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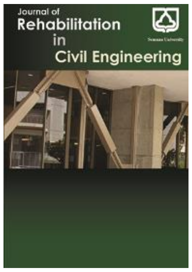

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The Effect of RC Core on Rehabilitation of Tubular Structures

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ABSTRACT

In the present study, the effect of core on shear lag phenomenon in tubular structures is investigated. Three different tubular structure models including model without core, model with central core and model with central core but eliminated in last 15 stories have been analyzed. A shear lag index is defined for evaluating these models. From examination of the results, the effective influence of core for improving the behavior of framed-tube structures has been concluded. The influence of core in reduction of shear lag in first story is estimated by 5%. Investigating the shear lag phenomenon of columns on web frame, it could be revealed that in top story the positive and negative shear lag phenomena have been occurred simultaneously.

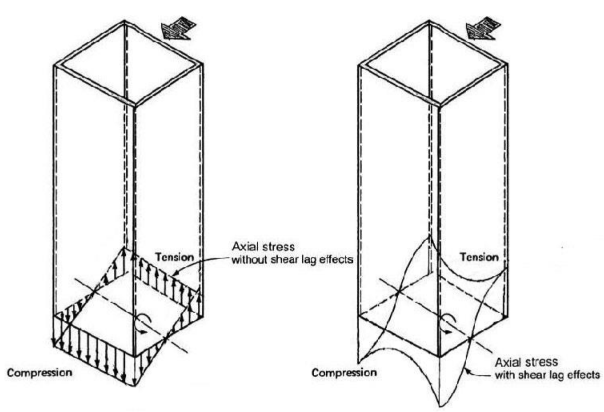
1. Introduction

The advancements of different structural systems allow for higher buildings. As the height of the building increase, the lateral resisting system becomes more important. The followings are the lateral resisting systems that are widely used: braced frames, moment resisting frames, outrigger and belt truss systems and framed tube structures. A system of cores provides additional stiffness to the structure and used for utilities and the elevator shaft.

The framed tube system has been used in many tall buildings as their primary structural system. These tube systems are affected by the shear lag effect. Shear lag is a nonlinear distribution of stresses across the sides of the section, which is commonly found in box girders under lateral load. This effect results in higher stresses at the corner columns than the inner columns of the sides. This reduces the structural efficiency of a tube structure and increases the lateral displacement of the building under lateral load.

2. Shear Lag Effect

Shear lag effect is relevant to any slender box element that is loaded laterally such as airplane wing structures and box girder bridges. This also includes the structural elements of buildings such as the core walls and the framed tube systems. The beam theory assumes that sections remain plane after bending. This assumption results in a linear distribution of bending stress in the cross section of the beam [1]. This assumption can only be true in a box section if the shear stiffness of the cross section is infinite or if there is no shear force in the box. If the shear force exists in the box, shear flow is developed across the flange and web panels [2-5]. Due to the shear flow between the flange and the web of tile box, tile panels displace longitudinally in the way that the middle portion of the flange and web lag behind that portion closer to the corner of the box section. This nonlinear longitudinal displacement of the flange and web results in the axial stress distribution as shown in Figure 1.



a) Without shear lag b) With shear lag

Fig. 1. Axial stress distribution in square hollow [5].

This shear lag effect reduces the effectiveness of the box structure by increasing the stress concentration at the web-flange junctions, reducing the axial stresses at the middle of the frame panels, which accumulates to increased lateral deflection of the structure [4].

2.1 Shear Lag in Framed Tube Structure

The framed tube building system in high-rise buildings consists of closely spaced columns around the perimeter of the building. A framed tube building behaves very much like a box girder and affected by shear lag. As shown in Figure 2, columns at the edge flange panel of the building experience higher axial stresses than the middle columns. The columns at the edge of the web panel also have higher axial stresses than the axial stresses according to the plane remains plane assumption. At the middle of the flange and web panels, the axial stresses in the columns are smaller than the axial stresses given by the plane remains plane assumption. In addition to reduced lateral stiffness, the nonlinear stress distribution of the axial stresses in framed tube building produces warping of the floor slab and consequent deformation of the secondary structures [1].

Many researchers studied shear lag effects in framed tubes structures and proposed methods to calculate the shear lag effect. In general, all the methods neglect the out-of-plane action of the frame panels because of the high in-plane stiffness of the floor slabs. Equivalent plane frame elements have been used to analyze the three dimensional system of framed tube building [6-20].

