Behaviour Of DNA Helix Shaped Reinforced Columns Under Axial Loads

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Abstract: Column forms a very important component in a structure. Supporting the slabs is the main function of the columns. Since columns support beams which in turn support walls and slabs, it should be realized that the failure of a column results in the collapse of the structure. The design of a column should therefore receive importance. Columns which show more ductile behaviour do not show a catastrophic failure and give warning prior to impending failure. The ductility of reinforced concrete columns is also important in evaluating their aseismicity behaviour, because the column with the excellent ductile behaviour would be capable of absorbing and dissipating seismic energy. In order to improve the ductility and various other parameters of the columns this project work advocates the use of DNA helical reinforcement along with steel and rubber ties as better substitute in place of conventional spiral helical reinforcement because of the improvements in the various column parameters observed by the use of DNA helical reinforcement in columns. It was found from the test results that there was a considerable amount of increase in the ultimate compressive strength, ductility, elastic modulus, shear modulus in the columns in which DNA helical reinforcement was used in comparison to conventional spiral helically reinforced columns.

I. INTRODUCTION

Column or pillar in architecture and structural engineering is a structural element that transmits, through compression, the weight of the structure above to other structural elements below. Thus column is a compression member. The term column applies especially to a large round support (the shaft of the column) with a capital and a base or pedestal and made of stone or any other material. A small wooden or metal support is typically called a post, and supports with a rectangular or other non-round section are usually called piers. Piers may also be circular as in bridges. For the purpose of wind or earthquake engineering, columns may be designed to resist lateral forces. Columns are frequently used to support beams or arches on which the upper parts of walls or ceilings rest. In architecture, "column" refers to such a structural element that also has certain proportional and decorative features. A column might also be a decorative element not needed for structural purposes; many columns are "engaged", that is to say form part of a wall.

Material Properties And Objectives

The aim of this project is to study the behavior of DNA helix reinforced slender columns under axial loads and compare the same with the conventional systems. The steps of work proposed to be done are mentioned as under:

1) Four slender column models would be cast whose features are as below:

Parameter	Model A	Model B	Model C	Model D
Concrete mix	M20	M20	M20	M20
Rubber type		Butyl rubber	Butyl rubber	
Steel Grade	Fe415	Fe415	Fe415	Fe415
Rubber tensile strength(kg/cm^2)	-	3.45 - 5.5	3.45 - 5.5	-
Column Length(mm)	1200	1200	1200	1200
Column diameter (mm)	100	100	100	100
Core diameter (mm)	60	60	60	60
Reinforcement pattern	DNA Helix	DNA Helix	DNA Helix	Spiral Helix
Diameter of main bars (mm)	12	12	12	12
Diameter of helical bars (mm)	10	10	10	10
Diameter of ties (mm)	6	8	10	8

Location of rubber ties	--------	up to 0.2l from junction at both ends	at mid-portion of column	--------
No of main bars	2	2	2	4
No of helical bars	2	2	2	0
Clear cover to r/f (mm)	20	20	20	20

Table 1 **Material properties and system features**

2) After 28 days from casting and proper curing of the models, these would be tested on the loading frame having capacity of 500kN under axial loading till failure.

3) During loading process following observations would be made:

a) stress-strain behavior for compressive strength evaluation

b) load-displacement characteristics the slope of which would yield stiffness and flexibility parameters

d) Effect of rubber on flexibility and stiffness of the column

e) Effect of position of rubber tires on the flexibility and stiffness of the column

4) Finally a comparison between the DNA helix reinforced and conventional spiral helix reinforced columns would be made by evaluating the respective parameters as discussed above.

II. EXPERIMENTAL PROCEDURE

This project aimed at replacing the conventional reinforcement in columns with DNA double helix type and subsequently studying the results from various tests to which these columns were subjected later on. Initially four columns were casted to study the behaviour of chosen unconventional reinforcement. For this three columns with DNA double helix reinforcement with alternate lateral rubber ties in addition to steel ties and one column with normal spiral reinforcement was provided. The process that followed to accomplish and whole the columns are discussed in detail as follows:

2.1 Caging

Steel cages were prepared using expertise of a local worker. It took a lot of time and manpower to prepare the DNA double helix reinforcement, the difficult part being twisting the reinforcement at exact specified lengths. It took a whole day to prepare the reinforcement cages, the reinforcement being prepared for a column diameter of 135 mm and length 1.2m. In DNA double helix reinforcement two straight longitudinal bars of diameter 12mm were provided accompanied by two DNA-helix strands of diameter 10 mm. The clear cover of 20mm was provided. The lateral steel ties provided were of diameter 10mm, 8mm and 6mm. In addition to steel in the lateral ties, rubber ties were provided at specified lengths. 125 mm hollow G.I pipe was used in forming the DNA and the spiral helix cages by twisting them on it which was the most difficult part in the project work because of the non-availability of any mechanical device for forming the DNA helix reinforcement owing to its unconventional form and non-usage in the existing structures. The grade of steel used was Fe415. These cages were then carried to NIT Srinagar were the casting for them would be done.

