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Research paper



Behavior of Plastic Tubular Specimens Filled with Brick-Aggregates Concrete Under Compressive Loads

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Abstract

This study represents results of an experimental test to investigate the effect on the compression strength of gravel and recycled brick aggregates concrete specimens confined using plastic tubes. Plastic tubes used to confine concrete which is produced using river gravel or broken brick as a replacement for river gravel. A compressive load was applied to the specimens gradually up to failure.
The results have indicated that as concrete compressive strength increased from (21.0 to 27.5)MPa, an increase in peak load of (3-46)% was achieved. Moreover, the brick aggregates concrete specimens have lower peak load as compared to gravel concrete and the peak load of confined specimens increased (3-6) times as compared to unconfined. Also, when the ratio of (height/diameter) of the concrete specimen increases from (2-4) the peak load decreased by about (2-12)%.
The use of brick aggregates as a replacement to river aggregates results in significant decrease in weight and cost of concrete members. As well, the use of plastic tubes as a concrete form is superior to other construction materials such as wood or steel forms, since plastic tubes reduce the cost of forms and time of construction, and it protects concrete used for underground construction.

Keywords: *Broken Brick; Concrete Column; Confinement; PP-R Pipes; Strength.*

1. Introduction

The continuous decadence in piers and piles of structures, especially those constructed in harsh environments such as piles of bridges, has raised the request for repairing and modifying existing concrete columns in building and passway substructures [1]. It is needful to repair the decadence and damaged concrete columns to raise their carrying capacity and ductility to get better durability and realization [2].
A composite system such as Concrete-Filled Tube (CFT) may be used for such rehabilitation and retrofitting. For many years, different types of confined columns had been used such as steel or FRP (fiber-reinforced polymer) pipes as the confinement material. But these types of materials are facing a lot of difficulties due to a number of factors such as abrasion resistant of steel when used in under-sea piling, and the high cost of industrialization FRP material [4]. An alternative to the use of composite materials tubing is to use plastic pipes. The pipes are corrosion resistance and are rather cheap as compared to the steel and FRP [4].
The plastic jacket also acts as permanent formwork. Formwork methods must be capable of carrying its own weight, the weight developed by fresh concrete, also live loads associated with the construction operation and equipment. The formwork that stay-in-place has been lately used as an alternative to the conventional formwork methods. Stay-in-place formwork methods are mainly assembled on site, hence facilitate the construction operation and reducing the construction time as the removal proceedings are eliminated. Furthermore, many of the stay-in-place formwork methods are made of lightweight and prefabricated materials [5].
Recently, many research efforts have been conducted to study the structural behavior of confined concrete columns using the commercially available UPVC plastic pipes. Thus this study focused on investigating the behavior of columns concrete filled in tubular made from plastic using Polypropylene random copolymer (PP- R) pipes. Due to good and important physical properties of PP - r such as properties of mechanical resistance, inertia to chemical aggression impact strength, corrosion resistance and higher working temperature and has general properties of low density, good balance of stiffness to toughness, low tendency to stress cracking and is easy to process and installation. PP-r becomes the most popular material used in the world's market as a construction material. [11].
The normal weight of concrete (self-weight) varies from (2200 to 2600) kg per cubic meter. And this is one of the main disadvantages of traditional concrete as this heavy-weight concrete makes it uneconomical construction material. For increase the efficiency of concrete as a construction material, attempts have been made to minimize its weight per cubic meter. A type of Concrete having self-weight ranging from (300 to 1850) kg per cubic meter is called light-weight concrete. Recently years, lightweight concrete has become more popular due to various advantages it offers over the traditional concrete [6]. Recycled aggregates (from construction, demolition and excavation wastes) are increasingly used as partial replacements of natural aggregates. Concrete can be successfully produced using recycled materials. The use of recycled aggregate concrete (RAC) has steadily increased during the last two decades and its current field of applications includes: lightweight concrete, lightweight aggregate, asphalt concrete, concrete exposed to high temperatures and road

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construction. The use of crushed waste as aggregate in concrete has begun in Europe since the Second World War [7]. Broken bricks are extensively used in parts of many countries for concrete making and the performance of this concrete is found to be quite satisfactory [8]. RAC wide work has established that using of many types of recycled aggregate such as contaminated broken brick, light-weight broken bricks, light-weight expanded clay, low-strength bricks, granulated plastic, glass and fiber-glass waste materials in concrete generate concrete with light weight, light density and low price [9].

