Turkish Journal of Science & Technology
18(2), 415-424, 2023

Research Paper
https://doi.org/10.55525/tjst.1256534

The Effect of Using Molybdenum Profile in Columns of Steel Building Models on The Modal Parameters

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(Geliş/Received: 25/02/2023; Kabul/Accepted: 30/08/2023)

Abstract: From past to present, building designs and materials used are developing. Especially against the destructive effects of ground movements and free vibrations on structures, many structural system designs and composite structure designs have been developed. The purpose of the composite structure design is to choose different types of materials according to the structural load-bearing system stress, in short, to choose the most advantageous material type according to the cross-sectional stresses or to eliminate the negative aspects of one material with the positive aspects of another material. It is a known fact that the dynamic performance of steel structure carrier systems is high under the influence of ground movements and free vibrations. However, in cases where the section geometry cannot be changed due to architectural concerns due to architectural design difficulties, there are cases where the rigidity of the structure is not sufficient. In such cases, profiles made of different materials other than steel can be used in order to increase the rigidity of the structure, especially in the columns, which are a very important component of the structural load-bearing elements. Therefore, in this study, the effect of using molybdenum profile instead of steel profile on modal parameters in model steel structure columns was investigated. In the light of the information obtained, a decrease of approximately 23.72 percent was observed in the period value in the 1st free vibration mode of the steel-molybdenum structure model. Thus, it is understood that the rigidity of the model steel structure system increases. In cases where it is not possible to change the architectural design in steel structures, it is recommended to use column profiles as molybdenum profiles instead of steel profiles in order to provide the necessary rigidity and increase rigidity.

Key words: Molybdenum profile columns, steel structures, modal parameters, finite element method

Çelik Bina Modellerinin Kolonlarında Molibden Profil Kullanımının Modal Parametrelere Etkisi

Öz: Geçmişten günümüze yapı taşıyıcı sistem tasarımları ve kullanılan malzemeler gelişmektedir. Özellikle yer hareketleri ve serbest titreşimlerin yapılar üzerindeki yıkıcı etkisine karşı birçok yapı taşıyıcı sistem tasarımları ve kompozit yapı tasarımı geliştirilmiştir. Kompozit yapı tasarımındaki amaç farklı türde malzemelerin yapı taşıyıcı sistem zorlanması durumuna göre tercih edilmesi kısacası kesit zorlanmalarına göre en avantajlı malzeme türünün seçilmesi veya bir malzemenin olumsuz yönlerinin başka bir malzemenin olumlu yönleri ile giderilmesi işlemidir. Çelik yapı taşıyıcı sistemlerinin yer hareketleri ve serbest titreşimlerin etkisinde dinamik performansının yüksek olduğu bilinen bir gerçektir. Fakat mimari tasarım zorluklarına bağlı olarak mimari kaygılar nedeniyle kesit geometrisinde değişiklik yapılamaması durumlarında yapı rijitliğinin yeterli olmadığı durumlar görülmektedir. Bu gibi durumlarda özellikle yapı taşıyıcı elemanlarının çok önemli bir birleşeni olan kolonlarda yapı rijitliğini artırmak amacıyla çelik dışında farklı malzemeden üretilmiş profiller kullanılabilir. Bu nedenle bu çalışmada model çelik yapı kolonlarında çelik profil yerine molibden profil kullanımının modal parametrelere etkisi araştırılmıştır. Elde edilen bilgiler ışığında oluşturulan çelik-molibden yapı modelinin 1. serbest titreşim modunda periyot değerinde yaklaşık yüzde 23,72 oranında bir azalma gözlemlenmiştir. Böylece model çelik yapı sisteminin rijitliğinin arttığı anlaşılmaktadır. Çelik yapılarda mimari tasarımın değiştirilmesinin mümkün olmadığı durumlarda gerekli rijitliğin sağlanması ve rijitliğin artırılması amacıyla kolon profilleri çelik profil yerine molibden profil olarak kullanılması önerilmektedir.

