IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 3, Ver. II (May- Jun. 2016), PP 18-29
www.iosrjournals.org

Effect of Suspended Systems on the Stress Strain Condition Of Residential R.C. Buildings

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Abstract: *This paper deals with the development of R.C. residential buildings in hot weather and severe climate conditions in IraqIn response to the requirements of the Sustainable Engineering. The development includes addition of suspended cantilever parts to the original reinforced monolithic frame to create suspended gardens. These gardens are necessary to improve living conditions including motion and serviceability requirements. The suspended parts consist of reinforced concrete cantileversuspended floor system strengthened with steel strands to resist the additional stresses and forces created by this addition. The research reveals these stresses and deformations with the necessary three-dimensional analytical experiments to obtain the best accurate suggestion. Staadpro 2014(2) is used in all calculations.*
Keywords: *suspended buildings, stresses, deformations, cantilever, strands*

I. Introduction

Due to bad policy of solving residential problem associated with population growth summarized with the distribution of a piece of land for each citizen the city area has grown up to become one of the largest cities in the world . This bad solution brought a lot of problems including difficult serviceability, decreasing the green areas, decreasing areas required for important hugeService and functional projects .Flat land made it difficult for rainwater drainage and created countless problems in sewage systems .Haphazard construction distorted the cultural landmarks of the city and architectural features. Sustainable engineering takes environmental engineering concepts to the next level by looking at the interactions between technical, ecological, social and economic systems and by avoiding shifting problems from one area to the other.Sustainability means living well within the ecological limits of a finite planet. More than ever, engineers need to find holistic and effective solutions to protect our vital life support systems and, at the same time, meet the needs of a growing human population.Concepts such as life cycle thinking, industrial ecology and sustainable systems engineering are important elements in the education and work practice of a sustainable engineer (fig.1)(5).Vertical construction gives effective solution residential problems and economy, it save the land area and simplifies the serviceability functions but it is found that this excellent solution functions well in cold regions, in hot weather conditions this solution does not function well therefore it is refused by the majority of the people of this land .therefore it was necessary to develop this system to answer the requirements of the people of this land.

II. Analytical Model

For the purpose of this research and the mentioned above goal a preliminary R.C model was suggested in the shape of fifth story R.C. multistory building (fig.2). For the building the suspended gardens cantilever R.C beams were added and extended from the exterior columns. For research purposes we exaggerated the length of these beams to be of total length of 10 m. actually this length is more than required to create a garden but it is necessary to reveal the stress – deformation relationship to judge the case. Such length may create serious cracks and or even damage of the structure if left withoutsupport. Here the support is provided by steel strands similar to suspended bridges (fig.2).Story height is imposed 3m, the building model is 3*5m c.c. bays in each direction(fig.3),total suspended area ($5*10=50m^2$) more than enough to create suspended garden, strands used have cross sectional area = $5cm^2$ with fy = 424mpa (usually use higher strength in 3 times), concrete normal with fc = 28 mpa (cylinder) ,code ACI 318-08(4) , imposed loads uniformly distributed total factored load of 12.5kN / m^2(fig.3), cross-sectional area of all beams are supposed 0.4*0.6m,columns square with dimensions 0.5*0.5m. Cantilever suspended beams are inverted T-section to be hidden and to allow for soil refill with the distribution of drainage pipe system.Slab monolithic with thickness 0.15 m. Supports fixed analysis 3-dimensional to take in consideration all the effects including biaxial bending moments in columns.

III. Preliminary Analysis

The preliminary 3-dimensional analyses of the model were not successful. Huge negative bending moments appeared in the end of cantilever-reinforced monolithic suspended beams. The unique interpretation of this result was that although using unique strand in end of the beams elastic deformations of the strands caused the appearance of these moments. As a result we tried to duplicate the strands using additional intermediate strands in the middle of the suspended cantilever beams. Successive repeated analysis showed a benefit for this addition but still not enough to decrease the negative moments. To solve this problem it was suggested to insert hinges in these critical points which finally gave a reasonable solution (fig.4).the results of these analytical attempts are not shown in this research. Parallel study and analysis for 14-july suspension bridge in Baghdad.shows identicalsimilar resultsconcerning the effect of thesedeformations on the stresses developed in the bridge. The assigned yielding strength of the strands selected has major effects on these stresses.The behavior of the suspended parts remains as cantilever beams due to these deformations although suspension support is provided.

IV. Final Analysis

Inserting Hinge in the start of each suspended cantilever beam is not a simple process due to the 3-dimensioal analysis and the existence of big number of members in the model. The sequence order of numbering members must be followed otherwise the control on the model is lost. Staadprohas some facilities that greatly simplifythe process of isolating similar members like creation of grouping and translational repeat and others. The parts of all the cantilever suspended beams containing the hinges must be inserted first in sequence in order to in insert the hinges all together in one simple process (example 1 to 50 i.e. member 1 to member 50 contains member release in bending moment MZ i.e. hinge).The analysis of the successful model shown in (fig.4). The deflected shape of the structure shows a maximum vertical displacement of 60mm in end of cantilever-reinforced monolithic suspended beams. the bending moment diagram shown in (fig.5)shows maximum positive bending moment MZ in intermediate points between cables , the reinforcement for these moments are acceptable in value with in controlled limit (RHO = 0.0044) .Maximum shear requirements are also within reasonable values situated in the outer exterior part of the suspended cantilever beam (fig.5).Loading diagrams, bending moment diagram and shear force diagrams with the reactions are shown in (fig.5) to(fig.12) the axial forces in beams and columns are shown in (fig.6)the brown color means compression, the blue color means tension .it is to be noticed that the top beam members of the basic frame are in tension zone , the lower beam members in compression zone. The cables are in tension, the cantilever suspended beams are subjected to bending moment and compression forces due to the effect of the tensile forces in cables. The change of the axial forces in the beams of the basic frame is interpreted as follows: due the effect of the suspended gardens the main structure tends to be opened from the top to bottom causing these effects which must be taken in consideration when analyzing and designing of these types of structures. The top members are to be designed not only as beams but also as tension members while bottom beams are to be designed as compression member i.e. as columns. Linear relationships of stress changes from tension in top members to compression in bottom members are noticed. Axial forces in the suspended cantilever beams are compression of big values which means that these members must also to be considered as compression members or as columns.it is to be noticed also that the exterior columns are subjected to axial force higher than interior columns in contrast with what is found in usual systematic structures. Thisis also interpreted due to the effects of the suspended gardens on whole structure(fig.6)another matter of interest is the stress values of the suspended strands to appreciate the adequacy of these cablesand their safety .The tensile force in the exterior outer cable is found 466 kN which give maximum tensile stress values of 237 Mpa . The tensile force in interior inner cable is found 810 kN which gives maximum tensile stress values of 405 Mpa.both value are situated within acceptable results in comparison with the supposed yielding strength of steel which is taken as 424 Mpa. it must be mentioned that real strands have yielding strength much more than this value (minimum three times higher) .all these values can be seen in successive figures.