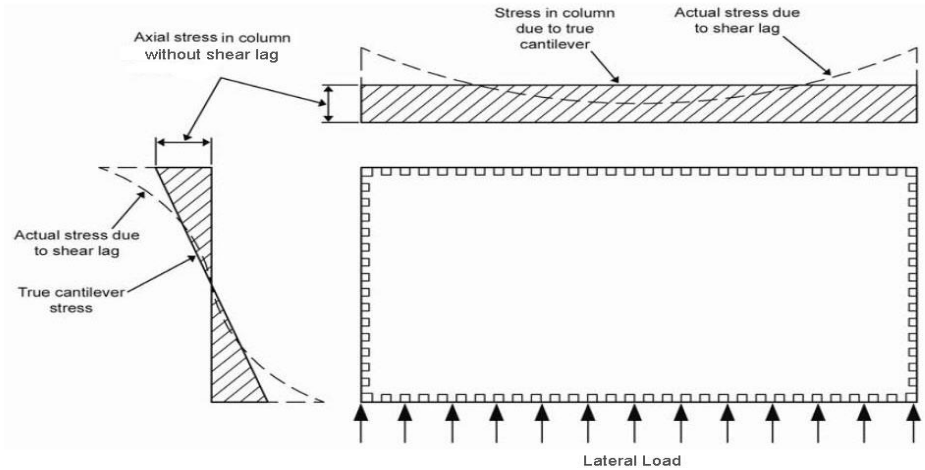


Fig. 2. Shear Lag in tubular systems [11].

Chang et al. [7] proposed equivalent solid shear walls to be used for the web panels of a cantilevered box structure and rigidly jointed beam-column frames for the flange panels. The axial displacement across the width of the flange was assumed to be either parabolic or hyperbolic cosine function. Khan and Amin [12] suggested that in preliminary design, the shear lag effect could be approximated using equivalent pair of channels for the framed tube structures. Coull and Bose and Coull and Ahmed [13, 14] used equivalent orthotropic membrane for the framed tube panels. Each orthotropic membrane has elastic properties that represent the axial and shear behavior of the actual panel. The bending stress distribution was assumed to be cubic in the web panels and parabolic in the flange panels. Similarly, Khan and Stafford Smith [15] used finite element analysis to determine the equivalent elastic properties for the membranes. Singh and Nagpal [21] concluded that "negative shear lag originates from positive shear lag and counteracts it". Positive shear lag occurs in the bottom portion of the building while negative shear lag occurs at the top portion of the building. There are few ways to reduce the effect of shear lag. Shear lag effect would not occur if the beam section has infinite shear stiffness. The stiffness of framed tube structure can be increased by increasing the ratio of the number of stories to the number bays, which will reduce the shear lag effect as reported by Singh and Naapal [21]. Shear lag effects can also be reduced by employing additional structural system in the framed tube system, which increases the stiffness of the overall structural system. Mega bracings can be used to increase the shear stiffness of the flange and web frames of the framed tube building. Belt trusses can also be added at multiple levels of a framed tube system. Belt truss effectively increases the shear stiffness of framed tube structures by integrating all the columns in the same face of the building [22-24].

The shear lag phenomenon is more prominent in framed-tube structures with central core. In the present study, the effect of core on shear lag phenomenon in tubular structures is investigated. Three different tubular structure models have been analyzed and a shear lag index is defined for evaluating these models.

3. Analytical Models

For analytical purposes, it is usually assumed that the in-plane stiffness of the floor system is so great that the floor slabs act as rigid diaphragms. Consequently, the cross-sectional shape is maintained at each story level and cross sections at these positions undergo only rigid body movements in plan. All horizontal displacements may then be expressed in terms of two orthogonal translations and a rotation. In addition, it is usually assumed that the out-of-plane stiffness of the floor slabs is so low that they do not resist bending or twisting. The floor system is assumed unable to provide any coupling action between opposite normal-to-wind frame that act as flanges to the side frames. Both the side and normal frames are therefore subjected largely to in-plane actions, and out-of-plane actions are generally negligible. When the building is subjected to lateral forces, the action of the floor system is then mainly to transmit the horizontal forces to the different vertical structural elements. Because the floor system does not participate in the Lateral load resistance of the structure and the floor loadings are essentially constant throughout the height, a repetitive floor structure can be used with economy in the design and construction [25].

The models used in this analysis are 32-meter wide, 90-storey, framed tube building with floor height of 3.9m to represent high-rise structures. Also four angle-section shear walls are used in corners of the structures. These framed tube structures including model without core, model with central core and model with central core but cut in last 15 stories have been analyzed.

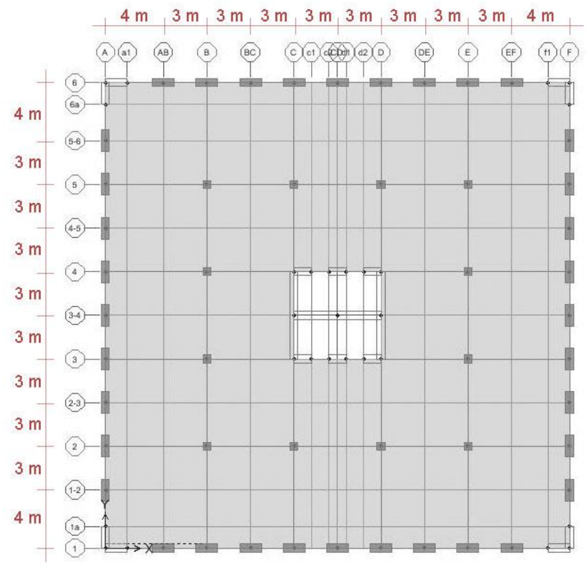


Fig. 3. General Plan of structural models.

