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Design and Modelling of Concrete Jacketing after Analysis of an Existing RC Building using ETABs

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Abstract - *Retrofitting has become the need of the hour in structural strengthening field. There are many existing structures which are seismically deficient and need to be structurally strengthened. One of the popular retrofitting techniques is concrete jacketing. The design of the concrete jacketing and its modelling on a software become an important part of the retrofitting strategy to be applied to an existing building. There is lack of sufficient codes and guidelines in retrofitting specially in India. The IS code 15988:2013 provides the guidelines for evaluation of existing buildings and design of retrofitting measures. This paper attempts to formulate a clear interpretation of the design of the concrete jacketing based on the said code and postulate the procedure for modelling of the jacket in ETABS software. The design procedure is formulated adhering to the codal guidelines as strictly as possible so that the column gains flexural strength and ductility after jacketing. The ETABs software is an extremely easy to use and versatile FEM software available to structural engineers today. However, the procedures to model a concrete jacketing are not well known. This paper will help in understanding the nuances of modelling of the same. The modelling procedure of jacketing described here provides close resemblance of the actual behavior of the jacketed section and hence would provide more realistic analysis results.*

Key Words: **Retrofitting measures, Concrete Jacketing, Local retrofitting, ETABS version 17.0.1, section designer, modelling.**

1. INTRODUCTION

Many of the recent earthquakes have had a devastating effect on the standing structures in those regions. The structures most vulnerable to damages have been the ones which had been designed and constructed prior to the adoption of seismic codes in that region. It becomes imperative on any nation to ensure that all its structures are earthquake resistant. It is highly impractical and uneconomical to demolish the existing seismically deficient structures and rebuild these facilities. The other viable alternative is to use seismic retrofitting to make them earthquake- resistant.

Seismic retrofitting can be defined as the addition or modifications adopted to an existing structure in order to strengthen it and enable it to withstand the expected earthquake loads in that region. There are various types of retrofitting methods in practice. These can be broadly divided into global and local retrofitting techniques.

Global retrofitting means the strengthening is done to the structure as a whole and the results can be seen in the structural performance. Some of the examples of global retrofitting are addition of shear walls, addition of steel braces, addition of infill wall, mass reduction etc.

The local retrofitting techniques stand for those techniques which are applied on individual members such as beams or columns of the structure which need intervention and aim to improve the performance characteristics of these members. This need not lead to change in the performance of the structure as a whole. Examples of such techniques are jacketing of beams, columns or footings using concrete jacketing, steel jacketing etc.

One of the most popular techniques in practice is the concrete jacketing technique when it comes to strengthening the weak columns. This method has shown improvement in the characteristics of the member as well as the structure as a whole.

In India, codes and guidelines for design and execution of retrofitting are not well-established. The structural engineers use the guidelines of other countries chiefly to make retrofit plans and design a suitable retrofit for the structure under study. The main codal provision providing general guidelines for design of retrofit in India is IS 15988:2013. This code is formulated to provide guidelines for evaluation of existing structures, and criteria for the design of a few important retrofit techniques.

This paper intends to bring out the interpretation cum design of a concrete jacketing for a column, based on the guidelines provided in the above-mentioned code. Also, the modelling of the concrete jacket section in an FEM software is paramount to making the correct analysis of the structure for seismic strengthening. The modelling of the section has been done on an extremely popular and versatile FEM software viz ETABs version 17.01.

2. LITERATURE REVIEW

There are several research work which have been carried out in the field of retrofitting using concrete jacketing. Some of

the literature used for reference during this study are as given below.

Rodrigues et al (2018) [1] in their paper have studied a few existing buildings in Nepal and proposed suitable retrofit measures in terms of concrete jacketing for weak columns, addition of shear walls and use of steel bracings. They have tried to bring out the effectiveness of these measures in terms of strength, and ductility.

Ismail (2013) [2] in his article has studied the effectiveness of various jacketing using steel, CFRP and concrete as methods of retrofitting. He evaluated the lateral displacement and lateral strength of the structural members with and without retrofit of an existing G+9 building. He concluded that the method of concrete jacketing improves the lateral strength as well as stiffness substantially.

Riyad et al (2016) [4] in their work evaluated the effect of shear wall and CFRP as retrofitting measures. He considered an eight storey RC building designed as per Moroccan code. He concluded that CFRP improved both the ductility as well as stiffness of the structure.

From the literature review it is seen that the retrofitting measures such as concrete jacketing, steel braces, shear wall etc. enhance the performance of the structure in terms of strength and ductility. Also, of the different types of jacketing on columns the concrete jacketing technique emerges as the most effective option. Hence the study on detailed design as well as modelling of concrete jacketing on the prevailing softwares is the way forward for fruitful studies in this field.

