TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 13973 - 13977

Comparison of Structural Stabilities of the Beams Built with Ordinary Grade Structural Steels at Different Design Fires

INKYU KWON
Professor, Department of Fire Protection Engineering, Kangwon National University, Samcheok, Korea
kwonik@kangwon.ac.kr

Article Info
Volume 82
Page Number: 13973 - 13977
Publication Issue:
January-February 2020

Article History
***Article Received**: 18 May 2019*
***Revised**: 14 July 2019*
***Accepted**: 22 December 2019*
***Publication**: 26 February 2020*

Abstract

It is regarded that the structural stability of the beams designed with structural steels is going to lose, may cause the severe deflections and result in structural failure at a severe fire situation. Therefore, the strategy to sustain the fire resistance of the beam is very essential requirement to every country. There are two ways of evaluation on the fire resistance for the structural members. The first one is to select the fire resistance structures from the regulation or standard. The second one is to calculate the structural stability based on scientific and engineering design processes and this method can utilize the sizes of structural element, boundary conditions, and fire loads, etc. In this study, the structural stability of the beam built with two kinds of structural steels having different lengths of the beam, sorts of design fires is calculated using mechanical properties derived from various temperatures. The results show that the structural stability of the beam is different by the kinds of the structural steels and deflections, maximum load capacities are decreased as the lengths of the beam is getting longer and structural stability at a fixed boundary condition is higher than that of a simple boundary.

***Keywords:** Beam, Fire engineering design, Fire load, Parametric fire*

I. INTRODUCTION

Steel framed structures is one of the best system to build a high-rise building in terms of an efficient construction method including not only the schematic design stage but maintenance. It is a common well-known information that there are lots of steels applied to building construction and the performance of the steels is getting weakened when the steels is exposed to fire situation. Therefore, the satisfaction of the fire resistance of the steel structure is very important and become a mandatory requirement from each nation. It is very common classification to distinguish the fire resistance by two categories. One is the prescription method that is very simple way to have the fire resistance in accordance with the requirement of the building regulation and standard. Another one is the performance based fire engineering design and this is described as an alternative method. Fire resistance can be achieved by evaluation of the structures using a scientific and an engineering technologies. Nowadays, the latter is more popular way to determine the fire resistance in structures. In this paper, to compare the fire resistance of the structural beams built with ordinary grade structural steels such as SS 400 and SM 400 which are widely used in steel framed buildings in Korea, a performance based fire engineering method was used.

II. EVALUATION OF STEEL BEAMS AT HIGH TEMPERATURES

A. Analysis Process

Evaluation of steel framed structures such as buildings and bridges in fire requires some engineering processes. First step is to make a

TEST Engineering & Management
January - February 2020
ISSN: 0193 - 4120 Page No. 13973 - 13977

scenario that express the severe condition of fire outbreak and a deep impact to the structure. Next stage is calculation of the structure at high temperatures using a heat analysis and a stress one step by step.

B. Mechanical Properties of Materials

When the beam is analyzed, to get a correct value it is very essential to use the proper mechanical and thermal data for the materials in a fire situation. In this paper, the mechanical data for the SS 400, SM 400 are shown in the Table 1, respectively.

Table 1. Mechanical properties in high temperatures

Sorts	Properties	Temperatures	Regressions
SS 400	YP	T ≤200℃	Cold value (240 MPa)
		200 ≺ T	-0.32T+303.21
	EM	T ≤100℃	Cold value (210 GPa)
		100 ≺ T	-0.22T +232.16
SM 400	YP	T ≤200℃	Cold value (240 MPa)
		200 ≺ T	-0.29T+293.44
	EM	T ≤200℃	Cold value (210 GPa)
		200 ≺ T	-0.26T +261.18

C. Conditions

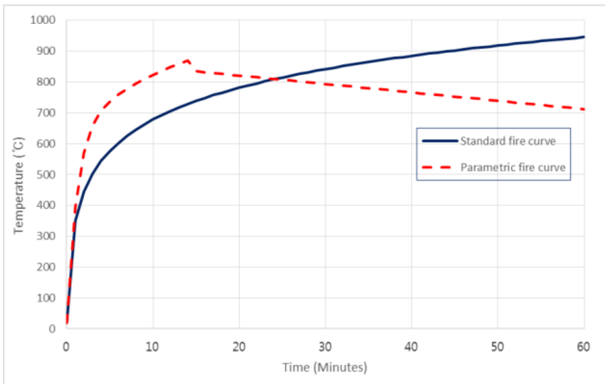
In general, the beam in the building can be designed by kinds of the boundary conditions and these are a simple beam and a fixed boundary one. The simple beam condition is designed as it is not sustained the moment at the both end, but the fixed conditioned beam can carry the moment at the both end. Therefore, in this calculation the simple and fixed condition are considered as a main boundary conditions. In addition, the beam lengths can be considered as a factor that affect to fire resistance in high temperature. Therefore, the three lengths, 4100, 4400 and 4700 mm would be regarded. To get the parametric fire curve in the compartment, the dimension, 3,000mm x 4,000 mm x 2,500 mm and one open(900 mm x 2,000 mm) are considered and the occupancy of the building is office.