The following assumptions are made to simplify the modeling process and the associated analysis:

• The floor slabs in the structure are considered to be rigid diaphragms within their own plane.
• The behavior of the structure is linear and elastic.
• No local bending exists in the joint areas or in the panels.
• The spacing of the beams and columns are uniform throughout the building height.

In order to evaluate the results of analysis a none dimensional parameter called here as shear lag index has been defined. The shear lag index is considered as the ratio of axial force of each column in an axis to axial force of corner column (wall) in that axis. It should be noted that the transverse section areas of all column and walls of both flange and web of structure are identical and so the axial forces are divided by a constant section area; consequently, the shear lag index defined here can accurately estimate the shear lag phenomenon in structural models. A preliminary study was performed by Kheyroddin and Mousavi [26] in which several structural models with 3 different stories in plan and different heights had been constructed. The target of the mentioned study was finding the optimized story level of core to be eliminated. The results had indicated that by eliminating 15%~20% of top stories of core, the global behavior of system would be improved.

3.1 Investigating the Shear Lag of Columns on Flange Frame

As it can be seen in Figure 4, the shear lag phenomenon for columns existing in the axis perpendicular to the direction of lateral load (Axis F) including the columns being in flange of framed-tube system for three cases have been investigated. These three cases are: Framed-tube system (TS), Framed-tube system with central core (TSC) and Framed-tube system with central core in which the core has been cut in 15 top floors (TSCC). The results of the mentioned analysis are described in terms of the shear lag index and are presented in Table 1. It is worth to mention that the shear lag indexes greater than 1 means existing of negative shear lag with respect to the corner columns (walls). As a direct consequent, if index of shear lag in a column closer to the central axis is greater than that of its adjacent column and further to the central axis, the negative shear lag will be occurred and conversely.

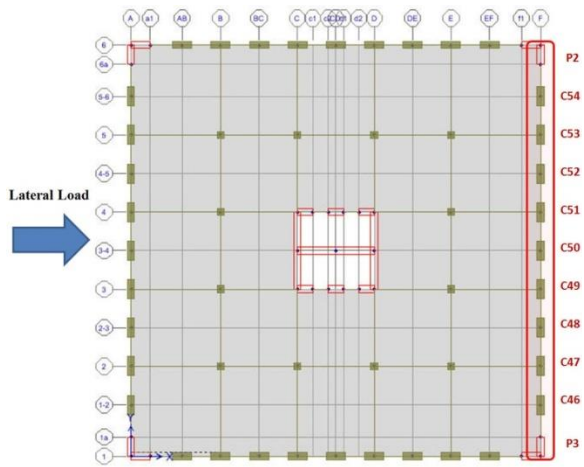


Fig. 4. Location of Columns on Flange Frame.

Table 1. Shear lag index of columns located with different distances with respect to central column and in different levels of stories.

Z/H	Column	P2	C54	C53	C52	C51	C50	C49	C48	C47	C46	P3
	Distance (m)	-16	-12	-9	-6	-3	0	3	6	9	12	16
1	STORY90-TS	1	0.08	0.23	0.51	0.62	0.65	0.62	0.51	0.23	0.08	1
	STORY90-TSC	1	0.66	0.64	1.17	1.31	1.40	1.31	1.17	0.64	0.66	1
	STORY90-TSCC	1	0.10	0.26	0.56	0.65	0.70	0.65	0.56	0.26	0.10	1
0.833	STORY75-TS	1	1.11	1.21	1.32	1.39	1.41	1.39	1.32	1.21	1.11	1
	STORY75-TSC	1	1.10	1.20	1.30	1.35	1.37	1.35	1.30	1.20	1.10	1
	STORY75-TSCC	1	1.07	1.15	1.24	1.29	1.31	1.29	1.24	1.15	1.07	1
0.667	STORY60-TS	1	0.95	0.96	0.97	0.97	0.98	0.97	0.97	0.96	0.95	1
	STORY60-TSC	1	0.95	0.97	0.98	0.98	0.98	0.98	0.98	0.97	0.95	1
	STORY60-TSCC	1	0.95	0.97	0.98	0.98	0.98	0.98	0.98	0.97	0.95	1
0.50	STORY45-TS	1	0.98	0.98	0.98	0.98	0.99	0.98	0.98	0.98	0.98	1
	STORY45-TSC	1	0.98	0.98	0.98	0.98	0.99	0.98	0.98	0.98	0.98	1
	STORY45-TSCC	1	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.98	0.98	1
0.333	STORY30-TS	1	0.96	0.95	0.95	0.94	0.94	0.94	0.95	0.95	0.96	1
	STORY30-TSC	1	0.96	0.96	0.95	0.95	0.95	0.95	0.95	0.96	0.96	1
	STORY30-TSCC	1	0.96	0.96	0.95	0.95	0.95	0.95	0.95	0.96	0.96	1
0.167	STORY15-TS	1	0.98	0.97	0.96	0.96	0.96	0.96	0.96	0.97	0.98	1
	STORY15-TSC	1	0.98	0.97	0.96	0.96	0.96	0.96	0.96	0.97	0.98	1
	STORY15-TSCC	1	0.98	0.97	0.96	0.96	0.96	0.96	0.96	0.97	0.98	1
0.011	STORY1-TS	1	0.90	0.84	0.81	0.79	0.78	0.79	0.81	0.84	0.90	1
	STORY1-TSC	1	0.92	0.88	0.84	0.83	0.82	0.83	0.84	0.88	0.92	1
	STORY1-TSCC	1	0.92	0.88	0.84	0.83	0.82	0.83	0.84	0.88	0.92	1

