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USE OF HOOKED STEEL FIBERS INSTEAD OF STIRRUPS IN BEAM-COLUMN CONNECTIONS

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Abstract: In an earthquake the energy should be dissipated by structural elements. The energy concentrated in beam-column connections. As a result of this, the concrete in the connection zone should not break, collapse and should stay stiff for no reduction in the load bearing capacity of connection. Because of this all codes forces design engineer and constructor to continue stirrups in beam or column without break in the connection. While application of reinforcement according to the design in construction stage , to put stirrups in connection is very hard and takes a lot of time also it is very hard to concrete this region also.

This study concerns with the use of hooked steel fibers instead of stirrups in beam column connections. Recent studies made clear that, use of steel fibers increase ductility, stiffness and toughness in concrete. In this study 5 beam-column connections are tested under cyclic loading. First specimen has stirrups in connection zone according to code, the rest have no stirrups but have hooked steel fibers instead in connection zone with varying volumetric ratio 0,000%, 0,250%, 0,375%, 0,500%.

The specimens are tested in Selcuk University Civil Engineering Department Structural Laboratory. Earthquake loads are simulated on the 1/1-scaled specimens and all vertical and horizontal displacements are taken by a dozen of LVDT and this data is sent and saved by the help of an electronic device and computer program. The experimental load – deflection capacities are found and compared.

Keywords: Beam column connection, hooked, steel fibers, cyclic loading

Kolon – Kiriş Birleşimlerinde Etriye Yerine Kancalı Çelik Fiberlerin Kullanımı

ÖZET: Depremlerde ortaya çıkan enerji yapısal elemanlar tarafından yutulmalıdır. Kolon kiriş birleşim bölgeleri ise bu durumda kırılmadan parçalanmadan ve yük taşıma kapasitesinde eksilme olmadan deprem kuvvetlerine karşı koymalıdır. Modern yapı şartnameleri kolon kiriş birleşim bölgesinde etriyelerin sıklaştırılması ve kesintisiz devam ettirilmesini öngörmektedir. Bu bölgeye etriye yerleştirilmesi oldukça zor ve zahmetli olmasından ötürü birçok binada etriyelerin birleşim bölgesinde devam ettirilmesi sağlanamamıştır. Bu çalışmada etriyeli, etriyesiz, hacimsel olarak %0.250, %0.375, %0.500 kancalı çelik fiber ihtiva eden beş adet 1/1 ölçekli kolon kiriş birleşimi numunesi tersinir tektarlanır yük altında test edilerek yük – deplasman grafikleri elde edilmiş ve etriye yerine kancalı çelik fiber kullanımının sonuçları irdelenmiştir.

Anahtar Kelimeler: Kolon – Kiriş Birleşimi, Kancalı Fiber, Yük – Deplasman

Introduction

The main ideas of codes are to have rigid, strong or ductile members. The design should have one of the previous characteristics.

Turkey is on Alp earthquake region, where earthquakes often occur and the earthquake resistant designs have vital importance. The last earthquakes showed that the damages are sometimes because of project and unsatisfactory material properties but often because of construction out of project.

The studies showed that the main mistake made in these types of structures is, not to continue stirrups in beam or column although it is forced by the building code. The stirrups put in connection region encircles concrete and not let it to collapse easily and give ductility to the connection and this enlarges the energy absorption capacity also. The earthquake forces concentrates in the connection region and forces the connection to deflect. The connection should have the ability of rotation without damage. If the concrete in connection region collapses the axial load capacity of the column suddenly decreases and the structure losses axial load bearing ability and collapses easily. The codes prevents this by having a plastic hinge in the beam on the surface of the column. This protects the column from damage a lot.Studies on steel fibers made clear that It is really hard and takes time to put stirrups in the connection region; on the other hand concreting this region is also very hard too. As a result to prevent from these and make it easy, in this study five 1/1-scaled beam-column connection having stirrups according to code, and having hooked steel fibers having 0,000%, 0,250%, 0,375%, 0,500% volumetrically are tested under simulated earthquake loads. The results of the tests are analyzed and the effect of steel fibers on the load and deflection capacity of connections is made clear.

