A Complete Study on Behaviour of Concrete Columns by Using Biaxial Geogrid Encasement

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Abstract

A new reinforced system is introduced to be used in concrete columns. This new reinforcement named Geogrid reinforced steel columns (GRSC), is a little satisfactory alternative to the rebar cage used in traditional reinforced concrete, for faster and easier construction.

Geogrids are an alternative tool in transportation and civil construction. They allow engineers to build where it otherwise would not be possible or would be cost prohibitive using traditional material. It is structured polymeric material usually made from polyethylene compounds.

1 Introduction

1.1 General

Reinforced concrete (RC) has been used in construction of different structures for centuries. Reinforced concrete is defined as concrete which is a mixture of cement, sand, gravel, water, and some optional other admixtures, combined with a reinforcement system, which is usually steel. Concrete is strong in compression but weak in tension, therefore may result in cracking and failure under large tensile stresses. Steel has high tensile capacity and can be used in areas with high tensile stresses to compensate for the low tensile strength of concrete.

The failure of any other part (beam or slab) of a structure may not cause so serious damage as that caused by the failure of a column. It can endanger even the whole structure. As such the columns must be analysed in all aspects namely strength, stability and serviceability point of view. Hence columns are most important part of any kind of structures.

Effective length

- The strength of a column and the manner in which it fails are greatly dependent on its effective length.
- A very short stocky steel column may be loaded until it reaches it yield point, and perhaps the strain hardening range.
- In essence, it can support about the same load in compression that it can in tension.
- As the effective length of a column increases, it's buckling stress will decreases.
- The steel column is said to fail elastically if the buckling stress is less than the proportional limit of steel when the effective length exceeds a certain value.

1.3 Geogrid columns

In each of these reinforcement systems concrete and biaxial geogrid, profiles, or a combination of these two are used to function as existing reinforcement systems.

1.3.1 Geogrid reinforced steelcolumns (GRSC):

This is anew geogrid steel reinforcement system that can be used inlongitudinal concrete members. GRSC is expected to perform as an integral system, geogrid performing the functionof lateral reinforcement. The proposed system is anticipated to be an alternative to the existing reinforcement systems with 5% strength loss in reinforced concrete members, notably in columns.
High intensity biaxial glass-fibre warp knitting geogrid with opening size (25x25)mm,tensile strength 50 kN/mwas exclusively and in the four corners we placed longitudinal (HYSD) steel bars Fe415. Therefore, the GRSC (Figure 1.2).

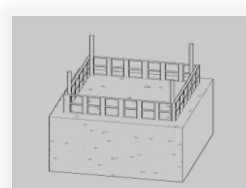

Fig: 1.2 Geogrid reinforced steel column

1.3.2 Geogrid reinforced column (GRC):

A new geogrid reinforcement system is introduced in concrete columns .This new reinforcement, named geogrid reinforced cage column (GRC)see figure(1.3).It is prefabricated in off-site and then placed inside the formwork eliminating the time-consuming and costly labour associated with cutting ,bending and tying steel bars in traditional rebar construction. Test results have shown that the compressive strength of specimen reinforced with GRC was 29% less compressive strength compared to traditional rebar reinforcement, because of its low compressive strength. And the tensile strength of this polyethylene based geogrid was 50kN/m. A case may be checked wearing a p.c.c column strength can be compared with geogrid, without longitudinal steel bars.

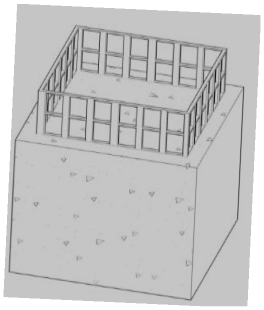

Fig: 1.3 Geogrid reinforced column

2.EXPERIMENTAL PROGRAM

The three types of specimens were constructed and tested up to failure monotonic axial load. The strength and displacement and effect of reinforcement with rebar and polypropylene geogrid strength of the column were investigated.