Figure 5 shows the curve of shear lag index for all three models in highest level (story 90). As it can be observed from the curve and considering the values of Table 1, it could be concluded that the difference of stresses between corner column and its adjacent column in both TS and TSCC systems compared with TSC system is greater by 4.7 to 4.8 percent; while the difference of shear lag index of mentioned systems are lower. These advantages and disadvantages indicate the effective influence of using core in framed-tube structures.

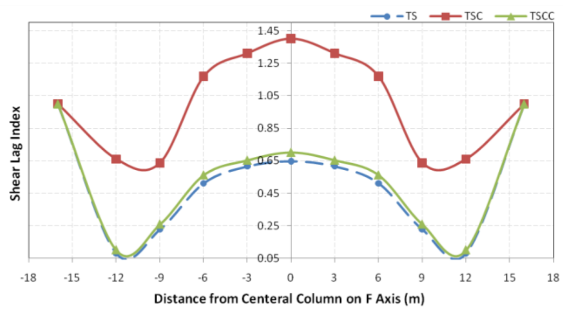


Fig. 5. Variation of shear lag index for columns on axis F in story No. 90.

Figure 6 shows the shear lag indexes in story No. 75 which is an evident representative for negative shear lag. Studying the curve, one can conclude that the amount of shear lag in TSCC system has been reduced by 7.9% and 4.8% with respect to TS and TSC systems respectively.

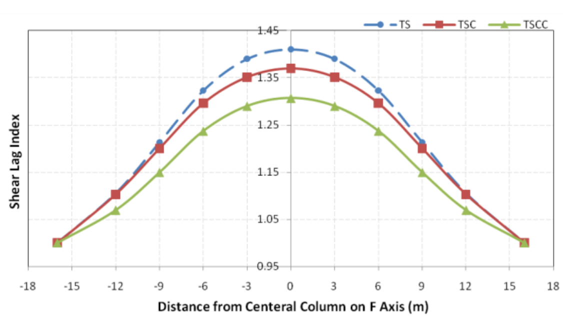


Fig. 6. Variation of shear lag index for columns in story No. 75.
(a developed sample for negative shear lag)

It can been seen from figure 7 that the shear lag index has been considerably reduced in story No. 60 and this phenomenon has been changed gradually to the positive shear lag by considering the other lower stories. As a similar consequent, the shear lag of this story in TSCC system is lower than the other systems too.

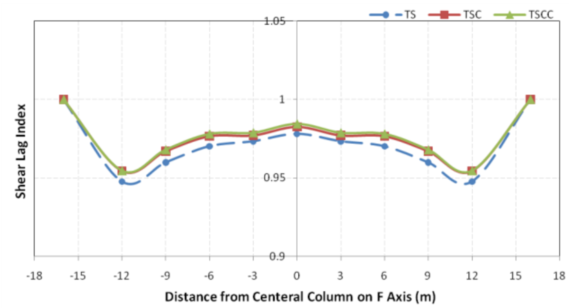


Fig. 7. Variation of shear lag index for columns in story No. 60.

Shear lag phenomenon for story No.45 is shown in Figure 8. As it can been seen from the Figure 8 and Table 1, the amount of shear lag is the lowest among the three models in this story. Also in all models, the columns C46 to C54 experience the lowest stress difference compared with each other; however this difference is between corner columns compared with the other ones and is not considerable.

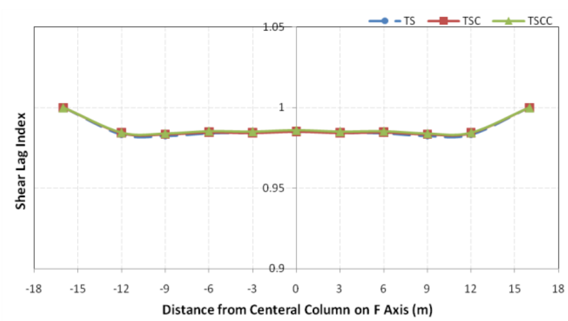


Fig. 8. Variation of shear lag index for story No. 45.

Curves of Figures 9 and 10 show the formation of shear lag phenomenon in stories No.30 and No. 15 respectively in which the TSCC model has the lowest amounts of shear lag index among all models. Figure 11 shows the improved trend of this phenomenon in first story and appear the considerable effect of core in reducing the phenomenon (by 5%).

