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RESEARCH ARTICLE

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Investigation of temperature effects in RC-Steel composite industrial building model with FEM

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Abstract

Today, composite structure design has become very popular. The most important goal in composite structure design is to create the most efficient structural system under load by using materials that respond positively to different cross-section effects. Industrial type buildings, on the other hand, consist of very wide openings. In addition, industrial buildings are required to be designed to be constructed quickly and simply. For all these reasons, there has been an increase in the construction of industrial buildings in the form of reinforced concrete-steel composite structures. The effect of temperature in buildings is a parameter that should be considered both in design and use. It is a scientific fact that the expansion and contraction coefficients of reinforced concrete and steel are different. The temperature effect has an even more important place in composite construction systems where both are used together. For all these reasons, in this study, a reinforced concrete-steel composite industrial building model was created and its responses at -50°C and 50°C were examined. As a result of the findings obtained, the effect of temperature in reinforced concrete-steel composite industrial structures should definitely be taken into account both in the design and in the use and maintenance stages.

Keywords: Industrial buildings; temperature effect; composite structures; finite element method

1. Introduction

Industrial buildings; It is the factory where all kinds of products are made and the buildings and structures for processes such as processing, assembly, mixing, cleaning, washing, packaging, storage, distribution and repair. All kinds of factories, sawmills, laundries, textile production facilities, energy production facilities, food processing

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facilities, filling and unloading facilities, dry cleaning facilities, mineral processing facilities, refineries and similar places are included in this class. Simply, industrial buildings are factories or other large facilities used primarily to produce or store raw materials, goods or services for economic purposes. They are specially planned from top to bottom, taking into account the storage processes. They are generally divided into some main classes according to the design, construction process and needs. These classes are generally divided into warehouse and distribution, production, light manufacturing (textile, furniture and home electronics, etc.), refrigeration and cold storage, data hosting centers, biotechnology, some shopping centers. Due to its complex structures, the industrial building construction process should be applied much more meticulously than other building construction processes. The industrial building construction process includes planning, design, pre-construction, security, post-construction processes, respectively. In terms of planning and design, they often have an architecture with large openings. For this reason, it has been seen that composite construction systems have been chosen recently in order to meet these and other special needs. It is ensured that all stages of the production process, from the supply chain to the assembly operation, are optimized in order to achieve the highest quality and efficiency in the industry sector. Every decision is thought through to the smallest detail, every detail is planned, and ultimately the most accurate solutions are produced. The buildings where all these activities are carried out must be designed correctly in terms of architecture and engineering. While designing industrial facilities and structures, it is necessary to plan with an understanding that is suitable for all production processes and business plans that are considered and progressed according to the principle of efficiency. In this way, possible problems that may arise in the future are solved from the very beginning. In addition, in order to keep up with the competitive conditions, the project must be designed correctly at the planning stage. With the design reflecting your brand and corporate identity, analysis of land and climate conditions, correct air conditioning, energy efficient design, efficient and effective use of natural resources, selection of building materials, recyclable and re-functional project design, management of industrial and industrial wastes, sustainability, storage and logistics. All factors, such as relevant planning, should be taken into account. It is known that simple, useful and short construction time is the most basic principle in planning and design purposes. In the post-construction process, maintenance of industrial buildings is very important. The main reason for this necessity is the production disruption and the fact that it includes a large number of people. Otherwise, with the collapse of the building due to neglect, both great loss of life and great financial losses can be experienced [1-11]. Some examples of industrial buildings are given in Fig 1.

Fig. 1. Examples of industrial buildings.

Composite structures have emerged as a result of an approach that highlights the positive aspects of different types of materials against different effects. Composite building systems have become an indispensable carrier system for high-rise building applications in the world, as they effectively reduce the self-weight of the building compared to reinforced concrete buildings and provide good performance in creating the desired structure ductility against seismic loads. These are the buildings that are designed and constructed by using different structural elements such as reinforced concrete structural elements and steel construction elements and concrete-light concrete at the same time in the structural load-bearing system. They can be applied in different types of buildings according to the needs. In recent years, composite structure design has come to the fore in industrial buildings. Especially, reinforced concrete-steel composite structure designs are known to be one of the most common types of composite structures [12-19]. Also, the effects of fire in a concrete-steel composite structure were investigated very closely [20].

Industrial buildings are exposed to the effects of temperature depending on the purpose of use or from the weather conditions of the environment. The temperature effect is of great importance in the design phase or in the use phase. In industrial buildings designed as a composite building system, the temperature effect is much more important. Ultimately it is a scientific fact that the expansion and contraction coefficients of different materials are different. This is true for concrete and steel. For these reasons, in this study, the temperature effect of the industrial building type designed with a reinforced concrete-steel composite structure system was investigated. The deformations of the structural carrier system under the influence of temperature are very important in order to interpret the effect. Researchers [21-32] have investigated the effect of temperature and fire in reinforced concrete, steel, etc. building systems, which also contribute to this study, with various methods.

