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STRENGTH ANALYSIS - BUILDING FRAME WITH POLYURETHANE CEMENT COMPOSITE (PUC)

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Abstract - *The polyurethane material is the main component of the new material polyurethane–cement composites (PUC) as a new material can be used for different structural purposes. The utilization of PUC material is a repairing material such as strengthening old bridge , The objective of this research was to find the displacement and pressure variation of building frame with and without PUC and compare it with CFRP. Analysis done by the help of Abaqus software. The PUC material considered as light weight material with highly strength due to less density comparing with normal concrete. The FEM package Abaqus/standard version v6.14 was used in this research.*

Key Words*: *polyurethane–cement composites- repairing material-building frame- strength- Abaqus v6.14

1.INTRODUCTION

Recently, many structural members of infrastructures have undergone serious strengthening or repair because of corrosion due to severe environments, high chloride content in the air and the use of de-icing salts, alkali effect, poor design other human errors and concrete aging. The latest surveys showed that reinforcement and maintenance costs for buildings, especially those exposed to unfavorable environment, had gradually increased in the past few decades.

To improve the working ability of concrete buildings, many techniques have been used in strengthening. The most common methods for strengthening beams and column have been the use of Carbon Fiber Reinforced Polymer (CFRP), steel plate bonding, external pre-stressing reinforcement and others, these methods are widely used at present. CFRP materials have good structural performance, high strength and light weight. CFRP can be easily installed, as they can be attached to a curved profile. However, these materials have their own shortcomings. The major drawback of CFRP is the high cost. Bonding steel plates have the disadvantages of weakened bonding caused by steel corrosion, increased dead load weight and difficulties in adapting to the concrete surface profile.

Polyurethanes are the most versatile of all polymers. Their applications include diverse types of foams, (soft and rigid), coatings, adhesives, sealants, and elastomers. Although the number of chemicals is small, the molecular weight of the reactants and the method of polymer formation can be varied widely to meet the desired properties of the final product.

PUC is a kind of composite material composed of polyurethane raw materials mixed with cement. Polyurethane (PU) is a high-performance polymer elastic material mainly based on the chemical compounds of poly isocyanate and polyester polyol. The harden range of PU is from 10 to 100 (IRHD), with good abrasion resistance performance, corrosion resistance, toughness and cohesiveness. PUC has the advantages of light quality, significant strength in compressive and bending. PUC has excellent bonding and adhesive properties with concrete materials, and it does not need additional adhesiveness for beam reinforcing.

The mixing ratio of the PUC components (polyol: poly isocyanate: cement) was 1:1:2.5 by weight. PUC after mixing is shown in Fig.1.1 Typical procedure for preparing polymer concrete samples the polyol component of the polyurethane elastomer system and the mineral aggregate were placed in a plastic bucket and blended with a jiffy-type mixer for 60s, after which the isocyanate component was added to the bucket. The contents of the bucket were mixed for another 60 s, and the slurry was poured or troweled into a form for curing.[1]

Fig.1.1 PUC material after mixing

Table 1.1 Advantages of Polyurethane when compared to conventional materials

Vs. Rubber	Vs. metal	Vs. plastic
High abrasion resistance	Light weight	High impact resistance
High cut & tear resistance	Noise reduction	Elastic memory
Superior load bearing	Abrasion resistance	Abrasion resistance
Thick section molding	Less-expansive fabrication	Noise reduction

Color ability	Corrosion resistance	Variable coefficient of friction
Oil resistance	Resilience	Resilience
Ozone resistance	Impact resistance	Thick section molding
Radiation resistance	Flexibility	Lower cost tooling
Broader hardness range	Easily moldable	Low temperature resistance
Castable nature	Non-conductive	Cold flow resistance
Low pressure tooling	Non-sparking	Radiation resistance

Polyurethanes possess high tear resistance along with high tensile properties. Polyurethane material properties will remain stable with minimum swelling in water, oil, grease. The major advantages of Polyurethane when compared with rubber, metal and plastic are given in Table1.1

1.1 OBJECTIVE

Formation of cracks are most common type of problem in any type of building. so, it is important to understand the cause and the measures to taken for prevention. Polyurethane cement composite is used to strengthen the cracked building. Main objective of this project strength analysis of repaired frame and compared the displacement and pressure generated with Carbon fiber reinforced polymer(CFRP) repaired frame, with ABAQUS 6.14v software.

