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Numerical Analysis of RC Shear Walls Carrying Braced Columns

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ملخص البحث

يهدف هذا البحث الي اجراء دراسة نظريه لمعرفة سلوك الأعمدة الخرسانيه المقيده و المثبته علي حوائط القص الخرسانيه المسلحه في المباني العاليه، تم عمل دراسه تحليليه باستخدام برنامج ETABS 2015. ومن المتعارف عليه ان الاعمدة تقوم بتحمل الاحمال الراسية بجانب جزء من الاحمال الجانبيه واحمال الرياح، و لذلك تم دراسة سلوك الأعمدة المقيدة علي حوائط القص الخرسانيه في ادوار مختلفه و نماذج مختلفه من المنشأت لمعرفه مدي تاثيرها و قدرتها علي تحمل الاجهادات. وكذلك عمل مقارنات في النتائج المحسوبه بين استخدام هذا النظام و استخدام نظام حوائط القص المتعارف عليه في المباني العاليه، و في نهاية البحث تم استنباط مجموعة من المنحنيات التي تفيد المهندس المصمم للمنشات الخرسانيه العاليه.

ABSTRACT

The present work is concerned with the analytical and theoretical study of the behavior of braced concrete columns over reinforced concrete shear walls in high-rise buildings. The braced columns over reinforced concrete shear walls are used to resist loading in high-rise buildings and lateral forces from wind and earthquakes. A linear analytical model was developed using the Finite Element Program (ETABS v 15.2.2) to analyze and design three dimensional high-rise buildings.

The analytical procedure consists of choosing the units, drawing three dimensional structural model, choosing material properties, classification of all elements of the frame sections such as (beams, bracing, and columns), wall piers and slabs sections, choosing reinforcing bars for all concrete sections, choosing supports, defining loads (dead, live, wind, earthquake and combination), run the analysis and design for all cases as well as parametric studies. In the cases studied, buildings consist of columns and walls as well as slabs. Walls are carrying columns connected together by means of beams or bracing or both beams and bracing, in many floors.

The analytical results show that using braced Rc columns instead of a total Rc shear wall decreases the bending moment in high rise buildings by about 60% while increasing the shear force five times that of the total shear wall (although it is safe to be carried by concrete sections).Analytical results show also that the percentage of drift is almost not changed when using braced columns with small sections than that of shear wall section.

Key words: Reinforced Concrete, Shear Walls, High-Rise Buildings, Lateral Loads, Bracing, Beams, Linear Analysis, Finite Element Method.

1. Introduction

Lateral loads can develop high stresses, produce sway movement or cause vibrations [12]. Therefore, it is very important for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral forces [5]. That is why the analysis and design of shear walls in high rise buildings are considered to be an interested subject for researchers and civil engineers [5, 6]. Typically, a continuous reinforced shear wall from the base of the building to its top, its thickness and steel reinforcement are gradually reduced with increasing height .This is due to the fact that the maximum values for shear and bending moment exist at the wall base and decrease upwards [4, 7, 8, 11 and 15]. For this reason, a structural accurate analysis method is proposed to replace shear walls in top stories by braced columns. The intention herein is to illustrate the use of the finite-element method in determining the stress distributions in braced RC shear walls as well as the prediction of more accurate values for the bending moments, axial and shear forces which act upon the connecting bracing between columns when the building is subjected to lateral loads.

2. Finite element modeling

In this paper different types of reinforced concrete idealized Statical systems for residential buildings are studied, where the main system of walls and frames are chosen. Models which represent the systems in simulation software are divided into six main systems according to wall section, height and position;

1) Four complete rectangular shear walls.
2) Combined system of shear walls and columns with cross bracing (truss system).
3) Combined system of shear walls and columns with tie beams (frame system).
4) Structural full plan of rectangular shear walls and frames.
5) Full plan of shear walls carrying columns with cross bracing.
6) Full plan of shear walls carrying columns with HZ beams.

3. Geometry of the model

The program is applied to fourteen reinforced concrete main models, which divided into four groups: group (1) consists of four models with twenty floors; the basic model is model 1 with four equal four walls as shown in Fig.(1) compared with models 1-a,b,c which have a combined system of shear wall and truss at variable heights as shown in Fig.(1).