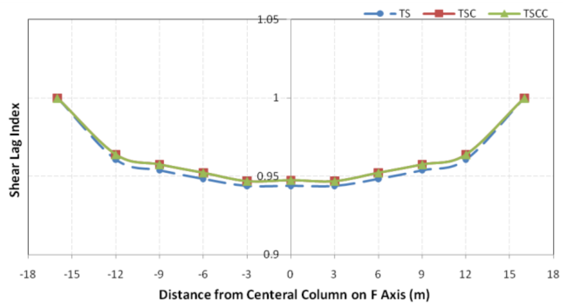


Fig. 9. Variation of shear lag in story No. 30.

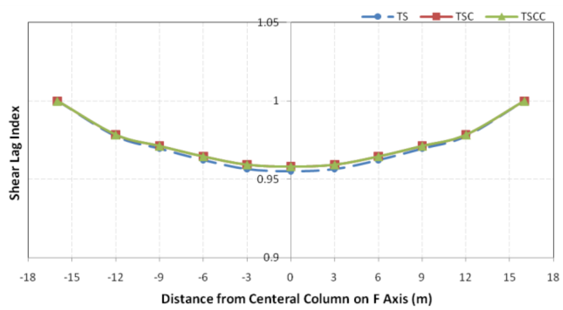


Fig. 10. Variation of shear lag index of story No. 15.

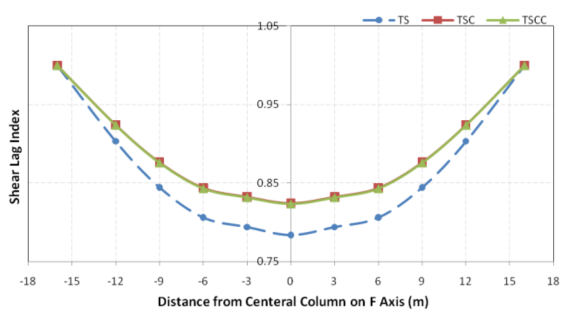


Fig. 11. Shear lag index in first story.

3.2 Investigating the Shear Lag of Columns on Web Frame

Figure 12 shows the investigation of shear lag phenomenon for columns on the axis parallel to lateral load direction (axis 6) including columns on web of framed-tube system for all TS, TSC and TSCC models. The results are shown in Table 3 using shear lag indexes. It should be noted that when absolute indexes for each column is greater than the absolute base indexes presented in Table 2, it shows the negative shear lag with respect to corner columns (walls). Similarly, if the difference between the index for the column located closer to the central axis and the one further is considerable, the negative shear lag phenomenon has been occurred and for counter.

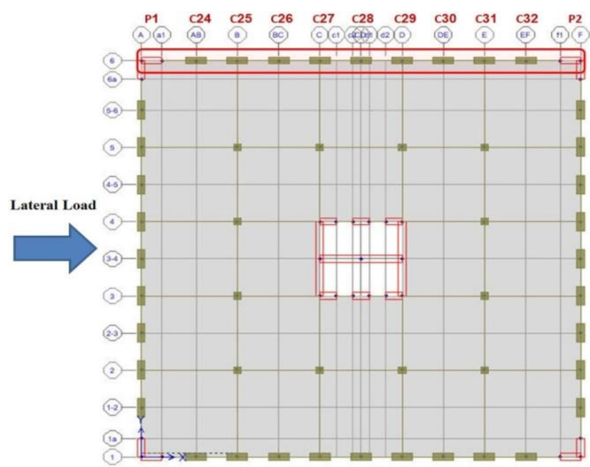


Fig. 12. Location of columns of axis 6 general plan of models.

Table 2. Amount of base shear lag index for columns on axis 6.

Column	**P1**	**C24**	**C25**	**C26**	**C27**	**C28**	**C29**	**C30**	**C31**	**C32**	**P2**
Distance from central Column	-16	-12	-9	-6	-3	0	3	6	9	12	16
Base Shear Lag Index	1	0.75	0.56	0.38	0.19	0	-0.19	-0.38	-0.56	-0.75	-1

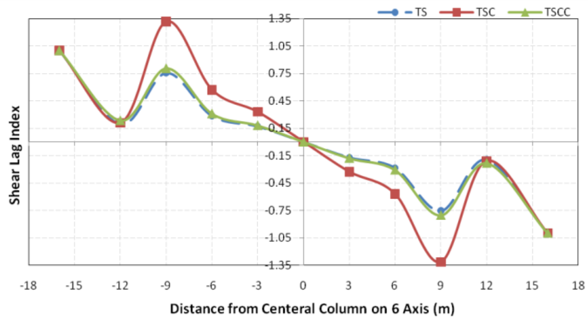


Fig. 13. Shear lag in story No. 90.

Table 3. Indexes of shear lag for columns of axis 6 in different story levels.