1.2 SCOPE OF STUDY

This study focuses on repair of damaged building frame by polyurethane cement composite and compared the displacement and pressure variation with carbon fiber reinforced polymer(CFRP).

2. METHODOLOGY

Step in methodology are listed below;

- Data collection
- Modelling
- Analysis

The first step is to identify issues and opportunities for collecting data and to decide what next step to take. Data from international journals, magazine, articles etc. After data collection validating the data.

2.1 DATA COLLECTION

Concrete is a composite material composed of coarse and fine aggregates bonded together with cement paste, that hardened over time. Polyurethane (PU) is a high-performance polymer elastic material mainly based on the chemical compounds of poly isocyanate and polyester polyol. Most of the polyurethane are thermosetting polymers that do not melt when heated.

The general data used of the analysis;

i. Concrete

i. Mass Density : 2400kg/m^3

Elastic properties used;

Young's modulus : 20000MPa

Poisson's ratio : 0.18

Concrete damage plasticity properties used;

Dilation angle	: 31
Eccentricity	: 0.1
K	: 0.668
Yield stress (compressive behavior)	: 25MPa
Yield stress (tensile behavior)	: 2.25MPa

ii. Polyurethane cement composite

Modulus of elasticity	: 4540MPa
density	: 1648kg/m^3
poisons ratio	: 0.27

iii. steel

2.2.ABAQUS 6.14v

Abaqus 6.14v is a software suited for finite element analysis and computer- aid engineering, originally released in 1978.The Abaqus products use the open-source scripting language python for scripting and customization.

i. Abaqus/Explicit

Abaqus/Explicit is a special-purpose analysis product that uses an explicit dynamic finite element formulation. It is suitable for modeling brief, transient dynamic events, such as impact and blast problems, and is also very efficient for highly nonlinear problems involving changing contact conditions, such as forming simulations.

Density	7850kg/m^3
Youngs's modulus	210000MPa
Poisson's ratio	0.3
Yield stress	350MPa

ii. Abaqus/CAE

Abaqus/CAE (Complete Abaqus Environment) is an interactive, graphical environment for Abaqus. It allows models to be created quickly and easily by producing or importing the geometry of the structure to be analyzed and decomposing the geometry into mesh able regions. Physical and material properties can be assigned to the geometry, together with loads and boundary conditions. Abaqus/CAE contains very powerful options to mesh the geometry and to verify the resulting analysis model. Once the model is complete, Abaqus/CAE can submit, monitor, and control the analysis jobs. The Visualization module can then be used to interpret the results.

Every complete Finite-element analysis consists of 3 separate stages:

- Pre-processing or modeling: This stage involves creating an input file which contains an engineer's design for finite-element analyzer (also called "solver")
- Processing or finite element analysis: This stage produces an output visual file.
- Post-processing or generating report, Image, animation etc. From the output file: This stage is a visual rendering stage.

3.VALIDATION

In the study presented by V.S. Sethuraman, K.Suguna, and P.N. Raghunath " Numerical Analysis of High Strength Concrete Beams using ABAQUS". The objective of this paper is to model and analyses an M60 concrete Beam using Abaqus for static load and verify the same using experiment. In recent years, Concrete having a compressive strength of 60 MPa and above is being used for high-rise buildings and long span bridges. ABAQUS is a suite of powerful engineering simulation programs, based on the finite element method (FEM) that can solve problems ranging from relatively simple linear analyses to the most challenging nonlinear simulations.

