PUNCHING TESTS ON FLAT-PLATES

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ABSTRACT: The connection between the slab and the column in flat-plate structural system, in which the slabs are carried directly by columns, is generally the most critical part affecting the overall performance of the structure. The sudden and brittle failure of the connection, called punching shear failure, takes place when a plug of concrete is pushed out of the slab immediately under the loaded area. Over the years, several experimental and analytical works have been carried out investigating the different aspects of the punching failure in flat-plates. Within the content of the study presented herein, 26 circular flat-plate specimens with monolithic square column stubs were tested well beyond failure point. Test specimens were approximately half scale isolated members representing the region of a multi-panel system around an interior column. The variables of the experimental investigation were the concrete compressive strength, load eccentricity, slab flexural reinforcement ratio and the existence of the Steel Fiber Reinforcement.

The experimental phase of this study was performed at Boğaziçi University Structures Laboratory, and the funding was provided by the Boğaziçi University Research Fund and The Scientific and Technical Research Council of Turkey.

INTRODUCTION

The reinforced concrete flat-plate structural system, in which slabs are carried directly by columns, is mostly favored due to the economical and architectural advantages. Flat-plate, a special type of flat-slab system is essentially constructed without drop panels and column capitals. Besides the economy in workmanship during the construction, a high modularity in floor space partitioning during the service life of the structure is available in flat-plate systems. The major concern with the flat-plate is its susceptibility to punching, which is a local brittle type of shear failure of the plate-to-column connection. Punching failure in slabs takes place under concentrated loads when a plug of concrete is pushed out of the slab immediately under the load. Punching failure in the connection occurs mainly due to gravity loads with or without unbalanced moments caused either by uneven span loading or earthquake type of lateral loads.

Flat-plate type of construction has been in use since the beginning of this century. At the initial stage of the construction practice, the structural system and the behavior of the slab-column connection was being analyzed by empirical formulas, and these methods were reported to be patented [1]. After the construction of the first flat-slab structure in 1906 in Minneapolis by C.A.P. Turner, the punching capacity calculation and the method of structural analysis have been the subject of numerous investigations, and multitude of equations have been developed. The need of having sound design equations has brought the flat-plates to the research field in 1913. The phenomena of punching was first introduced by Talbot [2], who conducted experimental research on single column footings, and observed the punching failure in laboratory. Over the time, extensive analytical and experimental research has been conducted on the capacity prediction, behavior and the structural analysis of flat-plate systems.

FACTORS INFLUENCING THE PUNCHING CAPACITY

The shear failure in reinforced concrete members is actually failure due to the principal tensile stresses. The failure occurs when the principal tensile stress exceeds the tensile capacity of the concrete. By its nature, this type of failure is sudden and destructive. For the structural members such as beams and columns, the shear loads exceeding the concrete capacity, are carried by the steel ties crossing the plane of shear cracks. In the case of flat-plates, for loads exceeding the concrete tensile capacity, the strength is increased either by increasing the concrete compressive strength in turn the tensile strength, increasing the slab thickness or by providing special type of shear reinforcement. From the published research results it can be concluded that, plate punching capacity is affected by a wide rage of variables such as material properties, dimensional ratios and special additives to concrete mixture.

Concrete Strength

The available research on concrete elements reveals that the structural behavior of the Normal Strength Concrete (NSC) is different than that of High Strength Concrete (HSC). The flat-plate punching design recommendations in building design codes are mostly applicable to the slab-column connections in monolithic concrete structures having concrete design compressive strengths not exceeding 41 MPa, which is NSC [3]. For higher concrete strengths, the reliability of these code equations need to be verified. In most of the design codes, square root of the concrete compressive strength is used to predict the punching capacity of the concrete slabs. The published research reveals that, the cubic root of the concrete compressive strength generally yields better results [4].

Flexural Steel

Several research projects have been carried out in order to investigate the effect of the flexural reinforcement on the punching load and behavior of the flat-plates. It is observed that the number of bars and their spacing in the punching zone is probably a better parameter to consider for the contribution of flexural steel to punching strength [5]. The punching loads increases with decreasing bar spacing, keeping the slab flexural capacity, P_{flex}, calculated by using Yield Line Analysis, constant [5]. Although smaller flexural bars with closer spacing is recommended for higher punching loads and better behavior [5], the flexural reinforcement can not be fully effective due to the bond failures and splitting if it is too closely spaced. The detailing of the reinforcement of reinforced concrete flat-plate structures is a very important aspect in preventing them from progressive failures after a local punching failure. In order to limit the progressive failures under gravity loads or seismic excitations slab compression reinforcement is recommended by the researchers [4].

Load Eccentricity

Slab-column connections in flat-plate structures carry a combination of shear and unbalanced moments. This combination of shear and unbalanced moment is unavoidable at the edge and corner columns and occurs at interior columns as a result of unequal spans and patterned or lateral loads. For gravity loads, it is assumed that the shearing loads are uniformly distributed over the critical punching perimeter. In the case of moment transfer, the moment induced shear stresses are added to the gravity shear forces. The unbalanced moments are transferred from the column to the slab by means of bending and torsional resistance of the vertical slab column interfaces. With higher gravity loads, the available shear capacity left over to resist unbalanced moments due to lateral loads is reduced [6].

