EFFECT OF BUCKLING LOADS ON MONOPANEL COLUMN SPECIMENS

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ABSTRACT

A monopanel system is a new building material system of ferrocement that consists of two thin ferrocement block-like faces and thick layer of low strength, density and cost polystyrene foam insulation between them as a core. The simple structure idealization of monopanel system is that the core provides shear transfer between the faces that provide flexural resistance. Transverse trusses made of steel bars having diameter of (3.5) mm which serve as tie reinforcement to prevent the thin ferrocement layer from local buckling, have been used in this research and they are connected by inclined steel bar forming trusses shape making an angle equal to 60° with the longitudinal bars. The core material can be made of low cost materials such as aerated concrete, expanded polystyrene concrete, polystyrene foam, which is used in the present research work.

Monopanel systems can be constructed on site or produced as precast units with very accurate and controlled dimensions. They can be used as walls, slabs, beams, columns and other types of similar construction. Such panels should therefore offer an excellent structural system not only for low cost housing but also for low-rise buildings (up to three stories) such as residential units.

The main object of this research is to present an experimental investigation on the behavior and load carrying capacity of monopanel columns. The experimental work includes testing nine monopanel columns, and has been investigated the effect of a different depths of monopanel columns on the behavior and the ultimate load capacity. Also comparisons of these results with the ACI-318M-08 code formulations have been made.

KEYWORDS: Columns, Ferro cement, Monopanel, Buckling

تأثير قوى الا نبعاج على نماذج أعمدة المونوبنل

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الموجز

نظام المونوبنل هو نوع من البناء الجديد الذي يتكون من طبقتين رقيقتين من الفيروسمنت تتخللهما طبقة سميكة من مواد عازلة ذات مقاومة وكثافة قليلتين وترتبط هاتين الطبقتين بواسطة عوارض مشبكة جملونيا مصنوعة من قضبان حديدية بقطر ٣.٥ ملم على هيئة قضبان طولية عدد٢ تربطهما أخرى تميل بزاوية مقدارها ٦٠ درجة مع القضبان الطولية ،هذه القضبان المائلة تقوم بمقاومة قوى القص المتولدة بين الوجهين من جراء تسليط الأحمال على أوجه وحدة المونوبنل المعرضة للأحمال.إن المادة التي تستعمل في لب المونوبنل ذات

كلفة قليلة وهذه المادة قد تكون من غبار السمنت أو من خرسانة البولي ستارين أو رغوة البولي ستارين(الفلين) التي استخدمت في هذا البحث.

يمكن صناعة المونوبنل في موقع العمل أو يكون مسبق الصب ويمكن السيطرة على مواصفاته و أبعاده بسهولة في كلا الحالتين. يمكن استخدام المونوبنل كجدران وبلاطات وأعمدة وكذلك كعتبات. هذا النظام لا يختص بالأبنية واطئة الكلفة فقط حيث يمكن تشييد الأبنية لغاية ثلاث طوابق مثل الوحدات السكنية والمدارس والمكاتب ومثيلاتها من الفنادق.

لقد تناول هذا البحث دراسة سلوك والتحمل الأقصى للأعمدة المصنعة في المختبر بموجب نظام المونوبنل. ومن خلال التجارب العملية لتسعة نماذج لأعمدة المونوبنل تمت دراسسة تأثير أحمال الفشل بأختلاف عمق الاعمدة حيث تمت دراسة هذه المتغيرات على السلوك والحمل الأقصى للنماذج كذلك أظهرت النتائج انه بالإمكان استخدام علاقات مدونة من دليل الخرسانة الامريكي ACI-318M-08 لحساب القوى بشكل أمين لعتبات المونوبنل .

INTRODUCTION

Construction materials have a vast concerning of the engineering within the end of the 19th century and were developed quickly within the passed years. This development considers the cost, construction time and safety to product the ideal construction materials; the monopanel system is one of solutions.