The results from traditional rebar, GRSC and GRC specimen with different amount of transverse and longitudinal steel were compared. The specimens were 700mm high and had 230mm X 230mm cross-sections with 40 mm clear cover the reinforcement .The specimen specification are provided in Table 2.1.

The characteristic concrete compressive strength for tested specimen M20 grade concrete was used.Table 2.2 illustrates the mixture properties as well as the concrete mechanical properties for the tested specimens.

The use polypropylene and highdensity polyethylene geogrid with opening size (25x25) mm with tensile strength 50kN/m.

Table 2.1 Details of tested column specimen

Grade	w/c	Cement(kg/m^3)	Fineaggregate (kg/m^3)	Coarse aggregate (kg/m^3)
M20	0.5	360	586.8	1195.2

The average measured compressive concrete cube strengthwas 18 MPa on the day of testing. The specimens and cubeswere taken out of the moulds one day after casting and cured insidewater tank for 7 days and then placed outside at room temperatureuntil the testing date. Geogrid reinforcement was made out of polypropylene or polyethylene. The openings on the steel tubeswere cut out by punching.

The load Vs displacement relationshipsfor the reinforcements were obtained from the compressive test. The measured average yield and ultimate stresses for the geogrid was 50kN/m. The 415 Mpalongitudinal bars, and 250 MPa for the transverse barsused in the rebar reinforced specimens, respectively.

The experimental work was conducted utilizing the universal testing machine 1000kN. All specimens were tested up to failure under monotonic loads. The specimens were subjected to axial vertical load applied at the specimens to achieve a constant stress distribution at the concrete cross section. The load was applied vertically at the centre of the specimens. When the load was applied to the entire section, the contribution by the concrete core to the total axial force was constant along the height of the column. Further, the bond strength had no influence on the structural behaviour of the column. The columns were tested under compression load (fig 2.2).

Group	**Column Designation**	**Column specimens dimension (mm)**			**Slenderness ratio h/D**
		Length (mm)	**Breadth (mm)**	**Height (mm)**	
C1	Traditional rebar columns	230	230	700	3.04
C2	Geogrid reinforced steel columns	230	230	700	3.04
C3	Geogrid reinforced columns	230	230	700	3.04

Table 2.2 Mixture properties of concrete M20 (1:1.63:3.32)

Figure : 2.1

Test setup

3.ANALYTICAL MODELING

The finite element model in ANSYS (SAS 2003) there are multiple tasksthat have to be completed for the model to run properly. Models can be created usingcommand prompt line input or the Graphical User Interface (GUI). For this model, theGUI was utilized to create the model. This section describes the different tasks andentries into used to create the FE calibration model.

3.1 Element Types

The element types for this model are shown in Table3.1. The Solid65 element was usedto model the concrete. This element has eight nodes with three degrees of freedom ateach node – translations in the nodal x, y, and z directions. This element is capable ofplastic deformation, cracking in three orthogonal directions, and crushing.

A Link8 element was used to model steel reinforcement and geogrid. This element is a 3Dspar element and it has two nodes with three degrees of freedom – translations in thenodal x, y, and z directions. This element is also capable of plastic deformation.

Table 3.1 -Element Type for Working Model

Material Type	ANSYS Element
Concrete	Solid 65
Steel reinforcement and geogrid	Link 8

3.3 Material Properties

Parameters needed to define the material models can be found in Table 3.3., there are multiple parts of the material model for each element.

Table 3.3 - Material Models for the Calibration Model

Material Model Number	Element type	Material Properties	
1	Solid 65	Linear Isotropic	
		EX	22360
		PRXY	0.2
2	Link 8	EX	200000
		PRXY	0.3
3	Link 8	EX	2500
		PRXY	0.18

Material models number 1 refers to Solid65 element requires liner isotropic and multilinear isotropic material properties to properly model concrete. EX is modulus of elasticity of the concrete (E_c), and PRXY is the poisson's ratio (γ). The modulus was based on the equation. And the Poisson's ratio was assumed to be 0.3

$E_c = 5000(f_{ck})^{1/2}$

Material Model Number 2 refers to the link8 element.