Fiber Reinforcement

Fiber reinforcing can be explained as the method of increasing the material and structural properties of a base material by adding a stronger fiber type material relatively in smaller amounts. Various types of fibers have been in use for the strengthening of the weaker matrix for many centuries. The addition of straw to mud bricks and to mud plastering in the adobe structures are the oldest well known fiber reinforcing application on the developing pathway of the fiber reinforcement technology. Only very limited experimental investigations are available related to the punching shear strength of flat plates with Steel Fiber Reinforcement (SFR). From the results of a series of tests on SFR concrete flat-plates, Swamy et.al. [7] and Alexander and Simmonds [8] concluded that the existence of SFR significantly increases the ultimate punching strength and the ductility of the connection

Dimensional Ratios

There is published research revealing that the punching strength is affected also from the dimensional ratios between the column and the plate. The ability of a slab to resist unit shear stresses diminishes as the size of the loaded area increases relative to the slab thickness [4]. Therefore the ratio of column size to the effective depth of the slab (r/d), has a bearing on the punching capacity of the flat-plate systems. Also the column shape and the column aspect ratio has a bearing on the punching loads. Experiments reveal that the strength of slabs with circular columns is greater than that of the square columns having the identical r/d and reinforcement ratios [4]. The column aspect ratio affects the punching capacity and the punching behavior. Experiments show that the punching strength for loading through rectangular areas having aspect ratios greater than two, are less than for loading through square areas [4].

RESEARCH SIGNIFICANCE

According to the available code design equations, the punching strength of the flat-plates depends solely on the mechanical properties of the concrete, nature of loading and the dimensions of the critical perimeter. On the other hand, the effect of spacing and the yield strength of slab flexural reinforcement, use of high-strength concrete, and the effect of additives such as SFR are not considered for the capacity calculations. The introduction of the HSC, produced by using high range water reducing agents, may have an influence on the specimen capacity and behavior. The design equations derived from the research on NSC specimens, need to be questioned for the case of HSC flat-plates.

RESEARCH PROGRAM

An experimental study on 26 circular flat-plates with reinforced concrete square column stubs, extending at the top and the bottom of the plate, was carried out. The test specimens were approximately half scale isolated members representing the region of a multi-panel system around an interior column. The effect of load eccentricity, concrete compressive strength, reinforcement ratio, and the existence of SFR were investigated experimentally. In all the specimens, the ratio of the compression reinforcement was half of that of the tension reinforcement. The post failure behavior and the energy absorption capacity of specimens were also investigated in order to quantify the effect of above mentioned variables on the post failure capacity and the energy absorption behavior. The cracking pattern and the load-deflection behavior of the specimens were also investigated in order to highlight the effect of these variables.

Test Specimens

For the investigation of the selected variables, 26 flat-plate specimens were prepared and tested. The variables were; the concrete compressive strength, amount of slab reinforcement, existence of SFR and the load eccentricity. The specimens were designed in such a way that, only one variable was changed at a time, enabling the comparison of the influence of that specific variable. Two different P_{flex}/P_{TS} ratios were used in the specimen design, P_{TS} being the connection capacity according to the TS-500 [9].

Flat-plate test specimens had two layers of reinforcement mesh, each having square grids. The plate thickness of the specimens was t=120 mm and the effective depth was d=100 mm. The slab reinforcement details of the specimens are given in Figure 1. The yield strength of the ϕ10mm rebar used in NSC specimens was 507 MPa and it was 471 MPa for the ϕ14mm rebar used in the HSC specimens. For the steel fiber reinforced NSC and HSC specimens, DRAMIX ZC 60/0.80 hooked end type galvanized steel fibers with high yield strength (f_y>1100 MPa) were used. In order to simulate the plate-to-column connection realistically, square column stubs (200x200 mm) were cast on the tension and compression sides of the slabs. The column stub on the slab tension side was necessary for the proper anchorage of the column longitudinal bars.
The specimen designation and the corresponding variables are given in Figure 2. Specimen designations were chosen in such a way that all the variables could easily be read from the name of the specimen. The specimen name tags have four variable fields.

In the first field, the concrete nominal compressive strength designation is presented; letter “N” stands for NSC with f_c’=20 MPa while letter “H” stands for HSC with f_c’=80 MPa. The second field, explains the level of P_{flex}/P_{TS} ratio, in turn the amount of slab reinforcement; “R1” stands for a P_{flex}/P_{TS} value of 1.084 and “R2” stands for a P_{flex}/P_{TS} value of 1.581 calculated using the nominal concrete compressive strength values. The third field of the specimen name tag gives the eccentricity of the applied load; “E0” is for concentric specimens, “E1” for a load eccentricity of 100 mm and “E2” for 200 mm eccentricity. The last field contains the data for the amount of SFR used in the specimen; letter “F0” was used for specimens without SFR and “F1” was used for specimens containing 75 kg/m^3 of SFR (approximately 1 per cent fiber in volume fractions, V_{fF}=1 per cent).

