International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 06, June-2021

Review Behaviour of Infilled Walls

Vishal Kr Gupta [1]
[1]P.G. Student, Mewar University,
Chittorgarh, Rajasthan, India

***Abstract*:– Due to scarcity of land, extensions of existing buildings are becoming the necessity & requirement for urban development and rebuilding process. New extensions are added to the existing buildings to create additional spaces because of the functional requirements. Vertical extensions can often offer the most discrete and economical way of increasing the capacity of an existing building. Vertical extensions inevitably results in increase in the loading on the existing building. In such cases, strengthening work to structural elements such as columns, walls and foundation becomes necessary.**

This report presents the analysis & strengthening aspects for vertical extension of an existing building. This is an actual extension project for a G+1 building along with a basement, situated in Rajpura, Punjab. The proposed extension is required to provide two additional storeys which will accommodate a double height multiplex along with other facilities. The structural analysis of the building is done in the STAAD Pro software. For the proposed vertical extension of the building, two options for structural system have been studied.

(a) RCC beam – column frame system with RCC floor and roof slab.

(b) Steel portal frame system with steel columns, beams & RCC slab at intermediate floor levels. Roofing consists of steel truss with asbestos sheeting. Separate STAAD models of the building are developed for structural analysis of both the above options. A STAAD model of the existing building alone is also developed to analyze the loads and obtain the design forces sustained by the existing building. Average increase in vertical forces at base in comparison to design forces sustained by existing building alone is 60% for R.C.C extension and 23 % with extension with steel structure. The increase in resultant moments is 66% for R.C.C extension and 28 % with extension with steel structure. Results of the structural analysis indicate that the extension with steel portal frame system results in lesser increase in design forces & would require lesser strengthening of the columns & foundation. Hence the steel portal frame is adopted as the structural system for the vertical extension.

The strengthening of the foundation is carried out by leveling the existing sloped footing by PCC & laying a new foundation over this leveled surface. The column strengthening is done by providing additional reinforcement outside the existing column & column section is enlarged by jacketing method.

1. INTRODUCTION

The purpose of buildings extends beyond merely providing habitat to people. Buildings should be designed in a manner which ensures security of their occupants. With structurally more secure buildings, people will feel more protected against unfortunate events such as acts of terrorism, etc. Hence, it is important to study the effects that blast loads can have on buildings. Blast loads are dynamic in nature, and can be calculated precisely, just like wind and earthquake loads.

The foremost aim of this work is to discuss and analyze the performance of different structural systems under the impact of blast loads in events of explosions. The method for mitigating effects of detonation has been discusses, thus preventing harm to life, property and equipment. Relevant literature has been studied thoroughly, with emphasis on topics like possibility of vulnerability evaluation, risk easing, developing ductility and structural response characteristics, etc.

1.1 TYPES OF EXTENSIONS

Although extension can be done in various ways depending on the requirement. Different types of extensions that can be done are as follows:-

1.1.1 Front extensions

Extensions at the front of a building are normally restricted to small additions such as porches and vestibules. This is because front extensions are the most conspicuous and thus can radically alter if not destroy the character of the building.

1.1.2 End extensions

An end extension is a form of side extension. It can occur if a building is being elongated or where an extension is being installed at the gable of an end-terraced block. In such circumstances the available space for expansion is likely to be limited. However, extensions to single-storey-framed buildings such as large supermarkets or warehouses are often two or more bays in length because of the spare space.

1.1.3 Side extensions

In residential property, an attached garage often forms the main type of side extension. In other instances, the side extension may be required to provide an enlarged or additional room. More usually, however, a two-storey extension comprising, say, a garage on the ground floor and a bedroom on the upper floor forms the main type of addition incorporating these functions.

1.1.4 Rear extensions

These extensions are very popular in mid-terraced residential dwellings because of the physical site constraints. Moreover, the planning constraints are usually less stringent at this part of the property.

1.1.5 Corner extensions

As indicated above, front extensions sometimes form part of a larger side extension. This solution allows the front of the building to have a minor increase in size along with a larger addition at the side

1.1.6 Combined lateral and vertical extensions

In rare cases an extension may involve an enlargement of the property both horizontally and vertically.

