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Analysis of Grouted Splice Sleeve Connection in Precast Column to Column Joint

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Abstract

In present scenario, Precast construction is replacing RCC structures in most of the locations all over the world. Economical and speedy construction is significance of precast structures. The primary objective of this research is to evaluate the stresses generated throughout the joint section . When the stresses are calculated, the reduction of section size or approach for economical design is possible. Results of stress analysis concerning the axial load in the form of pressure applied on column to column precast structure is assessed using finite element software i.e. ABAQUS. The connection maintained between two precast columns is executed by grouted splice sleeve and acts as a joint. The column has the cross section with both the sides 500mm and with the length of 4150mm. The longitudinal reinforcements bars protruding throughout both columns are 20mm diameter bars. obtain The performance of grouted splice sleeve is observed and stresses d in grout, grout sleeve steel and rebar connection both columns are obtained. The structure is divided in to finite parts and nodes using ABAQUS. The stresses every part of structure under certain pressure can be visible in visualisation at every node or instance of ABAQUS. Comparison of precast columns and a single RCC column is observed. The stresses developed and performance of model is visualised in this study. But the location of maximum stresses developed are seen to be varied in both the cases.

Introduction

In precast construction the joint between two structural elements plays a significant role in increasing the strength of structure. In this thesis the approach is to join the two precast column elements with splice using grouted sleeve. The term grouted splice sleeve contains of a hollow steel pipe and is grouted with high strength concrete. The rebar which connects two column elements will pass through the grouted sleeve and connects two columns is known to be splice. For gaining the strength of two prefabricated elements appropriate connection is required which is provided by grouted splice joint in column segments. Bond strength between grout and splice plays the important role in connection between the two precast segments. There is always a major disadvantage in cast insitu reinforced concrete construction (RCC) i.e, the onsite condition should be favourable for construction. The onsite conditions play a vital role in construction purpose. This could affect the quality and strength of RCC construction. The time consumed in RCC construction is more than precast construction, thus increases the cost of construction. To overcome these conditions precast construction are preferred. The structural elements are formed in the factory and then elements are assembled on site. Due to this process the speed of construction increases. The quality and strength of structural elements is maintained to greater extent. Instead of large sections of RCC structural elements, small precast sections can be assembled resulting in faster construction process.

Feasibility of grout in precast connections

The column to column connection is being tested by axial tension, shear test, four point bending with and without axial compression. The connection between two columns is in the form of grouted splice sleeve. The stress carried by the splice transfer from one column to another in tension failure test is viewed. Damage is developed in interface between two column units. The significance stress transfer in splice region is the important factor in this experiment. Due to these tests' failure took place in joint section of column. The direct tension test specified the effectiveness of the stress transfer along the splice region. Failure took place far from the joint section, outside the bar splice region or grout rebar region. Evaluation of bond strength of reinforcing bars is carried out to investigate the feasibility of utilizing a generic grout- filled reinforcing bar splice. Lap splice specimens and butt-splice specimens were tested with different confining steel within the grout filled steel pipe. High bond strength of reinforcing bars can be achieved by confining the grout surrounding the bars. Different characteristics of grout can be tested in the grout filled steel pipes to investigate the performance of the structure with respect to axial loads in further investigations.

Stress evaluation using ABAQUS

A formulation with concrete damage plasticity was implemented inABAQUScodetoevaluatethesteel-concretecompositebehaviourundermonotonicloads.Thenon-linearnumerical investigation of beam columnjointisperformedinABAQUSforobserving stresses and strain the particular portion of joint. Beam-column connection is donebyamechanicaljoint,thatcontainsofstructuralelementslikethreadedre-bars,nuts,couplers,andanchor re-bars. ModellingtechniquestocalculatestressandstraininABAQUSusedare:

- Nonlinearstress-strainrelationshipofunconfinedandconfinedconcreteundermulti-axialstressconditions.
- Concretedamagedplasticitymodel

