VOL. 14, NO. 13, JULY 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

A SURVEY OF STUDIES ON PLASTIC TUBES CONFINED PLAIN CONCRETE AS COMPRESSION MEMBERS

Ahmed Sagban Saadoon, Abdulnasser Mohammed Abbas and Ali Abdulhasan Khalaf
Civil Engineering Department, College of Engineering, University of Basrah, Iraq
E-Mail: ahmsag@gmail.com

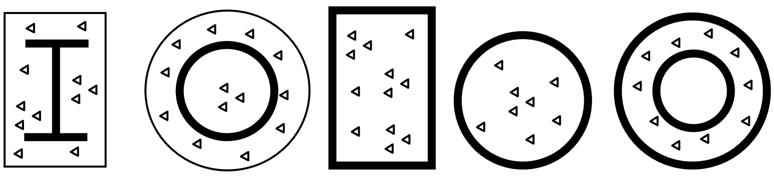
ABSTRACT

This paper reviews available reports, papers, theses, and conference papers on the use of plastic tubes confined plain concrete as compression members. Different hollow sections filled with concrete have been used as composite columns and many studies were performed in this area. However, there are few studies concerning with plain concrete filled plastic tubes. In this review, available published studies, on this type of composite columns, are reviewed and summarized to view the type of the studied columns and the main studied variables that affecting the behavior of these composite columns. More than (145) specimens are collected and showed in this review.

Keywords: composite columns, plastic tubes, compression members.

1. INTRODUCTION

Columns composed of more than one material are usually called composite columns. In these columns, different materials may work together to resist strains and stresses induced by external applied loads. In fact, conventional reinforced concrete columns may be referred as composite columns since they composed of steel and concrete, however the term 'composite columns' is usually used to refer applications such as sections filled with or encased in concrete as shown in Figure-1. Different materials have been widely used with concrete such as wood, steel, aluminum, fiber reinforced polymer (FRP) and plastic tubes. Fundamentally, unplasticised poly vinyl chloride (UPVC) pipes are hard to damage and last for long periods of time without the need for replacement and having lightweight, which permits easy handling, and impermeable to gases and fluids and durable. Hence these pipes are used extensively in the construction industry [1]. Plastic pipes, readily available for piping work, have been used, with concrete, as columns. This type of columns is generally referred to as Concrete-Filled Plastic Tube. The resultant is a cheap, more economical type of column for light weight construction. Plastic tube is Stay-in-place (SIP) formwork has been used as an alternative to the conventional formwork system. The systems are mainly assembled on site, hence simplifying the construction process and reducing the construction time as the removal procedure has been eliminated. One of the main advantages in the interaction between plastic tube and concrete is, local buckling of the tube is delayed by restraint of concrete and strength of concrete is increased by the confining effect of the tube [2].



(a) Encased (b) Concrete-filled

Figure-1. Different types of composite columns.

2. LITERATURE REVIEW

In 1978, Kurt [3] suggested using commercially available plastic pipes filled with concrete as columns. Specimens composed of various pipe diameters, thicknesses, and lengths were tested. Pipe diameters ranged from (38-100 mm), thicknesses ranged from (4.8-6.35 mm), and lengths varied from (200-1450 mm). For short and intermediate length columns, plastic-encased concrete showed a 45° shear failure mode. It was concluded that the strength of the concrete core was increased an average of 3.25 times the ultimate burst pressure of the pipe, and as the slenderness ratio reaches 20, slenderness effects begin to influence the ultimate load capacity of the column.

Marzouk and Sennah [4], in 2002, conducted an experimental study in which four concrete filled PVC columns were tested upto failure. All specimens were of 100 mm diameter and of different heights (270, 416, 562, and 758 mm) and were subjected to monotonically increasing axial load until compression failure occurred. They concluded that the use of PVC tube provides considerable lateral confinement to the concrete columns and as the slenderness ratio increases, the compressive strength of the concrete filled PVC tubes decreases.

Saadoon [5] in 2010 presented an experimental and theoretical study is to investigate the behavior of PVC-concrete composite columns. The main purpose of the experimental program was to investigate the structural behavior of PVC-concrete composite columns under axial compression loading conditions. The work was conducted in two stages. A series of (30) columns under axial compressive load were tested. It was found that the plastic pipe (PVC tube) provided sufficient lateral support of the concrete core and increased the ultimate strength of the column. The ratio of strength of PVC-concrete composite column to strength of plain concrete column ranged between 1.419 and 1.896 for columns with 30MPa concrete compressive strength, whereas it was between 1.118 and 1.405 for columns made with 50MPa. In the theoretical investigation fuzzy inference system and empirical equations was developed to predict the strength of PVC-concrete composite columns.