V. Building Construction

Another matter of interest which must be mentioned is construction process of such a building. the existence of cables is very necessary to support the suspended gardens .The construction of these cables cannot be delayed until the construction process is completed because the suspended gardens will collapse therefore the construction scaffolding for the lower floor must stay in place supporting the garden until the upper floor system is constructed and the strands are anchored meanwhile intermediate successive design process must be accomplished to design the intermediate beams as top beams because during this construction process ,the tension forces will be too high which requires additional reinforcement to be provided .

VI. Additional Requirements

As mentioned in the abstract of this research that the purpose of this research is to develop R.C. residential buildings to answer the living requirements of the man in hot climate in such away giving the feeling as if he lives in his own private home. There for we found that the intermediate solution between the living in a flat in residential building and owing the single home is required to save land area. We think that these types of buildings must be tall in height small in cross sectional area i.e. we think each story must contain only one flat or even two stories for one flat to give the feeling of living in your own private home and for better allow for the sun light to reach all remote points of the flat. In another words we are supposing the construction of single private houses one above other instead of building a single house on single area wasting the land.

VII. Associated Parallel Analytical Experiments

All the analytical models and calculations were preceded by comprehensive elastic analysis of 14-july suspension bridge in Baghdad based on the information available for the mentioned bridge for better understanding of the behavior of these types of structures (fig.2).The analysis for the bridge showed also big elastic deformations in strands and girders. All these analyses were achieved using staadpro 2014.

VIII. Successive Required Experiments And Models

This research requires the following important additional analyticaljobs:

1. To decrease the effect of axial effects and forces developed in internal and external members due to the suspending gardens we found it necessary to try the extension of the strands through the horizontal members of the main basic frame in both directions especially for top members where the maximum tensile forces and stresses appeared, this will prevent or decrease in our opinion the tendency of opening in the structure starting from the top.
2. It is important also to try different material strength properties especially for the strands because this may decrease the elastic deformations in these strands allowing for better control on the maximum negative bending moments appeared in the start of suspended cantilevers for the suspended gardens .
3. The change of the exaggerated length of the suspended gardens may decrease majority of stresses developed in the structure allowing for better control of these stresses to the more reasonable satisfaction results.
4. It is important also to draw a relationship between the length of suspended parts and the developed stresses in the structure especially in these suspended beams of the suspended gardens.
5. The optimization of location of the strands and the number and their number is also required to create the ideal suspended structure of this type.

IX. Conclusions

This preliminary research allows making the following conclusions:

1. Successful 3-dimensional theoretical modelin response to the requirements of the Sustainable Engineering is suggested as result of this research.
2. Preliminary results of analysis show huge negative moments in the suspended cantilever beams and deflections due to which, insertion of artificial hinge in the start of these beams becomes a fact of necessity.
3. All the top beam members are subjected to biaxial effects of bending moments and axial tensile forces in addition to other traditional stresses. Tensile forces are huge enough for the member to be considered as tension - member. Reinforcing these members must be considerably.
4. All the bottom beam members are subjected to biaxial effects of bending moments and axial compressive forces in addition to other traditional stresses.Compressive forces are huge enough for the member to be considered as compression - member. Reinforcing these members must be considerably.
5. Approximately linear behavior of change for the axial forces is noticed from the start to the bottom of structure.
6. The outer edge columns have compressive forces higher than the inner interior columns in contrast with the major types of traditional systematic regular structures due to the effect of suspended gardens on structure.
7. Suspended cantilever beams have big axial compressive forces; big bendingmoments, big shear forces in addition to other stresses, there for these members must also considered and designed as compression members.
8. The structure is imagined to be opened from the top to bottom therefore strengthening it is necessary by the extension of the strands through the interior top beams for better fixity.
9. The suspended cantilever beams must be inverted T-section .this is important to be hidden and to allow for the soil refilling of the garden and to maintain the level of the garden and the floor as the same level.
10. construction scaffolding for the lower floor must stay in place supporting the garden until the upper floor system is constructed and the strands are anchored meanwhile intermediate successive design process must be accomplished to design the intermediate beams as top beams because during this construction process ,the tension forces will be too high which requires additional reinforcement to be provided .
11. Successive trials and tests must be accomplished to determine the optimization of this type of structures including better proportionality, bettered insured anchorage of strands, number and positions of strands, relationship between the suspended cantilever beams spans and stresses, optimized height of such a structure.

