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Study on Expansion of Crack in RCC Beam by Using DIC – MATLAB

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ABSTRACT:

In a building cracks are of common occurrence. Usually cracks are develops in a building components whenever stress in the components exceeds its strength; internally induced stresses in a building components initially lead to dimensional displacement and finally cracking occurs. In the present paper MATLAB – DIC (Digital image correlation) technique is used to the RCC beam member to measure surface displacements and strain. Comparatively with traditional extensometer technique this MATLAB – DIC technique is easy and effective to define the zone where maximum displacement and maximum strains are localized. The study of strain and displacement in localized zone on the surface of RCC member under three point bending helps in designing structures which satisfies serviceability, sustainability and durability conditions.

Keywords: *Digital Image Correlation, Crack Expansion, Mat Lab.*

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1. INTRODUCTION

In a building cracks are of common occurrence. There are various causes for cracking in concrete, but most are related to quality of material, concrete specification, construction practices and by stresses due to induced forces. In a building components cracks are develops whenever stress in the building components exceeds its strength. Cracks are classified as structural cracks and non - structural. The structural cracks are due to faulty design, faulty construction or overloading. The non- structural cracks are develops due to internally induced stresses; internally induced stresses developed in a building components lead to dimensional displacement and cracking occurs. Ease of Use

A. Scope of study

In the present paper MATLAB - DIC technique is used to the RCC beam member to measure surface displacements. From this technique it is possible to define the zone where maximum strains are localized. The study of the width of the localized zone on the surface of RCC beams under three point bending helps in designing the building structural components with high and low reinforcements as per the requirements thus providing safety for the structure

B. MATLAB

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language. A proprietary programming language developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python. Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

Digital image correlation is an optical method that works tracking and image identifying techniques for accurate 2D and 3D measurements of changes in images. DIC is applied for measuring displacement, deformation, strain, optical flow and it is widely applied in many areas of science and engineering.

DIC is widely used in the field of image registration technique by comparing two images local correlation that is the identification of relationship between un- deformed and deformed images. In figure (a), the point F is prior to deformation at x,y coordinates and it is change to point G after deformation at x*,y* coordinates.

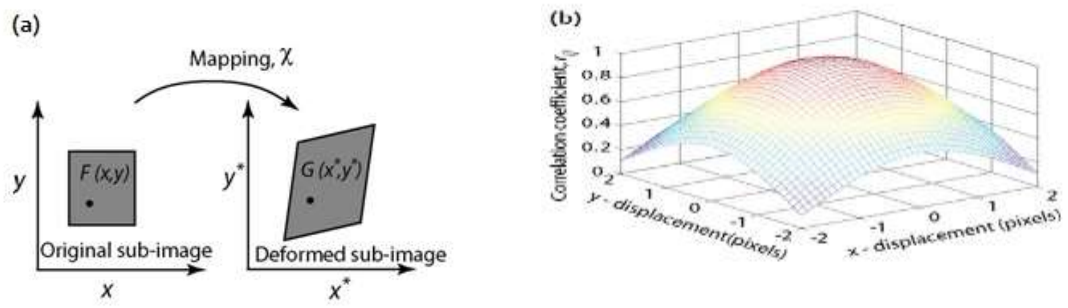


Fig 1 Principle of digital image correlation

The functional relationship is expressed as (Shih et al 2008)

$x^* = x + u(x, y)$ (1a)

$y^* = y + v(x, y)$. (1b)

Finite element method (FEM) is used for un-deformed images. FEM divides the images into several sub-images. Assume A is the un-deformed sub-image, and B is the deformed sub-image, the correlation coefficient (Equation 2) (Chu et al 1985) is used to define the relationship between sub-images A and B. After the deformation if sub-image B is exactly the same as sub-image of A; then correlation coefficient will be equal to 1. Similarly by using the same principle the strains between two deformed points are computed.

2. METHODOLOGY

2.1 Basic material testing

a. Cement

In this present work Ramco OPC 53g grade has been tested and used as per IS 4031:1988 and confirmed to IS 269-2015; Table 1 represents the physical properties of cement

Table 1: Physical properties of Ramco OPC 53G

1	Normal consistency in (%)	29	-
2	Specific Gravity	3.11	-
3	Intial Setting time (in Minutes)	153	Not less than 30 Min
4	Final Setting time (in Minutes)	277	Not more than 600 Min

b. Fine aggregate

Here manufactured sand has been used as fine aggregate and tested the same as per IS 2386-1963. The results are tabulated in Table 2.