Anahtar kelimeler: Molibden profil kolonlar, çelik yapılar, modal parametreler, sonlu elemanlar metodu

1. Introduction

In recent years, in the world and our country, the determination of the effect of vibrations on structures and structural behavior has become very important. [1]. Especially, the negative effects of environmental vibrations on structures draw attention. It is known that there is resonance in structures in another important issue. The “resonance” event that occurs in buildings is when the ground dominant period (hence its frequency) and the natural period of the building (hence its frequency) are the same, the addition of two forces in the same direction that cause the building to oscillate, and as a result, the oscillation (amplitude) of the building, hence the acceleration (therefore the acting force) is an increase. As a result of resonance, structures are exposed to great forces and thus

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to great damage. [2]. It is a known fact that environmental vibrations can cause structures to resonance. Therefore, free vibration analysis is very important. [3-7]. Building structures have a natural frequency and result in a harmonious movement. Smooth ripple motion occurs in a certain flow pattern along the height and length of the building. Seismic frequencies similar to the natural frequency of the foundation ground and the structure cause the greatest movement or shaking in the structure. Frequencies similar to the natural frequency of the structure increase motion, while frequencies that are dissimilar dampen motion. The natural frequency of low-rise buildings is generally expected to be higher than that of high-rise buildings. Low structures are prone to damage from high-frequency body waves, whereas tall structures are generally damaged by low-frequency surface waves. High-frequency waves (body waves) carry energy farther than low-frequency waves (surface waves). As a result, low structures are more prone to damage if they are located near the epicenter, while tall structures can be damaged even when they are located quite far from the epicenter. The Structure Period is equal to 1/natural frequency. Therefore, it is the opposite for the period. Vibration does not only occur as a result of external effects such as wind and earthquake. Structures constantly vibrate within themselves. The period of each structure changes according to the characteristics of the carrier system. The two most important factors that determine the period are the mass of the structure and the rigidity of the structure. Accordingly, the force on the structure depends on the mass of the structure and the acceleration of the structure. The acceleration value can be found depending on the period thanks to the spectrum graphs. The stiffness of the system can be interpreted by looking at the period values. The decrease in the period of the structure is related to the increase in the stiffness. In this case, it is expected that the displacements will decrease in a structure with a decreasing period. [8-14].

The aim of this study is that sometimes the desired rigidity cannot be achieved in steel structures. Section changes may not be possible due to architectural reasons. For such cases, the stiffness of the structure can be changed by changing the material in the structural system elements. For all these reasons, it is aimed to observe the effects of this change on the structural modal parameters and structural rigidity by changing the steel columns, which have critical importance in the structural system elements, and using molybdenum columns.

2. Materials and Methods

Molybdenum is an alloying element that increases hardenability, toughness, wear resistance, corrosion resistance, strength at high temperatures and creep resistance in cast irons, steels, heat resistant alloys and corrosion resistant alloys. It is frequently used in pure form or as a molybdenum-based alloy in parts used at high temperatures, abrasive and corrosive conditions. [15]. Molybdenum is a refractory metal used mainly as an alloying element in cast irons, steels and superalloys to improve some mechanical properties. In particular, molybdenum added to steels as an alloying element increases the tensile strength and yield limit of steels, and reduces the % elongation and section contraction. It also increases the hardenability, toughness, wear and corrosion resistance of steels. These properties that molybdenum gives to alloys; It is of great importance for materials used in high voltage, wide temperature ranges and extremely corrosive environment conditions. [16]. Molybdenum materials are used in many special areas from the nuclear industry to the chemical industry, from the defense industry to the aviation industry. Molybdenum has an excellent resistance to heat. Therefore, it has a special place in the steel and iron industry. It is especially known for giving hardness to steels. Like other refractory metals, molybdenum has a high density and melting point, and is resistant to heat and wear. At 2,623 °C (4,753 °F), molybdenum has one of the highest melting points of all metal elements, while its coefficient of thermal expansion is one of the lowest of any engineering material. Molybdenum also has a low toxicity. The modulus of elasticity of molybdenum has a higher value than metals such as magnesium, aluminum, titanium, cast iron and steel. Molybdenum is a transition metal with atomic number 42, atomic weight 95.95 g/mol, density 10.28 g/cm3 and in the 6B group of the periodic table. Its modulus of elasticity is 325 GPa, and the poisson's ratio is 0.31. Also yield strength is 565 MPa, tensile strength is 655 MPa, shear modulus is 126 GPa, bulk modulus is 230 GPa. [17-22].