Wang and Yang [6], in 2010, used high-density polyethylene pipes to confine concrete (PPC) as composite columns. The ultimate strength, stress-strain curve, ductility were studied and the effects of plastic-pipe thickness and compressive strength of core concrete on the behavior of tested columns were also investigated. Results indicated that: 1) the ductility ratio and energy absorption of PPC was (1.17 to 4.27) and (10.7 to 26) times that of common concrete, respectively; 2) the pipe thickness and concrete strength have significant effects on onset behavior and post-peak behavior of the stress-strain curves and the ultimate strength of PPC; and 3) the ductility ratio of PPC greatly increases with the increase of pipe thickness and decreases with the increase of concrete strength.

In 2013, Gupta [7] conducted an experimental study to investigate the effectiveness of UPVC tube for confinement of concrete columns. UPVC tubes having 140, 160 and 200mm external diameters and constant height of 500mm were used to confine the concrete having compressive strength 20, 25 and 40MPa. During the experiments, mode of deformation and corresponding load-compression curves were recorded and obtained results are compared with the existing models for confined concrete available in the literature. It was found that the predicted capacities of columns using different models are within ±6% of the experimental capacities, and that the UPVC tubes can be effectively used for confinement of the concrete columns and to enhance their load capacity, ductility as well as energy absorbing capacity.

Gupta and Verma [8], in 2013, presented an experimental study on columns prepared by filling reinforced concrete in UPVC tubes exposed to artificial sea water prepared in the laboratory. Totally, 72 reinforced concrete-filled UPVC tubular column specimens of length 800mm were casted by filling the reinforced concrete in UPVC tubes having 160, 200 and 225mm diameters. The diameter-to-thickness ratio and length-to-diameter ratio of the specimens vary from 22.48 to 40.14 and 3.56 to 5, respectively. Out of 72 specimens, 36 specimens were converted to bare reinforced concrete columns by removing the tubes. In total, 18 reinforced concrete–filled UPVC tubular and 18 bare reinforced concrete specimens were kept completely submerged in artificial sea water of salt concentration 20N for a period of 6 months. No degradation in the strength and ductility of reinforced concrete-filled UPVC tubular specimens was observed after submergence in sea water. It can be concluded that UPVC tube provides a safety jacket to encased concrete core, and as a result improve strength, ductility.

In 2014, Usha and Eramma [9] tested UPVC tubes filled with concrete loaded axially until failure to investigate their load carrying capacity. A total of (18) specimen of UPVC tubes of diameter 150mm, thickness 7.11mm with effective lengths of 500, 600, and 700mm were cast. M20 grade concrete of two different mixes having two different sizes of coarse aggregate 6.3 and 10mm was filled inside the UPVC tubes. All the columns failed by local buckling. As the length was increased the strength increased and it was higher for the mix which had 6.3mm size of coarse aggregate compared to 10mm size of coarse aggregate. It was found that, an increasing of about 1.6% in compressive strength of concrete columns when confined by UPVC tube.

Gathimba *et al.* [10], in 2014, presented an experimental program to investigate the effect of using UPVC tubes in confining short concrete columns on ultimate strength. Plastic tubes having varying diameters and heights were used to confine concrete of different strengths. The resulting composite columns were subjected to concentric axial compressive loads until failure. The principal failure mode was a typical shear failure. The results indicated that the ultimate strength of tested columns increases with increasing the concrete strength and it decreases with increasing the column height. Strength of confined concrete increased between 1.18 to 3.65 times that of unconfined concrete. The study showed a greater potentiality of plastics as concrete confinement construction materials of the near future.

Gobinath [11], in 2014, conducted an experimental study to investigate the effectiveness of PVC tube for confinement of concrete columns. PVC tubes having 180, 250 and 300mm external diameters and 600mm height were used to confine the concrete column. Conventional columns, without PVC confinement, of 180mm height were failed by local buckling.

In 2015, Abdulla [12] used a flexible material, thermoplastic tubes, to improve the concrete strength and durability in terms of toughness and energy dissipations. Two types of concrete stub columns, unconfined and confined by thermoplastic tube, were tested under axial compression for height/diameter (H/D) ratio of 0.5 to 4 in two different increments. Results showed that concrete-filled thermoplastic stub columns had increased the ductility index by 1.56-3.39 times and the strain at peak stress by 1.54-5.04 times over that of unconfined concrete, depending on geometric slenderness, H/D ratio and tube thickness (t). The confined columns deformed considerably but remained almost intact and the brittle explosive failure, associated with normal concrete columns, was avoided.

Through their study in 2015, Mostafa and Ata [13] tested four confined concrete columns with plastic tube (PVC) of different length (200, 300, 400, 600 and 900mm). Test results showed that the failure of short columns were generally marked by sudden fracture of the

ARPN Journal of Engineering and Applied Sciences

plastic tube near the top and bottom edges of the tube while long columns were generally failed due to shear cracks followed by yield of plastic tube. The experimental results for plain concrete column confined with PVC tube showed that this type of construction can be used for economical building.

