Kerbala Journal for Engineering Science

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Investigation of the Behavior of Steel Tubular Columns Filled with Reactive Powder Concrete and Comparison with ACI Design Criteria

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Received: 27 July 2021; Revised: 22 September 2021; Accepted: 22 September 2021

Abstract

This research studies the behavior of double tube steel columns filled with high-strength concrete (HSC) between the gap surrounded by the two pipes and others without filling. The columns are tested by using a concentrated centric load. The concentrated load was applied in the form of cycles by the increased load. Six samples of columns were examined with different variables. The study’s parameters in the experimental work are specific to the steel fiber in the concrete mix and type section and the other parameter to the non-filled tube. In terms of high strength concrete mix, the percentage of fibers used was 0.5% and 1.5% of the total concrete volume. As for the steel tube, a square and circular cross-section was used, as well as column length. Plotting the results obtained through load curves with deflection and the results were compared with samples non filled with concrete. The results showed that increasing the percentage of fibers in high strength concrete increases the maximum bearing of the column, while an empty tube has much less bearing than it is infilled with high strength concrete. Finally, the theoretical analysis of the results was performed with ACI. From the experimental results, the ACI provision gives underestimation about the load carrying capacity of the composite column and overestimation for only steel.

Keywords: Steel tubular filled concrete in double Skinned; reactive powder concrete (RPC); Tubes full with concrete; repeated loading

1. Introduction

Concrete filled double skin tube members (CFDST) are the brand-new class of traditional members filled with concrete where is a double tube is placed centrally and concrete sandwich between them. It usually possesses the same traditional pipes properties filled with only concrete (CFT). They have lighter weight and stronger bending rigidity and as a way to speed up bridge building despite the expense. Concrete filled double skin tube (CFDST) columns are also expected to have higher fire resistance capacities than their (CFT) counterparts because the former interior tubes are effectively protected by sandwiched concrete under fire conditions [1].

Steel members have the advantages of high tensile strength and ductility, while concrete members have the advantages of high compressive strength and stiffness. Composite members combine steel and concrete, resulting in a member with both materials' beneficial qualities. The advantage of concrete-filled circular steel tubular (CFT) columns is that the steel tube serves as a form for casting the concrete, which reduces construction costs. Also, no other reinforcement is needed since the tube acts as longitudinal and lateral reinforcement for the concrete core. In addition, the placement of longitudinal steel at the perimeter of the section is the most efficient use of the material since it provides the highest contribution of the steel to the section moment of inertia and flexural capacity. The steel tube's continuous confinement provided to the concrete core enhances the core’s strength and ductility. The concrete core delays local buckling of the steel tube by preventing inward buckling, while the steel tube prevents the concrete from spalling [2].

Composite steel-concrete architecture is commonly used to design new buildings and bridges, including high seismic risk areas. The composite column includes the sum of the strength of the steel tube and the concrete filled with it. The steelworks confine the concrete, while the concrete works to make the steel able to withstand the compressive strength, and this interaction between them gives better performance for the composite columns (CFST). The stresses of the concrete cause the local buckle of the steel tubes. In contrast, the tube serves to prevent this case. The steel tubes may be a Circular Hollow Section (CHS), Square Hollow Section (SHS), or Rectangular Hollow Section (RHS). as shown in Figure(1) [3].

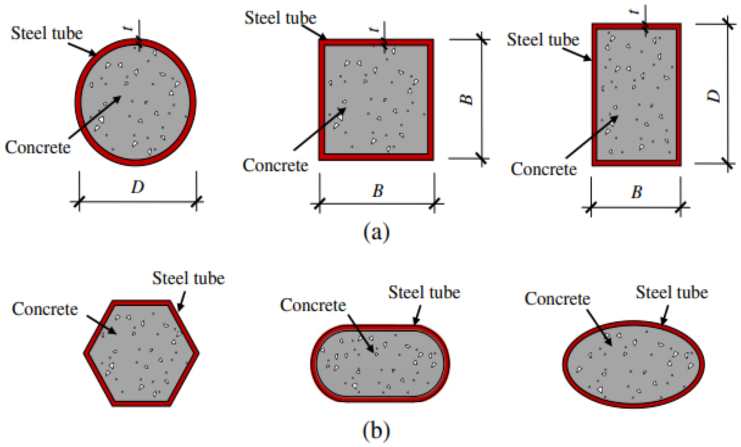

Figure 1 Traditional concrete-filled steel cross-sections.

