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Analysis And Design of A Multi Storey Building with Flat Slab (C+G+9) Using ETABS

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Abstract: A popular form of concrete building construction uses a flat concrete slab (without beams) as the floor system. This system is very simple to construct, and is efficient in that it requires the minimum building height for a given number of stories. Unfortunately, earthquake experience has proved that this form of construction is vulnerable to failure, when not designed and detailed properly, in which the thin concrete slab fractures around the supporting columns and drops downward, leading potentially to a complete progressive collapse of a building as one floor cascades down onto the floors below. Although flat slabs have been in construction for more than a century now, analysis and design of flat slabs are still the active areas of research and there is still no general agreement on the best design procedure. The present day Indian Standard Codes of Practice outline design procedures only for slabs with regular geometry and layout. But in recent times, due to space crunch, height limitations and other factors, deviations from a regular geometry and regular layout are becoming quite common. Also behavior and response of flat slabs during earthquake is a big question. The lateral behavior of a typical flat slab building which is designed according to I.S. 456- 2000 is evaluated by means of dynamic analysis. The inadequacies of these buildings are discussed by means of comparing the behavior with that of conventional beam column framing. Grid slab system is selected for this purpose. To study the effect of drop panels on the behavior of flat slab during lateral loads, flat plate system is also analyzed. Zone factor and soil conditions -- the other two important parameters which influence the behavior of the structure, are also covered. Software ETABS is used for this purpose. In this study relation between the number of stories, zone and soil condition is developed.

Keywords: Flat Slab, Flat Plate, Grid Slab, Storey Drift, Punching Shear, ETABS.

I. INTRODUCTION

Flat slabs system of construction is one in which the beams used in the conventional methods of constructions are done away with. The slab directly rests on the column and load from the slab is directly transferred to the columns and then to the foundation. To support heavy loads the thickness of slab near the support with the column is increased and these are called drops, or columns are generally provided with enlarged heads called column heads or capitals. Absence of beam gives a plain ceiling, thus giving better architectural appearance and also less vulnerability in case of fire than in usual cases where beams are used.

Basic definition of flat slab: In general normal frame construction utilizes columns, slabs & Beams. However it may be possible to undertake construction without providing beams, in such a case the frame system would consist of slab and column without beams. These types of Slabs are called flat slab, since their behavior resembles the bending of flat plates. A reinforced concrete slab supported directly by concrete columns without the use of beams.

Fig1. Slab With Columns.

II. COMPONENTS OF FLAT SLABS

Drops To resist the punching shear which is predominant at the contact of slab and column Support, the drop dimension should not be less than one -third of panel length in t hat direction.

Column Heads Certain amount of negative moment is transferred from the slab to the column at the support. To resist this negative moment the area at the support needs to be increased .this is facilitated by providing column capital/heads. Flat slabs are appropriate for most floor situations and also for irregular column layouts, curved floor shapes, ramps etc. The benefits of choosing flat slabs include a minimum depth solution, speed of construction, flexibility in the plan layout (both in terms of the shape and column layout), a flat soffit (clean finishes and freedom of layout of services) and scope and space for the use of flying forms. The flexibility of flat slab construction can lead to high economy and yet allow the architect great freedom of form. Examples are; solid flat slab, solid flat slab with drop panel, solid flat slab with column head, coffered flat slab, coffered flat slab with solid panels, banded coffered flat slab.

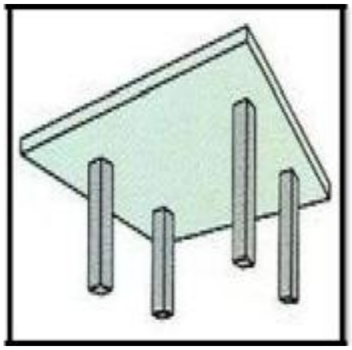

Fig2. Solid Flat Slab

Fig3. Coffered Flat Slab.