MATERIAL AND METHOD

Properties of Used Materials

Properties of normal aggregates

The normal aggregate used in this study is obtained from Göçü sand quarry in Konya. The aggregate obtained from Göçü sand quarry has dense unit weight of 1730 kg/m^3, loose unit weight of 1455 kg/m^3 , water absorption ratio of %8. For normal concrete, using Göçü sand there is made comparison with the suitable granulometric regions given in TS802 and appropriate ratios are found (Kaltakcı and Kamanlı, 1998).

Cement properties

In this study portland cement with additives (KPÇ 325) produced by Konya Cement Factory, having 3.15 kg/dm^3 unit weight is used

Properties of mixing water

The mixing water used in the study is obtained from Selcuk University Campus and it can be used as drinking water.

Properties of concrete

Grain size distribution is same for all concrete's. In mix design absolute value method is used. As in the code 350 dosage for concrete (C20) having W/C=0.50 is used for the connection samples .

Properties of reinforcing steel

The reinforcement used in the study is S420 and suitability of reinforcement is tested for TS 500 and TS 708. The same reinforcement details are used for normal and lightweight concrete beam specimens. The reinforcement used in the samples has the same type and radius for the specimens. The mechanical properties of reinforcing steels are given in Table 1.

Properties of fiber concrete

Fiber concrete can be stated by ACI (1973) as the mix of hydraulic cement, aggregate and fibers often separated non-continuously. ACI also states that the most suitable numeric parameter to classify fibers is 'length (l)/diameter (d) ratio. The hooked fibers have 60/0.80 l/d ratio and tension strength less than 1700 N/mm^2 (Saraoushian and Bayasi, 1991). The hooked fibers are glued to each other and after adding to concrete the glued fibers separated from each other and mixed non-continuously in the concrete (Craig, 1984).

Concrete Production and Curing

The concrete is produced in Selcuk University Structure Laboratory. No additives used for concrete production. The samples are cured for 14 days to have construction site stuations. Steel Plate molds are used as molds for specimens. The f_{cr} of concrete obtained from ϕ15/30 moulds are given in Table 2. Experimental Program

The experimental model to search the behaviour of a beam-column connections is given in Figure 1 and the schematic wiev of LVDT Placing is given in Figure 2.

Table 1. The mechanical properties of reinforcing steels.
***Tablo 1.** Donatıların mekanik özellikleri.*

Sample No	Diameter of thought (mm)	Diameter of found (mm)	Crossectional area (mm^2)	σ_{yield} (kg/cm^2)	σ_{crack} (kg/cm^2)	ε_{crack} %
1	12,0	12,1	114,93	4232	5374	25
2	14,0	14,1	156,07	4327	5417	23
3	16,0	16,2	206,02	4524	5545	21
			Average	4361	5445	23

Table 2. The f_{cr} of concrete used for specimens.
***Tablo 2.** Kullanılan betonların kırılma mukavemetleri.*

Sample No	7 day f_{cr} (kgf/cm^2)	28 day f_{cr} (kgf/cm^2)
1	143,6	215,0
2	145,0	218,0
3	144,0	212,0
4	144,5	220,0
5	144,0	210,0
Average	144,0	215,0