There have been several numerical and experimental investigations in the past, which focused on the structural behavior of double-skinned columns. The influence of various parameters sectionally characteristics: dimensions, steel type (carbon and stainless steel), concrete type, concrete age and performance patterns of the CFST is studied by Tao et al. [4] (2016). The experiment study indicates the weak effects of rising the cross-section and concrete age on the bond strength. It was concluded that the circular column develops higher bond strength than the square counterpart when they have the same cross-sectional dimension. Also, it was found that the decrease in bond strength ranged from 32% to 69% when stainless steel was used to replace carbon steel as well as longer the concrete age, gave lower the bond strength. For full-scale specimens tested at a concrete age of over three years, the bond strength decreased to a negligible value when normal concrete was used. In addition, Wang et al. [5] (2019) conducted a lot of practical experiments on double steel tubes filled with concrete (CFDST). The considered parameters of external tubes are resistance to rust, high strength steel CHS in inner tubes, three different grades of concrete infill (C40, C80 and C120). The experimentally and numerically derived data were then employed to assess the applicability of the existing European, Australian and North American design provisions for composite carbon steel members to the design of the studied CFDST cross-sections. Overall, the existing design rules are shown to provide generally safe sided (less so for the higher concrete grades) but rather scattered capacity predictions. The use of effective concrete strength is recommended for the higher concrete grades and shown to improve the consistency of the design capacity predictions. While (Sharif, Al-Mekhlafi et al. 2019) [6] examined the actions of stainless-steel tubes packed with CFRP-wrapped concrete under axial compression. CFRP covering restrains the stainless-steel tubes. The results explained that the CFRP sheets enhanced the axial compressive behavior of the square section tube (CFSST) column filled with concrete with respect to different D/ts ratios. For the wrapped specimens with a D/ts ratio of 37, the axial shortening capacity enhancement by adding one, two, and three CFRP plies with respect to the unwrapped specimen was, respectively, 70%, 145% and 210%. For the wrapped specimens with a D/ts ratio of 50, the axial shortening capacity enhancement was 36%, 150% and 216% due to the addition of one, two and three CFRP plies with respect to the unwrapped specimen, respectively. For the specimens with D/ts of 67, the axial shortening capacity improvement was 50%, 120% and 180% compared with the unwrapped one by using a CFRP jacket with one, two and three plies with respect to the unwrapped specimen, respectively. Eom et al. (2019) [7] This analysis produced four primary specimens. The specimens included steel pipes inside and outside, as well as concrete that filled the void between tubes. Two different shear connectors from the studs and sheet metal studs were used to create the best behavior. The result gave the ultimate load of the specimen with stud higher than specimen had steel plate, the M16 studs did not fail, and the steel plate studs failed under ultimate load. Therefore, the M16 studs are more suitable than the steel plate studs. However, Ibanez et al. [8] (2018) examined twelve sample of the steel tube columns packed with concrete under the influence of concentrated loads. The cross-section of the column, which was circular, square and rectangular, was studied. It observed that for NSC, only CFST columns with circular steel tubes show values of SI higher than one. This is due to the effect of the confinement, which leads to cross-sectional capacities higher than the sum of all the components. For square and rectangular specimens, the load-bearing capacity is not improved in any case. Duarte et al. [9] (2016) added rubber concrete for circular and square hollow tubes. The effect of compression of concrete was greatly affected by the type of section. The circular sections showed a higher confinement strength than the square.

High-strength materials were used in this study provide an important structural alternative to highly loaded buildings, and with the advancement of product science, high-strength concrete has become commercially affordable. One of these types of concrete is Reactive Powder Concrete (RPC) (1995) [10], which is a super strength and fatigue strength cemented substance with developed mechanical performance. It is a particular type of concrete that is more a filler than a normal concrete mixture. RPC is a fiber-reinforced, super plasticized, silica fume and cement mixture with a rather low water-cement ratio and very finer quartz sand (2004) [11]. It uses traditional cement in the RPC formulation, which is the crucial feature that increases the high-strength characteristics of concrete. With respect to aggregate, removal of the coarse aggregate system raises homogeneous mixture, and the remaining fine aggregate offers optimal dense mix. The high performance of concrete is obtained by reducing the water percentage and compensating for the decrease with a high-water reducer. Also, other materials are used for the mixture, such as silica fume, because it has a pozzolanic effect that improves the calcium silicate hydrate (CSH) component and also prevents high permeability [12] (2012). The enhancement of the interfacial transfer zones between binder and aggregate and between binder and steel fibers is another significant result of silica fume [13](2006). Steel fibers are added to the mixture of Reactive Powder Concrete to give high mechanical properties [14] (2013).

According to the researches discussed in this paper, it was concluded that there are no previous studies or investigations dedicated to predicting the influence of the repeated loading for CFDST columns filled with Reactive Powder Concrete. Therefore, the present study introduces an experimental investigation of the repeated loading case under various parameters such as; steel fiber ratio and type of section of steel tube.

2. Experimental work

2.1 General

The present experimental program consisted of a series of tests conducted on all materials used in this study, such as samples of the cube, cylinder, and seven concrete-filled double skin tabular column specimens. It was examined to represent all variables of the research plan. The CFDST is made up of inner and outer tubes, as well as sandwiched concrete between them, as illustrated in Figure (2). These specimens were cast with reactive powder concrete and another one without filling. All the specimens have a total length of (800 mm). The cross-section dimension of the external and internal diameter of the circular tube is 100mm and 50 mm. While the dimensions of square sections are (100*100) mm and (50*50) mm. The thickness for the circular and square sections is 2.2 mm. The variables of the practical part included: the percentage of steel fibers in the concrete mixture of about 0.5% and 1.5%, cross-sectional shape, and the steel non filled with concrete, as seen in Table 1 below.