The aim of this study is to examine the effect of temperature on the carrier systems of composite industrial buildings made of reinforced concrete and steel. It is known that industrial buildings are exposed to temperature effects due to their intended use. This type of buildings are the types of buildings where there are productions as freezers or where high temperatures occur. It is foreseen that this situation is likely to affect the structural carrier system. It is also a proven fact that the effect of temperature has different expansion and contraction properties in different material types. For all these reasons, in this study, a reinforced concrete-steel composite industrial building model was created with a simple architecture for a more realistic representation of the data. The reaction of the system was observed by applying the temperature effect of -50 °C and +50 °C degrees to this model. The selected temperature degrees, on the other hand, have been taken as reference by paying attention to the temperature effects that are likely to be exposed, and the previous studies given as a reference in the introduction.

2. Material and method

The finite element method is the process of transforming functions in an infinite dimensional function space into functions in a finite dimensional function space and then into vectors that can be traced in vector space by numerical methods. Finite element analysis (FEA) allows detailed visualization of where structures are bent or twisted and shows the distribution of stresses and displacements. Finite element method (FEM) software offers a wide variety of simulation options to control the complexity of both modeling and analysis of a system. Similarly, the desired level of accuracy and associated computation time requirements can be managed simultaneously to cater to most engineering applications. FEM ensures that all designs are built, refined, and optimized before the design is produced [33-35]. In this study, the finite element method was used in the modeling and analysis parts. As the software, the internationally valid SAP2000 software, which is the finite element software, was used.

2.1. RC-Steel Composite Industrial Building Model

Column elements were chosen as reinforced concrete. The fact that column rigidity is very important for structures and that reinforced concrete is more resistant to temperature effects than steel was effective in this selection. Industrial buildings are known for using wide openings in their plans. For this reason, steel profiles come to the forefront with their favorable position in wide openings. In the model design, two openings of 7.5 meters in the X direction and 4 openings of 6 meters in the Y direction were selected. The height of the first floor is 4.5 meters, and a second floor of 3 meters has been designed considering that there will be offices, lounges, etc. on it. The columns are designed as 50x70 reinforced concrete rectangular section. Concrete class is determined as C30 according to Turkish standards (TS 500). The beams were chosen as W18X76 steel I profile (American Society for Testing and Materials - ASTM). The slabs are designed as shell-thin, 0.04 meters of steel. Care was taken to use symmetrical and dimensional elements in the design of the model. The reason for this is that the temperature effect is desired to be seen more clearly without being dependent on any other effect. The YZ and XZ plans of the RC-steel composite industrial building model are given in Fig 2. The 3D finite element model of the RC-steel composite industrial building model is given in Fig 3.

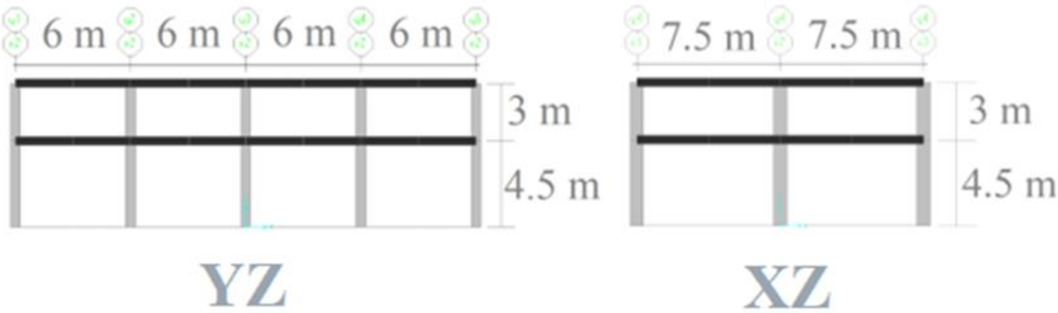

Fig. 2. The YZ, XZ plans and dimensions.

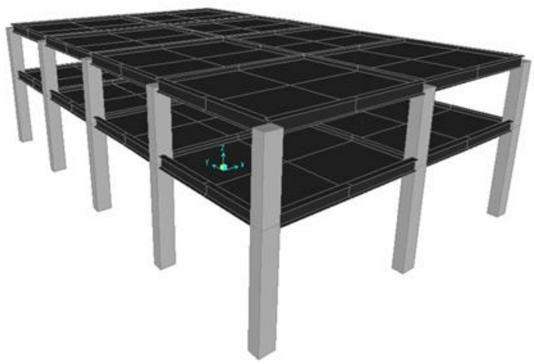

Fig. 3. The 3D finite element model of the RC-steel composite industrial building model.

3. Findings and discussion

The finite element model created should be analyzed for findings. The RC-steel composite industrial building model was first analyzed in the normal condition without the effect of temperature and the findings were obtained.

Afterwards, temperatures of 50°C and -50°C were applied to the whole system, respectively, and separate analyzes were made for each degree. It is aimed to reach a conclusion by comparing the obtained analysis findings (displacements) separately for each load-bearing element type (columns, beams and slabs).

The 3D deformation of the RC-steel composite industrial building model is given in Fig 4. as a result of the analysis performed only under the effect of dead loads without the effect of temperature.

