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Behavior of Flat Slab With Drop Area or Varying thickness

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ABSTRACT

This research presents the effect of drop area in the center of span with different thicknesses of drop using finite element method(FEM) .The numerical work here focus on the effect of drop area on deflection and shear stress on flat slap with drop area and compare it with flat slab without drop area. Nonlinear finite element on the slab specimens with drop area was realized using ANSYS software. the study models is flat slab with drop 0.06m and 0.12m with fixed and varying bottom with area of drop (2*2)m ,from this research it can be conclude that the best case of drop in deflection ,stress y and cracks is flat slab with drop 0.12m with varying bottom with area of drop (2*2)m.

1. Introduction

This research study the effect of drop area in the center of span with varying thickness on the deflection and shear stress and compared it with flat slab without drop area and also present the crack on flat slab. One of the most suitable finite element method is ANSYS because it is capable of analyzing the nonlinear behavior of a combination between 3D SOLID (concrete) and LINK elements (steel) in a structure based on the finite element procedure which can be utilized to describe the actual nonlinear behavior of flat slab with drop area. it study the effect of drop area in case of fixed and varying bottom surface of drop area and compared it with flat slab without drop as shown in figure (1).

Flat slab are one of the most generally structural system used nowadays. It is a two dimensional solid reinforced concrete of uniform thickness in most cases that transfers the load directly to the columns without the present of the beams. The flat slab system is a special structural form of reinforced concrete construction that holds major advantages over the conventional moment-resisting frames. The flat slab system provides architectural flexibility, unobstructed space, reduction of floor height ,these advantages further results in reduction in the cost of material, easier formwork and shorter construction time .Flat slab systems are also subject to significant reduction in stiffness resulting from the cracking that occurs from construction loads ,service gravity loads, temperature and shrinkage effects and lateral loads

(Tovi 30)(1) reviewed the history of the span-to-depth method of design. Span/depth ratios are based on knowledge of deflection and currently advanced made in the calculation of deflection. Eurocode is one of the most advanced design codes available, sufficient for use in checking deflection by calculation. The technique for calculating deflection in Eurocode is the deemed-to-satisfy span to-effective-depth ratio. These methods are compatible and economic for use with large designs Moss and Brooker [3].Markus A. Staller [4] carried out numerical and analytical studies on the punching shear capacity of point-supported, reinforced

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concrete slabs made of normal and high strength concrete. The numerical analysis consisted of calculations of selected punching tests using the finite element method and the examination of various geometric and material parameters. The calculations were made using the finite element program (MARC) which is suitable for linear as well as for geometric and physical, nonlinear static and dynamic calculations. Iyad Alkroosh, Hayder Ammash [5] Showed that the gene expression programming technique is successful in correlating between the punching shear strength and the significant factors affecting it. The GEP model has achieved high coefficient of determination and low mean values in training and validation sets indicating high accuracy and great capability for generalization. M.A. Eder [6] dealed with the modeling of punching shear failure in reinforced concrete slabs using nonlinear finite element analysis. An analytical procedure is presented for simulating punching failure. The procedure is validated for a large scale reinforced concrete flat slab without shear reinforcement that failed in punchin. M.Altug Erberiki(7)Developed fragility curves for flat slab structure system for which no fragility analysis has been undertaken before. A mid-rise flat-slab building is designed and modeled using the structural characteristics typical of flat-slab building. The preliminary evaluation of the structure indicates that the model structure is more flexible than conventional frames because of the absence of deep beams and/or shear walls. Leandro M. Trautwein etal [8] Showed that internal studs without embracement in the flexural reinforcement can be effective as shear reinforcement of flat slabs. The failure loads showed a reasonable improvement of the punching strength with the use of shear steel as compared to the punching strength of a slab without shear reinforcement. The punching failure of Slab E5 showed an improvement of 118% as compared to the punching failure of a similar slab without shear reinforcement. Megally and Ghali [9] presented a model for the nonlinear finite element analysis of interior and edge column-slab connections.

Numerical results indicate that the developed model provides realistic estimates of both the ultimate capacity and deformations of column-slab connections failing by punching shear. In addition, the analysis confirms that variations in mesh size and the locations of supports do not affect the results of the slabs being analyzed.