Finite element method was used method in this study. The SAP2000 package program was used in the modeling and analysis of the steel structure and the newly created structure consisting of molybdenum columns. It is known that the finite element method is widely used in academic studies. With the finite element method, [23-28] studies were used in the modeling and analysis stages. In order to comparatively investigate the effect of molybdenum profile usage on modal parameters, a steel structure model consisting of steel columns and a steel-molybdenum structure model consisting of molybdenum columns were created. In this study, ANSI/AISC 360-16 regulation was used. Modulus of elasticity is 325 GPa, and the poisson's ratio is 0.31, yield strength is 565 MPa, tensile strength is 655 MPa, shear modulus is 126 GPa, bulk modulus is 230 GPa parameters are used for molybdenum in The SAP2000 package program. The necessary parameters for the steel material were taken according to ASTM A992.

2.1. Steel Structure Model Using Steel Columns

The steel structure model is modeled with 4 spans in X and Y directions. Each span is taken as 4.5 meters. The steel structure model has 8 floors, with a floor height of 3.15 meters. Beams are W30X108 profile, columns are W36X135 profile, slab thickness is 0.02 meters. The total height of the building is 25.20 meters, and the width of the building in both directions is 18 meters. The model is designed symmetrically and simply. The purpose of this is to include fewer variables in the comparison phase. The dimensions of the steel structure model are given in figure 1 and the 3-dimensional view of the steel structure model is given in figure 2.