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- Meshdiscretization,meshdensity,meshcompatibility,andelementdistortion
- Modelling ofembeddedelements
- Modellingofcontactelements
- Assigningmaterialproperties

Before proceeding towards actual simulation of Precast two column segments, the experimental analysis on grout-filled splice performed by Amin Einea is being simulated using ABAQUS and the results are compared in following validation. The rebar splice grouted sleeve is tested under axial loading to investigate the failure of grouted sleeve.The same test is performed in ABQUS under the Pressure of 86.11KN/mm^2. This model shows the placement of rebars, boundary conditions applied at the bottom of the sleeve and pressure applied on the model. The visual high pressure effects confirmation is observed in the mid-section of a grouted sleeve.

The reliable design of beam column joints can be performed through non linear finite elementanalysis. In this study, replacement of RCC insitu construction with small precast segments for safe and economicdesign is performed. Grouted splice sleeve can be used between column to column joint to increase thestrengthofprecastsegments.Toevaluatethestressesobtainedinthegroutedsplicesleeveduetoaxialcompressionloadincolumn.Thiscanbeachievedbycalculatingthestressesatcriticalsection of precast joint by using the Abaqus software (finite element analysis).

Investigation

The precast column to column joint is designed in ABAQUS i.e., finite element software for checking the stresses in grout and rebar connection of two columns. After investigating the stresses, the precast structure will be compared with RCC monolithic column by applying same load to the appropriate structure

Specification

Precast column elements consist of cross section 500*500 and length of column is 4150mm. Four Grout pipes which has diameter of 63mm and grout diameter is 58mm. The length of pipe is 1000mm. Four 20mm Rebars are passing through grout from one column to another column. The length of rebar is 2000mm. It acts as a wire. 8 reinforcements @20mm passing in precast column units acts as a wire. Stirrups @8mm acts as a wire. Steel beam consist of cross section 500*500 and length of 2000m. Precast joint consists of cross section 500*500 and length is 20mm. Load applied is 2500KN.

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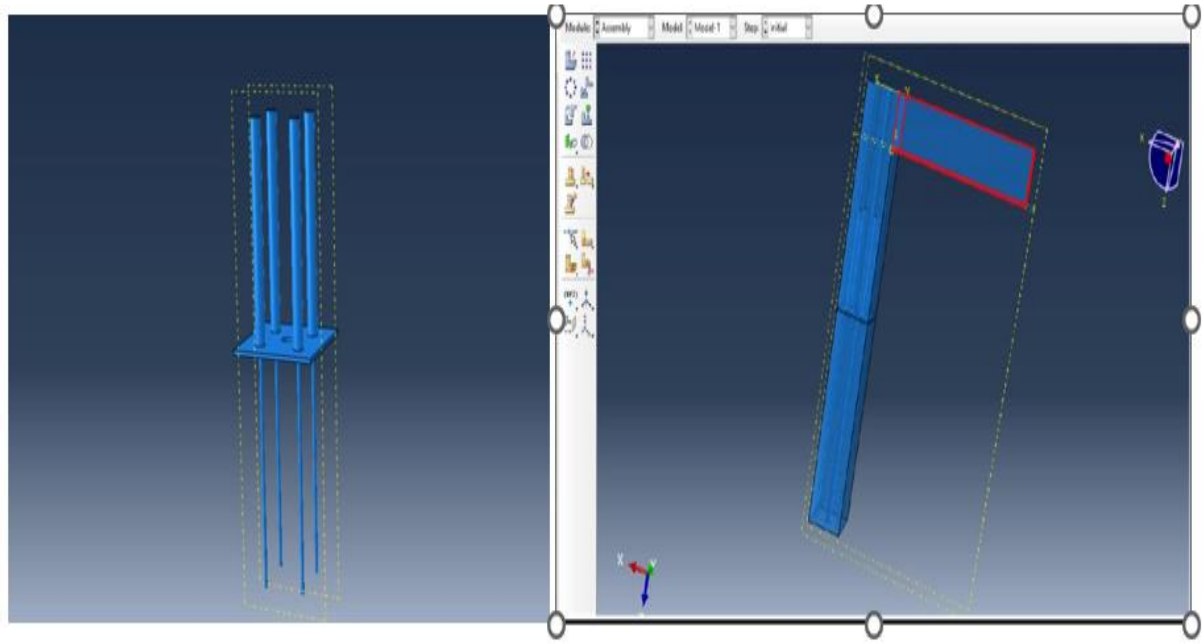