2.2 Moulding

To confine the concrete aluminium sheet moulds were used, purchased locally from a hardware store. The aluminium sheets were moulded into the shape of columns of specified diameter and length. Extra length was provided for concrete clearance at the top. Steel cages were then put into these moulds and concrete was placed. While casting the first column, the aluminium mould bursted laterally as it couldn't stand the pressure from concrete being placed. Binding wire was coiled around the moulds to provide the extra strength to withstand the lateral pressure from the concrete being placed. Later the aluminium moulds were secured by using riveted joints which gave enough strength to resist pressures coming on to it during casting.

2.3 Concreting

Materials required i.e. cement, sand and aggregates were purchased locally from a dealer. Cement of 43 grade was used and aggregates of size 3-5 mm were chosen. A nominal mix (by weight) M20 (1:1.5:3) was made and the columns were cast. The concrete was placed in the moulds with steel cages being kept at centre of the aluminium moulds. The concrete was well tamped and compacted with the help of a tamping rod. Concrete cubes were placed around the bottom of each mould to provide lateral stability to the columns. A day after, the columns were taken off the moulds and laid in the curing pond for a period of 7 days.

Figure 1 **Preparation of concrete mix**

2.4 Curing

A day after, the columns were taken off the moulds carefully and placed in the curing pond for a period of 7 days.

2.5 Testing On Loading Frame

After a period of 28 days first sample was ready to be tested on loading frame. Whole setup was prepared for testing but upon loading the first specimen axially at higher loads of 200 KN, the concrete at the base of column started to spall off owing to the cracks produced at the base. The instability in the column lead to eccentricity which resulted in the generation of overturning moments and the eventual overturn of column. So the column overturned before it could take the ultimate design load. As a consequence of the above shortcoming, it was envisaged after due deliberations with our guide, that the best option that would ensure restraint and also lead to the minimal change in the end conditions was to make G.I moulds which would be welded to 8 mm thick base plate (12”x12”) and the columns would be placed in them at the top and the base. Two G.I moulds were employed for the purpose to be provide at bottom and top of the column. Bottom Mould was filled with sand mixed with small iron bearings to hold still the column during loading. In the meantime, another model of the specimen which failed earlier due to overturning was made with all the parameters same as had been before. Subsequently, second specimen was placed on the frame with the above modification incorporated in the form of moulds being used, but in vain. At higher loadings the moments generated were so enormous that even the moulds slipped over the girders forming a couple and consequent overturning.

2.6 Cutting Of Columns

In order to continue the project, after very keen consultation with the luminaries including our guide it was concluded, that in addition to base instability due to spalling of concrete, the complicated manual loading setup at NIT Srinagar might have also contributed in some form to instability, therefore a unanimous decision was arrived at in which it was advocated that the columns be tested on the UTM as short columns. For this the columns were cut into two halves using motorized cutter and after this the cut off portions were smoothened using a grinder in order to ensure level and removal of any discontinuity. A total of 8 short columns were obtained after cutting the original columns now with different positions of rubber ties than in the original ones.

2.7 Testing On UTM

Due to initiation of the cracks leading to spalling of concrete from the base resulting in instability, due to which eccentricity crept in developing overturning moments and failure of all other measures taken to facilitate testing on loading frame, it was envisaged after due deliberations with our guide, that the best option that would be to test the columns on UTM. A total of 7 short columns were obtained after cutting the original columns now with different positions of rubber ties than in the original ones. The description of testing of individual specimens is as follows:

2.7.1 SPIRAL HELICALLY REINFORCED COLUMN

2.7.1.1 Specimen No.1

The features of this sample are as under;

1. Length of specimen = 600mm
2. Diameter of main longitudinal reinforcement = 12mmΦ (2#) and 10mmΦ (2#)
3. Diameter of steel ties = 8mmΦ
4. Spacing of ties = 125mm
5. Rubber ties used = 0
6. No of steel ties = 5
7. Failure pattern = Shear compression failure wherein cracks initiated from the bottom end.