Fig. (1) Green technology, sustainable engineering

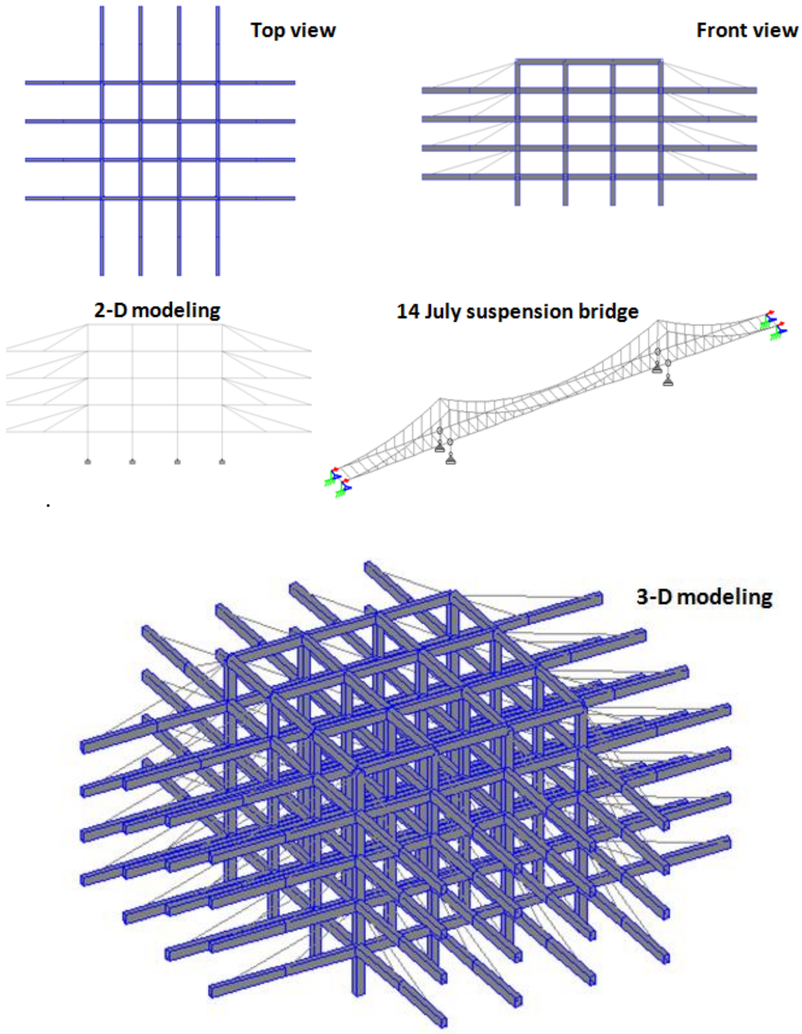
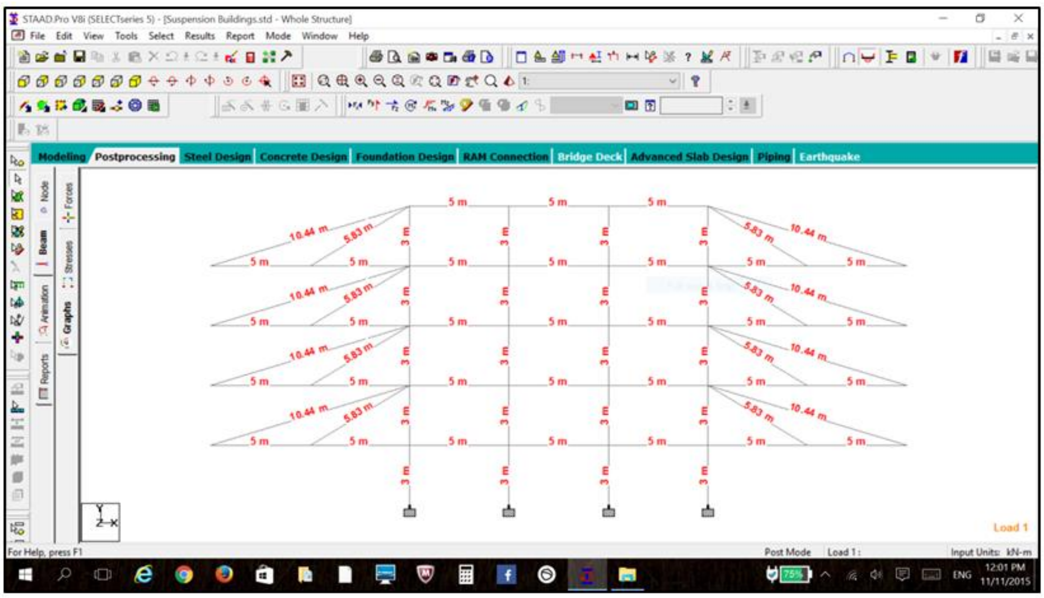


Fig. (2) 3-D modeling of suspended building



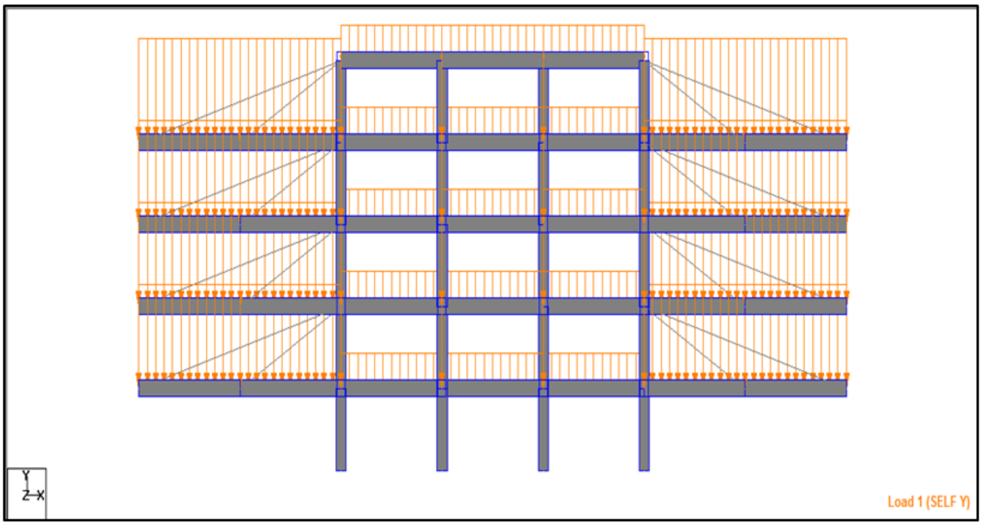
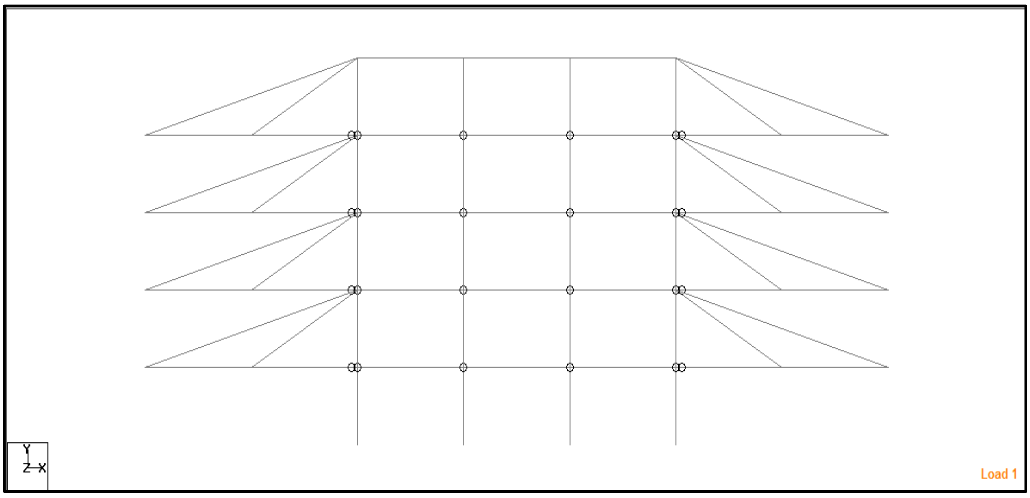