Table 2: Tests on manufactured sand

1	Specific gravity	2.56
2	Water absorption (%)	3.8
3	Zone	II

c. Coarse aggregate

In this investigation 20mm downsize of coarse aggregate were used and they were tested as per IS 2386-1963. The results are shown in Table 3.

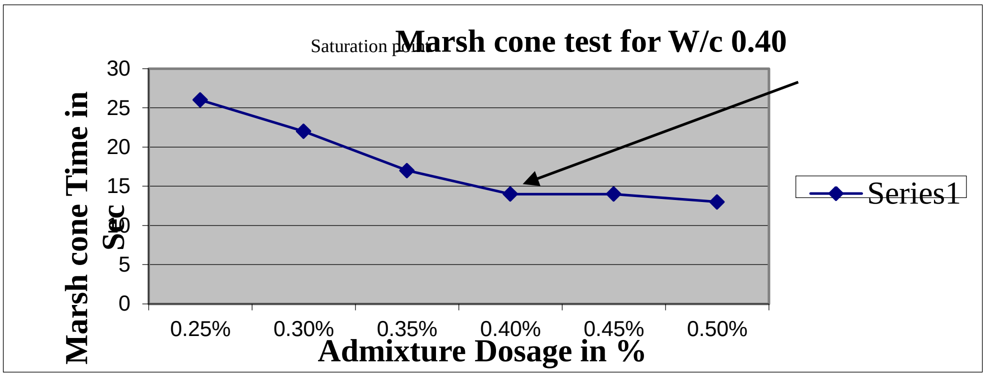
Table 3: Physical properties of Coarse aggregate

1	Specific gravity	2.62
2	Water absorption (%)	0.7
3	Impact value (%)	18.46
4	Crushing Value (%)	20.73
5	Flakiness index (%)	18.63
6	Elongation index(%)	19.48

d. Cement and admixture compatibility test (Marsh cone test)

Marsh cone test conducted to check the compatibility of Ramco OPC 53g and Super plasticizer Fosroc SP 430; Chart 1 represents Marsh cone test result

Chart 1: Marsh cone test result



C. Preparation of the RCC member

a. Mix design of M50 grade concrete by using IS10262-2009

The concrete mix design is done under the guidelines of IS: 456 - 2000 and IS: 10262 – 2009.

Table 4: Mix design of M50 grade of concrete

Particulars	M50 100%	M50 80%+20%	M50 65%+35%	M50 50%+50%
Cement (kg/m3)	440	384	343	286
GGBS (kg/m3)	-	100	185	286
Water (kg/m3)	176	176	176	176
Fine aggregate (kg/m3)	725	705	690	671
20mm (kg/m3)	628	597	597	581
12.5mm (kg/m3)	418	398	398	388
w/c ratio	0.4	0.36	0.33	0.31
Admixture in %	0.40%	0.40%	0.45%	0.45%

b. Casting and testing of cubes

Concrete cubes of size 150mm x 150mm x 150mm is casted and curried in curing tank for a period of 3 days , 7days and 28 days; compressive strength of concrete has been tested in compression testing machine to check is it passing the permissible limit as per Indian standards and project requirements.

D. Design, Casting and testing of RCC beam

a. Reinforcement Details

- Main reinforcement 2 of 12mm dia
- Hanger bars 2of 10mm dia
- Shear reinforcement 8mm dia 200 mm c/c

b. Casting and testing of RCC Beam

- Casting of RCC beam of size 0.2m x 0.3m x 1.25m
- Testing of a RCC beam by three point bend testing machine
- Capturing images of failure of beam by using digital camera
- Recording Flexural strength of RCC beam

E. Analysis of strain, displacements using MATLAB - DIC

Following are the set of programs that are coded and are executed in MATLAB pool for image processing and analyzing using DIC

- filelist_generator.m: It generates file name lists with max. 8 letters and „.jpg" at the end and creates a time_image list needed for merging stress and strain
- grid_generator.m : generates grid raster needed for the correlation code)
- large_displ.m : used when the displacement exceeds the correlation area
- automate_image.m : This function does all the hard correlation work
- displacement.m: This function will helps in analyzing your data
- RTCorrCode.m : "realtime"correlation code
- Multipeak_tracking.m : track multiple peaks along one axis

