# Study of failure of concrete columns , failure mechanisms and comparison of spiral helix, DNA Helix(simple), DNA Helix(rubber at middle), & DNA helix(rubber at end)

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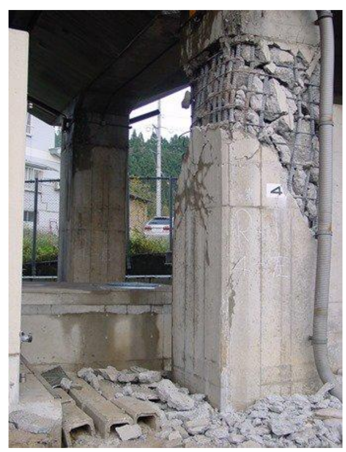
**Introduction :** Reinforced concrete column is a compression member and transfers the loads from structure to the ground through foundations. There are three types of concrete columns based on its height and lateral dimension. Long columns are those whose ratio of height to least lateral dimension is more than 12. When the height to least lateral dimension is less than 3, it is called a pedestal and if it is between 3 and 12, it is called as a short column. The load carrying capacity and modes of failure of a reinforced concrete column is based on the slenderness ratio. Slenderness ratio is the ratio of the effective length Le and least lateral dimension of the column as per Indian and British Standards. But as per American Concrete Institute Code of Practice, the slenderness ratio is defined as the ratio of effective length of column to its radius of gyration, which is same as used for structural steel design as per IS Code. Effective length of a column depends on its support conditions at ends. Based on the slenderness ratio of the column, there are three modes of failure of reinforced concrete columns. The columns are assumed to be centrally loaded (no eccentric loads).

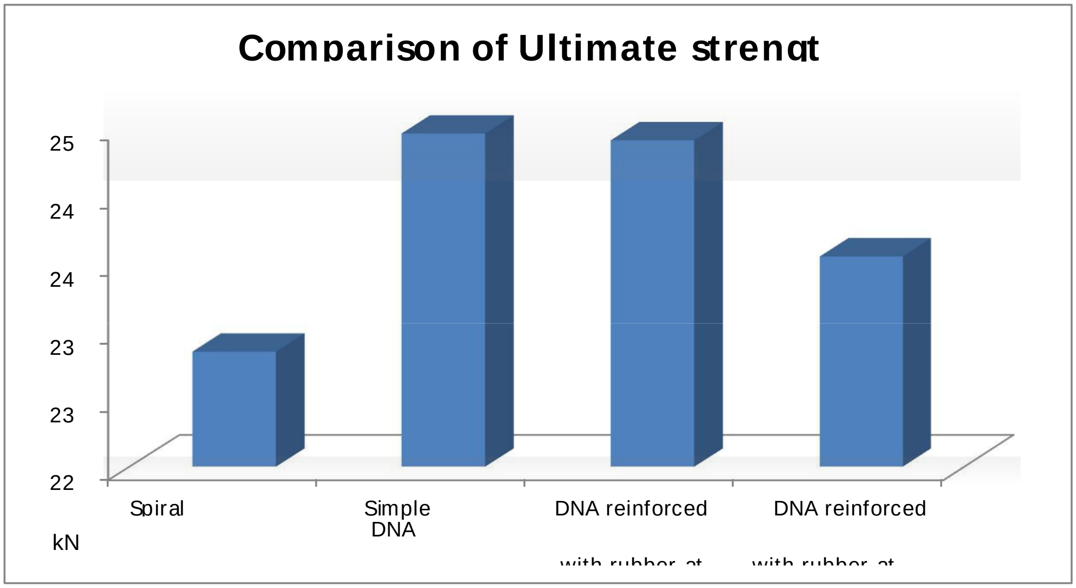
**Keywords:** Failure Process, reinforced concrete, rectangular column, stability-material failure.

**Modes of column failure**

**Mode 1**: Column Failure due to Pure Compression: When reinforced concrete columns are axially loaded, the reinforcement steel and concrete experience stresses. When the loads are high compared to cross-sectional area of the column, the steel and concrete reach the yield stress and column fails without undergoing any lateral deformation. The concrete column is crushed and collapse of the column is due to the material failure. To overcome this, the concrete column should have sufficient cross-sectional area, so that the stress is under the specified limit. This type of failure is generally seen in case of pedestals whose height to least lateral dimension is less than 3 and do not experience bending due to axial loads.