In this investigation, many trails had been done to study the feasibility of using locally available broken bricks as substitute for gravel aggregates for making recycled aggregate concrete (RAC). Normal concrete confined specimens using gravel aggregate are also produced and tested to compare their results with RAC made from broken bricks. Test results obtained are presented and discussed herein this paper.

2. Experimental Program

A total of 32 short specimens have been tested under a concentric axial compression load, (16) unconfined and (16) are confined concrete specimens by PP-r tubes. The variables investigated were the type of concrete (river gravel or brick aggregates concrete), different strengths (21 and 27.5)MPa, and two h/d ratios, namely (2 and 4).

2.1. Specimens Details

All specimens have a diameter of 73mm and heights of (140 or 280)mm depending on h/d ratio. Description and details of the test specimens are shown in Table (1) and figure (1). It may be noted that each specimen is designated to refer to the type of concrete, strength, and h/d ratio. For example, the specimen NC1R1-1 is a specimen made of normal concrete (in which gravel aggregate in use) with compressive strength 27.5MPa and h/d ratio (2). In addition to that each group from these groups has been made once confined and the other unconfined.

Table 1: Specimens details

Group No.	Specimen	h/d ratio	Specimen height (mm)	f'c at 28 days (MPa)	Type of Aggregate
Group I	NC1R1-1	2	140	27.5	River Gravel
	NC1R1-2				
	NC1R2-1	4	280		
	NC1R2-2				
Group II	NC2R1-1	2	140	21.0	River Gravel
	NC2R1-2				
	NC2R2-1	4	280		
	NC2R2-2				
Group III	BC1R1-1	2	140	27.5	Broken Brick
	BC1R1-2				
	BC1R2-1	4	280		
	BC1R2-2				
Group IV	BC2R1-1	2	140	21.0	Broken Brick
	BC2R1-2				
	BC2R2-1	4	280		
	BC2R2-2				

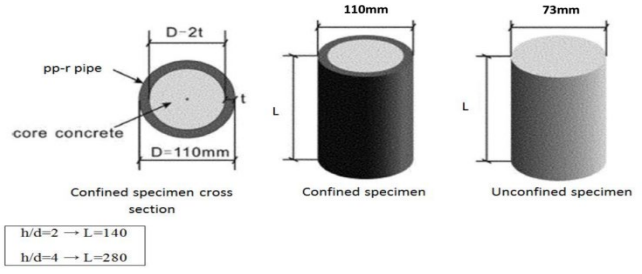


Fig. 1: Test specimens

2.2. Material Properties

2.2.1. Cement

Type (Type I) of Tasluja Ordinary Portland cement has been used. It was stored in suitable conditions to avoid any exposure to hazardous conditions.

2.2.2. Aggregate

Fine Aggregate: Al-Ukhaidher natural sand was used which satisfy the (Iraqi specification No. 45/1984).The grading of fine aggregate used is given in Table (2). Which comply with grading area (2), and Fineness modulus (3).

Table 2: Grading of fine aggregate

Sieve Size (mm)	% Passing	
	Fine Aggregate (%)	Limit of Iraqi Specification No. 45/1984 for Zone(2)
10	100	100
4.75	90	90-100
2.36	78	75-100
1.18	65	55-90
0.60	56	35-59
0.30	23	8-30
0.15	2	0-10

Coarse Aggregate: Round gravel of maximum size (20 mm) brought from Al-Niba'ee region was used. It satisfies the (Iraqi specification No. 45/1984), water absorption is 1%. Table (3) show the grading of this aggregate.