Casting of geogrid reinforced column with MS shuttering moulds

The link8 element isbeing used for the rebar. Therefore, thiselement is modelled as a linear isotropic element with a modulus of elasticity for the steel (E_s), and poisson's ratio (0.3).

Material Model Number 3 refers to the Link8 element. The Link8 element is being used for geogrid material which is subjected in the reinforced column.

Note that the density for the concrete was not added in the material model. Deflections were taken relative to a zero deflection point after the self-weight was introduced. Therefore, the self-weight was not introduced in this calibration model.

3.4 Modeling

The concrete column with rebar and geogrid were modeled as volumes. Since a quarter of the beam is modeled, the model is 700mm long with a cross-section of 230 x 230 mm.

Table 3.4 -Dimensions for concrete

Create block by dimension		
X1,X2 X- coordinates	0	230
Y1,Y2 Y- coordinates	0	700
Z1,Z2 Z – coordinates	0	230

The area of the link8 element for rebar 8mm, 6mm and geogrid was 50.24mm^2, 28.26mm2 and10.66mm^2.The meshing of the reinforcement is a special case compared to the volumes. No mesh of the reinforcement is needed because individual elements were created in the modeling through the nodes created by the meshof the concrete volume. However, the necessary mesh attributes as described above needto be set before each section of the reinforcement is created.

3.5 Meshing

To obtain good results from the Solid65 element, the use of a rectangular mesh is recommended. Therefore, the mesh was set up such that square or rectangular elements were created (Figure 3.5). The volume sweep command was used to mesh the steel rebar, geogrid and support. This properly sets the width and length of elements in the specimen to be consistent with the elements and nodes in the concrete portions of the model.

The overall mesh of the concrete, steel, geogrid and support volumes see fig (3.1&3.2) is shown in Figure. The necessary element divisions are noted. The meshing of the reinforcement is a special case compared to the volumes. No mesh of the reinforcement is needed because Individual elements were created in the modeling through the nodes created by the mesh of the concrete volume. However, the necessary mesh attributes as described above need to be set before each section of the reinforcement is created.

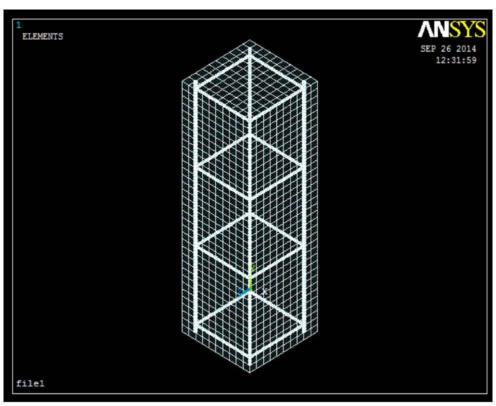

Figure 3.1 -Meshing of the concrete and rebar

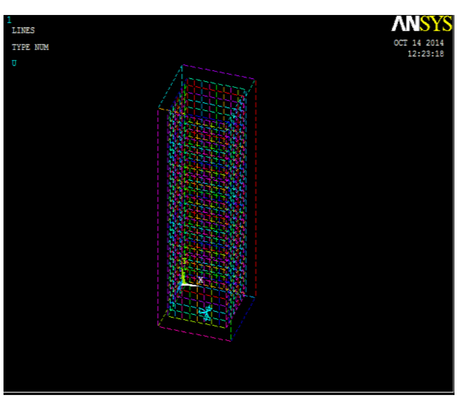

Fig 3.2-Meshing of concrete and geogrid material

3.6 Numbering Control

The command merge items merges separate entities that have the same location. The seitems will then be merged into single entities. Caution must be taken when merging entities in a model that has already been meshed because the order in which merging occurs is significant. Merging key points before nodes can result in some of the nodes becoming “orphaned”; that is, the nodes lose their association with the solid model. The orphaned nodes can cause certain operations (such as boundary condition transfers, surface load transfers, and so on) to fail. Care must be taken to always merge in the order that the entities appear. All precautions were taken to ensure that everything was merged in the proper order. Also, the lowest number was retained during merging.