II. RESULTS

A. Compressive strength of M50 grade of concrete

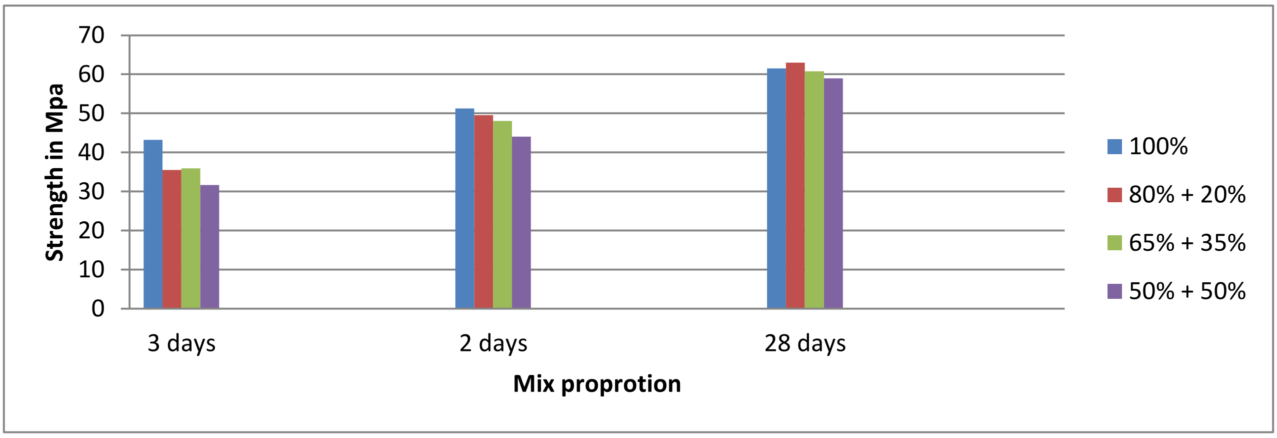
Compressive strength of concrete has been tested in compression testing machine and comparing test results with permissible limit as per Indian standards and project requirements. Table 5 shows the compressive test results and chart 2 indicates comparison of compressive strength of M50 grade concrete for various proportions.

Table 5: Compressive strength of M50 grade concrete

Compressive strength M50 grade concrete in N/mm2					
Sl No	Age of curing	100%	80%+20%	65%+35%	50%+50%
1	3	43.23	35.53	35.93	31.63
2	7	51.30	48.06	48.06	44.09
3	28	62.99	60.03	60.74	59.01

Target strength For M50 grade of concrete = 50 + 1.65 x 5 = 58.25 N/mm^2.

Chart 2: Compassion of compressive strength



B. Flexural strength of RCC beam under three point bending test

After 28days curing of RCC beams ; beams has been tested under three point testing machine (loading frame) and flexural strength calculated by using

$$\frac{3\ x\ P\ x\ L}{2\ x\ b\ x\ h2}$$ formual.

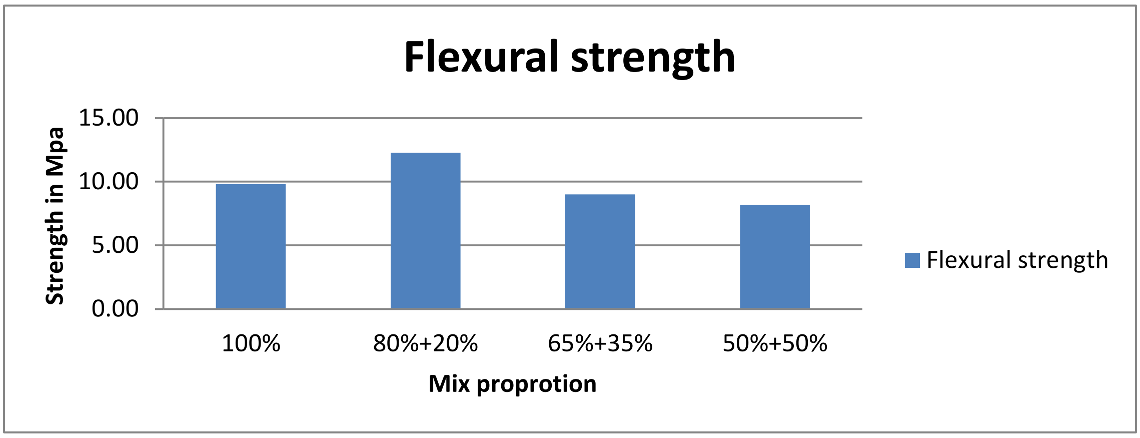
Table 6 represents flexural strength of RCC beams and Chart 3 shows flexural strength comparison

