Structural performance and strengthening of RCC interior joint with variable beam depth using Sika wrap

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Abstract - *Sika wrap becomes preferable for strengthening and retrofitting of RC structural elements due to its high strength-to-weight and high-stiffness-to- weight ratios. This study examines the structural performance and strengthening of RCC interior joint with variable beam depth using Sika wrap. In the first model, strengthening of beam connection is done by L-strip method. In the second model, strengthening of column connection is done by L-shaped plate method. In the third model, strengthening of joint connection is done by X-shape method. In the fourth model, strengthening of beam-column connection is done by L-shaped plate and wrap method. The structure will be analyzed using seismic analysis. This can be done by varying the depth of beam and finding which one possess more strength. Non-linear lateral loading test is carried out for beam-column connection with varying depth of beam on studying joint strength, target displacement and ductility for above all methods.*

Key Words: RC-beam column joint, Sika wrap, Strengthening, Finite element analysis, ANSYS

1. INTRODUCTION

In reinforced concrete (RC) buildings, connections between beam and column called beam-column joints are crucial parts of a building. Several parameters affect the behaviour of RC beam-column joints such as relative stiffness between beam and column, strength of concrete and reinforcement details. In fact, only vertical load is taken into consideration. This joint is most critical portion of a building under earthquake due to diagonal crack failure, which leads to the collapse. Such joints need special attention to increase capacity of existing damage joints through retrofitting.

A majority of studies concentrate on joint shear strengthening, and strengthening in the principal stress axis is found to be most effective. Only a limited number of studies evaluate combining several of these retrofit objectives into a more complete retrofit of the joint sub assemblage. In most studies, simple FRP wrapping is observed to be used for anchorage , which is not always effective. Instead, anchorage by means of FRP anchors or mechanical anchors is shown to be required to achieve adequate strengthening in most cases.

Nowadays, Sika wrap becomes preferable for strengthening and retrofitting of RC structural elements due to its high strength-to-weight and high-stiffness-to- weight ratios. Sika wrap comprises of unidirectional, carbon or glass fibre fabrics and structural epoxy resin based, impregnating resins. These unique combinations provide a wide range of strengthening and upgrading solutions to meet the many varied demands of different product and application. They are used for strengthening of reinforced concrete, masonry, brickwork, correcting structural design and construction defects, increasing resistance for increasing the strength and ductility and to seismic performance improving service life and durability.

Durability is a prerequisite for a strengthening system. The Sika wrap, plates, fabrics, and adhesives, all have excellent resistance to corrosive and aggressive chemical influences. There is no risk of underrusting. The performance of the Sika wrap has been demonstrated even in compression zones. A thicker plate, such as steel, would undergo sudden delamination but Sika wrap plates remain fully bonded until concrete failure in compression.

In this study, structural performance and strengthening of RCC interior joint with variable beam depth using Sika wrap is done. The investigation is conducted using the FEM software ANSYS 16.1.Modal, static and time history analysis will be conducted to obtain the response of various parameters.

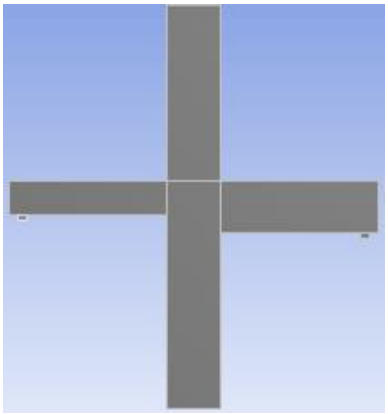


Fig 1: Reference beam column connections

2. FINITE ELEMENT MODELLING

2.1 GENERAL

To investigate structural behaviour of beam column connections, finite element models were developed using ANSYS 16.1. Element types are SOLID65 for concrete and beam188 for reinforcement were used to model different connections. SOLID65 is used for 3D modelling of solids with or without reinforcing bars and capable of modelling cracking in tension and crushing in compression. The element is defined by 8 nodes having three degrees of freedom at each node: translations in the nodal x,y,z directions.