Test Setup and Procedure

The specimens were supported over a circular boundary on which 12 evenly spaced tie-rods connected the test specimen to the reinforced concrete reaction block (Figure 3). The loading was applied through the lower column stub by a 1000 kN capacity manually controlled hydraulic ram. The level of the load was measured by a load cell mounted between the hydraulic ram and the roller support. The specimens were instrumented by electronic sensors such as a load reading device (Load Cell) and seven displacement measuring devices (LVDT). During the test, all the data was read and stored electronically.

Specimens were white washed before the test in order to trace the crack propagation during the test. It was tried to make the loading speed as low as possible and the loading regime of either of the specimens took approximately 10 to 15 minutes. During the test, load and displacement values were read at one second intervals by the electronic system. Applied load versus slab center net vertical deflection graph was monitored on the screen of the data acquisition system. At the time of punching failure, a sudden drop in loading was observed on the graph. Although significant drop in load capacity was defined as failure, the test specimens found another equilibrium position at a lower load level. This was called; residual or reserved strength. After excessive deflections, the load-deflection curve started to raise again. The test was terminated when this raise was observed on the computer screen.

EXPERIMENTAL RESULTS

The load-center deflection graphs of the specimens are given in Figure 4. The experimentally obtained values such as concrete cylinder compressive strength (f_c’), first cracking load level (P_{cr}), punching load level (P_p), residual load capacity (P_{re}), and their calculated counterparts are listed in Table 1.

Crack Formation

In all concentric NSC and HSC specimens with or without SFR, the first crack was observed on the tension side of the flat-plate and on four sides of the column at an average distance of 10 mm to column faces. In eccentric specimens, the first crack was only observed on the column front area at an average distance of 10 mm to column front face. The slope of the load-deflection curve, which is an indication of the plate stiffness, changed with the formation of the first crack. The cracks which appear at an average distance of 100 mm from the column face became the failure cracks when the punching took place in concentric and eccentric specimens. The average distance of 100 mm corresponds to the effective depth of the slab. In all of the specimens, regardless of the concrete strength, flexural reinforcement ratio, load eccentricity and SFR content, the compression side of the plates remained uncracked and uncrushed until the failure load. The number of cracks in specimens with SFR was much more than the number of cracks in specimens without SFR. The crack width and the crack spacing in specimens with SFR were smaller as compared to the counterpart specimens without SFR. The cracking in specimens with SFR was mostly confined to a region close to the column periphery.

Effect of Concrete Strength

The effect of concrete compressive strength is clearly observed on the load-deflection curves of the specimens. The initial slope of the load deflection curve is observed to be higher in HSC specimens as compared to the NSC specimens. Beyond the cracking point, the tangent stiffness values show the same trend. Post failure behavior of the specimens are also related to the plate concrete compressive strength. It is observed that the negative slope of the load deflection curve beyond the failure point increases as the f_c' increases, resulting abrupt failures in HSC specimens. The change in concrete compressive strength and the change in load capacities are compared in order to highlight the effect of f_c'. Increase in the square root of the plate concrete compressive strength and the change in P_{cr} and P_p values showed similar trends. The average increase in P_{cr} in specimens without SFR is 145% and the average increase in P_p in the same specimen group is 127%, corresponding to a 95% increase in the $(f_c')^{(1/2)}$. On the other hand, the change in capacities are observed to be more closely related to changes in the experimentally obtained split cylinder values.

Effect of SFR

It is observed from the test results that the SFR has a direct bearing on the specimen behavior and capacity. The punching failure of the flat-plate to column connections, is considered to be a brittle type of failure due to its abrupt nature. The effect of SFR on this type of failure may be summarized as the enhancement obtained in the energy absorption capacity, not only due to the increase in failure load, but also due to the large strain capacity provided at the post-failure stage. For both NSC and HSC, the slope of the descending portion of the load deflection curve was less steep when steel fibers were used. SFR may be considered as the most practical way to increase the punching capacity, post-failure residual strength, and the strain capacity with a minimum workmanship effort during the construction of the flat-plate building systems.

Plate Center Deflection

The center deflection of the plate at failure was influenced by the load eccentricity. In all the specimens, increasing load eccentricity resulted in decreasing center deflection at failure, regardless of the concrete strength, reinforcement ratio, and SFR content. In specimens with higher slab reinforcement ratio, the effect of load eccentricity on the center deflection at failure was more pronounced. It was observed that, the deflection profiles at failure load were also influenced by the variables of the experimental investigation. Investigation of the normalized deflection profiles revealed that, the increase in concrete compressive strength reduced the deflection regardless of the flexural reinforcement ratio and the SFR content.

Effect of Flexural Reinforcement

From the test results it was observed that, the punching and residual strength values of the specimens are influenced by the slab flexural capacity P_{flex} , which is calculated by using the actual material characteristic values and the Yield Line Theory. It is observed that, a linear regression between the P_{flex} and the above mentioned capacities give satisfactory results. It can definitely be concluded that the punching capacity increases with increasing flexural capacity or by the increasing tension reinforcement ratio. As can be seen from Table 1, as P_{flex} increased, the residual strength P_{re} increases.