3.7 Loads and Boundary Conditions

Displacement boundary conditions are needed to constrain the model to get a unique solution. To ensure that the model acts the same way as the experimental column, boundary conditions need to be applied one end is fixed and the other end was loadings exist axially. The symmetry boundary conditions were set first. The boundary conditions for planes of symmetry are shown in (Figure 3.3 and 3.4).

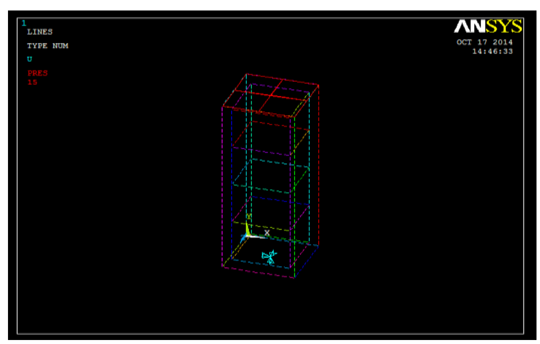

Figure 3.3 -Boundary conditions for plane of symmetry

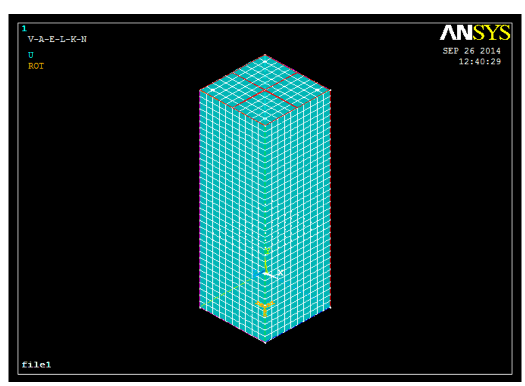

Figure 3.4-Boundary condition and pressure direction

4.RESULTS AND DISCUSSION

The all three types specimens Traditional rebar column (C1),Geogrid reinforced steel column (C2) and Geogrid reinforced column (C3) was very different in strength see table(4.1). A representative axial load-displacement is measured, Typically the specimens behaved elastically without cracking until the peak strength was almost reached .Suddenly the axial strength dropped about 1/2 of the peak strength.

Figure 4.1 indicates that the overall behaviour of Traditional rebar columns, Geogrid reinforced steel columns and geogrid reinforced columns. It can be concluded that the axial load carrying capacity of Grcs with traditional rebar column is 5 percent less in strength and the behaviour of C1 and C2 are similar.Specimen Grc had much smaller peak strength compared to traditional rebar reinforced columns and Grcs. This may be due to zero compressive strength of biaxial geogrid. The load carying capacity of Grc was 29 percent less was gained.

Group	**Column Designation**	**Column specimens dimension (mm)**			**First cracking (kN)**	**Peak strength (kN)**	**Displacement (mm)**
		Length (mm)	**Breadth (mm)**	**Height (mm)**			
C 1	Traditional rebar columns	230	230	700	560	785.8	8.9
C 2	Geogrid reinforced steel columns	230	230	700	520	746.3	7.84
C 3	Geogrid reinforced columns	230	230	700	515	559.05	7.47

Table4.1 Measured load-displacement values

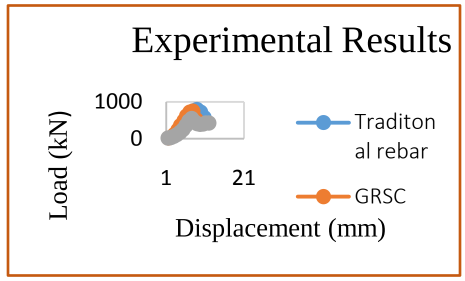

Figure 4.1: Load –Displacement curves **Tested specimens**

Fig 4.1.1 C1-Traditional rebar columns

C2-Geogrid reinforced steel columns

C3-Geogrid reinforced columns

The specimens behaved elastically without cracking until the peak strength was almost reached. The cracking usually started suddenly near the corners either the top or bottom of specimens.

