# Shear Strengthening of Shear deficient beams Using AFRP Wraps in varying orientation

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***Abstract*—The study evaluates on the nonlinear finite element analysis of shear deficient beams (SD) using Aramid Fiber reinforced polymer (AFRP). The shear deficient beam is strengthened with epoxy impregnated AFRP by varying thickness and orientation are modelled using ANSYS Software. The result obtained is then compared with control beam and shear deficient beam. Shear deficient beams externally strengthened with one layer of AFRP in Shear span and two layers of AFRP Strip of 50 mm width at the bottom of the beam are modeled and analysed. AFRP Fabric in the shear span is oriented at angles $45^0$ and $60^0$. The thickness of AFRP fabric is selected as 0.286. The analysis is done using ANSYS software. The parameters taken into account are the percentage increase in the maximum load carrying capacity and load deformation behaviour of epoxy-impregnated AFRP specimens.**

***Index Terms*—Nonlinear finite element analysis, AFRP, ANSYS, Shear span**

## I. INTRODUCTION

A structural beam that lacks the shear capacity to withstand the shear forces imposed on it is said to be shear-deficient. This usually happens when the reinforcing, material characteristics, or cross-sectional dimensions of the beam are insufficiently strong to withstand the imposed shear stresses. Shear inadequacies frequently occur in reinforced concrete and steel beams when the shear reinforcement—such as stirrups in concrete beams or web reinforcements in steel beams—is insufficient. Particularly close to supports or areas where shear pressures are greatest, these flaws may cause the beam to prematurely collapse as a result of shear cracking or possibly a shear rupture.

Advanced concrete technology makes considerable use of fiber-reinforced polymer (FRP) composites because of their superiority over conventional steel reinforcements. When combined with adhesives and anchorages, these materials can be used as the primary reinforcements to strengthen reinforced concrete (RC) beam members because of their high strength capacity and resistance to corrosion.

## II. MODELING OF SHEAR DEFICIENT BEAM AND CONTROL BEAM

The cross section of the beam chosen is 150 mm × 200 mm, its net span is 1500 mm, and its overall length is1800 mm. The stirrups are positioned at 160 mm apart. The material properties of Concrete and Reinforcement details given by Nawal Kishor Banjara and K. Ramanjaneyulu [1] are adopted in this study. The material properties of Concrete and Reinforcement are given in the table 1 and table 2 respectively.

The shear deficient RC beam SD is having three stirrups i.e. one at the middle and the other two are at the ends of the reinforcement at spacing 750 mm.

Control beams and Shear-deficient beams are modelled using element type SOLID 186 and reinforcement using REINF 264, respectively. ANSYS Version 2022 R1 is utilized for modelling both control beams and Shear deficient beam modelling. After having modelled the model, the meshing for both control and shear deficient beams is done as hexahedron mesh. Adaptive mesh-controlled size is used for meshing. The load is applied as 70 mm displacement according to displacement Convergence criteria. Also, the support condition provided is simply supported as shown in figure 1.

Table 1: Properties of Concrete

| Properties | Value |
|---|---|
| Grade of concrete | 40 Mpa |
| 28 days Compressive strength | 44.7 N/mm$^2$ |

| | |
|---|---|
| Poisson's ratio | 0.2 |
| Modulus of Elasticity | 31500 $N/mm^2$ |
| Uniaxial Compressive strength | 3.2 $N/mm^2$ |

Table 2: Properties of Reinforcing Steel

| Properties | Value |
|---|---|
| Yield stress | 500 $N/mm^2$ |
| Poisson's ratio | 0.3 |
| Modulus of Elasticity | 200,000 $N/mm^2$ |