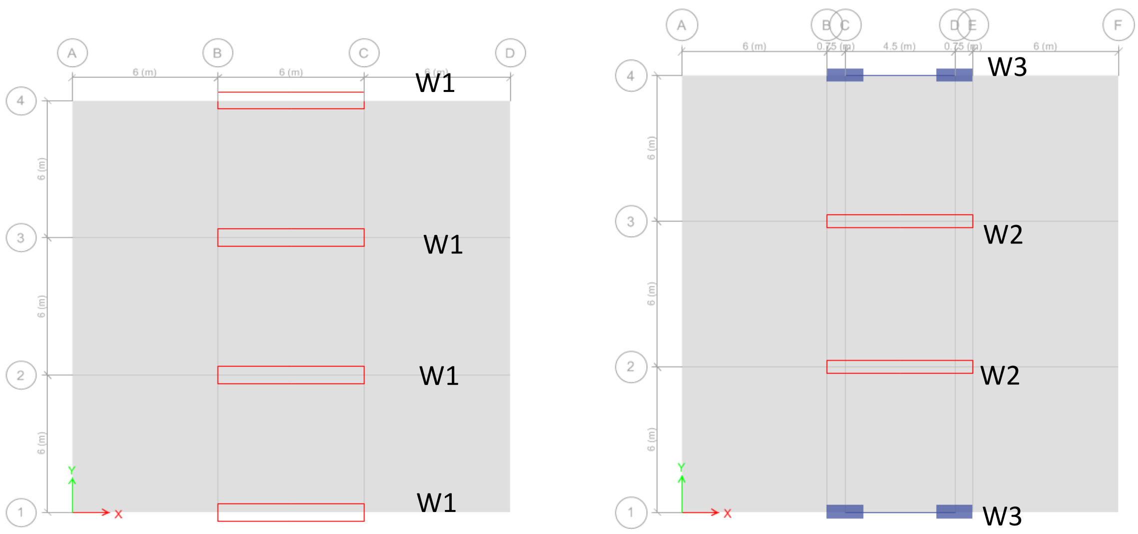
group (2) also consists of model 1 described before in comparison with models 1-d,e,f which consists of shear wall with frame system varied for different height.

group (3) consists of model 2 which is similar to model 1 but having thirty floors compared with models 2-a,b,c which consist of shear wall and truss system.

group (4)- consists of model 2 in comparison with models 2-d,e,f which consists of shear wall with frame system.

Table 1: Description of the proposed models used in the numerical program.

Group	Model	No. of floors	Applied system
1	Model(1)	20	Shear wall
	Model(1-a)		Shear wall+ Truss system for the top five floors.
	Model(1-b)		Shear wall+ Truss system for the top ten floors.
	Model(1-c)		Shear wall+ Truss system for the twenty floors.
2	Model(1)	20	Shear wall
	Model(1-d)		Shear wall+ Frame system for the top five floors.
	Model(1-e)		Shear wall+ Frame system for the top ten floors.
	Model(1-f)		Shear wall+ Frame system for the twenty floors.
3	Model(2)	30	Shear wall
	Model(2-a)		Shear wall+ Truss system for the top fifteen floors.
	Model(2-b)		Shear wall+ Truss system for the top twenty floors.
	Model(2-c)		Shear wall+ Truss system for the thirty floors.
4	Model(2)	30	Shear wall
	Model(2-d)		Shear wall+ Frame system for the top five floors.
	Model(2-e)		Shear wall+ Frame system for the top ten floors.
	Model(2-f)		Shear wall+ Frame system for the thirty floors.



(i) (ii)

Fig.1: (i)Structural plan of four equal shear walls W1 for model(1) - (ii)Structural plan of two equal shear walls W2 and two equal modified shear walls with truss or frame system W3.

4. Results and discussion

Analytical results should be considered for bending moment, shear force and drift for shear walls with truss system or frame system at all floor levels.

For moment it is found that when using cross bracing between two columns (truss system) over shear wall, the moment decreases about 60% from using the usual shear wall system in high rise buildings.

As illustrated in table (2) for 20 floor buildings; it is observed that the moment varies at the point of change from shear wall system to truss system at the certain floor chosen; this change confirmed that using truss instead of shear wall can carry the same load with great efficiency and small sections with decreasing percentage of reinforcement.

Although it is found that when using just a tie beam between the two columns (frame system), the moment decreases by about 15% only than using a total shear wall system in high buildings which can be illustrated clearly in table (3).

Table2: Shows the moment results obtained from the analysis of 20 floor building with different positions of truss system.

No. of stories	Straining action	Model(1)	Model(1-a)		Model(1-b)		Model(1-c)	
			Truss system	Shear wall	Truss system	Shear wall	Truss system	Shear wall
base	Moment (m.t)	2354	2402	2402	2402	2402	1843	2961
5		1494	1540	1540	1540	1540	1377	1703
10		748	782	783	578	987	747	818
15		220	155	314	234	235	256	212
20		0.0002	0	0.0525	-0.00728	0.00728	-0.00779	0.00779

Table3: Shows the moment results obtained from the analysis of 20 floor building with different positions of frame system.

