Compared between Experimental and numerical Study of Flat Slab that have Opening adjacent to Column with Embedded Shear Collar

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ABSTRACT

This study presents an experimental study and numerical study (ABAQUS program) of flat slab which has openings adjacent to the column by using several types of collar shear reinforcement to demonstrate its effect on the behavior of flat slab to resist piercing shear.
Where the shear reinforcement is considered one of the important solutions to increase the resistance of the slabs to the failure of the punching shear and it is also possible through the use of these collars to provide service openings next to the columns.
This research includes testing seven models of slabs with dimensions (1000 x 1000 x 75 mm), each slab contains a column with dimensions (200 x 200 x 150 mm) in the center of each slab. Reference model didn't have opening and without collar, another model have opening and without using collar and five models contain openings adjacent to the column, as well as various shapes of shear collars,
The results showed that the presence of openings led to a change in the behavior of the slabs, as well as the use of shear collars leads to an improvement in the behavior of the slabs compared to the model that contains an opening and does not contain shear collars. Where the presence of the openings adjacent to the column led to a ultimate load loss of (27%) and the use of these shear collars leads to reducing the ultimate load loss to (4-24%), depending on the type of collar used.
Where The percentages of differences between the experimental results and the numerical results of the greatest pregnancy range from (2.1 – 10.2) %

Keywords: Atmospheric air pollution, explosives and toxic substances, water and air pollution, UN Conference, black rain, black snow, hydrogen fuel.

Introduction

The United States and Europe were the first places in the world to produce reinforced concrete slabs that were directly supported by columns at the beginning of the 20th century. In most of their designs, the column capitals consisted of huge caps shaped like mushrooms, and their purpose was to make the process of transferring forces since slab to the column easier.
The use of flat slabs that did not have caps became more common during the decade of the 1950s as the practice gained popularity. Because of the ease with which they can be created as well as utilized, they have become highly prevalent for medium-height residential and office buildings as well as

parking garages. It's because of how cheap they are to produce (simple formwork and reinforcement, flat soffit allowing for easy placement of equipment, and installation underneath the slab [1].

Failure due to punching shear in a flat plate system typically occurs all of a sudden and contributes to the eventual collapse of flat plate structures. As a result, extreme vigilance is required in the design of slabs, and careful consideration should be given to the task of avoiding the condition of unexpected collapse. Because of the catastrophic scale of the failure that was revealed at the junction between the slab and the column, the attention of the engineers has been directed to it [2].

Researches significant

1. A study of the effect of having an opening adjacent to the column in flat slab and its effect on the structural behavior.
2. Compare between experimental and theoretical results.
3. Studying the effect of several types of shear collar to improve the behavior flat slab that contain opening adjacent to the column.

Material

1. **Cement**

In this investigation, (type I|) Portland cement was used (Baziany). To avoid exposure to various atmospheric conditions, it is stored in a dry environment. Tables 1 and 2 detail a findings for chemical analysis and physical testing conducted on the cement used in the project. This conforms to a specifications of Iraqi standard specification No. 5/1984 [3].

Table 1 Cement Chemical Analysis.

Oxide Composition	Abbreviation	Content by Weight (%)	Limit of Iraqi Specification No.5/1984[3]
Silica	SiO2	20.87	-
Alumina	Al2O3	4.15	-
Iron oxide	Fe2O3	3.39	-
Sulfate	SO3	2.57	< 2.8%
Lime	CaO	63.11	-
Magnesia	MgO	2.7	< 5%
Loss on ignition	L.O. I	3.72	< 4%
Free lime	F.L.	1.12	-
Lime saturation factor	L.S.F.	0.95	(0.66-1.02)%
Insoluble residue	I.R	0.69	< 1.5%

Table 2 Physical Test of Cement

Physical Characteristics	Results	Iraqi standard No.5/ 1984 [3]
Specific surface area (Blaine method) (m2/kg)	346 m^2/kg	(230 m2/kg) lower limit
Setting time (vacate apparatus) Initial setting time, (min.) Final setting time, (hrs)	 160 5	 Not less than 45min Not gretar than 10 hrs
Compressive strength, (MPa) 3 days 7 days	 22.4 27.2	 Not less than 15 MPa Not less than 15 MPa

1. Fine Aggregate

This study utilized natural sand from the Al-Ukhaidher region in Iraq for its concrete mixtures. The maximum size of the fine aggregate is 4.75 millimeters; the fine aggregate's grade is stated in Table 3. The results showed that the grading of the fine aggregate was within the limits of the Iraqi specification (IOS 45/1984) zon(2) [4].