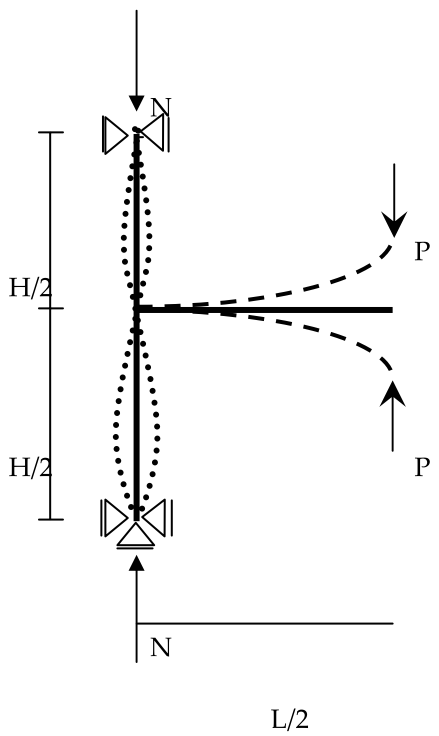

Figure 1. Beam-Column.
***Şekil 1.** Kolon – Kiriş Birleşim Detayı.*

Test Models

Five different test specimen are used to determine the behaviour of connection with stirrups and fibers of 0,000%, 0,250%, 0,375% and 0,500% volumetric ratios. The connection model details with stirrups is given in Figure 3 and the connections without stirrups are given in Figure 4.While loading thick steel plates are attached to column and beam ends.