Table 6: Flexural strength of RCC beam

Flexural Strength Results				
Sl. No.	Grade of concrete	Proportion	Load at 1st Crack(KN)	Flexural strength in Mpa
1	M50	100%	118	9.81
2		80%+20%	147	12.26
3		65%+35%	108	8.99
4		50%+50%	98	8.18

As per IS 456 -2000 limit for flexural strength of concrete is $0.7\sqrt{fck}$ that is $0.7\sqrt{50}$ = 4.95 Mpa therefore all our M50 grade proportion are passing the requirements.

Chart 3: Compassion of flexural strength



C. Horizontal and vertical displacement

Horizontal and vertical displacements for each beam are found by processing the images in MATLAB-DIC by using displacement command.

Fig 2 and Fig 3 represents horizontal and vertical displacement respectively.

Fig2: Horizontal displacement

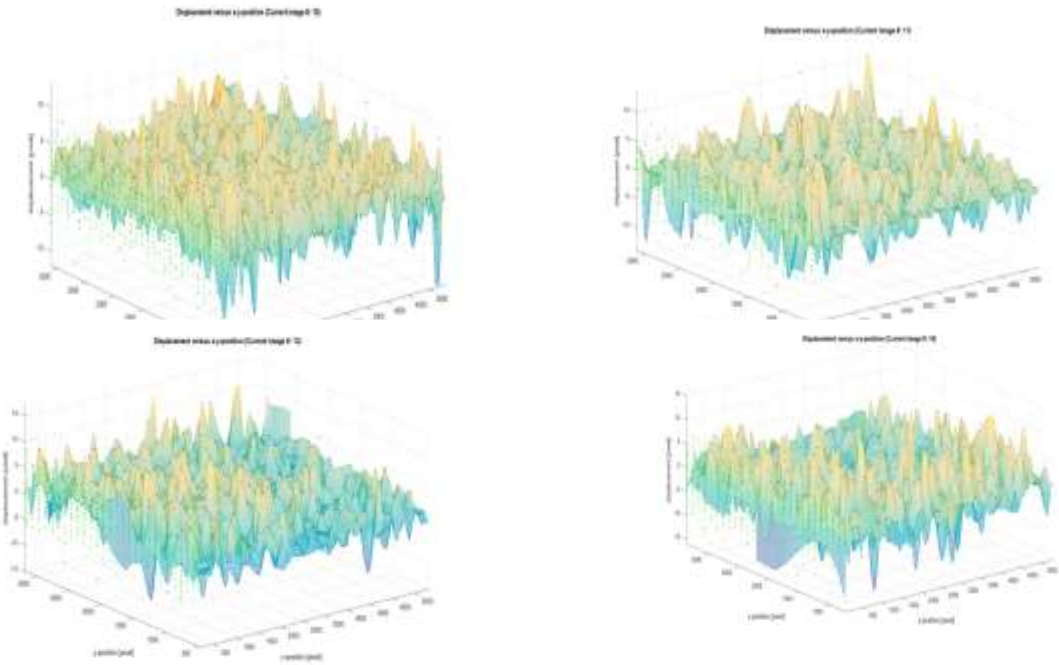
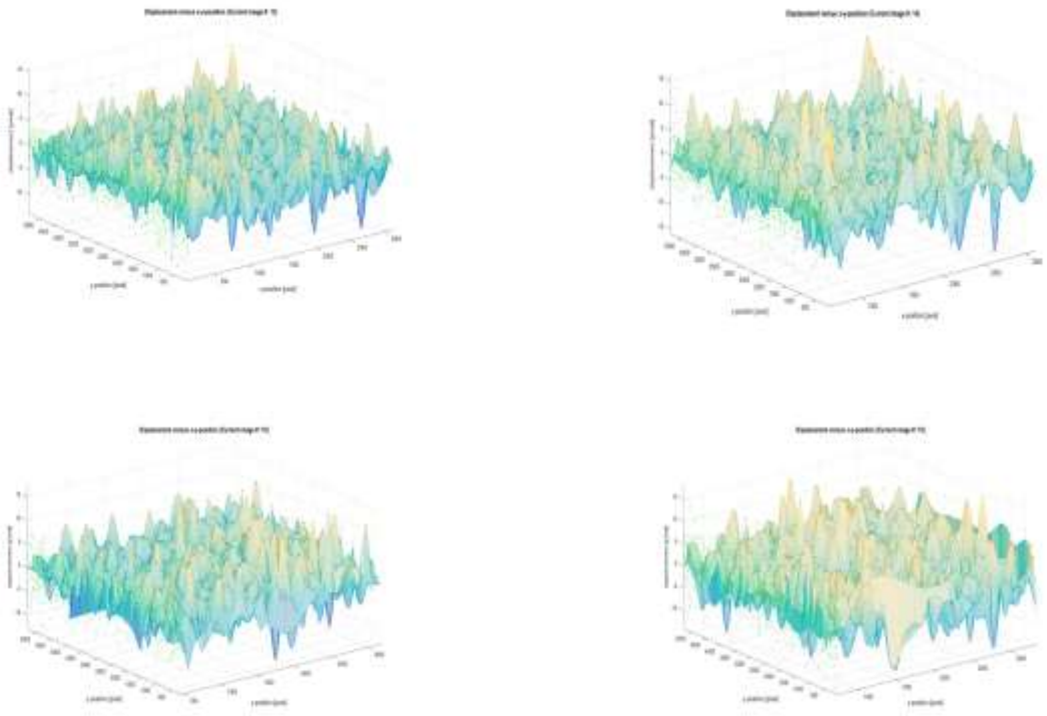