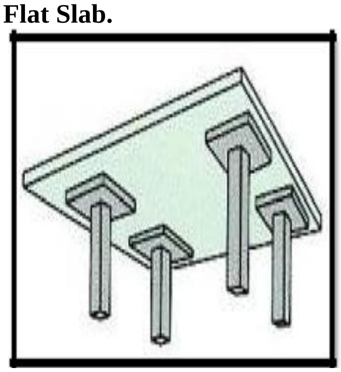

Fig4. Solid Flat slab with Drop Panels.

A flat slab is a flat section of concrete. These slabs are classically used in foundations, although they can also be used in the construction of roadways, paths, and other structures. Depending on the size and complexity of a flat slab, it may need to be designed by an engineer who is familiar with the limitations and needs of slabs, or it may be possible for a handy do it yourselfer to make one in an afternoon for a simple project. Typically, a flat slab is made with reinforced concrete, in which rebar is criss-crossed in the forms to provide support and reinforcement once the concrete is poured and hardened. The slab design is designed to be reinforced in several directions so that it can withstand stresses such as shifting ground, earthquakes, frost, and so forth. Failure to fully reinforce a flat slab can cause it to crack or give along weak lines in the concrete, which will in turn cause instability. For some sites, a flat slab is poured in situ. In this case, the site is prepared, forms for the concrete are set up, and the reinforcing rebar or other materials are laid down. Then, the concrete is mixed, poured, and allowed to cure before moving on to the next stage of construction. The time required can vary considerably, with size being a major factor; the bigger the slab, the more complex reinforcement needs can get, which in turn adds to the amount of time required for set up. Once poured, the slab also has to be examined and tested to confirm that the pour was good, without air pockets or other problems which could contribute to a decline in quality.

In other cases, a flat slab may be prefabricated off site and transported to a site when it is needed. This may be done when conditions at the site do not facilitate an easy pour, or when the conditions for the slab's construction need to be carefully controlled. Transportation of the slab can be a challenge if it is especially large. Barges, cranes, and flatbed trucks may be required to successfully move it from the fabrication site to the site of the installation. The flat slab foundation is not without problems. It can settle on uneven ground, allowing the structure to settle as well, for example, and during seismic activity, a slab foundation cannot hold up if the soils are subject to liquefaction. A flat slab can also become a major source of energy inefficiency, as structures tend to lose heat through the concrete. Advantages of flat-slab reinforced concrete structures are widely known but there are also known the disadvantages concerning their earthquake resistance. It is remarkable that both Greek codes, Reinforced Concrete Code and Seismic Code do not forbid the use of such structural systems however both Codes provide specific compliance criteria in order such structures to be acceptable.

The advantages of these systems are:

- The ease of the construction of formwork.
- The ease of placement of flexural reinforcement.
- The ease of casting concrete
- The free space for water, air pipes, etc between slab and a possible furred ceiling.
- The free placing of walls in ground plan.
- The use of cost effective prestressing methods for long spans in order to reduce slab thickness and deflections as also the time needed to remove the formwork.
- The reduction of building height in multi-storey structures by saving one storey height in every six storey’s thanks to the elimination of the beam height.

These structural systems seem to attract global interest due to their advantages mainly in countries in which the seismicity is low. The application of flat-slab structures is restrained due to the belief that such structures are susceptible to seismic actions. Moreover, it is known that in Central America, at the beginning of 1960’s, flat-slab structures displayed serious problems during earthquake actions.