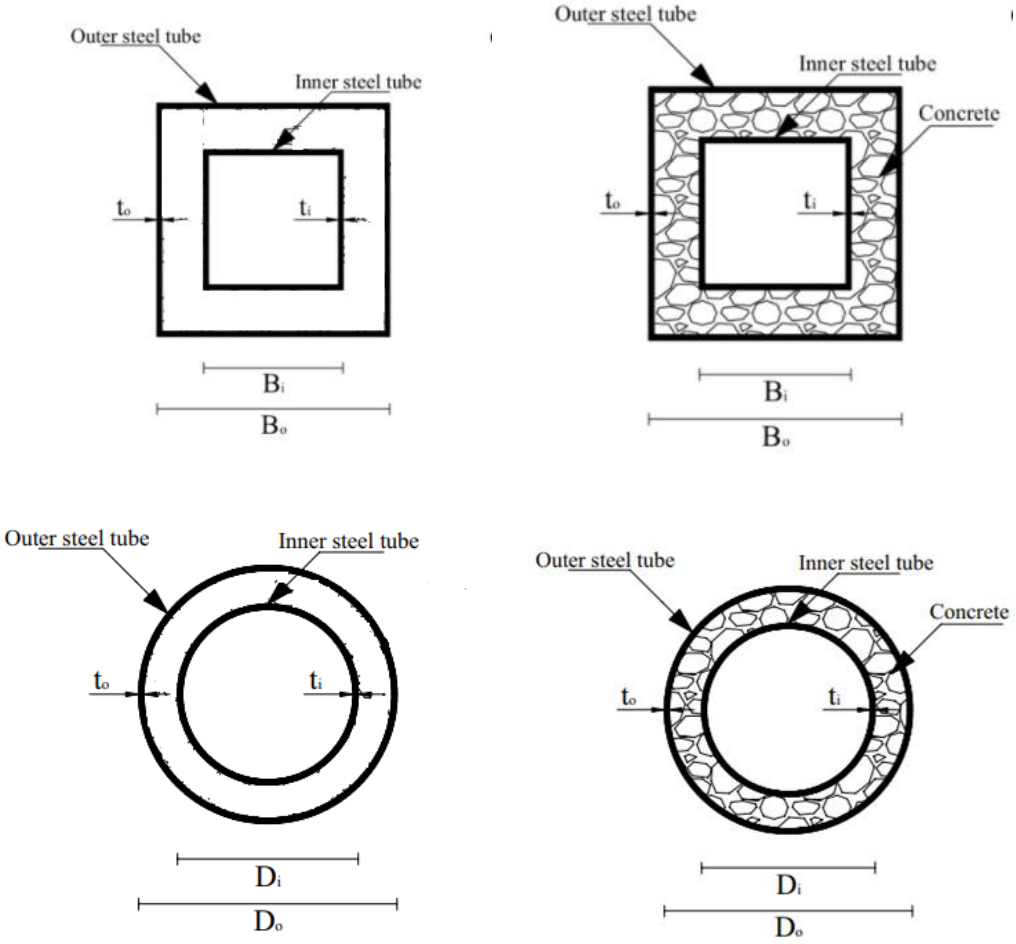

Figure 2 Cross-sections shape in the study

Table 1 Details of test specimens

Specimen design	Cross-section size of the outer tube (mm) (D)× t × L	Cross-section size of the inner tube (mm) (D)× t × L	Length to width ratio (L/B)	Concrete compressive strength fc′ (Mpa)	Yield stress Fy (Mpa)
SHS1(HSC)	100× 2.2 × 800	50× 2.2 × 800	80	73.3	344.6
SHS2(HSC)	100× 2.2 × 800	50× 2.2 × 800	80	90.32	344.6
SHS3 (empty)	100× 2.2 × 800	50× 2.2 × 800	80	0	344.6
CHS1(HSC)	100× 2.2 × 800	50× 2.2 × 800	80	73.3	344.6
CHS2(HSC)	100× 2.2 × 800	50× 2.2 × 800	80	90.32	344.6
CHS3 (empty)	100× 2.2 × 800	50× 2.2 × 800	80	0	344.6

CHS: Circular hollow section, SHS: Square hollow section

2.2 Preparing of specimens

The tube of the steel was provided in the length of 6 m. Fulad Mehr Company of Iran produced the structural steel tubing. The total length of tubes was cut in order to provide the laboratory length of the samples(required). The inner tubes were carefully placed at the middle of the outer tubes in the preparation of the test specimens to conform the center of the inner tube with the center of the outer tube. A plate was welded to the base of the steel tube with a thickness of 3 mm, while the upper part of the tube is left open to allow the concrete to pour. To create uniform load transfer around the cross-section during the processing of test, the welding points are smoothed. In double tube columns CFDST, the gap is equal between the outer and inner tubes by welding steel strips at a depth of 10 mm located at the tip of the samples. In CFDST, the upper inner tube opening is kept closed during the casting process to avoid fresh concrete entering, which is not desirable for the study. After the completion of the casting, the upper part of the inner tube can be opened to prepare the sample for coating. After that, the specimens were coated to prevent them from corrosion during the curing to prepare the column for testing.

2.3 Properties of Materials

2.3.1 Steel tubing

A tensile stress coupon test was done on steel tubing to determine the material properties. The curved tensile coupon specimens were extracted from tubes that were manufactured similarly by the same process. The typical tensile test is performed as seen in Plate (1). The three pieces of tensile coupon were taken to measure the average of yield stress (fy), the ultimate of strength (fu), and the elastic modulus (Es) of steel, which were lists in Table (2). The sample preparation, dimensions of the geometric properties of the steel coupon and test speed were complied with ASTM-A370 requirements, which suggests the descriptions of the coupon as per ASTM-A370 [15]. All samples were examined at the Iraqi Ministry of Construction and Housing's National Center for Laboratories and Structural Research.