Z/H	Column	P1	C24	C25	C26	C27	C28	C29	C30	C31	C32	P2
	Distance (m)	-16	-12	-9	-6	-3	0	3	6	9	12	16
1	**STORY90-TS**	1	0.19	0.75	0.28	0.17	0.00	-0.17	-0.28	-0.75	-0.19	-1
	STORY90-TSC	1	0.21	1.32	0.57	0.33	0.00	-0.33	-0.57	-1.32	-0.21	-1
	STORY90-TSCC	1	0.23	0.80	0.31	0.18	0.00	-0.18	-0.31	-0.80	-0.23	-1
0.833	**STORY75-TS**	1	0.86	0.77	0.54	0.28	0.00	-0.28	-0.54	-0.77	-0.86	-1
	STORY75-TSC	1	0.85	0.76	0.52	0.27	0.00	-0.27	-0.52	-0.76	-0.85	-1
	STORY75-TSCC	1	0.81	0.71	0.50	0.25	0.00	-0.25	-0.50	-0.71	-0.81	-1
0.667	**STORY60-TS**	1	0.76	0.54	0.37	0.19	0.00	-0.19	-0.37	-0.54	-0.76	-1
	STORY60-TSC	1	0.77	0.55	0.37	0.19	0.00	-0.19	-0.37	-0.55	-0.77	-1
	STORY60-TSCC	1	0.77	0.55	0.38	0.19	0.00	-0.19	-0.38	-0.55	-0.77	-1
0.50	**STORY45-TS**	1	0.74	0.56	0.37	0.19	0.00	-0.19	-0.37	-0.56	-0.74	-1
	STORY45-TSC	1	0.74	0.56	0.37	0.19	0.00	-0.19	-0.37	-0.56	-0.74	-1
	STORY45-TSCC	1	0.74	0.56	0.37	0.19	0.00	-0.19	-0.37	-0.56	-0.74	-1
0.333	**STORY30-TS**	1	0.73	0.53	0.36	0.18	0.00	-0.18	-0.36	-0.53	-0.73	-1
	STORY30-TSC	1	0.73	0.54	0.36	0.18	0.00	-0.18	-0.36	-0.54	-0.73	-1
	STORY30-TSCC	1	0.73	0.54	0.36	0.18	0.00	-0.18	-0.36	-0.54	-0.73	-1
0.167	**STORY15-TS**	1	0.73	0.55	0.36	0.18	0.00	-0.18	-0.36	-0.55	-0.73	-1
	STORY15-TSC	1	0.73	0.55	0.36	0.18	0.00	-0.18	-0.36	-0.55	-0.73	-1
	STORY15-TSCC	1	0.73	0.55	0.36	0.18	0.00	-0.18	-0.36	-0.55	-0.73	-1
0.011	**STORY1-TS**	1	0.58	0.41	0.28	0.14	0.00	-0.14	-0.28	-0.41	-0.58	-1
	STORY1-TSC	1	0.62	0.44	0.30	0.15	0.00	-0.15	-0.30	-0.44	-0.62	-1
	STORY1-TSCC	1	0.62	0.44	0.30	0.15	0.00	-0.15	-0.30	-0.44	-0.62	-1

Figure 13 shows the variation of shear lag for all models in story No. 90. As it can be seen from curve and also the values of Tables 2 and 3, the difference of stress between corner column and its adjacent column is approximately equal in all models. Considering the comparison between base shear lag indexes presented in Table 3 indicates that the variation is outgoing of being linear and also this difference is the lowest in TSCC system compared with the others. The mentioned variations for column C25 in TSC system shows the considerable amount and is about 2.36 times than the base amounts. In column C26 and the other ones ending to central column, the discrepancy between shear lag index and base shear lag index is lower.

With accurate study, it could be revealed that in top story the positive and negative shear lag phenomena have been occurred simultaneously.

Figure 14 shows the negative shear lag in story No. 75. The amount of shear lag indexes for two systems TS and TSC are close to each other while it presents a reduction equal to 5% for TSCC system.

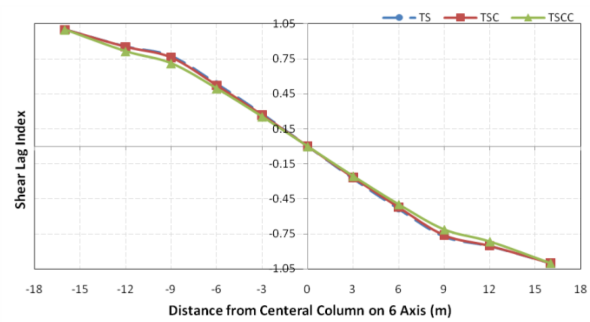


Fig. 14. Variation of shear lag index in story No. 75.

Considering the curves presented in Figures 15 to 18 and values of Table 2 and 3 for stories No. 60, 45, 30 and 15, one can easily understand the show rate in conversion of negative shear lag into positive in web of all three systems. The shear lag phenomenon in story No. 45 is at its least amount while it could be claimed that there is no shear lag in TSCC system at story No. 45.

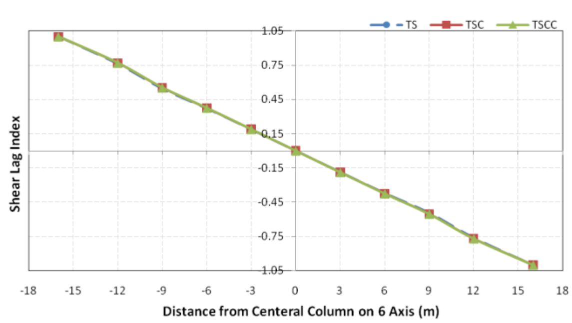


Fig. 15. Variation of shear lag in story No. 60.