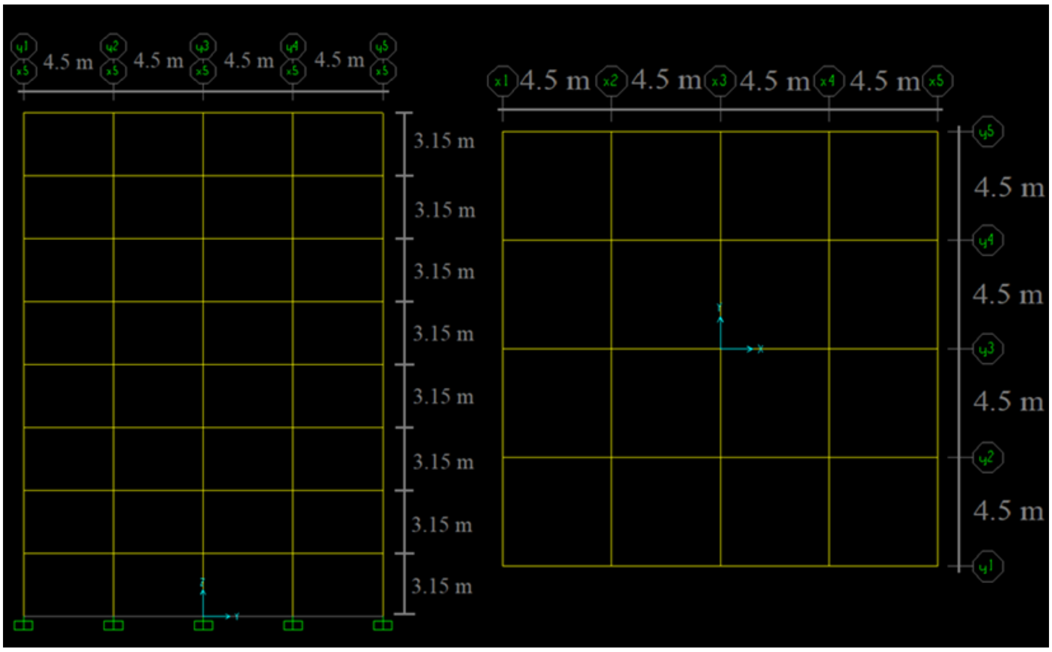

Figure 1. The dimensions of the steel structure model

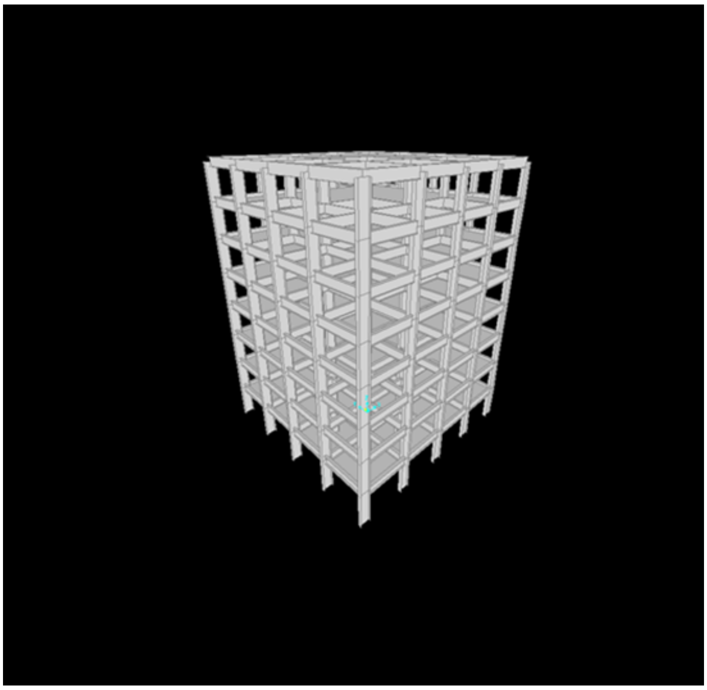

Figure 2. 3D view of the steel structure model with steel columns

2.2. Steel Structure Model Using Molybdenum Columns

In this model, the dimensions of the steel structure model, including the profiles, were fixed, and only the columns of the steel structure model were changed to molybdenum profiles (W30X108, W36X135) and a new model was created. Thus, it is aimed to make the analysis results more reliable and to determine the effect of the use of molybdenum profile on the modal parameters more accurately. The 3D shape of the newly created steel structure model is given in figure 3.