2.2 SCOPE

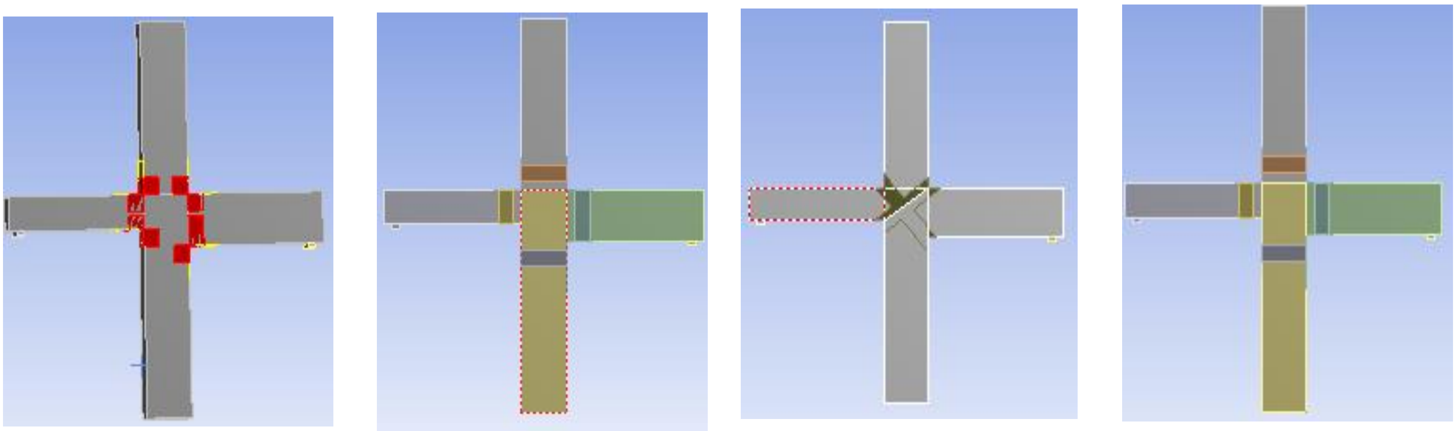
The work is limited to modelling and analysis of beam column connection by using ANSYS. The study includes the behaviour of four models for strengthening of beam, column and joints.The study in strengthening focusing on joint, beam and column indivitually. Strengthening of interior beam column connection with variable moment beams. Evaluating the performance of beam column connection in terms of load carrying capacity, yield displacement and ductility towards improving the seismic performance behavior. The structure will be analyzed using seismic analysis. It can be analyzed by finding the best model. This can be done by varying depth of beam and finding which one posess more strength. Non-linear lateral loading testing is carried out for beam column connection with varying depth of beam on studying joint strength, target displacement and ductility for above all methods.

2.3 GEOMETRY

The defected beam-column joint with various strengthening schemes are taken for analysis. In the first case interior beam connection failure is studied. In the second case interior column connection failure is studied. In the third case interior joint connection failure is studied and fourth case both beam and column connection failure is studied. The beam has 900 mm length and cross-sectional dimensions of first beam is 200x300 mm and cross-sectional dimensions of second beam is 200x200 mm. The cross-sectional dimension of the column is 200x300 mm and first column has 1000 mm length and second column has 1300 mm length. The total length of the columns was 2.3 m divided into two equal parts, lower part and upper part. Bilinear isotropic hardening is used to reproduce the plastic behaviour of materials.

The upper and lower reinforcement of the beam in addition to the main longitudinal steel reinforcement of the column were made from high tensile steel. The main steel reinforcement of the beam was three bars of 16 mm diameter, while the secondary steel reinforcement was two bars of 12 mm diameter. On the other hand, column was reinforced with four bars of 16 mm diameter at each corner of the column cross-section. The stirrups for both beam and column were mild steel bars of 8 mm diameter and spaced every 100 mm and 150 mm for the beam and the column .In addition, three stirrups were added at the beam-column joint.