Plate (1) Typical tensile test of coupons

Table 2 Properties of the steel coupon

No. of coupon	Yielding stress (Fy) Mpa	Ultimate stress (Fu) Mpa	Elongation at fracture %	Modulus of elasticity (Es) (Mpa)	Thickness (t)
1	337	393	23.7	200695	2.2
2	364	416	20	201350	2.2
3	333	385	10.9	201150	2.2
Average	344.6	398	18.2	201065	2.2

2.3.2 Cement

There are several commercial cement products in the local market. The conventional cement form KARASTA as Portland-limestone cement type CEM II/A-L, which is manufactured by LAFARGEHOLCIM, Karbala Cement Manufacturing Limited, KCML, has been chosen for this research. This type of cement was used for both NC and HSC mixture in the experimental work. It was stored in a dry region to avoid exposure to moisture. The test results show that the cement meets the specifications of Iraqi Specification No.5/1984. These experiments were carried out in the College of Engineering / Kerbala University's Materials Laboratory.

2.3.3 Fine aggregate

Natural sands from the Al-Ukhaider area are used in this type of concrete with quite fine sand. The largest granule size (0.6 mm) was used on only HSC mixtures. It was removed from the natural sand by a sieve analysis (600 µm). The findings of the very fine sand complied with the specifications of Iraqi No.45/1984.

2.3.4 Silica fume

Silica fume is a substance that inserting in a mixture of (HSC), which is known commercially by the name UAE (Megaadd MS (D)). This material is considered a pozzolanic material, which is very fine. Amorphous silica is one of the components of this material. It is also produced as a by-product of electric furnaces. The results show that the standard (ASTM C 1240-05) specification was compliant. In this study, the content of silica used in RPC mixtures was 22 per cent of the additive weight of cement.

2.3.5 Super plasticizer

In this research work, a wide range of water reduction admixture was used only for the HSC mixture. Sika company (Sika ViscoCrete ® 5930) supplied a superplasticizer of the third generation for concrete and mortar. This type is ideal for the manufacture of many types of concrete, and it can be used in both cold and hot environments. Sika ViscoCrete ®5930 launched a high water down to 30% and has several benefits in addition to reducing the water content of the mixture such as; better shrinkage and creeping behavior, and increased early strength and density. It met the ASTM C_494_99 grade F and G superplasticizer requirements.

2.3.6 Steel fibre

Generally defined, in the present analysis, the key parameter for the manufacture of ductile concrete was the steel fiber material, which also increases the compressive strength depending on its ratio from volume mix and improves the mechanical properties of the UHPCs. The aspect ratio (fibre length to fibre diameter) of the steel fiber was nearly 59. The tensile strength of the metal fibers and density was around 2850Mpa, and 7850kg/m^3, respectively. In this research, two fraction volumes of 0.5 %, and 1.5 % were adopted. Also, the plain concrete was used for reference as a guide.

3. Production of high strength concrete

3.1 Mix proportions and procedure

Some previous studies dealt with how to produce high strength concrete, such as (Al-Amery, and Kindeel) [16, 17]. The method of mixing was illustrated by adding the very fine sand to the silica fume and mixing in a dry state for 5 minutes to ensure homogeneity between powder particles and silica fume. After that, it was added to cement and mixing for about 5 minutes. Then, a quantity of water was added and mixing for five minutes. Eventually, the superplasticizer was added gradually and mixed well for about 3 minutes until the materials seemed properly mixed. Finally, the steel fibers were added gradually to ensure uniform distribution and mixed for 2-3 minutes described these stages in Plate (2). The total time of mixing was about 20 minutes for each mix. This procedure has been carried out according to (Will et al.) [18]. A high compressive strength of approximately 100 MPa after the completion of the casting process to get reactive powder concrete. The samples are left for a period ranging between 36-48 hours to harden, and they are treated with hot water that reaches 60 °C for a period of three days only. Then, complete treatment was performed by the age of 28 with normal water at 25 °C to obtain high material properties. The final trail mix is described in Table (3).

Plate (2) Steps of mixing

Table 3 Final Proportion of the Ingredients kg /m3

Mix	**Cement**	**Silica Fume**	**Very Fine Aggregate**	**W/(cm)**	**Superplasticizer**	**Steel Fiber ratio of volume mix**
RPC-0.5	900	200	1100	0.23	45	0.5%
RPC-1.5	900	200	1100	0.23	45	1.5%

Cm=Cement material

3.2 Casting of specimen

The tubes were well cleaned of the inner surfaces before inserting concrete in the molds to ensure stronger bonding of the hardened concrete between concrete and steel tube adhesion. In a vertical location, the tubes were filled, and the concrete was poured in two equal layers into the mold. Compaction was accomplished for a few minutes using electric vibrating and compaction rods to eliminate air voids and obtain well compacted concrete. Then, using a steel trowel, the excess concrete at the top edge of the tube is cut and is finely milled such that the upper surface of the steel tube appears at the same level as the surface of the concrete. All control specimens consisted of cubs. For each mix, the cylinders were filled and compacted into two layers at the same time. It was levelled by means of a steel trowel after the top layer had been compacted, as seen in Plate (3). specimens were protected Using nylon coverings to prevent water evaporation from fresh concrete. An important action to generate HSC is the curing of concrete. There are many treatment processes, such as steam curing, hot bath healing, or ambient temperature, that are used. In the current analysis, the samples were de-molded after 36-48 hours of casting and submerged in a hot water bath with 60 ºC for 3 days and then 25 ºC until the age of 28 days.

Plate (3) Mixing, placing and compacting of concrete.