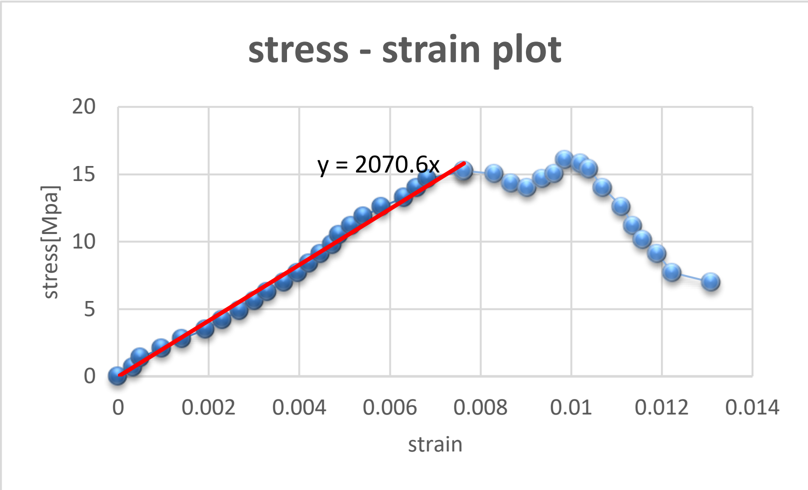
2.7.1.2 Specimen No.2

The features of this sample are as same as that of first sample

1. Failure pattern = Diagonal compression failure wherein cracks initiated from the bottom as well as top of the column.

III.OBSERVATIONS AND RESULTS

3.1 Spiral Reinforced Specimen 1



Graph 1 ***Stress strain curve spiral specimen***

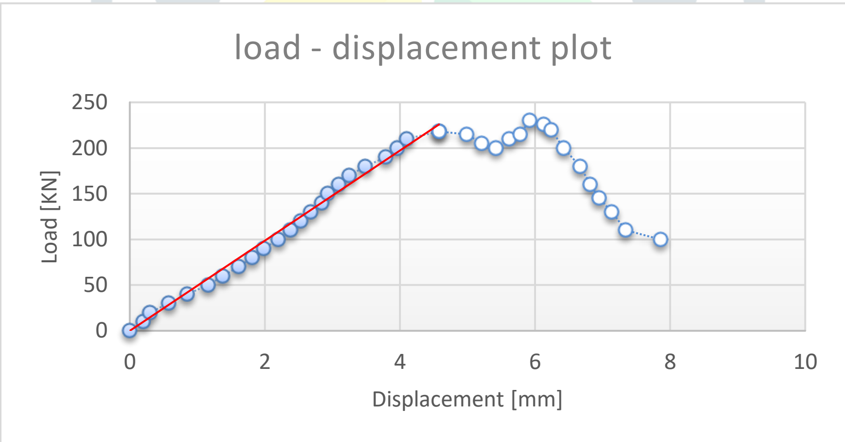
3.1.1 Observations and Results

Length of specimen (l) = 600mm
Diameter of specimen (d) = 135mm
Area of specimen (A) = $\pi/4 \times 135^2 = 14313.88\ mm^2$

(1) Ultimate compressive strength

Ultimate compressive strength = 230kN

(2) Ductility in terms of percentage strain = 36.042%

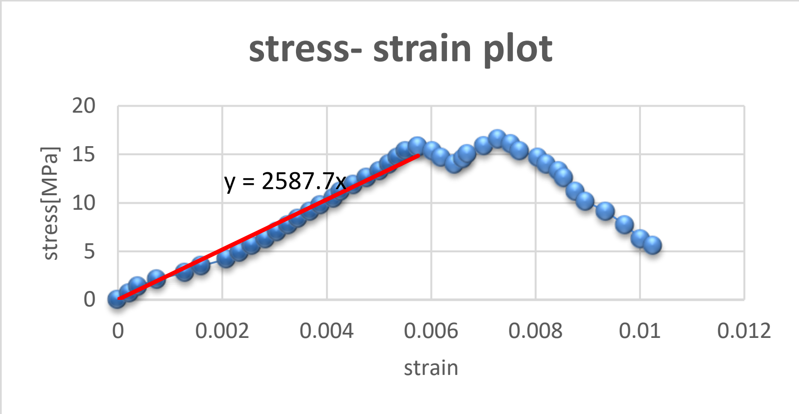


Graph 2 ***Load displacement curve spiral specimen 1***

Stiffness and flexibility parameters (from load-displacement curve)