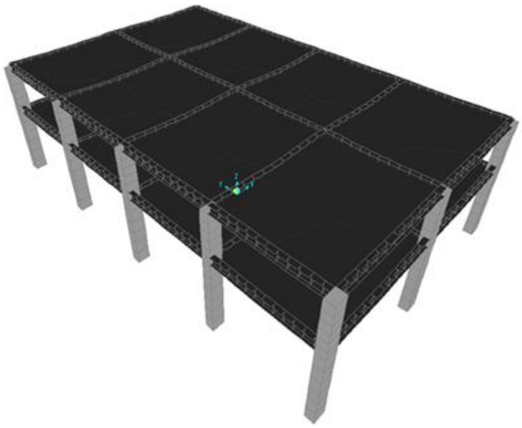

Fig. 4. The 3D deformation of the RC-steel composite industrial building model without the effect of temperature.

The 3D deformation of the RC-steel composite industrial building model is given in Fig 5. as a result of the analysis performed only under the effect of dead loads and with 50°C the effect of temperature.

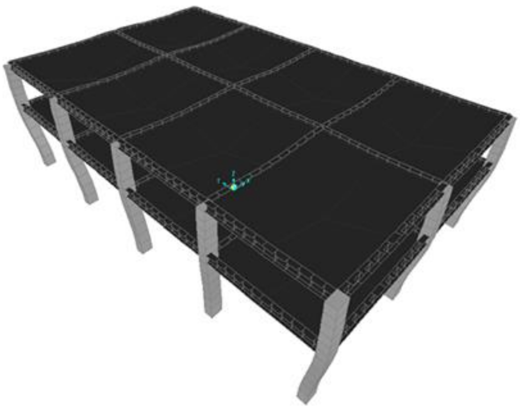

Fig. 5. The 3D deformation of the RC-steel composite industrial building model at 50°C.

The 3D deformation of the RC-steel composite industrial building model is given in Fig 6. as a result of the analysis performed only under the effect of dead loads and with -50°C the effect of temperature.

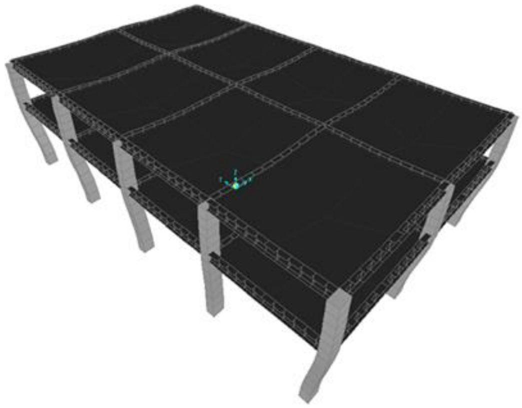

Fig. 6. The 3D deformation of the RC-steel composite industrial building model at -50°C.

When the 3-dimensional deformations are examined, the effects of expansion and contraction at 50°C and -50°C are clearly seen. However, since the building is a composite structure, it is necessary to reach a clearer result by examining the maximum displacements of the structural elements (columns, beams, slabs).

For the columns, displacements at normally, displacements at 50°C, displacements at -50°C and comparison of temperature effect are given in Table 1.

Table 1. Comparison of temperature effect on columns maximum displacement values.

Situation	U_{1max} (m)	U_{2max} (m)	U_{3max} (m)
Normally	0.000006522	0.000002526	-0.000253
At 50°C	-0.004403	-0.007038	0.003626
At -50°C	0.004414	0.007042	-0.003972
Normally and 50°C Absolute Value Difference (m)	0.004396478	0.007035474	0.003373
Normally and 50°C Absolute Value Difference (%)	67409.96627	278522.3278	1333.201581
Normally and -50°C Absolute Value Difference (m)	0.004407478	0.007039474	0.003719
Normally and -50°C Absolute Value Difference (%)	67578.62619	278680.6809	1469.960474
50°C and -50°C Absolute Value Difference (m)	1.1E-05	4E-06	0.000346
50°C and -50°C Absolute Value Difference (%)	0.249829662	0.056834328	9.542195256

The columns from which U_{1max}, U_{2max}, U_{3max} values are obtained at normally, 50°C and -50°C are given in Fig 7. comparatively. It is known that the absolute values of displacements are almost equal in unselected symmetrical columns due to the symmetrical design. These columns have only sign difference (negative or positive). The main reason for this situation is that the displacement directions are on the negative or positive axis.

