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EFFECT OF DIFFERENT PARAMETERS ON PUNCHING SHEAR FAILURE IN FLAT PLAT-EDGE COLUMN CONNECTION

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الملخص

تعرض الورقة هذه نتائج تحليل باستخدام نظرية العناصر المحدودة الغير خطية للخرسانة المسلحة عند مناطق اتصال العمود بالبلاطة المسطحة. وتم التحقق من هذا النموذج وذلك بمحاكاة نتائج معملية باستخدام برنامج (ANSYS). وقد تم استخدام سلسلة من نماذج العناصر لدراسة البلاطات المسطحة عند منطقة إتصال عمود الحافة بالبلاطة. في هذه الدراسة تم التحقق من تأثير نسب تسليح الانحناء وسمك البلاطة وأيضاً تأثير العمق الفعال وأبعاد العمود ومقاومة الخرسانة للضغط على سلوك البلاطات المسطحة عند منطقة الاتصال باستخدام نظرية العناصر المحدودة. إن سلوك قص الاختراق للبلاطات المسطحة قد أظهر محاكاة ملائمة للبلاطات المسطحة.

ABSTRACT

This paper presents the results of non-linear finite element analysis of reinforced concrete flat plate- edge column connections. The simulation of experimental data has been checked by using ANSYS software program. A series of finite element models are developed in order to perform the study on edge flat plates-column connection. The investigation has studied the effect of flexural reinforcement ratio, flat plate thickness and effective depth, column size and concrete compressive strength on the behavior of the flat plates-column connection. The simulation of punching shear behavior of flat plates-column connections is indicated to be satisfied results compared to experimental data.

KEY WORDS: Finite Element Analysis; Flat Plate; ANSYS; Edge Column Connection

INTRODUCTION

There is no doubt that punching shear is considered one of the most critical issues facing flat plate building systems which results from nature of this failure mode. The location of a slab could fail in shear by developing a failure surface due to overloads which can lead to punching shear failure. This type of collapse is the main reason of flat plate and flat slab buildings. Recently, this topic of research is the most interest areas in the field of concrete structures. Numerous tests have been carried out to estimate the punching shear strength of slabs. Vast number of theories has been put forward to predict the strength observed in these tests. In this study an experimental investigations and analytical approach adopted will be presents with comparison of the results.

PUNCHING SHEAR MECHANISM

Where a column rests on a two-way footing or when a two-way slab is overloaded with a concentrated load, diagonal tension cracks form that encircles the load or column. These cracks are invisible, except as flexural cracks. Such cracks extend into compression area of the slab and encounter resistance near the load similar to the shear-compression condition. The footing or slab continue to take load until fails around the column further out from the load or column. The first diagonal cracks thus proceed to failure in punching shear type of failure directly around the concentrated load.

Different Codes recommend a single punching shear strength calculated at a pseudo-critical distance from the column face or edge of the load for compromising between initial cracking and the final shear condition at failure for different ratios between column (or load) dimension and footing (or slab) thickness [1].

FINITE ELEMENT METOD

In this method, the slab is divided into a number of sub-regions or finite elements, which are generally triangular, rectangular or quadrilateral in shape. They are considered interconnected only at discrete points, called nodes, at the corners of the individual elements. The main issue in the application of the finite element method to linear elastic slab systems is to obtain a suitable force-displacement relationship between the nodal forces and the corresponding displacements at the nodal degrees of freedom. A further complication, in applying the method to reinforced concrete, is the derivation of a suitable set of constitutive relations to model the slab behavior under various loading conditions [2].

Modeling transverse shear by finite elements is one way of predicting behavior. In order to model transverse shear, proper finite element formulations must be used. For plate and shell structures this usually means using either three-dimensional elements or two-dimensional elements to model parts which can be approximated by such models. Three-dimensional elements are powerful and are an excellent choice for modeling details of the structure, but are inefficient for global analysis [3].

