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Axial Behavior of Corroded CHST Members Confined with AFRP Sheets

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Abstract*: Strengthening of structural members is a mechanism of promoting structures to upgrade its attainment under existing loads or to boost the fortitude of structural members to carry further loads. Any frailty at the time of designing or any other construction errors may lead to the cause of structural deterioration causing failures of the structural members. This paper presents an experimental study on the behavior of corroded Circular Hollow Steel Tubular (CHST) members strengthened with Aramid Fiber Reinforced Polymer (AFRP) composites. In this field, the experimental investigation is narrowed up to the usage of Glass Fiber Reinforced Polymer (GFRP) and Carbon Fiber Reinforced polymer (CFRP) and also in the application procedure i.e., the wrapping scheme. Prime advantages of AFRP over steel members are low weight, highly durable, corrosion resistance and easy applicability. The workability and the consonance of AFRP were studied in this paper to evaluate the confinement of AFRP in the strengthening effect of CHST members. The main deprivation of AFRP is the cost alone. So, in this experimental process, instead of going full wrapping, a special technique of spiral wrapping was adopted to get the closed confinement of AFRP. Totally twelve specimens were casted and tested to execute the experimental work including both control and wrapped specimens by controlling different parameters up to the failure mode. The experimental results uttered the increment in the load carrying capacity of the wrapped specimens. The involvement of AFRP in the better confinement was observed in the experimental results with the increase in the number of layers of AFRP strips. From the series of experiments, the results which were collected were compared with the control sample to determine the variation and then the axial stress-strain curve and load deflection curve were studied. It was also observed that, the local buckling was getting delayed with the increase in the number of layers of AFRP strips.

***Index Terms*: CHST columns, AFRP fabric, Retrofitting, External wrapping, Axial compression, Local buckling**

I. INTRODUCTION

The enormous leverages of steel structures in the structural application of offshore as well as inshore structures become popular in recent times.

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Steel structure being structurally sound such as high strength-to weight ratio, long durability, less weight, huge energy consumption capacity, high torsional austerity and so other factors. In recent times, the economical gratifications have also been identified by the engineers and the designers [1]. On the other hand, most often it has been noticed that, the steel structures get deteriorated when they are exposed to open environment as well as marine environment due to the crumbling, continues loading, increment in the continue traffic and extreme environmental effect, or a sequence of all these [11]. To ascertain the advantages of steel structures, hollow steel tubular sections are recently preferred by the different construction agencies and also a numerous experiments and researches are going on in this particular field [1, 3 & 7]. The most common factor of deterioration in steel structures is corrosion which happens when they are exposed to open environment due to severe conditions [1, 3, 5 & 9]. So to beat these complications, a structure needs a proper alimentation to regain its strength up to a certain extent [1, 9, & 11]. The conventional methods of historical accession in the strengthening of steel structures are external welding of steel plates, enlargement of sections which automatically increase the self-weight resulting a problem in the load distribution of the structures [3]. These methods need an on-going maintenance because when the new repaired section is again exposed into open atmosphere, it will further undergo corrosion [1, 3 & 9]. To mitigate the problem in the increment of self-weight, sometimes the effected part or member is replaced with a new one followed by the same problem in future for the inadequacy of the recent techniques.

The usage of hollow steel members are now getting a high performance in conventional building constructions, earthquake resistant structures, bridges and in both onshore and offshore structures due to its tremendous exquisite estates [9]. The application of FRP in the structural strengthening doesn't show any of these hurdles. There are plentiful superiorities in the usage of FRP in retrofitting of structural members for the sake of their negligible weight, high durability, immense stiffness and its propriety in the application in any complex profile. The use of FRP due to its high rigidity in the structural steel can effectively increase the fundamental and emaciated estates of steel structures [10, 9].