No. of stories	Straining action	Model(1)	Model(1-d)		Model(1-e)		Model(1-f)	
			Frame system	Shear wall	Frame system	Shear wall	Frame system	Shear wall
base	Moment (m.t)	2354	2402	2402	2402	2402	629	4175
5		1494	1540	1540	1539	1541	530	2250
10		748	782	783	189	1376	373	1192
15		220	42	427	61	408	190	278
20		0.0002	-0.2587	0.2587	-1.1492	1.1492	-3.442	3.442

These results can be represented graphically as in figs.2, 3, and 4 which show clearly the effect of using cross bracing between the two columns and figs.5, 6, and 7 show clearly the effect of using tie beams between the two columns at certain number of floors which carry the same loads of the shear wall in high rise buildings.

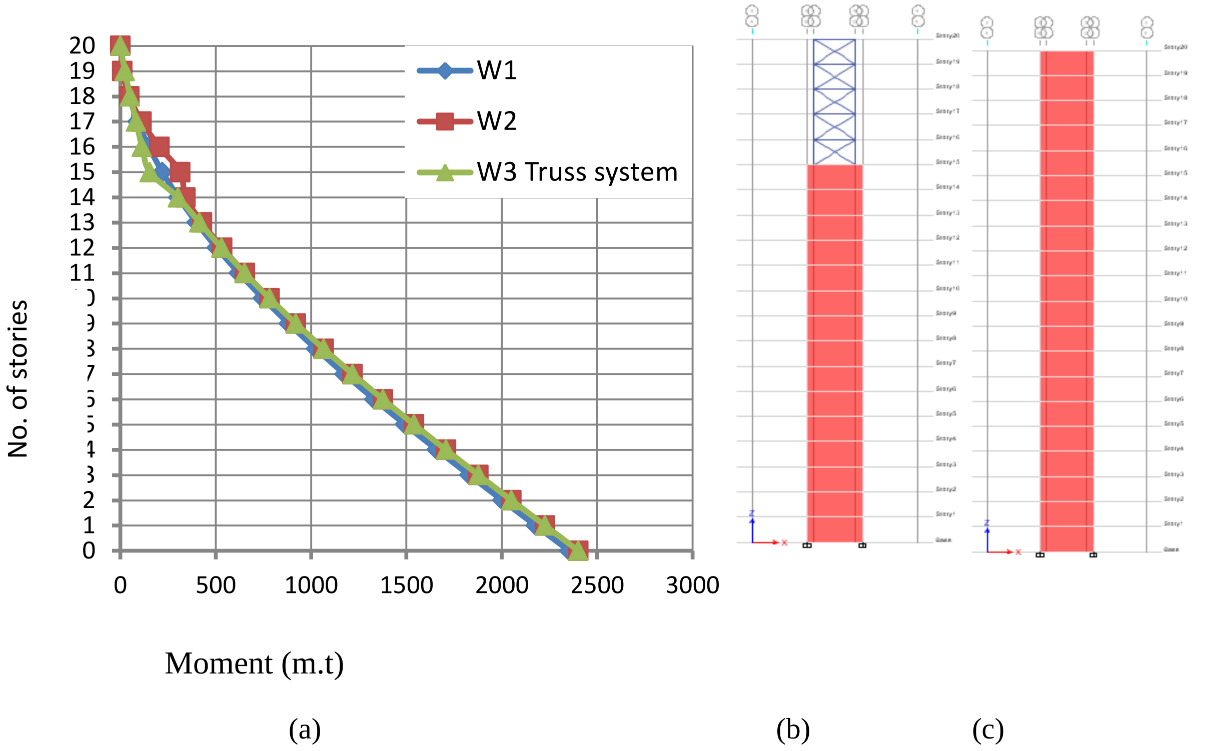


Fig.2: (a) Represents the comparison of bending moment results between W1, W2 and W3- (b) Elevation of W3 shear wall modified to truss system at 15th floor- (c) Elevation of shear wall W1 for model 1 and W2 for model (1-a).

