

# Development of iOS Application for Strengthening of Columns using CFRP

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**Abstract** - For strengthening of the existing columns and for retrofitting of the old building columns using CFRP (Carbon Fiber Reinforced Polymer) sheets are widely used now a days. To Strengthen the columns we have to first carry out the calculation of the number of CFRP plies required for the column to withstand the overcoming load on it, the number of plies is calculated by using an iOS application which is generated using XCODE software and swift language. For this first we carried out the Modeling and analysis of an G+8 Storied apartment building by using ETABS-2015 and extracting the load values imposed on the columns, then increasing four stories for the same building (G+8)+4. Extracting the load values from the modified building and comparing the same. By comparison we came to know that there is an increase in the 60% load on the columns from G+8 to (G+8)+4. The increased load values are then substituted in the application to get number of plies required to be wrapped on to the columns to get adequate strength.

**Key Words:** CFRP: Xcode: Swift language: Retrofitting: iOS

## 1. INTRODUCTION

Carbon fiber sheets have been applied to increase the concrete confinement and load resisting capacity of reinforced concrete columns. The confinement effectiveness of externally bonded CFRP jackets depends on several different parameters, such as, the type of concrete, steel reinforcement, thickness of the CFRP jackets (number of layers) stiffness (type of FRP) and loading conditions. Also, shape of the cross sections and sharp edges in the cross sections of columns can directly affect the confinement effectiveness of externally bonded concrete columns. The efficiency of FRP and CFRP confinement is higher for circular sections than square sections. The mitigation of the effect of this shape is achieved by smoothening the corners of rectangular sections with the effectiveness increasing with the rounding radius, until certain threshold value is reached. The ultimate strength of the confined concrete is closely related to the failure strength of the CFRP wrappings.

Xcode is Apple's IDE (integrated development environment), which you use to create iOS applications. The word "integrated" refers to the fact that Xcode brings together several different tools into a single application.

Xcode contains several tools, but the ones you'll use most of the time are the source code editor, debugger, and the Interface Builder. The iOS Simulator is an application that runs on your Mac and allows you to test your apps without using an actual iOS device. The iOS Simulator is part of the standard iOS SDK (Software Developmental Kit) installation. When you run your app in Xcode, you have the choice of launching it in the simulator or an actual device. If you choose to launch it in the simulator, Xcode will launch the iOS Simulator automatically.

Swift Playground is a revolutionary new app for ipads that makes learning swift interactive and fun. solve puzzles to master the basics using swift - a powerful programming language created by Apple and used by the pros to build many of today's most popular apps. Then take on a series of challenges and step up to more advanced creations. Swift playgrounds requires no coding knowledge, so it's perfect for students just starting out. It also provides a unique way for seasoned developers to quickly bring ideas to life. And because it's built to take full advantage of ipads, it's a first of it's kind learning experience.

## 2. METHODOLOGY

1. The extensive literature review is done to know brief about the topic.
2. Xcode software is used to develop the application with the swift language in iOS platform.
3. A Residential apartment building of G+8 story is selected for the study.
4. ETABS software is used for modeling and analysis of the building.
5. Building is analyzed for Equivalent Static Analysis.
6. Resulting load values are implemented in the application and the final results of number of CFRP plies required for the column to with stand the load is obtained.

As we are implementing new software to develop the application for the calculating of the number of plies

required for the column strengthening. XCODE and swift languages are the iOS based software and language, so we need to understand them that how they work on the iOS platform, how user friendly they are and how to write the program for the execution of our problem. So we took an worked example from (ACI 440.2R-08) for the base.

### 2.1 About programming

In the XCODE software we need to select required type of project for our application, as the software comprises of many type of projects, here we select 'tabled application', swift language is selected for the programming, here we are developing this application to run on i-phone and i-pads devices only. After that we get the main storyboard window for the preparation of the screens of the application, there we need to create a view controller for each screens. Each view controller needs a class as cocoa touch class. and then in the assistant editor of each view controller the required program is written using pre-defined functions in the swift language such as, String[ ], void( ), Float( ), Double( ), etc. after completion of implementation of the problem we have to run the program to check whether its right or wrong, if it shows errors we can debug them in debugging area provided in main storyboard. After completion we can look the preview of the application in the i-phone simulator and we can move further for using the same application to get the resulting values.

