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NUMERICAL ANALYSIS OF RC BEAMS WITH OPENINGS STRENGTHENED USING CFRP UNDER IMPACT LOADING

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Abstract - Transverse openings are often provided through reinforced concrete beams to accommodate utility ducts and pipes the opening in the shear zone of the reinforced concrete beams significantly reduces the load carrying capacity of the beam. The importance of this study is to evaluate the performance of beam with opening strengthened using CFRP under impact loading. In this numerical study total three beams were modelled, one beam with rectangular post opening considered as a control beam for comparison. The remaining two beams were externally strengthened by Carbon fibre reinforced polymer (CFRP) sheets with different strengthening techniques (Around the opening and inside the opening) in order to evaluate the performance of strengthened beam under impact load in ANSYS autodyne platform. Numerical results show that the load carrying capacity of beams with openings is highly influenced by the position of FRP laminates. From the overall study it can be concluded that CFRP lamination around the opening is better under impact.

Key words: ANSYS Autodyne, CFRP

1. INTRODUCTION

The requirement for casting or cutting openings in RC beams is a common one, usually to allow for the passage of services**.** Openings can be circular, square or rectangular in shape. Circular openings are normally used for electricity cables, telephone lines and computer networks while square or rectangular openings are used for air-conditioning services. The inclusion of opening in the web portion of beam produces discontinuities in the normal flow of stresses and thus leading stress concentration and early cracking around the opening. These stress concentration may leads to wide cracking which is unacceptable from aesthetic and durability viewpoints. Presence of these openings also produces many problems including reduction in the beam stiffness, excessive cracking, excessive deflection, reducing shear capacity, increase in deflection, increase in beam curvature and reduction in beam strength. The openings are of two type's small openings as well as large openings, Small openings are provided when the diameter of the opening is in a proportion of 40% of overall depth of the beam size. Small openings are provided in multistory buildings for the passage of utility

Fig 1.1; RC Beam with opening

ducts and pipes. Large opening are provided in beams of nuclear power plants and manufacturing industries for the passage of high velocity fluids. Velocity variations in the fluid flow through the pipe can cause explosions in the corner zone. Thus a blast and impact effects are generated at the corners of the openings. In this study the numerical analysis beams with opening strengthened using FRP fibers is carried out.

Strengthening of opening depends on whether those openings are pre planned or post planned. The openings in which parameters such as shape, size, orientation, etc. are very important during design stage are referred to as pre planned openings. In the case of pre-planned both the upper and lower chords are designed and reinforced to resist the internal forces due to external loads. Thus the internal strengthening around the opening is considered at the time of design stage. In the case of post planned openings, existing structural members such as beams require drilling of openings, to accommodate the new or existing services which are being relocated having clashed with the existing beam. These openings have a vital effect on the structural Capacity of existing member. The failure of beam under different kinds of loads is as shown in figure 1.4. To overcome such situations, strengthening material such as a fiber reinforced polymer (FRP) is used to strengthen the beams externally.

Fig 1.2; Strengthened beam with FRP laminates.

This method can be utilized for the strengthening of floor beams and other such structural members which are affected during drilling process. FRPs is considered as the most commonly used strengthening material for external treatment, which is recommended by research community and research personnel due to its excellent characteristics such as ultra-high tensile strength, light-weightiness, resistance to corrosion and easy application on site etc.
FRP wrapping can be inside or outside the openings as shown in figure: 1.3

Fig 1.3 CFRP laminations inside and around the openings

RC beam in concrete structures like rock sheds, check dams, nuclear power plants and manufacturing industries may be subjected to impact loads at the time of sudden collision between objects. The common type of impact incidents are explosions in military establishments, crane accidents while carrying specimens, rock falls affecting structures located at avalanche regions, machine vibrations in manufacturing industries, wind earthquakes in wind affected areas, explosive shocks due to far bomb blasts, environmental impacts etc.

Fig 1.4 failure of beam with opening under various loads

The finite element program AUTODYN is selected to model impact and blast load effect on strengthened beam for the study. AUTODYN is an explicit analysis program designed for highly nonlinear dynamic problems.

1.1 Scope and objective

- To model an RC beam with opening strengthened using CFRP sheets around and inside the opening
- To conduct numerical analysis on the strengthened beams under impact loading in ANSYS- autodyne platform
- To compare the results obtained from numerical analysis for finding which lamination method is best under impact loading

Scope of the study

- Method of lamination inside and around the opening.
- Study is extended from strengthening of opening to numerical analysis under impact loading

2. GEOMETRY

Rectangular cross section of 2000mm length, 150mm width, and 250mmdepth was modelled in solid works 16 and then which is imported to ANSYS Workbench platform. The beam consisting of two numbers of 12mm diameter bars at bottom, two numbers of 10mm diameter bars at top and 8mm diameter stirrups at 150mm centre to centre spacing. A steel hammer of weight 300kg is allowed to fall on the beam with a velocity of 5m/s for impact analysis

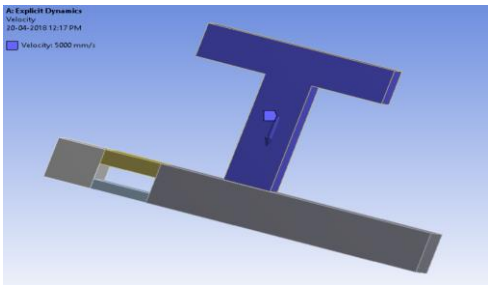

Fig. 2.1 Geometry

3. MATERIAL MODELS

A materials property is an intensive, often quantitative, property of some material. Quantitative properties may be used as a metric by which the benefits of one material versus another can be assessed, thereby aiding in materials selection.