III. METHODS OF ANALYSIS OF FLAT SLAB

Behavior of two-way slab system under gravity and lateral loads is complex. In the case of beam supported two way slabs, 100% of gravity loads on the slabs are transmitted to the supporting columns in both longitudinal at transverses directions. The mechanism of load transfer from slab to columns is achieved by flexure, shear & torsion in various elements. The slab beam columns system behaves integrally as a three dimensional system, with the involvement of all the floors of the building, to resist not only gravity loads, but also lateral loads. However a rigorous three dimensional analysis of the structure is complex, & not warranted except in very exceptional structures. Unlike the planer frames, in which beam moments are transferred directly to columns, slab moments are transferred indirectly, due to tensional flexibility of the slab. Also slab moments from gravity can leak from loaded to unloaded spans; this must be accounted for, in the analysis. Presently, the Indian Standard Codes provide the guidelines for design of flat slabs. These are basically empirical and are supported by the vast experimentation. But since the standard experimentation has been done on standard layouts and configuration of the slabs; these design procedures are limited in their scope and applicability. Nowadays, irregular layouts are becoming common, and it is in this light that standard codal procedures seem Inadequate.

A. Code definition of flat slabs

"The term flat slab means a reinforced concrete slab with or without drops, supported generally without beams, by columns with or without flared heads. A flat slab may be solid slab or may have recesses formed on the soffit so that a soffit comprises a series of ribs in two directions. The recess may be formed of permanent or removable filler blocks. A flat slab is reinforced concrete flat slab reinforced in two or more directions to bring the load acting normal to its plane directly to supporting columns without the help of any beam or girder." The above definition is very broad and encompasses the various possible column supported two-way slabs mentioned earlier. As mentioned earlier the code procedure is based on the elastic analysis of equivalent frames under the gravity loads and follows closely the 1997 version of the ACI code. However unlike the unified code procedure, there is no elaboration in the I.S code for the particular case of two way slab with beams along column lines.

B. Design Philosophy

There are three methods of analysis of flat slabs viz.

1. Direct Design Method (DDM)
2. Equivalent Frame Method (EFM)
3. Finite Element Method (FEM)

Out of this, first 2 methods are recommended by the I.S. code for determining the bending moments in the slab panel (approximate methods); either method is acceptable (provided the relevant conditions are satisfied).These methods are applicable only to two way rectangular slabs (not one way slabs), and in the case of direct design method the recommendations apply to the gravity loading condition alone (and not to the lateral load condition).

Finite element method: The structures having irregular types of plans with which the EFM has limitations in analysis can be analyzed without any difficulties by the FEM. FEM is a powerful tool used in the analysis of flat slabs. Most finite element programs are based on elastic moment distribution and material that obey Hooke's Law. This works for steel plates but reinforced concrete is an elasto-plastic material and ones it cracks its behavior is non linear. As a consequence the support moments tend to be overestimated and the deflection of the slab is under estimated. Currently, one of the main criticisms of the FEM analysis is its reliance on the elastic solutions that result in high peaked support moments over the column. These support moments are unlikely to be realized under service loads due to cracking and thus the service span moments will be correspondingly increased. While using finite element method following considerations are important.

- Choice of a proper finite element.
- Degree of disceretisation
- Overall computational economy.

Hence various finite element models are possible for the same problem. A model which can take into account all the important structural effects at the least computational cost is called as the best model. Dynamic Analysis

- Coefficient Method
- Response Spectrum method
- Time History Method

IV. BEHAVIOR OF FLAT SLAB UNDER LATERAL LOADING

A. General Building Behavior

The behavior of a building during earthquake is a vibration problem. The seismic motion of the ground does not damage a building by impact, or by externally applied pressure, but by internally applied pressure and internally generated inertial forces caused by vibration of building mass. It can cause buckling or crushing of columns and walls when the mass pushes down on a member bent or moved out of plumb by the lateral forces. This effect is known as the „P-ʌ‟effect and Greater the vertical forces, the greater the movements due to „P-ʌ‟. It is almost the vertical load that causes the building to fall down. The distribution of dynamic forces caused by the motion and the duration of motion are of concern in seismic design. Although the duration of motion is an important issue, we do not consider it for seismic design. In general tall buildings respond to seismic motions differently than low rise buildings. The magnitude of inertia force induced in an earthquake depends on the building mass, ground acceleration, the nature of the foundation, and the dynamic characteristics of the structure. For a structure that deforms slightly, the force 'F' tends to be less than the product of mass and ground acceleration. Tall buildings are invariably more flexible than low rise buildings, and in general, experience much lower accelerations than the low rise buildings. But a flexible building subjected to ground motions for prolonged period may experience much larger forces if its natural period is near that of ground period. Thus the magnitude of earthquake force is function of the acceleration of the ground, the type of structure and its foundation.