Geometry of beam column connection in finite element modelling is shown in Figure 2. Material properties of stirrup, main bars, concrete and Sika wrap are shown in Table 1. Bilinear isotropic hardening is used to reproduce plastic behavior of materials.



(a)L-shaped strip (b) L-shaped plate (c) X-shape (d) L-shaped plate and wrap

Fig 2: Geometry of different beam column connections(column strengthening by L-shaped strip, beam strengthening by L-shaped plate, joint strengthening by X-shape, both beam and column strengthening by L-shaped plate and wrap method)

TABLE 1. Material Properties of stirrup, main bars, concrete and Sika wrap

Material Properties	**Stirrup**	**Main bar**	**Concrete**	**Sika wrap**
Young's Modulus (MPa)	25000	25000	25000	23000
Poisson's ratio	0.15	0.15	0.15	0.3
Yield Strength(MPa)	250	400	3.1	3450

2.4 Meshing

Meshing is the process of dividing the whole component into a finite number of elements so that whenever the load is applied on the component it distribute load uniformly. The size of divided element must be as small as possible so that total number of elements divided must be large as possible, which helps the result to be accurate.

2.5 Loading and Boundary conditions

To simulate the real condition, beam-column joint were analyzed with fixed support at both column ends and point loading is given at both ends of beam. Loading is applied as displacement controlled till failure. Behaviour of beam column connection was studied by ANSYS. Boundary conditions of different methods of beam column connection are shown in Figure 3.

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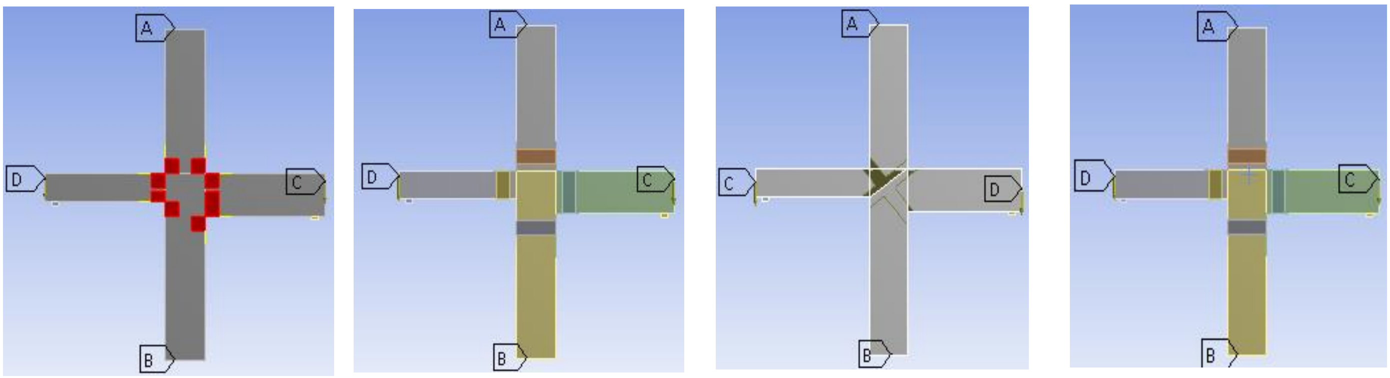