4. Concrete strength

The compressive strength test was carried out on cubes (100 * 100 * 100) mm According to B.S: 1881: part 116, the use of mechanical compression machines Capacity of 2000 kN. After 28 days of water treatment, all the cubes were tested. With a loading rate of 0.6 MPa / sec, the constant load was applied. The average value was used to describe the three specimens in order to represent the Compressive forces for each NC and RPC.

Table 4 Test result of cube concrete compressing

Average of three cubes (Mpa)	Average of three-cylinders (Mpa)	Mixture
73.3	55.5	RPC 1
90.32	73.5	RPC 2

5. Capacity prediction

The concrete containment influence is neglected by the ACI(318). The ACI equation for the ultimate axial strength (Pu; ACI) of a square column filled with concrete integrating the internal tube's contribution is given as

PU, (ACI) = (Asifsyi) + (Asofsyo) + 0. 85Ac ′ fc ………………………..(1)

Ac is the cross-sectional region of the concrete in both tubes, f'c is the unconstrained concrete cylinder strength, and Asi is the cross-sectional zone of the internal metal tube, where Aso is the cross-sectional area of the outer steel tunnels. Fsye and fsyi are, respectively, the yield characteristics of the external and inner sheet steel tubes. The capacity of column theoretical and experimental describe in Table 5.

Table 5 Describe the capacity of column theoretical and experimental.

Mixture	Column	Pu,Exp.	Pu, ACI	Pu, ACI/Pu,exp
RPC1	CHS1	775 KN	592KN	0.76
RPC2	CHS2	910KN	672 KN	0.73
Non filled	CHS3	300kN	346kN	1.1
RPC1	CHS1	815 KN	754KN	0.92
RPC2	CHS2	888KN	856 KN	0.96
Non filled	CHS3	300kN	341kN	1.1

6. Test Setup and Procedure

The general view of the test setup and instrument used in the experiment are shown in Plate (4). After the curing of samples had been completed (after 28 days of the cast the composite column), the column specimens were removed from water basins. Then it was cleaned and painted in order to clarify between them and show patterns of failure. Before the testing, iron caps 25 mm thick are set above the column for load distribution and fixation purposes, while The column's lower support is pinned. The longitudinal displacement of steel was measured by using four strain gauges. Two strain gauges were placed 2.5 cm from the top of the tube in perpendicular faces. The other two strains were placed in the mid-height of the column. Three Linear Variation Displacement Transducers (LVDT) were installed to determine the change in the column's vertical and lateral movement during the inspection process. The minimum readings for the division were about 0.01 mm with a slight effect of electrical noises. The horizontal deflection was measured in the middle of the column through two LVDT’s. Another sensor was used to measure the deflection at the top of the column. The machine of the test has a capacity of approximately 2000kN. The test was performed on the columns up to failure. The load was recorded by load cell with a capacity 2000 kN linked to a computer, as shown in Plate (5). Throughout the loading of the test specimens, a loading control rate of 0.6 KN/S was applied.

Repeated axial loading was applied to the specimen. The testing process was divided into two methods: repeated loading and static loading (last cycle of loading). The repeated test included six cycles of one direction repeated loads with different intensities. The specimen loaded each 10 kN gradually up to the maximum load level in that particular cycle and then unloaded. The maximum load in these cycles is 25% of the estimated ultimate load. Then, the same process will be applied with 50% and 75% (Pu is for the reference, that obtained from the samples have the same parameters). After that, loading of the specimen continues until failure (static loading).