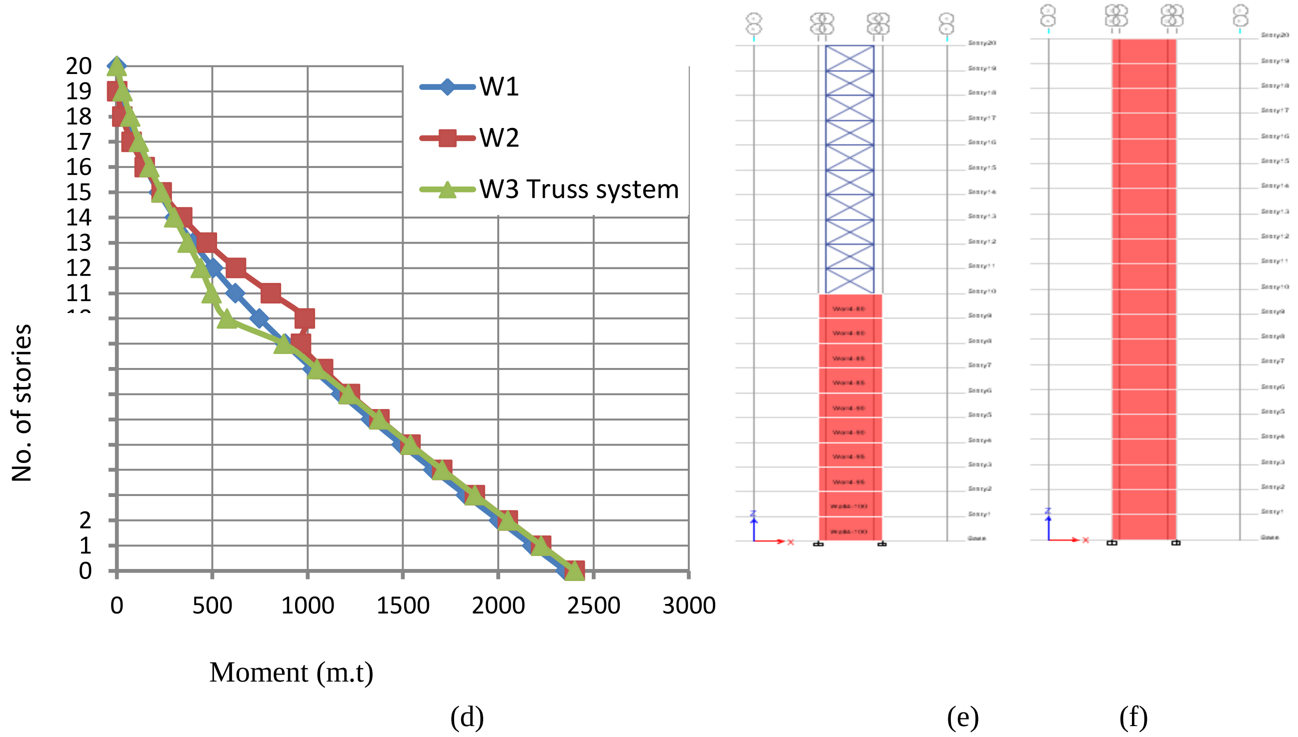
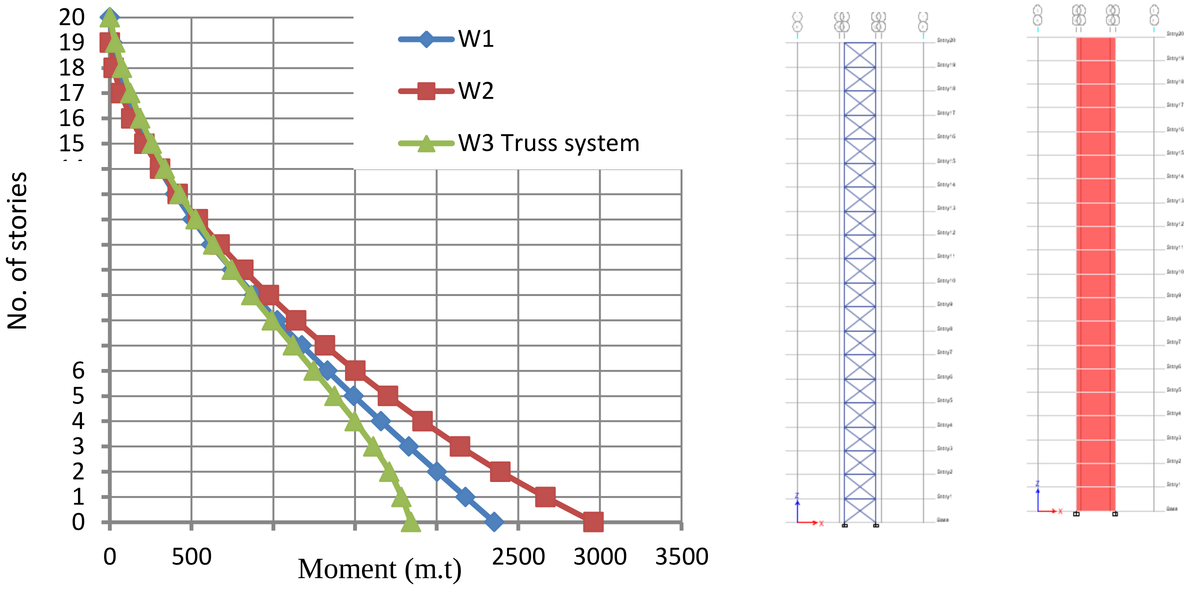