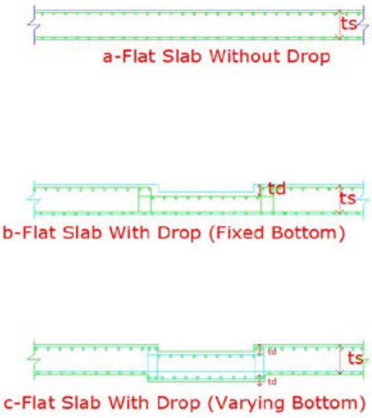

Figure 1: Studied models

2-modeling

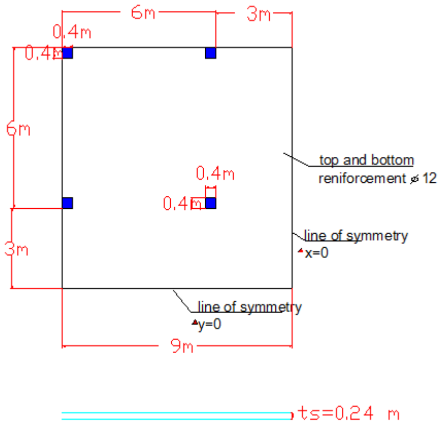

Figure 2: Reference model flat slab without drop

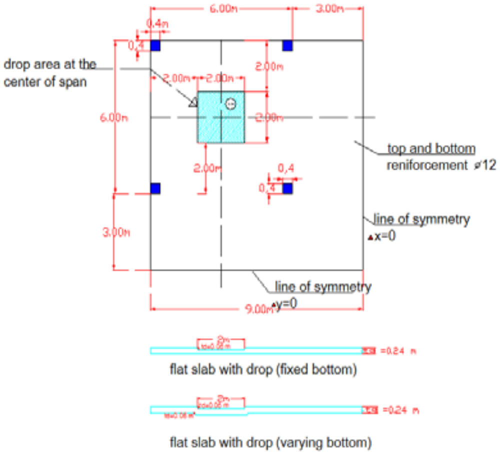

Figure 3: Second case of study drop 0.06m thickness with fixed and varying bottom

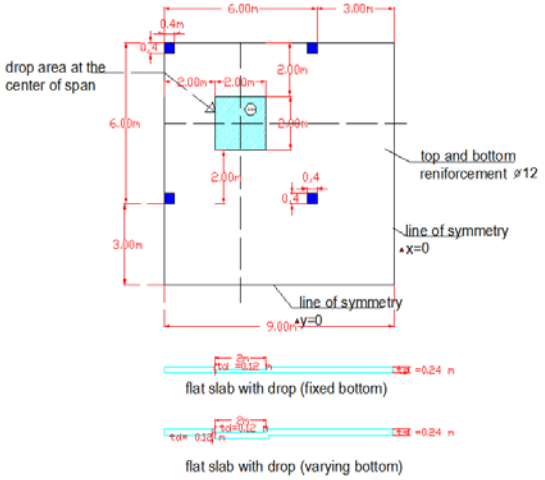

Figure 4 :Third case of study drop 0.12m thickness with fixed and varying bottom

3- Finite element analysis

3.1 Element Types

The ANSYS element library contains more than 150 different element types. Each element type has a unique number and a prefix that identifies the element category ,ANSYS [10] while concrete was modeled using 3-D 8-node solid elements. The solid element used is SOLID65.The main feature of this element is the ability to account for material nonlinearity. This element is capable of considering cracking in three perpendicular directions, plastic deformation and crushing, and creep. The element is defined by eight nodes having three translation degrees of freedom at each node in the x, y and z directions as shown in Figure (5)

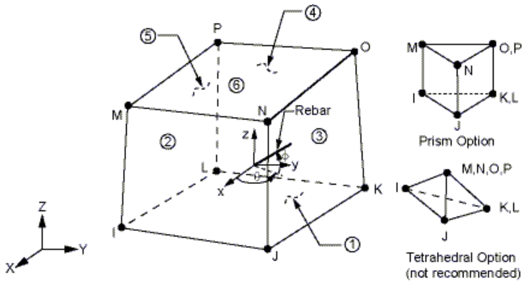

Figure 5:Solid 65 3D-reinforced concrete solid element, Ansys(10).

A LINK180 element is used to model steel reinforcement. The element is a uniaxial tension compression element with three degrees of freedom at each node translations in the nodal x, y, and z directions. This element is also capable of plastic deformation. Figure (6) shows the geometry of LINK180.