The advent of newer concrete making technologies has given impetus for making concrete of higher strength. As per our Indian standard IS 456: 2000 concretes are grouped as ordinary concrete, standard concrete and high strength concrete as given in Table 4.1. The code did not describe about UHSC, but the American Concrete Institute (ACI) categories the concrete as Normal Strength Concrete (NSC), High Strength Concrete (HSC) and Ultra High Strength Concrete. [21]

Table 3.1 Group of Concrete as per IS 456:2000

Sl. No	Name of Group of Concrete	Grade Designation
1	Ordinary Concrete	M10 to M20
2	Standard Concrete	M25 to M55
3	High Strength Concrete	M60 to M80

Note: M refers to mix and the number to specified compressive strength of 150 mm size cube at 28 days expressed in N/ mm2

The general data used of the analysis;

i. Concrete
ii. Mass Density : 2400kg/m^3
Elastic properties used;
Young's modulus : 20000MPa
Poisson's ratio : 0.18

iii. steel
Density 7850kg/m^3
Youngs's modulus 210000MPa
Poisson's ratio 0.3
Yield stress 350MPa

Dilation angle : 31
Eccentricity : 0.1
K : 0.668
Yield stress (compressive behavior) : 25MPa
Yield stress (tensile behavior) : 2.25MPa

Concrete damage plasticity properties used;

Model dimension is 2000x200x100mm and ultimate load applied is 90,100,115kN, and also the expected deflation and FEA deflation are given in table 4.2.

Table 3.2. Static Load FEA Test Results

Sl.no	Load kN	Expected deflation(mm)	FEA deflation(mm)	Error (%)
1	90	21	19.35	7.85
2	100	25	21.63	13.48
3	115	30	25.05	16.5

3.1 VALIDATION RESULT

The result obtained for total deformation is 19.35mm for 90kN, as shown in figure 4.2.

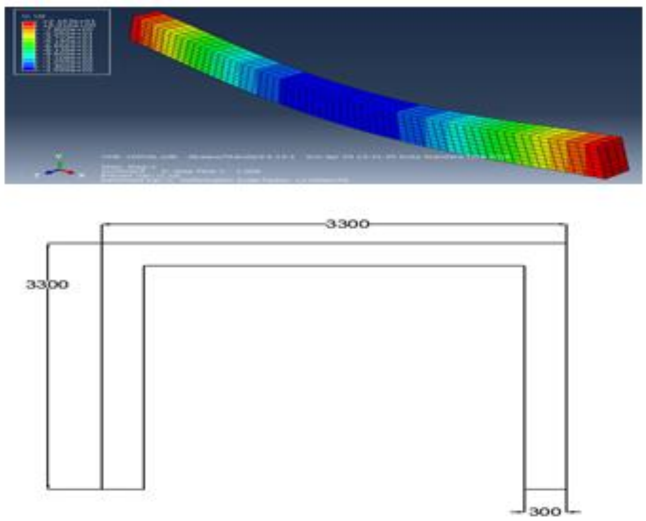

Fig 3.1 FEA displacement ,load 90kN

The percentage of error is 7.85%.

the result for 100kN, displacement is 21.63mm as shown in figure4.2. The percentage of error is 13.48%.

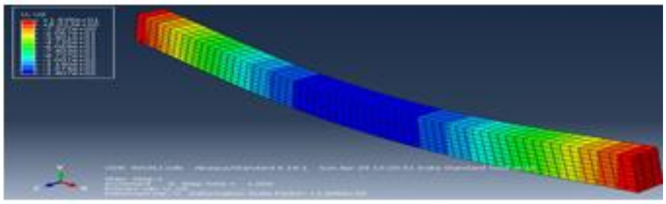

Fig .2 FEA displacement, load 100kN

the result for 115kN, displacement is 25.05mm as shown in figure4.3 The percentage of error is 16.5%.

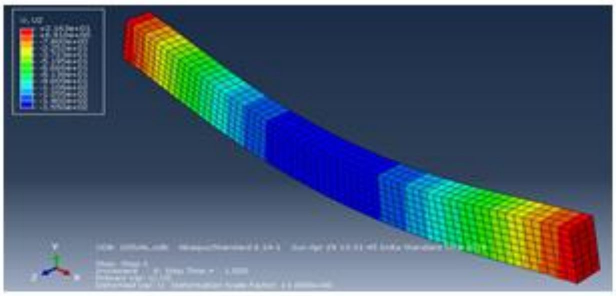

fig 4.3 FEA displacement, load 115kN

4. MODELLING

Modelling of structure had a prime importance in the software analysis. Each element in structure like beams, column are modelled as solids and their properties are assigned to them for its realistic nature. These are done using ABAQUS 6.14v.