Table 3: Grading of coarse aggregate

Sieve Size (mm)	% Passing	
	Coarse Aggregate (%)	Limit of Iraqi Specification No. 45/1984
37.5	100	100
20	99	95-100
14	-	-
10	54	30-60
5	9	0-10

Broken Bricks: obtained from bricks locally available by crushing. Grading was conducted by the National Center for Construction Laboratories and Researches Baghdad, Iraq. Maximum size (10 mm), water absorption is 14%. Table (4) show the grading of this broken brick aggregate.

Table 4: Broken brick aggregate grading

Sieve Size (mm)	Passing (%)	
	Broken Brick Aggregate (%)	Iraqi Specification (Limitation) No. 45/1984
37.5	100	-
20	١٠٠	١٠٠
14	-	-
10	٧٦	٥٠-٨٥
5	10	0-10

Both gravel and brick aggregate sieving on (5mm) sieve and then use the passing from this sieve to make the concrete specimens.

2.2.3. Water

Ordinary potable clear water was used for each mixing and curing of concrete in the experimental work.

2.2.3. Plastic Tubes

Tubes of Polypropylene Random Copolymer (**PP-R**) were used to confine plain concrete as column specimens and also used as molds for casting the unconfined plain concrete specimens. These (**PP-R**) PN20 pipes comply with DIN 8077 specification. It has nominal outside diameter (110mm), wall thickness (18.5mm), weight (5.01 kg/m), and length (4m) according to manufacturing specifications. **PP-R** is an adjusted copolymer with maximal

resistance to impact. The lower crystalline prevents the forming of tight cracks in the inside surface of the pipe. **PP-R** is characterized by its outstanding chemical resistance, they withstand acid and alkaline substances within a wide concentration and temperature spectrum. They safely withstand contact without any special precautions. Table (5) show the physical properties of PP-r tubes.

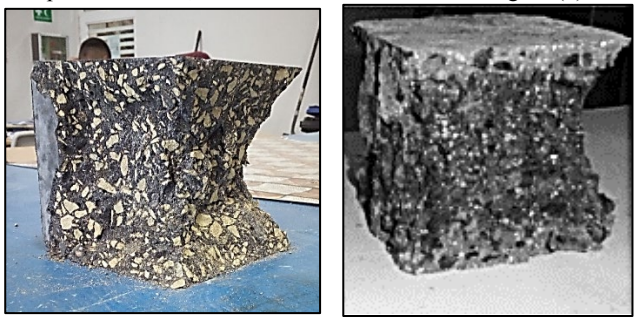
Table 5: Physical properties of PP-r [11]

Properties	Test Result
Density	0.895 g/cm3
Weight of Molecular	500000
190/5 MFI	0.5 g/10 min
Range of Melting	140°C - 150°C
Module (E)	800 N/mm2
Length expansion Coefficient	1 .5 X 10^{-4} K^{-1}
Thermal conductivity	0.24W/mK (at 20°C)

Tests of **PP-R** plastic tubes (without infill concrete) have indicate the average peak load of having a height (14cm) is 172.3 kN.

2.3. Concrete Mix Design

The concrete with two targeted compressive strength of (21.0 and 27.5)MPa was considered for each type of aggregates. The average compressive strength results obtained from testing (150)mm cubes and at 28-days of curing are 20.9 MPa and 27.1 MPa, respectively, The cubes are put in the compression device such that load is applied on the adverse side of the cubes as cast. The cubes are aligned cautiously and then the load is applied until the specimen failed, the failure modes as shown in figure (2).



Broken Brick Agg. Cube River Gravel Agg. Cube

Fig. 2: Cubes failure modes

The concrete mix proportions are given in Table (6) below. It was found that the used mix proportion produces good workability which ranges (4-6)cm for both types of concrete.