(a) Axial stiffness == 49308.76 N/mm
(b) Axial flexibility = 2.03×10^{-5} mm/N

3.2 Spiral Reinforced Specimen 2



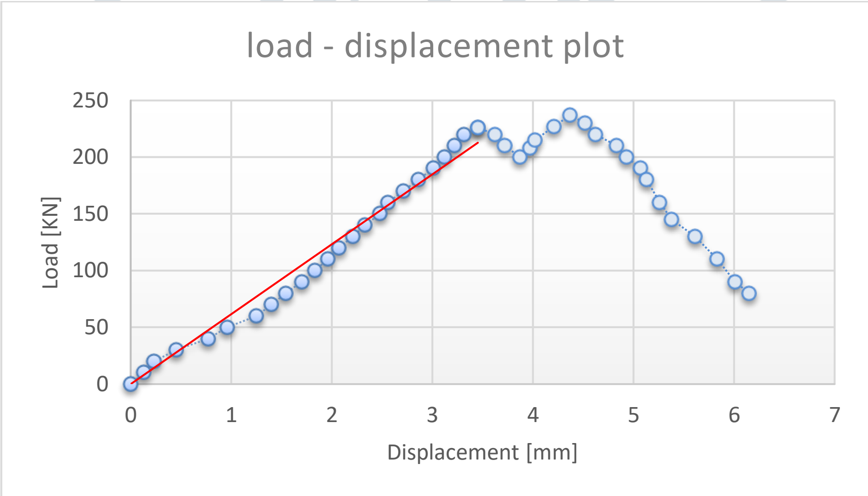
Graph 3 ***Stress strain curve spiral specimen 2***

3.2.1 Observations and Results

(1) Ultimate compressive strength

Ultimate compressive strength = 237kN

(2) Ductility in terms of percentage strain = 67.44%



Graph 4 ***Load displacement curve spiral specimen 2***

Stiffness and flexibility parameters (from load-displacement curve)

(a) Axial stiffness = 62500 N/mm
(b) Axial flexibility= 1.6×10^{-5} mm/N

3.3 Spiral Reinforced Specimen 1 And 2 Mean Values

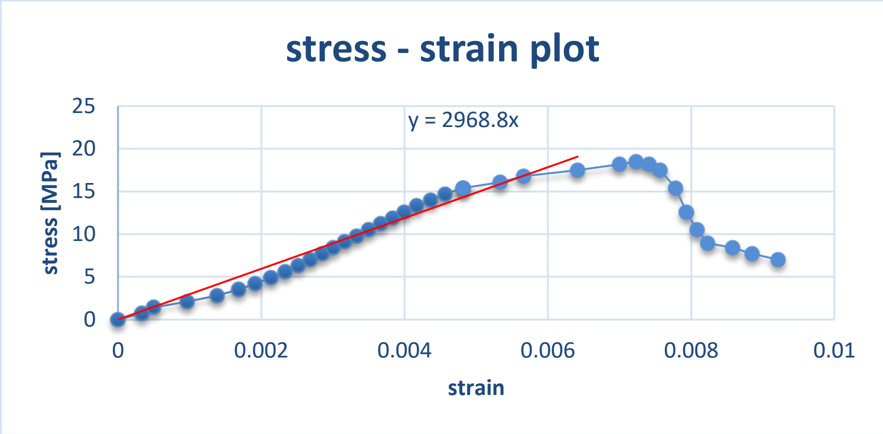
(a) Mean Ultimate compressive strength= 233.5kN

(l) Mean percentage ductility = 51.93%

3.4 Simple DNA Reinforced Columns

3.4..1 Simple DNA Specimen 1

Failure Pattern : Compression failure wherein cracks initiated from the top end propagating towards mid region



Graph 5 ***Stress strain curve simple DNA specimen 1***

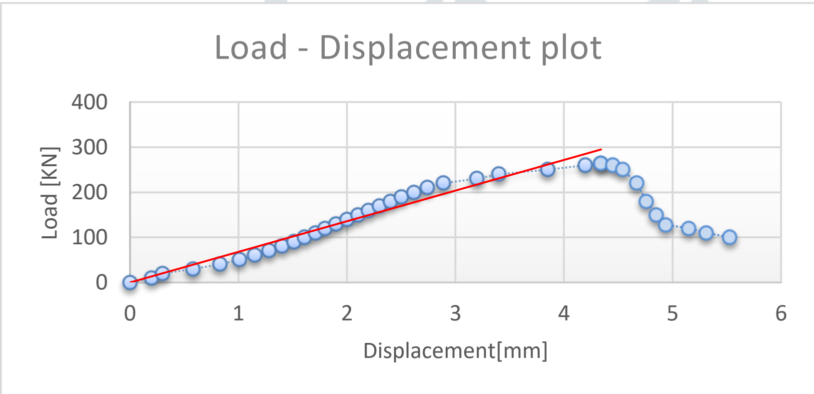
3.4..2 Observations and Results:

Length of specimen (l) = 600mm
Diameter of specimen (d) = 135mm
Area of specimen (A) = $\pi/4 \times 135^2 = 14313.88\ mm^2$

1.Ultimate compressive strength

Ultimate compressive strength = 264kN

2. Ductility in terms of percentage strain = 27.67%



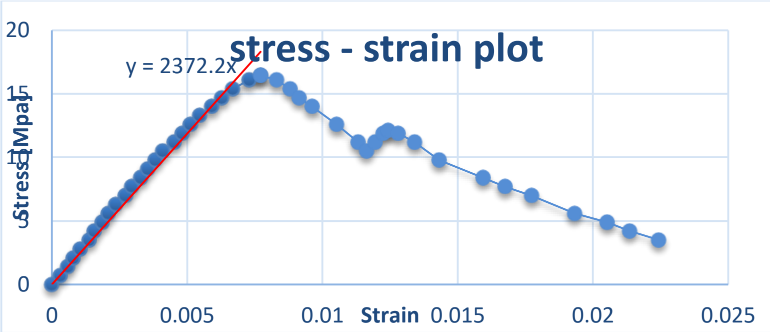
Graph 6 ***Load displacement curve simple DNA specimen 1***

Stiffness and flexibility parameters (from load-displacement curve)

(a) Axial stiffness = $k= (P_2-P_1) /(L_2-L_1) =(237-0)\times10^3/(3.33-0)= 71171.17$ N/mm
(b) Axial flexibility= $\delta= (L_2-L_1) /(P_2-P_1) =(3.33-0) /(237-0)\times10^3= 1.41\times10^{-5}$ mm/N

3.5 Simple DNA Specimen 2

FAILURE PATTERN: Fine hairline diagonal shear cracks developed from the top end and subsequently propagated towards centre causing diagonal shear compression failure.



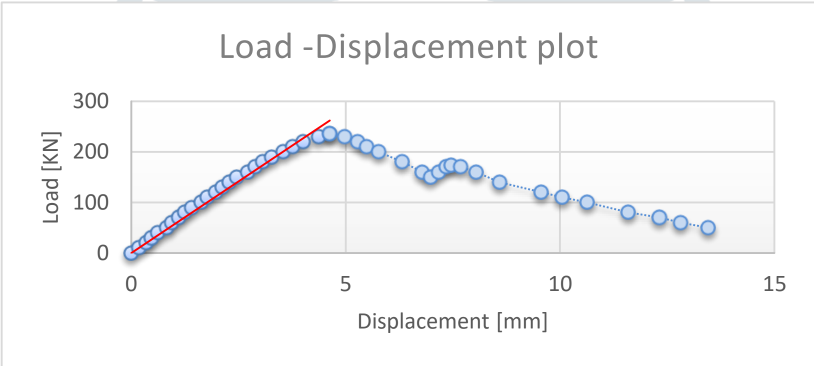
Graph 7 ***Stress strain curve simple DNA specimen 2***

3.6 Observations and Results:

(1)Ultimate compressive strength

Ultimate compressive strength = 235kN

(2) Ductility in terms of percentage strain = 30.40%



Graph 8 ***Load displacement curve simple DNA specimen 2***

Stiffness and flexibility parameters (from load-displacement curve)

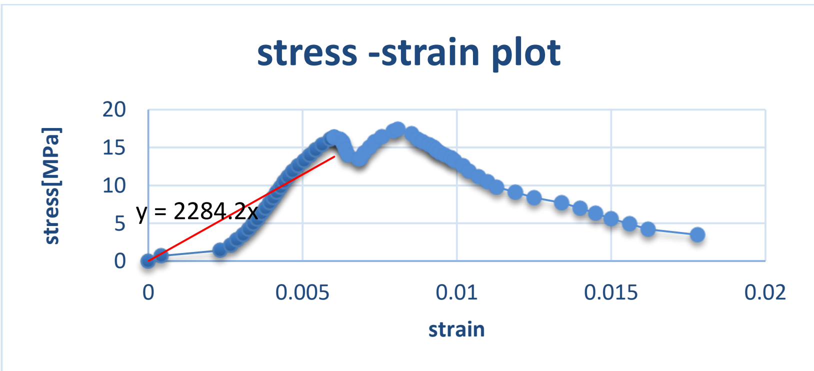
(a) Axial stiffness = k = $(P_2\text{-}P_1) / (L_2\text{-}L_1) = (200\text{-}0)x10^3 / (3.55\text{-}0)$ = 56338.03 N/mm
(b) Axial flexibility = $\delta = (L_2\text{-}L_1) / (P_2\text{-}P_1) = (3.55\text{-}0) / (200\text{-}0)x10^3 = 1.78x10^{-5}$ mm/N

3.7 Simple DNA Specimen 1 And 2 Mean Values

(a) Mean Ultimate compressive strength= $F_m = (F_1+F_2)$ /2 = (264+235) /2 = 249.5kN

(l) Mean percentage ductility = (27.67+30.4)/2 = 29.04%.