Size if beam	:300x300mm
Size if column	:300x300mm
Diameter of main bar	:16mm
Diameter of stirrups	:8mm
c/c distance b/w column	:3300mm
Height of frame (up to top of beam)	:3300mm
Spacing of stirrups	:125mm

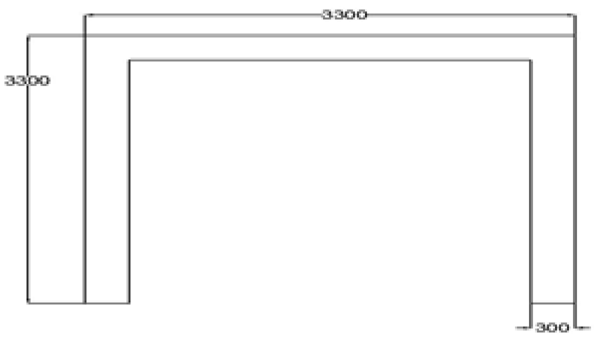

Fig 4.1 Model used of analysis

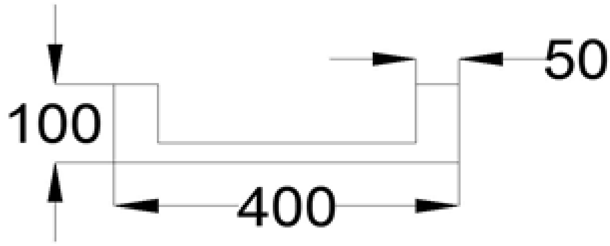

Fig 4.2. PUC measurement

Polyurethane cement composite attached on the bottom of the beam of strengthening. The dimension provided as shown in figure 5.2. Same measurement is taken for both models.

The PUC (Poly-Urethane-Cement) is a high-performance polymer elastic material, contains the isocyanate and urethane compounds. These two materials as the main can developed a different series of polyurethane-cement composite with variable densities values.

Meshing plays a vital role in the FEA since the properties and governing relationships are assumed over the discretized elements and expressed mathematically on the specified points called nodes. Hence increasing the number of elements in a Finite element model will increase accuracy but at the same point it will take more time to solve the equations. The below figure 5.3 show the meshed models.

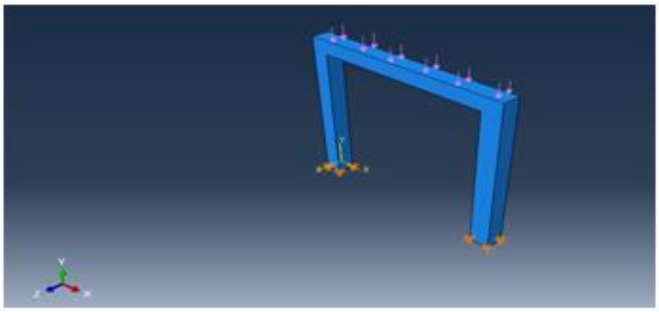

Fig 4.3. Meshed concrete frame

The reinforcement is provided is 16mm diameter bar as main and 8mm diameter bar 125mm c/c as stirrups. Both the ends are fixed and applied a load of 50 tons uniformly distributed on the top of the beam, as shown in figure 5.4

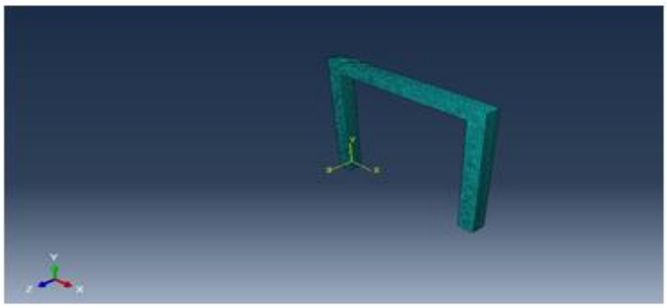

Fig 4.4 Load and boundary condition

4.1. RESULT

i. Concrete frame without PUC

Pressure generating is changes with load applied. The maximum pressure generated due to the load 50 tons is 32.46 kN , as shown in figure 4.5.