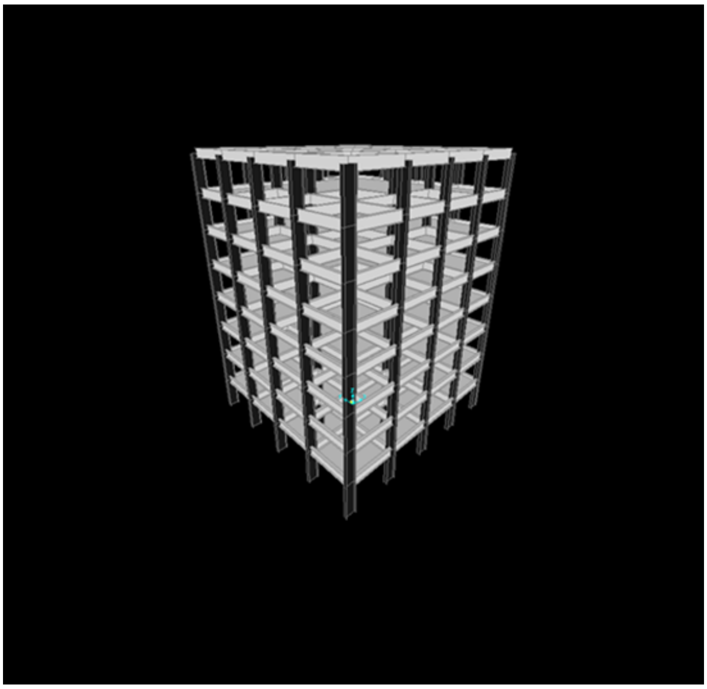

Figure 3. 3D view of the steel structure model with molybdenum columns

3. Findings and Discussion

Both models were analyzed by finite element method, respectively. Modal parameters were obtained with the help of SAP2000 package program. Obtained modal parameters (Mode shapes and period) are presented under separate headings and finally the results are meticulously compared. For comparison, the first 5 mode shapes and period values of each model were taken into account.

3.1. Analysis of Steel Structure Model Using Steel Columns

The mode shapes of the first 5 modes are given together with the period values in figures 4,5,6,7,8 respectively.

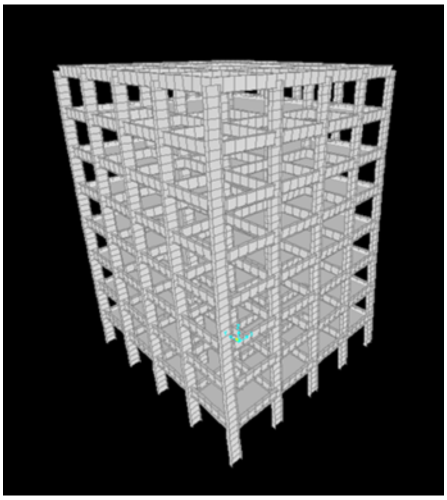

Figure 4. 1. Mode (period value = 0.862881 s)

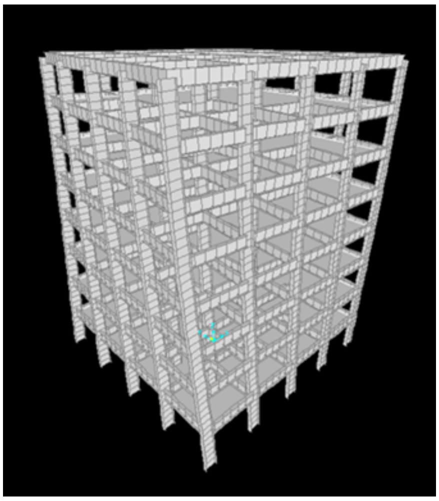

Figure 5. 2. Mode (period value = 0.514943 s)

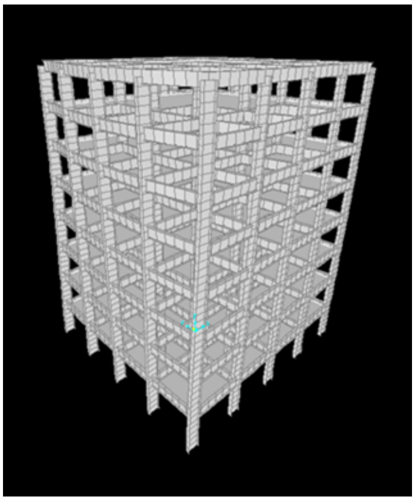

Figure 6. 3. Mode (period value = 0.355794 s)

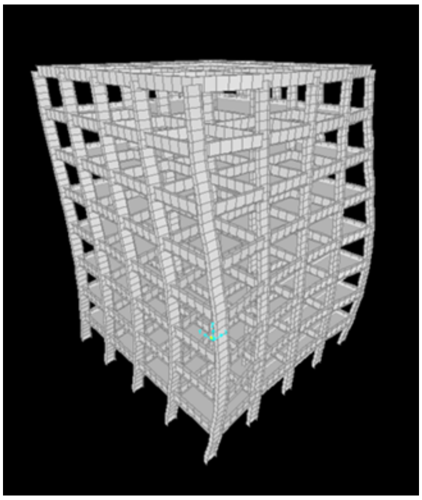

Figure 7. 4. Mode (period value = 0.324945 s)