Modelling Behaviour of test columns

In this research linear analsis was done for the all the three cases, under one end fixed other end free case by changing the material properties. The experimental results were used to validate the analytical predictions.

Table4.2 Stress value from analytical study

The stress and stress at the innterfaces were investigated in each every individual material (see Table 4.2) .The yeilding stress was very less compared to steel bar, This was a factor of gaining less strength in geogrid column compared to traditional rebar column.See (fig 4.2,4.2,4.3,4.4,4.5 and 4.6) which developed in ANSYS Finite element analysis software.

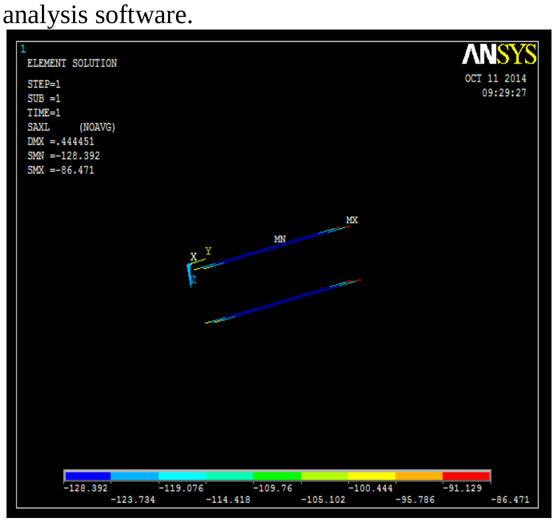