Fig 3: vertical displacement

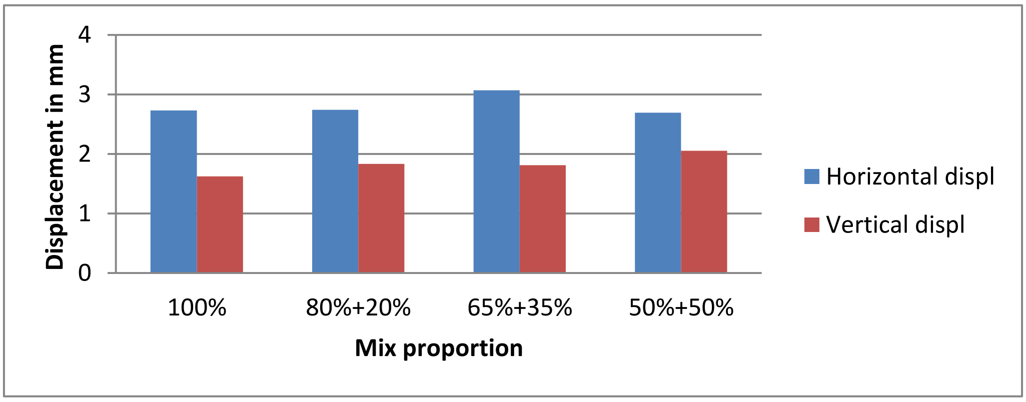


In the above horizontal and vertical displacement results Red indicates higher scale displacements and Blue indicates lower scale displacements. By comparing the displacement results it's found that horizontal displacements are greater than vertical distance due to bending.

Table 7: Horizontal and vertical displacement

Sl. No.	Proportion	Horizontal displacement in mm	Vertical displacement in mm
1	100%	2.73	1.62
2	80%+20%	2.74	1.83
3	65%+35%	3.07	1.81
4	50%+50%	2.69	2.05

Chart 4: Compassion of horizontal and vertical displacement



A. Horizontal and Vertical strain plots

Horizontal and vertical strain plots are represents strain at different points in each images; Fig 4 and Fig 5 are horizontal and vertical strain plots of each mix respectively.