Fig. (3) Dimensions & Loadings



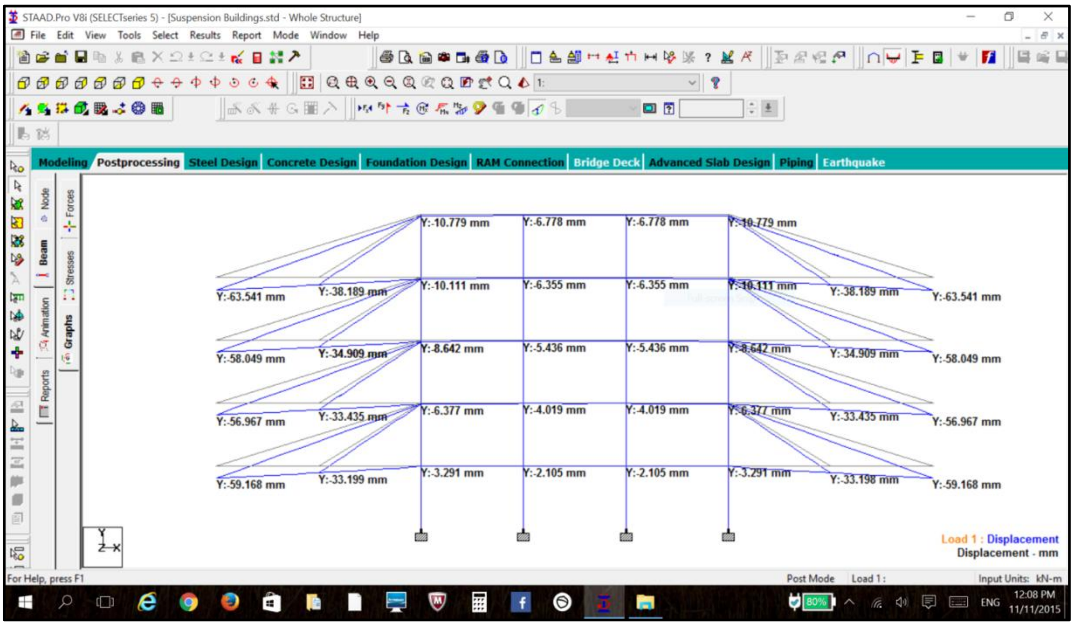


Fig. (4) Inserting hinges with maximum vertical displacements

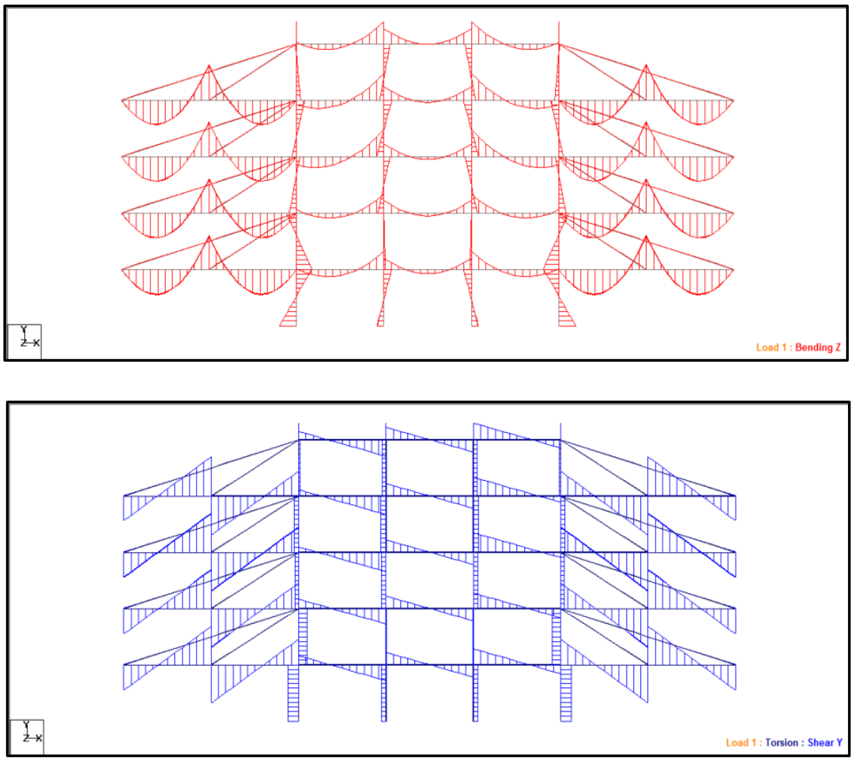


Fig. (5) Bending moments Mz& Shear forces Fy