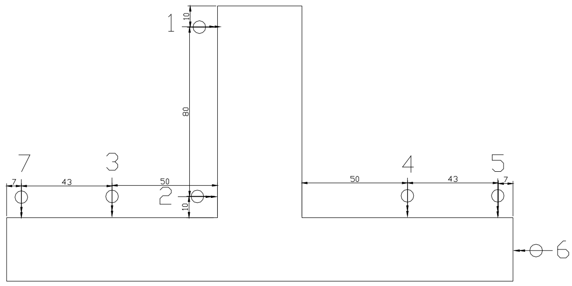

Figure 2. Schematic View of LVDT's.
***Şekil 2.** LVDT'lerin şematik görünümü.*

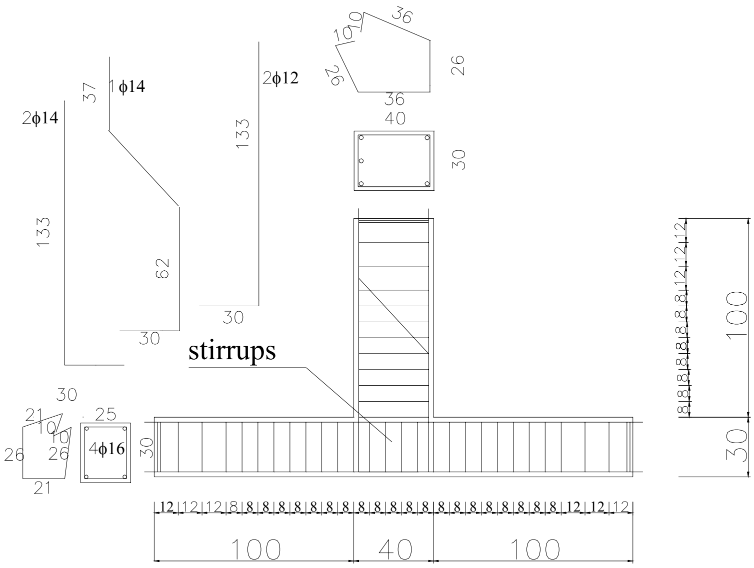

Figure 3. Connection with stirrups.
***Şekil 3.** Etriyeli birleşim detayı.*

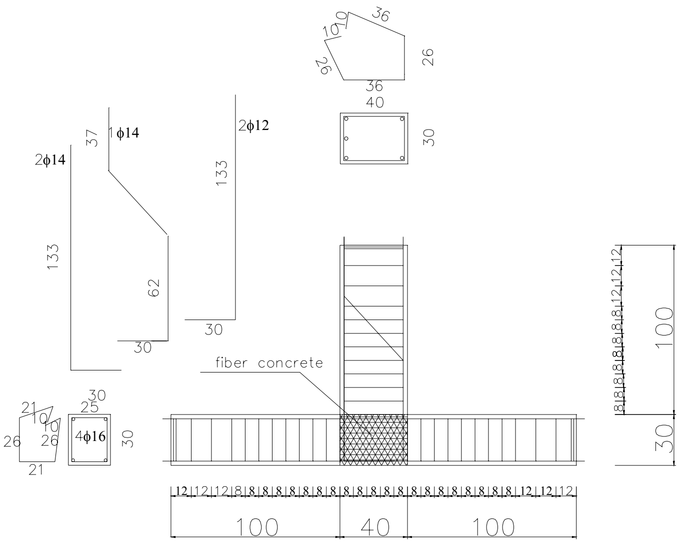

Figure 4. Connection without stirrups.
***Şekil 4.** Etriyesiz birleşim detayı.*

TEST RESULTS

Obtained Moment-Rotation Graphics obtained under cylic loading are given in Figure 5, 6, 7, 8, 9. The columns are under 25 tons of axial loading.

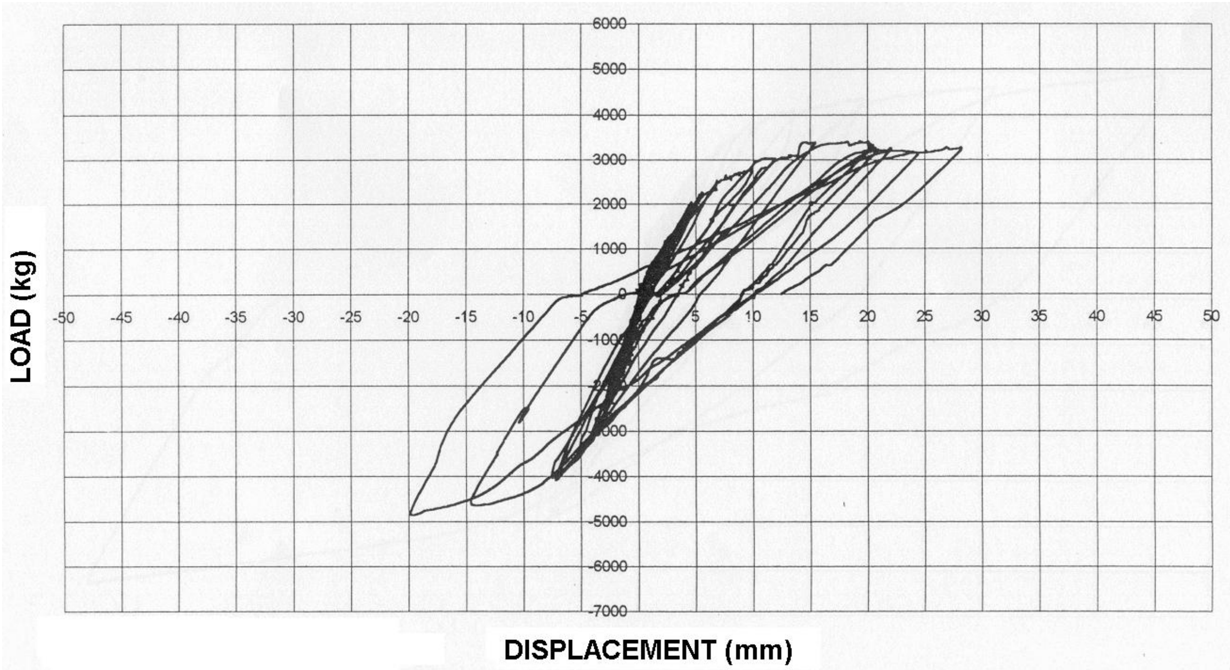

Figure 5. Load-Deflection graphics for sample having stirrups.
Şekil 5. *Etriyeli numune için yük – deplasman grafiği.*