Gathimba [14], in 2015, used UPVC plastic tubes to confine concrete. Concrete of varying class strengths (C30, C25, and C20) were used to fill UPVC tubes. The tubes had outer diameters of 55, 83 and 110mm and thicknesses of 2, 2.5 and 3mm. The composite columns had slenderness ratios of 2, 3 and 4. Results showed that UPVC pipes are effective in confining concrete. Confined strength values increased between 1.18 to 3.65 times the unconfined strength values.

In 2016, Oyawa *et al.* [15] studied, experimentally and analytically, the structural response of composite concrete filled plastic tubes under compressive load regime. Plastic tubes having varying diameters and heights were used to confine concrete of different strengths. Results obtained in the study clearly demonstrate the effectiveness of plastic tubes as a confining medium for infill concrete, attributable to enhanced composite interaction between the plastic tube and infill concrete medium. The strength of confined concrete increased between 1.18 to 3.65 times that of unconfined strength. It was noted that lower strength infill concrete had the highest confined strength possibly due to enhanced composite interaction with the confining plastic tube. The study further proposes an analytical model for the determination of confined strength of concrete.

In their experimental stud in 2016, Abhale *et al.* [2] tested twelve PVC tubes filled with concrete under axial loads to investigate their load carrying capacity. PVC tubes were of dia. 152.4 mm, thickness 5mm and with effective length of 500 and 600mm. it was stated that the confinement of concrete columns with PVC tubes improves their compressive strength, improvement in strength is dependent on the concrete strength and geometrical properties of the tubes, as the length increases the ultimate axial strength of the column decreases considerable, and local buckling is less due PVC confinement. The experimental result was compared with the theoretical results. The experimental result was about 1.19% greater than theoretical result.

Fakharifar and Chen [16], in 2016, presented a new composite confinement system of FRP wrap and PVC tube with and without an impact absorption medium (compressible foam) in between. As part of this work, five concrete filled PVC tubes with 152 mm in diameter and 305 mm in height were tested under monotonically increasing axial loads in compression.

In 2017, Saadoon and Jasim [17] proposed empirical design equations to predict the ultimate strength of PVC-concrete composite columns. It was shown that the proposed empirical equations are capable of predicting the values of ultimate loads of PVC-concrete composite columns in a good agreement with the experimental values. The average values of ratios of experimental to predicted values of ultimate loads were 0.990 and 0.991 for the first and second proposed empirical equations, respectively.

Also Saadoon and Jasim [18], in 2017, presented a theoretical study to predict the ultimate strength of PVC-concrete composite columns. The study aimed at to investigate the potential of using fuzzy inference system (FIS) to predict the strength of the composite columns. Two models, Mamdani and Sugeno FIS model, having three inputs, one output, and twenty linguistic rules were constructed. According to the coefficients of correlations, both of the proposed models had high prediction performance. The obtained values were very close to the experimental results. The average values of ratios of experimental to predicted ultimate loads were 0.994 and 0.999 for the Mamdani and Sugeno FIS model, respectively.

Through their comparative study in 2017, Princy and Bhagavathi [19] investigated the structural behavior of concrete filled stainless steel, mild steel and PVC tube stub columns using M30 concrete. The slenderness ratio was taken as less than 12. Experiments were undertaken to examine the interaction between the stainless steel tube, mild steel tube, PVC tube and rebar. The size of stub columns was 150mm in diameter and 300mm in height. Compressive strength of PVC stub columns was 13 MPa which is 9.5 % lesser than normal stub columns. PVC pipe is in light weight compared to other materials, so it has very low load carrying capacity.

In 2018, Azeez *et al.* [20] presented an experimental research on the concrete filled PVC tubes short columns with various typical strengths of the infill concrete; C20, C25, and C40. A total of 36 columns, using PVC tubes, were tested to investigate the column’s behaviour and 18 cylinder concrete columns. The columns were 200mm height, 100mm external diameter and 3.5 and 4.8mm tube thickness. The column resistance showed an increment of between 32.24-83.25% higher compared to the control column specimens. Design equations for the concrete-filled PVC tubes columns were also proposed.

Ngamsangiem [21], in 2018, studied the compressive strength and flexural strength of cylindrical foam cement (CF) and foam cement-filled PVC tube (CF-PVC) specimens. The CF specimens were 100mm in diameter and 200mm in height. While the CF-PVC specimens had an outer diameter of 47.7, 59.4, 75.95 and 114.28mm, a thickness of 1.43, 1.45, 1.48 and 1.50mm and a length of 200mm for compression test and 650mm for bending test. Results showed that the PVC casing contributed to foam cements better compressive strength 434.62%, 382.13%, 319.36%, and 204.15% of 47.7, 59.4, 75.95 and 114.28mm, respectively. Test results indicated that PVC tubes can be effectively used for confinement of the foam cements and to enhance load capacity and ductility.