3.8 DNA Reinforced Columns With Rubber Ties In Middle Portion

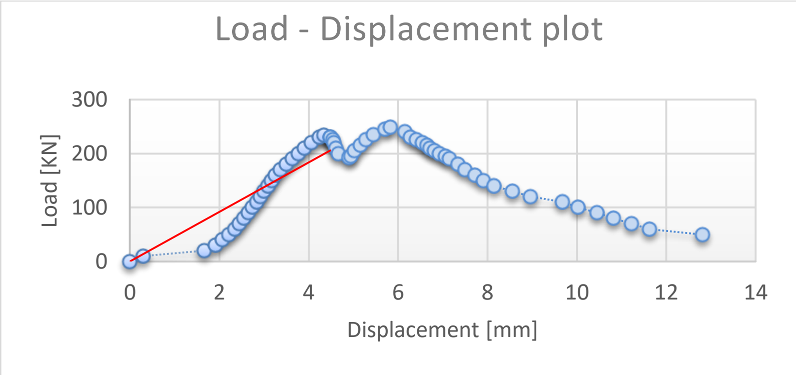


Graph 9 ***Stress strain curve DNA with rubber at middle***

Failure pattern = Fine hairline cracks initiated from bottom as well as top end and propagated towards the mid region followed by crack widening and eventual crushing failure

3.9 Observations and Results:

(1) Ultimate compressive strength
Ultimate compressive strength = 249kN
(3) Ductility in terms of percentage strain
Ductility = 88.57%



Graph 10 ***Load displacement curve DNA with rubber at middle***

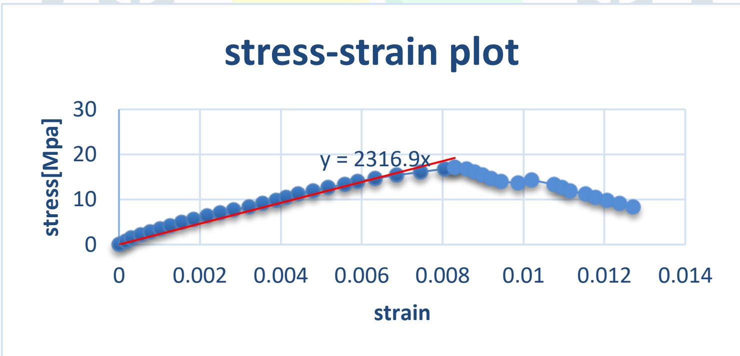
Stiffness and flexibility parameters (from load-displacement curve)

(a) Axial stiffness = k = $(P_2-P_1) / (L_2-L_1) = (140-0)x10^3 / (3.1-0) = 45307.44$ N/mm
(b) Axial flexibility = $\delta = (L_2-L_1) / (P_2-P_1) = (3.1-0) / (140-0)x10^3 = 2.21x10^{-5}$ mm/N

DNA Reinforced Columns With Rubber Ties At End

3.10 DNA With Rubber Ties At End Portion Specimen 1

Failure pattern = Although fine cracks initiated from top end but major cracks that led to failure developed at the base of the column and propagated towards central and top region resulting in crushing of column

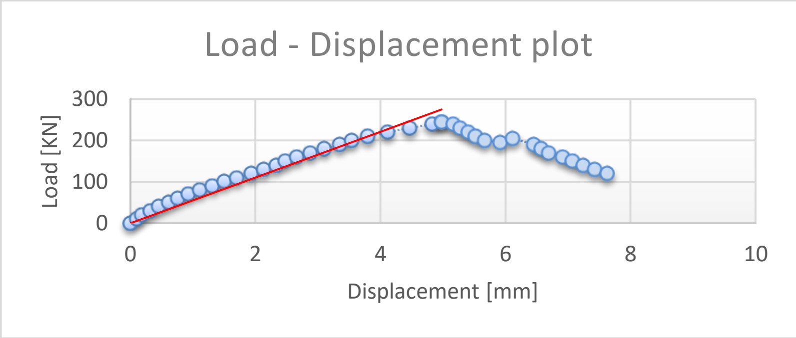


Graph 11 ***Stress strain curve DNA with rubber at ends specimen 1***

3.11 Observations and Results:

Length of specimen (l) = 600mm
Diameter of specimen (d) = 135mm
Area of specimen (A) = $\pi/4 \times 135^2 = 14313.88$ mm^2