Fig 4.2 Stress in steel bar (C1) model

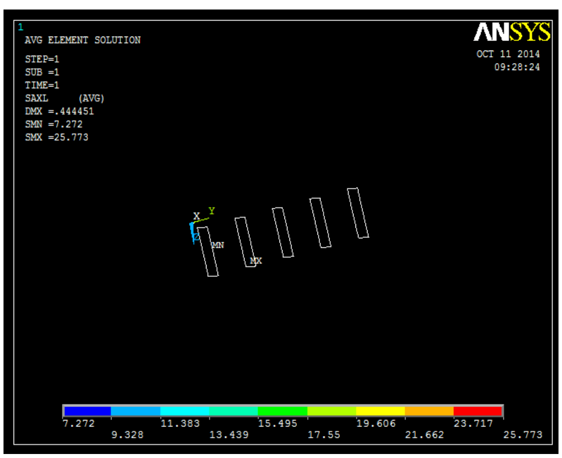

Fig 4.3 Stress in steel ties (C1) model

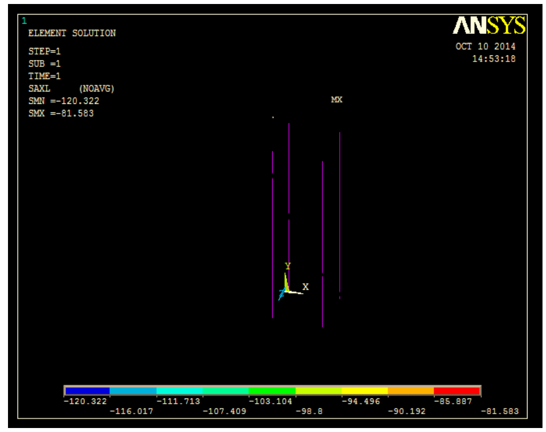

Fig 4.4 Stress in steel bar (C2) model

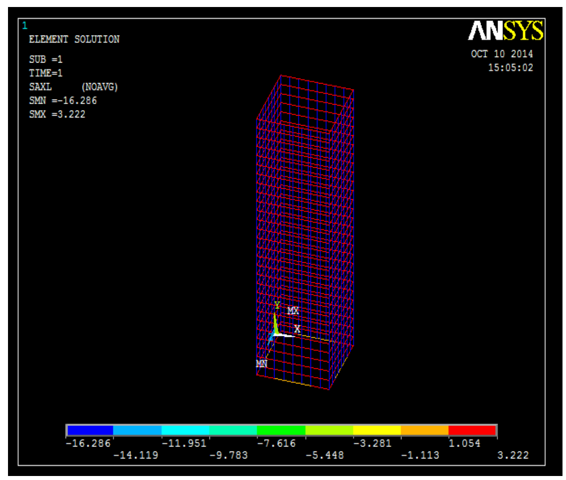

Fig 4.5 Stress in geogrid (C2) model

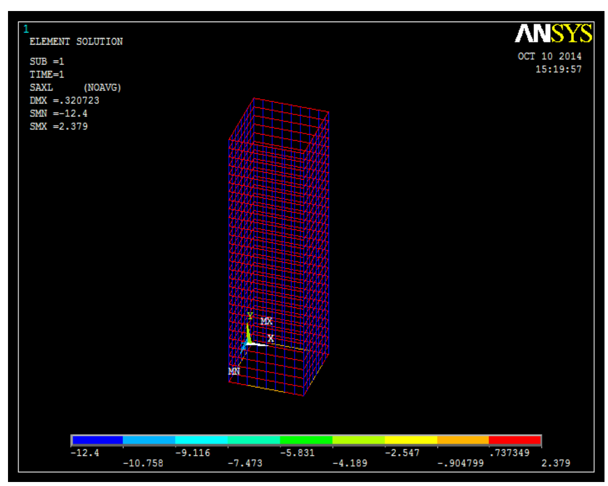

Fig 4.6 Stress in geogrid (C3) model

The stress at interface between concrete and reinforced material was found through the analytical model,we can observe that by placing longitudinal steel bars along the corners of the geogrid encased concrete columns the stress at the interface was increased compared to third case see (fig.4.7,4.8,4.9,4.10,4.11 and 4.12).