Al-Aasam *et al.* [22], in 2018, presented an experimental test to investigate the effect on compression strength of gravel and recycled brick aggregates concrete specimens confined using plastic tubes. A compressive load was applied to the specimens gradually up to failure. Results indicated that as concrete compressive strength

VOL. 14, NO. 13, JULY 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

increases from 21 to 27.5MPa, an increasing in peak load of 3 to 46% was achieved. Moreover, the brick aggregates concrete specimens had 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) %.

Govintharaj *et al*. [23], in 2018, presented an experimental study on axially loaded UPVC tubes filled with concrete to investigate their load carrying capacity. UPVC tubes were of effective lengths of 500, 600 and 700mm. whereas the concrete core was of 150mm in diameter. M20 grade of concrete of two types of fine aggregate was filled inside the UPVC tubes. The load-displacement and stress-strain curves were recorded in that study.

In 2019, Abdulla [24] evaluated experimentally the behavior of slender concrete columns encased in a thin, flexible plastic pour-in form under increasing axial load by testing two groups of columns. Group one included seven unconfined concrete specimens and group two included nine steel-fibered concrete specimens with or without the plastic pour-in form. Different end-restraint conditions were used at the top and bottom ends of the columns. Results showed an increase in strength of 42 to 71% for specimens with pour-in form over plain concrete columns. The experimental results were compared with the calculated results showing good agreement.

The above available published papers are summarized to view the type of the studied plastic-concrete columns and the main studied parameters that affecting the behavior of these composite columns. More than (145) specimens are collected from open literature and showed in this review. Plastic-concrete specimens reinforced, wrapped, retrofitted or enhanced with other materials like steel bars, steel sections, FRP sheets, FRP tubes, plastic sockets and basalt strips, are not implied herein. Summary of experimental results of plain concrete filled plastic tubes are shown in Table-1.

Table-1. Summary of studied concrete-filled plastic tubular columns.

Ref.	Specimen	f_t (MPa)	E_t (MPa)	f'_c (MPa)	Diam. D(mm)	Thick. t(mm)	Length L(mm)	P_{exp} (kN)	f_{exp} (MPa)
[3]	6	40.9	2760	C20.6	114.3	6.35	203.2	315.1	
	7	40.9	2760	C20.6	114.3	6.35	457.2	309.3	
[4]	5			C36	106	3	270	318.0	
	3			C36	106	3	416	311.0	
	2			C36	106	3	562	291.0	
	1			C36	106	3	758	287.0	
[5]	220A1	49.6	2770	C24.1	110	3.2	220	278.7	
	400A1	49.6	2770	C24.1	110	3.2	400	272.3	
	600A1	49.6	2770	C24.1	110	3.2	600	265.6	
	800A1	49.6	2770	C24.1	110	3.2	800	254.3	
	1000A1	49.6	2770	C24.1	110	3.2	1000	240.1	
	220B1	49.6	2770	C23.7	110	5.3	220	331.6	
	400B1	49.6	2770	C23.7	110	5.3	400	327.0	
	600B1	49.6	2770	C23.7	110	5.3	600	322.3	
	800B1	49.6	2770	C23.7	110	5.3	800	316.3	
	1000B1	49.6	2770	C23.7	110	5.3	1000	300.7	
	220A2	49.6	2770	C39.4	110	3.2	220	369.2	
	400A2	49.6	2770	C39.4	110	3.2	400	360.8	
	600A2	49.6	2770	C39.4	110	3.2	600	350.3	
	800A2	49.6	2770	C39.4	110	3.2	800	338.6	
	1000A2	49.6	2770	C39.4	110	3.2	1000	328.9	
	220B2	49.6	2770	C39.0	110	5.3	220	438.0	
	400B2	49.6	2770	C39.0	110	5.3	400	428.6	
	600B2	49.6	2770	C39.0	110	5.3	600	420.7	