II. RELATED WORK

In past counting the present, it has been recorded that, the research activities in this area is limited up to the usage of CFRP. To demonstrate the effect of CFRP on the strengthening of steel column, in 2014 Sreedhar Kalavagunta et al. [6]

performed an experimental investigation on steel columns strengthened with CFRP. The whole experimental process was done in two aspects, where in the first stage, on two retrofitted specimens of length 200mm,
width 50mm and Fe 500 grade steel, tensile test were conducted for procuring the bond strength and recommended that, the maximum load was obtained in 100mm bond length. Secondly, on cold formed lipped steel channel sections strengthened with CFRP, both experimental and analytical study were conducted and the test results revealed that, the load carrying capacity of strengthened specimens were increased by 16.75%. In 2014, to authenticate the estate of CFRP in hollow steel structures, M C Sundarraja et al. [1] went through a series of experiments and analytical study in the axial behavior of hollow square steel sections strengthened with CFRP. By changing the parameters such as width of CFRP strips, number of layers they studied the confinement of CFRP strips in the strengthening of hollow steel sections. At the end of the descriptive study they inferred that, the increase in the thickness of CFRP strips and number of layers deferred the local buckling and helped to carry more loads. The maximum increment of the load carrying capacity was found to be 44.32% from the control sample. C Wu et al. [2] studied the effect of ultra-high modulus CFRP foliate on the strengthening of double strap steel joints in 2012. In this study, they changed the parameters as different bonding agents so as to contrast the clout of the bonding agents in the bolstering of load carrying capacity. For forecasting the relation between the bond strength and effective bond length, they derived analytical models which resemble a well with the experimental results in load carrying capacity, deflection and the relationship between the bond-slips. To probe the yield capacity of short steel tubular circular column sections retrofitted externally with CFRP in 2011, Jimmy Haedier et al. [4] attended both experimental and analytical investigation on cold form short steel tubular columns. They did their strengthening by full external wrapping of CFRP fabrics. The results got from the series of experiments, announced that, the procurement level in the yield amplitude and slenderness value of the specimens heightened with the united use of the twain hoop and protensive CFRP fabrics. The analytical investigation was accomplished with classic access pursued in AS/NZS 4600, AS 4100 and Euro-code 3. The result achieved from analytical investigations was diverged by 18% from the results of experimental investigation. In 2017, B Rajesh Babu et al. [3] forged an analytical model for square hollow structural steel sections cloaked with CFRP strips to anticipate the lateral internment strength applied by the CFRP strips. They also concluded that, the confinement of the CFRP strips increased with the increase of the strip width and the number of layers. To improve the structural properties of square hollow sections, I-sections and inverted T-sections, K Ranjith et al. [5] did both empirical and rational studies by adopting CFRP strips in 2017. By governing different parameters such as width of the strips and number of layers, a symbolic development in the betterment of overall structural properties were obtained from the results of both experimental & analytical studies after applying CFRP strips for strengthening. In 2014, B Shanmugavali et al. [7] did an experimental investigation to study the usefulness of CFRP in the strengthening of circular hollow steel sections. The also studied the characteristics of CFRP retrofitted hollow steel sections under axial compression by maintaining two different (D/t) ratio of 29.01 & 31.04 and also spacing of the CFRP strips as parameters. The sample specimens the used were 139.7mm diameter, 600mm height and two thicknesses of 4.5mm and 4.8mm. The maximum increment in the load carrying capacity was found as 25% with respect to control sample in two layers of CFRP strips with thickness of 4.8mm. Ashvini et al. [8], in 2015 studied the achievement of CFRP on the strengthening effect of circular hollow steel sections with two different parameters of CFRP wrapping. They did the external wrapping of CFRP in the whole surface of hollow steel sections one in longitudinal direction and another in the transverse direction. The test results that were obtained showed that, the CFRP strengthened in the transverse direction gave the best performance in the load carrying capacity and also immense the ductility of the hollow steel sections. In 2012, S Sivasankar et al. [9] did an experimental study to enhance the ductile property and energy absorption of hollow steel structural tubes confining with CFRP by adjusting different parameters such as width of the strips, spacing of the strips and also the number of layers. After the sequence of experiments they concluded that, the load hoisting capacity and the ductility of the hollow steel sections upgraded after wrapping with CFRP strips. Totally eighteen samples were casted and all the samples were tested up to the failure mode to study the complete axial behaviour of all the samples. They also concluded that the load carrying capacity of the hollow steel columns, were increased with the increase of number of layers and the local buckling was deferred after confining with CFRP strips.