B. Building Behavior

Tall buildings respond to seismic motions differently than low rise buildings. The magnitude of inertia force depends on the building mass, ground acceleration, the nature of foundation, and the dynamic characteristics of the structure. Tall buildings are invariably more flexible than low rise buildings, and in general experiences much lower accelerations than low rise buildings. The magnitude of earthquake force is not a function of the acceleration alone, but influenced to a great extent by the type of response of the structure and its foundation. This interrelationship of building behavior and seismic ground motion also depends on the time period. Some factors which affect the building behavior are discussed here.

1. Influence of soil: The seismic motion that reaches a structure on the surface of the earth is influenced by local soil conditions. Low to mid-rise buildings have time period between 0.1 to 1 sec range, while taller more flexible buildings have periods between 1to 5 sec or greater. Harder soils, and bed rock transmit short period vibrations (caused by near field earthquake) while filtering out longer period earthquakes (caused by distant earthquakes), whereas softer soils will transmit longer period vibrations.

2. Structural response: If the base of structure is moved suddenly, the upper part of the structure will not respond instantaneously, but will lag because of inertial resistance and flexibility of the structure. Because earthquake ground motions are three dimensional, building deforms in a same manner. But inertia forces generated by horizontal components of ground motions required greater considerations for seismic design since adequate seismic resistance to vertical seismic loads is provided by member capacities required for gravity load design.

3. Load Path: Buildings are generally composed of vertical and horizontal structural elements. A complete load path is a basic requirement for all buildings. Seismic forces originating throughout the building, mostly in the heavier mass elements such as diaphragms, are delivered throughout the connections to diaphragm; the diaphragm distributes these forces to vertical force resisting system such as shear walls and frames. Through frame these forces are transferred to foundation; and foundation transfers these forces to supporting soil. Interconnecting, members needed to complete the load path is necessary to achieve good seismic performance.

C. Flat slab building behavior under lateral loading

The behaviour of flat slab structures for gravity loads is well established. However, behavior under lateral displacement is not well understood and lateral design methods are not well established. Frame action provided by flat slab and column is generally insufficient for buildings taller than 10 stories. The lateral behavior of flat slab structures is in doubt because of the relative flexibility of the connections when compared with beam column joints. A flat slab column framing is generally inadequate as a primary lateral load resisting system for multi-storey structures in high seismic risk zones because of problems associated with excessive drift. A system consisting of shear walls and flat slab with proper bracing systems is usually recommended for high rise buildings. Even there is a concern as to whether the connection possesses sufficient lateral displacement capacity to survive lateral deformations which can be reasonably expected. The stiffness of the typical wall or frame system is insufficient to protect the slab column connection from yield. Hence attention must be given to its inelastic seismic response. I.S. 1893-2002 says that "Since the lateral load resistance of the slab column connection system is small, flat slabs are often designed only for gravity loads, while the seismic force is resisted by shear walls. Even though slabs and columns are not required to share the lateral forces, these deforms with rest of the structure under seismic excitation. The concern is that under such deformations, the slab column system should not lose its vertical load capacity."

The slab column connections are subjected to gravity shear and unbalanced moment during earthquake. Transfer of shear and unbalanced moments is critical in flat slab behaviour, especially for horizontal loading which requires substantial unbalanced moment to transfer between slab and column. Unbalanced moment is transferred by combination of flexure, torsion and shear in the flat slab around the periphery of column faces. The shear from the unbalanced moment transfer is added to the gravity shear at connections. When combined shear becomes too large, a brittle punching failure will occur. If the connections are not properly detailed, punching failure may lead to progressive collapse. The concrete will provide a certain level of shear resistance around the columns but this may need to be supplemented by punching shear reinforcement arranged on concentric perimeters. Thus during transfer of loads either due to gravity or due to earthquakes, behavior of flat slab building depends on strength and behavior of slab connection.