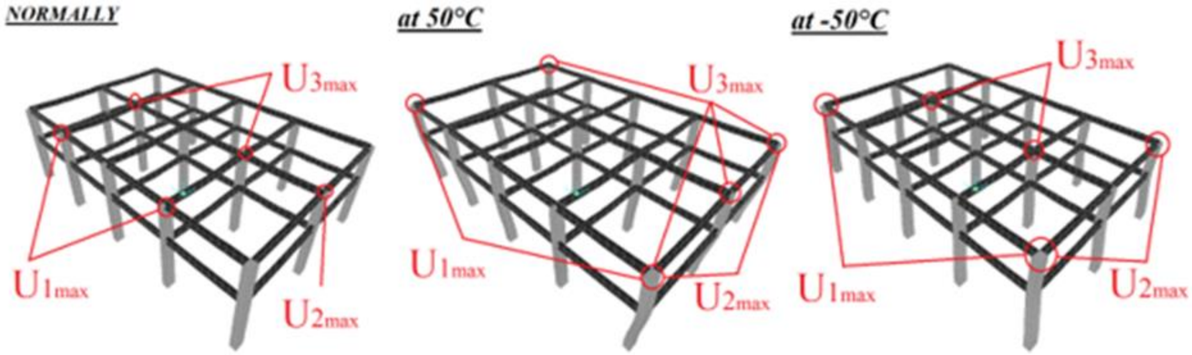

Fig. 7. Columns with maximum displacement (U_1, U_2, U_3).

For the beams, displacements at normally, displacements at 50°C, displacements at -50°C and comparison of temperature effect are given in Table 2.

Table 2. Comparison of temperature effect on beams maximum displacement values.

Situation	U_{1max} (m)	U_{2max} (m)	U_{3max} (m)
Normally	0.000002015	-0.00000105	-0.00189
At 50°C	-0.004391	-0.007029	0.003275
At -50°C	-0.004395	0.00703	-0.005406
Normally and 50°C Absolute Value Difference (m)	0.004388985	0.00702795	0.001385
Normally and 50°C Absolute Value Difference (%)	217815.6328	669328.5714	73.28042328
Normally and -50°C Absolute Value Difference (m)	0.004392985	0.00702895	0.003516
Normally and -50°C Absolute Value Difference (%)	218014.1439	669423.8095	186.031746
50°C and -50°C Absolute Value Difference (m)	4E-06	1E-06	0.002131
50°C and -50°C Absolute Value Difference (%)	0.091095422	0.014226775	65.06870229

The beams from which U_{1max}, U_{2max}, U_{3max} values are obtained at normally, 50°C and -50°C are given in Fig 8. comparatively. It is known that the absolute values of displacements are almost equal in unselected symmetrical beams due to the symmetrical design. These beams have only sign difference (negative or positive). The main reason for this situation is that the displacement directions are on the negative or positive axis.

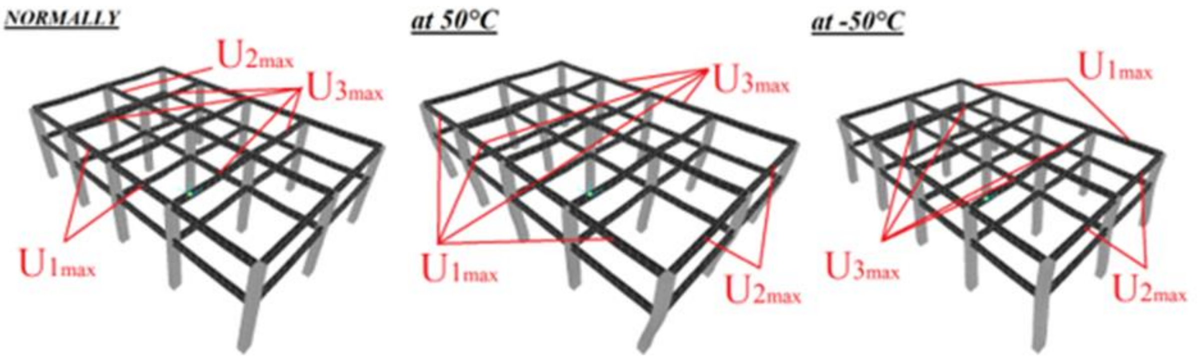

Fig. 8. Beams with maximum displacement (U_1, U_2, U_3).

For the slabs, displacements at normally, displacements at 50°C, displacements at -50°C and comparison of temperature effect are given in Table 3.

Table 3. Comparison of temperature effect on slabs maximum displacement values.

Situation	U_{1max} (m)	U_{2max} (m)	U_{3max} (m)
Normally	-0.000002379	0.000000594	-0.013039
At 50°C	-0.002198	-0.005276	-0.010209
At -50°C	0.002202	-0.005277	-0.016559
Normally and 50°C Absolute Value Difference (m)	0.002195621	0.005275406	-0.00283
Normally and 50°C Absolute Value Difference (%)	92291.76124	888115.4882	-21.70411841
Normally and -50°C Absolute Value Difference (m)	0.002199621	0.005276406	0.00352
Normally and -50°C Absolute Value Difference (%)	92459.89912	888283.8384	26.99593527
50°C and -50°C Absolute Value Difference (m)	4E-06	1E-06	0.00635
50°C and -50°C Absolute Value Difference (%)	-0.181983621	-0.018953753	-62.20001959

The slabs from which U_{1max}, U_{2max}, U_{3max} values are obtained at normally, 50°C and -50°C are given in Fig 9. comparatively. It is known that the absolute values of displacements are almost equal in unselected symmetrical slabs due to the symmetrical design. These slabs have only sign difference (negative or positive). The main reason for this situation is that the displacement directions are on the negative or positive axis.