Figure 0:1Orientation of column

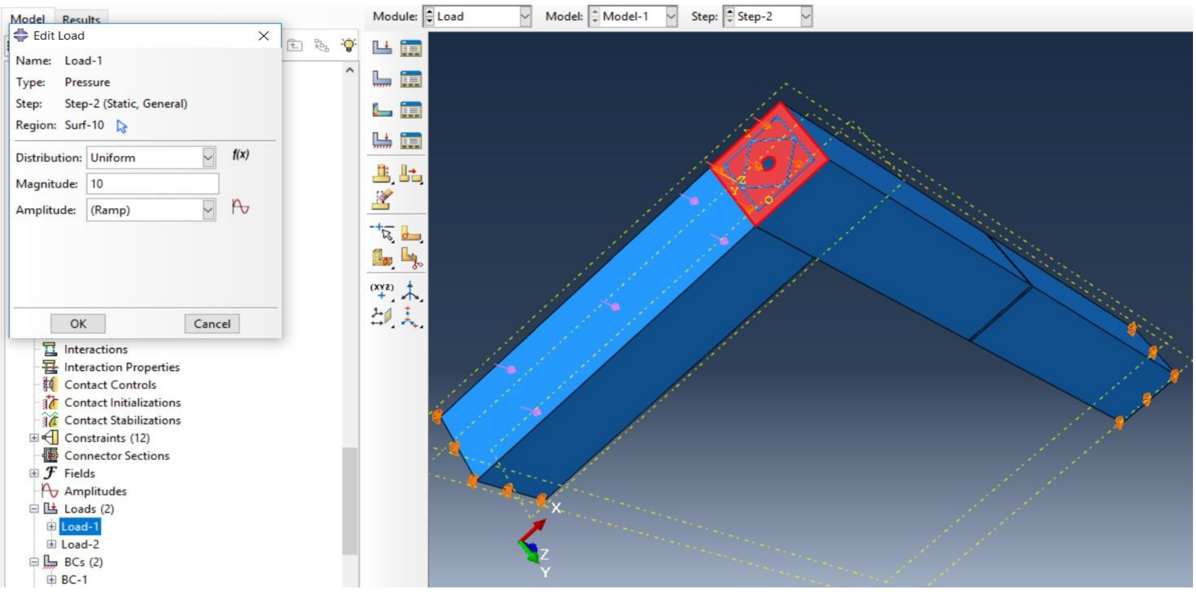

Figure 0:2Load Applied on column surface

Meshing Technique

ThesignificanceofMeshmoduleistogeneratethefiniteelementmesh.ThemeshingtechniquethatABAQUSwillusetocreatethemesh,theelementshape,andtheelementtype.ABAQUSusesanumberof differentmeshingtechniques.Thedefaultmeshingtechniqueassignedtothemodel is indicated by the colour of the model when you enter the Mesh module. The size ofmesh can be controlled manually, it depends upon the approximation of the data we have toobtain.

After meshing the part, if the changes are made in assembly of module then it will affect

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themeshing of module. The parts in which changes are happened, those parts will have to meshonce again.

In this study, for all the parts auto meshing is performed. Meshing of grout pipe, grout insidethe pipe and grout rebar are important factors in the module. Due to meshing, the calculationofstressesatnodesarecalculated.