A model for predicting punching shear failures at interior slab-column connections is developed based on experimental results obtained from previous studies. This model has been incorporated into a new reinforced concrete slab element for the nonlinear analysis program, Drain-2DM, along with the desired unloading behavior when a punch occurs. The reinforced concrete slab element was tested by modeling a 4 story reinforced concrete frame building that experienced punching shear damage during the Northridge Earthquake. The observed punching shear failures were successfully post calculated using the reinforced concrete slab element [4].

THE STUDY MODELS

In order to verify the finite element model for simulating the behavior of column-flat plate connections, ANSYS was performed to test 7 of the experimental work specimens from literature review [5-8].

The Table (1) shows the details of different specimens of compressive strength of the concrete, slab and column dimensions, effective depth and reinforcement ratio.

The steps of flat plate simulation process for edge column connections, where (1F) flat plate was chosen to model in the ANSYS program from experimental work specimen [7, 8].

Table 1: Details of the different specimens

Column Position	Researchers	Series Flat plate, Name	Constant/Variable Controlling Data and Their Ranges								
			Slab Size(m) L*B*t_s	Col Size (m) b*c	Material Property (MPa)			Effective Depth (m)	Reinforcement ratio		
									Flat plate		Col
					f'c	f_t	fy		Top	Bot	VI.
Edge flat plate-Column Connection	Ref.[5,6]	H	1.6*0.9*0.2	0.25*0.25	20	2.5	360	0.18	1.10	1.10	1.63
		N	1.8*1.1*0.2	0.4*0.4	20	2.5	360	0.18	1.10	1.10	2.03
	Ref.[7,8]	1F	2.2*2.2*0.11	0.25*0.25	25	2.5	516	0.09	1.16	1.16	1.56
		2F	2.2*2.2*0.11	0.25*0.25	26.9	2.5	516	0.09	1.16	1.16	1.56
		3F	2.2*2.2*0.11	0.25*0.25	27.5	2.5	516	0.09	1.16	1.16	1.56
		4F	2.2*2.2*0.11	0.15*0.60	26.3	2.5	546	0.09	1.18	1.18	1.56
		5F	2.2*2.2*0.11	0.15*0.60	27.7	2.5	546	0.09	1.18	1.18	1.56

RESULTS

Many results may be obtaining from a previous data processing and analysis as follow: in flat plate (1F) analysis stop under the load influential 95.3kN, so the failure load of flat plate in the ANSYS program 95.3kN. As shown in Figure (1).