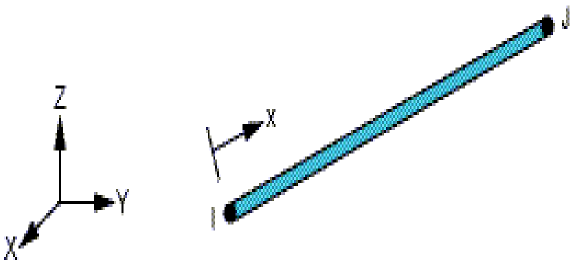

Figure 6:LINK180 element geometry Ansys(10).

3-2 Real Constants

The properties of the element that depend on the element type such as cross section area of beam element called in ANSYS as real constants, which clarified for every element in. Not all element types require real constants, and different elements of the same type may have different real constant values, such as cross section areas of link element refers to steel rebar. In case of concrete, real constants defined only for SOLID65 element, ANSYS [10]. Crushing stiffness factor (CSTIF) for concrete is set to be 0.01. LINK180 has two main real constants; cross sectional area, and added mass (mass / length). Both tension and compression capability is chosen. Real constants of the steel reinforcement no 12 with cross section area 11.3m2.

3-3 Materials:

The FEM input data for concrete in ANSYS are 24KN/mm2 for the elastic modulus,0.2 for The Poisson ratio while The maximum compressive strength in the uniaxial condition was taken as 40 N /mm^{2}and The tensile strength was taken as 0.1 of the compression strength 3.8N/mm2. The multi linear isotropic concrete model uses the von Mises failure to define the failure of concrete. The compressive uniaxial stress-strain relationship for the concrete model was obtained using the following equations to compute the multilinear isotropic stress-strain curve for the concrete.The ascending branch of the uniaxial stress- strain curve was represented as shown in figure (7).The shear transfer coefficients were taken as 0.25 and 0.8 for open and closed respectively.

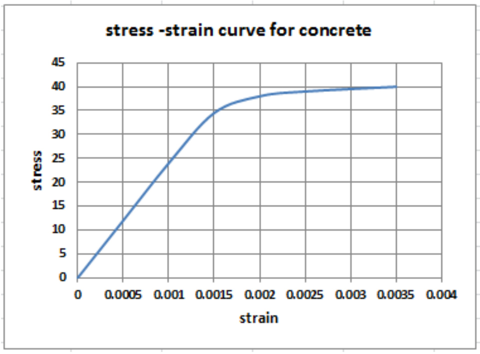

Figure 7: Stress – Strain curve for concrete

$\boldsymbol{fck, c = fck(1.0 + 5\sigma 2/fck) \ \ for \ \ \sigma 2 \leq 0.05fck}$ .... Equation (1)

$\boldsymbol{fck, c = fck(1.125 + 2.5\sigma 2/fck) \ \ for \ \ \sigma 2 > 0.05fck}$ ....Equation (2)

$\boldsymbol{\varepsilon c2, c = \varepsilon c2\,(fck, c/fc)^2}$.....................Equation(3)

$\boldsymbol{\varepsilon cu2, c = \varepsilon cu2 + 0.2\sigma 2/fck}$ .... Equation(4)

$\boldsymbol{\sigma 2/fy = 0.055048 - 0.001885\ (B/t)},$ $\boldsymbol{(17 \leq Bt \leq 29.2)}$...............................Equation (5)

$\boldsymbol{\sigma 2/fy = 0.0}$,$\boldsymbol{(29.2 \leq B/t \leq 150)}$...........Equation (6)

Where; fck, c, $\varepsilon c_2, c$,and $\varepsilon cu_2, c$ are strength, strain at reaching maximum strength, and the ultimate strain of confined concrete.
While, fck, εc_2 and $\varepsilon cu_2$are the same characteristics but for unconfined concrete.
σ2 is the effective lateral compressive strength at ultimate limit state. The stress-strain relationship of infill concrete was calculated to each cross-section of the CFST columns according to its dimensions and utilized in the finite-element analysis.

Steel

The steel material for the finite element models was assumed to be an elastic-perfectly plastic material and identical in tension and compression Figure (8).Poisson's ratio of 0.3, EX is 200kN/mm^2 and yield stress is 360 N/mm2 was used for the steel reinforcement in this study.