Table 6: Concrete mix component quantities for ($1m^3$)

Compressive Strength at 28 days (MPa)	Grade 21.0		Grade 27.5	
Type of Aggregate	River Gravel	Broken Brick	River Gravel	Broken Brick
Cement (kg)	300	300	400	350
Fine Aggregate (kg)	600	750	600	750
Coarse Aggregate (kg)	1200	540	1200	540
Water/cement ratio	0.55	0.8	0.5	0.65
Mix Proportions	1:2:4	1:2.5:1.8	1:1.5:3	1:2.5:1.8
Avg. Compressive Strength (MPa)	20.9	20.5	27.2	27.0

2.4. Concrete Mixing and Placing

The concrete was mixed using a horizontal (0.19 m^3) capacity rotary mixer. Before casting, all molds (plastic tubes) have been cleaned, and their internal surfaces were lightly greased to prevent the adhesion of hardened concrete to internal surfaces of the cube molds. To get un-confined status for a concrete specimen of the same diameter as confined specimens, similar **PP-R** was used as a mold for casting of specimens. Concrete is poured into the mold in three stages and well compacted using a standard compacting metal rod of circular section with a diameter of (١٦mm), and (٦٠٠mm) long. After 24 hours, the specimens are cured by potable water for a period of twenty-eight days.

2.4. Test Measurements and Instrumentation

The experimental work was carried out utilizing compression devices at the laboratory of Building and Construction Technical Engineering (BCTE) department of Al-Esraa College University. The specimens were let to dry before testing, and to unconfined specimens the PP-R molds were removed by cutting it as shown in Figure (3). Monotonic loads were applied on all specimens for tested up to failure. Specimens were undergone to concentric axial compressive load, applied on the specimens, center by means of a hydraulic jack through uniform iron end plates to achieve a constant stress distribution at the concrete cross-section. The load was applied to the entire specimen section. An incremental loading procedure was used to test the specimens.



Fig. 3: Specimen setup cubes

3. Experimental Program

3.1. Observed Behavior

All specimens behaved more or less in the same manner during the loading process. Phonemes were heard during the middle or early stages of loading, that may be attributed to the micro-cracking of the concrete. The failure patterns of specimens can be divided into two categories; shear failure and outward buckling. As shown in Figure (4), shear failure is exhibited for the unconfined specimens. Characteristic of typical shear failure is that concrete is ruined by the stress of shear in one direction. The direction of the crack of shear can be arbitrated by the appearance of the specimens.



Fig. 4: Shear failure of unconfined specimens

The other observed type of failure mode was buckling failure that leads to confined specimen crushing due to compression. Buckling failure can be classified into two types. Overall buckling and local

buckling (drum-type or bulging), this was observed to occur near the bottom, top or mid-height of the specimen as shown in Figure (5(a)). The pulp of concrete does not crack in one direction, and the look of the specimen turns out to be a drum type because of the strong confinement by the plastic pipe. Reference [10] also observed similar type of failure. While overall buckling occurred along the overall height of the specimen as shown in Figure (5(b)).



a. Local buckling occur near mid-height



b. Overall buckling

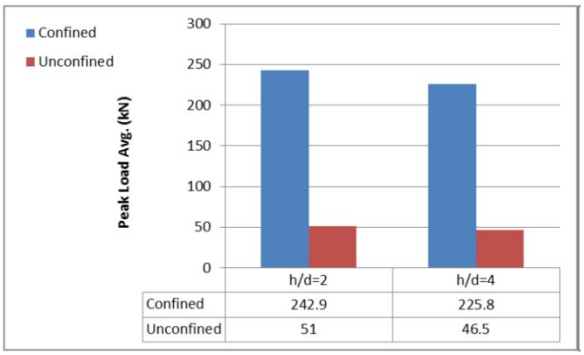
Fig. 5: Typical specimen's failure modes

3.2. Observed behavior

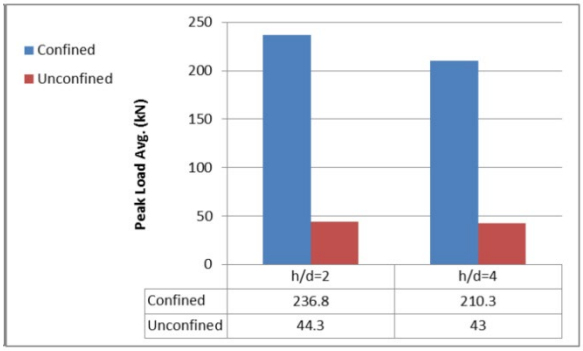
The effect of confinement on the load carrying capacity and the compressive strength of the specimen are shown in Table (7) and Figure (6) for both concrete grades, type of aggregate and (h/d) ratio.