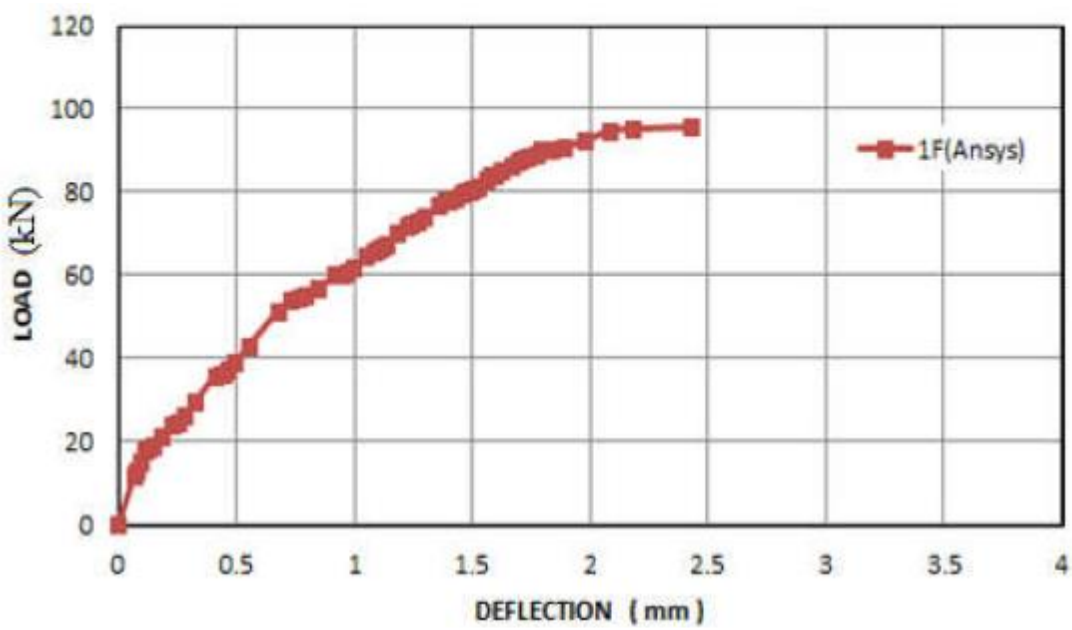

Figure 1: failure load of flat plate (1F) in the ANSYS program

Steel reinforcement stress

Study of steel reinforcement stress has important effect for usage to distinguish type of occurred collapse for steel or concrete. Also, if steel reinforcement stress exceeds yield stress, a steel collapse will occur and steel reinforcement stress less yield stress, a concrete collapse will occur. For this flat plate (1F), steel stress was equal to 88 MPa, and it lesser than a yield stress, so the collapse of concrete occurred, as shown in Figure (2).

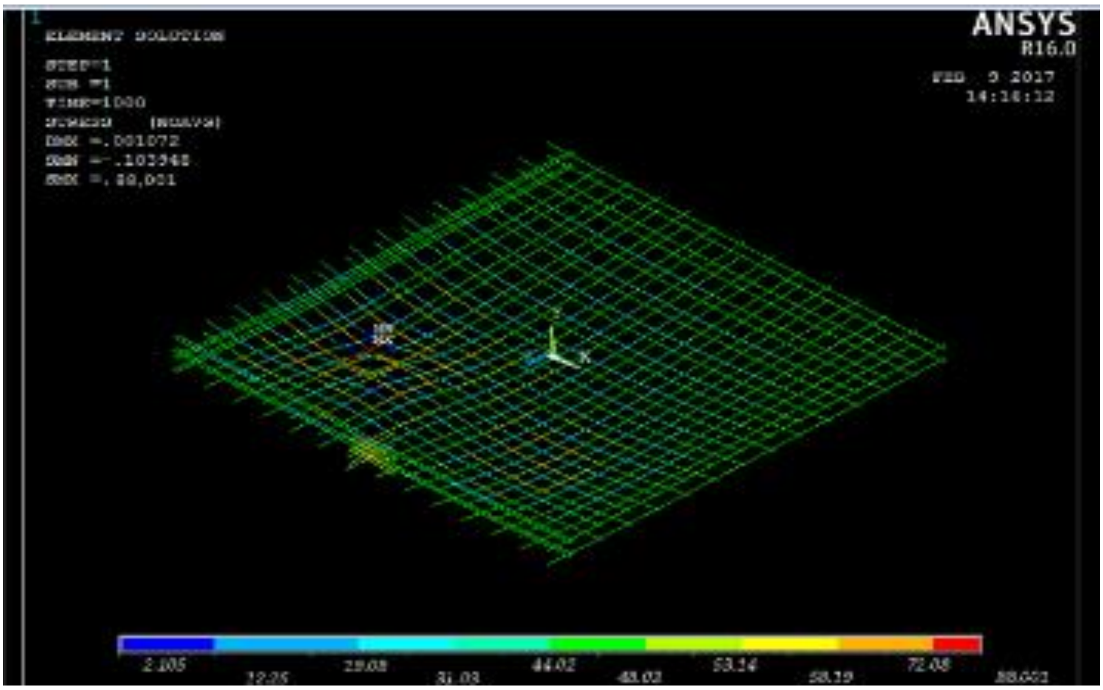

Figure 2: Steel reinforcement stress- Link180 for model (1F) from ANSYS

Deflection

One of the most important characteristics of ANSYS program is its ability to give deflection curve with load at distance (d) from the edge of the column as shown in Figure (3).