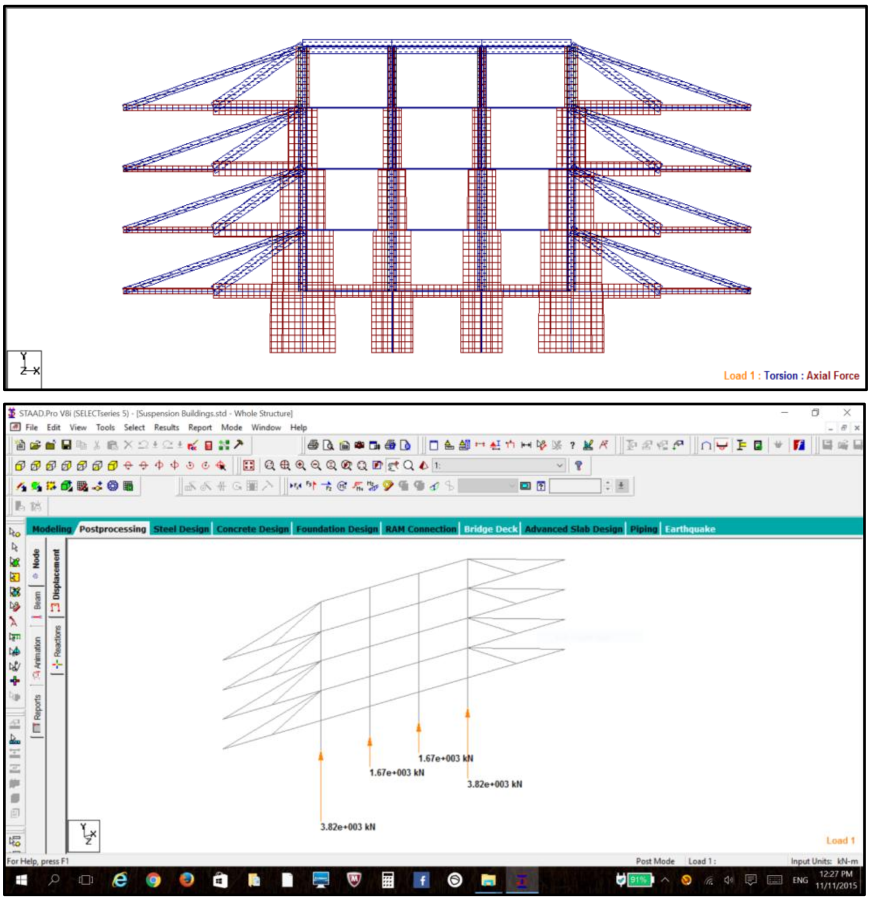


Fig. (6) Axial forces Fx& Reactions RykNS brown = compression, blue = tension

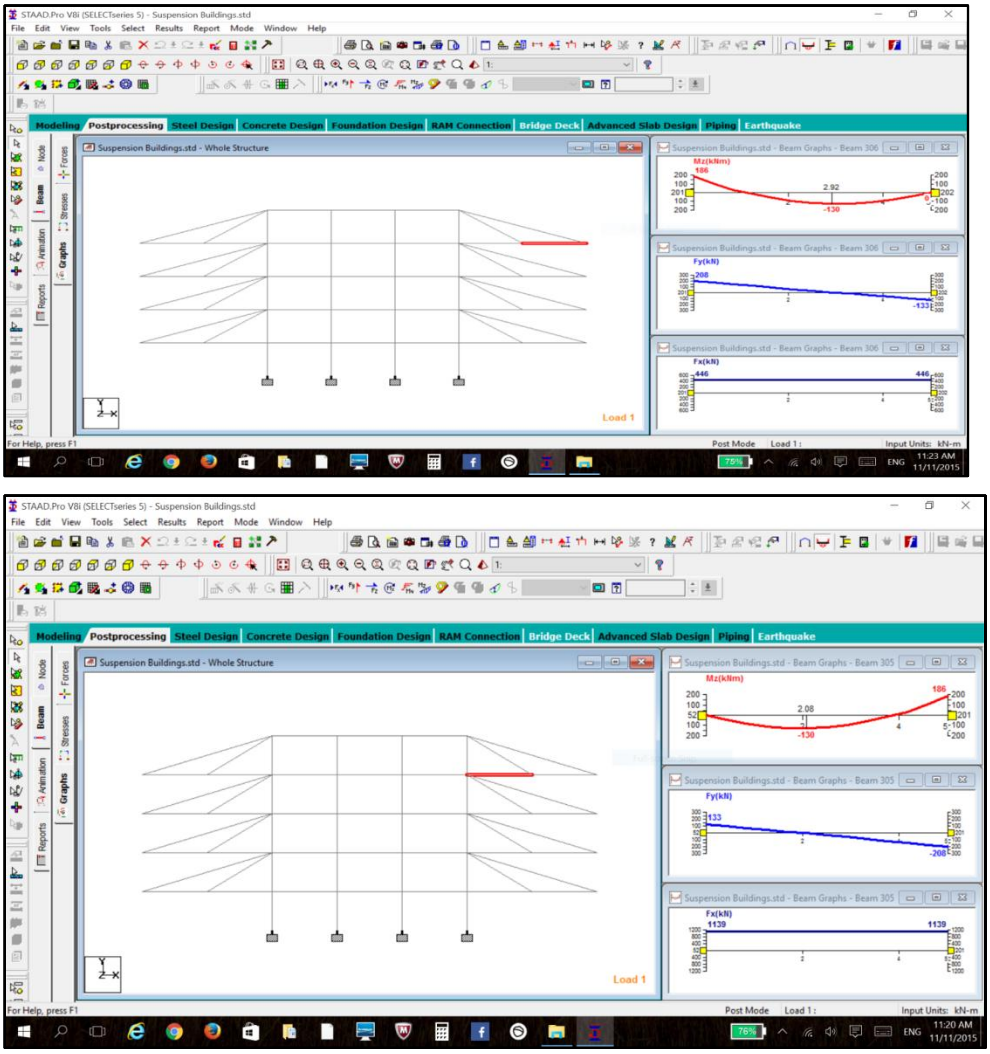
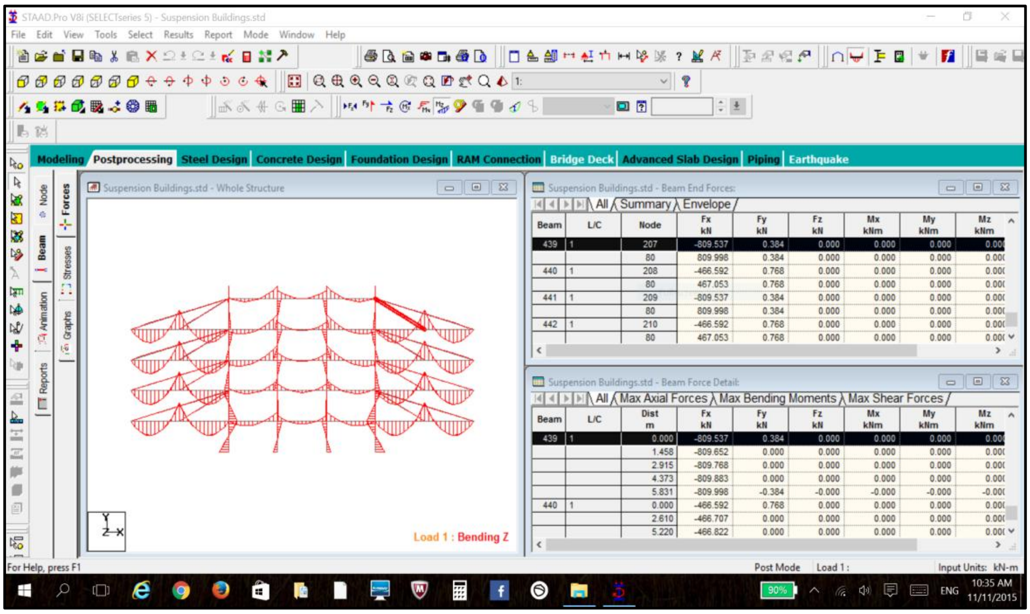


