Experimental Study on BFRP Confined Concrete in Stub Elements

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Abstract: ***In the present experimental study to investigate the compressive behaviour of concrete stub column confined by a new class of composite material originated from basalt rock, basalt fiber reinforced polymer. In this study confinement with FRP jackets is a useful reinforcement technique to improve the strength and ductility of concrete column subjected to axial compression loads, especially in those that have a stub column and concrete column. A basalt sheet is used for this project to increase the stability of the concrete structure. The ultimate load carrying capacity of externally bonded BFRP concrete stubs will be evaluated experimentally. A stub column specimens and circular column specimens were casted with different aspect ratios (B/D=1, B/D=1.56, B/D=1.93) with different layers of BFRP wrapping (1layer, 2layer, 3layer) and different grade of mix (M_{25} & M_{45}). The axial compressive load to be applied for the element and to check the stability of the concrete. The properties of concrete such as compressive strength, split tensile strength, flexural strength and density were determined as per relevant Indian and ASTM standards. It can be concluded that as the number of basalt layer wrapping increases the compressive and flexural strength that also increases when compared to the conventional concrete in stub column.***

Keywords: Confinement, Basalt fiber reinforced polymer (BFRP), compressive strength, aspect ratio, columns.

1. Introduction

Many of the older structure to need the strengthening, rehabilitation and retrofitting. The reason for the strengthening of concrete structures, deterioration by ageing or corrosion caused by environmental factors, for future work load increasing the structure and earthquake areas. The Fiber reinforced polymer wrapping to be used for strengthening of concrete column like circular and non circular column. The wrapping of FRP composite sheets around concrete columns is a promising method for structural strengthening and repair. It's based on FRP´s unique properties in terms of strength, lightness, chemical resistance and ease of application. The experimental and analytical fields on concrete specimens of circular columns since the development of FRP wrapping started in the 1980s, and later on, columns of square and rectangular cross-sections. The different types of fiber reinforced polymers are used for increasing the strength of the concrete structures. There are

- Steel fiber reinforced concrete.
- Polypropylene Fiber Reinforced.
- Glass fiber Reinforced.
- Asbestos Fibers.
- Aramid Fiber.
- Corbon Fiber.
- Organic Fiber.
- Basalt Fiber.

Basalt fiber is an inorganic fiber material. The first attempts to produce basalt fiber were made in the United States in 1923 by Paul Dhe was granted U.S. Patent. Basalt fiber is a material made from extremely fine fibers of basalt, which is composed of the minerals plagioclase, pyroxene, and olivine.

Basalt is a dark gray to black, medium grained dense volcanic rock, thus mineral, and 100% inorganic. The typical diameter of the basalt fiber lies between 9 and 13 microns, which guarantees the best possible compromise between stability and durability.

A stub column is a column whose length is sufficiently small to pre- vent failure as a column, but long enough to contain the same residual stress pattern that exists in the column itself. A stub is a short element meant to be a connection to another structure element. It is either vertical or horizontal.

The aim of the project is to achieve the following:

- The main objective of the project is to investigate the strength and of the BFRP confined concrete in stub element using the different aspect ratio.
- To investigate the properties of the BFRP confined concrete in stub element.
- To arrive the mix proportion for M25 and M45 grade of concrete.
- To investigate the effect of changing the sequence of BFRP on the structural behavior and to check the performance of the stub column concrete.

2. Literature Survey

ArathiKrishna, et al. (2019) In this paper to present the Experimental Study on Strengthening of RC Short Columns with BFRP Sheets BFRP materials are non-corrosive, non-magnetic, and chemical resistant and they are progressively being used for repair, rehabilitation, and strengthening of structures that are not stable enough to carry loads. The main objective of the tests was to conduct experimental analysis on the load carrying capacity and to study the failure patterns of BFRP confined columns. In this experimental work, the columns were cast and wrapped with BFRP sheets and the tests were being conducted and material properties of relevant material reviewed. Mix proportion adopted was M25 that is nominal mix proportion to get the 28th-day compressive strength as 25 N/mm2. The w/c (water cement) ratio of 0.5 was used. The average compressive strength obtained at the 28th day of concrete was 26.373 N/mm2. The conclusion of this paper is Axial strength of the columns can be increased efficiently by providing wrapping in the form of confinement using fibers.