The increase in the slab reinforcement ratio directly affects the flat-plate unit width bending moment capacity (m). A 50% increase in the slab reinforcement ratio caused an increase of approximately 44% in the unit width bending moment capacity of NSC and HSC specimens. Although it was observed from Table 1 that an increase in the flexural capacity results in an increase in the P_p and P_{re} values, the rate of increase in these capacities are smaller than that of r, (and m) in the specimens. In other words, an increase of 50% in r caused an increase of 10% in P_p for NSC-without-SFR specimens. A similar increase in r of HSC-without-SFR specimens caused approximately 20% increase in the P_p. Beside the flat-plate load capacities, the increase in the slab reinforcement ratio resulted in significant changes in the load-deflection behavior of the specimens. It was observed from the test results that the increase in r causes an increase in the post-cracking tangent stiffness in specimens, regardless of the concrete compressive strength and the load eccentricity. The residual strength (P_{re}), for all the specimens, increased with the increasing reinforcement ratio, r.

Effect of Load Eccentricity

Flat-plate specimens were loaded under three different load eccentricities; 0, 100, and 200 mm. The failure load, post-cracking stiffness of the load deflection curve, as well as the residual load capacity are observed to be influenced by the eccentricity of the applied load. With increasing eccentricity, a reduction in the punching capacity of the specimens was observed regardless of the concrete strength, slab reinforcement ratio, and the SFR content. The effect of load eccentricity on the strength and deformation characteristics of the specimens are given in Figure 4.

Per cent change in P_p with increasing eccentricity is comparable in NSC and HSC specimens without-SFR. For an eccentricity of 100 mm, NSC specimens failed at loads approximately 15 per cent less as compared to the concentric ones. On the other hand, an eccentricity of 200 mm, led to a capacity drop of 36 per cent as compared to the concentric specimens. The percentage of drop in punching capacity with increasing load eccentricity is slightly less in HSC specimens. Addition of SFR to NSC and HSC specimens increased the percentage of drop in P_p with the increasing eccentricities. For NSC-with-SFR specimens the average capacity loss (with respect to concentric specimen) for an eccentricity of 100 mm, was 22 per cent, while it was 15 per cent in NSC-without-SFR specimens. A similar trend was observed for higher eccentricities. The influence of eccentricity in HSC specimens was similar to that of NSC specimens.

Residual Load Capacity

The residual load P_{re}, at which the load capacity stabilized in the post-failure region, was influenced by the load eccentricities in a similar manner to the P_p values. It can be observed from Figure 4 that, the per cent drop in P_{re} with increasing eccentricity was more pronounced in specimens with higher slab reinforcement ratio (R2 series). It was difficult to judge the effect of eccentricity on P_{re} in specimens with SFR.

Capacity Prediction of Code Equations

The design equations related to the punching strength in the building codes, i.e. TS-500 [9] and ACI-318-95 [10] are used to predict the load capacities of the flat-plate specimens tested. ACI-318-95 specifies an upper bound for the concrete compressive strength (f_c'=69 MPa) that will contribute to the shearing strength of the concrete. In TS-500 the concrete strength properties are given in tabular form, and the maximum value of f_c' in these tables is 50 MPa. Although an upper limit for concrete compressive strength is not given explicitly in TS-500, the f_c'=50 MPa should be considered as the limiting value over which the proposed equations may not be valid. In the punching shear capacity calculations of the flat-plate specimens using the ACI-318-95 design equations, limitation on f_c' was taken into consideration. On the other hand, for TS-500 predictions, the concrete compressive strength beyond 50 MPa is considered to be contributing to the shearing strength, in a similar manner to lower strength concrete. The code predictions are comparable with the experimental results for the concentric and eccentric normal strength concrete specimens (e=100 mm) without SFR. The ratio of experimental to calculated values for the eccentric specimens with e=200 mm are consistently below unity, indicating a prediction on the unsafe side for both ACI-318-95 and TS-500. Comparatively, TS-500 results in better predictions for the e=200 mm eccentric specimens, regardless of the slab reinforcement ratio.

CONCLUSONS

The punching shear failure of the flat-plate to column connections is a brittle type of failure due to its abrupt nature. This abrupt nature becomes more pronounced with the increasing concrete compressive strengths. The initial and post-cracking stiffness of the specimens increases with the increasing concrete strength.. Addition of SFR to NSC and HSC specimens result in an increased punching capacity and an increased punching deformation, leading to a higher energy a6bsorbtion capacity at failure. Increasing the plate flexural capacity causes a relatively smaller increase in punching capacity. The per cent drop in punching load due to eccentricity is comparable in NSC and HSC specimens. Available code equation predictions are comparable with the experimental results for the NSC concentric specimens, and need to be calibrated for higher concrete strengths and for bigger eccentricities.