D. Structural Dynamic behavior of Multiple-degree-of-freedom (MDOF) systems

1. Degree of freedom: Any mass can undergo six possible displacements in space - three translation and three rotations about an orthogonal axis system. The number of independent displacement required to define the displaced position of all the masses relative to their original position is called number of degree of freedom (DOFS) for dynamic analysis.

- Single Degree of Freedom System
- Multi Degree of Freedom System
- Continuous System

2. Classification of vibration

- Free and forced vibration
- Undamped and damped vibrations
- Linear and non-linear vibration

Free and forced vibrations: If a system, after an initial disturbance is left to vibrate on its own, the ensuing vibration is known as free vibrations. No external force acts on the system. The oscillation of a simple pendulum is an example of free vibration. If a system is subjected to an external force (often a repeating type of force) the resulting vibration is known as a forced vibration. The oscillation is known as forced vibration. The oscillation that arises in machines such as diesel engines is an example of force vibration. If the frequency of the external of the external force coincides with one of the natural frequencies of the system, a condition known as Resonance occurs and the system undergoes dangerously large oscillation, failures of such structures as building, bridges, turbines and airplane wings have been associated with the occurrence of Resonance.

Undamped and damped vibrations: If no energy is lost or dissipated in friction or other resistance during Oscillation, the vibration is known as Undamped Vibration. If any energy is lost in this way, however, it is called Damped vibration. In many physical systems, the amount of damping is so small that it can be disregarded for most engineering purposes .however consideration of damping becomes extremely important in analyzing vibratory system near resonance.

Linear and non-linear vibrations: If all the basis component of a vibratory system, the spring, the mass and the damper behave linearly the resulting vibration is known as linear vibration. If however, any of the basic component behave nonlinearly the vibration is called non linear vibration.

Analysis of Flat Slab: The seismic analysis and design of buildings are traditionally focused on reducing the risk of loss of life in the largest expected earthquake. Building codes are based on their provisions on the historic performance of buildings and their deficiencies and have developed provisions round life safety concerns i.e. to prevent the collapse under the most intense earthquake expected at site during the life of the structure. These provisions are based on the concept that the successful performance of buildings in areas of high seismicity depends on combination of strength, ductility manifested in the details of construction, and the presence of the fully interconnected, balanced, and complete lateral force resisting system.

E. Advantageous Features of ETABS (Version 9.7.2)

Software ETABS (Extended Three Dimensional Analysis of Building Structures) is used for seismic analysis and to study the behaviour of flat slab buildings. ETABS is the Integrated Software for Analysis, Design, and Drafting of Building Systems. ETABS is very useful for linear as well as nonlinear analysis of buildings. Input for buildings becomes very easy and also 'user interface' explains us various modelling and analysis procedures. Engineering News Record has also declared that ET ABs as the only reliable software for seismic analysis of buildings. For nearly 30 years ET ABS has been recognized as the industry standard for Building Analysis and Design Software. Today, continuing in the same tradition, ETABS has evolved into a completely Integrated Building Analysis and Design Environment. The System built around a physical object based graphical user interface, powered by targeted new special purpose algorithms for analysis and design, with interfaces for drafting and manufacturing, is redefining standards of integration, productivity and technical innovation. The integrated model can include Moment Resisting Frames, Braced Frames, Staggered Truss Systems, Frames with Reduced Beam Sections or Side Plates, Rigid and Flexible Floors, Sloped Roofs, Ramps and Parking Structures, Mezzanine Floors, Multiple Tower Buildings and Stepped.