Sakol Suon, et al (2019). This paper to investigate an experimental study on the Compressive behavior of basalt FRP-confined circular and non-circular concrete The main objective of this study is to observe the difference between compressive behavior of circular and non-circular concrete specimens jacketed with BFRP composite. BFRP sheets are proposed in present study to test under monotonic axial compression. FRP composite can be effectively used in improving the overall compressive behavior of confined concrete. The ultimate stress and strain of all the confined specimens were enhanced almost linearly with an increase in number of BFRP layers. The load bearing capacity of BFRP-confined specimens was improved almost linearly when the cross-section shape was changed from non-circular to circular.

K. Kirthika, et al (2018) In this paper to study the Experimental Investigations on Basalt Fiber-Reinforced Concrete The all basalt fibers, an inert mineral fiber is gaining more importance due to its exceptional properties, which include resistance to corrosion and low thermal conductivity. Concrete of M30 grade was used in the present study. Fresh and hardened properties of the BFRC were compared with control concrete. Flexural strength or modulus of rupture of concrete was determined by applying the failure load on prismatic specimen after 28 days. That is increase in compressive, splitting tensile, flexural strength and elastic modulus of concrete at 28 days. BFRC has very dense and compact structures. The increase in compressive, splitting tensile, flexural strength and elastic modulus of concrete at 28 days having 0.5% volume fraction (13 kg/m3) of basalt fiber was in the order of 26.79, 42.71, 44.06 and 35.23%, respectively, as compared to control concrete. The impact resistance of BFRC was found to be more than double as compared to control concrete Venkata subbaiah, et al (2018). This paper to investigate the An experimental study on compressive behavior of concrete cylinders confined with glass and basalt fiber reinforced polymer. FRP composites are due to their high strength-to-weight and stiffness-to-weight ratios, corrosion resistance, light weight, and potentially high durability. The Mix proportion of M20 grade of concrete, M25 grade of concrete, M30 grade of concretes are used and it's to be wrapped with 270 GSM, 350 GSM, 470 GSM sheets of glass and basalt fiber. When it's compared to the conventional concrete. The conclusion of this paper For wrapped with glass fiber reinforced polymer gsm 470, the compressive strength of concrete is increased for a maximum of 4.20 %, 7.05%, 8.4% when compared with conventional concrete for M20, M25, M30 grade concrete and For wrapped with basalt fiber reinforced polymer gsm 470, the compressive strength of concrete is increased for a maximum of 6.88%, 7.76%, 8.67%, when compared with conventional concrete for M20, M25, M30 grade concrete.

3. Materials and Methods

3.1 Portland Pozzolana cement

Cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Hydraulic cements (e.g., Portland Pozzolana cement) set and become adhesive due to a chemical reaction between the dry ingredients and water.PPC grade cement is a type of Portland cement characterized by the presence of pozzolana particles like fly ash, volcanic ash. In this project to use PPC 43 grade of cement.

3.2 Fine Aggregates

The fine aggregate used in the study was river sand .Fine aggregates passing through 4.75mm sieve was taken.

3.3 Coarse Aggregates

Construction aggregate, or simply aggregate, is a broad category of coarse- to medium-grained particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. In this Study to use 10mm size of aggregate. In concrete Elements With thin section closely spaced reinforcement or small corner consideration should be given to the use of 10mm nominal maximum size.

3.4 Basalt Fiber Reinforced Polymer Sheet.

Fibers are used in concrete to improve its structural integrity. Nowadays, among all basalt fiber, an inert mineral fiber is gaining more importance due to its exceptional properties, which include resistance to corrosion and low thermal conductivity. It also improves the tensile strength, flexural strength and toughness of concrete.