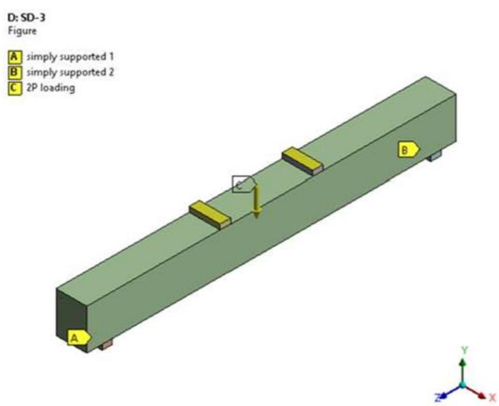



Figure 1: Support condition diagram of SD beam

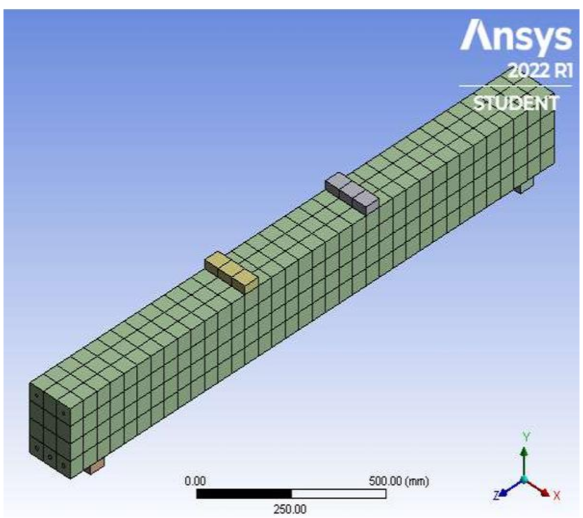



Figure 2: Mesh model of Control beam

For the control beam, a maximum load carrying capacity of 94.612 kN and a corresponding deformation of 7.66mm are found. Also, Shear-deficient beams have a maximum load carrying capacity of 60.7 kN and a corresponding deformation of 4.39 mm.

## III. ANALYSIS OF SHEAR DEFICIENT BEAMS EXTERNALLY STRENGTHENED WITH AFRP IN SHEAR SPAN BY VARYING ORIENTATION

Figure 3 illustrates the modeling and analysis of shear-deficient beams that are externally strengthened with one layer of AFRP in the shear span and two layers of AFRP Strip 50 mm wide at the bottom of the beam. AFRP Fabric having thickness 0.286 in the shear span is oriented at angles $45^0$ and $60^0$. The Material properties of AFRP and epoxy are given in table 3.

Table 3: The Material properties of AFRP and epoxy.

| Material | Modulus of Elasticity ($N/mm^2$) | Tensile Strength (MPa) | Poisson's ratio | Layer thickness (mm) |
|---|---|---|---|---|
| APRP | 1310000 | 47.2 | 0.3 | 0.286 |
| Epoxy | 3800 | 45 | 0.21 | 1 |

B2L-S1L-SZ85-L45D – AFRP Strengthened beam with two layers of 50mm width AFRP at the bottom side and one layer of AFRP inclined at $45^0$ degrees on the Shear span of the beam.

B2L-S1L-SZ85-LR45D – AFRP Strengthened beam with two layers of 50mm width AFRP at the bottom side and one layer of AFRP inclined at $45^0$ degree and placed in opposite direction on the Shear span of the beam.

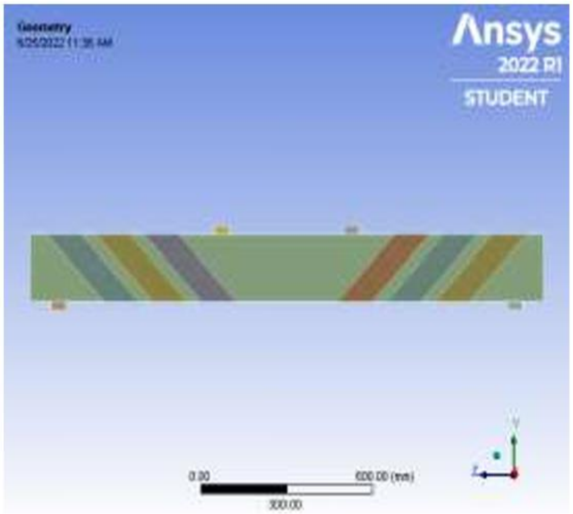
X-42.5SZ-45D – AFRP Strengthened beam with two layers of 50mm width AFRP at the bottom side and one layer of 42.5 mm AFRP wrapped in X shape on the Shear span of the beam.