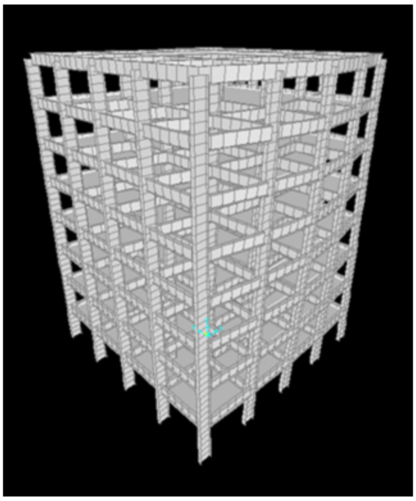

Figure 8. 5. Mode (period value = 0.276291 s)

3.2. Analysis of Steel Structure Model Using Molybdenum Columns

The mode shapes of the first 5 modes are given together with the period values in figures 9,10,11,12, and 13 respectively.

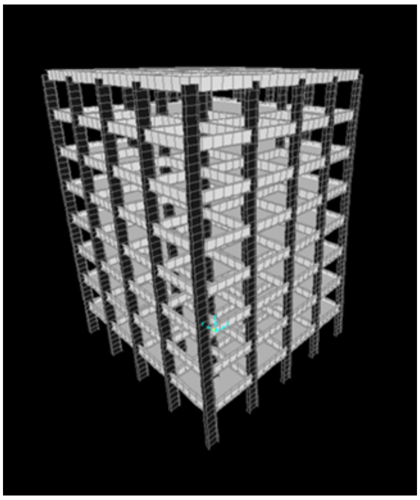

Figure 9. 1. Mode (period value = 0.658191 s)

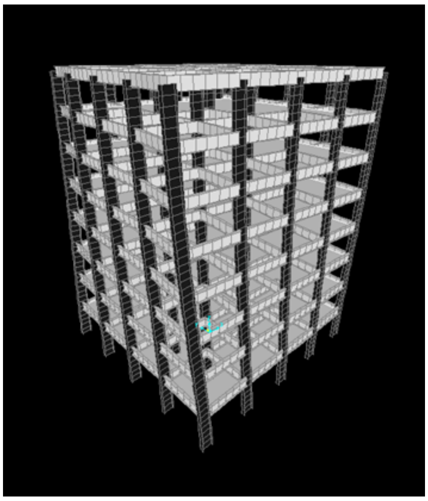

Figure 10. 2. Mode (period value = 0.442845 s)

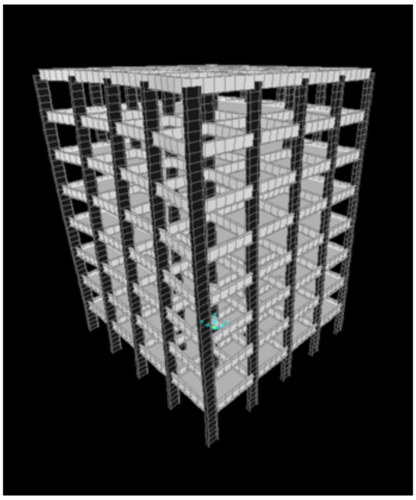

Figure 11. 3. Mode (period value = 0.318558 s)

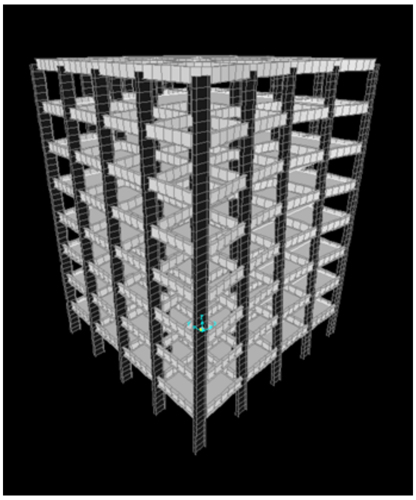

Figure 12. 4. Mode (period value = 0.26628 s)