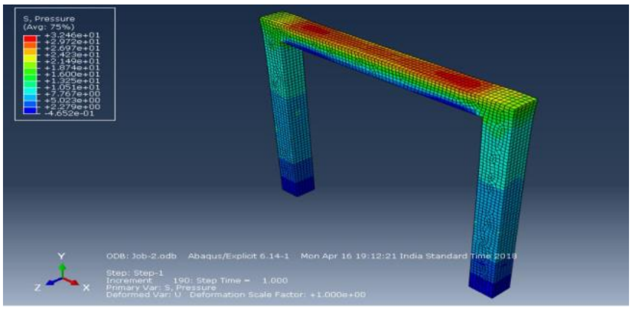

figure 4.5 pressure variation

The pressure is maximum at a particular time, it's the point before damage of structure, in this case it is 32.45kN, after damage the stress decreasing

Based on the displacement values we can easily concluded that the frame damage.

The maximum displacement is 46.66mm before strengthening, as shown in figure4.6

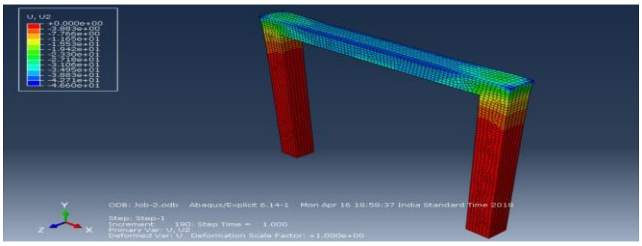

Fig4.6 Displacement u2, y- direction

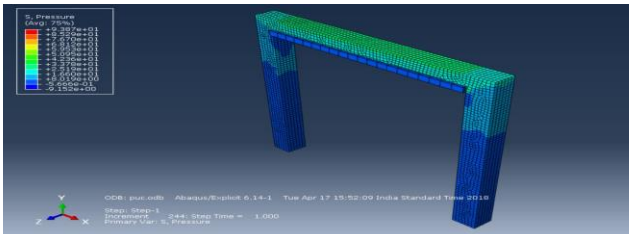

Fig. 4.7 PUC , pressure variation

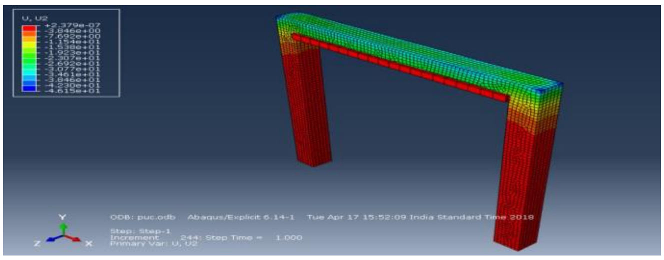

Fig 4.8 PUC, displacement

5. CONCLUSIONS

strengthening with PUC material of building frame was proven to be a reliable and easy-to operate technique. Comparing with normal concrete and CFPR, Polyurethane cement composite is lightweight material, highly deformable, and very good strength. High bonding between old concrete and polyurethane. According to the experimental result, this material (PUC) can be used for different purpose of construction field, such as repairing deteriorated concrete structural elements, strengthening the structure members (beams, columns, piers, etc.). This material (PUC) has not only great clear positive effect of strengthening RC T-beam, but also has an extensive application prospect. The displacement is reduced after PUC applied. i.e. for normal frame the displacement is 46.55 and it reduced to 19.23 as compared with CFRP, it is less.

Improving the load carrying capacity of repaired structure compared with CFRP i.e. for actual case 32.46kN and increases to 93.87kN. The PUC cost is compared with other repairing material it is effective

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