Table 1: Properties of basalt fiber

Fiber Rein forced Polyer	Density (kg/m^3)	Tensile strength (Mpa)	Elastic modulus (Gpa)
Basalt	2.63	3200-3850	93

The current experimental study was carries by conducting preliminary tests for mix design of concrete and for M25 and M45 grade concrete. And the mix proportion shown in table.

Table 2: Mixproportion for M_{25} grade concrete

Ingredients	Quantities	Proportion
Water	220.48kg/m³	0.45
Cement	489.96kg/m³	1
Fine Aggregate	879.68kg/m³	1.79
Coarse Aggregate	803.54kg/m³	1.64

Table 3: Mixproportion for M_{45} grade concrete

Ingredients	Quantities	Proportion
Water	220.48kg/m³	0.45
Cement	612.4kg/m	1
Fine Aggregate	779.67kg/m³	1.27
Coarse Aggregate	759.47kg/m³	1.24

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Then cylinders of size 100mm X 300mm are casted and tested for compressive strength of the cylinders warped basalt fiber reinforced polymer (BFRP) After 28 days curing.

4. Result and Discussion

4.1 Flexural Strength Test

The Flexural strength is Increases with an increasing the Grade of Concrete. The 28 Days Flexural strength is Increases when Compared to the 7 Days Flexural test for both M25 and 45 Grade of Concrete. The 7 days Flexural Strength of M25 and M45 Grade of concrete is 2.9Mpa and 3.28Mpa. The 28 days Flexural Strength of M25 and M45 Grade of concrete is 4.98Mpa and 5.6Mpa.

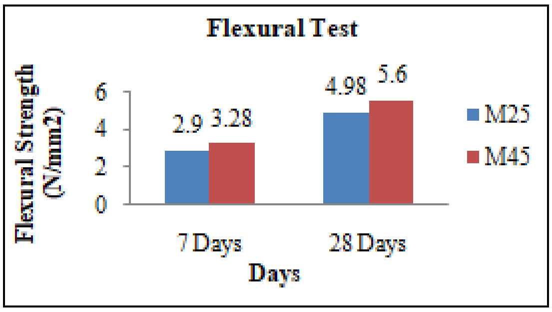

Figure 1: Comparison of flexural Test

4.2 Split Tensile Test

The Split Tensile strength is Increases with an increasing the Grade of Concrete. The 28 days split tensile strength is increases when compared to the 7 days split tensile test for both M25 and 45 Grade of Concrete. The 7 days Split Tensile Strength of M25 and M45 Grade of concrete is 1.7Mpa and 2.17Mpa. The 28 days Split Tensile Strength of M25 and M45 Grade of concrete is 3.96Mpa and 4.22Mpa.

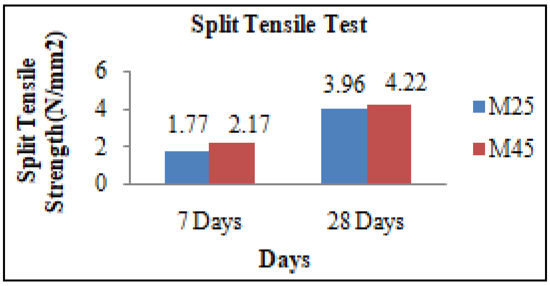

Figure 2: Comparison of Split Tensile Test

4.3 Compressive Strength Test

The test result of Cube Specimen compressive strength at 7 and 28 days given in Figure 3.The 7 and 28 days compressive strength Increase with an increasing the Grade of concrete. The 7 days Compressive Strength of M25 and M45 Grade of concrete is 18.64Mpa and 31.69Mpa. The 28 days Compressive Strength of M25 and M45 Grade of concrete is 25.4Mpa and 43.1Mpa.