REFERENCES

1. ERSOY, Ugur *Reinforced Concrete 2: Slabs & Footings* Evrim Yayinevi, Istanbul Turkey, 245p., First Edition, 1995 (in Turkish)

2. Talbot, A.N. Reinforced Concrete Wall and Column Footings Bulletin 67, University of Illinois Engineering Experiment Station, March 1913

3. ACI-ASCE Committee 352 "Recommendations for Design of Slab-Column Connections in Monolithic Reinforced Concrete Structures," (ACI 352.1R-88) *ACI Structural Journal*, V.84, N.6, pp.675-696, November-December 1988

4. ASCE-ACI Task Committee 426 "The Shear Strength of Reinforced Concrete Members - Slabs," *Proceedings, ASCE*, V.100, ST8, pp.1543-1951, August 1974

5. Ozselcuk, Akin "Contribution of Flexural Steel to Punching Strength," M.S. Thesis, Department of Civil Engineering, Middle East Technical University, Turkey, 55 pp , 1980

6. Pan, A.P., Moehle, J.P. Reinforced Concrete Flat Plates under Lateral Loading: An Experimental Study Including Biaxial Effects Report No UCB/EERC-88/16, Earthquake Engineering Research Center, University of California at Berkeley, 262 pp., October 1988

7. Swamy, R.N., Ali, S.A.R. "Punching Shear Behavior of Reinforced Slab-Column Connections Made with Steel Fiber Concrete," *ACI Journal*, V.79, N.5, pp.392-406, September-October 1982

8. Alexander, Scott D.B., Simmonds, Sidney H. "Punching Shear Tests of Concrete Slab-Column Joints Containing Fiber Reinforcement," *ACI Structural Journal*, V.89, N.4, pp 425-432, July-August 1992

9. TS-500, Building Code Requirements for Reinforced Concrete, Turkish Standards, April 1984 (in Turkish)

10 ACI 318-95, Building Code Requirements for Reinforced Concrete, American Concrete Institute, Detroit, Michigan

TABLE 1- Experimental and Calculated Values for the Flat-Plate Specimens

Specimen	Experimental				Calculated			Expr./Calc	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	f_c' MPa	P_{cr} kN	P_p kN	P_{re} kN	P_{flex} kN	P_p [9] kN	P_p [10] kN	(3/6)	(3/7)
NR1E0F0	21.62	49	187.87	63	210	195.29	185.40	0.96	1.01
NR1E1F0	19.29	42	158.60	65	208	154.40	164.30	1.03	0.97
NR1E2F0	18.46	36	117.62	49	205	129.93	151.37	0.91	0.78
NR2E0F0	20.00	71	201.59	78	298	187.83	178.32	1.07	1.13
NR2E1F0	20.85	52	178.35	79	299	160.52	170.81	1.11	1.04
NR2E2F0	20.12	44	130.06	66	298	135.64	158.02	0.96	0.82
HR1E0F0	74.01	107	331.38	136	424	361.32	331.21	0.92	1.00
HR1E0F0r	74.98	136	370.61	159	425	363.68	331.21	1.02	1.12
HR1E1F0	74.98	127	357.06	146	425	304.40	310.73	1.17	1.15
HR1E2F0	74.98	105	261.95	118	425	261.85	292.64	1.00	0.90
HR2E0F0	63.73	120	404.99	175	603	335.29	318.31	1.21	1.27
HR2E0F0r	74.70	126	489.36	177	612	363.00	331.21	1.35	1.48
HR2E1F0	74.70	120	395.84	162	612	303.83	310.73	1.30	1.27
HR2E2F0	74.70	88	327.30	164	612	261.36	292.64	1.25	1.12
NR1E0F1	19.57	59	265.93	155	270	185.80	176.39	1.43	1.51
NR1E1F1	19.57	55	210.94	125	270	155.51	165.49	1.36	1.27
NR1E2F1	19.57	54	188.09	96	270	133.78	155.85	1.41	1.21
NR2E0F1	19.26	87	244.95	172	347	184.32	174.99	1.33	1.40
NR2E1F1	19.26	79	192.08	150	347	154.28	164.17	1.25	1.17
NR2E2F1	19.26	57	141.87	105	347	132.71	154.61	1.07	0.92
HR1E0F1	81.32	132	575.97	275	593	378.75	331.21	1.52	1.74
HR1E1F1	81.32	126	405.41	-	593	317.01	310.73	1.28	1.30
HR1E2F1	81.32	126	368.75	210	593	272.70	292.64	1.35	1.26
HR2E0F1	79.28	185	691.27	295	761	373.97	331.21	1.85	2.09
HR2E1F1	79.28	160	528.41	265	761	313.01	310.73	1.69	1.70
HR2E2F1	79.28	150	410.46	-	761	269.25	292.64	1.52	1.40