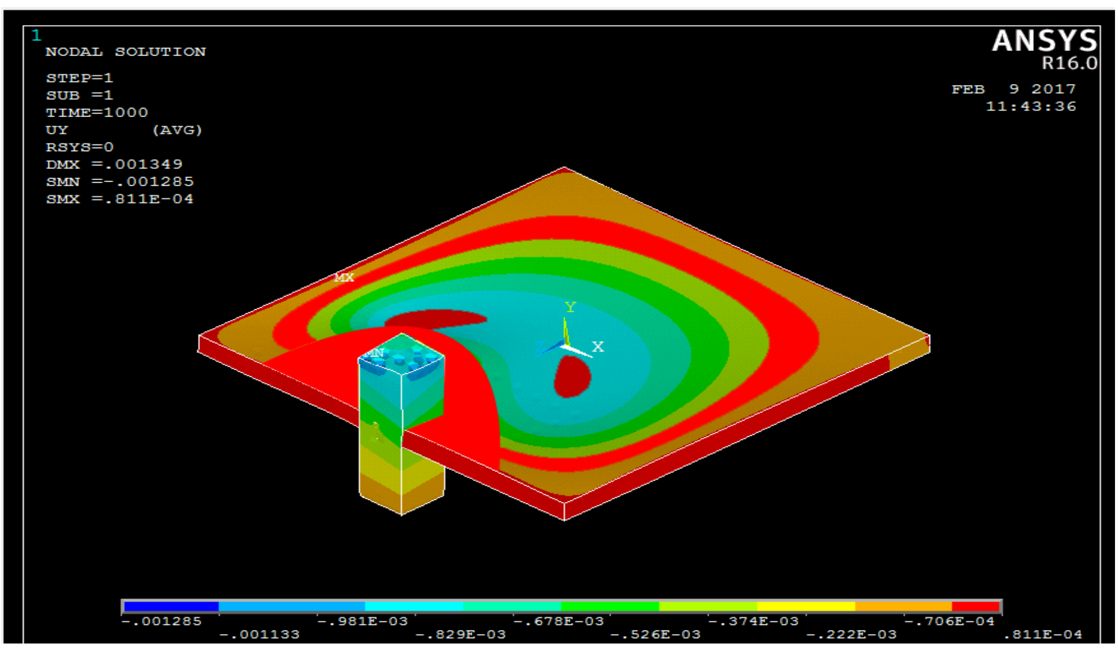

Figure 3: 3D- Deflection in flat plate for model (1F) from ANSYS

In comparison of deflection curve in flat plate for model (1F) between ANSYS and experimental study are nearly the same as it is shown in Figure (4).