The M25 Grade test result of stub Column Specimen compressive strength at 28 days given in Figure 4. The compressive strength is increased with increase the Grade of Concrete, Increase the Aspect ratio and also increasing the Layer of BFRP wrapping. M25 Grade Compressive strength of Stub column at 28 days ranges from Aspect Ratio1 28.16MPa to 31.29MPa. The Aspect Ratio 1.56 Stub Column obtained from maximum compressive strength of 31.98MPa and minimum compressive strength is 29.93MPa. The Aspect Ratio 1.93 Stub Column obtained from maximum compressive strength of 33.20MPa and minimum compressive strength is 30.90 MPa. The M45 Grade test result of stub Column Specimen compressive strength at 28 days given in Figure 5. M45 Grade Compressive strength of Stub column at 28 days ranges from Aspect Ratio1 47.68MPa to 51.46MPa. The Aspect Ratio 1.56 Stub Column obtained from maximum compressive strength of 52.56MPa and minimum compressive strength is 48.97MPa. The Aspect Ratio 1.93 Stub Column obtained from maximum compressive strength of 53MPa and minimum compressive strength is 50.31MPa.

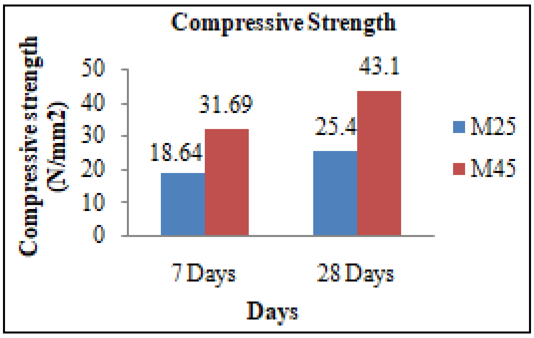

Figure 3: Compressive Strength of Cube

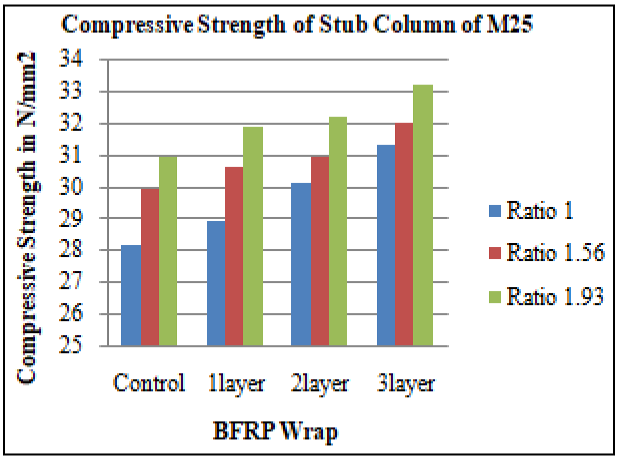

Figure 4: Compressive Strength of Stub Column in M25 grade concrete

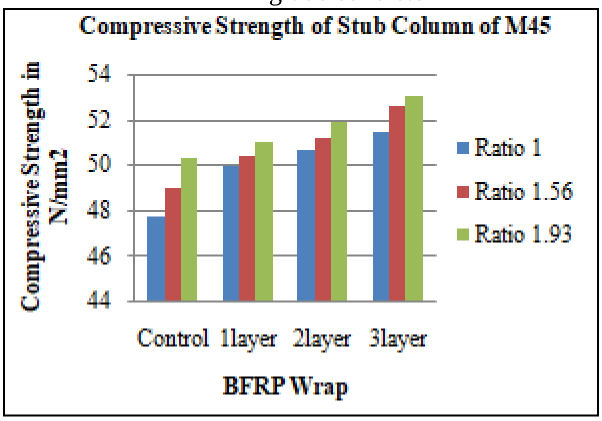

Figure 5: Compressive Strength of Stub Column of M45 grade concrete

4.5 Ultimate load bearing Capacity

Ultimate Load bearing Capacity to calculate the M25 and M45 Grade of Concrete of Aspect Ratio 1, 1.56 and 1.93. The Ultimate Load bearing Capacity is increased with increase the Grade of Concrete, Increase the Aspect ratio and also increasing the Layer of BFRP wrapping. M25 Grade Ultimate Load bearing Capacity of Stub column at 28 days ranges from Aspect Ratio1 440kN to 489kN. The Aspect Ratio 1.56 Stub Column obtained from maximum Capacity of 499kN and minimum Capacity is 467kN. The Aspect Ratio 1.93 Stub Column obtained from maximum Capacity of 520kN and minimum Capacity is 484kN.