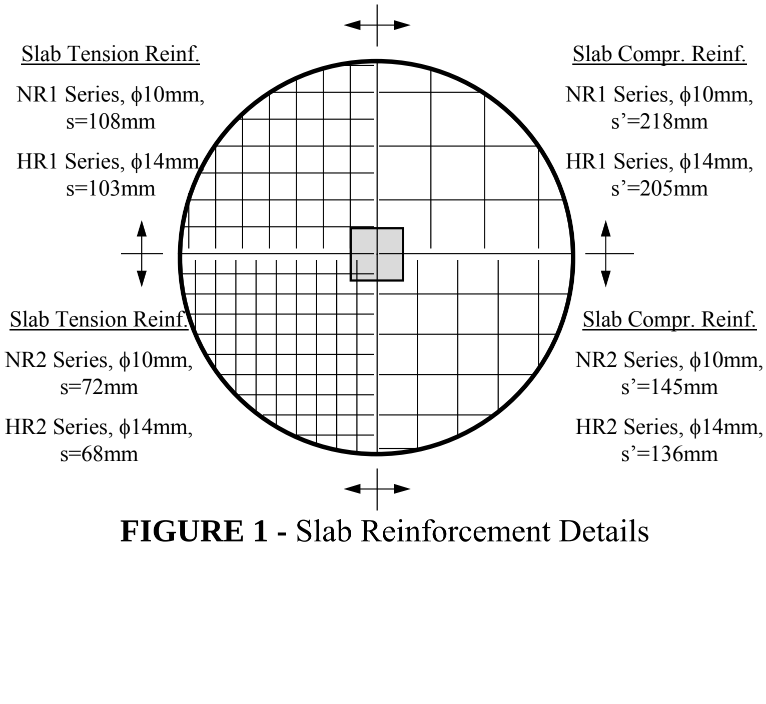


FIGURE 1 - Slab Reinforcement Details

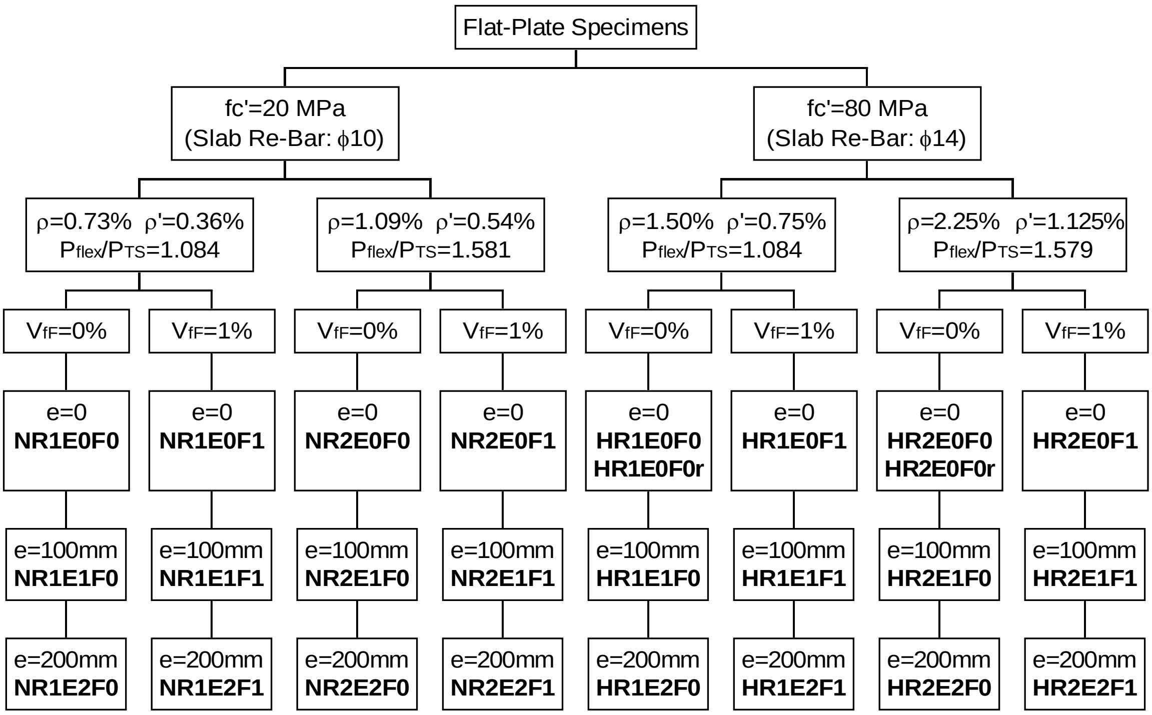


FIGURE 2 - Designation of Specimens and List of Variables

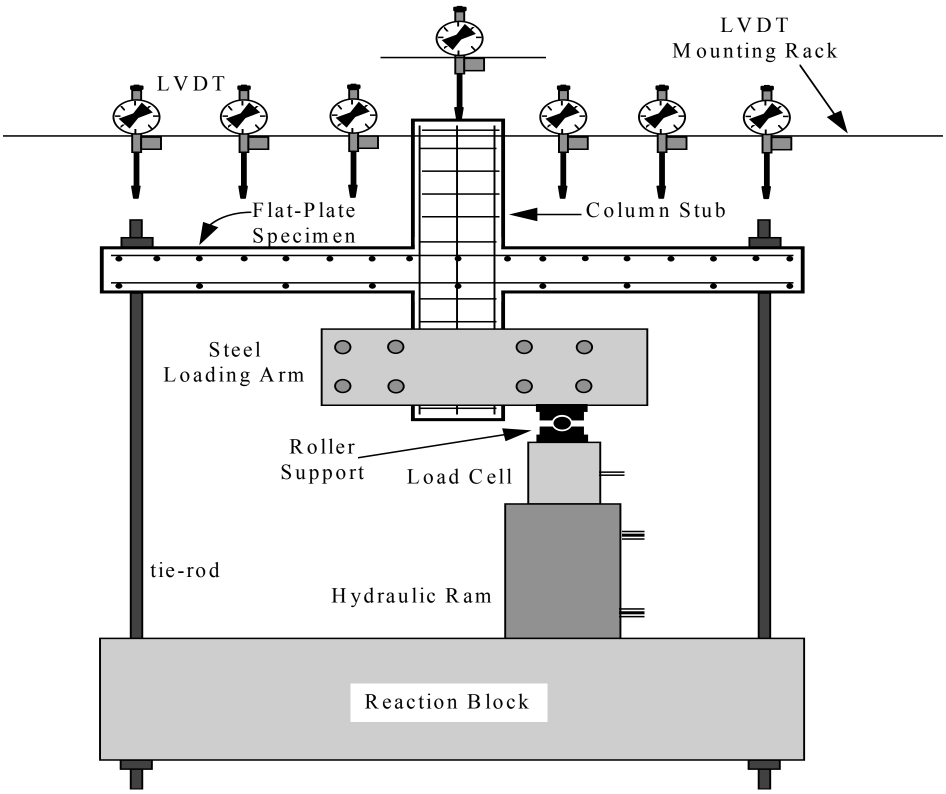