Table 3 Sieve Analysis of Fine Aggregate

Sieve size (mm)	Cumulative percentage weight Passing (%)	Limits of the IQS No.45/1984 (zone 2) [4]
10	100	100
4.75	100	95-100
2.36	83.56	80-100
1.18	63.6	50-85
0.60	38.8	25-60
0.30	14.68	5-30
0.15	3.08	0-10

2. Coarse Aggregate

Crushed gravel with maximum size of (12.5 mm) was used throughout this work. The crushed river coarse aggregate was washed and cleaned with water several times and then dried in the air. It was then used in a saturated surface dry condition. Table 4 shows the grading of the coarse aggregate and the limits specified by Iraqi specification (IOS 45/1984) [4].

Table 4 Sieve Analysis of Coarse Aggregates

Sieve size (mm)	Cumulative percentage weight Passing (%)	Limits of the IQS No.45/1984 [4]
19	100	-
12.5	100	90-100
9.5	91.89	85-100
4.75	3.53	0-25
2.36	0.02	0-5

3. Steel Reinforcement

The deformed bars that used throughout the present study are of 6mm in diameter. The spacing between bars was 75 mm in two direction. The deformed bars are used for reinforcing the reference slab specimens throughout the present study. The tension test results of such bars are listed in Table 5 while figure 1 shown the testing machine of that tests.

Figure 1 Test Setup for Steel Bar

Table 5 Tension tests results for steel bars within this study*

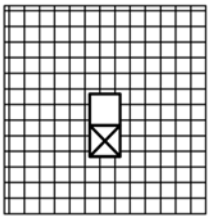
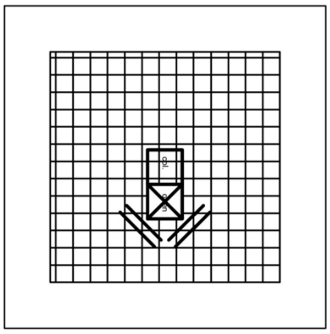
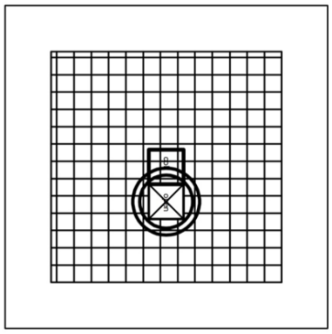
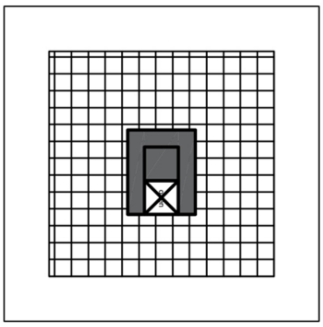
"Nominal	"Actual	"Weight	"Yield stress	"Ultimate

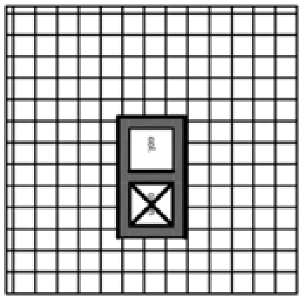
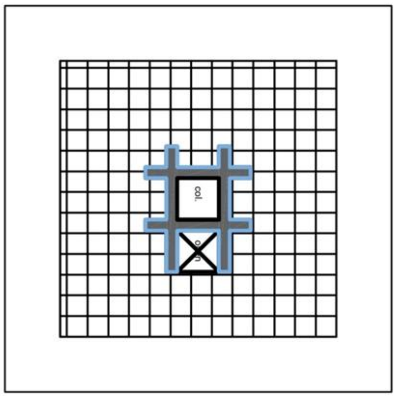
diameter mm”	diameter mm”	(kg/m)”	MPa”	strength MPa”
6	5.92	0.216	435	554
4	3.93	0.169	425	538

Experimental program

The experimental work is based on testing seven specimens, divided into according to type of the shear head reinforced, details are shown in table 6.