F. Modelling steps

As a case study, plan of existing flat slab building for commercial building is selected which is located near Pune (zoneIII and soil type II i.e. medium soil condition). Same building is analyzed for other zones and soil conditions and their storey drifts are compared. Existing structure consists of two buildings connected together. One part consists of only offices and other part includes all utilities like staircase, lifts, washrooms etc. The part which consists of offices only is built with flat slabs while other is beam column frame structure. For the simplification in the analysis, the part which consists of offices is selected. Software ET ABS is used for the analysis. For this, Plan dimensions of an existing flat slab building are taken as fixed dimensions.

- With the same loading conditions, requirement of column free space, greater floor to floor height and number of stories of that of existing building, three different types of slabs viz. grid slab, flat slab and flat plate slab are designed.
- Models of all buildings are prepared in ETABS with given loading conditions. To compare the behaviour of the floor diaphragm of the flat slab, grid slab and flat plate building during lateral condition, stiffness of columns is kept same. Columns are assumed to have the same size at the particular storey level.
- Edge beams of the same dimensions are provided along the periphery of the flat slab and flat plate building:
- Thickness of the slab is provided according to the deflection requirement and to resist the one way and two.

F. Gravity Loads

Dead Load (DL):-DEAD LOAD is defined as the the load on a structure due to its own weight (self-weight). It also added other loads if some permanent structure is added to that structure.

Live Load (LL):-LIVE LOAD Or IMPOSED LOAD is defined as the load on the structure due to moving weight. The LIVE LOAD varies according to the type of building. For example generally for a Residential Building the LIVE LOAD is taken as 2kn/m2.

1. Dead Load Calculation: Main Wall Load (From above plinth area to below the Roof) should be the cross sectional area of the wall multiplied by unit weight of the brick. (unit weight of brick is taken as 19.2 kn/m3). According to the IS-CODE PLINTH LOAD should be half of the MAIN WALL LOAD. Internal PLINTH LOAD should be half of the PLINTH LOAD.

Parapate Load should be the cross sectional is multiplied by unit weight.

Slab Load should be combination of slab load plus floor finishes. SLAB LOAD can be calculated as the thickness of slab multiplied by unit weight of concrete (according to IS-CODE unit weight of concrete is taken as 25 kn/m^3).and FLOOR FINISHES taken as .1.5 kn/m2.

2. Live Load Calculation

Live Load is applied all over the super structure except the plinth .Generally LIVE LOAD varies according to the types of building. For Residential building LIVE LOAD is taken as ----2kn/m2 on each floor and 2kn/m2 on roof.

G. Critical Load Combinations

While designing a structure, all load combinations, in general are required to be considered and the structure is designed for the most critical of all. For building upto 4 storeys, wind load is not considered, the elements are required to be designed for critical combination of dead load and live load only. For deciding critical load arrangements, we are required to use maximum and minimum loads. For this code prescribes different load factors as given below :

- Maximum load = wmax = 1.5(DL + LL)
- Minimum load = wmin = DL

The maximum positive moments producing tension at the bottom will occur when the deflection is maximum or curvature producing concavity upwards is maximum. This condition will occur when maximum load (i.e. both DL and LL) covers the whole span while minimum load (i.e. only DL) is on adjacent spans.

consideration may be limited to combination of: Design dead load on all spans will full design live loads on two adjacent spans (for obtaining maximum hogging moment.)

V. PROPERTIES OF CONCRETE

Grade of concrete: Concrete is known by its grade which is designated as M15, M20, M25 etc, in which letter M refers to concrete mix and the number 15, 20, 25 etc. denotes the specified compressive strength ($f$ck) of 150mm size cube at 28 days, expressed in N/mm2. Thus, concrete is known by its compressive strength. In R.C. work M20, M25 grades of concrete are common, but higher grades of concrete should be used for severe and very severe and extreme environment.

Compressive strength: Like load the strength of concrete is also a quantity which varies considerably for the same concrete mix. Therefore a single representative value known as characteristic strength,is arrived at using statistical probabilistic principles.