X-85SZ-45D - AFRP Strengthened beam with two layers of 50mm width AFRP at the bottom side and one layer of 42.5 mm AFRP wrapped in X shape on the Shear span of the beam.

B2L-S1L-SZ85-LR60D – AFRP Strengthened beam with two layers of 50mm width AFRP at the bottom side and one layer of AFRP inclined at $60^0$ degree and placed in opposite direction on the Shear span of the beam.

X-42.5SZ-60D – AFRP Strengthened beam with two layers of 50mm width AFRP at the bottom side and one layer of 42.5 mm AFRP wrapped in X shape ($60^0$) on the Shear span of the beam.

X-85SZ-45D - AFRP Strengthened beam with two layers of 50mm width AFRP at the bottom side and one layer of 42.5 mm AFRP wrapped in X shape ($60^0$) on the Shear span of the beam.

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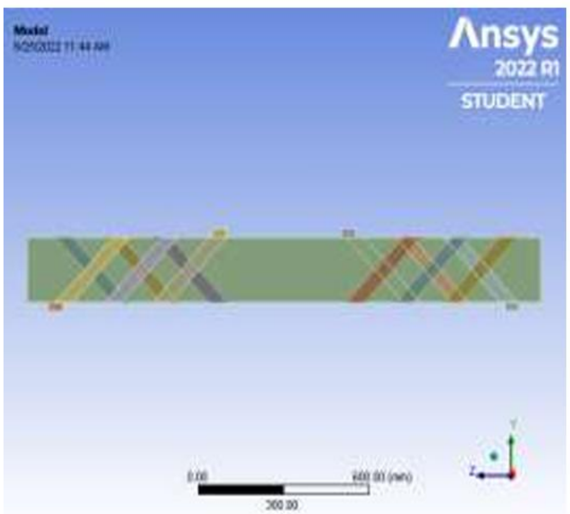


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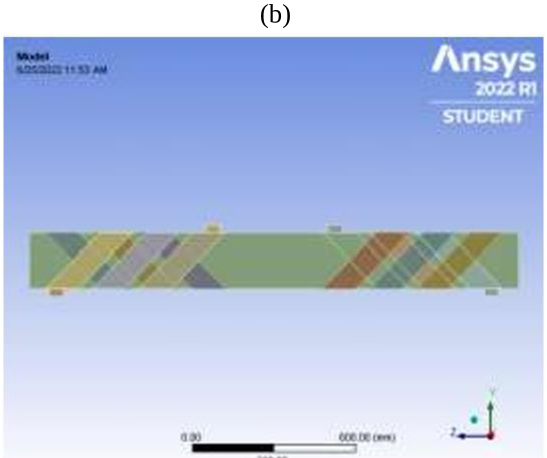


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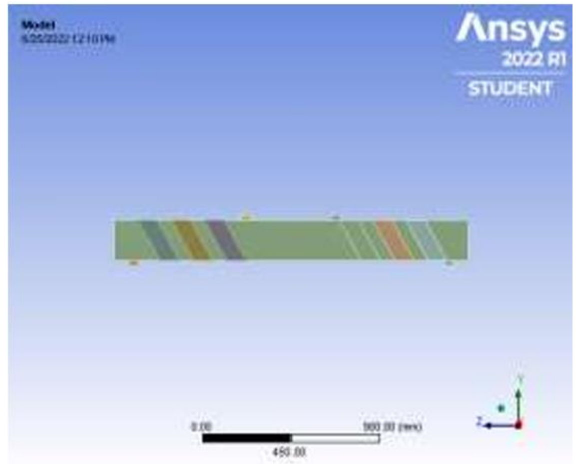