(1) Ultimate compressive strength
Ultimate compressive strength = 244kN
(2) Ductility in terms of percentage strain
Ductility = 61.06%



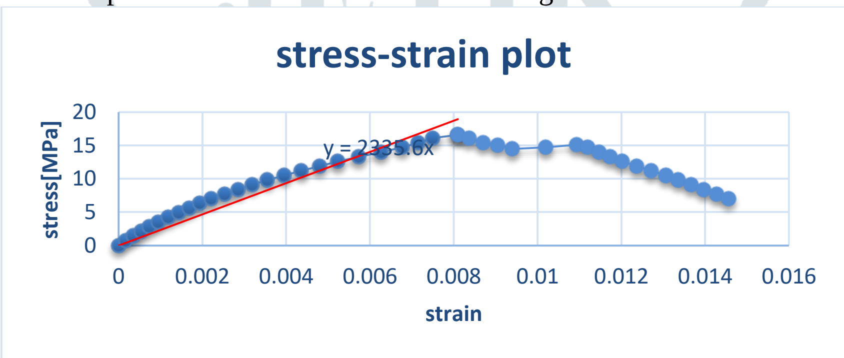
Graph 12 ***Load displacement curve DNA with rubber at ends specimen 1***

Stiffness and flexibility parameters (from load-displacement curve)

(a) Axial stiffness = k = $(P_2\text{-}P_1) / (L_2\text{-}L_1)$ = $(210\text{-}0)\text{x}10^3 / (3.8\text{-}0)$ = 55263.15 N/mm
(b) Axial flexibility = δ = $(L_2\text{-}L_1) / (P_2\text{-}P_1)$ = $(3.8\text{-}0) / (210\text{-}0)\text{x}10^3$ = $1.81\text{x}10^{-5}$ mm/N

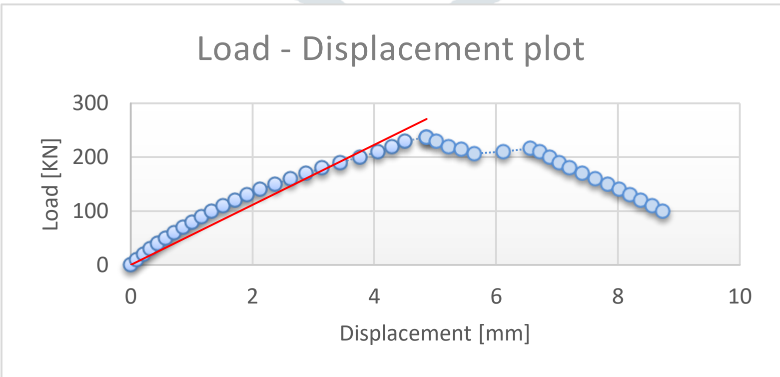
3.12 DNA With Rubber Ties At End Specimen 2

Failure pattern = Fine cracks initiated from top end which gradually scattered and widened diagonally producing diagonal compression failure and eventual crushing.



Graph 13 ***Stress strain curve DNA with rubber at ends specimen 2***

(1)Ultimate compressive strength
Ultimate compressive strength = 237kN
(2) Ductility in terms of percentage strain
Ductility = 90.7%



Graph 14 ***Load displacement curve DNA with rubber at ends specimen 2***

Stiffness and flexibility parameters (from load-displacement curve)

(1)Axial stiffness = k = $(P_2\text{-}P_1) / (L_2\text{-}L_1)$ = $(200\text{-}0)\text{x}10^3 / (3.76\text{-}0)$ = 53191.49 N/mm
(2)Axial flexibility = δ = $(L_2\text{-}L_1) / (P_2\text{-}P_1)$ = $(3.76\text{-}0) / (200\text{-}0)\text{x}10^3$ = $1.88\text{x}10^{-5}$ mm/N

3.13 DNA With Rubber At Ends Mean Values of Specimen 1 And 2

(a) Mean Ultimate compressive strength= $F_m = (F_1+F_2) /2$ = (244+237) /2 = 240.5kN