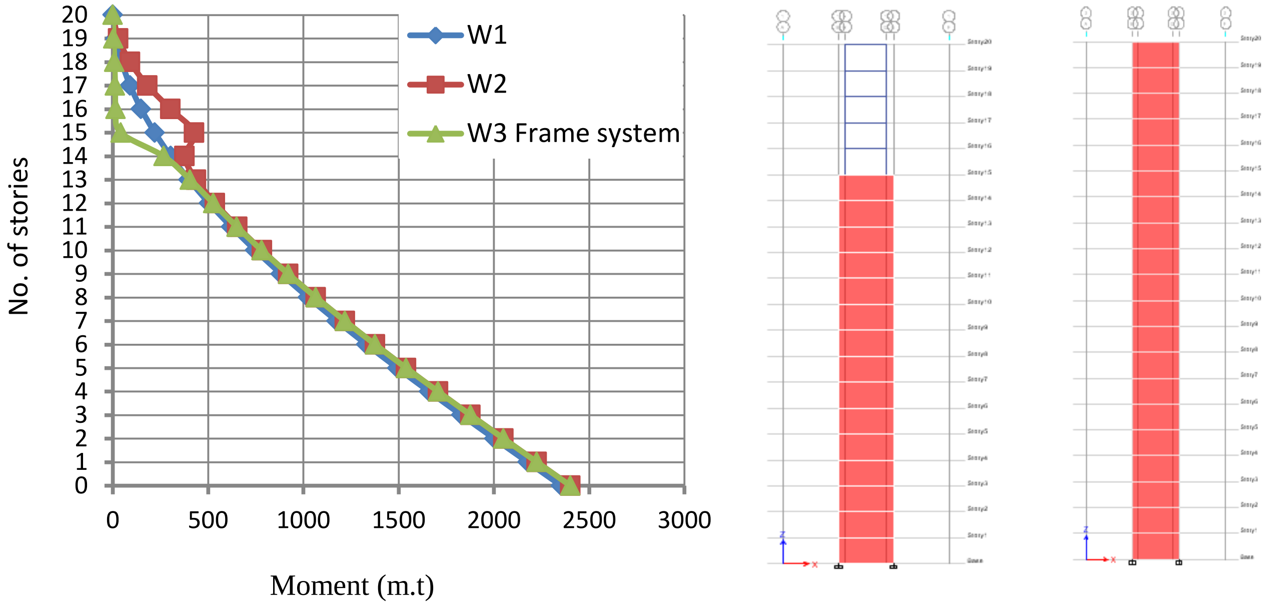
Fig.3: (d) Represents the comparison of bending moment results between W1, W2 and W3-

(e) Elevation of W3 shear wall modified to truss system at 10th floor- (f) Elevation of shear wall W1 for model 1 and W2 for model (1-b).



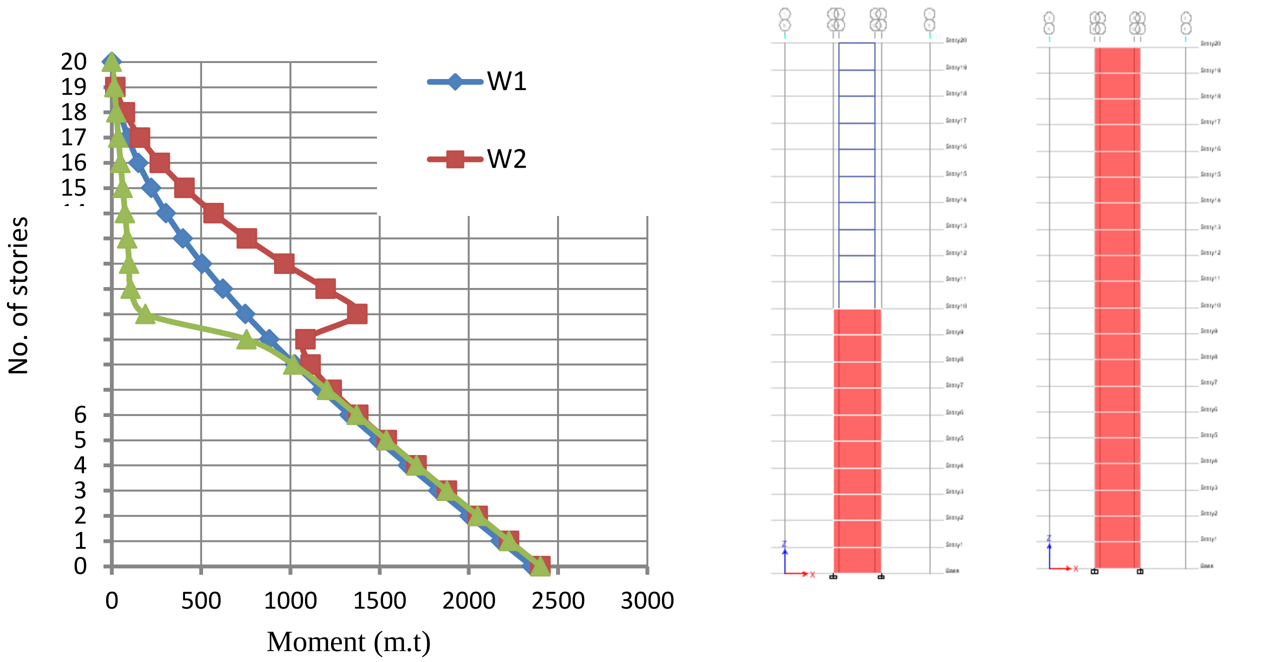
(g) (h) (i)