In 2015, P R Jagtap et al. [11] reviewed some research papers regarding the suitable guidelines for design, selection and application of FRP for external strengthening of steel structures. They discussed about the mechanical properties of different FRPs such as aramid, basalt, carbon and coir and their effects on the strengthening of steel structures. They also discussed about the bond behaviour of different FRPs and the way for applying FRP for strengthening of structures. After reviewing a numerous papers they concluded that, the better material for strengthening steel member id CFRP.

Kambiz Narmashiri et al [12] conducted both experimental and numerical study in 2010, on the improvement of flexural behaviour of steel I-beams by using CFRP strips. Totally 5 specimens were tested by applying CFRP on the web of the I-beams. In one set, the applied CFRP on the both sides of the web whereas in the other set they applied CFRP on the one side of the web with CFRP ratios of 0.72 and 0.48. It has been seen that after using CFRP on web, it increased the load carrying capacity by 51% and also usage of less CFRP in the shear Zone with same amount of load carrying capacity of steel I-beam was the main prominent gratification of this research.

As mentioned earlier, corrosion is one of the prominent factors for the deterioration of steel structure. When steel structures are exposed to different extreme environment, they start reacting with the moisture of the environment in the presence of oxygen to form rusts on their surfaces. The corrosion circumstances in marine environment are a convoluted process in the presence of both organic as well as in organic matters, where the metallic structures are bared in operating conditions.

Due to the presence of such particles, biological activity is prominent for the metabolic activities in ionic transport phenomena with bio-electrochemical action. [13].

Homero Castaneda et al. [13] studied the influence of sulphate-reducing bacteria on metallic structures in 2008, when they are exposed to artificial seawater in sterile situation, covered the surface of steel or any metal with two layer after 30 days. It also confined that, the artificial sea water in antiseptic conditions accelerates to form a layer on the steel structure with two different layers after 30 days of exposure. In 2011, B Anand et al [14] told that, there is a broad use of mild steel in chemical industry under different conditions in handling acidic, alkaline and salt solutions. They also noticed that, chloride ions, nitrate ions and also sulphate ions in aqueous solution are notably responsible and expedite corrosion in mild steel. They studied the inhabitation of mild steel by putting the sample in a corrosion medium of 1N citric acid and 1N sulphuric acid in both the presence and absence of inhibitor, Allamanda Blanchetti used in their experiment by weight loss method. V R Rathi et al. [15] did experimental investigation on corrosion of mild steel, tor steel and CRS steel by weight loss method in 2010. The steel bars they used were cleaned thoroughly with polish paper to remove all the dusts and previous rusts then the initial weight of the bar was taken. Then the bars were inserted in CLARCKS solution which was consisted of one litre of concentrated hydrochloric acid, 20g of antimony oxide (Sb_2O_3) and 50g of tin chloride ($SnCl_2$). The formula they used to find out the corrosion percentage by weight loss method was,

[(Initial wt. – Final wt.) / Initial wt.] x 100

They also found the corrosion rate per year by the formula,

Corrosion rate mm / year = 87.6W/DAT

Where, W = weight loss in milligrams

D = density of steel in g/cm^3

A = Surface area of steel in cm^2

T = Time of exposure in hours.

The past researches shows that up to now, the strengthening and retrofitting of structural members are concentrated only in the usage of CFRP and also it has been seen that, the strengthening scheme was only done by using horizontal CFRP strips with changing different strip widths and the spacing in between. This paper represents a new technique of strengthening scheme with the usage of AFRP strips in helical wrapping and the results obtained by following this new technique was quite satisfactory. It has also been seen that the usage of AFRP rather than CFRP is quite cost effective and provides better stiffness and durable estate.

III. MATERIALS USED

A. *Circular Hollow Steel Tubular (CHST) members*

The members chosen for this experimental study was short columns, of outside diameter 88.9mm and thickness of 4mm as per IS : 1164 1998, Steel Tubes for Structural Purpose [16]. The length of the members was taken as 600mm and thus a slenderness ratio of 20 was achieved. The yield strength of the steel specimens that were provided by the manufacturer was 250N/mm^2.