### 3. ANALYSIS OF RESIDENTIAL BUILDING

In this work we selected an multi - storied apartment building for retrofitting of the columns. the modeling and analysis is done using ETABS. The apartment building is G+8 storied, we extended the building by 4 stories and the analysis is done, then in the result we can observe the increase the load on the columns, the load values and Area of steel values of G+8 storied building and (G+8)+4 storied building is compared in the results. The plan view of the building is shown in fig.1 the G+8 storied building is shown in fig.2 and correspondingly the G+12 storied building is shown in fig.3

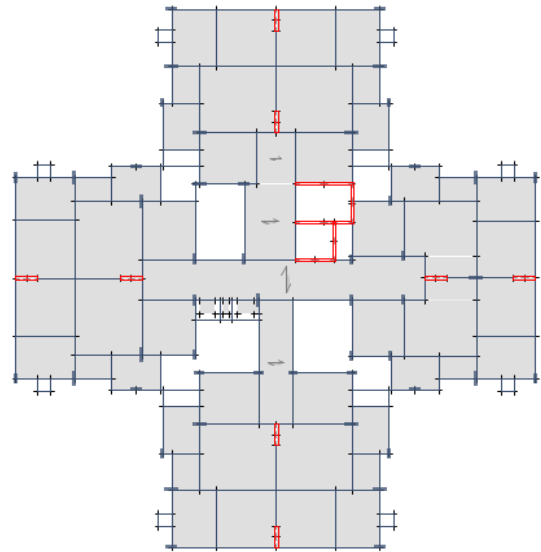


Fig -1: Plan view of the residential apartment building

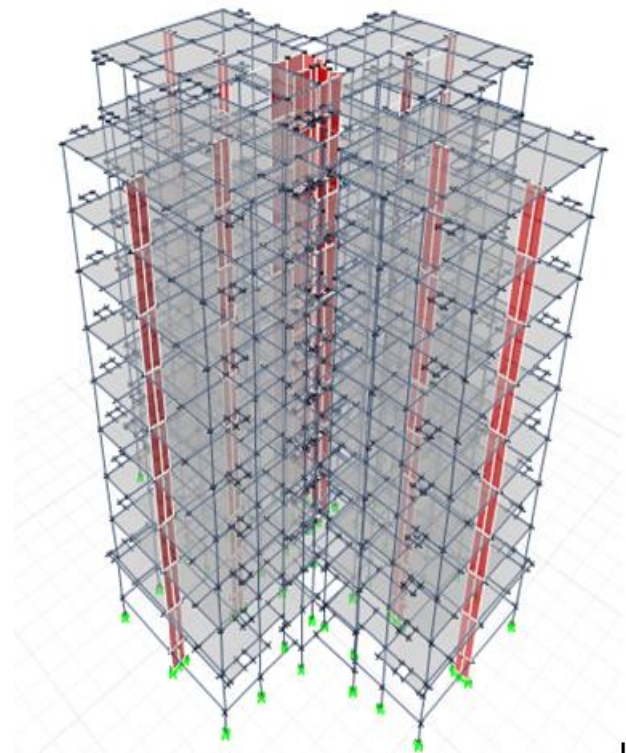


Fig -1: 3-D view of G+8 storied building

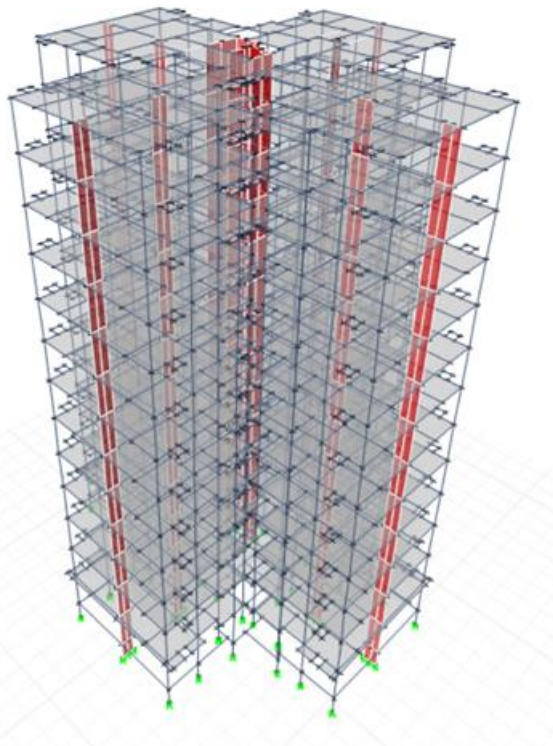


Fig -3: 3-D view of G+12 storied building

Table-3: Material properties of the building

Grade of Concrete	M25
Grade of Steel	Fe500
Density of Concrete	25kN/m <sup>3</sup>
Young's Modulus of Concrete	2.5x10 <sup>4</sup> N/mm <sup>2</sup>
Young's Modulus of steel	2x10 <sup>5</sup> N/mm <sup>2</sup>
Poisson's ratio of concrete	0.3

Forces from critical load combination out of load cases 6 to 21 are considered for design check. The design has been carried out as per the guidelines in IS: 456-2000.