Fig.4: (g) Represents the comparison of bending moment results between W1, W2 and W3- (h) Elevation of W3 shear wall modified to truss system at 20th floor- (i) Elevation of shear wall W1 for model 1 and W2 for model (1-c).



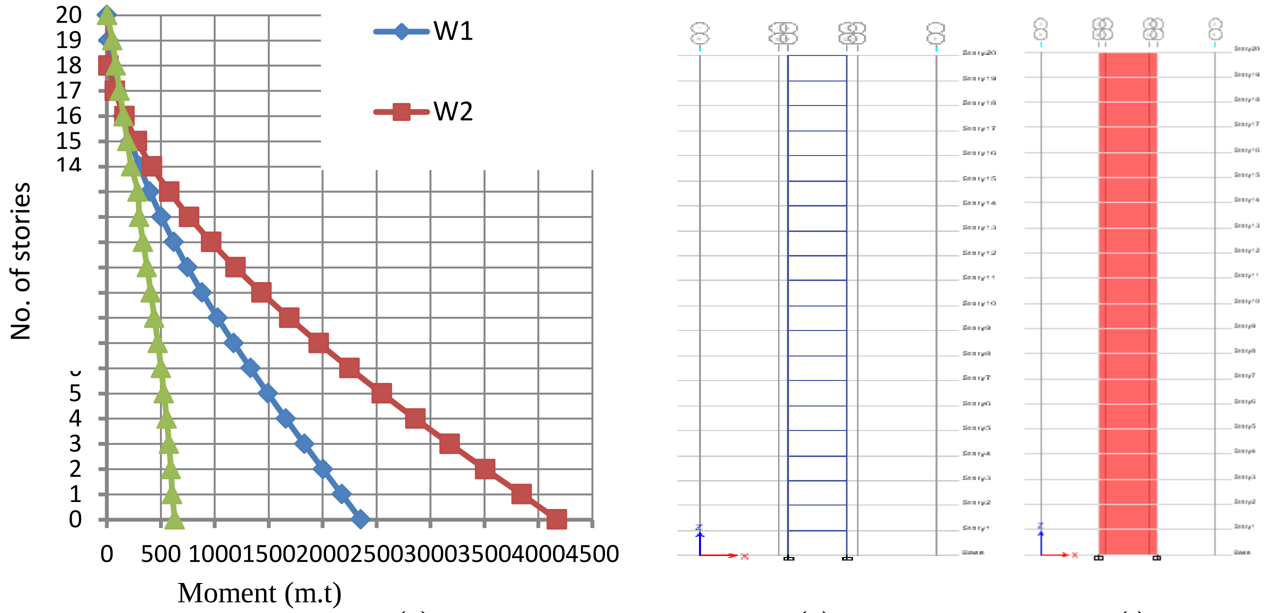
(j) (l) (k)

Fig. 5: (j) Represents the comparison of bending moment results between W1, W2 and W3- (k) Elevation of W3 shear wall modified to frame system at 15th floor- (l) Elevation of shear wall W1 for model 1 and W2 for model (1-d).



(m) (n) (o)

Fig.6: (m) Represents the comparison of bending moment results between W1, W2 and W3- (n) Elevation of W3 shear wall modified to frame system at 10th floor- (o) Elevation of shear wall W1 for model 1 and W2 for model (1-e).



(p) (q) (r)

Fig.7: (p) Represents the comparison of bending moment results between W1, W2 and W3- (q) Elevation of W3 shear wall modified to frame system at 20th floor- (r) Elevation of shear wall W1 for model 1 and W2 for model (1-f).

For shear it is found that the truss system increases the shear at the modified floor 5times the value of the total shear wall although the concrete section can carry it then it decreased again in the next floors.

However when using frame system, the shear increased about 22% then decreased again by the same percentage.

Table4: Shows the shear results obtained from the analysis of 20 floor building with different positions of truss system.