VOL. 14, NO. 13, JULY 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

	800B2	49.6	2770	C39.0	110	5.3	800	408.1	
	1000B2	49.6	2770	C39.0	110	5.3	1000	391.2	
[6]	PE0.6-C30	26	1000	M34.9	110	4.61	220		23.0
	PE1.0-C30	26	1000	M34.9	110	7.35	220		25.0
	PE1.6-C30	26	1000	M34.9	110	10.3	220		27.1
	PE0.6-C45	26	1000	M58	110	4.61	220		28.8
	PE1.0-C45	26	1000	M58	110	7.35	220		30.0
	PE1.6-C45	26	1000	M58	110	10.3	220		29.5
	PE0.6-C60	26	1000	M74.9	110	4.61	220		42.9
	PE1.0-C60	26	1000	M74.9	110	7.35	220		39.0
	PE1.6-C60	26	1000	M74.9	110	10.3	220		36.6
[7]	T160M20PC1	27.5-52	3380	M23.6	160	4.25	500	638	
	T160M20PC2	27.5-52	3380	M23.6	160	4.25	500	640	
	T200M20PC1	27.5-52	3380	M23.6	200	5.85	500	1026	
	T200M20PC2	27.5-52	3380	M23.6	200	5.85	500	1044	
	T140M25PC1	27.5-52	3380	M28.6	140	3.9	500	530	
	T140M25PC2	27.5-52	3380	M28.6	140	3.9	500	511	
	T140M40PC1	27.5-52	3380	M43.5	140	3.9	500	714	
	T140M40PC2	27.5-52	3380	M43.5	140	3.9	500	742	
[9]	6.3CFFTC500	13.79		M20	157.11	7.11	500	675.4	
	6.3CFFTC600	13.79		M20	157.11	7.11	600	696.5	
	6.3CFFTC700	13.79		M20	157.11	7.11	700	716.2	
	10CFFTC500	13.79		M20	157.11	7.11	500	644.2	
	10CFFTC600	13.79		M20	157.11	7.11	600	661.7	
	10CFFTC7000	13.79		M20	157.11	7.11	700	682.7	
[10]	C-110/2-C20	40	3000	C20.7	110	2.5	220	167.3	17.6
	C-110/2-C25	40	3000	C27.2	110	2.5	220	181.3	19.1
	C-110/2-C30	40	3000	C30.7	110	2.5	220	195.3	20,5
	C-110/3-C20	40	3000	C20.7	110	2.5	330	161.8	17.0
	C-110/3-C25	40	3000	C27.2	110	2.5	330	171.8	18.1
	C-110/3-C30	40	3000	C30.7	110	2.5	330	180.2	19.0
	C-83/2-C20	40	3000	C20.7	83	3.0	166	131.1	24.2
	C-83/2-C25	40	3000	C27.2	83	3.0	166	140.6	26.0
	C-83/2-C30	40	3000	C30.7	83	3.0	166	144.8	26.8
	C-83/3-C20	40	3000	C20.7	83	3.0	249	121.9	22.5
	C-83/3-C25	40	3000	C27.2	83	3.0	249	133.2	24.6
	C-83/3-C30	40	3000	C30.7	83	3.0	249	135.5	25.0
	C-83/4-C20	40	3000	C20.7	83	3.0	372	119.7	22.1
	C-83/4-C25	40	3000	C27.2	83	3.0	372	130.2	24.1
	C-83/4-C30	40	3000	C30.7	83	3.0	372	132.5	24.5
	C-55/2-C20	40	3000	C20.7	55	2.5	110	60.1	25.3
	C-55/2-C25	40	3000	C27.2	55	2.5	110	67.5	28.4

ARPN Journal of Engineering and Applied Sciences

	C-55/2-C30	40	3000	C30.7	55	2.5	110	69.6	29.3
	C-55/3-C20	40	3000	C20.7	55	2.5	165	58.8	24.7
	C-55/3-C25	40	3000	C27.2	55	2.5	165	64.0	26.9
	C-55/3-C30	40	3000	C30.7	55	2.5	165	66.0	27.8
	C-55/4-C20	40	3000	C20.7	55	2.5	220	54.7	23.0
	C-55/4-C25	40	3000	C27.2	55	2.5	220	55.1	23.2
	C-55/4-C30	40	3000	C30.7	55	2.5	220	62.6	26.3
[12]	1	56.53	3500		75	4	33.5		74.6
	2	56.53	3500		75	4	50.25		67.7
	3	56.53	3500		75	4	67		47.2
	4	56.53	3500		75	4	83.75		42.3
	5	56.53	3500		75	4	100.5		40.9
	6	56.53	3500		75	4	117.25		35.8
	7	56.53	3500		75	4	134		36.5
	8	56.53	3500		75	4	167.5		34.8
	9	56.53	3500		75	4	201		34.5
	10	56.53	3500		75	4	234.5		33.0
	11	56.53	3500		75	4	268		32.1
	13	56.53	3500		90	4.5	40.5		73.2
	14	56.53	3500		90	4.5	60.75		65.71
	15	56.53	3500		90	4.5	81		46.02
	16	56.53	3500		90	4.5	101.25		42.2
	17	56.53	3500		90	4.5	121.5		39.43
	18	56.53	3500		90	4.5	141.75		38.73
	19	56.53	3500		90	4.5	162		36.72
	20	56.53	3500		90	4.5	202.5		35.71
	21	56.53	3500		90	4.5	243		34.7
	22	56.53	3500		90	4.5	283.5		33.4
	23	56.53	3500		90	4.5	324		30.87
	25	56.53	3500		110	5	50		70.6
	26	56.53	3500		110	5	75		60.25
	27	56.53	3500		110	5	100		42.91
	28	56.53	3500		110	5	125		41.5
	29	56.53	3500		110	5	150		37.83
	30	56.53	3500		110	5	175		37.23
	31	56.53	3500		110	5	200		35.62
	32	56.53	3500		110	5	250		35.79
	33	56.53	3500		110	5	300		32.7
	34	56.53	3500		110	5	350		31.62
	35	56.53	3500		110	5	400		30.21
[13]	PVC-20	35		M25	110		200	293.0	35.5
	PVC-30	35		M25	110		300	235.0	29.5