Fig 4: Horizontal strain plots

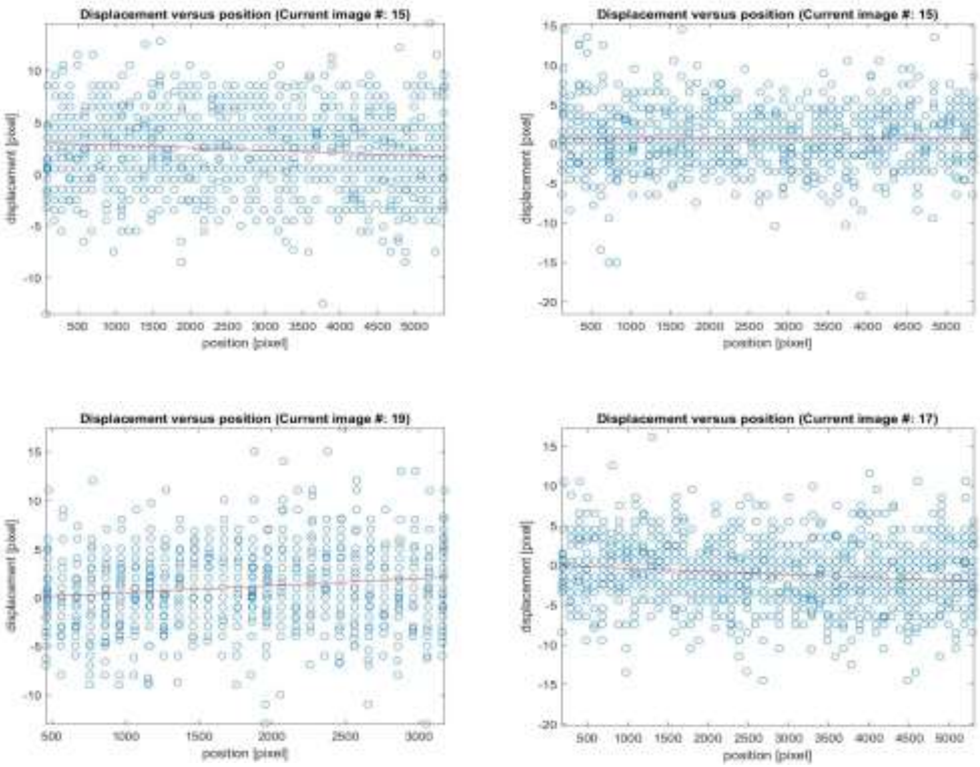
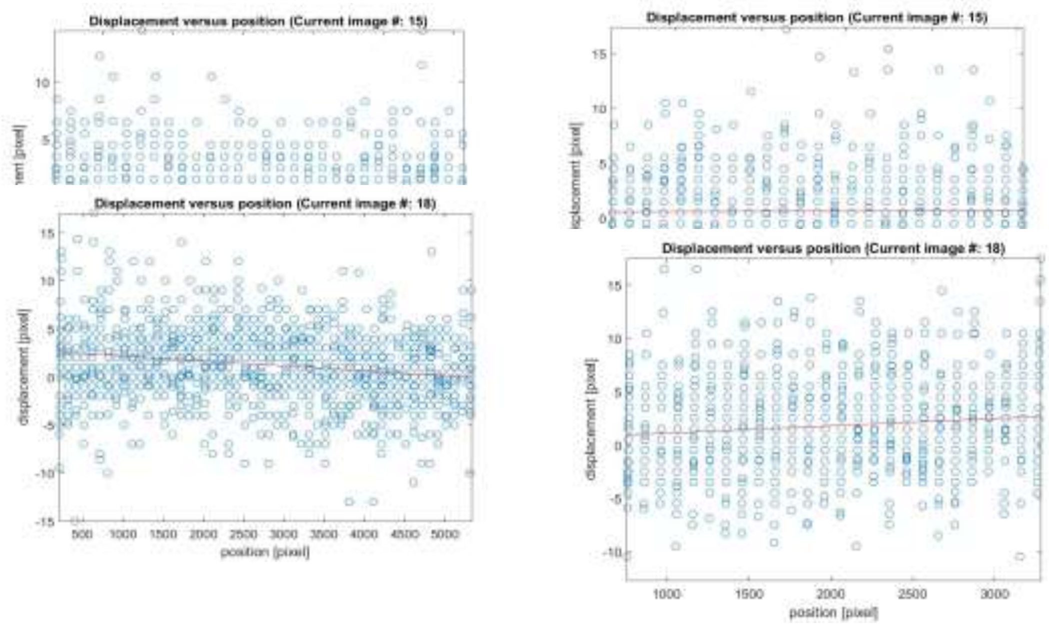