Characteristic strength: It is defined as that value of the strength below which not more than 5% of the test results are suspected to fall,(i.e., there is 95% probability of achieving this value, or only 5% probability of not achieving the same).

Characteristic strength of concrete in flexural member: It may be noted that the strength of concrete cube does not truly represent the strength of concrete in flexural member because factors namely, the shape effect, the prism effect, state of stress in a member and casting and curing conditions for concrete in the member. Taking this into consideration the characteristic strength of concrete in a flexural member is taken as 0.67times2.6 the strength of concrete cube.

Design strength(fd) and partial safety factor(γd) for material strength : The strength to be taken for the purpose of design is known as design strength and is given by

Design strength (fd) = characteristic strength($f$ck)

Partial safety factor for material Strength (γm)

The value of γm depends upon the type of material and upon the type of limit state. According to I.S. code,

γm = 1.5 for concrete and γm = 1.15 for steel.

Design strength of concrete in member = 0.67$f$ck / 1.5 = 0.446 $f$ck ≈ 0.45 $f$ck

Generally concretes are strong in compression and very negligible respond (almost zero) to the tension. So reinforced (steel bars) are provided to resist the tension and to counteract the moment which can't resist by the concrete. The partial safety factor for concrete generally taken as 1.5 due to non-uniform compaction and inadequate curing and partial safety factor for steel is taken as 1.15.The compressive strength of concrete is always taken as because it is always lesser than the cube strength. So for the design work the maximum strength of the concrete is taken as -0.67fck/1.5=.45fck and for steel is fy/1.15=.87 fy.

Punching Shear Data: Flat slab exhibits higher stress at the column connection .They are most likely to fail due to punching shear which will occur due to the concentration of shear forces and the unbalanced bending and twisting moments . It has to be noted that the punching shear failure is rather more critical than the flexural failure. Such a concentration of shear force and moments leads to unsymmetrical stress distribution around the slab-column connections. The local and brittle nature of the punching shear failure is in the form of crushing of concrete in the column periphery before the steel reinforcement reaches the yield strain. The observed angle of failure surface is found to vary between 26° and 36°. Thus the punching shear capacity of a slab (in absence of shear reinforcement) depends on the strength of concrete, the area of tension reinforcement, the depth of the slab and the column size. The sudden disaster effect of the punching shear is a critical problem for any designer. Punching shear is a type of failure of reinforced concrete slabs subjected to high localized forces. In flat slab structures this occurs at column support points. The failure is due to shear:

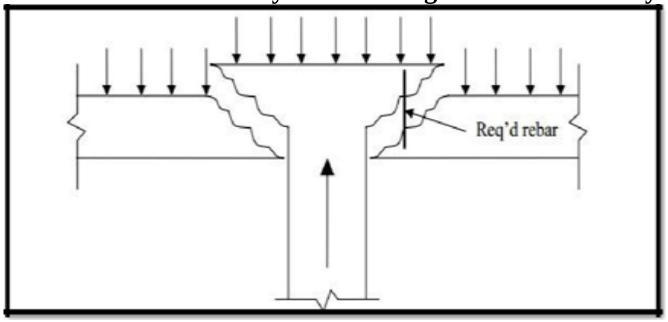

Fig5. Punching Shear failure.

Fig6.Global collapse of the structure due to punching shear.

When the flat slab is exposed to a concentrated load larger than the capacity, the effect on the slab is referred to punching shear. In these slabs, the sheer force per unit length can become high close to the area of loading. If the capacity for punching in the slab is exceeded, a punching shear failure may occur within the discontinuity regions (D-region) of the flat slab. This type of failure is a brittle failure mechanism, and may cause a global failure of the structure. Punching shear failure is a typical failure for slab-column connection. The above figure shows an example of a global failure of a structure due to punching shear.