B. *Aramid fiber reinforced Polymer (AFRP)*

Aramid Fiber Reinforced Polymer (AFRP) is high modulus heat resistance synthetic fiber. Aramid fibers are having wide-ranging estates of high strength with low density, good abrasion resistance, inert to most organic solvents, high melting point (generally greater than 500° C), low flammability and so on. The furnished properties of aramid fiber by the manufacturer are given in Table 1. The AFRP used for this experimental investigation was low modulus ARP fabric with elastic modulus of 240kN/mm^2 and the corresponding tensile strength of 3950N/mm^2. The measured thickness of the fiber fabric was 3mm and can be smartly fitted into any coveted shape. Figure 1 shows the type of bi-directional AFRP fabric used in this experimental investigation.

C. *Epoxy Resin 520 / Epoxy Hardener D*

A prime section in the class of adhesives are epoxy adhesives also called as structural adhesives or engineering adhesives, can be achieved from a mixture of epoxy resin along with hardener.

Fig. 1. Bi-directional aramid fiber fabric.

Table 1. Properties of AFRP.

S. No	Properties of Aramid FRP	Value
1.	Modulus of Elasticity	240kN/mm^2
2.	Tensile Strength	3950 N/mm^2
3.	Weight	480gm/m^2
4.	Density	1.82g/cm^2
5.	Thickness	3mm

Table 2. Properties of Epoxy Resin and Epoxy Hardener D.

Properties	Epoxy resin 520	Hardener D
Type	Solvent modified resin	Polyamide
Appearance	Colorless liquid	Clear liquid

Mix viscosity at 27°C	650+/-100	650+/-100
Specific gravity	1.15-1.18	0.98 ± 0.1
Pot life	1.5 – 2 hours	__
Storage stability	12 months	6 months

Epoxy resin 520, used in this experimental study is of conservative viscosity liquid epoxy resign. In full cured state after polymerization with FRP, it shows a high chemical resistance and abrasion resistant properties. The properties of epoxy resin and harder provided by the manufacturer is shown in the Table 2.

IV. EXPERIMENTAL PROCESS

A. Artificial Corrosion of Samples

There are numerous methods of artificial corrosions that were adopted by different researchers in past. In this experimental research, the artificial corrosion was adopted by using Rusty 3000, as mentioned bellow. First of all, normal white vinegar (acetic acid) was sprayed over the surface of the steel columns and the sample was left free for 20 – 30 minutes for drying. Then the mixture of Rusty 3000 was prepared and the CHST samples were dipped into the solution for accelerated corrosion. After dipping in Rusty-3000 within 5 minutes the corrosion rate increases. Rusty-3000 is a chemical blend of one part of Vinegar (Acetic acid) by seven parts of Hydrogen Peroxide with 20gm of normal table salt (Sodium Chloride). The ratio of vinegar and hydrogen peroxide was 1:7 by weight. Due to the corrosion, the weight of the column samples were increased initially and them started reducing gradually. The corrosion process of the specimens was carried out up to the start of the reduction of the weights of the column samples.

Table 3.Corrosion percentages.

Sample no.	Initial weight (kg)	Final weight (kg)	Corrosion percentage (%)
1	4.677	4.612	1.39
2	4.810	4.740	1.46
3	4.700	4.675	0.53
4	4.789	4.725	1.34
5	4.777	4.665	2.34
6	4.756	4.669	1.83
7	4.759	4.681	1.64
8	4.725	4.672	1.12
9	4.900	4.836	1.31
10	4.783	4.750	0.68
11	4.782	4.742	0.84
12	4.775	4.745	0.63

Fig. 2. Some corroded samples.

Figure 2 shows some of the corroded samples. The corrosion percentage of the column samples that were calculated is given in the Table 3.

B. AFRP Bonding

Before applying AFRP, the column surfaces were cleaned with acetone to remove the impurities from the surface. Proper marking and alignment was done on the AFRP sheet before cutting it into required strip width. GFRP surface mate was applied to the whole external lateral surface of the column specimens for avoiding galvanic corrosion, tough the surface mate will not play any role in load hoisting. In this experimental research the wrapping scheme was adopted in a new technique of Helical Wrapping throughout the length of the samples. The helical wrapping was adopted for 50mm strip width with an intermediate spacing of 45mm with one parameter of number of layers. The main objective of adopting such type of wrapping scheme in this experimental work was to get a closed wrapping throughout the length of the columns instead of full wrapping to achieve an economical strengthening procedure. One, two and three layers of AFRP strips were applied in three sets of columns each of three samples. Figure 3 shows samples after the surface preparations and the wrapping scheme of AFRP strips.