Fig. (7) Outer & inner suspended cantilevers



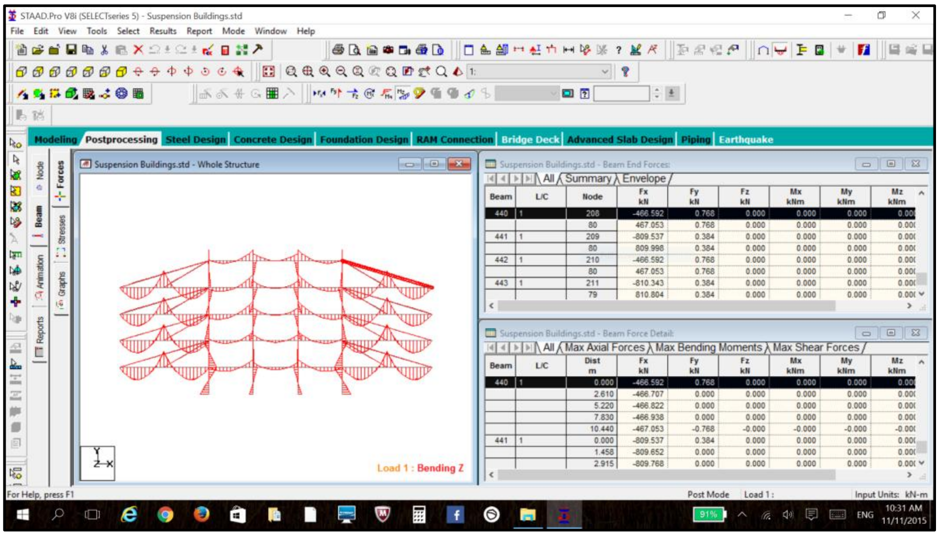


Fig. (8) inner& outer suspended tension cables with Tmax = 810,466 kNS respectively