FIGURE 3 - Loading System and Location of LVDT's

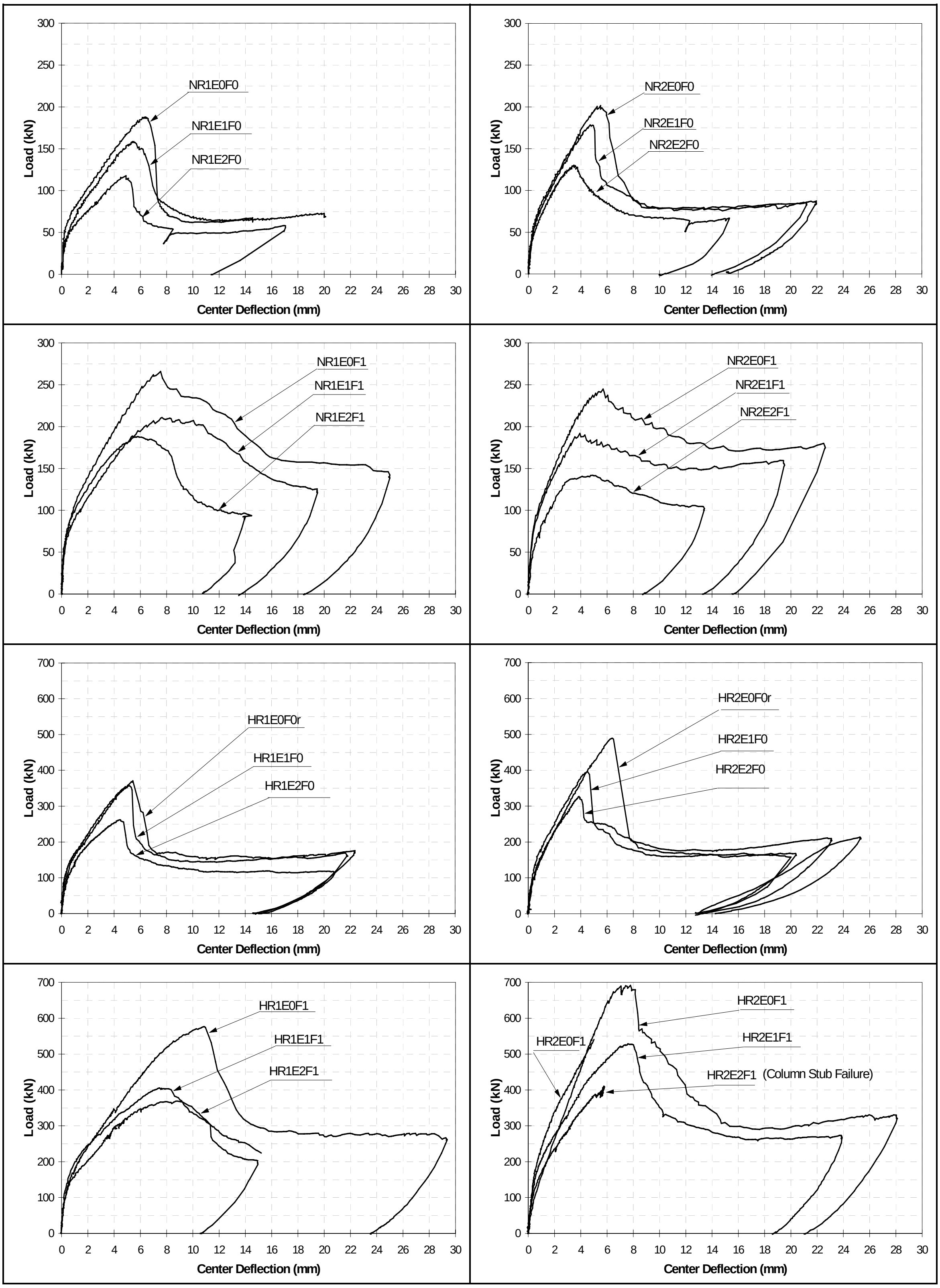


FIGURE 4 -Load Deflection Curves of Specimens

SUNUŞ PROGRAMI

KAYIT :9.00-9.20

AÇILIŞ :9.20-9.30 CEVDET ALEMDAR Tel Ürünleri Müd.