Load transfer distribution

Aspects of load transfer that should need to be considered include:-

- The effect of concentrated load on supporting elements,
- The effect of eccentricities on the supported and the supporting elements (design consideration and assumptions),
- The ability of reinforcement in concrete structures to provide adequate tying action. (For robustness requirements)

1.2 BACKGROUND AND SCOPE

Vertical extensions can often offer the most discrete and economical way of increasing the capacity of an existing building. They are often formed either in the roof space or basement. Such changes are of course less obtrusive than lateral extensions. In many cases the only obvious signs of, say, most vertical extensions are upward because there is nearly always free space to expand in that direction.

In contrast, downward vertical extensions are limited because of the physical restrictions imposed by the substructure and soil conditions. On rare occasions the latter type of extension may still be feasible if a basement is required in a very tight site. Moreover, because of their impact on the extra requirements for stairs and services in the building, vertical extensions are sometimes more complex than lateral additions.

The main focus of this project was on strengthening of existing building in Rajpura (Punjab). This choice was based upon the fact that the project was carried out with support from Tech Pecific, a structural designing firm located in Mohali (Punjab). Even if the methods discussed here are meant to be applicable mainly to storey extension projects, it should also be possible to apply the results of this project to other types of situations where strengthening is needed. It should however be noted that the choice to focus on strengthening for storey extension may limit the number of investigated strengthening methods.

2. LITERATURE REVIEW

To be able to make use of existing knowledge concerning storey extensions, several reference projects have been studied. Information has been collected through research involved in storey extension projects. The focus was on the structural solution for vertical extension and integration of the new structure to the existing structure.

2.1 CASE STUDIES

2.2.1 VERTICAL EXTENSION IN CITY CRONAN

At the time the project was one of the big ongoing projects in central Stockholm and comprising 50,000 m2 refurbishment and extension as shown in fig 2.1. This vertical extension project was performed under the design and build contract model. The construction system was prefabricated steel columns and pre-cast concrete slabs. The existing building was built in the seventies and its structural system is site cast concrete slabs and columns. Two houses in the block were merged together by the extension. The buildings were vertically extended with two and four floors. The project was characterized of high complexity. The complication of the foundation resulted in many uncertainties in the construction process. The just-in time production philosophy was used in the project.

2.2.2 VERTICAL EXTENSION IN KLARA ZENIT

The existing building is from the late sixties and was built with site cast concrete slabs and pre-cast concrete columns. The buildings in the block were extended with one floor and with two storeys detached houses on top. The extra floor was built with site cast slabs and the houses were made of prefabricated timber elements. Also refurbishment of the existing building was a large part of the project. The total area involved was 68,000 m2.

Figure 2.1 City Cronan after reconstruction

2.2.3 VERTICAL EXTENSION IN HUSBY

The existing buildings were built during the seventies. The buildings had five floors and its structural system is site cast concrete slabs and pre-cast concrete columns. The project involved vertical extension of three buildings and each building was extended with one-storey volumetric student study bedroom apartments. The project comprised 35 new apartments as shown in fig (2.2). The existing building was from the early seventies with concrete structural frame. Early in the project the client decided to use a highly prefabricated building system in order to minimize the disturbance to the surroundings. Characteristic of this vertical extension project was its high level of prefabrication.

Figure 2.2 Husby project after reconstruction

2.2.4 VERTICAL EXTENSION IN BERZELII PARK

The building in the project Berzelii Park is placed in an area with many hotels, theatres, restaurants and commercial buildings in the Nybro bay in Stockholm as shown in fig (2.3). The vertical extension was on a theatre hall, built at the beginning of the last century, which had already been extended with five floors during the late sixties. The project included demolition of three floors, refurbishment of the existing building and vertical extension with four floors. The theatre and the original facade were to be conserved. The vertical extension's structural system was a combination time was during the years 2000 to 2002.

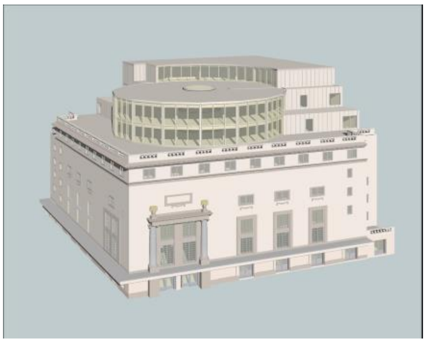

Figure 2. 3 Outline of the Berzelii Park project after reconstruction

2.2.5 NDUSTRIALISED BUILDING WITH LIGHT-GAUGE STEEL FRAMING SYSTEMS

This research has studied the experiences from the Swedish industrial building process with light-gauge steel. In the following section two examples of projects using an industrialized building process with light-gauge steel will be briefly described. Kv. Näktergalen As part of a research project the Naktergalen project was studied (Persson, 1997) (Andersson, Borgbrant, 1998). Its aim was to compare different building systems and processes with each other. The Näktergalen project (kv Näktergalen phase II) consists of three different phases. During the planning of the second phase, it was decided to build two identical buildings. Two different building systems were used whereby an analysis and comparison between the two building systems were possible to complete. A traditional concrete building system was compared with the industrialized building method of light-gauge steel framing.