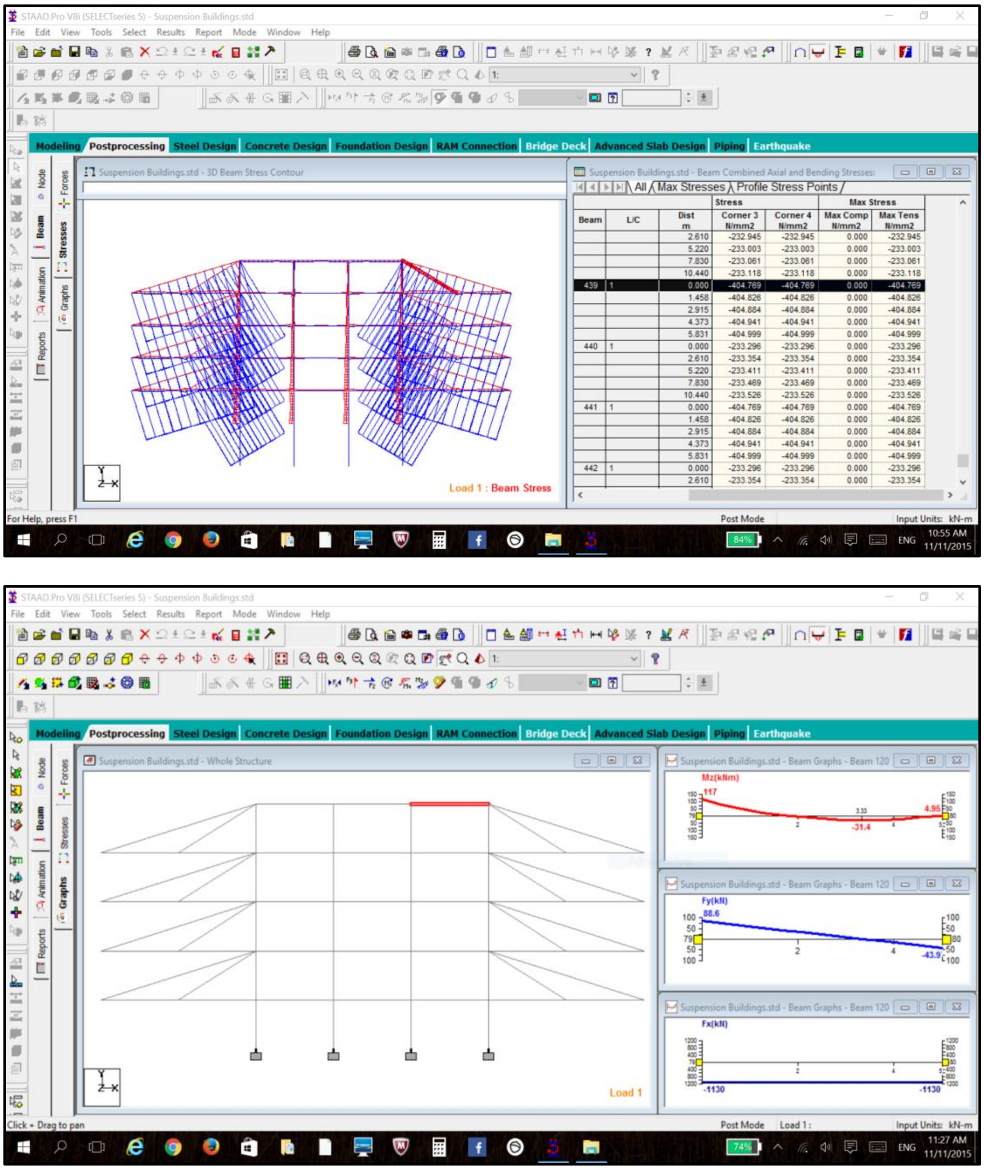


Fig. (9) Max.tensile stress of 405 mpa in cable with stresses in top beam

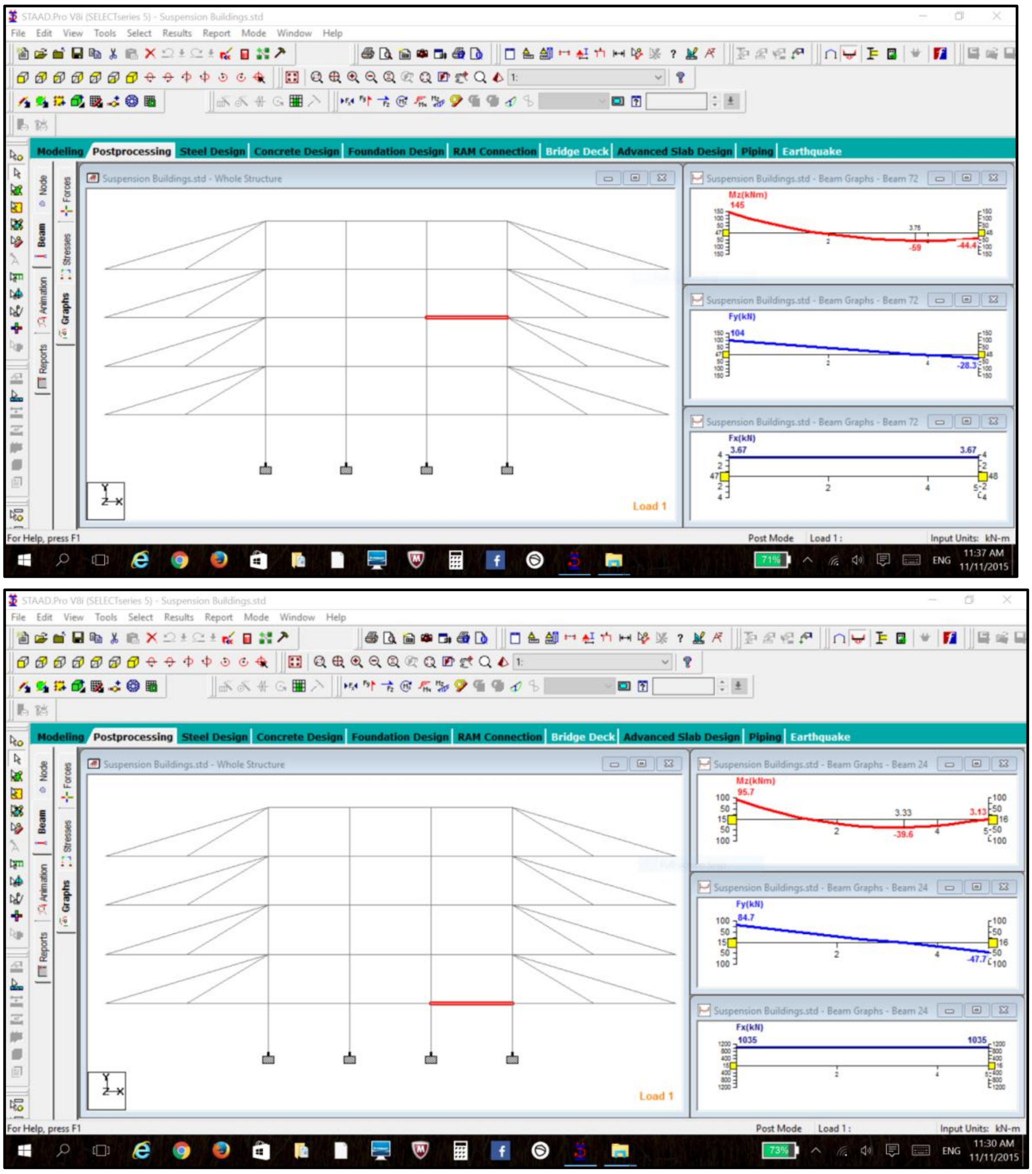
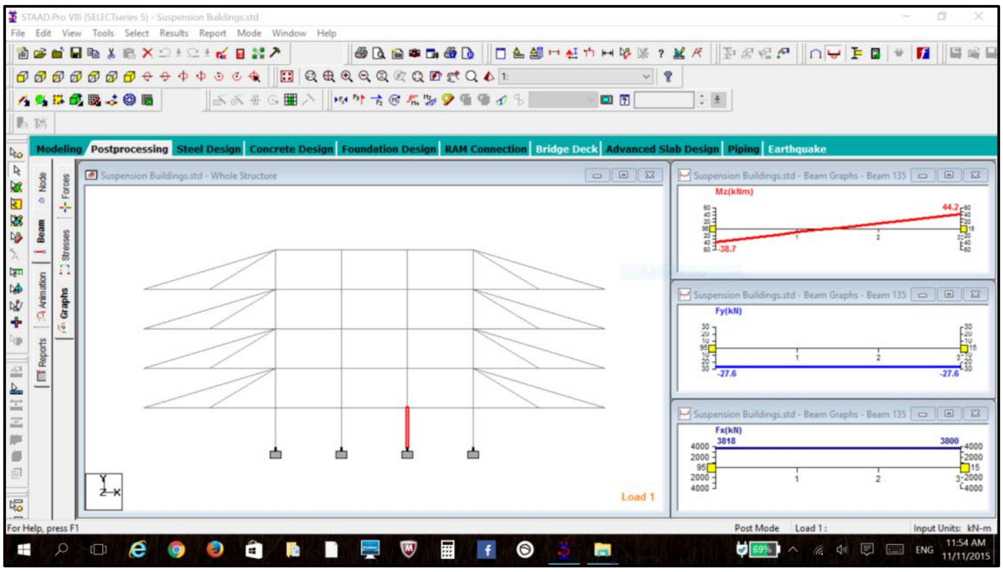