1. OTURUM : 9.30- 10.50

OTURUM BAŞKANI : Prof. Dr. M.ALİ .TAŞDEMİR İTÜ İNŞAAT FAKÜLTESİ

9.30-9.50 : İnş.Yük.Müh. MUSTAFA GENÇOĞLU / Prof.Dr. İLHAN EREN
İKİ YÖNLÜ TEKRARLI YÜKLEMELER ALTINDAKİ BETONARME KENAR KOLON -KİRİS BİRLEŞİMLERİNDE KULLANILAN ÇELİK TEL TAKVİYELİ BETONUN ETKİLİ BÖLGESİNİN ARAŞTIRILMASI İTÜ İNŞAAT FAKÜLTESİ

9.50-10.10 : Y.Doç.Dr.OĞUZ CEM ÇELİK / Prof.Dr. FERİDUN ÇİLİ
Prof.Dr. KAYA ÖZGEN İTÜ MİMARLIK FAKÜLTESİ
17 AĞUSTOS 1999 KOCAELİ (İZMİT) DEPREMİ VE HASARLI YAPILARIN ONARIMI / GÜÇLENDİRİLMESİ.

10.10-10.30:Prof.Dr.Müh.ERGİN ARIOĞLU İTÜ MADEN MÜH. BÖLÜMÜ
Y.Müh. BAŞAR ARIOĞLU YAPI MERKEZİ HOLDİNG AŞ
Dr. Müh. CANAN GİRGİN YAPI MERKEZİ HOLDİNG AŞ
TÜNELLERDE ÇELİK LİFLİ PÜSKÜRTME BETON KAPLAMA TASARIMI,MEKANİK BÜYÜKLÜKLER VE KALİTE KONTROL İLKELERİ

10.30-1050: Doç Dr. KEMALETTİN YILMAZ SAKARYA ÜNİVERSİTESİ
Öğretim Görevlisi ŞABAN CAVGA SAKARYA ÜNİVERSİTESİ
AGREGA GRANÜLOMETRİSİNDEKİ DEĞİŞİMİN ÇELİK TEL TAKVİYELİ BETONLARIN PERFORMANSI ÜZERİNE ETKİLERİ

ARA : 10.50-11.00

2. OTURUM : 11.00- 12.00

OTURUM BAŞKANI : Prof.Dr. SAİM AKYÜZ. İTÜ İNŞAAT FAKÜLTESİ

11.00- 11.20: Prof.Dr. MEHMET ALİ TAŞDEMİR. İTÜ İNŞAAT FAK.
ÇELİK TEL TAKVİYELİ YÜKSEK DAYANIMLI BETONLARIN MEKANİK DAVRANIŞI

11.20-11.40: Yrd.Doç.Dr.HASAN YILDIRIM.
HAFİF VE YARI HAFİF BETONLARDA ÇELİK LİF KULLANIMININ ETKİSİ

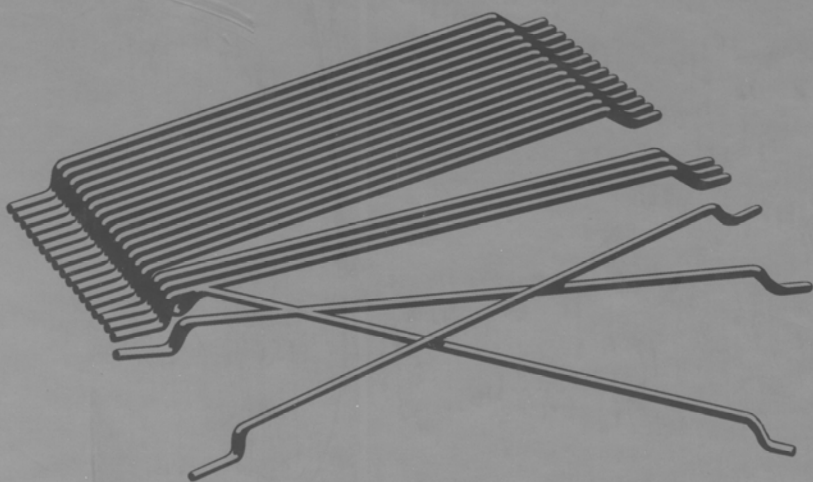
11.40- 12.00: Yrd.Doç.Dr. ŞEVKET ÖZDEN KOCAELİ ÜNİVERSİTESİ
PUNCHING TEST ON FLAT-PLATEST

ARA : 12.00-13.20

ÇELİK TEL DONATILI BETONLAR

BEKSA

ÇELİK TEL DONATILI BETONLAR SEMPOZYUMU



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