2.2.6 VERTICAL EXTENSION OF HOTEL – GOTHIA CENTRAL TOWER

Gothia Central Tower, located in central Goteborg, was built in 1984 and initially reached 62 m above the ground with its 18 storeys. It consists mainly of in-situ cast concrete with a big core in the middle of the tower for stability, Samuelsson, E. (2013-01-24). Load-bearing walls between hotel rooms go downwards through the building except at the lower entrance and conference floors, where columns are used instead. The building is mainly founded on footings on top of the bedrock, but short end-bearing piles have been used in some places. Six new storeys are being added at the time of writing, giving the building a new height of 83 m. Some slabs and beams in the upper storeys of the original building have been strengthened with carbon fiber reinforced polymers. The slabs were strengthened with regard to bending moment and the beams were strengthened to be able to spread the high concentrated loads from the new steel columns that were placed on top of the beams near the edge. The anchorage of the new part was achieved by attaching post-tensioned steel plates to the upper core. These plates extend several storeys downwards where they are anchored into the existing core.

2.2.7 VERTICAL EXTENSION IN OFFICE BUILDING ETC. – BONNIER'S ART GALLERY

Bonnier's Art Gallery is located in central Stockholm and was built upon an existing three-storey building. The original superstructure consists of columns, walls and slabs of in-situ cast concrete founded on footings on bedrock, Skelander (2013-02-12). The old building lies in a steep slope which means that all three storeys are visible at one side of the building while the road on the other side of the building is in level with the roof of the old structure. Five new storeys were added in 2006. Many of the original columns were too weak for the extension and needed to be strengthened. This was achieved by section enlargement, Skelander (2013-02-12). Stability issues were solved by a new stabilizing stairwell in prefabricated concrete and a new concrete wall that was installed at one gable, ELU (2013). The wall was prefabricated in the added part while the continuation of this wall in the old building was strengthened through section enlargement.

2.2.8 VERTICAL EXTENSION IN RESIDENTIAL BUILDING- APELSINEN

A storey extension is planned on a four-storey building located in Kungsbacka, 30 km south of Goteborg. The original structure was built in 1976 with a load-carrying system of concrete walls mainly oriented in the transverse direction of the building, Johansson (2013-01-31). The building is located on varying thickness of clay above bedrock and two thirds of the structure is founded on end-bearing piles, while the other end is founded on footings due to a shorter distance to the bedrock. A two- storey extension is yet to be carried out along with renovation of the apartments in the building. The structural design for the extension and its accompanying strengthening was carried out. No real weaknesses were detected in the building. Strengthening of the foundation will also be required and extra piles are to be added and connected to the load-bearing walls through lintels.

2.2.9 Hotel – Scandic Rubinen

Hotel Scandic Rubinen is located at Kungsportsavenyn in central Goteborg. The original building was built in the '60s and consists mainly of in-situ cast columns and beams, Jarlén (2013-03-13). On top of the beams prefabricated TT-slabs are supported. The height of the original building varies and the lower part contains three storeys above ground plus one basement.

At the time of writing a storey extension is being built on the lower part of the hotel. As can be seen in Figure 2.4 five new storeys are added so that the extended part will reach the same height as the left part in Figure 2.4. The new structure consists of steel columns and HSQ-beams with hollow core slabs, Jarlen (2013-03-13). To minimize the height of the beams, the steel columns stand with a spacing of 4 m, which can be compared with 12 m for the columns in the original structure.

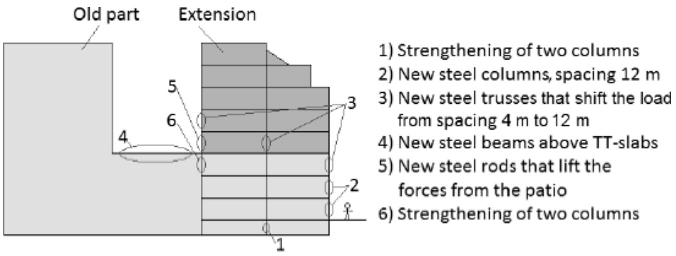

Figure 2.4 Section through Scandic Rubinen

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 06, June-2021

3. ANALYSIS AND DESIGN FOR VERTICAL EXTENSION OF A BUILDING

3.1 PROJECT DETAIL AND BACKGROUND

The present chapter deals with the analysis and design of an existing building in order to extend the existing building with further two more stories.