No. of stories	Straining action	Model(1)	Model(1-a)		Model(1-b)		Model(1-c)	
			Truss system	Shear wall	Truss system	Shear wall	Truss system	Shear wall
base	Shear (t)	59	59	59	59	59	19	98
5		55	56	56	56	56	41	71
10		45	46	46	27	-7	40	52
15		28	49	9	22	36	27	32
20		5	8	4	10	0.9	11	0.2

Table5: Shows the moment results obtained from the analysis of 20 floor building with different positions of frame system.

No. of stories	Straining action	Model(1)	Model(1-d)		Model(1-e)		Model(1-f)	
			Frame system	Shear wall	Frame system	Shear wall	Frame system	Shear wall
base	Shear (t)	59	59	59	59	59	7	110
5		55	56	56	56	56	8	104
10		45	46	46	189	-97	10	81
15		28	75	-16.5	4	55	11	48
20		5	1.2	10	4	7	15	3.4

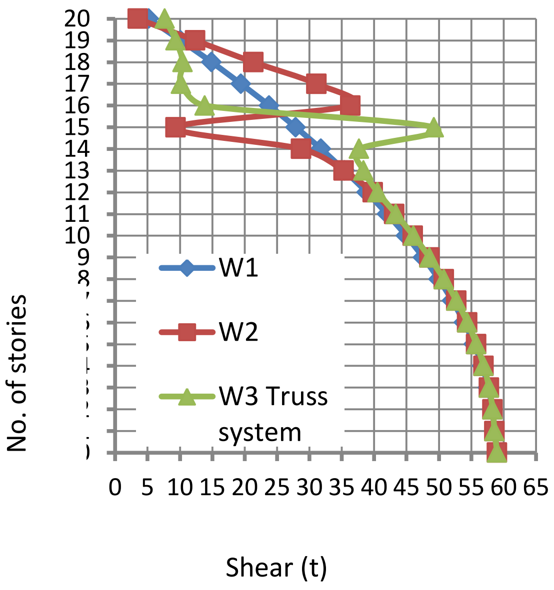


Fig.8: Represents the shear force comparison between the shear wall W1 of model 1, shear wall W2 of model (1-a), and truss system W3 of model (1-a).

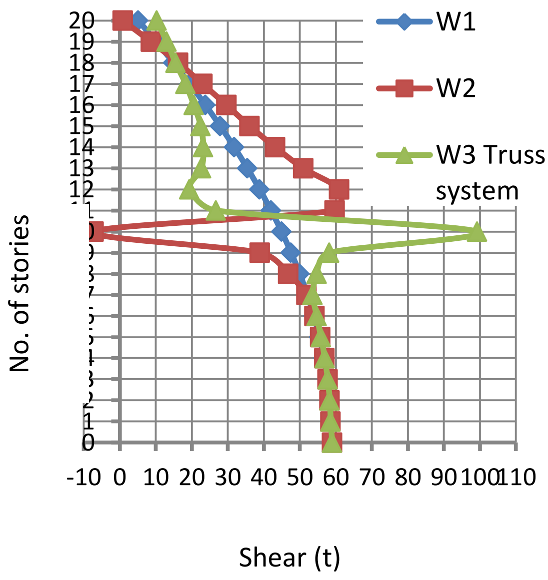


Fig.9: Represents the shear force comparison between the shear wall W1 of model 1, shear wall W2 of model (1-b), and truss system W3 of model (1-b).

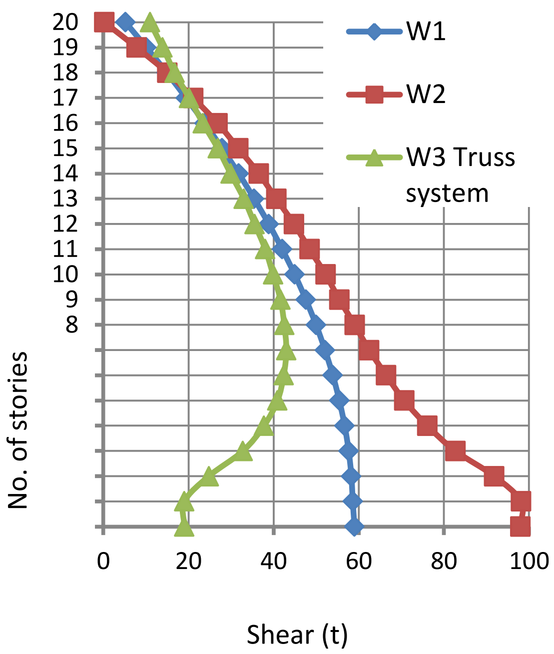


Fig.10: Represents the shear force comparison between the shear wall W1 of model 1, shear wall W2 of model (1-c), and truss system W3 of model (1-c).