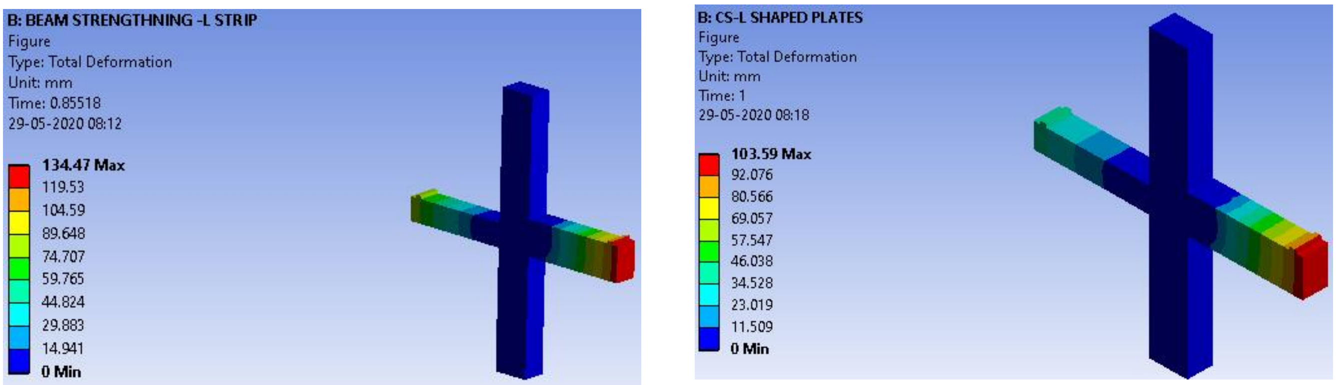
(a)L-shaped strip (b) L-shaped plate (c) X-shape (d) L-shaped plate and wrap

Fig 3: Boundary conditions of beam column connection

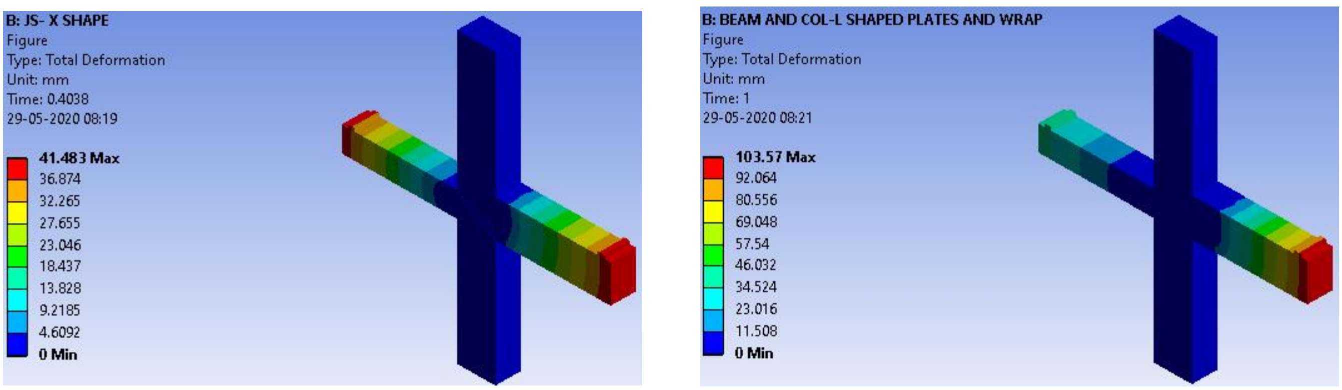
3. ANALYTICAL RESULTS AND DISCUSSIONS

3.1 Total deformation

Total deformation of different methods of beam column connection are shown below.



a)L-strip method b)L-shaped plate method



c)X-shape method d)L-shaped plate and wrap method

Fig 4: Total deformation of different methods of beam column connection.

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TABLE 2. Different method comparison of axial ultimate load and deformations of beam column connections.