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

	PVC-60	35		M25	110		600	227.5	26.7
	PVC-90	35		M25	110		900	218.0	26.4
[16]	CFPT-G40#1	50.36	4030	C49.5	168	7.11	305		52.6
	CFPT-G40#2	50.36	4030	C49.5	168	7.11	305		49.5
	CFPT-G40#3	50.36	4030	C49.5	168	7.11	305		47.8
	CFPT-G40w1	50.36	4030	C49.5	168	7.11	305		55.5
	CFPT-G40w2	50.36	4030	C49.5	168	7.11	305		58.2
[20]	PC20t1	52	3000-3800	M26.3	100	3.5	200	246.18	
	PC20t2	52	3000-3800	M26.3	100	4.8	200	273.87	
	PC25t1	52	3000-3800	M30.15	100	3.5	200	268.78	
	PC25t2	52	3000-3800	M30.15	100	4.8	200	296.88	
	PC40t1	52	3000-3800	M50.22	100	3.5	200	376.43	
	PC40t2	52	3000-3800	M50.22	100	4.8	200	411.43	
[21]	CF-PVC1.5				47.9	1.33	200		6.95
	CF-PVC2.0				60.1	1.55	200		9.98
	CF-PVC2.5				76.1	1.88	200		14.51
	CF-PVC4.0				114.3	2.55	200		34.46
[22]	NC1R1-1	32.4	800	M27.2	110	18.5	140	237.2	
	NC1R1-2	32.4	800	M27.0	110	18.5	140	248.5	
	NC1R2-1	32.4	800	M27.2	110	18.5	280	215.3	
	NC1R2-2	32.4	800	M27.0	110	18.5	280	236.2	
	NC2R1-1	32.4	800	M20.9	110	18.5	140	237.8	
	NC2R1-2	32.4	800	M20.5	110	18.5	140	235.7	
	NC2R2-1	32.4	800	M20.9	110	18.5	280	217.1	
	NC2R2-2	32.4	800	M20.5	110	18.5	280	203.5	
	NC1R1-1	32.4	800	M27.2	110	18.5	140	242.4	
	NC1R1-2	32.4	800	M27.0	110	18.5	140	237.9	
	NC1R2-1	32.4	800	M27.2	110	18.5	280	210.6	
	NC1R2-2	32.4	800	M27.0	110	18.5	280	210.0	
	NC2R1-1	32.4	800	M20.9	110	18.5	140	218.3	
	NC2R1-2	32.4	800	M20.5	110	18.5	140	231.4	
	NC2R2-1	32.4	800	M20.9	110	18.5	280	211.1	
	NC2R2-2	32.4	800	M20.5	110	18.5	280	207.3	
[24]	2-1			C33.7	110	5	1100	256	
	2-4			C33.7	110	5	1000	279.4	
	2-5			C33.7	90	4.5	1000	176	
	2-8			C33.7	75	4	1100	99.5	

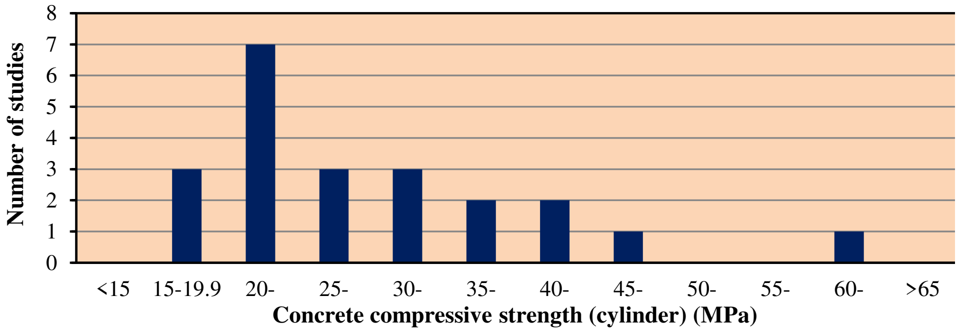
f_t, E_t, D, and t represent ultimate tensile strength, modulus of elasticity, outer diameter and thickness of plastic tube, respectively, L represents length (height) of composite column, f'_c represents compressive strength of concrete (C cylinder strength, M cube strength), P_{exp} and f_{exp} represent ultimate compressive load and strength of composite column, respectively.