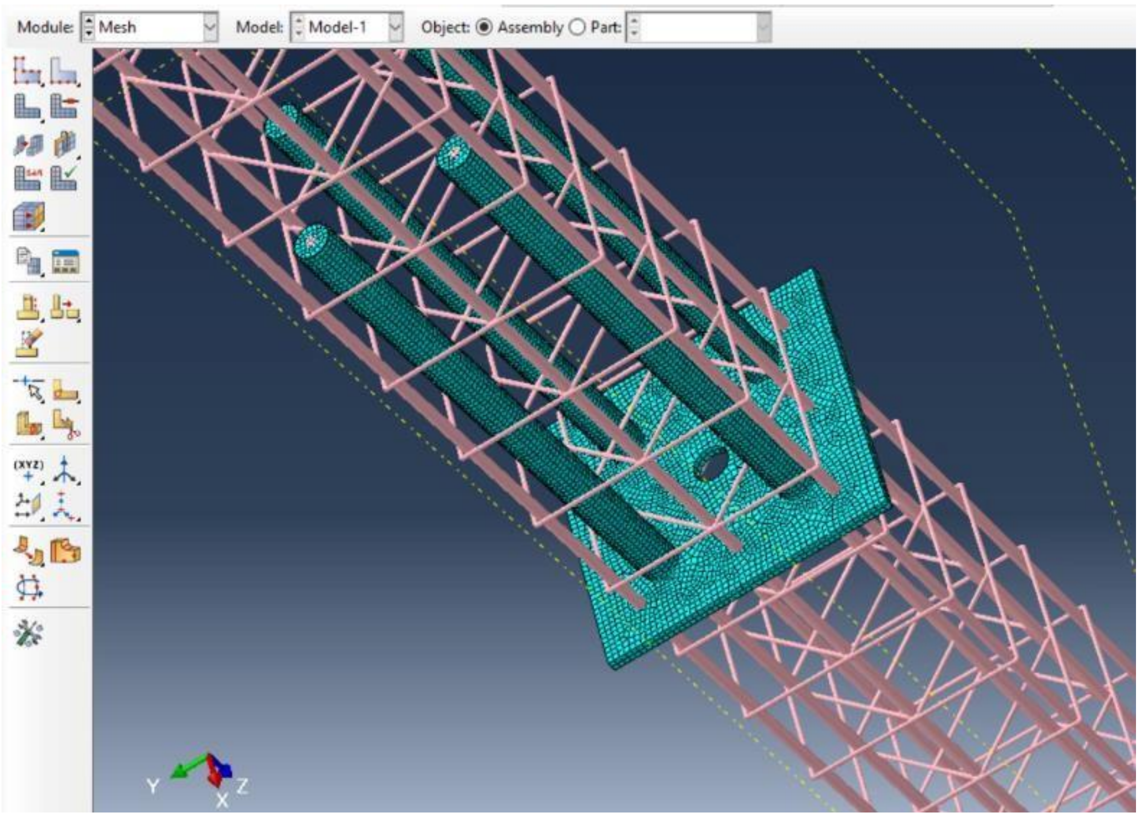

Figure 0:3Meshing of Grout pipe

Results & Discussion

Visualization

After completing the job, all the output of the design is observed in the Visualization module.The use of Visualization module to read the output database that ABAQUS generated duringthe analysisandtoviewthe resultsofthe analysis.

Inthisstudy,simulationofstressesisperformedtoinvestigatethestressesthroughoutthejointin precast column structure. But the stresses generated in column model is also a importantfactortoobserve the variationofstressesdevelopedinbothprecastandRCC structure.

Because of connection of two column units in Precast model, the stresses generated in thisstructureisgreaterthanRCCstructure.Theaccuracyofoutputdatainprecastmodelisgreaterbeca

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use of auto meshing the model, there was increase in the meshes developed in the twocolumn units. Greater amount of stresses is developed in joint section and where the beam istiedtocolumn.Invisualizationmodel,themaximumamountofstressesdevelopedinalloverthe structureis188.4N/mm^2shownbelow:

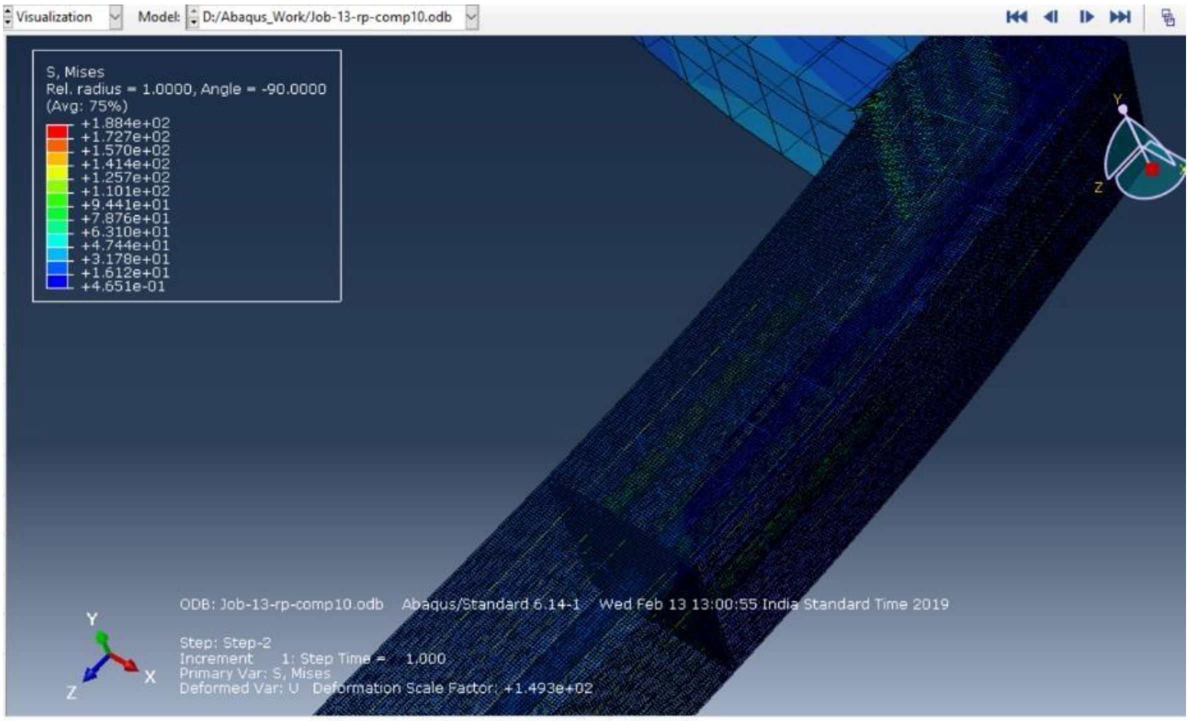

Figure 0:1Stresses in model

In RCC column model, the column is monolithic. There are no joints connecting the columnunits, so the stresses developed in this model is at column beam joint, reinforcements and attheendofcolumn.Thestressesdevelopedarelessascomparedtoprecastmodelbecausethereisonly onecolumnunit.TheapproximationismoreinRCCmodel.Theamountofmeshesareless and the nodes are less, therefore, the variation of stresses throughout the RCC modeldiffers. In Visualisation model, the maximum amount of stresses developed in all over thestructureisspecifiedinleftcornerofthe figureshownbelow:

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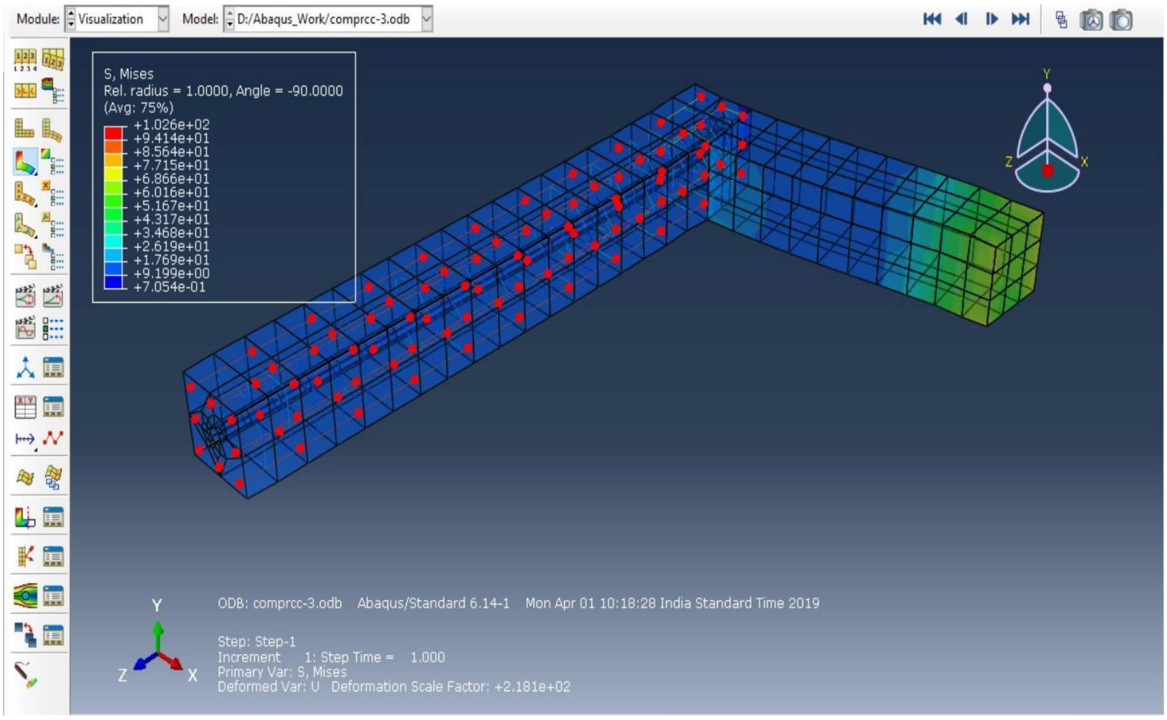

Figure 0:2Stress in RCC

The maximum stresses developed due to axial compressive load on column are on mainreinforcementbarofRCCsection.Themaximumstressdevelopedis102.6N/mm^2.Inthemid-sectionofRCCcolumnstressesdevelopedare varying around85 N/mm^{2}to 90N/mm^2.

Stressvariationinjointsection

Jointsectionconsistsofthreeparametersgroutpipewhichhasmaterialsteel,groutconsistsofhigher concrete grade i.e. M80 and grout rebar. Due to axial load applied on the column,stresses generated in joint section are visualised in ABAQUS. The column section will try tobuckleandthegroutpipesubjectedtotensionwillgeneratemorestressesascomparedtogroutpipe subjectedtocompression.The stresses developed in finite element analysis software ABAQUS are observed in outputfile. Output file shows at which nodes the stresses, displacement, forces, moments etc, aredeveloped.InthisstudyWehaveselectedthepartofwhichthestressesaretobeinvestigated.Theexampleofselectionofpartinwhichstressesare evaluated isshown in figurebelow. Thestressesaregeneratedinthesteelpipe,groutrebar(steel),andgroutM80ingroutedsplicesleeve under the axial compressive load are as shown in the table no.1. Total amount of fourgroutsleevesare analyzedsituatedbetweenprecastcolumnsegments.