The building is a commercial complex situated in Rajpura (Punjab). A proposal for extending the building was given by the owner of the building. The proposed extension is required to provide two additional storey which will accommodate a double height multiplex along with other facilities.

The existing building is 68.57m long and 33m wide. It is a G+1 structure along with a basement. The columns are spaced at 4.8m and 6.2m in longitudinal and transverse direction respectively. Each storey height is 3.65 m.

3.2 ANALYSIS & DESIGN METHODOLOGY

The architectural design for the proposed extension has been carried out by M/S Incubis Architects, New Delhi. The structural analysis of the building is done in the STAAD Pro. Software. A STAAD model of the existing building is developed to analyze the loads and obtain the design forces sustained by the existing building. Separate STAAD models are developed for the analysis and design of the vertical extension and also to evaluate the effects of the structural model developed. Two alternatives for structural systems have been studied for the proposed extension.

(a) RCC beam – column frame system with RCC floor and roof slab.

(b) Steel portal frame system with steel beams / RCC slab at intermediate floor levels. Roofing consists of steel truss with asbestos sheeting.

3.3 LOAD COMBINATIONS

The various load combinations considered for the analysis of the RCC structure are as follows:-

(a) 1(D.L + L.L)
(b)1.5 (D.L + L.L)
(c) 1.2 (EQX + D.L) + 0.6 L.L
(d) 1.2 (EQZ + D.L) + 0.6 L.L
(e) 1.2 (- EQX + D.L) + 0.6 L.L
(f) 1.2 (-EQZ + D.L) + 0.6 L.L

The various load combinations considered for the analysis of the Steel structure are as follows:-

(a) 1.0 (D.L + L.L)
(b) 1.5 (D.L + L.L)
(c) 1.2 (EQX + D.L) + 0.6 L.L
(d) 1.2 (EQZ + D.L) + 0.6 L.L
(e) 1.2 (EQX + D.L) - 0.6 L.L
(f) 1.2 (EQZ + D.L) - 0.6 L.L
(g) 0.9 D.L + 1.5 EQX
(h) 0.9 D.L + 1.5 EQZ
(i) 0.9 D.L -1.5 EQX
(j) 0.9 D.L – 1.5 EQZ
(k) 0.9 D.L + W.L (IN X-DIRECTION)
(l) 0.9 D.L + W.L (IN Z- DIRECTION)

3.4 SPECIFICATIONS OF NEW STRUCTURE

The new structure consists of steel tubular sections/ built-up sections and ISMC sections. The elevation of the whole structure showing existing RCC columns and new steel columns. The layout plan and sections of the new steel portals over the existing structure. The thickness of the deck slab is 75 mm above decking sheet. The decking sheet is used as sacrificial shuttering also.

4. STRENGTHEINING OF EXISTING BUILDING

4.1 STRENGTHENING OF STRUCTURAL MEMBERS

Strengthening is an improvement over the original strength. The need to strengthen slabs and columns came up quite often. Strength of the building is generated from the structural dimensions, materials, shape, and number of structural elements, etc. Due to the variety of structural condition of building, it is hard to develop typical rules for strengthening. Each building has different approaches depending on the structural deficiencies.

In the design of strengthening approach, the engineer must comply with the building codes. The results generated by the adopted strengthening techniques must fulfill the minimum requirements on the buildings codes, such as deformation, detailing, strength, etc.

4.2 METHODS OF STRENGTHENING

There are many relatively new technologies developed for strengthening. Some of the methods by which strengthening can be possible is as follows:-

4.2.1 Strengthening with Shotcrete

To minimize formwork and labor shotcrete can often be a good substitute to conventionally cast concrete, when it comes to strengthening of concrete members. Shotcrete is basically an approach where concrete is sprayed onto the surface instead of being cast in moulds. The process requires experienced workers if a good result should be achieved.

There are two different basic ways to apply the shotcrete. The first method implies that the almost dry components are sprayed through a hose with help of compressed air. The water is then added in the nozzle. This approach is known as the dry method.

Another way is to use the wet method, where the concrete is already mixed with water before it is pumped through the hose. The dry method is normally used for strengthening of concrete members, while the wet method is preferred for bigger projects, e.g. when tunnels are strengthened.