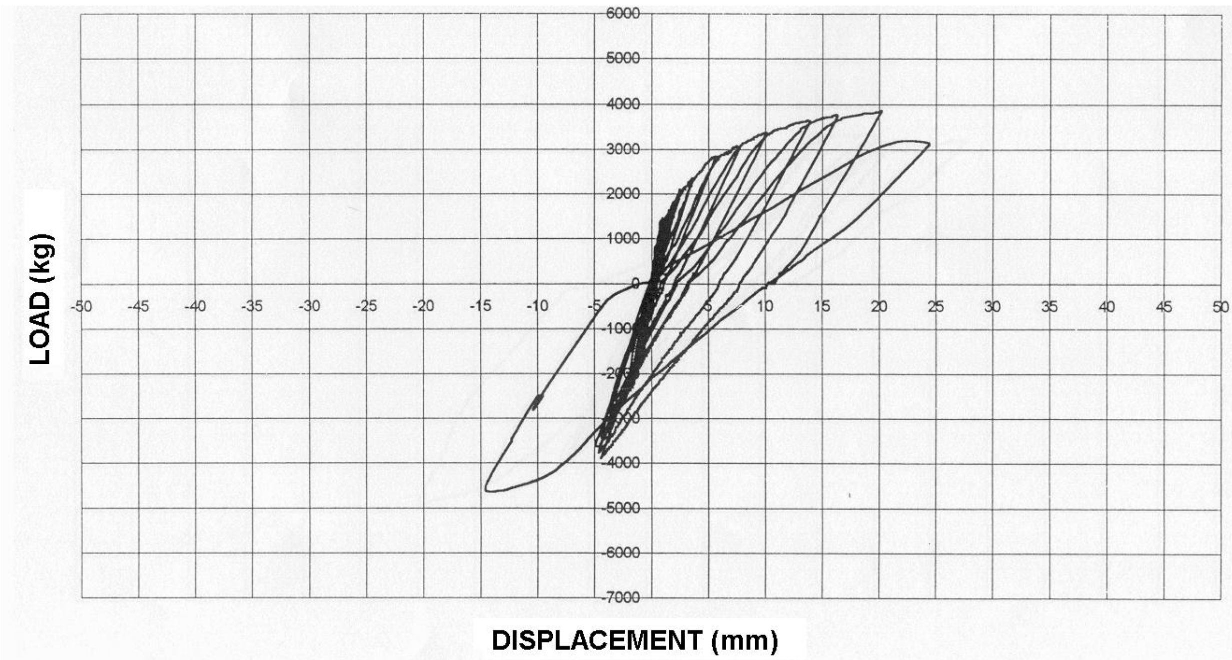

Figure 6. Load-Deflection graphics for sample having 0,000% fibers.
Şekil 6. *%0.000 fiberli numune için yük deplasman grafiği.*