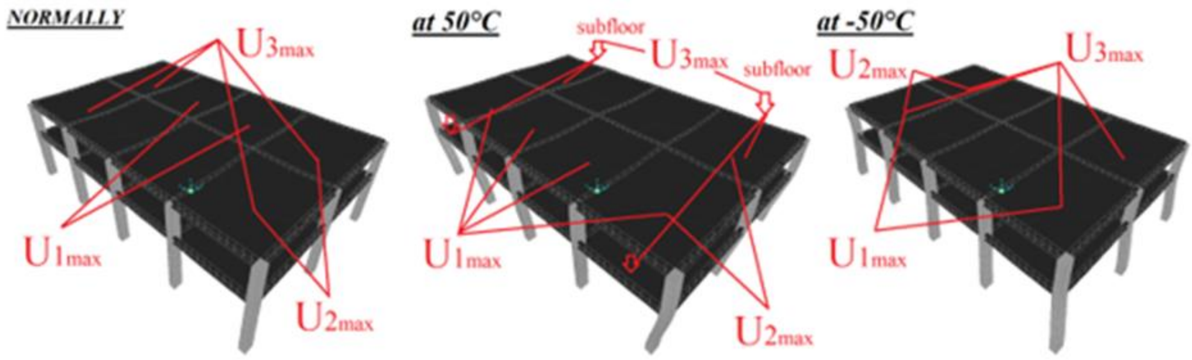

Fig. 9. Slabs with maximum displacement (U_1, U_2, U_3).

The maximum displacement values (U_{1max}, U_{2max}, U_{3max}) obtained were made into comparative graphs for columns, beams and slabs. The graph of maximum displacement for columns is given in figure 10, the graph of maximum displacement for beams in figure 11, and the graph of maximum displacement for slabs is given in figure 12. In the graphs, blue color represents U_{1max}, orange color U_{2max} and gray color U_{3max}.

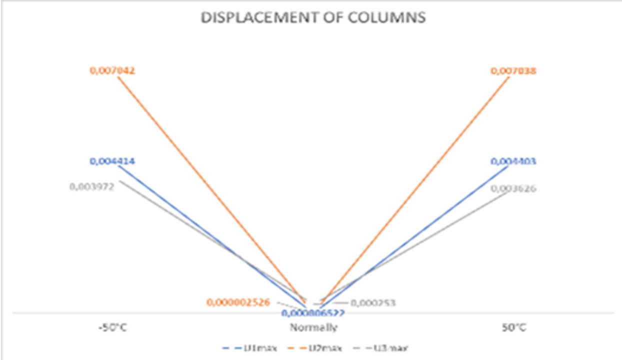

Fig. 10. Displacement of columns graph.

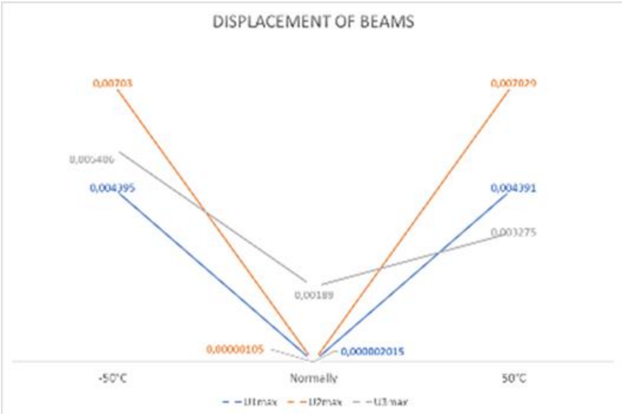

Fig. 11. Displacement of beams graph.

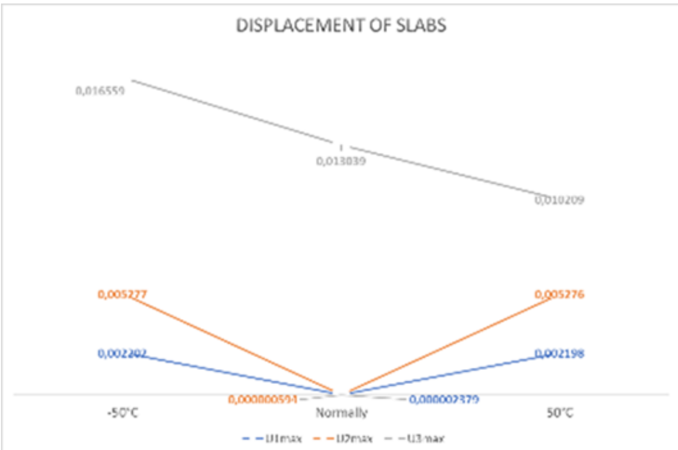

Fig. 12. Displacement of slabs graph.

4. Conclusions

When the 3-dimensional deformations of the reinforced concrete-steel industrial structure model are examined at 50°C and -50°C, the expansion and contraction conditions are clearly seen.