III. FIRE PERFORMANCE OF BEAM AND DISCUSSIONS

The calculation of the beam designed with SS 400 and SM 400 was done with a program that was developed by the author and programed using an excel sheet. That program utilizes the mechanical and thermal properties of each steels and calculate the history of steel temperatures as the time is increased and structural stabilities such as maximum load carrying capacity and deflection tendency are calculated while the surface temperatures of the beam are changed.

A. Surface temperatures

Surface temperatures of the steels in high temperature are increased as the time is passed, for the fire load can produce not only heat but light during combustion period. In this study, to determine the surface temperature of each steels, the thermal properties such as specific heat and thermal conductivity are used. To get the structural stability in high temperature, two kinds of design fires from the Korean Standard and the Eurocode one were applied. Generally, a standard fire curve that is defined in each nation's standard and a natural fire curve that is derived from each compartment condition. In this study, to compare the structural stability, the maximum load and deflection, two design fires were used. Standard fire curve and derived parametric fire curve are shown in the Figure 1. The calculated surface temperatures of two steels are expressed in Figure 2 and Figure 3.



January - February 2020
ISSN: 0193 - 4120 Page No. 13973 - 13977

Figure 1. Design fires

B. *Simple Beam*

When the loading is applied into the beam, the structural stability is active and as the loading is applied, the maximum allowable capacity and deflection is increased gradually and then if the stability is reaching to the limitation, the beam would be failed in high temperature. Thus, the collapse of the beam in a fire is dependent on the fire loads and duration of the fire, etc.

After calculation of the structural stabilities with not only mechanical but thermal data of the SS 400, the maximum load versus elapsed time is derived and shown in the Figure 4.

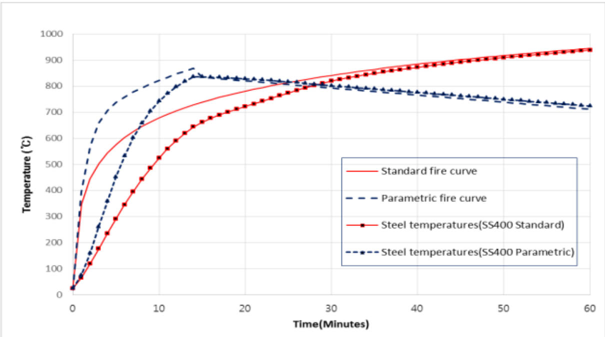


Figure 2. Surface temperatures from SS 400

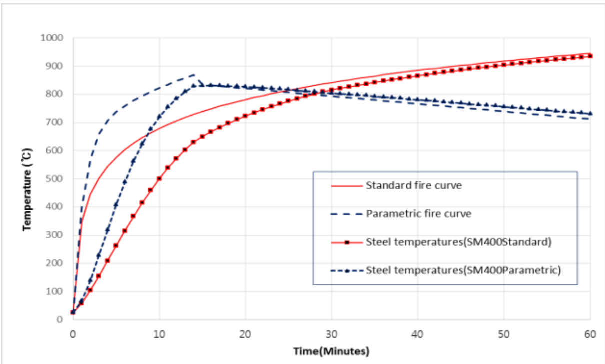


Figure 3. Surface temperatures from SM 400

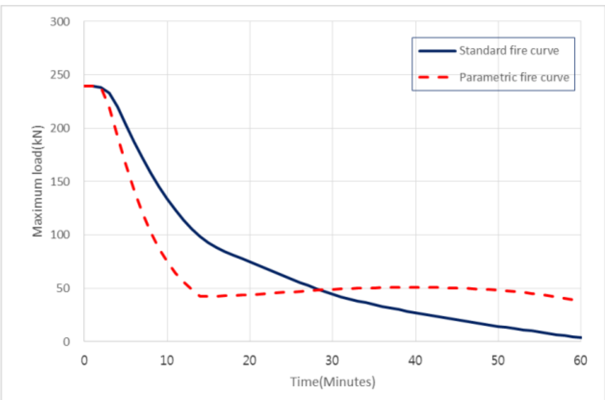


Figure 4. Maximum load versus times(SS400)

There are little differences at the increasing surface temperatures from a standard fire curve and a parametric fire curve in SS 400 and SM 400 for the thermal properties and increasing patterns are almost the same.

The deflection of the simple beam is going to increase when the time is passed. But in case of parametric fire curve, the increasing pattern is turned into reduce after about 12 minutes due to decreasing history of design fire(Figure 5). From this result, it is clear that the surface temperature of the steels is dependent on the fire load. Therefore, the standard fire curve can be regarded as much conservative in case of fire situation.