M45 Grade of Stub column with aspect ratio 1 attain the load bearing Capacity ranges from 745kN to 804kN. The Aspect Ratio 1.56 Stub Column obtained from maximum Capacity of 820kN and minimum Capacity is 764kN. Stub column with aspect ratio 1.93 attain the load bearing Capacity ranges from 788kN to 830kN.

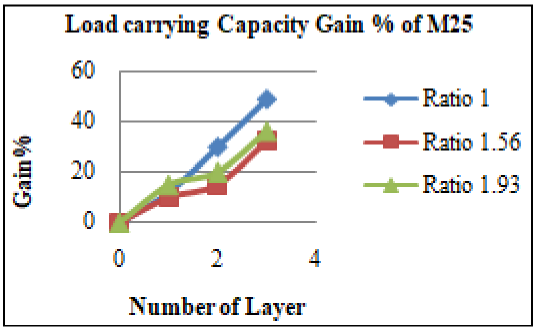

Figure 6: Load carrying Capacity Gain % of M25

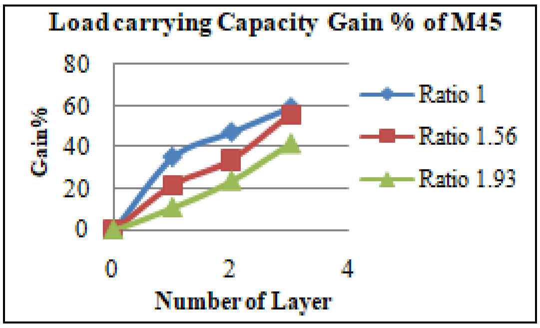

Figure 7: Load carrying Capacity Gain % of M45

4.6 Elastic Modulus

Elastic Modulus to calculate the M25 and M45 Grade of Concrete of Aspect Ratio 1,1.56 and 1.93 with use of Compressive strength of concrete. The Elastic Modulus is increased with an increase the Grade of Concrete, Increase the Aspect ratio and also increasing the Layer of BFRP wrapping. M25 Grade Elastic Modulus of Stub column at 28 days ranges from Aspect Ratio1 26.53kN to 27.96kN. The Aspect Ratio 1.56 Stub Column obtained from maximum Modulus of Elasticity is 28.27kN and minimum Modulus of Elasticity is 27.35kN. The Aspect Ratio 1.93 Stub Column obtained from maximum Capacity of 28.80kN and minimum Modulus of Elasticity is 27.79kN.

M45 Grade of Stub column with aspect ratio 1 attain the Modulus of Elasticity ranges from 34.52kN to 35.89kN. The Aspect Ratio 1.56 Stub Column obtained from maximum Modulus of Elasticity of 36.24kN and minimum Capacity is 34.98kN. Stub column with aspect ratio 1.93 attain the Modulus of Elasticity ranges from 35.46kN to 36.40kN.