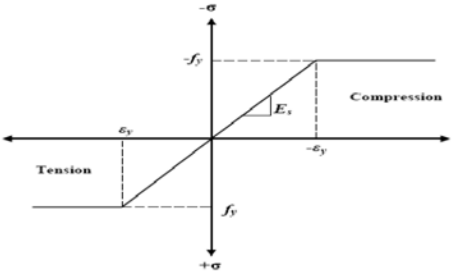

Figure 8: Stress-Strain curve for steel (11).

4-Analysis

4-1 verification

The verification of the nonlinear finite element modelling was achieved by comparing the results with existing experimental results .The experimental tests studied the deflection of flat slab in terms of the failure loads , The test specimens were 1:10scale models of concrete flat slab ,supported by sixteen column and having equal span in two directions perpendicular to one another . The model flat slab were designed to BS8110:Structural design of concrete (1985)(12)
In this model the the span length =500mm center to center of coulmn the thickness of slab was 25mm the coulmn were square with side width of 50 mm and 150 mm long two layers of element were used to represent the effective depth of the slab each layer had a thickness of 12.5 mm Due to symmetry only one half of the connection was modelled . Along the line of symmetry AB ,BC and CD The node are given specified displacement uy=0,ux=0,uy=0 respectively. The node on the bottom layer of the slab at the coulmn position were given a specified displacement uz=0 as shown in figure 9.

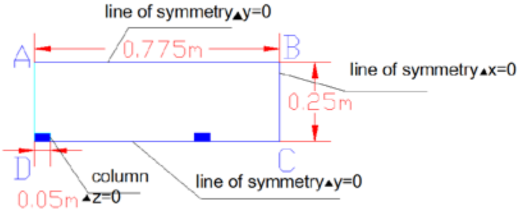

Figure 9:The slab of verification modeled.

Tensile tests were performed on three rods from each test. Each rod was 1.6mm in diameter and 250 mm long From the results the average yield strength was found to be 700 N/mm2.The tensile yield stress for the steel is 670 N/mm2.

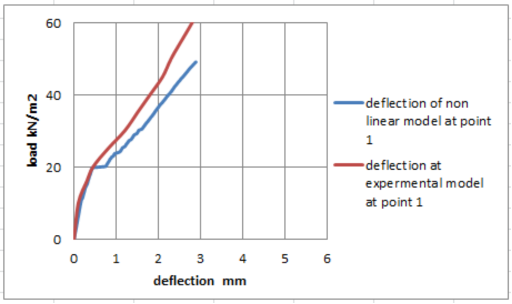

Figure9: Load-deflection curves at point 1

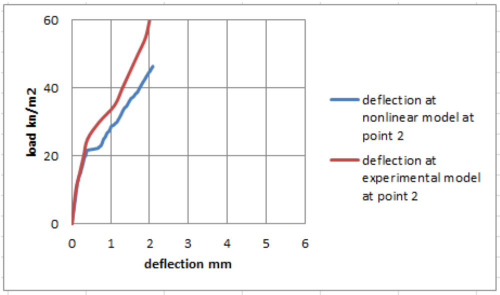

Figure 10: Load-deflection curves at point 2

Comparison between finite element and experimental Behavior of the tested model, Load-deflection curves and the failure load Patterns were obtained from ANSYS and compared with experiment. the failure load in experimental work was 0.065N/mm2 and in the ANSYS was 0.06 N/mm2 ,and also deflection ,this indicate that the results of experimental work is so close to the result in ANSYS, therefore, the validity of the numerical analysis using ANSYS is granted.

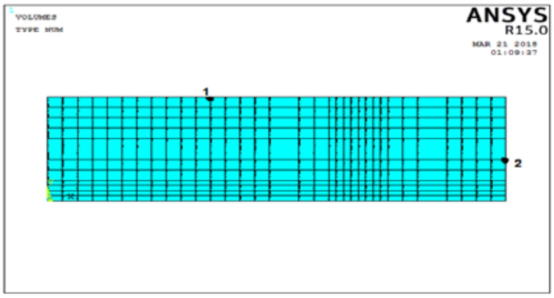

Figure 11: The location of the point 1 and 2 in modelled slab in ANSYS.

5-Results and discussion

The results of the parametric study of the nonlinear numerical models are evaluated and discussed in this section. the nonlinear models were used to calculate the deflection and stress y of the slab without drop and compared to slab with drop area 2*2m and varying thickness 0.06m and 0.12m with fixed and varying bottom. The X axis of the graph represents the deflection and the Y axis represents the uniform load. The failure load of flat slab without drop is 2 t/m2,while flat slab with drop 0.06m fixed and varying is 2t/m2,1.83 t/m2 respectively and 1.94t/m2,1.84 t/m2 For flat slab with 0.12m fixed and varying bottom .