Table 6 Characteristics of Test Slabs.

Specimens	Opening and Dimension	Shear Head Reinforcement	Shape
R	Without	Without	
RO	150*150	Without	
SOD	150*150	Diagonal bars (150mm) at opening corners.	
SOS	150*150	Collar as stirrups shape around opening.	
SOP	150*150	Plate in tension face with 375*375mm.	

SOC1	150*150	Angle collar (300*300mm) around column and opening.	
SOC2	150*150	Angle collar (375*300mm) around column and opening.	

Numerical program

1. **Material Modeling of Concrete**

Depending on the (Abaqus) program, the specimen can be formed by choosing the command (With Standard/Explicit Model) when opening the program, as through it all the parts related to the specimen are created (the user interface responsible for the structural analysis of the shape, whether the analysis is static or dynamic). In order to create finite element model using (Abaqus) program, several steps must be completed and errors should be avoided to run and analysis the models correctly, which includes determine the type of elements, material properties, choose the correct interaction between the parts, choose the acceptable mesh, and then apply a non-linear analysis. The elements types that were used to finite elements modeling of the selected solid slab using (Abaqus) program are shown in Table 7. It is worth noting that each element was used to represent a certain part of the solid slab with collars.

Table (7) Finite Element Representation of Structural Components

Specimen Components	Finite Element Representation	Element Designation in Abaqus
Steel plate, Steel angle	Shell/Extrusion	Linear quadrilateral, Type S4R
Concrete	Solid	Linear hexahedral, Type C3D8R
Steel Reinforcement	Solid	Linear hexahedral, Type C3D8R

2. **Properties and Parameters**

The term "parts" are used to define the geometrical properties of the elements such as dimensions, thickness, cross-sectional area, and diameters. The shape is also determined whether it is two-dimensional or three-dimensional, with the choice of the type and basic feature of the drawn shape, in addition to many other variables. As for the properties of the material, it is used to introduce the properties and behavior of the materials approved in the research, depending on the mechanical properties of the materials examination, such as the modulus of elasticity, stress-strain curve, Poisson's ratio, density and yield state. Each type of element contains many details of the basic information that is identified with the elements in the (Abaqus) program library and the parameter value of the elements needs to be similarly represented by the tests of solid slab.

3. Modeling and Meshing Concrete

To form the concrete block in (Abaqus) program, the element is first selected (creating a part), as a list appears containing space modeling, choosing three dimensional and type of deformation, whether the shape is deformable or fixed, and the basic feature through which the type and shape of the element is determined. The concrete is defined as a solid material after the identification process, the dimensions of the cross-section of the concrete section are entered, which is equal to (1000×75mm) and length of (1000mm). Now the concrete model is equipped to be divided into small and regular bodies to obtain a smooth analysis process and also to obtained accurate results (this process is called mesh). Square or rectangular bodies are used when making the mesh, as well as adopting the same mesh numbers used for all the formed elements. Modeling and meshing of the concrete block is shown in Figure (2).

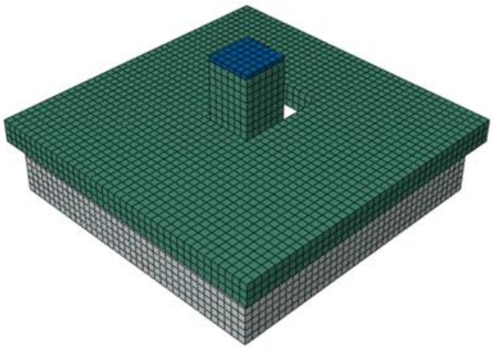


Figure 2 Modeling and Meshing of Concrete Block

4. Steel Reinforcement Modeling

The reinforcement can be modeled with different methods in Abaqus including smeared reinforcement in the concrete, beam elements with the embedded region or built in rebar layers. In this study, embedded region was used for modeling reinforced steel. The effective way of reinforcement modeling is a truss element of which the only necessary input is the cross sectional area of bars.