Plate (4) Install of the test specimen

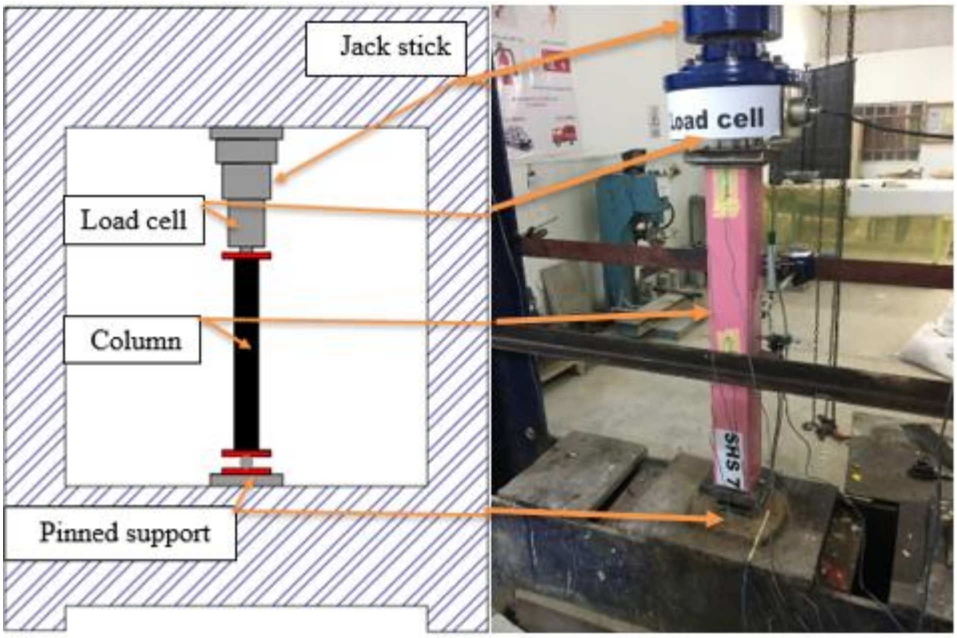

Plate (5) Testing machine

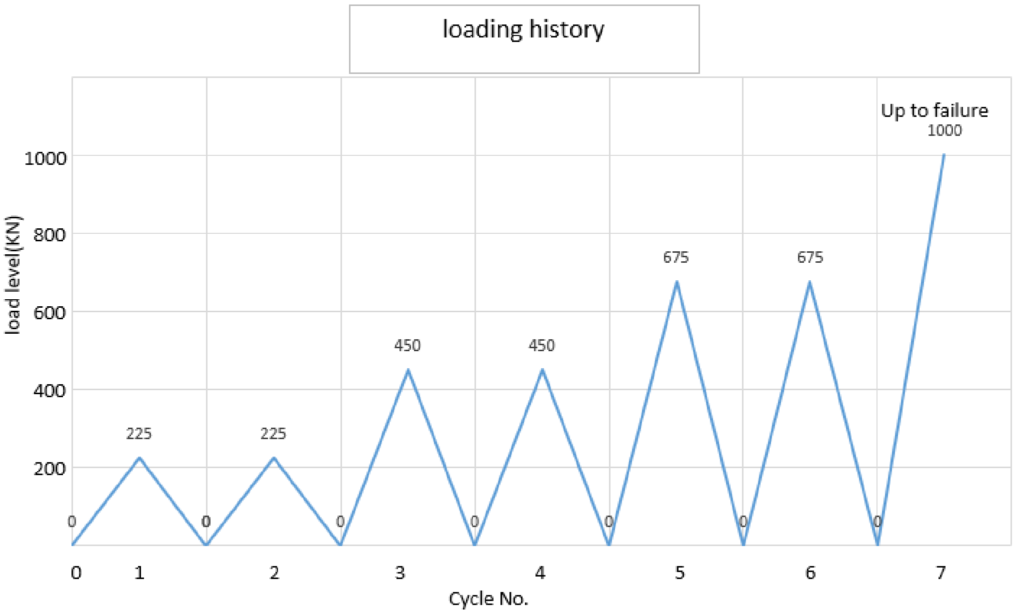

Figure 3 process of loading

7. Results and Discussion

7.1 Load-axial shortening

The effect of the added steel-fiber ratio in the concrete mixture and the cross-section of the sample, as well as the effect of non-filled concrete from load-axial shortening relationship, can be known. Three LVDTs were installed on the column, one of them to measure the vertical shortening, and others recorded the lateral movement of each column, and four strain gauge update in the mid and top of the column to find out that the tube where reached the yield stress region or not. The yield stress of steel was determined by the tension coupon testing. During the testing, it was observed that the steel started to bend approximately 80 percent of the final column endurance, as shown in Plate (6). The load-deflection and the deflected shape of all these columns are illustrated in Figures (4) to (9)

Plate (6) Mode failure of column

7.1.2. Circular section

7.1.2.1 Influence of steel fiber

High-strength concrete mixtures (RPC) were designed with two different percentages of steel fibers. Figures (4) and (5) show first and second percentage was 0.5 % and 1.5 %, respectively from the volume of the mix. This rise led to an increase in the compressive strength and thus increased the section's stiffness. It was noted that the volumetric expansion of the concrete was reduced by the increase in the compressive strength, which in turn delayed the crushing of concrete in the tube and local buckling. The rapid rise in the section's compressive strength from (CHS1) 73.3 to (CHS2) 90.32 reached to 17.41 % increase in the section's strength. The ultimate load of (CHS1) is 910kn while the (CHS2) is 775kn. In the first, second and third loading cycle for (CHS1) and (CHS2) sample, the deformation was approximately 2,.3,4 and 3,7,8 (mm) respectively, but in the failure (last cycle of loading) 6.5mm for the sample (CHS1) and 10 mm for (CHS2). Compared to the section non-filled with concrete (CHS3), the rates of increase in the final capacity of the column by 0.5 % and 1.5 % for the column were 158.83% and 200.24%, respectively. The greater the compressive strength, lead the deflection curve to the sudden failure curve. On opposite in which (CHS3) appeared a high curved ductility of the column as shown in figures (4), (5), (6). The value for deflection at ultimate load in the sample (CHS1, CHS2, and CHS3) reached about 6.5,10,and 11 mm respectively. The contribution of steel fiber in inhibition of both plastic shrinkage cracks. As excessive forces are applied to a member and cracks, begin to develop, the even distribution of fibers throughout ensures they will be present at the side of fatigue. At the moment that cracks start forming, the tensile forces are applied to transfer into the fibers, which can have tensile strengths over 2850MPa. The fibers bridging the cracks lend their strength to the member, allowing it to remain ductile, withstand increasing stresses, and impede crack propagation.