A monopanel system is a new building type having a lightweight and a low cost with respect to alternative systems. This system has an isolation core made of polystyrene foam and contains trusses shape, called lacing made of steel bars having diameter of 3.5mm making an angle equals to 60^o with the longitudinal skeletal bars, which is usually made of the same material. This lacing system resists the shear effects.

The core material can be made of aerated concrete, expanded polystyrene concrete, polyurethane foam, no fines concrete, polystyrene foam, etc. The density of polystyrene foam is very low equals 16 kg /m^3. This low density and porous structure give the core excellent thermal and sound insulation properties. Also the monopanel system can be made in site or precast to very accurate and controlled dimensions.

Expanded polystyrene concrete is one type of lightweight concrete which consists of expanded polystyrene beads used as aggregate and Portland cement as binding material. Expanded polystyrene is made by polymerizing styrene to form small beads with spherical shape [(1)] with a very low bulk density ranging from 12 to 18 kg/m3 and very low water absorption. These properties of polystyrene beads are considered as disadvantages in concrete, causing difficulties in mixing by floating and segregation. A number of investigators studied the properties of polystyrene concrete.

(Al-Shawaf[(3)], 1987) showed that the compressive strength of polystyrene concrete increases as the density is increased and the porosity of the expanded polystyrene concrete increases with the increase of polystyrene content as well as the water absorption which indicates the open void — content of the concrete due to polystyrene addition. He found a relationship between the dry density and water-cement ratio for expanded polystyrene concrete which shows that an increase in the water– cement ratio causes a significant decrease in density.

(Fauzzi[(5)], 1997), reported that the density of lightweight concrete decreases when the expanded beads to cement ratio is increased, so by using various expanded polystyrene beads to cement ratios, lightweight concrete with densities ranging from 350 to 580 Kg/m^{3}can be obtained. She also concluded that the compressive strength, flexural strength, modulus of elasticity and Poisson´s ratio are directly proportional to the density and water cement ratio.

Several investigations were carried out on the behavior and strength of ferrocement members. The most notable studies can briefly be summarized as follows:

(Kalita,et al.[6]**,1986)** presented a work to study the behavior of W-shape ferrocement folded plate units. The folded plate specimens were designed for an effective width of 640 mm longitudinal and cross bars were 90 mm and 300 mm respectively, with two layers of galvanized wire mesh hexagonal opening, one on either side of the skeletal reinforcement. The folded plate roofing element was tested over an effective span of 3250 mm and subjected to a uniformly distributed load by placing burnt clay bricks in layers. The amount of loading to produce a maximum allowable deflection was found to be equal to 1.47kN/m2.

(Mansur,et al.[7]**, 2001)** studied the punching shear strength of simply supported ferrocement slabs. The study represented the results of punching shear tests on 31 square ferrocement slabs were it is simply supported on all four sides and tested under a central concentrated load. The parameters investigated included the width square loaded area, mortar strength, volume fraction of reinforcement, and depth of slab and the effective span length. All slabs failed first in punching without total separation, and then exhibited a second peak in the load-deflection history. Both the cracking load and the punching shear load are increased with the increase in the width of square loaded area, mortar strength, volume fraction of reinforcement, and depth of slab. The perimeter for punching shear failure was found to be located at a distance of 1.5h (where h is the thickness of slab) from the edge of the loading plate.

(Ravindrarajah et al. [9, 10]**, 1997 and 2003)** concluded that partial replacement of normal weight coarse aggregate with polystyrene aggregate reduces the unit weight, compressive strength and modulus of elasticity depending on the level of replacement, the compressive strength is more sensitive to the change in the unit weight than the modulus of elasticity. They also showed that concrete mixture with the largest amount of polystyrene beads produces a peak temperature of 85.6^oC compared to 70.6^oC for the control concrete mixture.