Fig. (10) Stresses in middle & lower beams



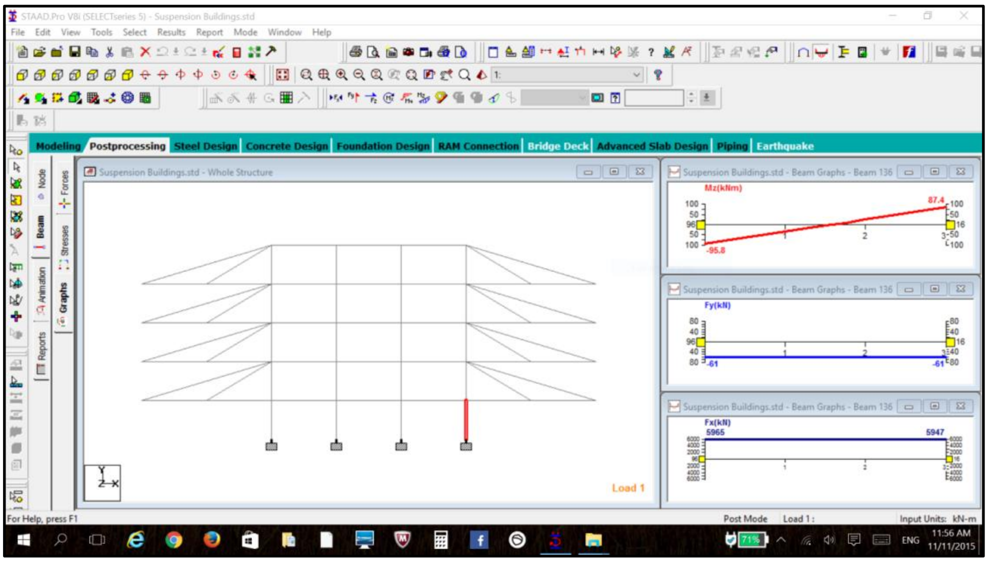


Fig. (11) Stresses in inner and outer bottom columns

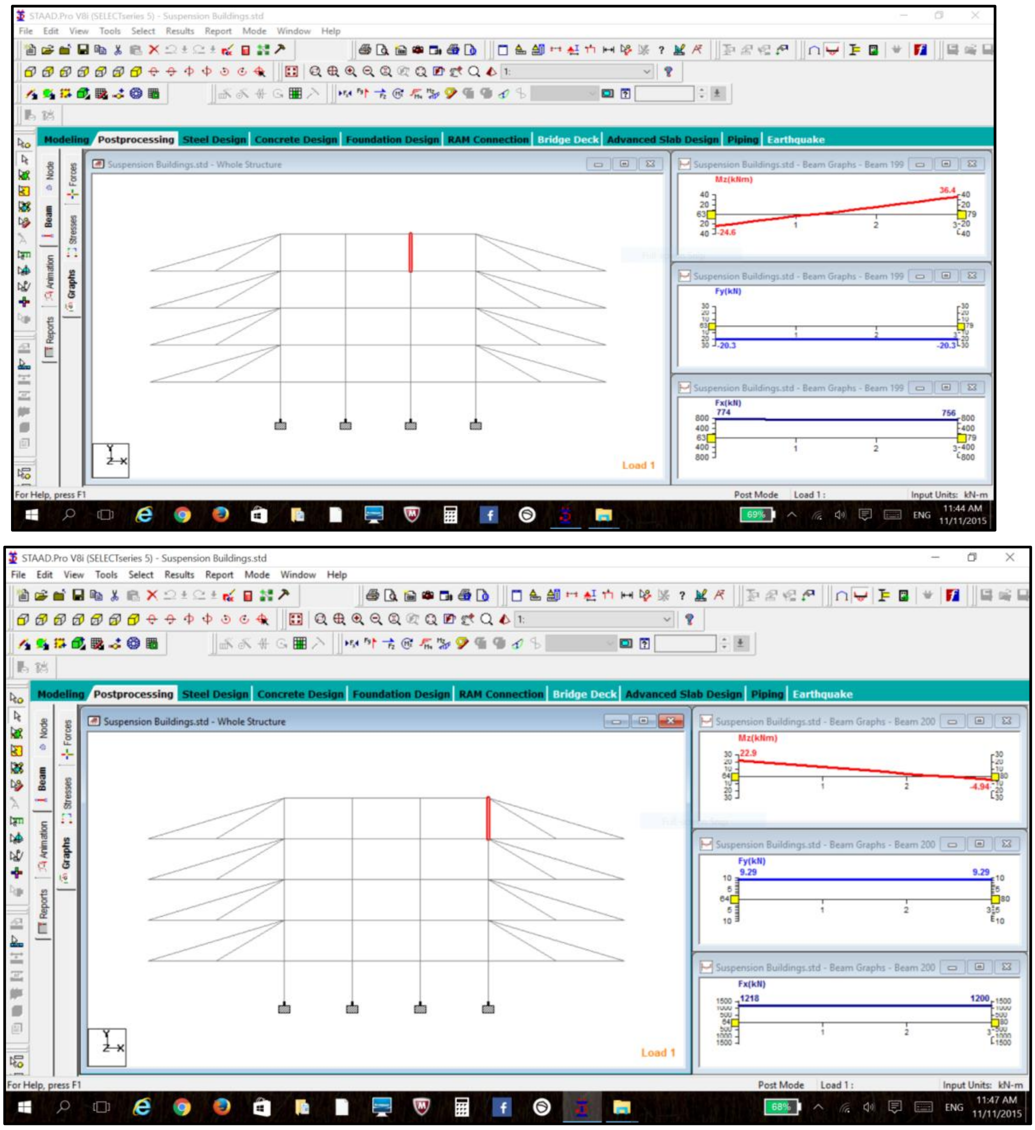


Fig. (12) Stresses in inner and outer top columns

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