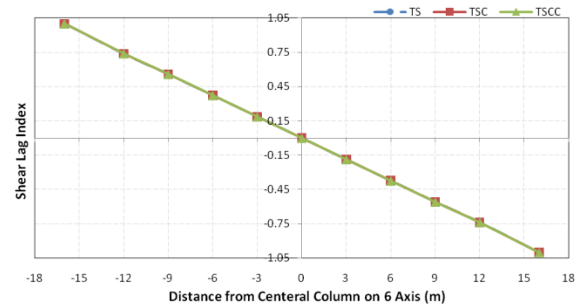


Fig. 16. Variation of shear lag index in story No. 45.

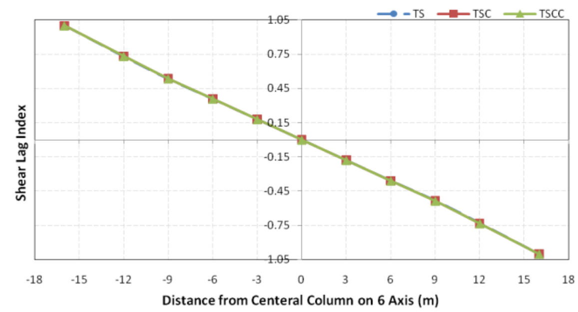


Fig. 17. Variation of shear lag index in story No. 30.

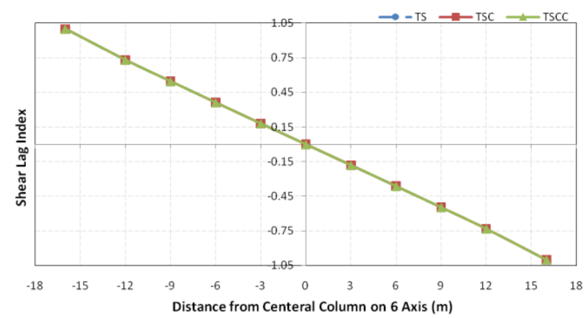


Fig. 18. Variation of shear lag index in story No. 15.

Figure 19, presents the shear lag index for first story. Considering the curve and comparing the amount of shear lag index due to Table 3 and Table 2, it could be understood that in this story the shear lag phenomenon is completely positive in webs of models and these values are exactly identical for both TSC and TSCC systems which are 7% lower than that of TS system.

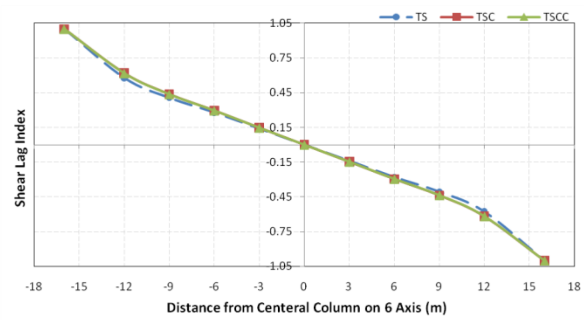


Fig. 19. Variation of shear lag index in first story.

4. Conclusion

- The influence of core in reduction of shear lag in first story is estimated by 5%.
- The amount of shear lag in story No. 45 is the lowest among the three models. Also in all models, the columns on flange, experience the lowest stress difference compared with each other; however this difference is between corner columns compared with the other ones and is not considerable.
- Considering the flange columns of story No. 60, one can conclude that the amount of shear lag in TSCC system (Framed-tube system with central core in which the core has been cut in 15 top floors) has been reduced by 7.9% and 4.8% with respect to TS (Framed-tube system) and TSC systems (Framed-tube system with central core) respectively.
- In story No. 90, it could be concluded that the difference of stresses between corner column and its adjacent column in both TS and TSCC systems compared with TSC system is greater by 4.7 to 4.8 percent; while the difference of shear lag index of mentioned systems are lower. These advantages and disadvantages indicate the effective influence of using core in framed-tube structures.
- It could be understood that in first story the shear lag phenomenon is completely positive in webs of models and these values are exactly identical for both TSC and TSCC systems which are 7% lower than that of TS system.
- The shear lag phenomenon for columns on web frame in story No. 45 experience its least amount while it could be claimed that there is no shear lag in TSCC system at story No. 45.
- Investigating the shear lag phenomenon of columns on web frame, it could be revealed that in top story the positive and negative shear lag phenomena have been occurred simultaneously.
- Positive shear lag occurs in the bottom portion of the building while negative shear lag occurs at the top portion of the building.
- To sum up, it can be generally concluded that the influence of core in reduction of shear lag is considerable; however cutting the core in top stories will improve the behavior of structural system by decreasing the negative shear lag phenomenon.