Table 7: Specimen Load Capacity and Confinement Effectiveness

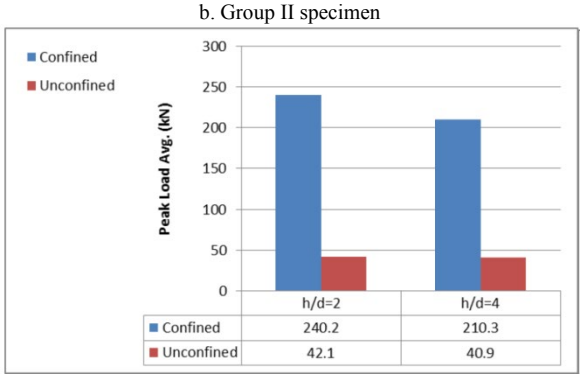
Group No.	Specimen	h/d ratio	Strength f'c at 28 days (MPa)	Confined Model		Unconfined Model		Confinement Effectiveness	
				Peak Load (kN)	Peak Load Avg. (kN)	Peak Load (kN)	Peak Load Avg. (kN)	Pc/Pu	Increment percentage (%)
Group I	NC1R1-1	2	27.5	237.2	242.9	50.3	51.0	4.8	376
	NC1R1-2			248.5		51.7			
	NC1R2-1	4		215.3	225.8	50.3	46.5	4.9	386
	NC1R2-2			236.2		42.7			
Group II	NC2R1-1	2	21	237.8	236.8	43.0	44.3	5.3	435
	NC2R1-2			235.7		45.6			
	NC2R2-1	4		217.1	210.3	42.6	43.0	4.9	389
	NC2R2-2			203.5		43.4			
Group III	BC1R1-1	2	27.5	242.4	240.2	46.7	42.1	5.7	471
	BC1R1-2			237.9		37.5			
	BC1R2-1	4		210.6	210.3	46.0	40.9	5.1	414
	BC1R2-2			210.0		35.7			
Group IV	BC2R1-1	2	21	218.3	224.9	29.4	28.9	7.8	678
	BC2R1-2			231.4		28.4			
	BC2R2-1	4		211.1	209.2	26.6	28.4	7.4	637
	BC2R2-2			207.3		30.2			



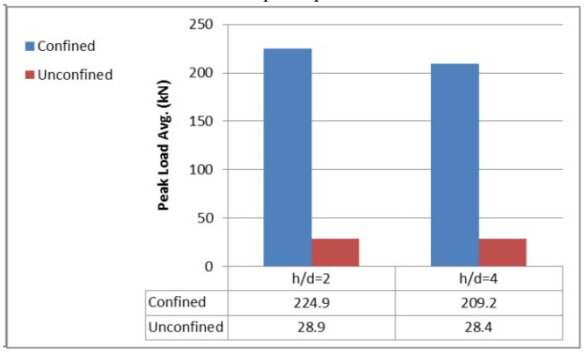
a. Group I specimen



b. Group II specimen



c. Group III specimen



d. Group IV specimen

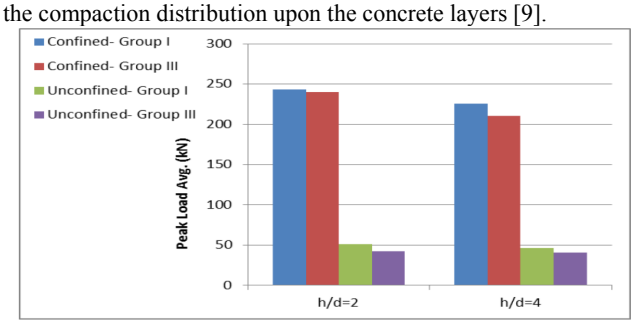
Fig. 6: Effect of Confinement on the Load Carrying Capacity of Specimen

From the above results, it can be observed that the confining concrete specimens using plastic pipes enhance the load resisted by specimens. The increase in confined specimen strength range between 4.8 to 7.8 times.