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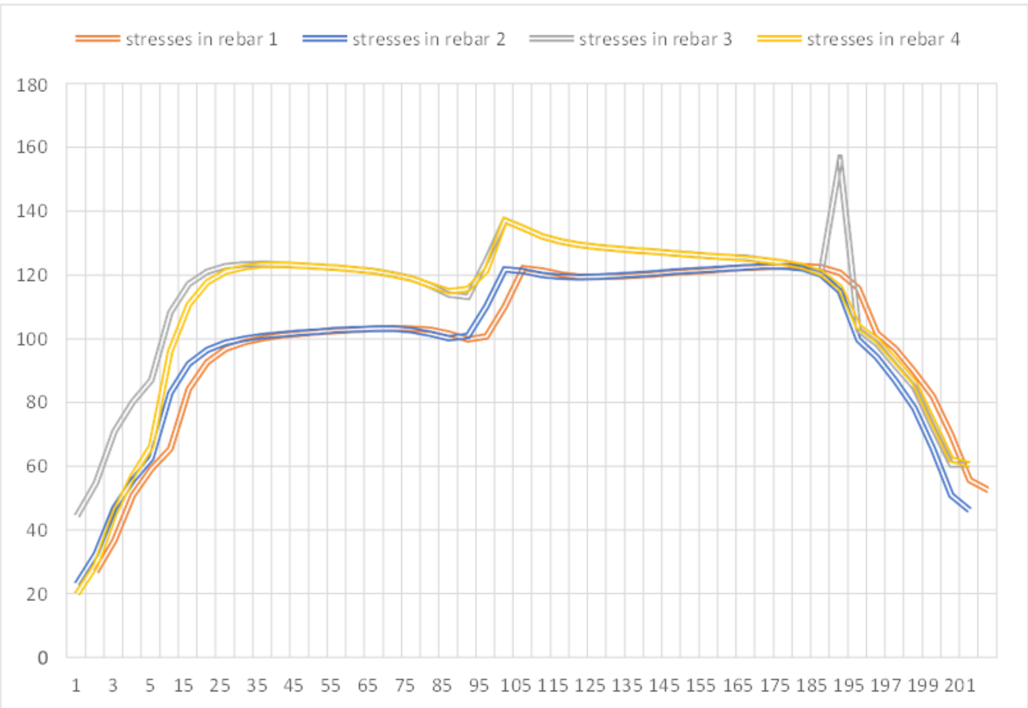
Table 0-1Maximum Stresses developed in Joint section

Part	Material	YieldStrength (N/mm^2)	Totalnodes	Nodeno.	MaximumStresses (N/mm^2)
GroutPipe1	**Steel**	**250**	**6027**	**2128**	**102.233**
GroutPipe2				**2128**	**101.96**
GroutPipe3				**2128**	**118.919**
GroutPipe4				**2128**	**120.024**
Grout inPipe1	**Grout**	**80**	**4530**	**1357**	**25.452**
Grout inPipe 2				**3025**	**21.284**
Grout inPipe 3				**3180**	**21.281**
Grout inPipe 4				**1357**	**25.512**
Groutrebar1	**Steel**	**250**	**201**	**100**	**122.088**
Groutrebar1				**100**	**121.696**
Groutrebar1				**100**	**137.174**
Groutrebar1				**100**	**136.926**

Comparisonofstressesdevelopedinfourgroutrebar:



Thehigheststressdevelopedduetoloadingislessthanthe material'syieldstrength

1. Higheststressdevelopedingroutpipesteelmaterial=120.024N/mm2<250N/mm2.
2. HigheststressdevelopedinthegroutM80=25.512N/mm2<80N/mm2.
3. Higheststressdevelopedingroutrebar=137.17N/mm2<250N/mm2.

Conclusion

Evaluation of Stresses using ABAQUS (Finite element analysis software) is proven to beaccessibleandhandfultechnique.Atanysectionorlocationofstructuralsegments,thestressesare easilyanalyzedwiththistechnique.

Fromthisstudy, particular conclusionscanbemade:

- MaximumstressgeneratedinPrecastcolumnsegments is188.4N/mm^2.
- MaximumstressgeneratedinRCCcolumnsectionis102.6N/mm^2.
- The stresses generated in precast model is greater than stresses generated in RCCmodel.
- The higher amount of stresses are generated in Precast model, because the column isdivided in to two segments, but still it is safe as the stresses developed are below theyieldstrengthofmaterial.
- TheprecastsegmentconnectionscanbefurtheranalyzedbyloweringthegradeofgroutfromM80 toM60.

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