Fig. 3. Samples after surface preparation and AFRP bonding.

C. Designation of Samples

The designations of the control as well as the wrapped specimens are given in the Table 4.

Table 4. Sample descriptions.

Designation	No. of specimens
Control- CC	3
CHST-SP-1L (Sample wrapped with one layer)	3
CHST-SP-2L (Sample wrapped with two layers)	3
CHST-SP-3L (Sample wrapped with three layers)	3

D. Experimental setup

All the CHST members were tested under Universal Testing Machine (UTM) of ultimate capacity of 100 ton. The specimens were fitted and mounted on the UTM with dial gauge for recording axial vertical displacement and pellets were fitted on the external surface of the CHST members just at the center of all the specimens to measure the strain by Demountable Mechanical Strain Gauge for gauge length of 200mm. After placing the CHST members in the UTM, the leveling of the specimens were checked by using sprit level. The behavior of the CHST members were studied by applying axial compressive load gradually in small increment and the vertical displacement and the Demac reading (for strain) was recorded at a regular interval of time in the loading period. All the specimens were loaded up to the ultimate failure of the specimens. The ultimate load for each CHST members along with the failure modes were recorded and studies in details. Figure 4 shows the experimental set-up for one sample.

Fig. 4. Set-up for experiment.

V. RESULTS AND DISCUSSIONS

Table 5 shows the test results that were recorded during the testing of samples. From the experimental results it was observed that after applying AFRP strips, the load carrying capacity and the local buckling of the CHST members were improved and the also a betterment in the energy absorption capacity was noticed.

A. Failure Modes

To study the axial behavior of all the CHST columns, the samples were tested up to the failure. The ultimate load for the control sample was 321kN and the corresponding deflection was 7.71mm. Figure 5 shows the failure mode of control sample. The control column failed by local buckling in ultimate load and after that reaching beyond the ultimate load, a slight lateral bend was noticed unlike the strengthened specimens.

The ultimate load for specimen CHST-SP-1L was 356kN and the deflection in the peak load was 7.29 mm. Figure 6 shows the failure mode of CHST-SP-1L. Here, the column was failed by local buckling but it doesn't bend laterally due to high stiffness provided by the AFRP wrapping. At the failure stage, the fiber fractured with a huge sharp metallic sound forming cracks on the AFRP.

In the case of CHST-SP-2L, the ultimate peak load was 399kN and the deflection at the peak load was further reduced to 7.2mm. Figure 7 shows the failure mode of CHST-SP-2L. A minor buckling at the foot of the column was observed and small fiber breakage was observed in the AFRP strip in the middle of the CHST member.

The ultimate load carrying capacity of CHST-SP-3L was 431kN and the corresponding displacement was 6.85mm. In this case, it was noticed that, there was inner buckling rather than the outer buckling due to the great stiffness provided by the AFRP wrapping. Figure 8 shows the failure mode of CHST-SP-3L. Due to helical wrapping and also continuous strips, a great stiffness was provided throughout the specimen unlike the horizontal wrapping explained in the literatures.

Table 5.Test results of CHST members.

Sl No.	Column samples	Ultimate load at failure (kN)	Percentage increase in load carrying capacity (%)	Deflection at ultimate load (mm)
1.	Control -CC (1)	319	-	7.67
2.	Control -CC (2)	321	-	7.71
3.	Control -CC (3)	315	-	7.23
4.	CHST-SP-1L (1)	356	10.90	7.29
5.	CHST-SP-1L (2)	354	10.28	7.31
6.	CHST-SP-1L (3)	351	9.35	7.38
7.	CHST-SP-2L (1)	392	22.12	7.17
8.	CHST-SP-2L (2)	399	24.30	7.20
9.	CHST-SP-2L (3)	395	23.10	7.08

10.	CHST-SP-3L (1)	425	32.40	6.97
11.	CHST-SP-3L (2)	429	33.64	6.79
12.	CHST-SP-3L (3)	431	34.27	6.85

Fig. 5. Failure mode of control sample.

Fig. 6. Failure mode for one layer.

Fig. 7. Failure mode for two layers.