**Mode 2**: Column Failure due to Combined Compression and bending Failure: Short columns are commonly subjected to axial loads, lateral loads and moments. Short columns under the action of lateral loads and moments undergo lateral deflection and bending. Long




Graph 15: **Comparison of the ultimate compressive strengths of various models**

## Modulus of elasticity

DNA helix columns exhibited a higher elastic modulus as compared to spiral helix columns with the mean elastic modulus of DNA reinforced columns exceeding elastic modulus of simple spirally helix columns by 4.14% which implies that DNA helix columns resist elastic deformations effectively. DNA helix reinforced columns without the use of rubber ties showed higher elastic modulus 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. The increasing values of moduli are as DNA rubber at middle< DNA rubber at ends< Spiral helix< Simple DNA helix

## Poisson's ratio

The mean value of the Poisson's ratio of DNA helix reinforced columns is 0.206 whereas this value for simple spirally helix reinforced columns is 0.244 thus implying that the DNA helix columns undergo less lateral strain for the same axial strain as compared to spiral helix columns within elastic limit. The increasing values of Poisson's ratio are
Simple DNA helix< DNA rubber at ends< Spiral helix< Rubber at middle

## Shear modulus

The mean shear modulus of DNA helix reinforced columns exceeds the shear modulus of spirally helix reinforced columns by 8.207% which clearly indicates that the DNA helix columns are more stiff to transverse displacements and resist shear stresses effectively under axial loading. This may be attributed to behaviour of DNA helical reinforcement which acts partly as longitudinal and partly as a transverse reinforcement and the use of lateral ties in turn enhances the same. This effect is observable within the elastic limit contrary to action of transverse reinforcement beyond the ultimate load in conventional tied columns. Simple DNA helically reinforced column showed highest resistance to shear deformations. The increasing order of shear modulus is as DNA rubber at middle< Spiral helix< DNA rubber at ends< Simple DNA helix

**Bulk modulus**

Spiral helix columns have a higher bulk modulus i.e. 1615.80 MPa as compared to mean bulk modulus of DNA helix columns which implies that the spiral columns have better ability to withstand changes in volume when compressed in all directions as compared to DNA helix columns. In other words DNA helix columns are more compressible. DNA helically reinforced column without rubber exhibited least bulk modulus. The increasing order of bulk moduli is as:

Simple DNA< DNA with rubber at ends< DNA with rubber at middle< Spiral helix

**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 because of the better confinement of the concrete core by double helical strands which in turn are confined by ties and rubber strands. 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. In simple DNA helical column the ductility is minimum even less than the spiral helical column because of the minimum tie size which yielded quite easily in the post peak region.

**Axial stiffness and flexibility**

Spiral helix columns were found to be slightly stiffer as compared to DNA helix columns by 1.99% in general and as compared to DNA helix columns with rubber at ends by 1.59% in particular which shows that DNA helix columns with rubber at ends are useful for use at junctions owing to their slightly improved flexibility without appreciable loss in stiffness. Comparing the specimen individually 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 (4nos) 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.

**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 be considered because of the larger length of the DNA helical reinforcement as compared to the other specimen. This finding does not preclude the use of DNA helical reinforcement in longer columns with definite improvement of performance over spiral helical reinforcement.

**CONCLUSIONS:**

- The compressive strength of DNA helix reinforced columns exceeds compressive strength of spiral helix columns by 5.496% because of effective confinement.
- DNA helix columns exhibited a higher elastic modulus as compared to spiral helix columns with the mean elastic modulus of DNA reinforced columns exceeding elastic modulus of simple spirally helix columns by 4.14% which implies that DNA helix columns resist elastic deformations effectively.
- The mean of spirally helix reinforced columns thus implying that the DNA helix columns undergo less lateral strain for the same axial strain as compared to spiral helix columns within elastic limit.
- The mean shear modulus of DNA helix reinforced columns exceeds the shear modulus of spirally helix reinforced columns by 8.207% which clearly indicates that the DNA helix columns are more stiff to transverse displacements and resist shear stresses effectively under axial loading and this effect is observable within the elastic limit contrary to action of transverse reinforcement beyond the ultimate load in conventional tied columns.
- Spiral helix columns have a higher bulk modulus as compared to mean bulk modulus of DNA helix columns. In other words DNA helix columns are more compressible when stressed in all directions.
- Spiral helix columns were found to be stiffer as compared to DNA helix columns by 1.99% in general and as compared to DNA helix columns with rubber at ends by 1.59% in particular which shows that DNA helix columns with rubber at ends are useful for use at junctions owing to their slightly improved flexibility without appreciable loss in stiffness.
- This 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 because of the better confinement of the concrete core by double helical strands which in turn are confined by ties and rubber strands.
- The DNA helix column with rubber at middle in spite of larger length exhibited improved characteristics as compared to the other specimen. This finding does not preclude the use of DNA helical reinforcement in longer columns

with definite improvement of performance over spiral helical reinforcement.

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