(l) Mean percentage ductility = (61.06+90.70)/2 = 75.88%

IV. Conclusions And Recommendations

4.1 Conclusions

The following conclusions were drawn from the experimental results (as tabulated below) obtained from tests conducted on the conventional spiral helix and DNA helically reinforced columns:

Parameters	Spiral helix	DNA helix(simple)	DNA helix(rubber at middle)	DNA helix(rubber at ends)
Ultimate compressive strength(KN)	233.5	249.5	249	240.5
Young's modulus (E) MPa	2328.34	2666	2282.05	2326.25
Poisson's ratio(μ)	0.244	0.159	0.258	0.202
Shear modulus (G) MPa	933.09	1153.55	907.86	967.6
Bulk modulus (K) MPa	1615.80	1287.7	1573.14	1301.3
Axial Stiffness (k) N/mm	55734.84	63731.65	45337.74	54861.72
Flexibility (δ) mm/N	1.82×10^{-5}	1.60×10^{-5}	2.21×10^{-5}	1.83×10^{-5}
Ductility (%)	53.55	29.04	88.57	75.88

4.2 Ultimate compressive strength

The ultimate compressive strength of DNA-helically reinforced columns was found to be greater than conventional spiral helically reinforced columns with the mean ultimate compressive strength of DNA reinforced columns exceeding compressive strength of spiral helix columns by 5.496%.

4.3 Modulus of elasticity

DNA helix reinforced columns without the use of rubber ties showed higher elastic modulus thereby resisting elastic deformations effectively as compared to DNA helical columns in which alternate rubber ties were used which showed lower values of E and these values of DNA rubber columns were comparable with simple spiral helix column.

4.5 Axial stiffness and flexibility

Simple DNA helix columns without rubber showed maximum stiffness and hence least flexible behaviour. The increasing order of stiffness in columns was found as

Rubber at middle < Rubber at ends < Spiral helix < Simple DNA helix

Rubber at middle DNA specimen was found to have maximum flexibility which can be attributed to the maximum number of rubber ties used in the specimen (4#) which was followed by DNA helix with rubber at ends in which 2 rubber ties were used. The stiffness of spiral helix columns were found to be in between simple DNA helix and DNA helix in which rubber ties were used.

4.6 Ductility

The increasing order of ductility is as

DNA helix < Spiral helix < Rubber at ends < Rubber at middle

In simple DNA helical columns without rubber, the size of the lateral steel ties was 6mm and the rubber ties used were 2 in number whereas in DNA helix column with rubber at middle, the size of steel ties used was 10mm and 4 rubber ties were used. This indicates that the size of the steel ties and number of rubber links have an important influence on the ductility characteristics of the columns with larger diameter steel ties and higher number of rubber links contributing to increased values of ductility. The ductility values of DNA helical columns with rubber at ends was found to be in between simple DNA and DNA rubber at middle specimen because in these columns 8mm ties were used and the number of rubber links were only 2 in number.

4.7 Effect of length of DNA helix on column parameters

In the DNA helix column with rubber links at middle the length of the specimen tested was 720mm whereas in the other DNA samples the length was 600mm. The DNA helix column with rubber at middle in spite of larger length exhibited improved characteristics in terms of ultimate compressive strength, ductility, stiffness and flexibility parameters which can solely be considered because of the larger length of the DNA helical reinforcement as compared to the other specimen. This finding reveals that DNA helical reinforcement can be advantageously used in longer columns with definite improvement of performance over spiral helical reinforcement.

4.8 Recommendations And Future Scope

DNA helix columns in general exhibited increased ultimate strengths as compared to the spiral helix columns which implies they can be conveniently employed as a substitute and an improved alternative form of reinforcement to the conventional forms. An important observation regarding the improved performance of DNA helical column with rubber at middle in spite of longer length of the column suggests that there is a huge scope for experimenting on this aspect and to study that how effect of length of DNA helix reinforcement affects different parameters so that they can be advantageously used in long columns as well. The size of the steel ties and the number of rubber links played a very important role on the ductility of the columns tested. Larger diameter steel links and higher number of rubber links resulted in higher ductility values which can be attributed to the increased confining pressure. On the other hand smaller diameter ties and lesser number of rubber links exhibited lower ductility values. So by adjusting the above two parameters required ductility can be achieved. DNA helix columns without rubber showed stiffer behaviour as compared to the spiral helix columns but if rubber is incorporated in the form of alternate links, we get relatively higher flexibility values which paves way for the use of this reinforcement at beam column junctions which are susceptible to plasticization during an earthquake or any accidental lateral loading. Therefore DNA helically reinforced columns have a number of aspects on which detailed future experimentation can be conducted and the same can be studied extensively for further improvisations.

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