ARPN Journal of Engineering and Applied Sciences

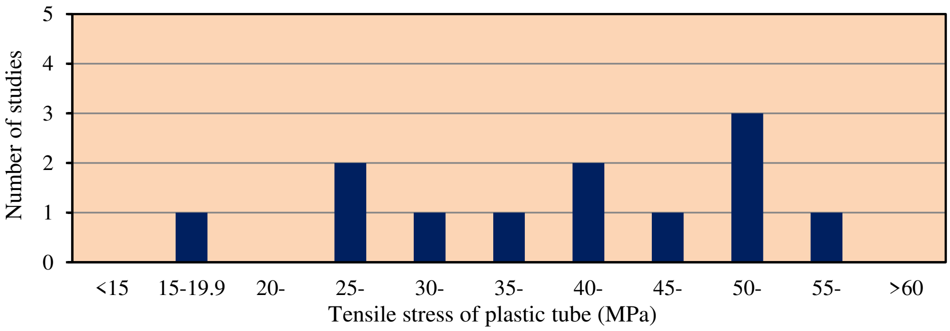
www.arpnjournals.com

3. STATISTICAL SURVEY

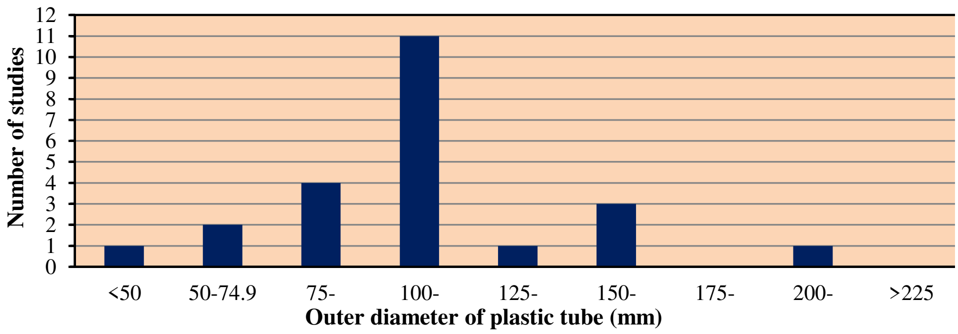
To know in what areas there is a lack of works in studying some parameters which may affect the performance of concrete-filled plastic tubular columns; the numbers of previous studies concerning different parameters (concrete strength, tube's strength, tube's diameter, D/t ratio and L/D ratio) are surveyed and presented in Figure-2. As can be noticed from this figure, there is a lack of test investigations on some aspects, like the use of concrete of high strength, tubes of diameter greater than 175 mm, and columns with D/t and L/D ratio greater than 45 and 10, respectively. Hence, more investigations on the structural performance of these composite columns are needed.



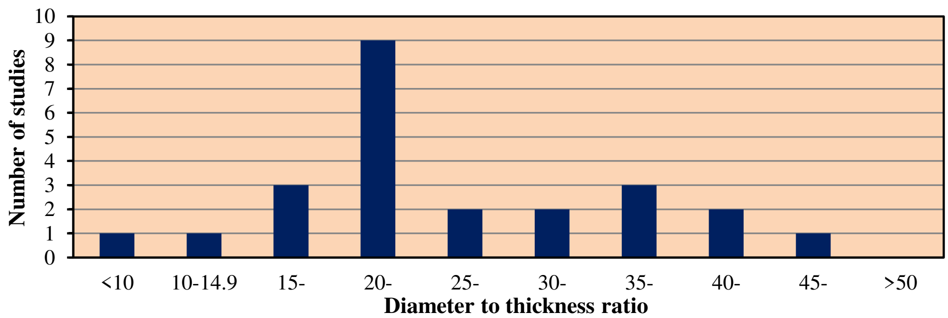
(a)



(b)



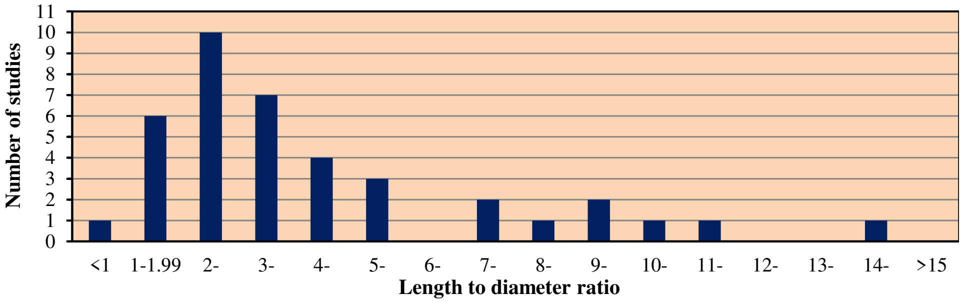
(c)



(d)

VOL. 14, NO. 13, JULY 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com



(e)

Figure-2. Number of studies dealt with different parameters.

4. CONCLUSIONS

The most important conclusions that can be drawn from this review relating concrete-filled plastic tubular composite columns are the followings:

a) The plastic tube provided sufficient lateral support to the concrete core and increased the ultimate strength of these composite columns.
b) The behavior of these composite columns depends on various parameters, such as loading style, concrete strength, D/t ratio and L/D or slenderness ratio.
c) As the slenderness ratio increases, the compressive strength of these composite columns decreases.
d) There is a lack of experimental investigations on some areas, like the use of high strength concrete, eccentric loading and large size specimens. Hence, more investigations on the structural performance of these composite columns are needed.