In the reinforced concrete columns of the model, the maximum displacement in the x direction under the effect of 50°C temperature was -0.004403 meters in the y direction -0.007038 meters and 0.003626 meters in the z direction. Under the temperature effect of -50°C, it was seen as 0.004414 meters in the x direction, 0.007042 meters in the y direction, and -0.003972 meters in the z direction. Initially, these displacement values are 0.000006522 meters in the x direction, 0.000002526 meters in the y direction, and -0.000253 meters in the z direction. In this case, reinforced concrete columns made very high horizontal displacements compared to the first case with the effect of temperature. From this, it can be concluded that the temperature effect has a very negative effect on the horizontal stiffness. In the vertical, it was noted that the column moves in the positive direction at 50°C. It is concluded that there are fluctuations in the columns with the expansion of the system. In addition, there is a very large increase of approximately 1333.20% when compared to the initial vertical maximum column displacement. Although it is relatively less than the horizontal increase, this situation draws attention. At -50°C, the vertical displacement is in the negative direction and is the same as the start. This is an indication of the shrinkage effect. Again, considering the initial vertical maximum column displacement, there is a huge increase of about 1470%. In this case, it can be said that the vertical rigidity is negatively affected. It has been observed that the negative temperature effect causes more displacements in the horizontal and vertical columns than the positive temperature effects. From this point of view, negative temperature values for the columns are more dangerous in this model. In addition, it was clearly seen that the columns most affected by the temperature effect were the corner columns. In the initial case, on the contrary, the columns with the maximum displacement are the columns positioned in the middle. In addition, although the columns are reinforced concrete, it has been observed that they are adversely affected by the temperature effects.

The maximum displacement in the x direction of the steel profile beams of the model under the effect of 50°C was -0.004391 meters in the y direction -0.007029 meters and 0.003275 meters in the z direction. Under the temperature effect of -50°C, it was seen as -0.004395 meters in the x direction, 0.00703 meters in the y direction, and -0.005406 meters in the z direction. Initially, these displacement values are 0.000002015 meters in the x direction, -0.00000105 meters in the y direction, -0.00189 meters in the z direction. In this case, the steel profile beams have made very high horizontal displacements compared to the first case with the effect of temperature. From this, it can be concluded that the temperature effect has a very negative effect on the horizontal stiffness. In the vertical, it was noted that there was a positive movement of the beam at 50°C. It was concluded that with the expansion of the system, there are fluctuations in the beams as well as in the columns. In addition, there is a large increase of approximately 73.28% when compared to the initial vertical maximum beam displacement. This increase is quite small compared to the columns. At -50°C, the vertical displacement is in the negative direction and in the same direction as the start. This is an indication of the shrinkage effect. Again, considering the initial vertical maximum beam displacement, there is a large increase of about 186.03%. In this case, it can be said that the vertical rigidity is negatively affected. It has been observed that the negative temperature effect of the beams in the horizontal and vertical directions, as in the columns, causes more displacements than the positive temperature effects. From this point of view, negative temperature values for beams in this model are more dangerous, especially in vertical displacements. In addition, it is clearly seen that the beams most affected by the temperature effect are the horizontal side beams and the vertical beams. This situation is almost similar in the initial state.

The maximum displacement in the x-direction was -0.002198 meters in the y-direction, -0.005276 meters in the y-direction, and -0.010209 meters in the z-direction, in the steel slabs of the model under the effect of 50°C temperature. Under the temperature effect of -50°C, it was seen as 0.002202 meters in the x direction, -0.005277 meters in the y direction, and -0.016559 meters in the z direction. Initially, these displacement values are -0.000002379 meters in the x-direction, 0.000000594 meters in the y-direction, and -0.013039 meters in the z-direction. In this case, the steel slabs have made very high displacements in the horizontal compared to the first situation, as in the columns and beams, with the effect of temperature. From this, it can be concluded that the temperature effect has a very negative effect on the horizontal stiffness. On the vertical, it was noted that the displacement value of the slab decreased at 50°C. It has been concluded that the horizontal stresses that occur with the expansion of the system affect this situation. In addition, there is a decrease of approximately -21.70% according to the initial vertical maximum slab displacement. This increase is quite small compared to columns and beams. At 50°C and -50°C, the vertical displacement is in the negative direction and in the same direction as the start. Considering the initial vertical maximum beam displacement at -50°C, there is an increase of approximately 27%. In this case, it can be said that the vertical rigidity is negatively affected. However, this effect is very small compared to columns and beams. In this case, it can be said that the section thickness, being a plate element, and the stresses coming from the columns and beams have an effect. It has been observed that the negative temperature effect of the slabs causes more displacements than the positive temperature effects, as in the columns and beams. In the vertical, there is a situation that seems positive even at the beginning at the positive temperature value. From this point of view, negative temperature values for slabs in this model are dangerous, especially in horizontal displacements. In addition, the slabs that are most affected by the effect of temperature are the slabs with low continuity on the side frames, the same as the normal situation in the horizontal and vertical.

It has been understood that the greatest displacement differences are observed in the U_2 direction, due to the fact that the stiffness in the U_2 direction is the lowest in addition to the temperature effect.