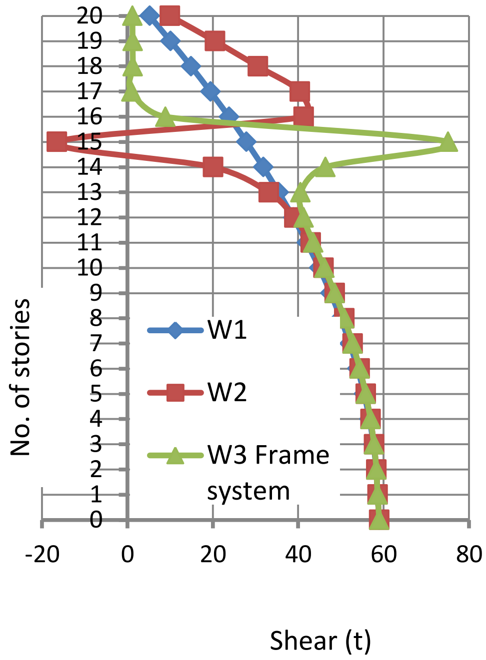


Fig.11: Represents the shear force comparison between the shear wall W1 of model 1, shear wall W2 of model (1-d), and truss system W3 of model (1-d).

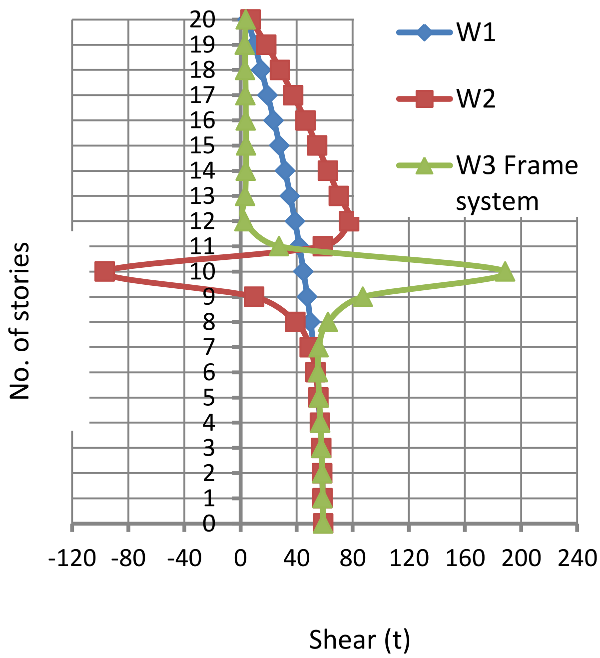


Fig.12: Represents the shear force comparison between the shear wall W1 of model 1, shear wall W2 of model (1-e), and truss system W3 of model (1-e).

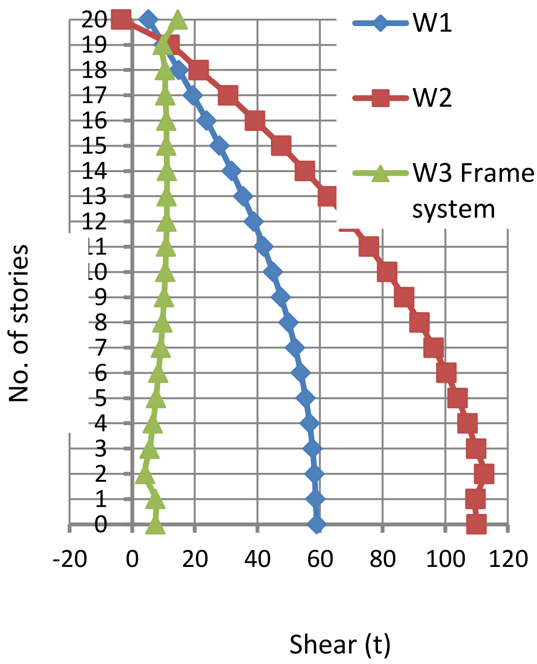


Fig.13: Represents the shear force comparison between the shear wall W1 of model 1, shear wall W2 of model (1-f), and truss system W3 of model (1-f).

5. Conclusions

The main conclusions derived based on this study, are presented as follows:

1. Braced columns over reinforced concrete shear walls can be used in high rise buildings, to resist loads especially lateral loads.

2. Braced columns over reinforced concrete shear walls decrease the bending moment in high rise buildings by about 60 % to 70% approximately.

3. Braced columns over reinforced concrete shear wall increase stiffness and durability of high rise buildings against lateral loads.

4. The braced system increases the height of high rise buildings with the same displacement conditions.

5. Using braced columns instead of shear walls along the building height results in increasing the shear forces in columns with respect to their concrete sections, and decreasing the moment compared with its value on shear wall, therefore this solution is considered as an economical solution.

6. All structural engineers are encouraged to used bracing between coupled shear walls in high rise buildings.

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