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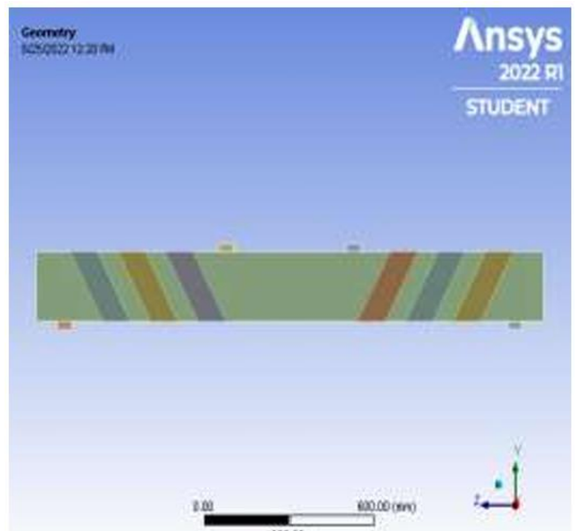


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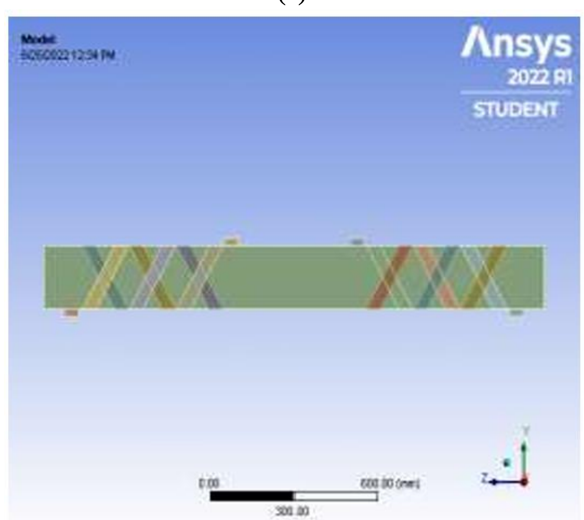

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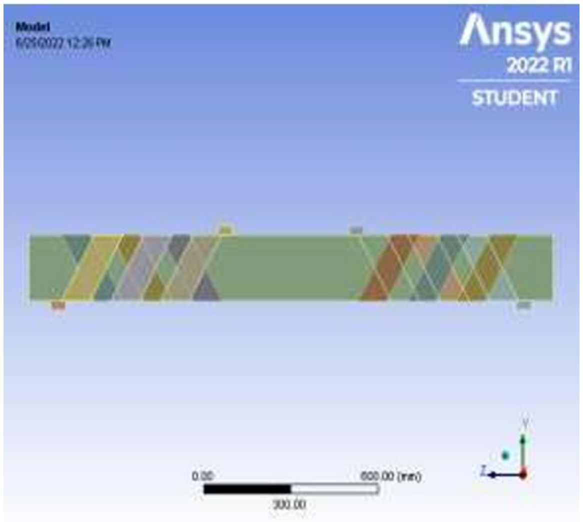


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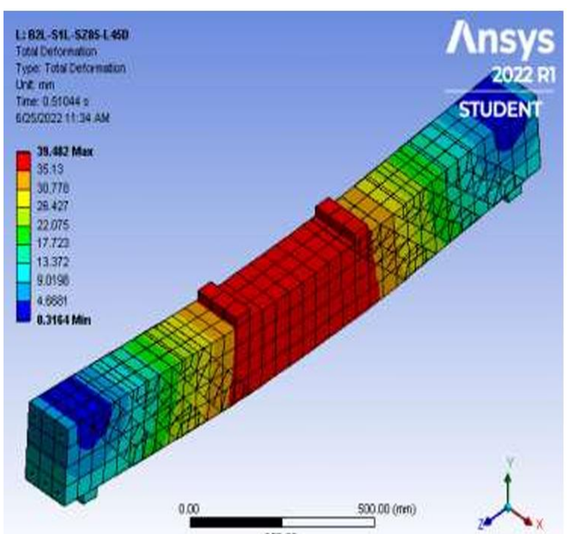
Figure 3: Modelling of (a) B2L-S1L-SZ85-LR45D (b) X-42.5SZ-45D (c) X-85SZ 45D (d) B2L-S1L-SZ85-L45D (e) B2L-S1L-SZ85-LR60D (f) X-42.5SZ-60D (g) X 85SZ-60D

## IV. ANALYSIS

Analysis is carried out to study the performance of strengthened shear deficient beams with varying orientation as shown in figure 4. Nonlinear static structural analysis is carried out in ANSYS software.