EXPERIMENTAL WORK

This section presents the materials used for constructing the monopanel column and describes the method adopted in the preparation and testing of the monopanel structural elements. It also includes details of the testing procedures.

MATERIALS

1-Cement:

Ordinary Portland cement type (I) manufactured in Iraq designated as Kufa was used throughout this investigation. It was stored in air-tight plastic containers to avoid the effect of dampness and to maintain uniform quality. The percentage oxide composition and physical properties of the cement are shown in **Table 1** and **Table 2** respectively. The results conform to the Iraqi specification No. 5/1984.

2- Fine aggregate:

Natural sand with maximum size of 2.36 mm was used in this investigation. It was brought from Al-Najaf region. The sand is separated by sieving; its grading satisfies the fine grading in accordance with B.S. specification No.882/1992 and the Iraqi specification No.45/1984. Results indicate that the sulfate content and the fine materials content are within the requirements of the Iraqi specification No.45/1984. **Tables 3** and **4** show the properties of fine aggregate used in the present research work.

3-Reinforcement:

Locally available mild galvanized steel welded wire meshes of 12.0 mm square opening with a diameter 0.6 mm have been used throughout the experimental work. And Smooth mild steel bar with of 3.5mm was used for the lacing and skeletal reinforcement. **Table 5** shows the physical properties of reinforcement.

4-Polystyrene Foam:

Polystyrene foam with low density of (16 kg / m^3) was used as a core filling material.

5-Water:

Ordinary tap water was used throughout this investigation for mixing and curing test specimens.

MIXING AND CONTROL SPECIMENS

The mixing process of mortar was performed in a pan type mixer. The specified dry materials (cement and sand) were well mixed to attain uniform mixing. The required amount of tap water was then added and the whole mix ingredients were mixed for 3-minutes.

One type of mix proportion was considered throughout the research. The sand and cement were thoroughly mixed in a ratio of one part by weight of cement to two and half parts of sand (1: 2.5). The water cement ratio used to maintain a slump of (100±5 mm) was 0.5. To establish the mortar mechanical properties shown in **Table 6**, a number of control specimens were cast and tested, three cylinders of 100 x 200 mm, three cubes of 50 x 50 x 50 mm and three cylinders of 150 x 300 mm were used to estimate the compressive strength, the modulus of elasticity and the split tensile strength. Three prisms of 100 x 100 x 400 mm have been used to estimate the modulus of rapture. These tests were in accordance with the British standard BS.1881 and the American standards ASTM-C39, ASTM-C109, ASTM-C469 and ASTM-C78.

RESULTS OF MONOPANEL COLUMNS TESTS

The experimental work of the nine monopanel columns was divided into three groups (I, II and III). **Table 7** shows the column specimen details of groups I, II and III. Also **Figure 1** shows the geometry of groups I, II and III of Monopanel column specimens. The experimental results included the measured failure loads, the buckling (lateral deflection) at the center of height of column.

All monopanel columns were tested under a compression force applied at a centre of column face up to failure. **Table 8** gives the details of the ultimate loads of each monopanel column groups. The ratios of ACI-Code 318 M-08 ultimate load to the value of experimental ultimate loads are listed in **Table 8** too.

According to the experimental results, when the depth to width ratio is increased from 1 in group I to 3 in group II , the ultimate load increases by amount 1.11 of the load in group I , and the buckling at the center of height of column at ultimate load decreases by 13.02 percent. Also when the depth to width ratio increased from 1(in group I) to 4 (in group III), the ultimate load increases by amount 1.67 of the load in group I, and the buckling at ultimate load decreases by 21.3 percent. While, when the depth to width ratio of specimen is increased from 3 to 4, the ultimate load increases by amount 0.263 of the load in group II, and the buckling at the center at ultimate load decreases by 9.52 percent. **Figures 2**, **3** and **4** show the load –central buckling behavior obtained at different loading stages for monopanel column specimens. **Figure 5** presents the crack pattern for monopanel column specimens and the loading testing machine.