### 4. STRENGTHENING OF COLUMNS

The method of increasing the bearing capacity of the structural materials internally or externally by using other strengthening material is known as strengthening. Now a days the strengthening of the structural components are need to be done so as to increase the life span of the structures and to carry the more loads. By strengthening the existing structural elements the number of floors can be increased for multi-storied buildings or any overlaying structures on the shorter buildings can be constructed.

### 3.1 Properties

For the analysis of the building we used the ETABS software. the grade of concrete considered is M25 and that of steel is Fe500 for reinforcement used for the analysis, as per IS 456:2000 the material elastic properties are taken.

Table-1: General details of building

Number of stories	G+8
Building type	Reinforced Cement Concrete
Seismic Zone Story height	Zone II
Soil type Seismic zone	Medium soil (Type II)
Story height	2.95m
Response reduction factor	3
Importance factor	1

Table-2: Structural members of building

Thickness of slab	0.15m
Column	In-situ column
Beam	In-situ Beam
Wall thickness	0.23m

### 4.1 Load Comparison Between The Models

Here we compared the load values of the G+8 building and the G+12 building, by comparing the values we can observe the increase in load values of the modified building to the actual building, and there is a calculated increase in 60% of the total load. That increase in load values is calculated and tabulated in the below table for each and every group of columns. The increased load values of the G+12 model in substituted in the iOS application to get the results.

Table-4: Load comparison

Group No	Columns	G+8 Model		G+12 Model		Avg Load difference
		Basement	Ground Floor	Basement	Ground Floor	
1	200 x 1125mm	3403.67	3386.50	6012.75	5991.70	2607.15
2	200 x 1050mm	3767.54	3745.56	4976.00	4944.72	2407.60
		1907.80	1897.68	4110.87	4098.30	2201.86
3	200 x 750mm	2569.86	2510.10	3590.80	3575.90	1043.40
4	200 x 600mm	1918.90	1900.00	2743.81	2725.30	825.00
5	200 x 525mm	1319.00	1303.86	1937.17	1915.95	615.00
		1094.50	1066.60	1739.33	1709.20	643.50



## 4.2 Number of plies required for the columns of G+12 model:

For strengthening of the existing columns we need to do the wrapping of the CFRP around the surface of the columns, for that we required the number of plies of the wrappings needed to be applied. to calculate that we developed the application that works on the iOS platform. By modifying the existing apartment building we obtained the excessive load on the columns that effects mostly on the basement floor columns and on the ground floor columns, so we need to strengthen those columns, for that we tabulated the load values of the both floors. by entering the load values in the application we get the number of plies for each floors and each for each group of columns. No of plies for columns is tabulated.

**Table-5: Number of plies for the column**

Columns	Load of G+12 Model (kN)		No. of Plies required	
	Basement	Ground Floor	Basement	Ground Floor
200 x1125mm	6012.75	5991.70	6	6
200 x 1050mm	4976.00	4944.72	5	5
	4110.87	4098.30	4	4
200 x 750mm	3590.80	3575.90	3	3
200 x 600mm	2743.81	2725.30	2	2
200 x 525mm	1937.17	1915.95	2	2
	1739.33	1709.20	2	2

## 5. CONCLUSION

- By using the CFRP wrappings we can increase the strength of the existing columns without much difficulty.
- Here, in the tabulations the no. of plies required for the columns to with strand the extra load (+4 storey) are obtained from the iOS application developed using the Xcode software.
- Xcode software of iOS is easy to learn as compared to the Android and its user friendly also, gives easy access for the users.
- More time is be saved by the application as it avoids the time consumption for the manual calculations, we can get the results very quickly.
- Load values and the moment values are collected from the ETABS and the conventional column design is done using Excel sheet.

We then transfer the values of load carried by G+8 model, load carried by G+12 model and the dimensions of the column.

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