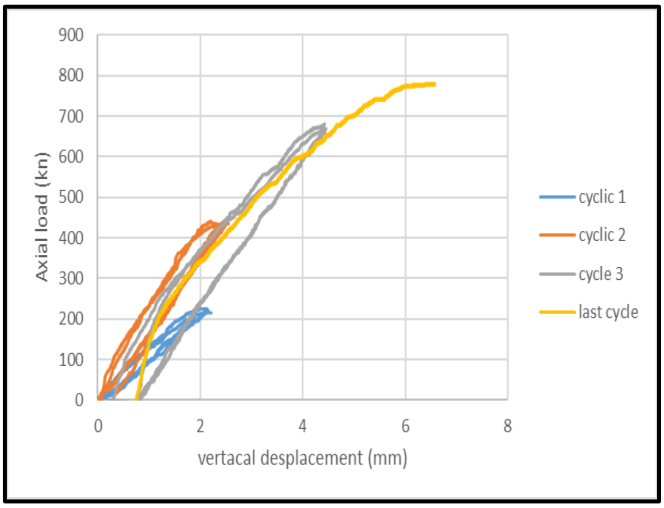

Figure (4) Specimen (CHS1) with steel fiber ratio 0.5%

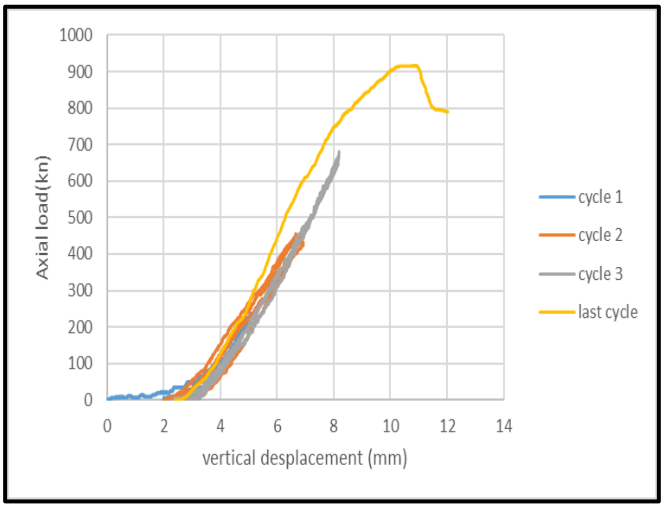

Figure (5) Specimen (CHS2) with steel fiber ratio 1.5%

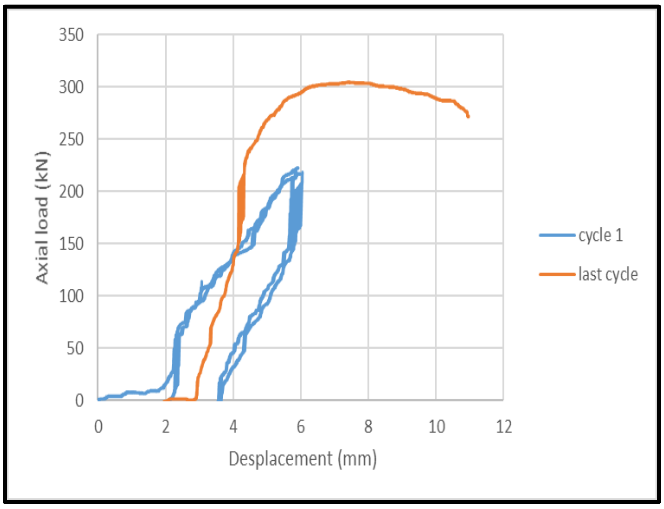

Figure (5) Specimen (CHS3) Non filled with concrete

7.1.3 Square Section

7.1.3.1 Influence of steel fiber

Steel fibers were used in two different percentages in high-strength concrete mixtures (RPC). Figures (7) and (8) show that the first and second percentages were 0.5 and 1.5 %, respectively. This increase in compressive strength increased the stiffness of the section. The volumetric expansion of the concrete was reduced as the compressive strength of the concrete increased. As a result, delayed concrete crushing in the tube and local buckling is reduced. The section's compressive strength increased steadily from (SHS1) 73.3 to (SHS2) 90.32, leading to an increase of 9.62 % in strength. Where (SHS1) had a maximum load of 810 kN and (SHS2) had a maximum load of 888 kN. The deformation of the (SHS1, SHS2) sample was nearly equal in the first and second loading cycles.

The displacements of cycles one, two and three were 2, 4, and 6mm for (SHS1) and (SHS2), respectively. Compared to the section with only steel tube (SHS3), the rates of increase in the final capacity of the column by 0.5 % and 1.5 % for the column were 138.23 % and 161.17% respectively. The greater the compressive strength, lead to the sudden failure curve. On opposite in which appeared a high curved ductility (SHS3) of the column as shown in Figures (7), (8), and (9). The value for deflection at ultimate load in the sample (SHS1, SHS2, and SHS3) reached about 8, 9, and 12mm, respectively.