In the light of all this information, it has been observed that there are great changes in the horizontal displacements of the 50°C and -50°C RC-Steel composite industrial building model under the influence of temperature and are adversely affected. Significant increases were observed in vertical displacements, although not as much as in horizontal displacements. It is predicted that in this degree of stiffness losses, major damages may occur in the building under combined loads. It was concluded that the temperature effect of 50°C and -50°C adversely affected the rigidity and stability of the system. In addition, it is a fact that the loss of life and property will be high in case of damage to industrial buildings. It is known that there is a possibility of reaching temperatures of 50°C and -50°C for industrial buildings. For this reason, attention should be paid to the effects of temperature in the design, use and maintenance of industrial buildings. Temperature insulation of the industrial buildings' carrier elements must be done.

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References

[1] M. Stratton, "Industrial Buildings," in *Conservation and Regeneration,* 1st ed. London, England: Taylor & Francis, 2000.

[2] J. T. San-José, R. Losada, J. Cuadrado, and I. Garrucho, "Approach to the quantification of the sustainable value in industrial buildings," *Building and Environment*, vol. 42, pp. 3916-3923, 2007, doi: 10.1016/j.proeng.2013.04.118.

[3] M. A. Habib, M. Hasanuzzaman, M. Hasanuzzaman, A. Salman, R. and Mehadi, "Energy consumption, energy saving and emission reduction of a garment industrial building in Bangladesh," *Energy*, vol. 112, pp. 91-100, 2016, doi: 10.1016/j.energy.2016.06.062.

[4] D. Katunsky, A. Korjenic, J. Katunska, M. Lopusniak, S. Korjenic and S. Doroudiani, "Analysis of thermal energy demand and saving in industrial buildings: A case study in Slovakia," *Building and Environment*, vol. 67, pp. 138-146, 2013, doi: 10.1016/j.buildenv.2013.05.014.

[5] X. Dou, D. Xie, Z. Wang, P. Xiao, and H. Wang, "Improved buoyancy-driver hybrid ventilation system for multiple-heat-source industrial buildings," *Case Studies in Thermal Engineering*, vol. 26, no. 101059, 2021, doi: 10.1016/j.csite.2021.101059.

[6] G. Gourlis, and I. Kovacic, "Building Information Modelling for analysis of energy efficient industrial buildings – A case study," *Renewable and Sustainable Energy Reviews*, vol. 68, pp. 953-963, 2017, doi: 10.1016/j.rser.2016.02.009.

[7] J. Reisinger, M. A. Zahlbruckner, I. Kovacic, P. Kán, and X. Wang-Sukalia, "Framework proposal for automated generation of production layout scenarios: A parametric design technique to connect production planning and structural industrial building design," in *Proc. EG-ICE 2021 Workshop on Intelligent Computing in Engineering in Berlin*, *Universitätsverlag der TU Berlin,* 2021, pp. 22-33, doi: 10.14279/depositonce-12021.

[8] J. Reisinger, M. A. Zahlbruckner, I. Kovacic, P. Kán, X. Wang-Sukalia, and H. Kaufmann, "Integrated multi-objective evolutionary optimization of production layout scenarios for parametric structural design of flexible industrial buildings," *Journal of Building Engineering*, vol. 46, pp. no. 103766, 2022, doi: 10.1016/j.jobe.2021.103766.

[9] B. Glumac, and N. Islam, "Housing preferences for adaptive re-use of office and industrial buildings: Demand side," *Sustainable cities and society*, vol. 62 no. 102379, 2020, doi: 10.1016/j.scs.2020.102379.

[10] R. A. Danhaive, and C. T. Mueller, "Combining parametric modeling and interactive optimization for high-performance and creative structural design," in *Proceedings of IASS Annual Symposia, International Association for Shell and Spatial Structures (IASS)*, 2015, pp. 1-11, doi: 10.1016/j.autcon.2015.02.011

[11] D. Chinese, G. Nardin, and O. Saro, "Multi-criteria analysis for the selection of space heating systems in an industrial building," *Energy*, vol. 36, pp. 556-565, 2011, doi: 10.1016/j.energy.2010.10.005.

[12] A. Tedia, and S. Maru, "Cost, Analysis and Design of Steel-Concrete Composite Structure Rcc Structure," *Journal of Mechanical and Civil Engineering*, vol. 11, pp. 54-59, 2014, doi: 10.9790/1684-11125459.

[13] Q. Q. Liang, *Analysis and Design of Steel and Composite Structures*. 1st ed. London, England: CRC Press, 2014.

[14] Y. C. Wang, "Steel and Composite Structures," in *Behaviour and Design for Fire Safety*, 1st ed. London, England: CRC Press, 2002.

[15] J. Nie, J. Wang, S. Gou, Y. Zhu, and J. Fan, "Technological development and engineering applications of novel steel-concrete composite structures," *Frontiers of Structural and Civil Engineering*, vol. 13, pp. 1-4, 2019, doi: 10.1007/s11709-019-0514-x.

[16] A. Kasımzade, and S. Tuhta, "Analytical Numerical and Experimental Examination of Reinforced Composites Beams Covered with Carbon Fiber Reinforced Plastic," *Journal of Theoretical and Applied Mechanics*, vol. 42, pp. 55-70, 2012, doi: 10.2478/v10254-012-0004-1.