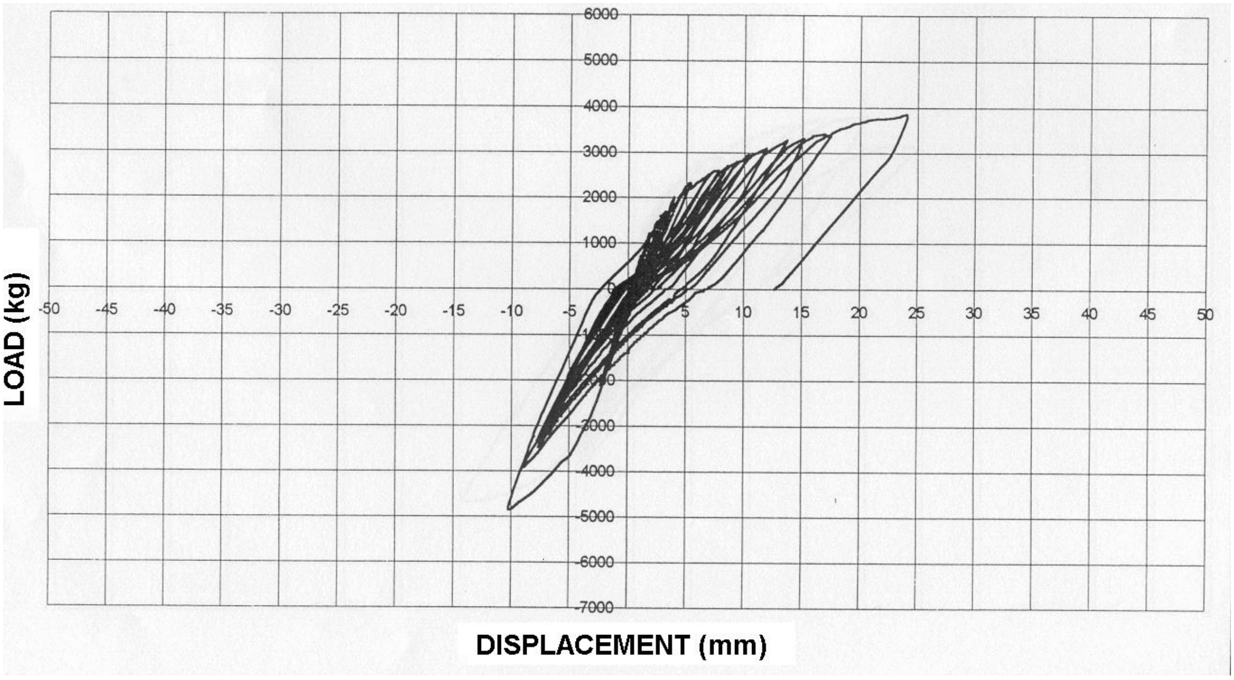

Figure 7. Load-Deflection graphics for sample having 0,250% fibers.
Şekil 7. *%0.250 fiberli numune için yük deplasman grafiği.*

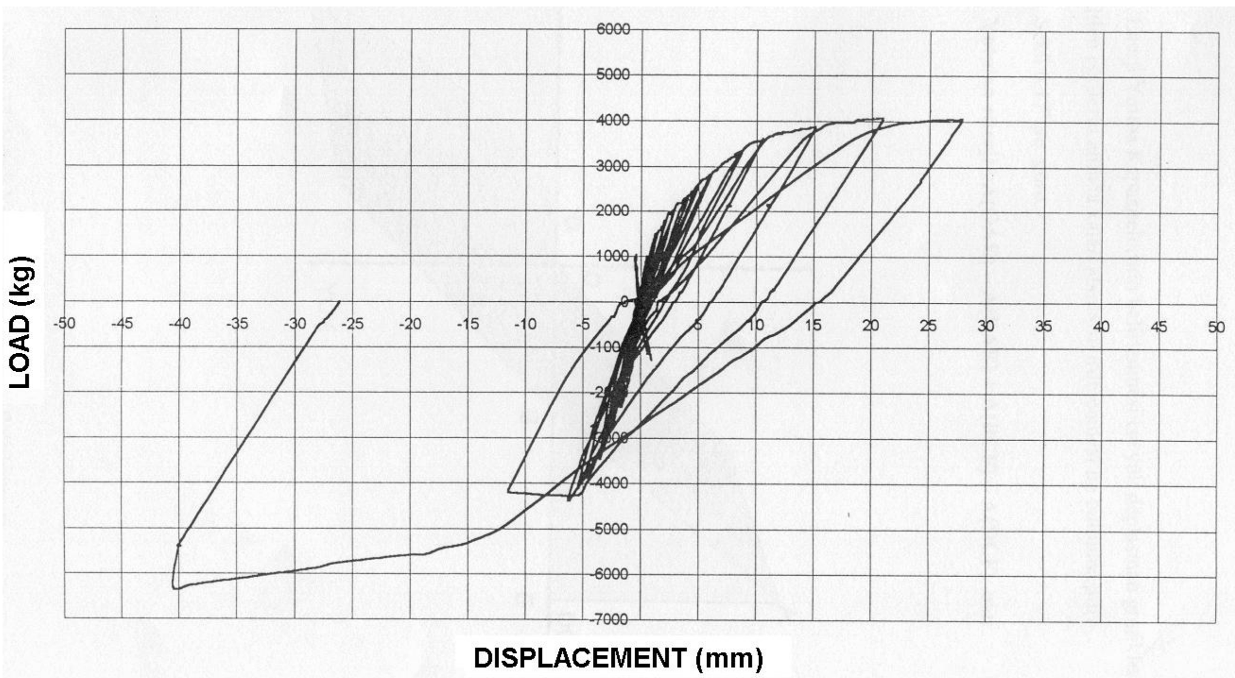

Figure 8. Load-Deflection graphics for sample having 0,375% fibers.
Şekil 8. *%0.375 fiberli numune için yük deplasman grafiği.*