Results

1. Ultimate Load

The ultimate loads of the modeled slabs were indicated by the state that the slabs no longer can support additional load . Table (8) shows the ultimate load and ultimate deflection of all tested slabs obtained from the numerical study (ABAQUS) and experimental tests. The percentages of differences between the experimental results and the numerical results of the greatest pregnancy range from (2.1 – 10.2) %.

Table 8 Experimental and Numerical (ABAQUS) Ultimate Load.

Specimens	Ultimate load Pu (kN)		$\frac{Pu \text{ FEM}}{Pu \text{ EXP.}}$	Ultimate Central Deflection Δ_u (mm)		$\frac{\Delta_u \text{ FEM}}{\Delta_u \text{ EXP.}}$
	EXP.	FEM		EXP.	FEM	
R	96	101	1.052	7.4	8	1.081
RO	70	74	1.057	7	8.1	1.15

SOD	73	76	1.041	7.3	5.9	0.80
SOS	75	78	1.04	8.5	9.1	1.07
SOP	81	84	1.037	10	9.2	0.92
SOC1	88	97	1.102	7	10	1.42
SOC2	91	93	1.021	9	9.2	1.22

2. Load-Deflection Behavior

Figures (3) to (9) show the experimental and numerical (ABAQUS) Load-Central deflection behavior of all tested slabs.

In general, it can be noted from the Load-Deflection plots that the finite element analysis agrees well with the experimental results throughout the entire range of behavior.