Strengthening method	Total Deformation (mm)	Ultimate load (kN)
Beam failure	22.33	70.03
BS-L strip method	134.47	91.85
Column failure	20.53	73.82
CS-L shaped plate method	103.59	91.55
Joint failure	18.44	73.77
JS-X shape method	54.82	81
Both beam column failure	23.92	69.95
BS-L shaped plate and wrap method	103.57	91.32

NS:- BS-beam strengthening, CS-column strengthening. JS-joint strengthening, BC-beam column strengthening

The analytical result of beam failure, column failure, joint failure and their strengthening methods are interpreted. Their behavior throughout analysis is studied from the recorded data obtained from the deformation bahaviour and load carrying capacity using ANSYS. From results, it is clear that all strengthening methods improve the total deformation and ultimate load carrying capacity.

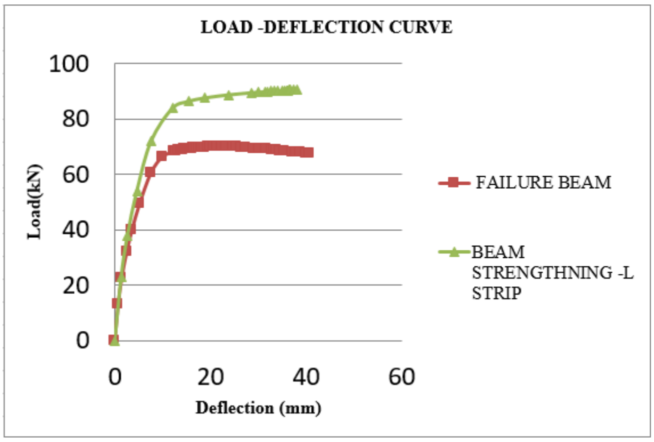

Fig 5: Load – Deflection curves for beam strengthening

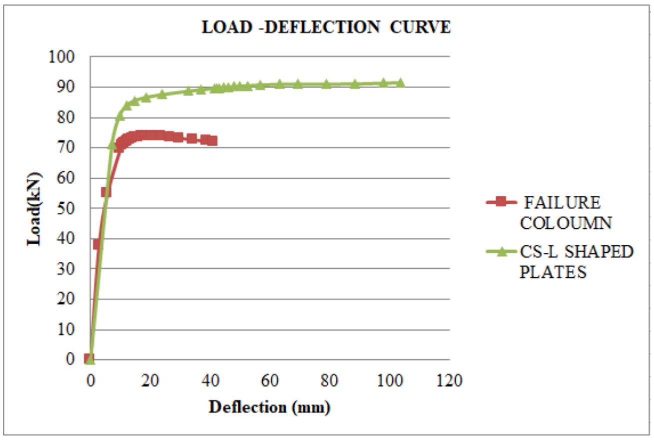

Fig 6: Load – Deflection curves for column strengthening

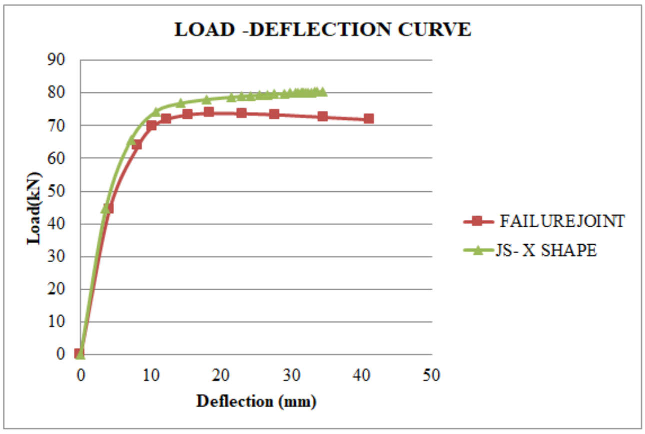

Fig 7: Load – Deflection curves for joint strengthening

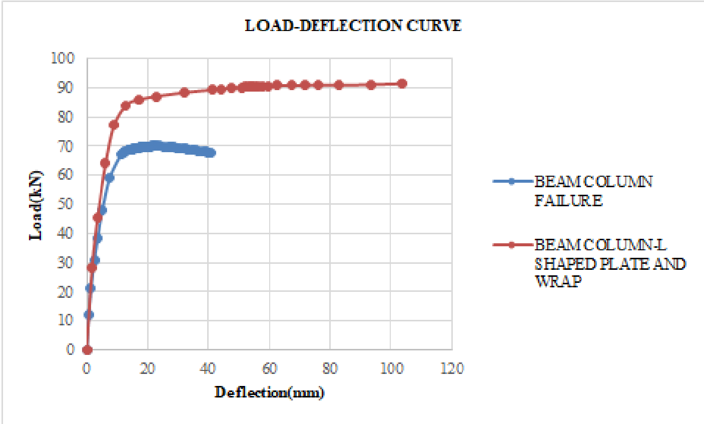

Fig 8: Load – Deflection curves for beam column strengthening

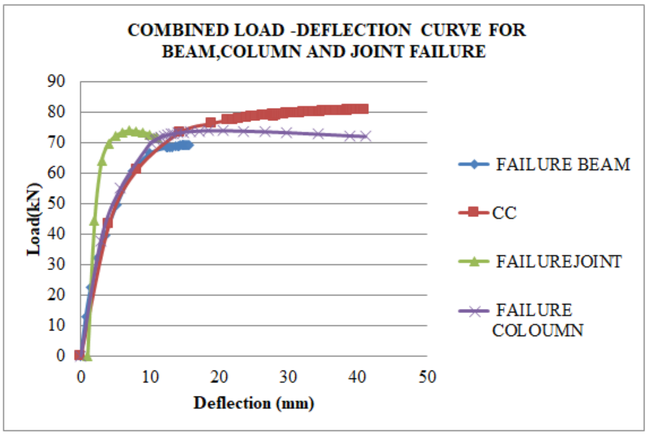

Fig 9: Load – Deflection curves for beam ,column and joint failure

TABLE 3. Comparison of deflection, ultimate load, percentage of increase in load, yield displacement and ductility in the case of beam strengthening

	Deflection (mm)	Load (kN)	% of increase in load	Yield displacement (mm)	Ductility
Beam failure	22.33	70.03	1.00	3.5794	6.24
L-strip method	88.62	88.76	26.75	3.58	24.78