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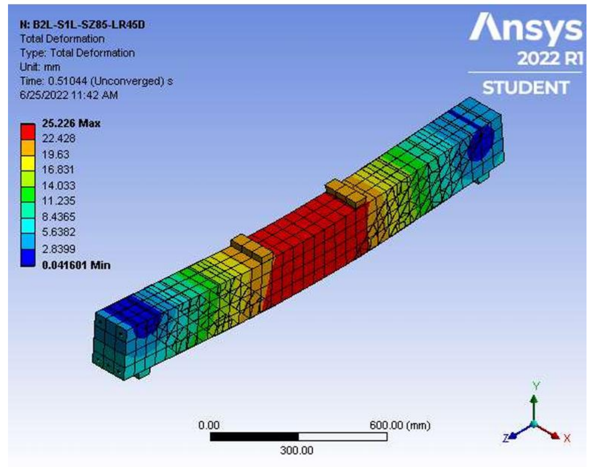


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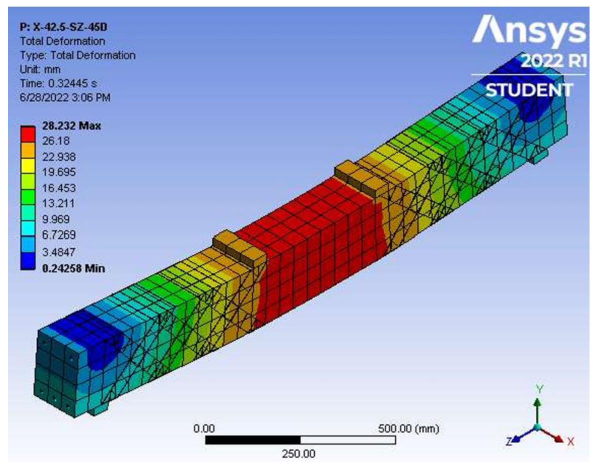


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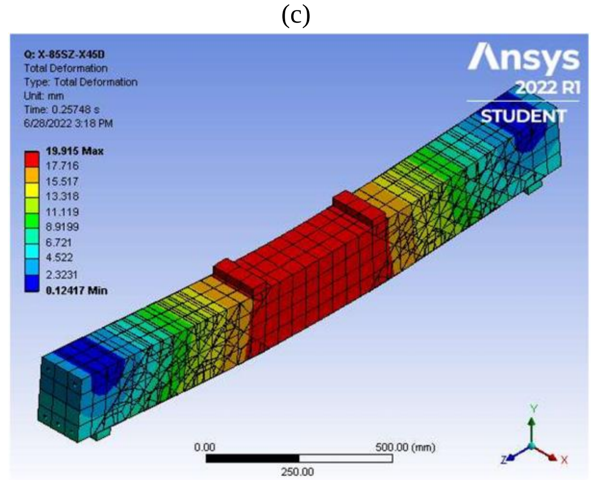


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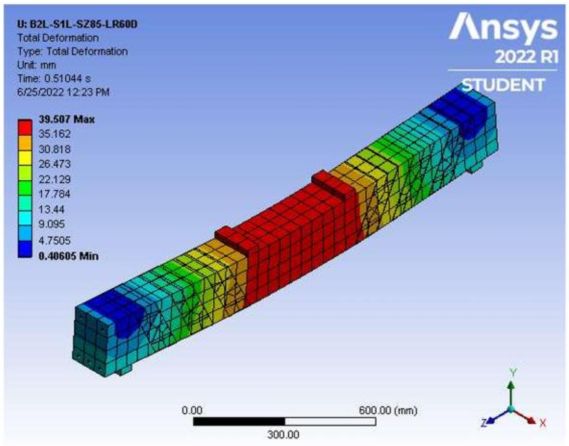