4.2.2 Strengthening with externally mounted steel

Regular reinforcement bars can of course be used in the added concrete, when performing a section enlargement on a member. There are however also other areas of application in which steel can be used to strengthen concrete members, for example by externally mounted sheets and profiles or as means to apply a prestressing force.

Steel profiles can also be used to improve the resistance of structural members. These can be used for various kinds of members and be installed in different manners.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 06, June-2021

4.2.3 Strengthening members with prestressing steel

Prestressing is primarily suited for strengthening members with regard to the flexural capacity. The most common application is to use it on beams or slabs. Prestressing of existing members functions in a similar manner as internal post tensioned tendons without bond, but with the tendons (or single strands) connected only to the exterior of an already existing structural member by end-anchors and deviators. Deviators are used to change the angle of the tendon to acquire a better utilization of the prestressing. Since it is at the deviators and anchors that the forces are transferred to the concrete, it is not possible to follow the moment curve in the same way as with internal tendons.

4.2.4 Strengthening with fiber reinforced polymers

Fiber reinforced polymers (FRP) is a composite material consisting of fibers surrounded by a polymer matrix. The matrix is what keeps the fibers together and transfers the forces between the individual fibers, Different materials can be used as matrix, but one that is epoxy based is most commonly used. At present, strengthening of concrete structures with FRP composites is not treated in the Euro codes or any other standards. Designers who use FRP strengthening are therefore referred to available handbooks or material manufacturers. However, the structure needs to be evaluated, if it is appropriate for FRP composites before any FRP strengthening measures are taken.

4.3 STRENGTHENING OF FOUNDATIONS

The reactions for the existing foundation and reactions after the extension are shown in fig 4.1 and fig 4.2 respectively.

The foundation layout plan is shown in Fig 4.3, which shows existing foundation and foundation after the extension. The foundation with hatching shows existing foundation represented with ‘F’ while foundation represented with ‘NF’ shows new foundation which is provided for the extension.