REFERENCES

[1] M. V. Titow. 1984. P. V. C. Technology. Springer.

[2] R. B. Abhale, S. B. Kandekar and M. B. Satpute. 2016. PVC confining effect on axially loaded column. Imperial Journal of Interdisciplinary Research (IJIR). 2(5): 1391-1394.

[3] C. E. Kurt. 1978. Concrete filled structural plastic columns. Journal of the Structural Division, Proceedings of the American Society of Civil Engineers. 104(ST1): 55-63.

[4] M. Marzouck and K. Sennah. 2002. Concrete-filled PVC tubes as compression members. Proceedings of the International Challenges of Concrete Construction Congress, Scotland, U.K. 4: 31-37.

[5] A. S. Saadoon. 2010. Experimental and theoretical investigation of PVC-concrete composite columns. Ph. D. Dissertation, University of Basrah, Iraq.

[6] J. Y. Wang and Q. B. Yang. 2010. Experimental study on mechanical properties of concrete confined with plastic pipe. ACI Materials Journal. 107(2): 132.

[7] P. K. Gupta. 2013. Confinement of concrete columns with Unplasticized Poly-vinyl chloride tubes. International Journal of Advanced Structural Engineering. 5(1): 19.

[8] P. K. Gupta and K. V. Verma. 2013. Study of concrete-filled unplasticized poly-vinyl chloride tubes in marine environment. International Journal of Advanced Structural Engineering. 5(1): 1-8.

[9] C. M. Usha and H. Eramma. 2014. Experimental study on concrete filled unplasticised poly vinyl chloride (UPVC) tubes. International Journal of Advanced Technology in Engineering and Science. 2(7): 331-338.

[10] N. K. Gathimba, W. O. Oyawa and G. N. Mang'uriu. 2014. Compressive Strength Characteristics of Concrete-Filled Plastic Tubes Short Columns. International Journal of Science and Research (IJSR). 3(9): 2168-2174.

[11] G. Gobinath and K. Selvi. 2014. An experimental study on behaviour of RC column with PVC cover. International Journal of Engineering Research & Technology (IJERT). 3(11): 1112-1117, November.

[12] N. A. Abdulla. 2014. Concrete filled thermoplastic tube under compression. Proceedings of the First International Engineering Conference (IEC2014), Erbil, Kurdistan Region of Iraq. p. 60.

[13] O. Mostafa and S. S. Ata El-Kareim. 2015. Behavior of confined columns under different techniques. World Academy of Science, Engineering and Technology International Journal of Structural and Construction Engineering. 9(1): 70-78.

[14] N. K. Gathimba. 2015. Performance of UPVC pipe confined concrete columns in compression. M. Sc. Thesis, Jomo Kenyatta University of Agriculture and Technology.

[15] W. O. Oyawa, N. K. Gathimba and G. N. Mang'uriu. 2016. Structural response of composite concrete filled plastic tubes in compression. Steel and Composite Structures. 21(3): 589-604.

[16] Fakharifar M. and Chen G. 2016. Compressive behavior of FRP-confined concrete-filled PVC tubular columns. Composite Structures. http://dx.doi.org/10.1016/ j.compstruct.2016 .01. 004.

[17] A. S. Saadoon and N. A. Jasim. 2017. 'Empirical design equations for PVC-concrete composite columns. International Journal of Engineering Science Invention. 6(10): 71-78.

[18] A. S. Saadoon and N. A. Jasim. 2017. Prediction of ultimate strength of PVC-concrete composite columns using FIS models. Elixir Civil Engineering. 112: 48886-48891.

[19] P. R. Princy and P. T. Bhagavathi. 2017. Comparative study on composite stub column. International Journal of Innovative Research in Science, Engineering and Technology. 6(5): 7822-7827.

[20] A. A. Azeez, N. Jamaluddin, N. A. Rahman, D. R. Hassen and A. N. Attiyah. 2018. Experimental and Analytical Study of PVC Confined Concrete Cylinders. Journal of Engineering and Applied Sciences. 13(8): 2145-2151.

[21] C. Ngamsangiem. 2018. Experimental study on foam cement filled poly vinyl chloride (PVC) tubes. The 23rd National Convention on Civil Engineering, Nakhon Nayok, Thailand, July 18-20.

[22] H. S. Al-Aasam, R. Y. Hassan and R. J. Aziz. 2018. Behavior of plastic tubular specimens filled with brick-aggregates concrete under compressive loads. International Journal of Engineering & Technology. 7(4.20): 408-413.

[23] P. Govintharaj, R. D. Babu and N. Nanthakumar. 2018. An experimental on un-plasticized poly vinyl chloride [UPVC] encased concrete column. International Journal of Innovative Research in Technology (IJIRT). 5(1): 340-342.

[24] N. A. Abdulla. 2019. Influence of plastic pour-in form on mechanical behavior of concrete. Structures. 19: 193-202.