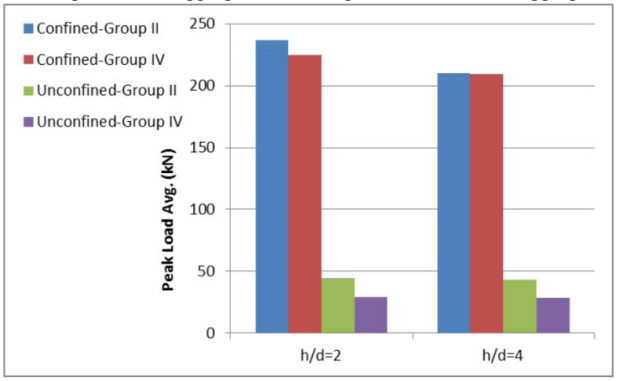
Higher value is associated with specimens produced using broken bricks as compared to the strength of specimens produced using river aggregates. Higher values are also associated with lower strength specimens and lower (h/d) ratios.
The enhancements in strength is attributed to the confinement effect of plastic pipes. The confinement of concrete specimens provided by plastic tubes results in specimens being compressed longitudinally and radially, rather than comprised longitudinally which enhanced the load capacity of the tested specimens.
Reference [4] have also observed similar behavior and stated that the effect of confinement.

3.3. Effect of Broken Bricks as Course Aggregate in Concrete

The effect of using broken bricks aggregate on the load carrying capacity and the compressive strength of specimens as shown in Figure (7).
Test results in Figure (7(a)) show that the confined specimen (Group III) had to decreased in peak loads about (1%, and 7%) and for unconfined specimen about (17%, and 12%), respectively compared with the peak loads for the confined and unconfined specimen (I).
Also, test results in Figure (7(b)) show that the confined specimen (Group IV) had to decreased in peak loads about (5%, and 1%) and for unconfined specimen about (35%, and 34%), respectively compared with the peak loads for the confined and unconfined specimen (II).
From the results shown above, it can be concluded that using of broken bricks in concrete reduces its load carrying capacity and the compressive strength of the specimen. But from the results shown above, it can be concluded that this decreasing ratio in peak loads significant reduced for confined specimen compared with unconfined column specimen.
The reduction in strength may be referred to that the broken bricks failed to develop proper, adequate bond with concrete and cement matrix, the mixture required more water to earn the required slump because of a lot of porosity of the surfaces of the broken bricks, The broken bricks made the mixture unworkable because of roughness of the surfaces of broken bricks aggregates affecting the compaction distribution upon the concrete layers [9].



a. Group I, Gravel Aggregates vs. Group III, Broken Brick Aggregates



b. Group II, Gravel Aggregates vs. Group IV, Broken Brick Aggregates

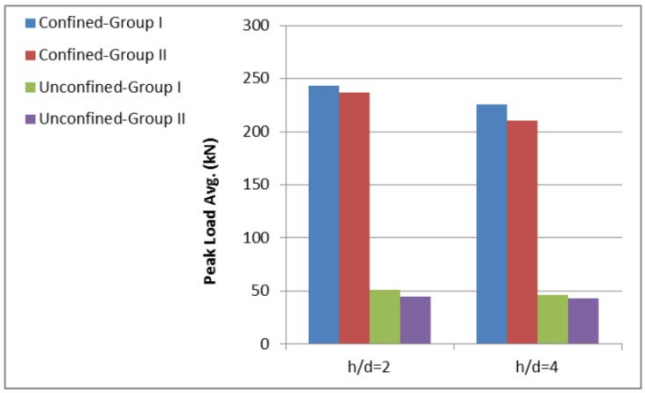
Fig. 7: The Effect of Use Broken Bricks Aggregate on the Load Carrying Capacity