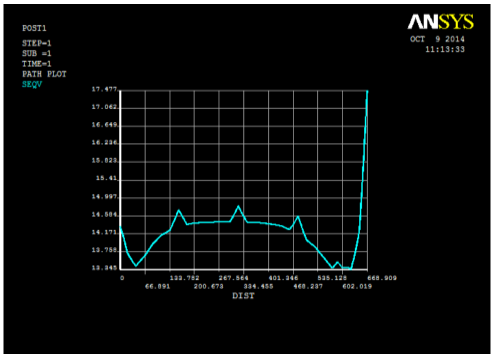

Fig 4.7 Stress at interface in (C1) model longitudinal rebar

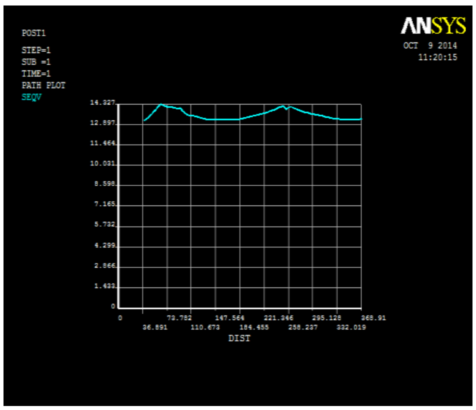

Fig 4.8 Stress at interface in (C1) model rebar lateral ties

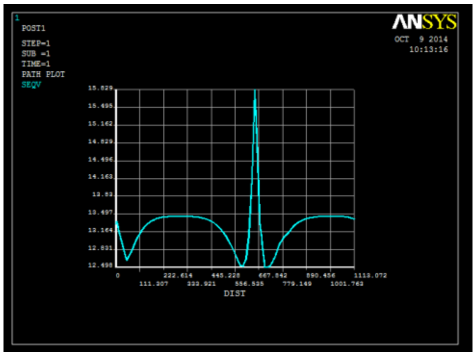

Fig 4.9 Stress at interface in (C2) model longitudinal rebar

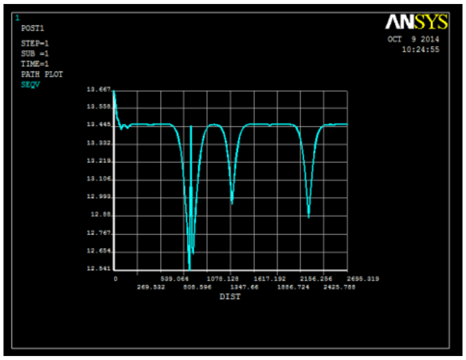

Fig 4.10 Stress at interface in (C2) model geogrid lateral direction

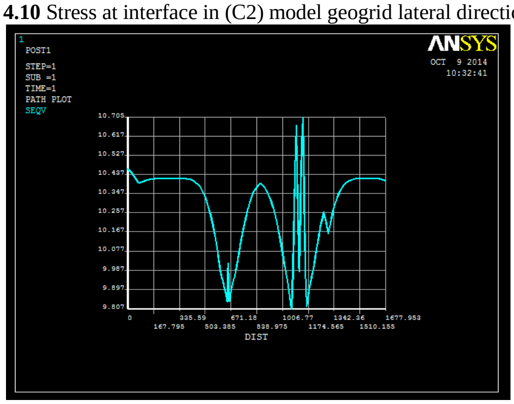

Fig 4.11 Stress at interface in (C3) model geogrid longitudinal direction

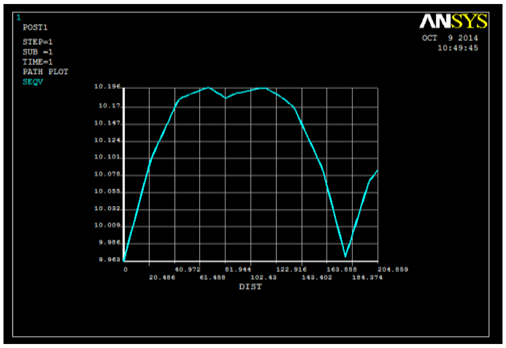

Fig 4.12 Stress at interface in (C3) model geogrid lateral direction

5. CONCLUSION

From the experimental and practical investigations carried out in the study, the following major findings can be arrived at

1. A new geogrid reinforcement termed GRSC is proposed for longitudinal reinforced members GRSC is an anticipated to be an alternative to the existing reinforcement systems and lower construction cost as it eliminates the labour cost associated with cutting, bending and tying reinforcing ties.
2. The columns with rebar gives the better confinement than the geogrid, this may be due to low tensile and compressive strength of geogrid.

3. The test results shows that the load carrying capacity of columns with geogrid and longitudinal steel reinforcement is 5% less than the load carrying capacity with traditional rebar reinforcement, so the GRSC shows a little reduction of its strength.
4. The strength reduction of two models GRSC and GRC compared withtraditional rebarspecimens give 5% and 29% respectively.
5. From FEM analysis it is observed that the failure stresses at the interface in traditional system with GRSC and GRC systems was compared, and found that the stresses in traditional reinforcement is more.
6. A result of analytical work, the stresses developed steel in traditional rebar column - 86.47N/mm^2(compression),Geogrid reinforced steel columns-81.53N/mm^2(compression) and geogrid reinforced columns-2.37N/mm^2(tension) respectively. From the above result can conclude that compression stress in GRCS is more compared to GRS.
7. This research shows that in second case with increasing the tensile strength of geogrid grade, the confinement of the concrete compressive strength of the column specimen will increase.

From the experimental and analytical analysis it was observed that geogrid is a better replacement of steel ties.

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