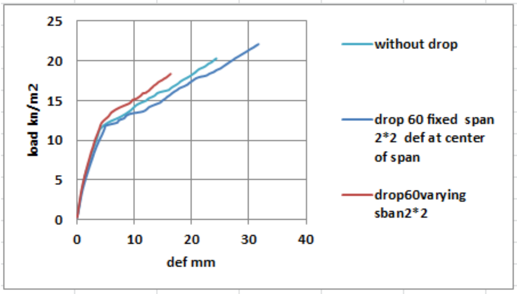

Figure 12: Load- deflection at 3 cases of drop 0.06m

Figure (12) Indicate the different in deflection in flat slab without drop and compared it with drop 0.06m in thickness and area 2*2m in the centre of span at two cases the first case drop 0.06m with fixed bottom and the second case with varying bottom. From this curve we include that deflection increase in the case of flat slab with drop 0.06m with fixed bottom with 23.3%percent when compare it with flat slab without drop and the deflection decrease in the case of drop 0.06m with varying bottom with 32.5% percent compared with flat slab without drop.

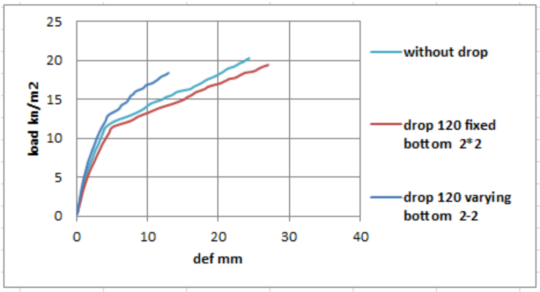

Figure 13:Load -deflection at 3 cases of drop 0.12m

Figure (13) It is clear that the slab with drop 0.12m with fixed bottom increase in deflection with 10%percent in compared with flat slab without drop ,while the case of drop 0.12m with varying bottom decrease in deflection with 40%percent when compared it with flat slab without drop.

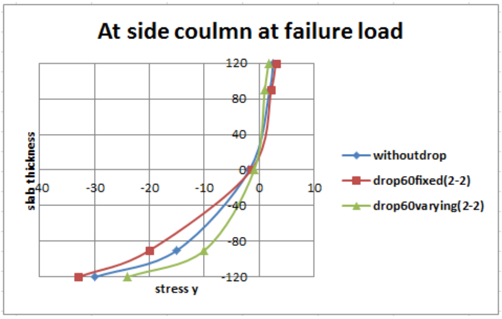

Figure 14:Stress y at side column at failure load at drop 0.06m

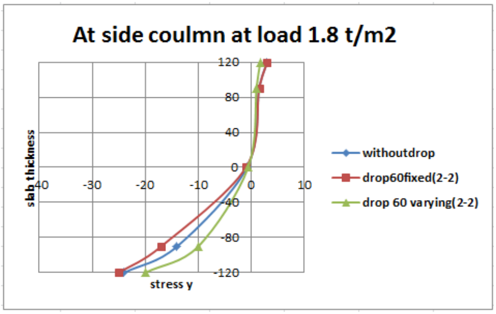

Figure 15: Stress y at side column at load 1.8 t/m^2 at drop 0.06m

Figure 14,15 shows the stress y at the side column at failure load and load 1.8 t/m2 from this curves it clear that the neutral axis its direction to the compression region and the stress of flat slab with drop 0.06m with fixed bottom increase by 9% when compared with flat slab without drop and stress decrease in the case of flat slab with drop 0.06m varying bottom by 20% from the reference case in the failure load .while in the load 1.8 t/m2 the stress of slab with drop 0.06m fixed bottom increase by 4% and decrease in the case of flat slab with drop 0.06m varying bottom by 16% .Overall its indicate that the moment transferred to the column decrease in the case of flat slab with drop 0.06m varying .