CONCLUSIONS

The conclusions emerged from the experimental work are summarized as following:-

1-Experimental results of testing monopanel column specimens reveal that they are acceptable structural elements for rushed construction processes, and they may safely be used to construct small housing units and small structures.

2- The failure load increased by increasing the depth dimension of monopanel column, as the depth to width ratio increasing from 1 to 3 the ultimate load increased by 111 percent. Also the ultimate load increased by 167 percent as the depth to width ratio increasing from 1 to 4. While, when the depth to width ratio increased from 3 to 4, the ultimate load increased by 26.3 percent.

3- The experimental results show that when the depth of specimen increases in a ratio from 1 to 3, the buckling at ultimate stage decreases by 13.02 percent. In addition, when the depth of a specimen increases in a ratio from 1 to 4 the buckling (at ultimate stage) decreases 21.3 percent. While, when the depth of specimen increases in a ratio from 3 to 4, the buckling at ultimate stage decreases by 9.52 percent. Hence by increasing the depth of monopanel column specimen, the buckling at the center of height decreased.

4- It can be noticed that the ratio between the theoretical to the experimental ultimate load is (0.3) compared with the ACI-Code 318 M-08 provisions requirements. Area of steel for columns of group I is ($9.8mm^2$), for group II is ($23.7mm^2$), and for group III is ($31.1mm^2$). The gross area for columns, properties of reinforcement and the mechanical properties of mortar mix is the same as for monopanel column specimens.

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Table 1 Percentage oxide composition* and compounds of cement used in this investigation.

Oxide composition	Percentage, by weight	Limit of Iraqi specification No. 5/1984
CaO	61.2	-----
SiO_2	21.87	-----
MgO	2.6	5.0 (max)
Fe_2O_3	3.04	-----
Al_2O_3	5.8	-----
SO_3	2.21	2.80 (max)
Loss on ignition	1.5	4.0 (max)
Insoluble residue	1.1	1.5 (max)
Lime saturation factor	0.85	0.66-1.02
Main compounds	Percentage, by weight	Limit of Iraqi specification No. 5/1984
C_3S	53.65	-----
C_2S	18.73	-----
C_3A	9.33	5.0 (min)
C_4AF	10.12	-----

Table 2 Physical properties of the cement used in this work*

Physical property	Test result	Limit of Iraqi specification No. 5/1984
Specific surface area (Blaine method), m^2/kg	322	230 (minimum)
Setting time (Vicat's method) Initial setting, hrs: min Final setting, hrs : min	2:15 4:35	1 hr (minimum) 10:00 hr(maximum)
Compressive strength of Mortar, N/mm^2 3-days 7-days	19.5 28.45	15.0 (minimum) 23.0 (minimum)
Autoclave expansion, %	0.23	0.8 (maximum)

* Chemical and physical tests were conducted by National Center for Construction Laboratories and Research (NCCLR).

Table 3 Grading of natural sand used in this research.

Sieve size (mm)	Cumulative of tested sand passing %	Limits of B.S.882:1992 Overall grading	Limits of Iraqi Specification No.45/1984 for Zone No. (3)
9.52	100	100	100
4.75	98.7	89-100	90-100
2.36	92	60-100	85-100
1.18	88	30-100	75-100
0.600	78.3	15-100	60-79
0.300	28.6	5-70	12-40
0.150	5	0-15	0-10

Table 4 Physical properties of fine sand used in this study.

Physical properties	Test results	Limits of Iraqi specification No.45/1984
Specific gravity	2.61	-
Sulfate content, %	0.4	≤ 0.5 %
Absorption, %	1.5	-
Materials finer than75µm, %	2.8	≤ 5%

Table 5 Properties of reinforcement.

Measured diameter (mm)	Modulus of elasticity E (MPa)	Yield stress f_y (MPa)	Ultimate stress f_u (MPa)
0.6	175000	350	580
3.5	200000	400	690

Table 6 Mechanical properties of mortar mix (average of three specimens).