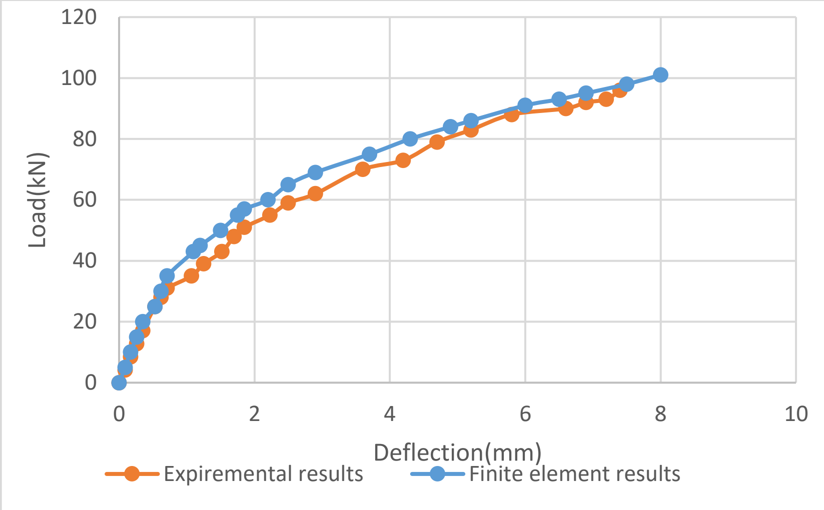


Figure 3 Experimental and numerical results comparison of R specimen

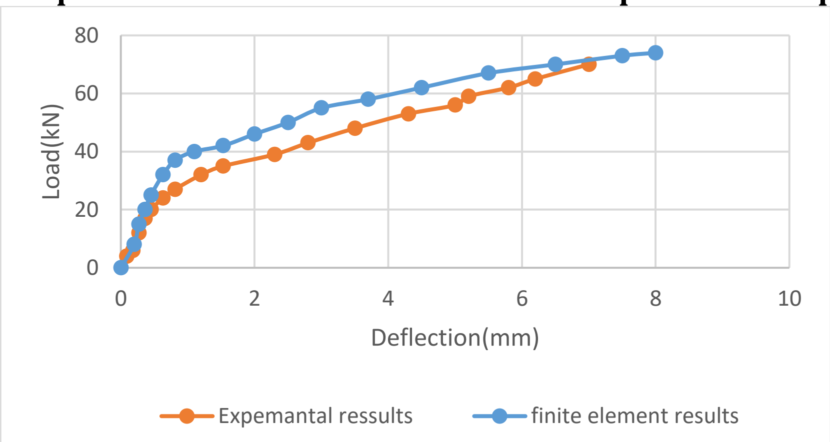


Figure 4 Experimental and numerical results comparison of RO specimen

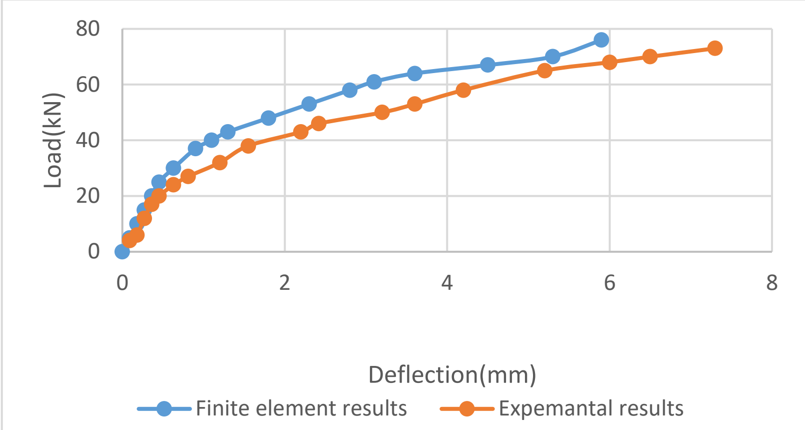


Figure 5 Experimental and numerical results comparison of SOD specimen.