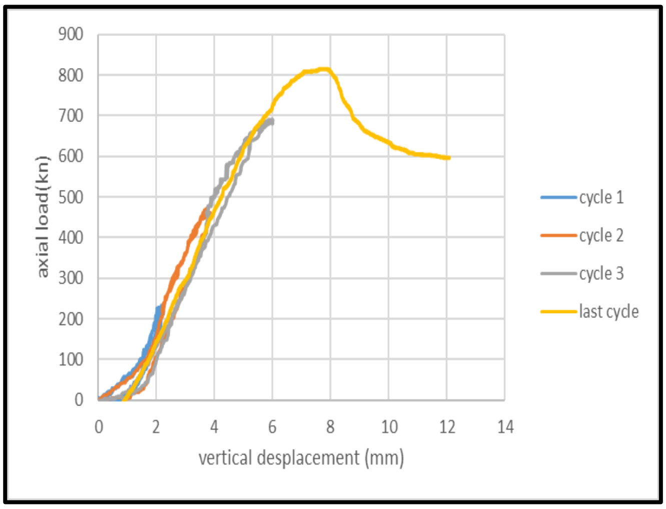

Figure (7) Specimen (SHS1) with steel fiber ratio 0.5%

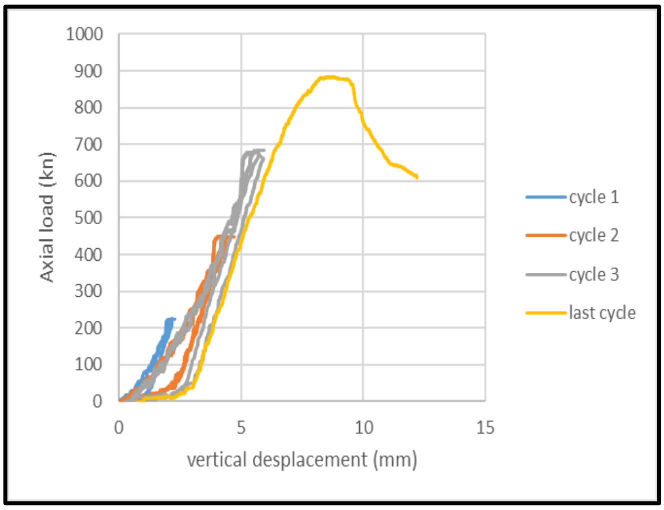

Figure (8) Specimen (SHS2) with steel fiber ratio 0.5%

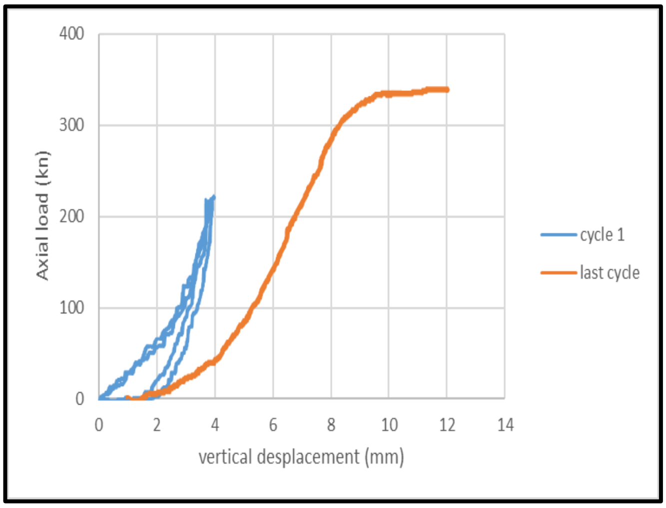

Figure (9) Specimen (SHS3) Non filled with concrete

9. Conclusions

1- Through the research identified how the composite columns behaved under the influence of repeated loading. The columns filled with high strength concrete have a higher bearing than the columns without concrete under the influence of the same cross-section of the column.

2- The increase in the ratio of steel fibers in the concrete mixture (RPC) from 0.5% to 1.5% significantly increased the compressive strength and thus improved the seismic endurance of the composite column.

3- The high confinement of the circular cross-section leads to higher endurance of the section. Also, higher resistance for the short columns than the square column is shown.

4- The theoretical analysis of the columns according to the ACI Code show underestimated ultimate experimental load. It is mean that the ACI is safe for the expectation of bearing the composite columns.

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التحقيق في سلوك الأعمدة الأنبوبية الفولاذية المملوءة بخرسانة المسحوق التفاعلي ومقارنتها بمعايير تصميم ACI

الخلاصة: الأعمدة المركبة المكونة من أعمدة فولاذية ثنائية الانبوب مملوءة بخرسانة عالية الاداء هي إحدى الطرق التي تجمع بين خصائص الخرسانة والفولاذ وأسرع في البناء مع قوة ضغط أفضل. تتكون هذه الطريقة من لحام أنبوبين من الفولاذ في أقسام مختلفة ولحامهما بشكل مركزي ، وملء الفجوة بينهما بمسحوق الخرسانة التفاعلي. تتكون الدراسة الحالية من جزء عملي يتضمن صب سبعة عمود مركب من أقسام دائرية بخصائص مختلفة لمعرفة أدائها المحوري. تم تقسيمها إلى مجموعتين ، المجموعة األولى مملوءة بمسحوق الخرسانة التفاعلية ، والمجموعة الثانية غير ممتلئة. جميع األعمدة لها أبعاد مقطع عرضي بقطر (100)مم وبسمك 2.2 مم. كانت أطوال العينات 800 مم رللدائري والمربع زتم فحص خصائص األنبوب بالكود األمريكي ، مما يحقق أداء مقبول من خالل االنثناء المحلي. تم توصيل الانابيب الفولاذية بشكل مزدوج باللحام. تضمنت متغيرات الجزء العملي: نسبة ألياف الصلب في الخليط الخرساني حوالي 5.0 ٪و 1.5 ، ٪ ,شكل المقطع العرضي للانبوب ، والانبوب الغير ممتلئ. تم تطبيق الحمل محورًيا وتركز على العمود. أظهرت نتائج العمل أن الانابيب الفولاذية المملوءة بخرسانة مسحوق رد الفعل تعطي مقاومة قصوى عالية مقارنة بالاعمدة غير ممتلئة في حالة استخدامها.. تمت مقارنة النتائج التجريبية للقوة القصوى مع متطلبات كود البناء للخرسانة الانشائية *ACI* ،أعطت معايير التصميم المذكورة توقعًا لألقسام الفولاذية الدائرية أقل وبمقدار تحفظ عالي جدا.