Meshing:

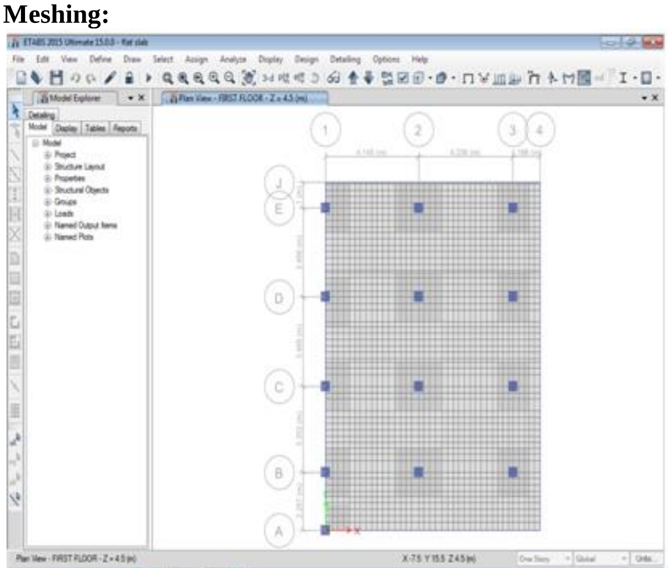

Fig7. Meshing of the Slab.

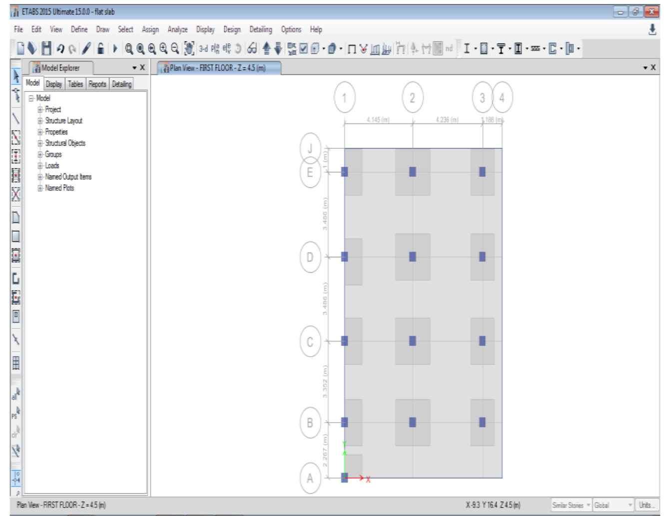

Fig20. Column Drop.

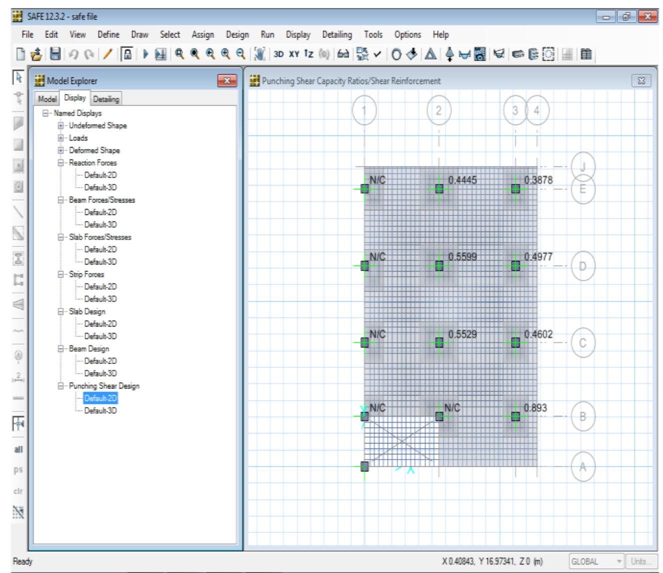

Fig21. Punching Shear

VI. CONCLUSION

For improving drift conditions of flat slab in higher seismic zones lateral load resisting system should be coupled with slab column frame and or stiffness of column should be increases. The negative moment's section shall be designed to resist the larger of two interior negative design moments for the span framing into common supports. Drops are important criteria in increasing the shear strength of the slab.

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