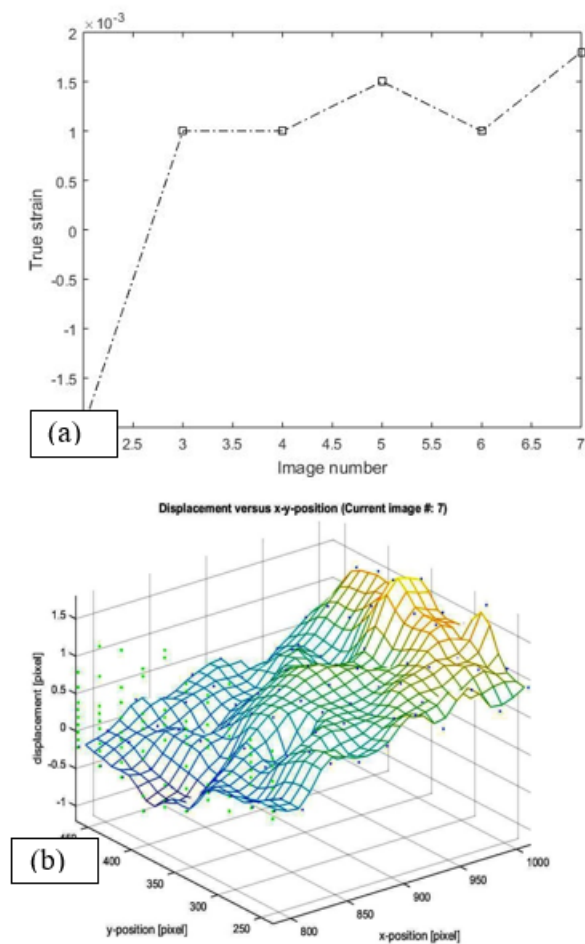


FIGURE 5. (a) Strain Graph for 12.5% Replacement (b) Deflections Graph at different Loading conditions for 12.5 % Replacement of Plastic

demonstrates the ability to handle global changes in the stiffness of simple structures, such as B. beams, using strain measurements that automatically recognize concrete. The DIC Results for different Mix Proportions ($E = 5000 \sqrt{fck}$ MPa) is described in Table 1.

3.6. PC (Control Mix)

PC Refers to concrete cubes with 0% plastic replacement of coarse aggregates. The DIC technique was utilized to assess the fracture propagation and complete strain field of the tested concrete depicts the DIC test’s primary setup. The displacement diagrams are as follows Figure 7. shows the Displacement (pixel) in the X-direction. The Strain diagram (pixel/ pixel) in Figure 8. Shows the strains in ξ_{xx}

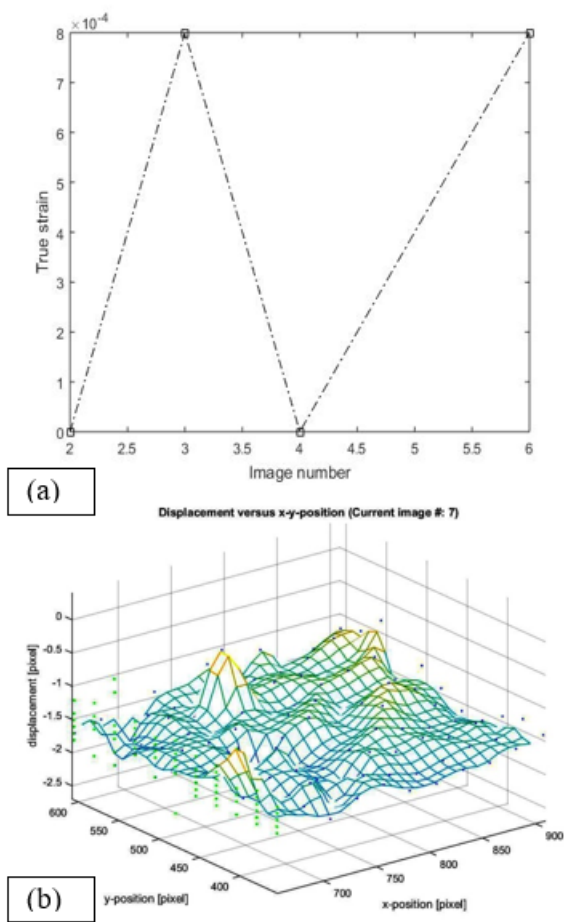


FIGURE 6. (a) Strain Graph for 15% Replacement (b) Deflections Graph at different Loading conditions for 15 % Replacement of Plastic

TABLE 1. DIC Results for different Mix Proportions ($E = 5000 \sqrt{fck}$ MPa)

Mix	Strain (ϵ) pixel	Strain (ϵ)) mm	Stress($\sigma = E \epsilon$)) MPa
PC	1.6×10^{-3}	0.200×10^{-3}	5.000
P1	1.3×10^{-3}	0.162×10^{-3}	4.060
P2	2.2×10^{-3}	0.275×10^{-3}	6.875
P3	1.8×10^{-3}	0.225×10^{-3}	5.625
P4	0.8×10^{-3}	0.100×10^{-4}	2.500

4. Conclusion

DIC is good for displacement & strain measurements. It is a simple, economical and flexible method. It is suitable to replace upto 10% replacement of plastic waste, after that the strength start

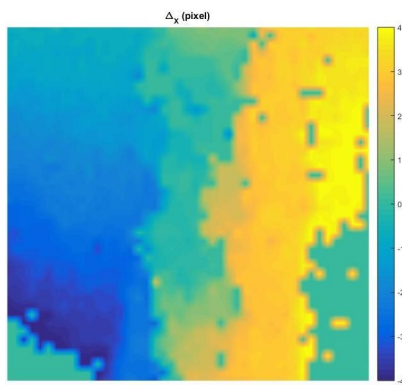


FIGURE 7. Displacement (pixel) - X-direction

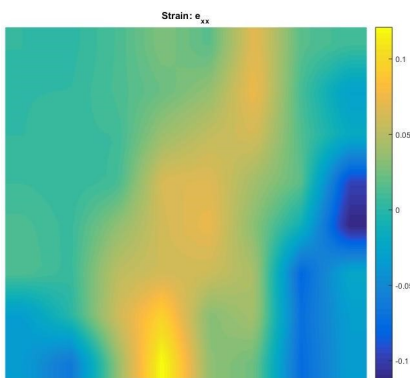


FIGURE 8. Strain (pixel/pixel) - xx

decreasing. Recycled plastic mix can be used for temporary construction works and construction. DIC results show good stress values upto 10% plastic replacement.

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