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EFFECTS OF USING ST52 STEEL ON LIGHTENING INDUSTRIAL FRAMES COMPONENTS

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Resumen: Al determinar el tamaño de los componentes estructurales industriales, se da prioridad al desplazamiento, estrés o resistencia. La estrategia de iluminación de los marcos industriales depende del factor dominante. En el presente estudio se investigan los efectos del uso de acero ST52 de alta resistencia sobre los componentes de los marcos industriales de iluminación. Los modelos se cargan con base en el Capítulo 6 de las Normas Nacionales de la Construcción de Irán (Edición 2013), y se diseñaron utilizando el Código AISC-LRFD. En los modelos diseñados, el alcance del hangar y la altura de las columnas son variables y otras especificaciones del hangar se consideran constantes. Los hangares son de un solo tipo; Los tramos del hangar son 12m, 15m, 20m, 25m, y 30m; Las alturas útiles de los hangares son 6m, 8m, 10m, y 12m; Y la longitud de todos los hangares se selecciona 42m. Los modelos 3D y 2D de los marcos se diseñan y analizan utilizando el software SAP2000; Y se desarrolló un modelo estadístico de los resultados para el peso del bastidor, la banda de columna máxima y la banda de viga máxima (viga). Los resultados sugieren que en los hangares donde el estrés y la fuerza son los factores dominantes, el uso de acero ST52 ayuda a reducir el peso de los marcos industriales, mientras que en los hangares donde el desplazamiento es el factor dominante, el tipo de material ST37 a ST52 prácticamente no tiene efecto sobre la iluminación la estructura. Además, el uso de acero de alta resistencia tiene un efecto máximo sobre la reducción del espesor del acero, siempre que no se produzca pandeo en la sección.

Abstract: When determining size of the industrial structural frames components, priority is given to displacement, stress, or strength. The strategy of lightening industrial frames depends on the dominant factor. In the present study we investigate effects of using ST52 high strength steel on lightening industrial frames components. The models are loaded based on Chapter 6 of National Building Regulations of Iran (2013 Edition), and designed using AISC-LRFD Code. In the designed models, hangar span and height of columns are variable and other hangar specifications are considered as constants. The hangars are single-span type; hangar spans are 12m, 15m, 20m, 25m, and 30m; useful heights of hangars are 6m, 8m, 10m, and 12m; and length of all hangars is selected 42m. 3D and 2D models of the frames are designed and analyzed using SAP2000 software; and a statistical model of the results for frame weight, maximum column web, and maximum beam (rafter) web was developed. The results suggested that in hangars where stress and strength are the dominant factors, using ST52 steel helps reducing weight of the industrial frames, while in hangars where displacement is the dominant factor, changing type of material from ST37 to ST52 has practically no effect on lightening the structure. Also, using high strength steel has maximum effect on reducing thickness of the steel, provided that no buckling is generated in the section.
Keywords: *high strength steel, ST52, lightening, hangar, LRFD*

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1. INTRODUCTION

Industrial frames are the structures developed usually to provide large spaces. They have large spans, sloped or curved ceilings, and steel components. In Iran they are known as “hangars”. There are various types of ceiling for these structures, the most common of which is a ceiling made of a beam (rafter) or a truss to support the ceiling shell. These structures are usually light and mostly designed for wind. Developers of the industrial units, as investors, tend to build the industrial space they need at the lowest cost. Therefore an important criterion of designing industrial frames is reducing final weight of the structure. This criterion can be achieved through changing a number of design parameters. One of such parameters is using high strength steel in industrial frame components design. In this study we discuss effects of material type parameter, i.e. using high strength or normal steel, in industrial frames components design. Increased strength of steel results in reducing weight of the consumed steel, reduces size of the structure sections, and consequently reduces total weight of the frame.

2. TYPES OF STEEL

2.2. Normal Steel

This type of steel is classified as mild-carbon steel and is coded as ST37. Construction profiles are made of this type.

2.3. High Strength Steel (Low Alloy High Strength Steel)

This type of steel is produced by adding a small amount of alloys such as chrome, copper, magnesium, nickel, etc., to carbon steels. Adding such alloys minifies crystal structure of the iron and consequently increases its strength. This type of steel is coded as ST37. Table 1 compares the mechanical characteristics of these two types of steel.

In many industrial countries, high strength steels are used as conventional steel and what is considered as high strength steel is of a higher resistance compared to the values shown in Table 1.

The question is if using high strength steel always results in reducing size or thickness of the components in steel components design. Therefore, this study aims to evaluate utilizing capacity of high strength steel for reducing size and thickness of the industrial frames components.