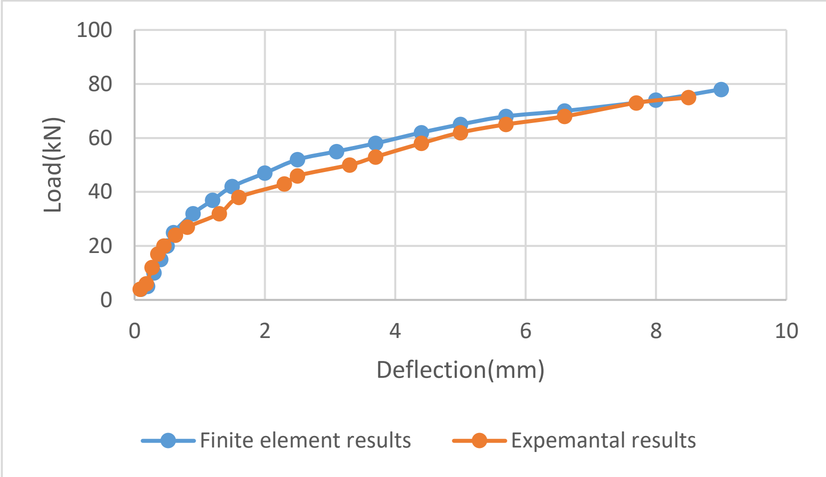


Figure 6 Experimental and numerical results comparison of SOS specimen

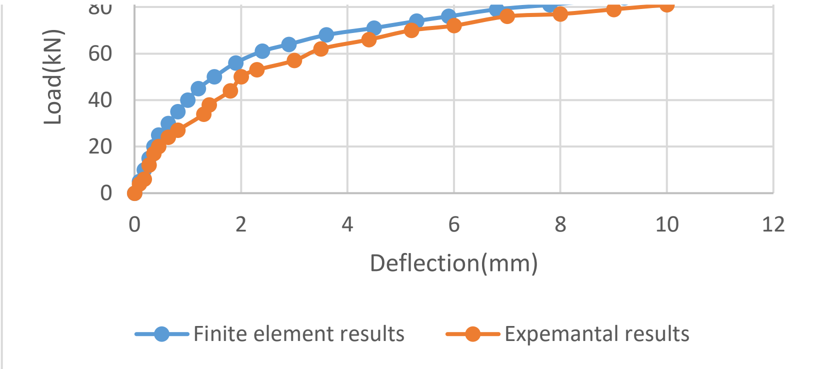


Figure 7 Experimental and numerical results comparison of SOP specimen

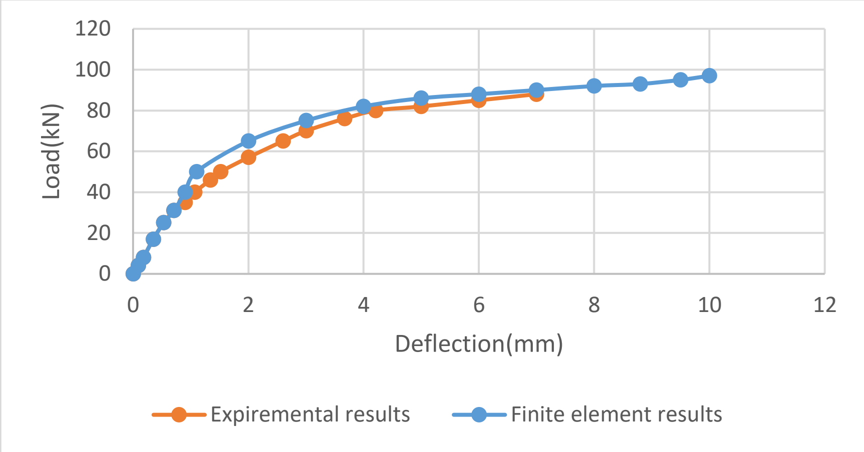


Figure 8 Experimental and numerical results comparison of SOC1 specimen

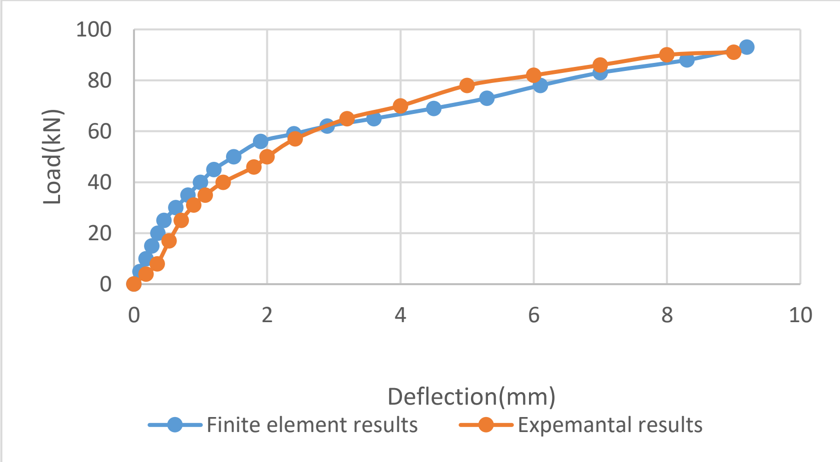


Figure 9 Experimental and numerical results comparison of SOC2 specimen

Reference

1. Aurelio, M., "**Punching Shear Strength of Reinforced Concrete Slabs**", ACI Structural Journal, V. 105, No. 4, July-August 2008.
2. Tuan, N., "**Punching Shear Resistance of High Strength Concrete Slabs**", Electronic Journal of Structural Engineering, Department of Civil and Environmental Engineering ,The University of Melbourne, 2001, PP. 52-59
3. Iraqi Specification (IQS), No.5/(1984), "**Portland Cement**", Ministry of Planning, Central Organization for Standardization and Quality Control.
4. Iraqi specification (IQS), No.45/(1984), "**Aggregate from Natural Sources for Concrete and Construction**", The Ministry of Planning, Central Organization for Standardization and Quality Control.