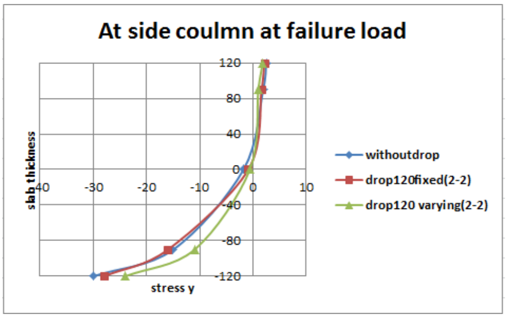

Figure16: Stress y at side column at failure load at drop 0.12m

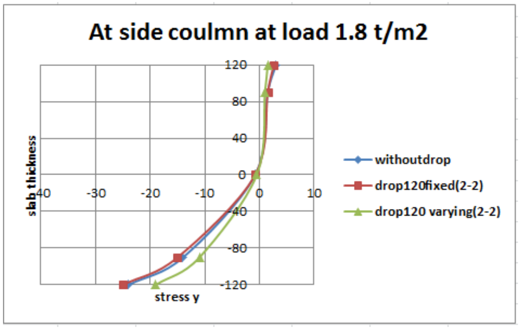

Figure17:Stress y at side column at load 1.8 t/m^{2}at drop 0.12m

From the figure 16,17 its illustrate the stress y at drop 0.12m with fixed and varying bottom at failure load and 1.8t/m^2 load at side column .it shows that the neutral axis its direction to the compression zone .Its also noticeable that the stress of drop 0.12 m fixed is so closed to the stress of slab without drop its only increase by 6% , and decrease by 20% in the case of flat slab with drop 0.12m varying bottom, also in the case of load 1.8 t/m^2 stress y increase in case of fixed bottom by 4% and decrease by 20% in case of varying bottom when compare with reference case.

It can be concluded from the graph that the moment transfer to the column from slab with drop 0.12m varying is smaller than the moment transfer from drop with fixed bottom.

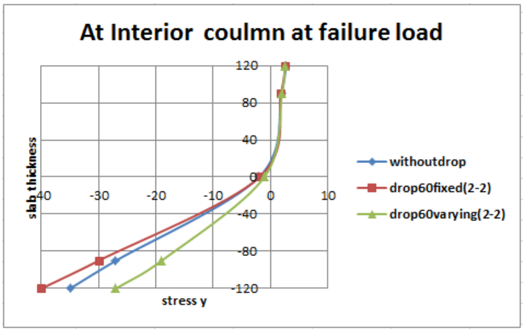

Figure 18:Stress y at Interior column at failure load at drop 0.06m

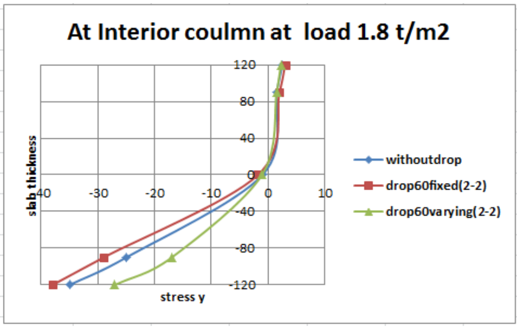

Figure 19:Stress y at Interior column at load 1.8 t/m^2 at drop 0.06m

It can be seen from Figure 18,19 that stress y increase in value at the interior column than the side column it also indicate that stress increase at drop 0.06m with fixed bottom by 12.5%and decrease by 22%in case of varying bottom ,while in case of load 1.8 ton the stress increase and decrease by 7%and 22% in fixed and varying case respectively .and the neutral axis its direction to compression. and the change in stress in failure load to load 1.8 t/m^2 is decrease in slab without drop ,drop 0.06m fixed and 0.06m varying by 0%,5%,0% respectively. We can see that drop with varying bottom 0.06m transfer the lowest value of moment to the interior column.