3. MODELING

To study the subject issue we selected the case study method. Accordingly we designed 40 hangars with

Steel Type	Yield Stress (F_y) (kg/cm^2)	Ultimate Stress (F_u) (kg/cm^2)	Modulus of Elasticity (E) (kg/cm^2)
ST37	2400	3600	$2.1*10^6$
ST52	3400	5100	$2.1*10^6$

Table 1. Comparing Mechanical Characteristics of Normal Steel VS High Strength Steel

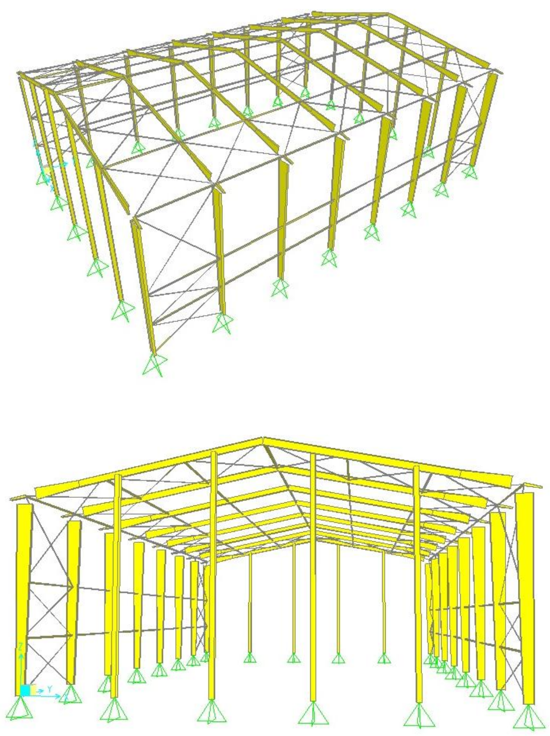

Figure 1. 3D Image of the Designed Hangars

different spans and column heights. 3D image of the hangars is shown in Figure 1.

Constant parameters used in design of all the hangars are:

Frame ceilings are sloped type with a slope of 20%, Length of hangars is 42m, consisting of 8 frames along the length, and distance between the frames (width of the load bearing zone) is 6m. Hangars loading specifications: Snow load is 100 kg/m^2; Design wind load is 38.3 kg/m^2; dead load of the ceiling is 30 kg/m^2; regional seismic coefficient is 0.3; seismic behavior coefficient is 5; and project risk category is 3 (i.e. conventional structures). As shown in Figure 1, two rows of cross bracing are used at the two ends of hangars, and hangar columns are supported by pin joints.

4. DESIGN

For loading the hangars, a combination of loads as per the 2013 edition of Chapter 6 of National Building

Hangar Span (m)	Maximum Useful Height of Column (m)	Column Web Height (Bottom) (cm)	Column Web Height (Top) (cm)	Column Web Thickness (cm)	Column Flange Thickness (cm)	Column Flange Width (cm)
12-15-20-25-30	6-8-10-12	20~50	40~110	0.6~1.5	0.8~2.2	15~25

Table 2. Results of Column Design Calculation

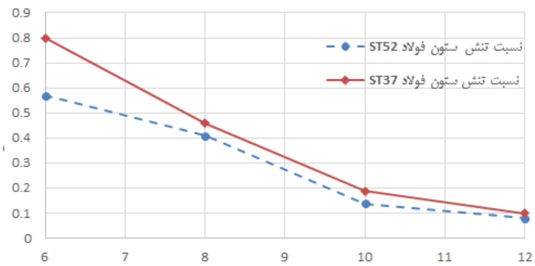

Figure 2. Comparing Stress Ratios of the Columns (Stress Ratio Vs. column height)

Regulations of Iran (Loading Code) were applied, and the hangars were designed in SAP2000 software based on AISC-LRFD code. In order to work out effects of the frames on each other, under the imposed loads, stress ratio and efficiency of the sections for 3D model frames were taken into consideration.

4.2. Effect of High Strength Steel on Columns Design

In columns with pin joints, due to large bending moment at top of the column, and absence of such moments at bottom of the column, there is a maximum need to the moment of inertia at the top. Therefore, section of the hangar columns will take a non-prismatic form. According to Chapter 10 of National Building Regulations of Iran, the critical stress caused by flexural buckling is a function of slenderness of the column and values of steel yield stress and module of elasticity (Az'hari, 2014). Therefore, using high strength steel increases critical stress of the columns. In bending behavior the level of increased yield stress increases directly the section capacity. Therefore, when using high strength steel instead of normal steel, we may reduce size and thickness of the plates. Size and thickness of the plates can be reduced to the extent that no local buckling is created in the component. In controlling local buckling of the frame components, width to thickness ratio, as shown in table 1-4-3-10 of Chapter 10 of National Building Regulations of Iran (National Building Regulations Office, Ministry of Roads and Urban Development, 2013), is the limiting factor. Equations 1 and 2 show the relation between thickness and yield stress of the frame components for controlling local buckling:

$$\frac{b}{t_w} \leq 0.38\sqrt{\frac{E}{F_y}} \qquad (1)$$

Controlling local buckling of the I-shaped sections flange made of steel plate

$$\frac{h}{t_w} \leq 3.76\sqrt{\frac{E}{F_y}}\,(1 - 2.75C_a) \qquad (2)$$

Controlling local bucking of the I-shaped sections web made of steel plate

The design procedure consists of determining minimum size and thickness of the hangar frames components through a trial and error method, in a way that the components resist the imposed loads. Table 2 provides a summary of the results of the hangar columns design calculations.

Changing only type of the steel has no effects on lateral displacement of the structure; but, if size of the section is reduced due to it, the lateral displacement shall increase. Therefore, in structures where displacements are the controllers, displacement of the structure is a limiting factor of reducing size of the column sections. When it is possible to reduce size of the columns, it is better to reduce thickness of the plates as well.

The results of hangar columns design calculations and comparing use of high strength steel versus normal steel are indicative of reduced rate of stress generated in columns sections. This result for 12m span hangars with various column heights is shown in Figure 2.

In the designed models, it was noted that in hangars with 12m, 15m, and 20m spans using high strength steel will not make it possible to reduce size or thickness of the column section;

but, in hangars with 25m and 30m spans using high strength steel can reduce size and thickness of the column section plates considerably.

4.3. Effect of High Strength Steel on Rafters Design

As per the code regulations, the yield stress (F_y) has a direct effect on flexural strength of the rafters.

Hangar Span (m)	Maximum Useful Height of Column (m)	Rafter Web Height (Beginning) (cm)	Rafter Web Height (End) (cm)	Rafter Web Thickness (cm)	Rafter Flange Thickness (cm)	Rafter Flange Width (cm)
12-15-20-25-30	6-8-10-12	40~75	20~40	0.6~1.2	0.8~1.5	15~20

Table 3. Results of Rafters Design Calculation

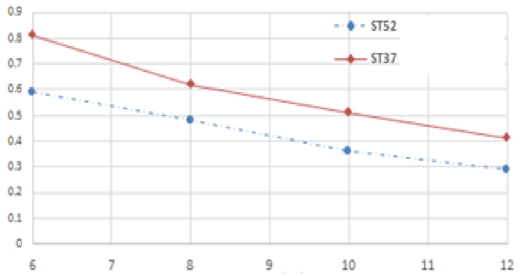

Figure 3. Comparing Stress Ratio of the Rafter (Stress Ratio Vs. column height)

the other hand, reducing size of the rafters section reduces their stiffness and drift. Increasing length of the rafters span makes them more sensitive against drift. Therefore, in longer spans, it is less feasible to use capacity of the high strength steel; but in shorter spans, it is possible to utilize this capacity. Also, the best way to utilize capacity of the high strength steel is reducing size of the rafters instead of reducing the thickness. Table 3 summarizes results of hangar rafters design calculations.
When designing the rafters, it is necessary to control buckling of plates, as there is a large surface of low thickness plate. In the designed models, since we had used minimum thickness of the plate (6 mm) in 12 and 15 m spans, it was no more possible to reduce the thickness. When using high strength steel in 20m spans, we reduced thickness of the rafters. Also, in 25 and 30 m spans, due to large size of the spans, using high strength steel had no effects on reducing size or thickness of the rafters. According to the design calculation results, using high strength steel reduces stress ratio of the rafters in all hangars. Figure 3 shows the stress ration generated in rafters of a 15m span hangar for the two types of steel.

5. FINDINGS

Using high strength steel has no effects on lateral stiffness of the structure if size of the components remains the same, and its sole effect is reducing the stress generated in the components (Figures 2 and 3).

The most significant effect of using high strength steel is reducing thickness of the consumed steel, provided that no local buckling is generated in the section. That is to say for a given size of frame components section, using high strength steel shall reduce the thickness considerably.
As for of the rafters, as bending stiffness is needed to control rafters drift and ceiling vibrations, height of the section remains the same, and thickness of the plates is reduced. Increasing length of the rafter spans reduces effects of using high strength steel.

6. CONCLUSION

In components designed based on strength criterion, using high strength steel is economically feasible. However, in some components, where displacement or drift are the dominant design factors, using high strength steel will not reduce the costs. Proper use of the capacity of high strength steels reduces weight of the structure and therefore makes the design more economic.
the future studies are recommended to make an economic comparison between use of high strength steel and use of normal steel in various structures including building structures, bridges, truss structures, etc. The results can be provided to the engineering society as design recommendations.

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