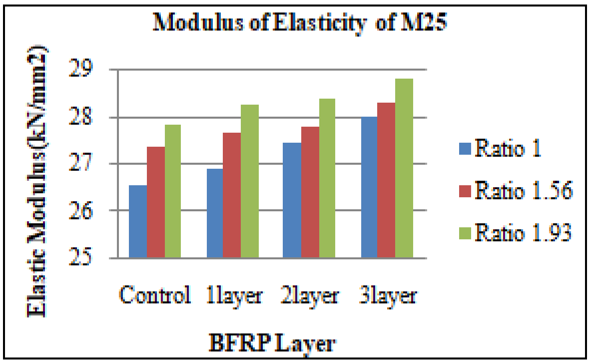

Figure 8: Modulus of Elasticity of M25

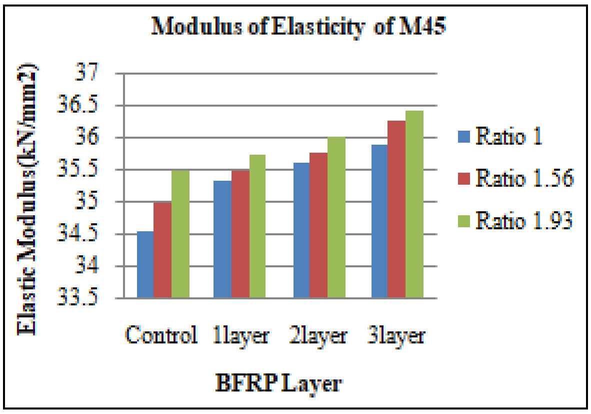

Figure 9: Modulus of Elasticity of M45

4.7 Load Buckling Characteristic

Buckling Load to calculate the M25 and M45 Grade of Concrete of Aspect Ratio 1, 1.56 and 1.93 with use of Elastic Modulus of concrete. Buckling Load is increased with an increase the Grade of Concrete and also increasing the Layer of BFRP wrapping. Buckling Load is decreased with an increase the Aspect Ratio of Concrete. M25 Grade Buckling Load of Stub column at 28 days ranges from Aspect Ratio1 is 59.17x10^3kN to 62.36 x10^3kN. The Aspect Ratio 1.56 Stub Column obtained from maximum load is 40.30 x10^3kN and minimum load is 38.99 x10^3kN. The Aspect Ratio 1.93 Stub Column obtained from maximum load of 33.38x10^3kN and minimum load is 32. x10^3kN.

M45 Grade of Stub column with aspect ratio 1 attain the load from 76.99 x10^3kN to 80.05 x10^3kN. The Aspect Ratio 1.56 Stub Column obtained from maximum load of 51.66 x10^3kN and minimum load is 49.86 x10^3kN. Stub column with aspect ratio 1.93 attain the load ranges from 41.10 x10^3kN to 42.19x10^3kN.

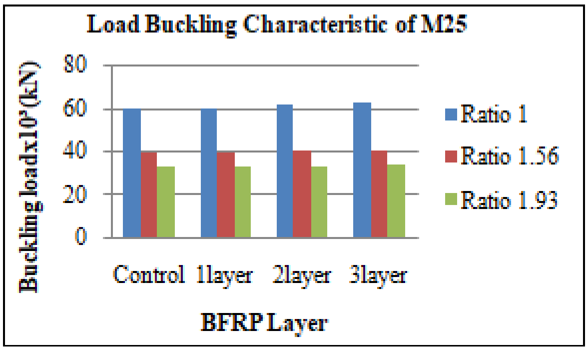

Figure 10: Load Buckling Characteristic of M25

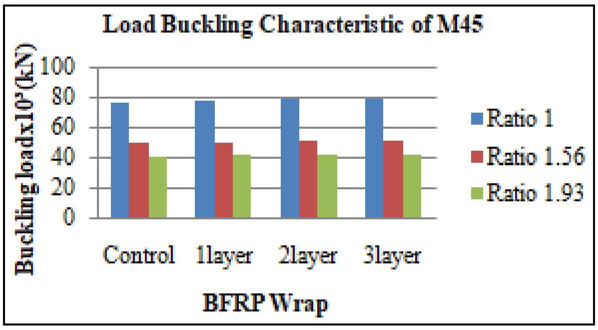

Figure 11: Load Buckling Characteristic of M45

4.8 Failure mode

The failure was characterized by a vertical rupture of BFRP wrap for most of the specimens. Prior to rupture, there were snapping sounds of hardened epoxy fracturing around the specimens. After the concrete cracked from inside, the BFRP started to effectively confine the specimens. One should also ensure that the failure will not happen at end regions by increasing the number of wrapping layers in the end regions. The columns having aspect ratios 1, and 1.56, when wrapped with 1, 2, 3 layers showed a very slight increase in strength than that with aspect ratio 1.93.