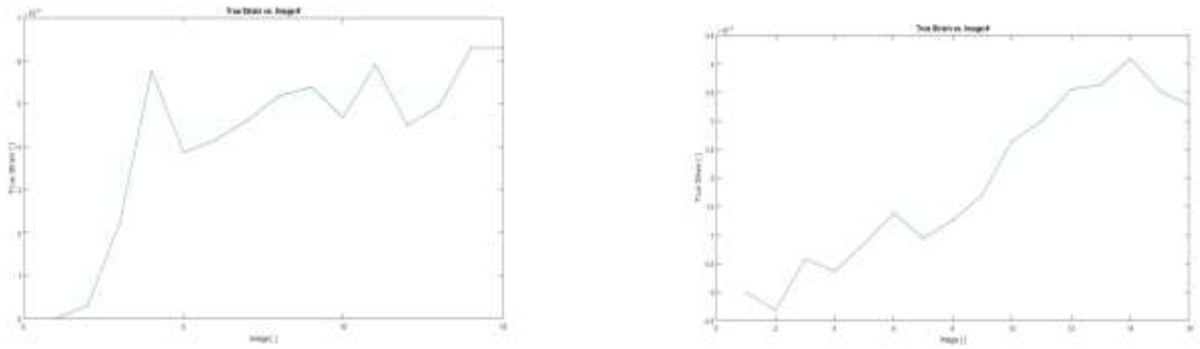
Fig 5: Vertical strain plots



B. True stain v/s plot for 2 considerable points

Compressive strain and tensile strain of each mix proportion are found by processing the data of horizontal strain plots and vertical strain plots which is found as above. Fig 6 and Fig 8 shows the compressive strain and tensile strain respectively

Fig 6: Compressive strain



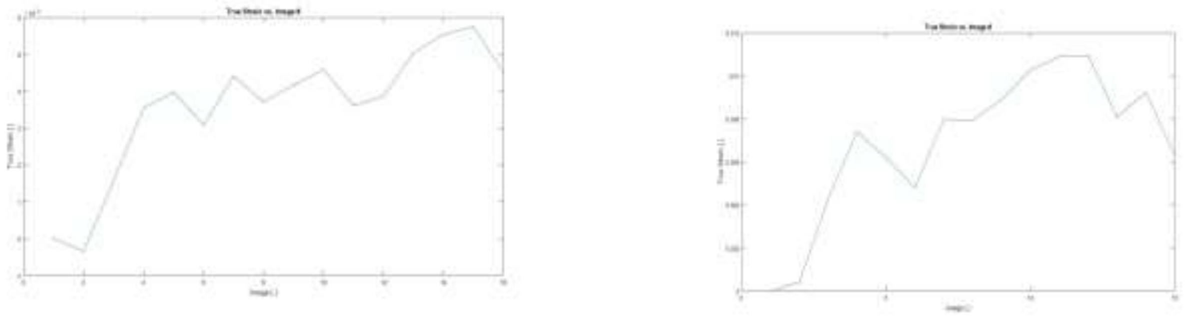


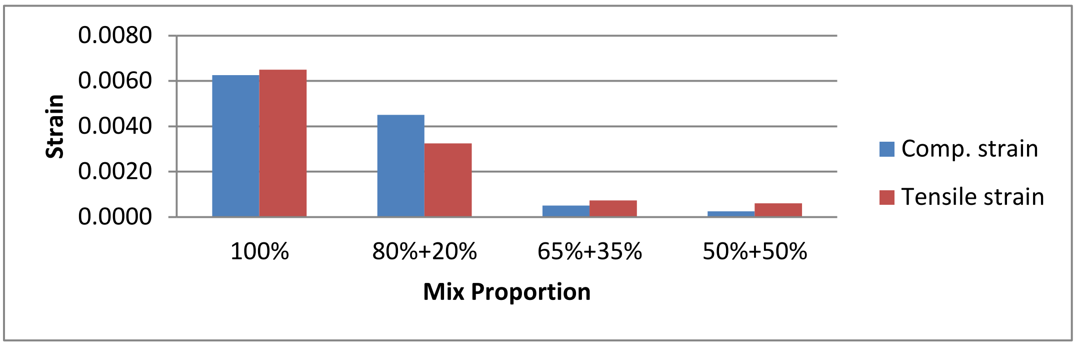
Fig 7: Tensile strain

Table 7 and Chart 5 shows the comparisons of compressive strain and tensile strain and the results indicates both tensile strain and compressive strain decreases by increasing GGBS percentage

Table 7: Compressive strain and tensile strain

Sl. No.	Grade of concrete	Proportion	Compressive strain	Tensile strain
1	M50	100%	0.0063	0.0065
2		80%+20%	0.0045	0.0033
3		65%+35%	0.0005	0.0007
4		50%+50%	0.0003	0.0006

