Structural Integrity of RCC Modular Concrete Structure

Seshananda Reddy Kuncham and M. Ramesh Kannan

1Division of Structural and Geotechnical Engineering, School of Civil Engineering, Vellore Institute of Technology Chennai, Tamil Nadu, India
2Email: rameshkannan.m@vit.ac.in

Abstract. The structural integrity of composite structural elements is very significant. This corroborates for RCC modular reinforced concrete structural systems as well. In this research, a detailed 3D Finite Element Analysis (FEA) of commonly built RCC modular concrete system is perceived. The FEA of RCC modular concrete structure is carried out using an industrial standard cutting edge software. This is a comprehensive attempt on the modelling and analysis of RCC modular concrete structure as per BIS standard.

1. Introduction

The modular construction has many advantages over conventional construction such as lesser construction time, promising resource wastages and enhancing quality. This type of construction will reduce both construction time and cost as a whole. There is no well-defined standards or procedure to analysis and design modular concrete structures. Many specialized companies create their own standards and design procedure using trail-and-error or rule of thumb from experience construction personnel [1-4]. In this research, a comprehensive analogy of analysis of modular RCC structure is perceived.

2. Preliminary Modelling

Initially, a 3D solid model is created using Simulia ABAQUS, which is a sophisticated Finite Element Analysis (FEA) software used to determine the structural integrity of Engineered structures. The parts or components of the modular RCC structural elements cognate to the real-time project are created [3,4]. Each part of the model was created separately and assembled. After entering all the dimensions of all walls and slab of the model, reinforcement bars (standard dimensions) for the entire structure is created.

After arranging all the parts in model, the material properties are incorporated. The dimensions of the wall structure is 4000 x 3000 mm, thickness of wall is 200 mm and the slab thickness is 200 mm, dimensions of the door is 1200 x 2100 mm, dimensions of the windows are 1000 x 1000 mm, and dimensions of the slab is 4400 x 4000 mm. The diameter of reinforcement bar used for this structure is 12 mm [3].

Figure 1. 3D solid model of the modular RCC structure.
The reinforcement bars were placed with 150 mm c/c spacing and near doors and windows are with 100 mm c/c spacing. After creating all the parts, need to give the material properties for concrete and steel. The mass density of concrete is 2400 kg/m$^3$. Modulus of elasticity is taken as 25000 MPa. Poisson’s ratio for the concrete is taken as 0.2. For steel, the Modulus of elasticity provided is 21000 MPa and Poisson’s ratio for the steel is 0.3. Grade of concrete used for this model is M25 and the grade of steel used is Fe 415.

![Figure 2. Reinforcement detailing of the 3D modular RCC structure model.](image)

After creating all the parts for the structure, assemble all the parts for creating a model. Thereafter, provided 12 mm diameter of reinforcement for each side of the wall with a spacing of 150 mm at the walls and 100 mm nearer to the door and windows as per BIS standards [5-7].

![Figure 3. 3D meshed model of the modular RCC structure.](image)

After assigning the reinforcement to the structure, meshing is carried out, with a meshing global size value of 200 mm for all the parts.
Figure 4. Support/boundary conditions for the 3D FEA model of the modular RCC structure.

The support condition which is provided for this structure is all sides are fixed condition. For any modular concrete structures, all sides of walls are fixed permanently, for that u1, u2, u3, ur1, ur2, ur3 are selected and assigned zero in the ABAQUS [9-11]. The loads are provided separately to the slab part. Selecting the steps which need to apply the loads for the structure. Based on the conditions criteria from real-time site data, loads are applied on the slab portion, say 4 kPa (uniformly) [8-12].

Figure 5. Providing loading conditions for the 3D FEA model of the modular RCC structure.

3. Finite Element Analysis (FEA) of Modular RCC structure
Once the preliminary model gets created, a new job is assigned for analyzing the structure in ABAQUS [13-16]. In that job, selecting the created job model and then the entire structure. Opening the job manager, in that select the model and submitting the structure for finite element analysis. Every part which are provided already are selected and submitted. The results are generated and interpreted.

4. Results and Discussion
The 3D FEA model is analyzed for maximum deflection, stress and strain.
Figure 6. Maximum deflection for the 3D FEA model of the modular RCC structure.

The maximum deflection was found to be 18mm. It means that the structure deflects a maximum of 18mm along the vertical direction.

Figure 7. Maximum stress values for the 3D FEA model of the modular RCC structure.

After analyzing the structure, the results for the stresses is $2.348 \times 10^{-2}$ MPa. That means the stresses from all the forces acting in all the directions in that slab. From these stress results, it is observed that the stresses acting on the top is more compared to the bottom stresses. From the analysis, the maximum deflection is found to be 18 mm, which is very minimal and within the allowable limit [14-16]. The structure behaves like a rigid jointed tunnel structure, which is a remarkable feature of modular or monolithic structures [8,14,15].

5. Conclusion
This is a comprehensive attempt on the modeling of modular concrete structures in ABAQUS and to elucidate the structural integrity thereof. In this research, the 3D modular RCC concrete structure is analyzed to determine the structural parameters. This 3D FEA model could be extended further to incorporate seismic analysis.

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