B. Load-Deflection Behavior

The load deflection behavior of all the CHST members was plotted in a curve for studying the relative stiffness of the specimens. It has been noticed that the vertical displacement of the members in the case of wrapped samples are reducing with the increase of the number of layers. The maximum deflection was observed in the control sample due to the absence of external stiffness that was provided by AFRP wrapping in the case of strengthened specimens. The maximum stiffness was observed in the CHST-SP-3L of 62.92N/mm. It has been observed that the ductility property of the CHST members improved with the increase of the number of layers of AFRP strips.

Fig. 8. Failure mode for three layers.

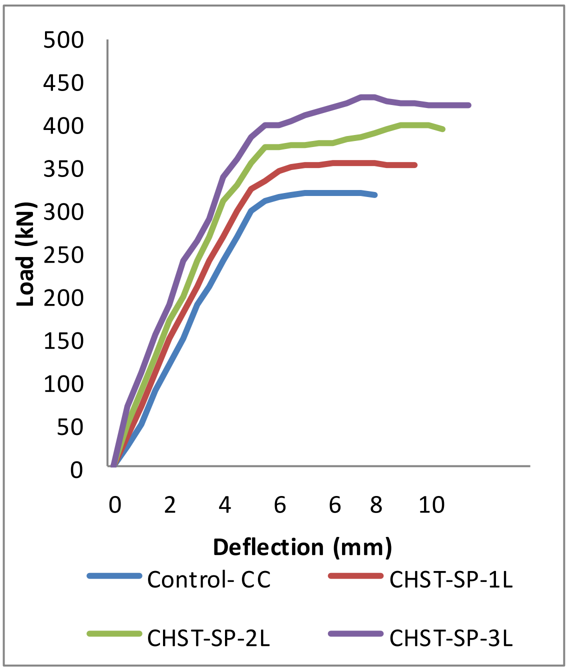

Fig. 9. Load Vs Deflection curve.

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Figure 9 shows the load deflection curve of all the specimens and the variation in the curves inferred that the external wrapping of AFRP strips delayed the local buckling providing a better stiffness. The stiffness from the experimental research for the optimum samples from each group is shown in the Table 6.

Table 6. Stiffness of the CHST members.

Column Designation	Ultimate load (N)	Deflection (mm)	Stiffness (N/mm)
Control -CC	321 x 10^3	7.71	41.63 x 10^3
CHST-SP-1 L	356 x 10^3	7.29	50.07 x 10^3
CHST-SP-2 L	399 x 10^3	7.2	55.42 x 10^3
CHST-SP-3 L	431 x 10^3	6.85	62.92 x 10^3

C. Axial Stress-Strain Behavior

To study the behavior of elasticity of the CHST members and also to study about the elastic modulus, the stress-strain curve was plotted in a graph for all the wrapped and un-wrapped specimens. Figure 10 shows the Stress-Strain curve of all the samples. From the graph it can be concluded that up to a certain value of stress, all the CHST members behaved elastically. The CHST columns which were wrapped with AFRP showed better axial deformation as compared to the un-wrapped specimens. From the stress-strain curve it is clear that the modulus of elasticity (E) increases with the number of layers. The deformation of the wrapped samples as compared to the control specimens was much better and the buckling was also getting delayed due to the stiffness provided by the external wrapping of the CFRP strips.

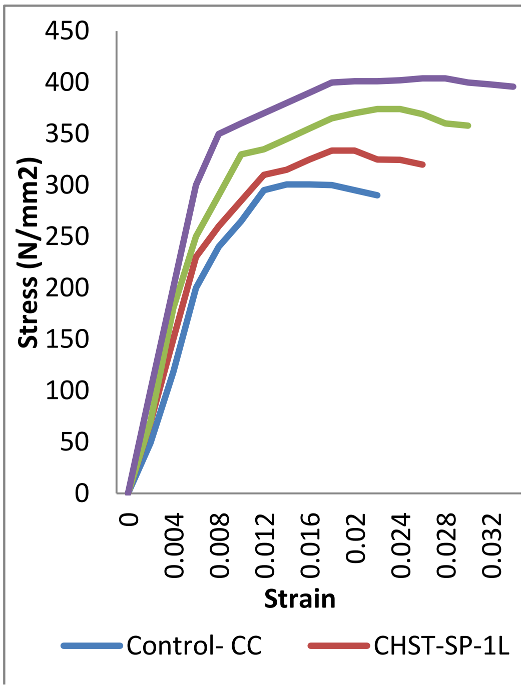

Fig. 10. Stress Vs Strain curve.