Mix proportion (Cement-Sand)	Compressive strength (MPa)		Splitting strength (MPa)	Modulus of rupture (MPa)	Modulus of elasticity (MPa)
	f'_c	f_{cu}	f_{ct}	f_r	E_m
1:2.5	20.3	26.6	2.12	2.71	22646

Table 7 Details of groups I, II and III of monopanel column specimens

Group	Depth D(mm)	Width W(mm)	height H(mm)	Face thickness t(mm)	No. of lacing(ties)	Core depth(mm)
I	150	150	900	25	5	130
II	450	150	900	25	5	430
III	600	150	900	25	5	580

Table 8 Ultimate loads for Monopanel column specimens

Group	D	Experemental Ultimate load (kN)	Ultimate load (kN) according to ACI-Code 318 M-08	$\frac{P_{ACI}}{P_{Exp.}}$
I	150	9	2.82	0.314
II	450	19	6.56	0.345
III	600	24	8.521	0.355

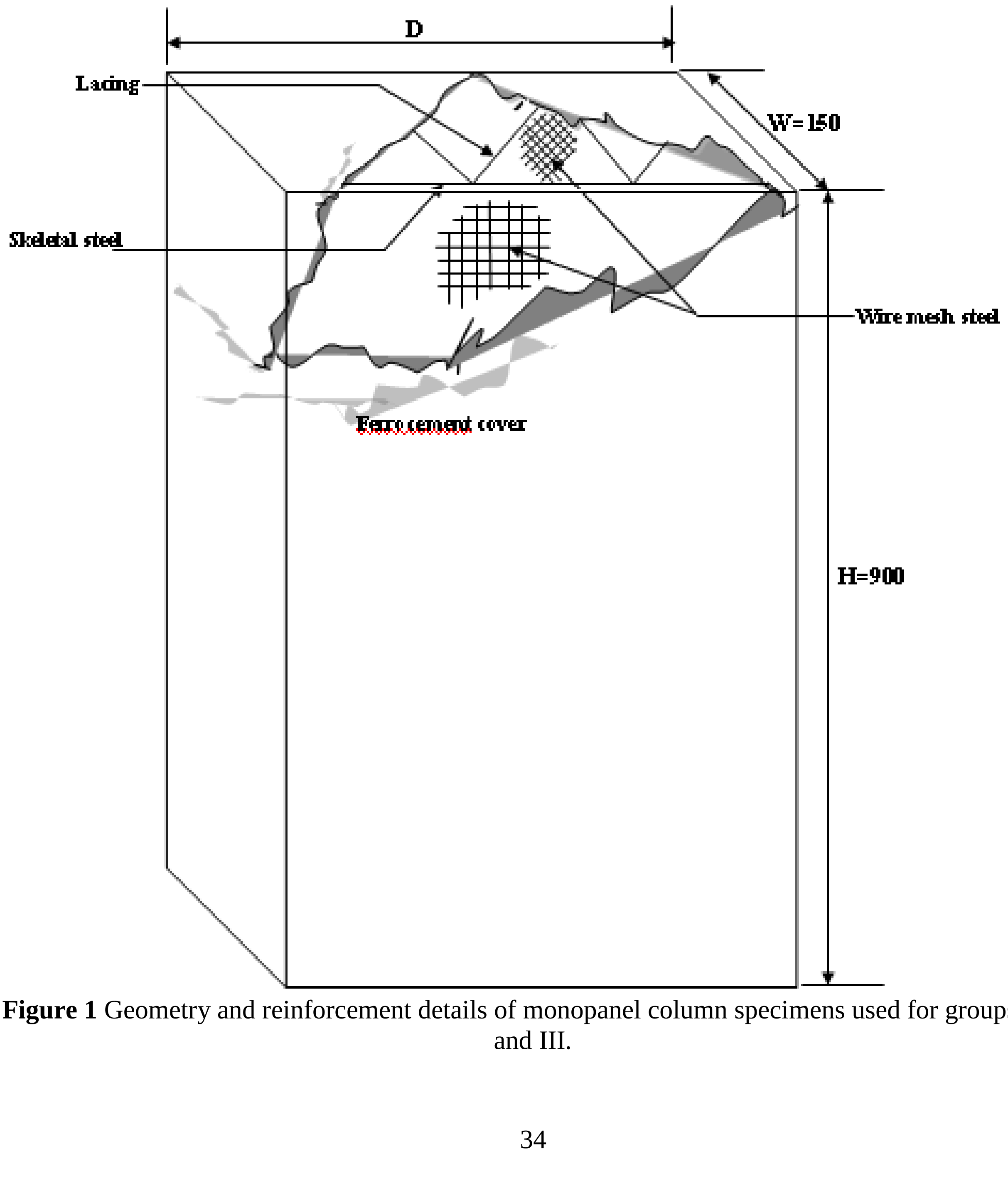

Figure 1 Geometry and reinforcement details of monopanel column specimens used for groups I, II and III.

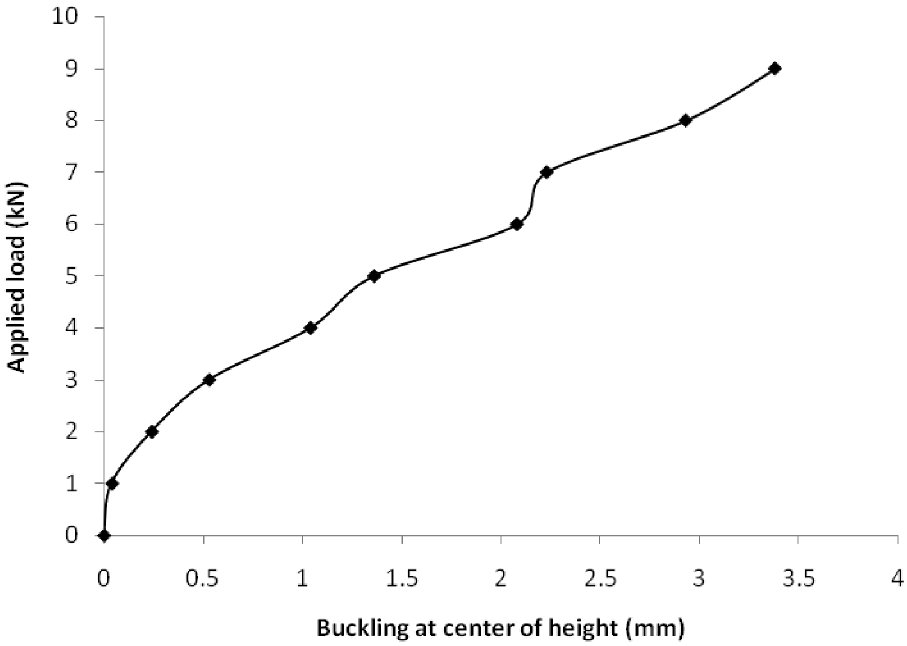

Figure 2 Buckling at center of height of monopanel column with D=150 mm.