[17] S. Tuhta, "GFRP retrofitting effect on the dynamic characteristics of model steel structure," *Steel and Composite Structures*, vol. 28, 223–231, 2018, doi: 10.12989/scs.2018.28.2.223.

[18] S. Tuhta, "Analytical and Operational Modal Analysis Applications in Composite Structures," in *Investigation of Wind Pressure Effect on Modal Parameters of GFRP Water Tank with OMA*, Ankara, Turkey: Nobel Academic Publishing, 2022.

[19] S. Tuhta, "Analytical and Operational Modal Analysis Applications in Composite Structures," in *Determination of Wind Speed Effect on Dynamic Parameters of Full-Scale Lighting Pole by OMA*, Ankara, Turkey: Nobel Academic Publishing, 2022.

[20] Y.C. Wang, "Performance of steel–concrete composite structures in fire," *Prog. Struct. Engng Mater*, vol. 7 pp. 86-102, 2005, doi: 10.1002/pse.197.

[21] Y. Anderberg, "Modeling steel behavior," *Fire Saf. J*, vol. 13 pp. 17–26, 1988, 10.1061/(ASCE)MT.1943-5533.000004.

[22] A. H. Buchanan, *Structural design for fire safety*. NY, USA: Wiley, 2001.

[23] G.-Q. Li, and S. X. Guo, "Experiment on restrained steel beams subjected to heating and cooling," *J. Constr. Steel Res*, vol. 64, pp. 268–274, 2008, doi: 10.1007/s12205-017-0403-6.

[24] V. Kodur, M. Dwaikat, and R. Fike, "High-Temperature Properties of Steel for Fire Resistance Modeling of Structures," *Journal of Materials in Civil Engineering*, vol. 22, pp. 423-434, 2010, doi: 10.1061/(ASCE)MT.1943-5533.0000041.

[25] W.Y. Wang, B. Liu, and V. Kodur, "Effect of Temperature on Strength and Elastic Modulus of High-Strength Steel," *Journal of Materials in Civil Engineering*, vol. 25, 174-182, 2013, doi: 10.1061/(ASCE)MT.1943-5533.0000600.

[26] V. Kovalchuk, Y. Hnativ, J. Luchko, and M. Sysyn, "Study of the temperature field and the thermo-elastic state of the multilayer soil-steel structure," *Roads and Bridges - Drogi I Mosty*, vol. 19, pp. 65-78, 2020, doi: 10.7409/rabdim.020.004.

[27] E. Ünlüoğlu, İ. Topçu, and B. "Yalaman, Yüksek Sıcaklıkta Kalmış Yapılarda Pas Payının Betonarme Çelik Donatı Özeliklerine Etkisi," *Teknik Dergi*, vol. 18, pp. 4145-4155, 2007. [Online]. Available: https://dergipark.org.tr/tr/download/article-file/136674

[28] K. Arslan, D. Çelik, Y. Öztürk, and M. E. Efe, "Betonarme Soğutma Kulesi Tipi Yapıların Rüzgâr ve Sıcaklık Yükleri Etkisi Altındaki Davranışı," *Journal of the Institute of Science and Technology*, vol. 11, pp. 1218-1229, 2020, doi: 10.21597/jist.769510.

[29] İ. Oruç, "Rüzgâr, Sıcaklık ve Deprem Etkisi Altındaki Yüksek Yapılarda Taşıyıcı Sistemlerin Tasarımı ve Analizi," Yüksek Lisans Tezi, Konya Teknik Üniversitesi Lisansüstü Eğitim Enstitüsü, Konya, 2021.

[30] N. Mahsanlar, "Yüksek sıcaklık etkisinde beton davranışı," Yüksek Lisans Tezi, Yıldız Teknik Üniversitesi Fen Bilimleri Enstitüsü, İstanbul, 2007.

[31] Y. Z. Yüksel, "Sıcaklık etkisi altındaki tabakalı kompozit plakların statik ve titreşim davranışlarının incelenmesi," Yüksek Lisans Tezi, Bursa Teknik Üniversitesi Fen Bilimleri Enstitüsü, Bursa, 2018.

[32] S. Elhıdır, S. Tuhta, and F. Günday, "Analysis of Reinforced Concrete Chimneys under the Effect of Temperature Change with Finite Element Method," *JournalNX*, vol. 8, pp. 14–19, 2022, doi: 10.17605/OSF.IO/74G5Z.

[33] A. A. Kasımzade, *Finite Element Method Fundamentals and Applications in Structural Mechanics*. Ankara, Turkey: Nobel Academic Publishing, 2018.

[34] A. A. Kasımzade, *Structural Design and Analysis in The Light of Current Regulations with SAP2000 on The Basis of FEM*. Ankara, Turkey: Nobel Academic Publishing, 2022.

[35] S. Tuhta, "Investigation of Steel Slit Panel Effect on Modal Parameters of Reinforced Concrete Structure by Finite Element Method," *International Journal of Innovations in Engineering Research and Technology*, vol. 8, pp. 104-112, 2021, doi: 10.17605/OSF.IO/E26D8.