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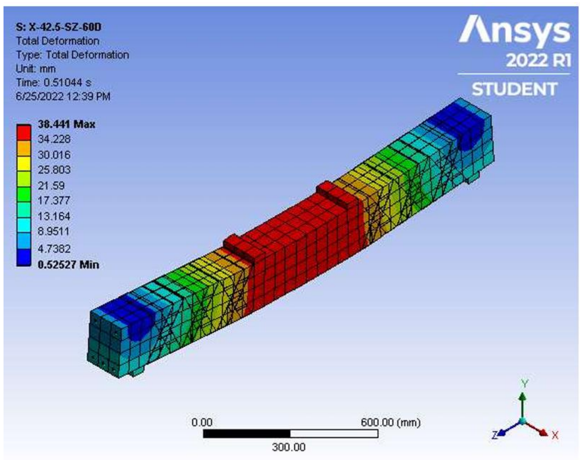


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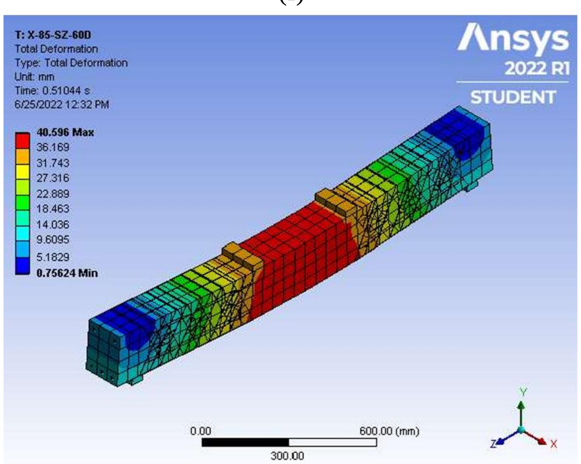


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Figure 4: Total deformation of (a) B2L-S1L-SZ85-L45D (b) B2L-S1L-SZ85-LR45D (c) X-42.5SZ-45D (d) X-85SZ-45D (e) B2L-S1L-SZ85-LR60D (f) X-42.5SZ-60D (g) X-85SZ-60D

## V. RESULT

Static analysis of Strengthened Shear deficient Beam by varying orientation is perfomed. The percentage increase in load of $45^0$ and $60^0$ orientation of AFRP with SD Beam are given in table 4 and 5 respectively.

Table 4: Load deflection comparison of $45^0$ orientation of AFRP with SD Beam

| Models | Deflection | Load | % increase in load |
|---|---|---|---|
| SD | 4.396 | 60.7 | 1 |
| X-42.5SZ-45D | 27.77 | 119.35 | 49.14 |
| B2L-S1L-SZ85-LR45D | 22.95 | 119.61 | 49.25 |
| B2L-S1L-SZ85-L45D | 34.24 | 125.23 | 51.53 |
| X-85SZ-45D | 19.68 | 128.13 | 52.63 |

Table 5: Load deflection comparison of $60^0$ orientation of AFRP with SD Beam

| Models | Deflectio n | Load | % increas e in load |
|---|---|---|---|
| SD | 4.3961 | 60.7 | 1 |
| X-42.5SZ-60D | 32.74 | 115.65 | 47.51 |
| B2L-S1L-SZ85-LR60D | 30.131 | 116.38 | 47.84 |
| X-85SZ-60D | 29.734 | 119.2 | 49.08 |

## VI. CONCLUSION

- By varying the orientation of the AFRP, the load carrying capacity of the beam increases for the models X-85SZ-45D and X-85SZ-60D. For $45^0$ orientations of AFRP, X-85SZ-45D beam have maximum value of ultimate load carrying capacity (128.13kN) and corresponding deformation (19.68mm).
- Also, for $60^0$ orientations of AFRP, X-85SZ-60D beam has maximum value of ultimate load carrying capacity (119.2kN) and corresponding deformation (29.73mm).
- Thus, $45^0$ orientations of AFRP gives better results for load carrying capacity than $60^0$ orientations of AFRP. Also, from the above

results AFRP can be used for strengthening shear deficient beams.

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