The closed continues wrapping that was offered by the helically wrapped AFRP strips provided a better stiffness throughout the longitudinal direction of the whole specimen in length wise and resist the local buckling.

D. Ultimate Load

The main objective for retrofitting a structure is to improve the structural behavior by increasing the load carrying capacity of the member or structures. In this paper the axial behavior of the both strengthened and un-strengthened CHST members by AFRP was studied and the ultimate load carrying capacity of the specimens was compared.

Figure 11 shows the variation of load carrying capacity of various specimens used in the experimental work. The ultimate load bearing capacity of CHST-SP-3L is increased by 34.3% from the control sample. In the case of two layers and one layer the strength increased by 24.3% and 10.9% respectively from the control sample. The strength of the CHST member of two layers is increased by 12.1 % from the CHST one layer and the strength of CHST three layers is increased by 21.1% with comparison to CHST one layer. The increment in axial load carrying capacity of CHST three layers with comparison with CHST two layers is 8%.

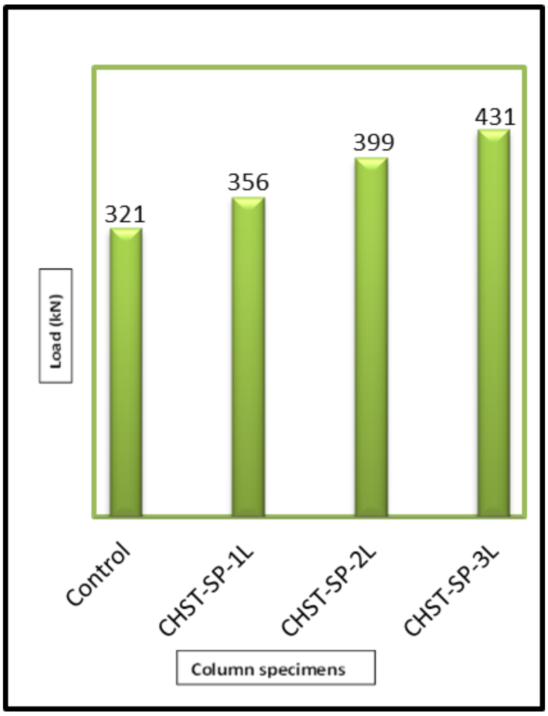

Fig. 11. Ultimate load of CHST members.

VI. CONCLUSIONS

Confining with AFRP for the enhancement of axial behavior of CHST members is a competent way for achieving a smooth and sound strengthening process. For studying the axial behavior, failure modes, load-deflection curve, stress-strain curve, stiffness property, modulus of elasticity and the ultimate load carrying capacity of the CHST members were discussed.

The overall conclusion from the experimental study is the strength of hollow steel tubular sections or any other structural members can be gratified immensely by applying AFRP for its high stiffness after polymerization with bonding agents.

After doing the series of the experiments following conclusion can be inferred.

- AFRP strips increases the load carrying capacity of the CHST members and also helped to get a high axial deformation.
- The stiffness as well as the elastic modulus (E) of the CHST members were also increased after applying the AFRP strips and showed better results with the increase of the number of layers of AFRP strips.
- Due to the helical wrapping scheme, a closed wrapping format was obtained which provided a uniform stiffness throughout the section of the CHST members, results in the increment of axial load carrying capacity.
- As compared to the past researches of horizontal wrapping, it can be concluded that, the technique of helical wrapping is more effective in the improvement of the structural properties of CHST members.
- The stiffness of the CHST in case of three layers was immensely increased by 51.14% as compared to control sample. Thus it can be said that, the usage of AFRP improve the ductility behaviour of the CHST columns and is suitable for the strengthening of earthquake resistant buildings.
- The ultimate load carrying capacity of CHST members after applying three layers of AFRP strips was increased by 34.3% from the control sample.
- It has also been noticed that, after applying AFRP and on increasing the number of layers the deflection is reducing at high load. This is due to the high stiffness provided by the AFRP strips.
- Thus the usage of AFRP in the structural improvement of CHST members puts value and economic as compared to CFRP in the field of strengthening of structures.

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