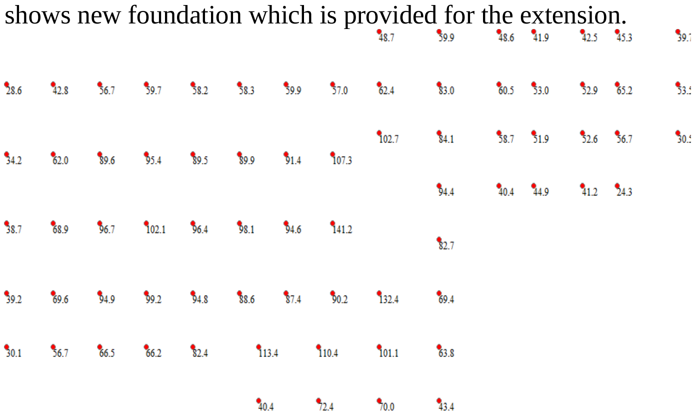

Figure. - 4.1 Reactions for the existing foundation

Figure. - 4.2 Reactions after existing foundation

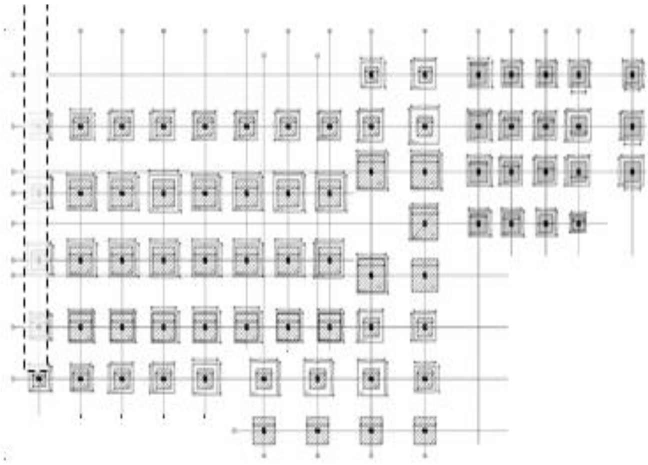

Figure. - 4.3 Foundation layout plan

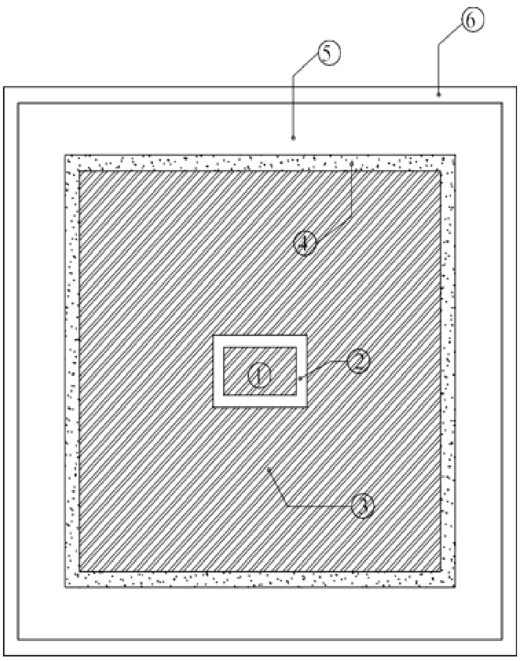

Figure - 4.4 (Dimensional Plan of Foundation showing Strengthening)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 06, June-2021

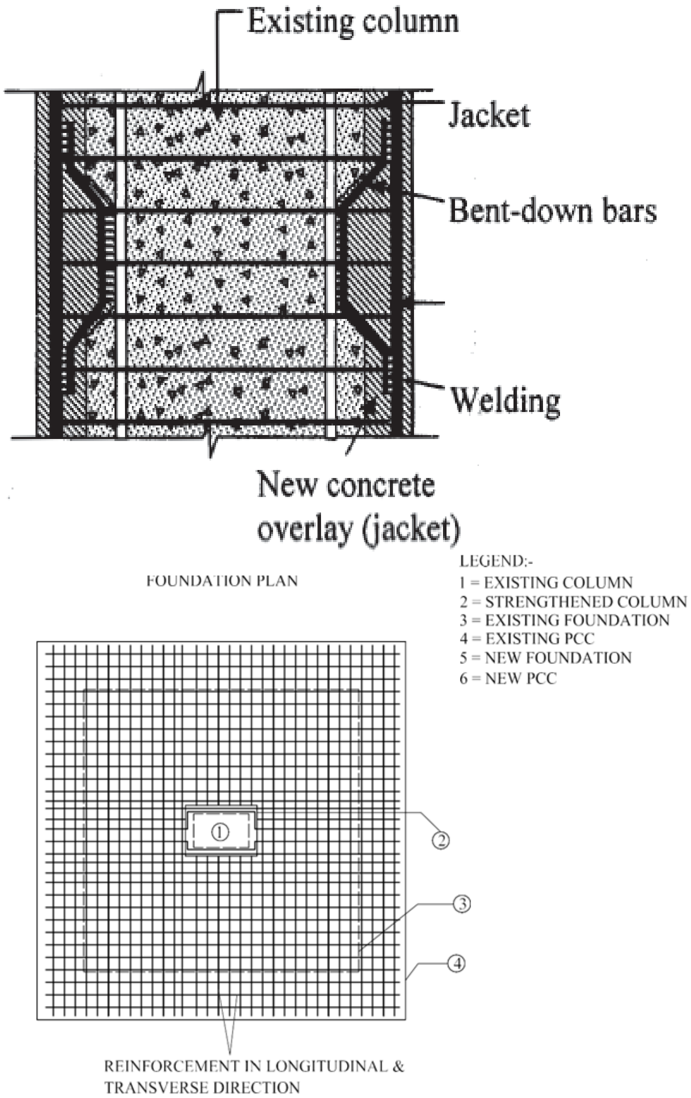

Figure - 4.5 (Reinforcement Detail of Foundation showing Strengthening)

4.4 REINFORCED CONCRETE STRENGTHENING OF COLUMNS

Jacketing is one of the most frequently & popularly used techniques to strengthen reinforced concrete columns. With this method, axial strength, bending strength, and stiffness of the original column are increased. Reinforced concrete jacketing improves column flexural strength and ductility. Jacketing serves to improve the lateral strength and ductility by confinement of compression concrete. The common practice for interface treatment consists of increasing the roughness of the interface surface and applying a bonding agent, normally an epoxy resin. Closely spaced transverse reinforcement provided in the jacket improves the shear strength and ductility of the column.