3.1 Concrete 35 MPa

M35 concrete is used. M35 is a common type of concrete grade used were higher strength of concrete is required. It has higher flexural strength compared to other grades. The P-alpha equation of state was used in *ANSYS Autodyn* to model the concrete before the pores collapsed and it was fully compacted. After the concrete is fully compacted, *ANSYS Autodyne* is reverts to the polynomial equation of state. Material properties of Concrete 35Mpa is listed below table; 1.

Table; 3 Material properties of CFRP

Parameters	Value
Young's Modulus	$1.21E^{-5}$ MPa
Density	1950 kg/m^3
Poisson's ratio	0.27
Shear modulus	4700 Mpa

4. ANALYSIS RESULT AND DISCUSSION

In this numerical study total three beams were modelled, one beam with rectangular post opening considered as a

control beam for comparison (B1). The remaining two beams were externally strengthened by Carbon fibre reinforced polymer (CFRP) sheets with different strengthening techniques i.e. around the opening and inside the opening. CFRP around the opening (B3) and CFRP inside the opening (B2)

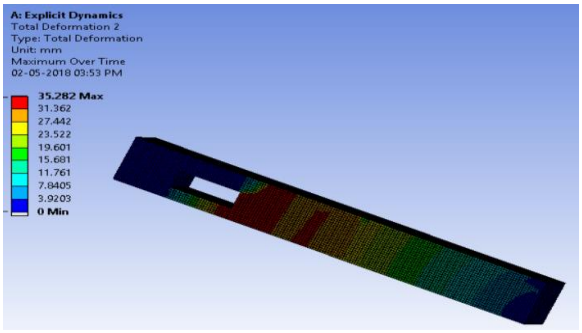

Fig. 3.1 Total deformation non- strengthened beam

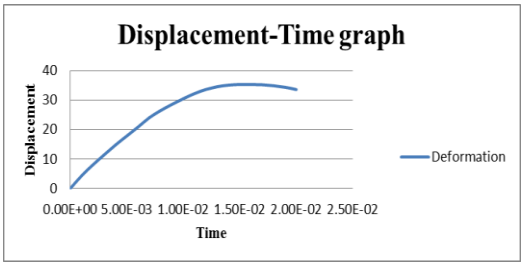

chart-1 Displacement time graph of control specimen

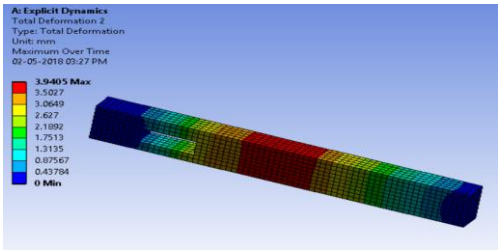

Fig. 3.2 Total deformation non-strengthened beam

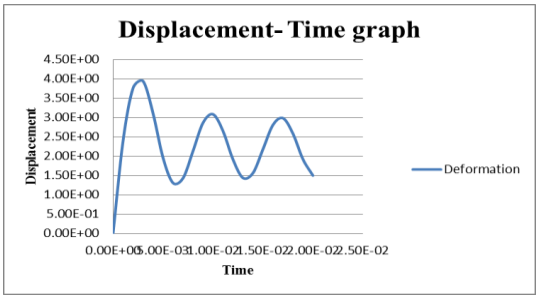

chart-2 Displacement time graph of CFRP around model

Table.5 Total deformation

Parameter	Control beam(B1)	CFRP Inside(B2)	GFRP Around (B3)
Total deformation	35.282mm	8.9mm	3.94mm

Numerical results presented in the table5, from the table it is clear that the presence of an opening reduces the load carrying capacity and decreases the total deformation .The total deformation obtained as 35.282 mm due to the presence of a 300x100mm rectangular opening within shear zone.

The percentage of decrease in total deformation for the beam strengthened with CFRP around the opening (B3) was 88.83% as compared to non- strengthened beam (B1).

4. CONCLUSION

The importance of this study is to evaluate the performance of beam with opening strengthened using CFRP under impact load. This strengthening system provides an economical and multiple solutions for extending the service life of opened reinforced concrete beams. The proposed study is to improve the understanding of reinforced concrete beams with web openings under impact load when strengthened with FRP. This proposal gives new challenges for engineering practice, professionals and who are working in the field of strengthening of reinforced concrete structures especially in RC beams with openings. From the overall study, it can be concluded that the strengthening with CFRP around the opening is more efficient under impact and is considered as best strengthening scheme.

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