3. MODEL USED FOR STUDY

For the purpose of study, a hypothetical four storey school building is considered. This building represents a structure presumably built before the seismic codes were adopted or implemented. This structure hence had been designed only for gravity loads and it lies in zone V. Some of the salient features of the building are as given below.

a. Bays- 4 m x 7.5 m, 4 m x 3 m.
b. Columns section- 300 mm x 600 mm,
c. Beams- 300 mm x 700 mm
d. Height of floor- 3.15 m.
e. Slab thickness- 150 mm
f. Concrete grade- M 20.
g. Steel rebar grade- Fe 415
h. Building design code- IS 456 :2000

The seismic data used for modelling are as below:

a. Seismic zone- V
b. Soil type- 2
c. Response reduction factor- 3
d. Importance factor- 1.5
e. Damping- 5 %

The loads combinations considered are as given below.

a. 1.5(DL)
b. 1.5(DL +LL)
c. 1.2(DL+LL±EQX)
d. 1.2(DL+LL±EQY)
e. 1.5(DL ± EQX)
f. 1.5(DL ± EQY)
g. 0.9DL ± 1.5EQX
h. 0.9DL ± 1.5EQY

The plan and 3D view of the building used for the modelling is as below:

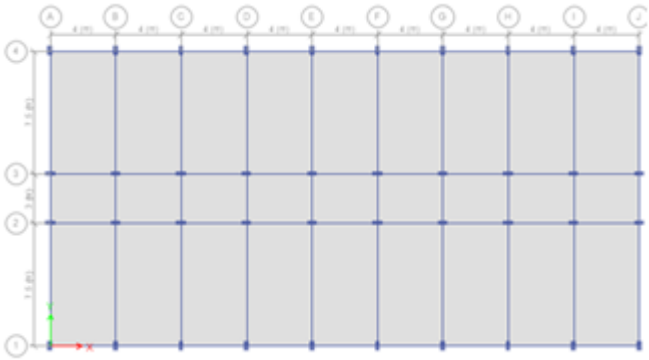

Fig – 1: Plan of four storey school building

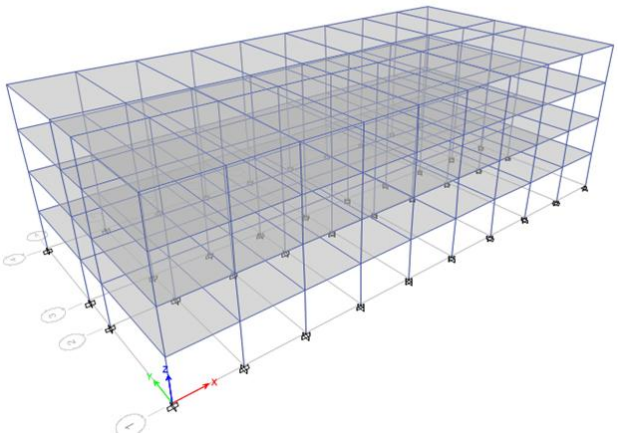

Fig – 2: 3D view of four storey school building

4. PROPOSED METHODOLOGY

The methodology adopted to conduct the study is as under.

a. A four storey building is modelled and analyzed in ETABs software by response spectrum analysis.

b. The seismic loads in terms of axial load and moment are obtained from the analysis results. The concrete jacket is designed as per IS 15988:2013.

c. The concrete jacket section designed is modelled in ETABs using section designer for further study.

5. DESIGN OF SECTION FOR CONCRETE JACKET

The results of the seismic (response spectrum) analysis are presented here. The columns are shown in red depicting overstressed members having demand- capacity ratio more than one. The building is clearly found deficient as the columns are failing under seismic loads.

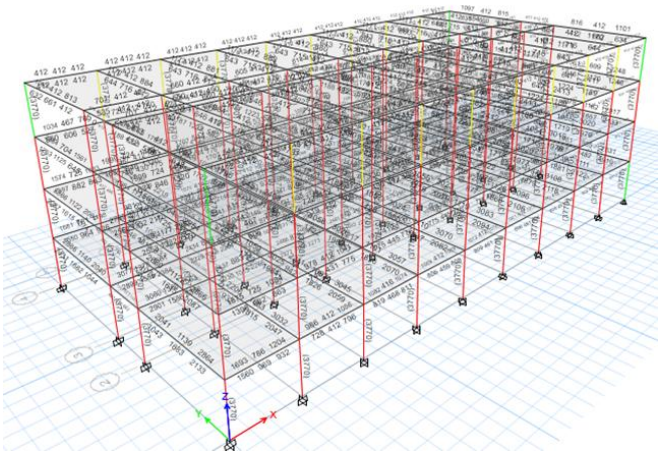

Fig – 3: Design check after response spectrum analysis

The ultimate axial load and the ultimate moment are found from the analysis results. The calculations for design of concrete jacketing are illustrated here. This has been done based on the guidelines provided in IS 15988:2013.