TABLE 4. Comparison of deflection, ultimate load, percentage of increase in load, yield displacement and ductility in the case of column strengthening

	Deflection (mm)	Load (kN)	% of increase in load	Yield displacement (mm)	Ductility
Column failure	20.53	73.82	1.00	2.8751	7.14
L-shaped plate method	103.59	91.55	24.02	7.1711	14.45

TABLE 5. Comparison of deflection, ultimate load, percentage of increase in load, yield displacement and ductility in the case of joint strengthening

	Deflection (mm)	Load (kN)	% of increase in load	Yield displacement (mm)	Ductility
Joint failure	18.44	73.77	1.00	4.1018	4.50
X-shape method	54.82	81.00	9.80	3.58	15.31

TABLE 6. Comparison of deflection, ultimate load, percentage of increase in load, yield displacement and ductility in the case of both beam column strengthening

	Deflection (mm)	Load (kN)	% of increase in load	Yield displacement (mm)	Ductility
Beam column failure	23.92	69.95	1.00	11.201	2.14
L-shaped plate and wrap method	103.57	91.32	30.56	3.5697	29.01

4. CONCLUSIONS

In this study, different methods were adopted to strengthen beam, column and joint connection using Sika wrap and following conclusions were arrived at:

1. Comparing the analytical result we can confirm that deflection in strengthened specimen is comparatively lesser than that of unstrengthened specimen.
2. Ultimate load carrying capacity of retrofitted specimen will be more compared with unstrengthened specimen.
3. The percentage of increase in load,ductility of retrofitted specimen will be more when compared with normal specimen.
4. From overall study it can conclude that strengthening with Sika wrap increases the servicability of structure.

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