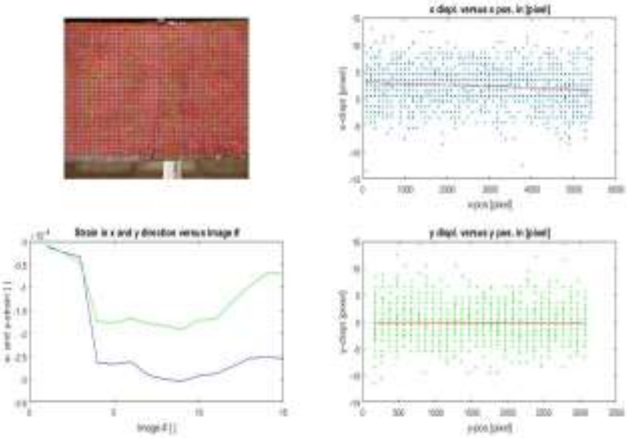
Chart 5: Compressive strain and tensile strain



C. RT corr results

In the fig 7 A signifies Raster points. Raster points are the heart of correlation since the results depend on them and crack propagation are explained and crack density are depicted using them. The other figures pertaining to RT corr depicts the relation between H and V displacements and strains.

Fig 7: RT corr results



D. Peak displacement

The displacements along any axis can be depicted by this programme helpful in analyzing and designing. The peak displacement are listed below for the set of images processed

Fig 8: Peack displacement

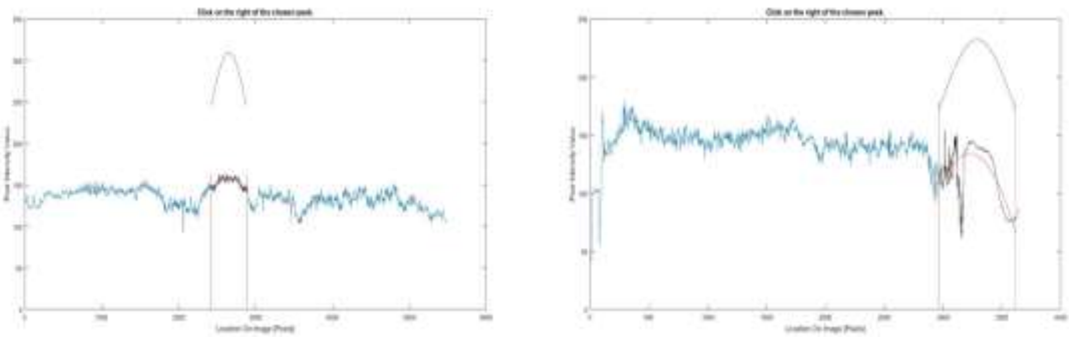


Table 7: Compressive strain and tensile strain

Sl no.	IMAGE No.	Horizontal Displacement mm	Vertical Displacement mm
1	Image 1	2.644	3.228
2	Image 2	2.641	3.211
3	Image 3	2.652	3.211
4	Image 4	2.655	3.205

5	Image 5	2.637	3.194
6	Image 6	2.645	3.195
7	Image 7	2.674	3.208
8	Image 8	2.684	3.195
9	Image 9	2.648	3.198
10	Image 10	2.665	3.19
11	Image 11	2.68	3.182
12	Image 12	2.669	3.157
13	Image 13	2.652	3.164
14	Image 14	2.614	3.169
15	Image 15	2.667	3.581
16	Image 16	2.61	3.56

IV . CONCLUSION

In this paper work RCC beams were casted and tested in loading frame by three point bending method. While testing failure of beam is capture by using digital camera and both strain and displacement of RCC beam are analyzed by using MATLAB – DIC.

Analysis of paper

(i) In this paper work cement is partially replaced by GGBS i.e; 20%, 35% and 50% and all the mixes are achieving target strength.

(ii) By partial replacement of cement by GGBS reduce the demand of cement and reduces the cost of concrete mixes.

(iii) Environmental green product can manufacture by using by-product GGBS in concrete mix.

(iv) Flexural strength of RCC beam calculated and compare for different cement and GGBS proportion. Flexural strength are passing the IS requirements.

(v) In this paper by using MATLAB – DIC displacement, stain and crack expansion can analyzed

(vi) By three point test and DIC; Study on crack initiation and crack expansion can be determined.

(vii) In this method it’s able to identify the development of micro cracks and major crack at different stages of loading but in traditional method; we can observe only major cracks formation at certain load.

(viii) In traditional method strain can computed by using strain dial gauge but in this present paper both compressive strain and tensile strain are computed by analyzing the captured image and its gives accurate result than traditional.

V . REFERENCE

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