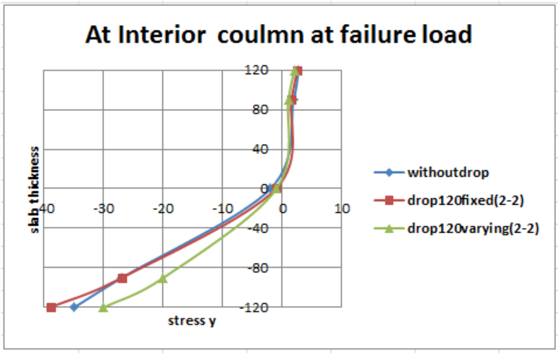

Figure20 : Stress y at Interior column at failure load at drop 0.12m

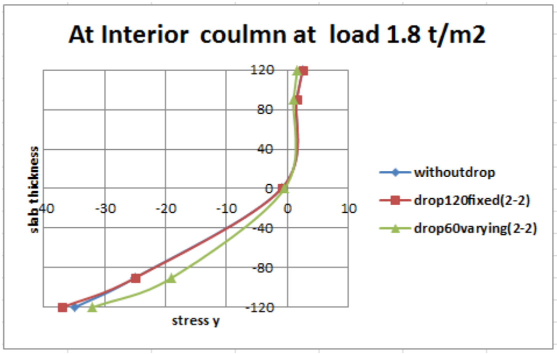

Figure21:Stress y at Interior column at load 1.8 t/m^2 at drop 0.12 m

Figure 20, 21 indicate the stress y at drop 0.12m fixed and varying at interior column at failure load and load 1.8 t/m^2 from this figure we can be conclude that neutral axis direction to compression while stress y is nearly to the slab without drop in case of fixed drop 0.12m while decrease in case of varying drop 0.12m by 14%. We can say that moment that transfer to internal column decreased in cases of varying bottom with drop 0.12m.

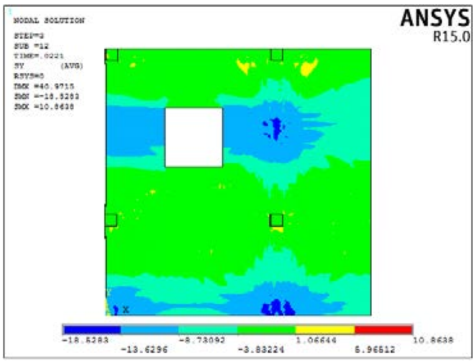

Figure21:Stress y the top of slab with drop 0.06m fixed

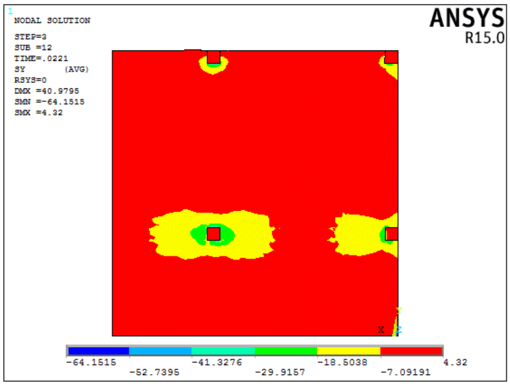

Figure22: Stress y the bottom of slab with drop 0.06m fixed

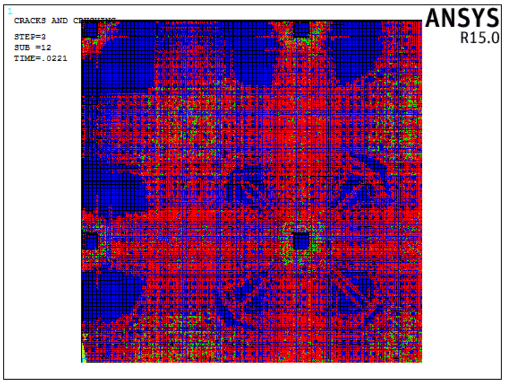

Figure23: Cracks of flat slab with drop 0.06m fixed bottom

Conclusion

Based on the numerical study, the following conclusions can be deduced

*For a drop area with area 2*2 m and thickness 0.06m it shows a reduction in deflection in case of varying bottom by 32.5% compared with flat slab without drop and increase in deflection by 23.5% in fixed bottom case. while the stress y and the moment decrease by 20% and increase by 9% compared with reference case in case of side column but in the interior column it decrease and increase by 22%,12.5% respectively in the status of varying and fixed bottom at failure load.

*When the drop area is 2*2m in area and 0.12m in thickness the deflection is less in deflection in case of varying bottom than slab without drop by 40%, Whereas the case of fixed bottom increase by 10% compared with reference case at failure load .On the other hand ,the stress y and the moment increase by 6%and decrease by 20% at the case of fixed and varying bottom in case of side column ,while the percentage is so close to the reference case in case of fixed bottom and decrease by 14% in case of varying bottom at failure load .

*From the above analysis results it could be concluded that, the percentage reduction in deflection and moment is more for slab with drop area 0.12m in thickness and 2*2m in area with varying bottom when compared with slab without drop area .then the best case of drop area is drop area with 0.12 m thickness with varying bottom.

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