The minimum specifications for jacketing:-

a) Strength of the new materials shall be equal or greater than those of the existing column. Concrete strength shall be at least 5 MPa greater than the strength of the existing concrete.

b) For columns where extra longitudinal reinforcement is not required, a minimum of 12Φ bars in the four corners and ties of 8Φ @ 100 c/c should be provided with 135° bends and 10Φ leg lengths. Minimum jacket thickness shall be 100 mm.

c) Lateral support to all the longitudinal bars shall be provided by ties with an included angle of not more than 135°.

d) Minimum diameter of ties shall be 8 mm and not less than one-third of the longitudinal bar diameter.

e) Vertical spacing of ties shall not exceed 200 mm, whereas the spacing close to the joints within a length of ¼ of the clear height shall not exceed 100 mm. preferably, the spacing of ties shall not exceed the thickness of the jacket or 200 mm whichever is less.

Column strengthening is achieved by increasing the column section for the entire height and a cage of additional main reinforcement bars with shear stirrups is provided right from the foundation as per the requirement of additional load. The longitudinal reinforcement usually is concentrated in the column corners because of the existence of the beams and passed through the holes drilled in slab and by placing new concrete in the beam column joints.

Typical cross section of column with jacketing is shown in Fig. 4.6.

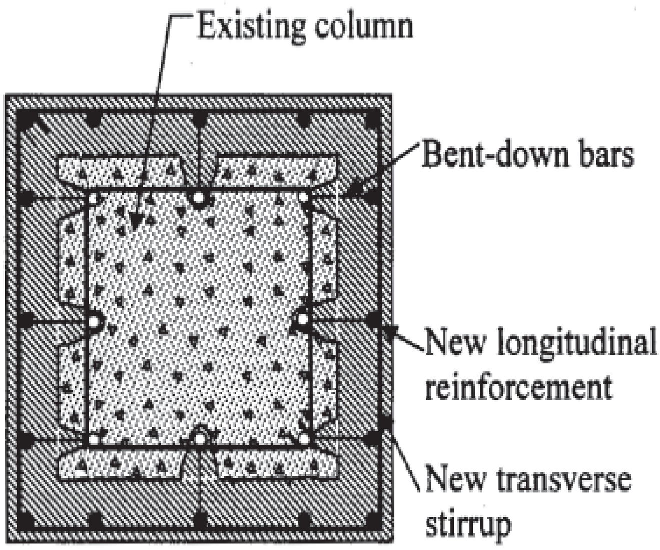

Figure 4.6 Jacketing of column

In this project, based on the results of the analysis some columns need to be strengthened. The column layout plan is shown in Fig 4.7.

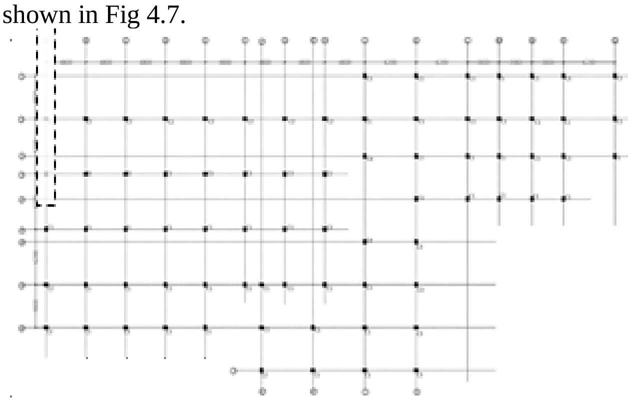
Figure 4.7 Column layout plan

5. CONCLUSIONS

Two alternatives for structural systems have been studied for the proposed extension.

(a) RCC beam – column frame system with RCC floor and roof slab.

(b) Steel portal frame system with steel beams / RCC slab at intermediate floor levels. Roofing consists of steel truss with asbestos sheeting. Based on the STAAD analysis of the above models and the model of existing building, following results are obtained.

i. Average increase in vertical reaction at base for extension with RCC beam – column frame system is 60% in comparison to the reactions for existing building alone.
ii. Average increase in vertical reaction at base for extension with Steel portal frame system is 23% in comparison to the reactions for existing building alone.
iii. The increase in resultant moment in comparison to existing building is 68% for R.C.C extension
iv. The increase in resultant moment in comparison to existing building is 30 % with extension in steel structure.

Results of the structural analysis indicate that the extension with steel portal frame system results in lesser increase in design forces & would require lesser strengthening of the columns & foundation. Hence the steel portal frame is adopted as the structural system for the vertical extension.

The strengthening is required for foundations and columns to support the increased loads due to vertical extension. The strengthening of foundations carried out by providing new foundation over the exiting foundation. The increased area for laying the new foundation is provided by excavating the soil around the existing footing & filling by PCC.