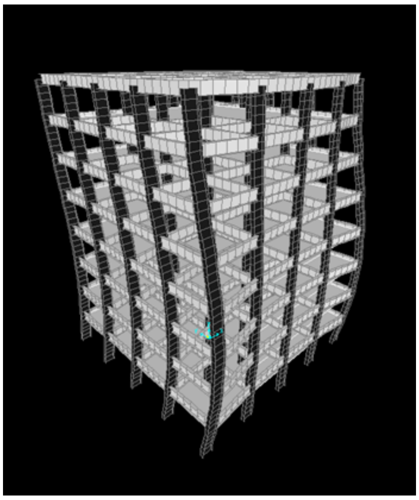

Figure 13. 5. Mode (period value = 0.251915 s)

3.3. Comparison of Analysis Results

The modal analysis results of both models are compared in tables. In Table 1, period values and comparisons of both models are given. Mode shapes are compared in Table 2.

Table 1. Comparison of period values each mode

	1. Mode	2. Mode	3. Mode	4. Mode	5. Mode
Steel Column Model	0.862881	0.514943	0.355794	0.324945	0.276291
Molybdenum Column Model	0.658191	0.442845	0.318558	0.26628	0.251915
Difference (s)	0.20469	0.072098	0.037236	0.058665	0.024376
Difference (%)	23.72	14.00	10.46	18.05	8.82

Table 2. Comparison of mode shapes each mode

	1. Mode	2. Mode	3. Mode	4. Mode	5. Mode
Steel Column Model	Translational (Y)	Torsional	Translational (X)	Translational (Y)	Translational (Y)
Molybdenum Column Model	Translational (Y)	Torsional	Translational (X)	Translational (Y)	Translational (Y)

4. Conclusions

When the 1st mode period values of the steel structure model consisting of steel columns and the steel structure model consisting of molybdenum columns are compared; 0.20469 seconds, 23.72% decrease was observed in percent. When the 1st mode shape of both models is examined, translation in the Y direction is observed in both cases.

When the 2nd mode period values of the steel structure model consisting of steel columns and the steel structure model consisting of molybdenum columns are compared; 0.072098 seconds, 14.00% decrease was observed in percent. When the 2nd mode shape of both models is examined, translation in the torsion is observed in both cases.

When the 3rd mode period values of the steel structure model consisting of steel columns and the steel structure model consisting of molybdenum columns are compared; 0.037236 seconds, 10.46% decrease was observed in percent. When the 3rd mode shape of both models is examined, translation in the X direction is observed in both cases.

When the 4th mode period values of the steel structure model consisting of steel columns and the steel structure model consisting of molybdenum columns are compared; 0.058665 seconds, 18.05% decrease was observed in percent. When the 4th mode shape of both models is examined, translation in the Y direction is observed in both cases.

When the 5th mode period values of the steel structure model consisting of steel columns and the steel structure model consisting of molybdenum columns are compared; 0.024376 seconds, 8.82% decrease was observed in percent. When the 5th mode shape of both models is examined, translation in the Y direction is observed in both cases.

In the light of all this information, it has been determined that the highest decrease in the period value, especially in the 1st mode, is experienced when the columns are used as molybdenum profiles in the steel structure model. Decreases were also observed in the period values in other modes. In this case, it can be easily said that the rigidity of the structure model increases. In addition, the fact that there is no change in mode shapes is interpreted positively. More research should be done on the use of molybdenum profiles in steel structures. According to the results of this study, column profiles can be used as molybdenum profiles instead of steel profiles in cases where the rigidity of the column cross-sections of steel structures needs to be increased without changing their dimensions.

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