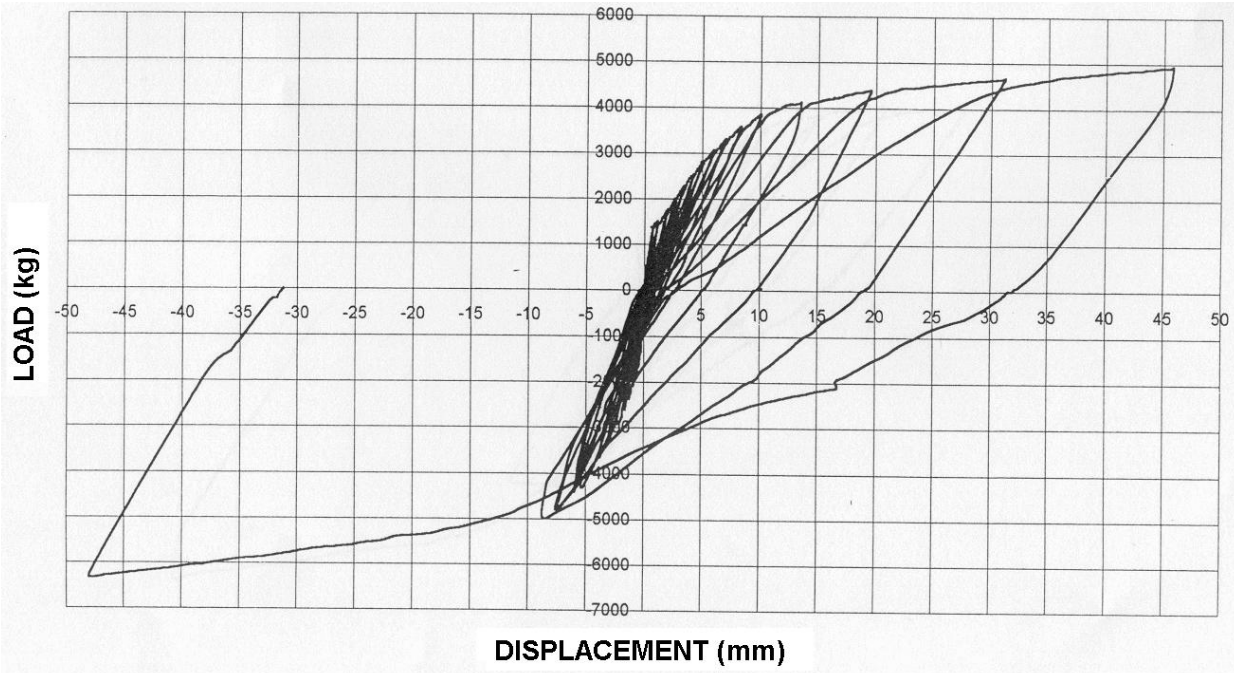

Figure 9. Load-Deflection graphics for sample having 0,500% fibers.
Şekil 9. *%0.500 fiberli numune için yük deplasman grafiği.*

CONCLUSION

Experiments showed that added fibers instead of stirrups made the connection much more ductile and this cause enlargement in the load bearing and deflection capacity of the connection. The load bearing capacity of the connection increased. For the sample having 0,000% fibers have limited deflection capacity and the concrete in the connection zone collapsed and after this the connection lost the load bearing capacity. In all specimens the plastic hinge occurred at the face of the column on beams as the codes wanted. As a result with much more studies comparing the connections with stirrups and fibers instead should be made to clarify the affect of fibers . From wives of load bearing and deflection capacity it can be said that fibers can be used instead of stirrups on the connections. Also by increase in load-deflection capacity the energy absorption capacity of the connection increased also (Akın, 1999).

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