REFERENCES

[1] Leonard, J. (2004). “Investigation of Shear Lag Effect in High-rise Buildings with Diagrid System”. MSc Dissertation, Illinois Institute of Technology.

[2] Azhari M., Bradford M.A. (1999). “Elastic Initial and Post-Local Buckling of Profiled Through Girders”. International Journal of Engineering, IJE, Vol. 12, No. 1, pp. 1-12.

[3] Riyazi, M., Esfahani, M.R., Mohammadi, H., (2007). “Behavior of Coupling Beams Strengthened with Carbon Fiber

Reinforced Polymer Sheets”. International Journal of Engineering, IJE, Vol. 20, No. 1, pp. 49-58.

[4] Kheyroddin, A., Zahiri R. (2008). “Investigation of the Shear Lag Behavior in Braced Tubular Structures”. 6th Structural Specialty Conference, CSCE 2008.

[5] Taranath, B.S. (2005). “Wind and Earthquake Resistant Buildings Structural Analysis and Design”. Marcel Dekker, New York.

[6] Foutch, D.A., Chang, P.C. (1982). “A Shear Lag Anomaly”. Journal of structural engineering, ASCE, 108(ST7), pp. 1653-1657.

[7] Chang, S.T., Zheng, F.Z. (1987). “Negative Shear Lag in Cantilever Box Girder with Constant Depth”. Journal of structural engineering, ASCE, 113(1), pp. 20-33.

[8] Kristek, V., Studnicka J. (1991). “Negative Shear Lag in Flanges of Plated Structures”. Journal of structural engineering, vol. 117, no12, pp. 3553-3569.

[9] Shushkewich, K.W. (1991). “Negative Shear Lag Explained”. Journal of Structural Engineering, Vol. 117, No. 11, November, pp. 3543-3546.

[10] Lee, S.C., Yoo, C.H., Yoon, D.Y. (2002). “Analysis of Shear Lag Anomaly in Box Girders”. Journal of Structural Engineering, Vol. 128, No. 11, November.

[11] Ali. Mir M., Moon, K.S. (2007). “Structural Developments in Tall Buildings: Current Trends and Future Prospects”. Architectural Science Review, Volume 50.3, pp 205-223.

[12] Khan, F.R., Amin, N.R. (1973). "Analysis and Design of Frame Tube Structures for Tall Concrete Buildings". The Structural Engineer, Vol. 51, pp 85-92.

[13] Coull, A., Bose, B. (1975). “Simplified Analysis of Framed-Tube Structures”. Journal of structural engineering, ASCE, 101(11), pp. 2223-2240.

[14] Coull, A., Ahmed, A.A. (1978). “Deflections of Framed-Tube Structures”. Journal of structural engineering, ASCE, 104(5), pp. 857-862.

[15] Khan, A.H., Stafford Smith, B. (1976). "Simplified Method of Analysis for Deflections and Stresses in Wall-Frame Structures". Building and Environment, Y. ll, No. 1, pp.69-78.

[16] Ha, H.K., Moselhi, O., Fazio, P.P. (1978). “Orthotropic Membrane for Tall Building Analysis”. Journal of the Structural Division, Vol. 104, No. 9, September, pp. 1495-1505.

[17] Kwan, A.K.H. (1994). “Simple Method for Approximate Analysis of Framed Tube Structures”. Journal of Structural Engineering, Vol. 120, No. 4, April.

[18] Kristek, V., Bauer, K. (1993). “Stress Distribution in Front Columns of High-Rise Buildings”. Journal of structural engineering, ASCE, 119(5), pp. 1464-1483.

[19] Chang, P.C. (1985). “Analytical Modelling of Tube-in-Tube Structure”. Journal of structural engineering, ASCE, 111(6), pp. 1326-1337.

[20] Connor, J.J., Pouangare, C.C. (1991). “Simple Model for Design of Framed-Tube Structures”. Journal of structural engineering, Vol. 117, No.12, pp. 3623-3643.

[21] Singh, Y., Nagpal, A.K. (1994). “Negative Shear Lag in Framed-Tube Buildings”. Journal of structural engineering, ASCE, 120(11), pp. 3105-3121.

[22] Stafford-Smith, B., Cruvellier, M., Nollet, M-J., Mahyari, A.T. (1996). “Offset Outrigger Concept for Tall Buildings”. Tall Building Structures--A World View, Council on Tall Buildings and Urban Habitat, pp. 73-80.

[23] Nair, R.S. (1998). “Belt Trusses and Basements as ‘Virtual’ Outriggers for Tall Building”. Engineering Journal, AISC, Vol. 35, No. 4, 4th Quarter.

[24] Hoenderkamp, J.C.D., Snijder, H.H., (2003). “Preliminary Analysis of High-Rise Braced Frames with, Facade Riggers”. Journal of Structural Engineering, Vol. 129, No. 5, May.

[25] Taranath, B.S. (1988). “Structural Analysis and Design of Tall Buildings”. McGraw-Hill, New York.

[26] Mousavi, S.J. (2001). “Investigation of Seismic Behavior of Tube in Tube Systems in High-Rise Buildings”. M.Sc. Dissertation, Semnan University.