Columns strengthening is achieved by wrapping existing columns with a four sided jacket of concrete reinforced with longitudinal steel & transverse ties.

6. FUTURE SCOPE

The topic of storey extensions and consequent strengthening is very vast. To build a new structure on top of an old brings many issues that differ from a regular project. So it is beneficial if the designers have access to as much important information as possible. The most prominent thing that can be investigated more thoroughly is experiences from executed projects. It would be good for the designers to have access to an extensive collection of buildings with storey extensions. The main information about structural system used, strengthening methods and important experiences could be stated for each building. If this collection of projects was large enough, and well organized, the designer could quite easily find one or several examples that were similar to the project at hand.

REFERENCES

[1] Handbook on repair, restoration, condition assessment and rehabilitation of RCC Buildings, Central Public Works Department, New Delhi.
[2] MOFFAT, I. 1987. Method of adding additional stories to an existing storied building. Dec 29, 1992. USA patent application 842,572. Feb. 3, 1987.
[3] Analysis & Design of R.C.C. Jacketing for Buildings by Vedprakash C. Marlapalle, P. J. Salunke, N. G. Gore (International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-3 Issue-3, July 2014)
[4] Bhavar Dadasaheb O. et al. / International Journal of Research in Modern Engineering and Emerging Technology
[5] Manual for Retrofitting of Existing Vulnerable Buildings. Rai, DC, Draft code with complementary on seismic evaluation and strengthening of existing buildings, IIT Kanpur.
[6] Building Adaptation by, James Douglas Heriot-Watt University, Edinburgh, UK.
[7] BROTO, C. (2004), New Concepts in Renovating, Barcelona, Structure.
[8] CRAVEN, J. (2008) Adaptive Reuse of Older Buildings, The Newyork Times Company.
[9] JODIDIO, P. (2007) 100 Great Extensions and Renovations, Australia.
[10] Al-Emrani, M., Engstrom, B, Johansson, M. And Johansson, P. (2010): Barande Konstruktioner Del 1 (Load-bearing structures Part 1, in Swedish), Division of Structural Engineering, Chalmers University of Technology, Goteborg, Sweden, 2010.
[11] Alen, C. (2013-02-25): Professor in Geotechnical Engineering at Chalmers University of Technology.
[12] Bergenudd, C. (1981): Pabyggnad (Storey extension, in Swedish), Lund Institute of Technology, Sweden.
[13] Vertical extension of existing buildings by use of light gauge steel framing systems by Susan Bergsten Lulea University of Technology Division of Structural Engineering Steel Structures Lulea, April 2005
[14] Yin, R. (1994), Case Study Research, design and methods, Saga Publications, volume 5.
[15] Beal, D. (2008). A Review of the Concrete Technology and the Design Aspects of Structural Capacity of the Brisbane City Hall.
[16] JODIDIO, P. (2007) 100 Great Extensions and Renovations, Australia.
[17] FEILDEN, B. (2003), Conservation of Historic Building, Oxford.
[18] Alagusundaramoorthy, P. (2002): Shear Strength of R/C Beams Wrapped with CFRP Fabric, Research Report, University of Kentucky, Lexington.
[19] Bergenudd, C. (1981): Påbyggnad (Storey extension, in Swedish), Lund Institute of Technology, Sweden.
[20] Blaschko, M. and Zilch, K. (1999): Rehabilitation of concrete structures with CFRP strips glued into slits, Technical University of Munich, Munich, Germany.
[21] Sirju K., and Sharma A.K. 2001. "Strengthening of Reinforced Concrete Members under Compression and Bending." Structures & Building Vol. 146, pp.277-231.
[22] Nounu G., and Chauhary Z. 1999. "Reinforced Concrete Repairs in Beams." Construction and Building Materials Vol. 13, pp.195-212.
[23] Mohamed H., Kunieda M., and Nakamura H. 2012. "Strength and Ductility of RC Beams Strengthened with Steel-reinforced Strain Hardening Cementitious Composites."Cement & Concrete Composites Vol. 34, pp.1061-1066.
[24] Guidelines for Retrofitting of Concrete Structures - Draft published by JSCE, Sept. – 1999.
[25] Seismic Retrofitting of Existing Building – The master builder, Vol. 3 Dr. H. S. Rao. Aug.- Sept. 2001.
[26] Structural Audit of Existing Buildings – I. H. Shah.
[27] New and Emerging Technologies for Retrofitting and Repairs – Dr. Gopal Rai.
[28] Manual for Retrofitting of Existing Vulnerable Buildings.