3.4. Effect of Varying (Height / Diameter) Ratio on the Load Carrying Capacity

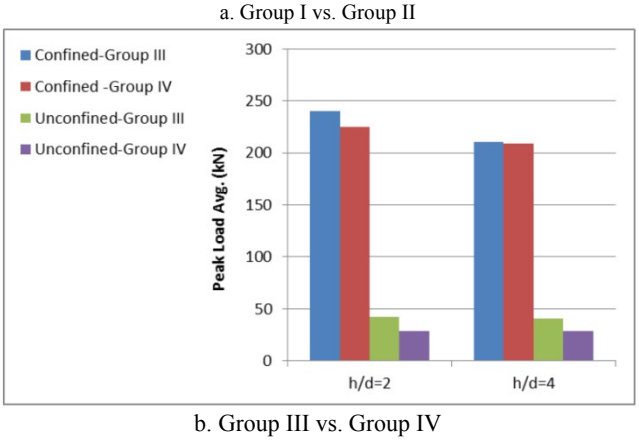
The effect of varying height to diameter (h/d) ratio on the load carrying capacity of the specimen was spotted that the capacity of load values, were decreasing with increasing in (h/d) ratio. The decrease fall in the range (2% to 12%), which indicate that the stiffness has an effect on specimens were increased with decreased in (h/d) ratio.

3.5. Effect of Compressive Strength of Concrete (Grade of Concrete) on Load Carrying Capacity and Compressive Strength of Specimen

The effect of compressive strength of concrete on the carrying capacity of load and the compressive strength of the specimen shown in Figures (8).
Test results in Figure (8(a)) show that the specimens in Group I shows an increase in peak load by about (3%, and 7%) for confined concrete and about (8% and 15%) for unconfined, compared with peak load with specimens of Group II, respectively.
The test results in Figure (8(b)) also show that the specimens in Group III had to increased in peak load about (1%, and 7%) for confined and about (44%, and 46%) for unconfined, compared with peak load for Group IV, respectively.
This increasing was may be due to the specimen in Group I and Group III had a compressive strength greater than the strength of specimen in Group II and IV. So, this led to an increase in specimen stiffness and improved the resistance to cracking in the specimen, and as a result, the overall strength of the specimen was increased.



a. Group I vs. Group II



b. Group III vs. Group IV

Fig. 8: The Effect of compressive strength of concrete (grade of concrete) on the load carrying capacity

4. Conclusion

Depending on the results and observations which were obtained, the following conclusions can be drawn:

1. Two type of failure are monitored during the tests. The first one is Shear failure which exhibited for the unconfined specimens and the second one appeared in confined specimens which presenting into two type overall buckling and local buckling (drum-type or bulging).
2. It was found out that plastic tubes are very effective for confining of concrete, as proved by the raised of peak load for all cases. The improvement in the peak load ranges from (376 to 678)%, (473 % as a typical average improvement for all cases).
3. Using of broken bricks in concrete reduces its load carrying capacity and the compressive strength of the specimen. But this decreasing ratio in peak loads significant reduced for confined specimen compared with unconfined specimen which ranged from (1 to 7)%. Which mean that the used of broken bricks as a substitute for river gravel aggregates shows advantages from construction and an economic stand-points by a significant decrease in weight and cost of concrete members.
4. This study has found that broken bricks specimens confined with PP-r pipes can be used satisfactorily as composite materials for making concrete of acceptable strength characteristics.
5. It was spotted that the values of the load capacity were decreasing with increasing in height to diameter (h/d) ratio. The decreasing ratio in the range (2 to 12)%.
6. The peak load increased as the compressive strength of concrete value was increased. It was found that as (f'c) increasing from (21 MPa) to (27.5 MPa) the percentages of increase in the peak load range about (1 to 46)%.

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