Figure 12: Effectiveness of BFRP Wrapping

Fig13 & 14 shows the effect of cross-sectional aspect ratio on concrete columns wrapped with BFRP. As evident from the figure, increasing aspect ratio led to increased ultimate strengths. Columns with aspect ratio 1 resulted in smaller ultimate load values as compared with that of columns with aspect ratio 1.56 and1.93. It compares the gain in axial load carrying capacity for different aspect ratios. The columns having aspect ratios 1.56and 1.93, when wrapped with one layers showed a very slight increase in strength than that with aspect ratio 1.0.

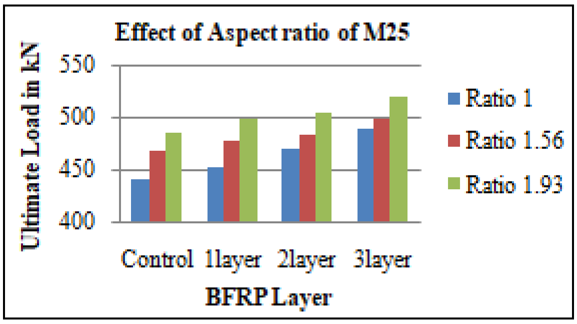

Figure 13: Effect of Aspect ratio of M25

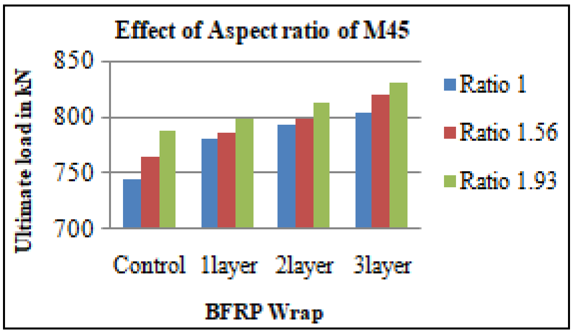

Figure 14: Effect of Aspect ratio of M45

4.10 Load Deflection Characteristics

A deflection-softening behavior, where the load-deflection curve dramatically drops as the load continues to be applied. Specimens made with BFRP behaved differently as compared to Different layer of Wrapped Specimen. The load-deflection curve for these Specimens represents the ability of the specimen to continue to sustain load after substantial concrete cracking.. The Controlled and BRP Wrapped Specimen's load was linearly increased and deflection is Decreased with layer of BFRP increased.

5. Conclusion

An experimental study on the compressive behavior of concrete specimens has been presented in this paper. A total of 72 specimens were tested under monotonic axial compression under the effect of 3 parameters (Different grade, and FRP layers). Based on the results, the conclusion of this study can be summarized as follows:

- Newly developed BFRP composite can be effectively used in improving the overall compressive behavior of confined concrete.
- Density of the cubes tends to decrease with increase in Grade of concrete. Density of the Stub column tends to decrease with increase in Grade of concrete and simultaneously increases with increase in Layer of BFRP.
- Compressive strength of both cube and Stub column seems to be directly proportional to M25 and M45 and also the increasing the BFRP layer.
- Load bearing capacity and Elastic Modulus of stub column increased with an increasing the Grade of concrete and also increasing the BFRP layer. Flexural strength and Split tensile property also varies as such as compressive strength parameters.
- Load buckling Characteristics of BFRP confined concrete in Stub element increase the buckling load with

an increasing the Grade of concrete and decrease with an increasing the aspect ratio of concrete.

- The effectiveness of BFRP confinement in Stub column specimens was increased with an increase in Layer of BFRP. The ultimate strength was found to increase almost linearly with an increase in Layer of BFRP and increase in Layer Grade of concrete while the ultimate strain was found to decrease accordingly.
- The load-deflection curve for all Specimen behaves almost linearly which represent the Stub column's Cracked and un-cracked condition. Once the cracking load is reached a linear response is evident resulting from the increased stiffness of the cracked and Un cracked section. The Controlled and BFRP Wrapped Specimen's load was linearly increased and deflection is Decreased with layer of BFRP increased.

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