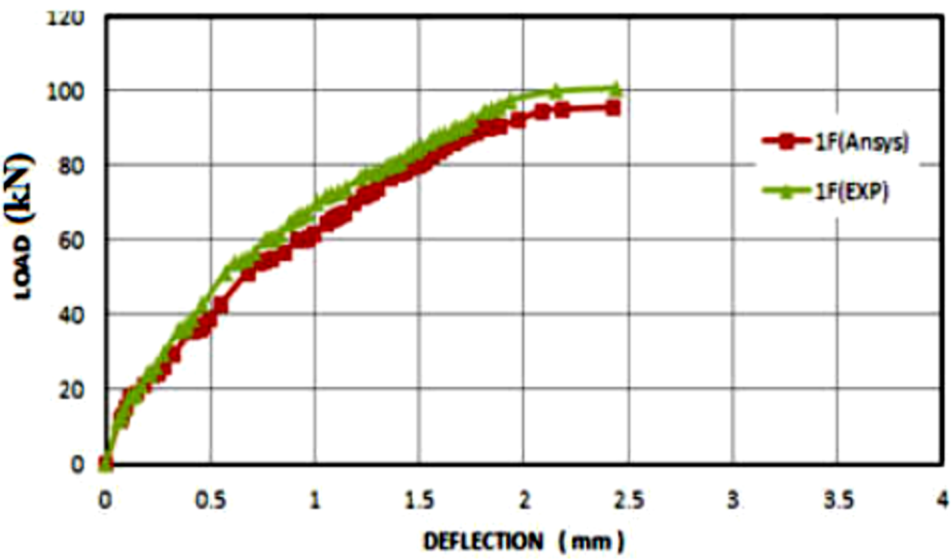

Figure 4: Load deflection curves for the experiment and numerical analysis

RESULTS ANALYSIS FOR EDGE COLUMNS CONNECTION OF FLAT PLATES

Analysis Results

After processing the data and performing analysis for the appropriate boundary conditions, ANSYS program has the possibility to give accurate results. The results of the simulation analysis for 7 of different specimens are shown in the following Table (2).

Table 2: The results of the simulation

Column Position	Researchers	Series	Flat plate Size(m) L*B*t_s	Col Size (m) b*c	Material Property (MPa)			Load Failure (KN)
					f'c	f_t	fy	
Edge flat plate-Column Connection	Ref [5,6]	H	1.6*0.9*0.2	0.25*0.25	20	2.5	360	353.9
		N	1.8*1.1*0.2	0.4*0.4	20	2.5	360	388.0
	Ref [7,8]	1F	2.2*2.2*0.11	0.25*0.25	25	2.5	516	95.3
		2F	2.2*2.2*0.11	0.25*0.25	26.9	2.5	516	145.2
		3F	2.2*2.2*0.11	0.25*0.25	27.5	2.5	516	158.5
		4F	2.2*2.2*0.11	0.15*0.60	26.3	2.5	546	163.8
		5F	2.2*2.2*0.11	0.15*0.60	27.7	2.5	546	167.1

Comparison Results

The results of the ANSYS program were compared with a literature experimental data with an average accuracy 92%. Simulation of ANSYS program gives very near results to the experimental work, and the value of results of simulation less than value of the experimental results in most of the specimens. The use of non-linear analysis of finite element method reduces the time, effort required, and helps to determine a failure load compared with experimental work. Table (3) shows the difference between results of ANSYS program and for literature experimental results.

Table 3: Different Numerical results against experimental results.

series	Flat plate-column connection	Load EXP (KN)	Load ANSYS (KN)	Error (%)
H	Edge	328.92	353.92	7.60
N		390.50	388.012	0.63
1F		106	95.3	10.09
2F		149.8	145.2	3.07
3F		112.4	158.5	29.30
4F		168.1	163.8	2.55
5F		171.3	167.1	2.45

Parametric Study for Edge Flat Plate-Column Connection 6.3.1Column Size

Size of the column is one of the main variables that effect on the resistance of punching shear of flat plate. Generally, increasing dimensions of the column from 250mm to 400 mm increases of the flat plate resistance for punching shear. However, it sometimes becomes uneconomic. As shown in slab H, N which has dimensions 250x250mm and 400*400mm respectively and slab thickness remain the same of 0.2 m. The load failure in slab H around 353.9 kN compared to the load failure in slab N which is approximated to 388 kN. It can be calculated as increased in percentage of 9% as shown in Figures (5).