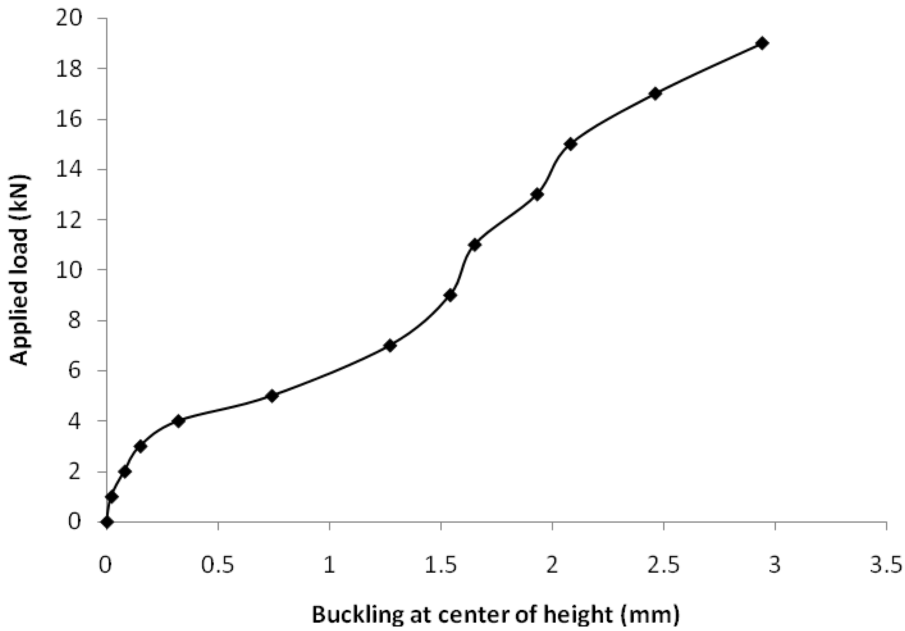

Figure 3 Buckling at center of height of monopanel column with D=450 mm.

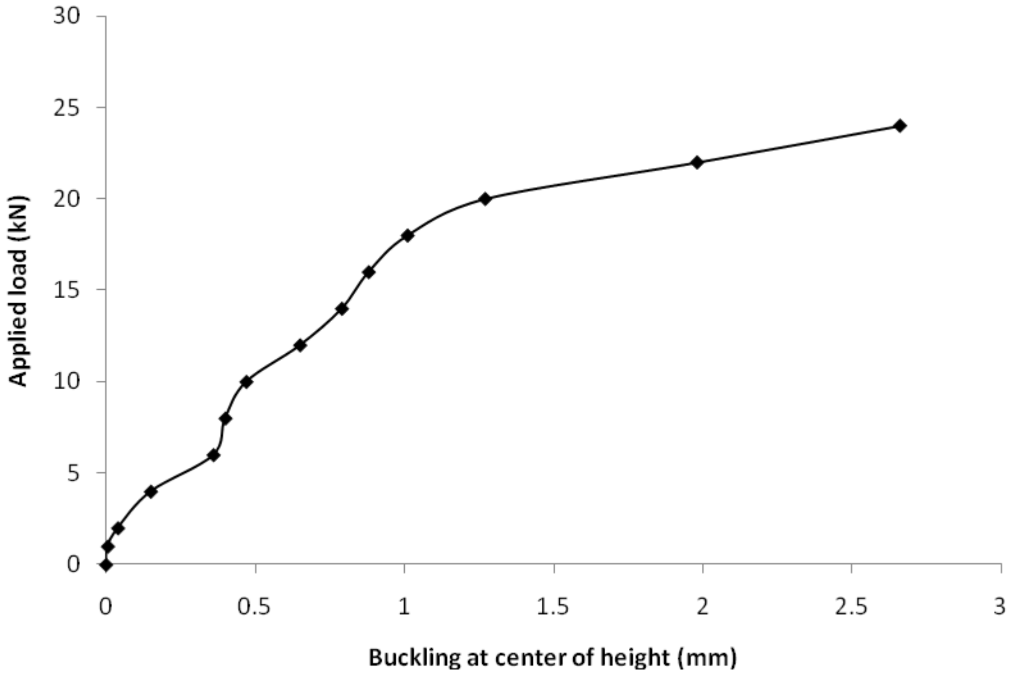

Figure 4 Buckling at center of height of monopanel column with D=600 mm.

Figure 5 Buckling crack pattern for monopanel column specimens and the loading testing machine.