Height of Column = 3.15 m, Width (b) = 300 mm,

Depth (D) = 600 mm, d' (effective cover) = 50 mm,

Concrete grade (old concrete) = 20 N/mm^2

Grade of reinforcement steel = 415 N/mm^2

Reinforcement provided (12-20Ø) =3769.9 mm^2

Ultimate Axial Load (P_u) = 1766.6 kN,

Ultimate Moment (M_u) = 632.19 kN-m

$P_u = 0.4 \times f_{ck} \times A_c + 0.67 \times f_y \times A_{sc}$

As per above codal guidelines, the concrete strength should be minimum 5 MPa higher than the strength of the old concrete.

Hence, f_{ck} = 25 N /mm^2 Assuming $A_{sc} = 0.8\% A_c$

$1766.6 \times 10^3 = 0.4 \times 25 \times A_c + 0.67 \times 415 \times (0.8\ \%) \times A_c$

or $1766.6 \times 10^3 = 12.22\ A_c$ or $A_c = 144566.28$ mm^2

A_c required = $1.5 \times 144566.28 = 216849.43$ mm^2

According to the codal provisions, least jacket width has to be 100 mm.

B = 300+100 +100 = 500 mm,

D = 600 +100 +100 = 800 mm

Hence assuming new cross section as 500 x 800 mm

A_c provided = 40,000 mm^2 > A_c required

Reinforcement required-

d'/D = 50 / 600 = 0.06

$P_u/ (f_{ck}\ bD) = 1766.6 \times 10^3 / (25 \times 500 \times 800) = 0.177$

$M_u/ (f_{ck}\ bD^2) = 632.19 \times 10^6 / (25 \times 500 \times 800^2) = 0.079$

From the design aids, referring to the P-M curve,

$p/ f_{ck} = 0.025\ \%$, p = 0.025 x 25= 0.625%

Area of steel = 0.625 % x 500 x 800 = 2500 mm^2

As per code, area of steel for jacketing to be provided

= (4/3) A_s

= (4/3) x 2500 = 3333.33 mm^2

Area of steel already provided = 3769.9 mm^2

Least quantity of steel = 0.8% of c/s area of jacketed section

0.8% x (500x800-300x600) = 1760 mm^2

Hence provide 12-20 Ø for jacketing section.

Area provided = 1.71% A_c

6. MODELLING OF CONCRETE JACKET IN ETABS

The modelling of the concrete jacket section on ETABs is a crucial step in the process of modelling and analysis of the structure. The ETABs an FEM software provides the provision to model it appropriately which is a relatively new feature which is not well known in the field of academics. The steps are presented here presuming that modelling for existing building is already done on the software.

a. Define new jacketing material.

b. Define section property by adding new property under frame sections and choose the section designer option.

c. In the section designer, define design type as concrete column keeping the 'reinforcement to be checked' option. The base material is the existing column material.

d. Go to 'Draw', choosing concrete shape as 'rectangle' and feed the details of the existing column dimensions, reinforcement size and quantity.

e. Repeat the same procedure to draw the concrete jacket around the existing column section. Define the details of web and flange along with the new reinforcements in the jacket section.

f. Choose interaction surface keeping the option of 'include phi' in 'show design code data'. Close the section designer.

g. Select the columns to be jacketed as planned. Assign section properties in 'frame' as the new jacket section defined in the above steps.

This completes the modelling of the concrete jacket. The section is depicted in the figure below.

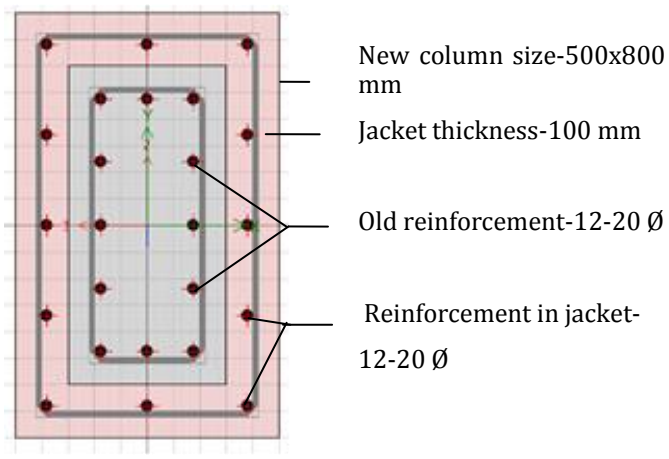

Fig – 4: Section of jacketed column

7. CONCLUSIONS

The guidelines for evaluation of existing structures and strengthening measures is provided in a general way in the IS 15988:2013. Apart from this there are hardly any codes available in India for detailed design of retrofit measures. Attempt has been made to interpret and use the guidelines in the said code to design a suitable concrete jacket. The design obtained is satisfactory and can be safely used for analysis purpose.

The modeling of the whole retrofitted member on ETABs has been very rarely attempted earlier. It is very crucial to model the jacket in the FEM software correctly so that the responses of the structure obtained through analysis performed gives more reliable and precise results. The modelling procedure of the designed concrete jacket has been attempted successfully and described in this paper. The procedure here provides close resemblance of the realistic behavior of the jacketed section which would help in a more reliable analysis.

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