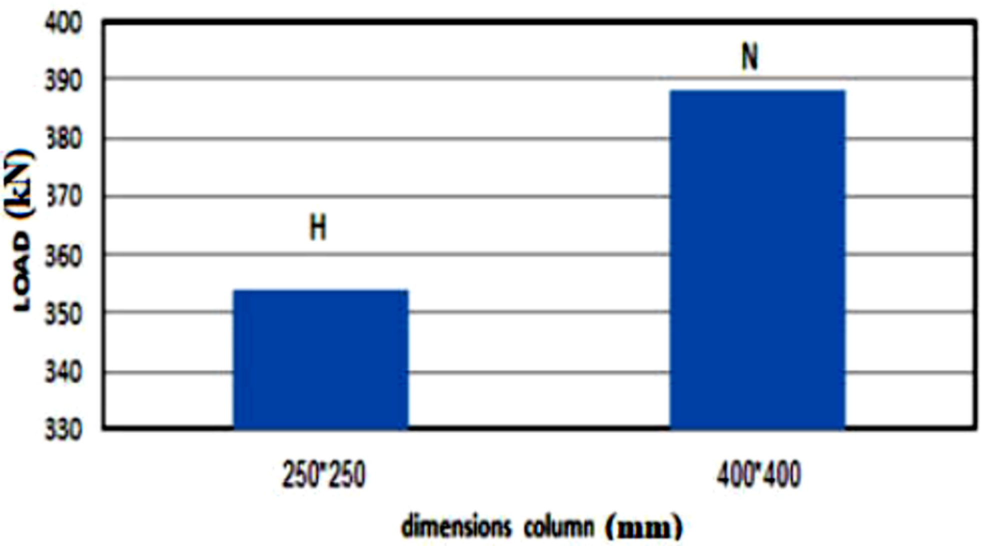

Figure 5: Influence column dimensions on failure load for edge column

Concrete Compressive Strength

The compressive strength of concrete has a major influence on the punching shear strength behavior of flat plate [9]. The load failure increased from 95.3 kN in slab 1F to 158.5 kN in slab 3F for compressive strength 25 MPa and 27.5 MPa respectively. This leading to increase the percentage of loading failure around 66% in Figure (6) shows the influence compressive strength on failure load.

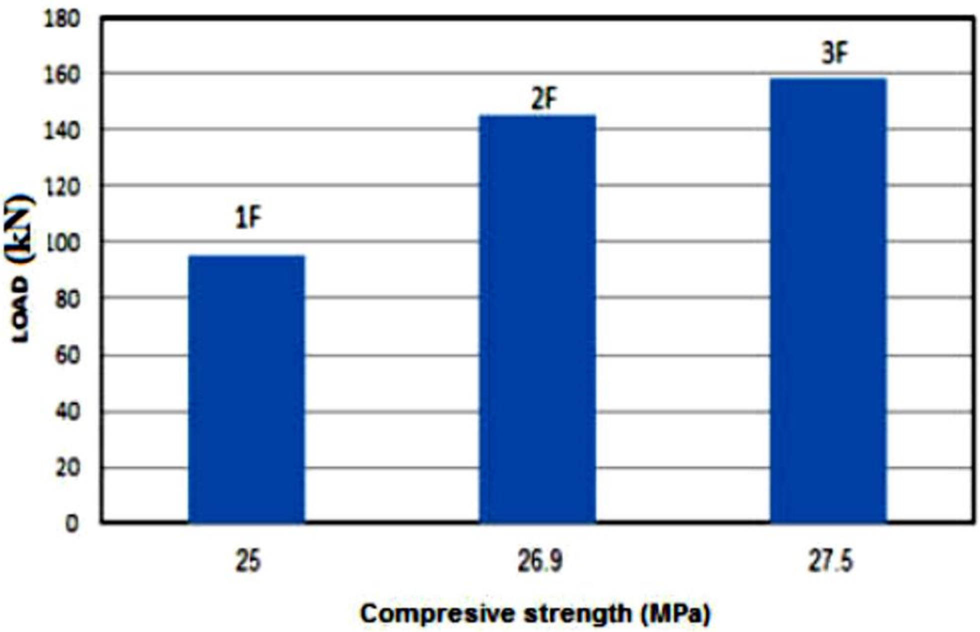

Figure 6: the difference of influence concrete strength on failure load for edge column

CONLUSIONS

From the investigations carried out the following deductions can be made for nonlinear analyses of reinforced concrete plates:

- There is an agreement between numerical and experimental results can establish the validity and acceptability of the computational models. It can be noticed that Load-deflection curves show very close results at the load history for all the test flat plates.
- Column dimension increasing or loading area can increase with the ultimate load capacity.
- Compressive strength of concrete has a remarkable effect on the punching shear strength for reinforced concrete.

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