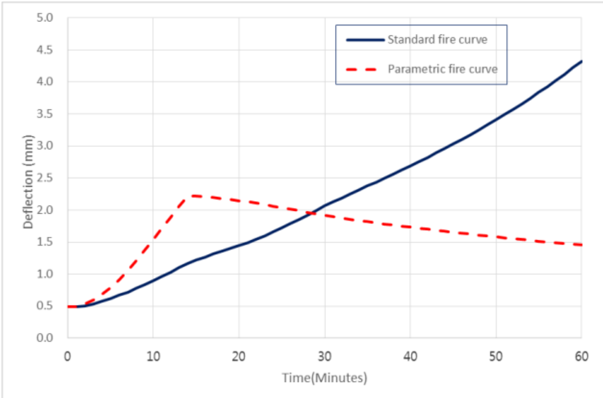


Figure 5. Deflection versus elapsed times

C. *Fixed Beam*

In figure 6 and figure 7, the maximum load and deflection at a fixed boundary condition are shown, respectively. According to two figures, the tendency of the maximum load and deflection at a fixed condition are similar to those from the simple beam but the reduction ratio of the maximum load and deflection showed a big different. Therefore, the structural stability in the fixed condition is regarded as a much stable than that at the simple beam.

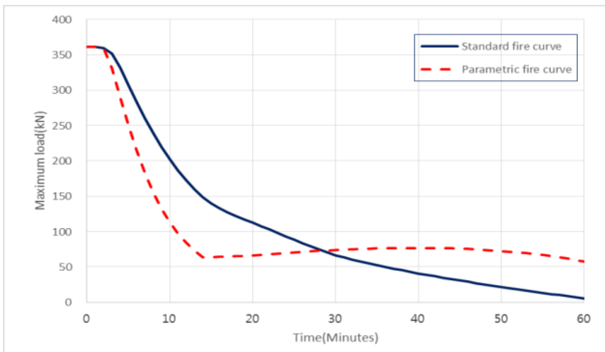


Figure 6. Maximum load versus times

January - February 2020
ISSN: 0193 - 4120 Page No. 13973 - 13977

D. Beam Lengths

As the beam lengths are increased, the structural stability of the beam can be reduced but it is not easy to ascertain what size it is reduced to. Therefore, to certify the stability is necessary in fire condition. At first, to clarify the difference in high temperature, maximum load and deflection are compared in the simple beam condition at the 4100 mm in length. The results are showed in Figure 8 and Figure 9, respectively.

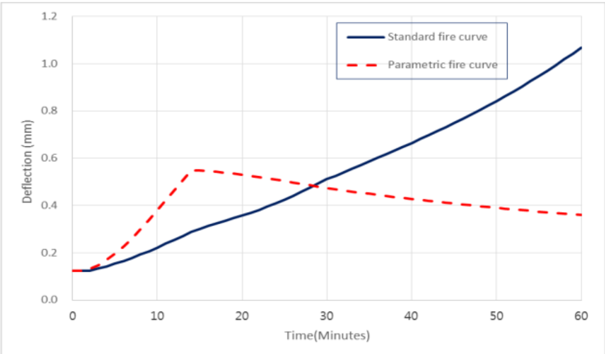


Figure 7. Deflection versus elapsed times

a) 4100mm in simple and fixed beam

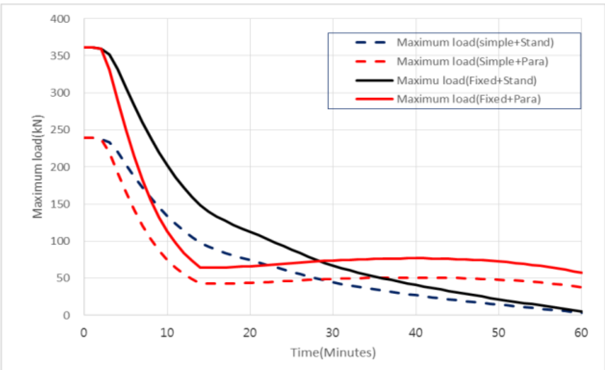


Figure 8. Maximum load at two boundary condition

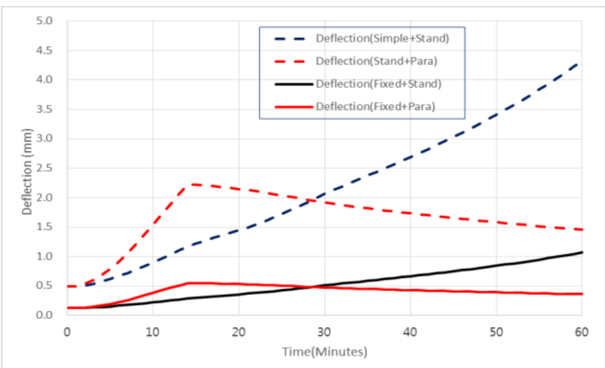


Figure 9. Deflection at two boundary condition

According to comparison with two results, the fixed boundary condition is regarded much safer than that from simple beam in case of fire and it is clear that structural stability at the fixed condition is superior to that at the simple one in structural aspect.

b) 4100mm to 4700mm in simple beam

It is regarded as an important factor to know how the capacity of load carrying capacity is sustained due to difference of the length in fire situation. Therefore, the maximum loads and deflection versus elapsed time are calculated and expressed in Figure 10 and Figure 11.

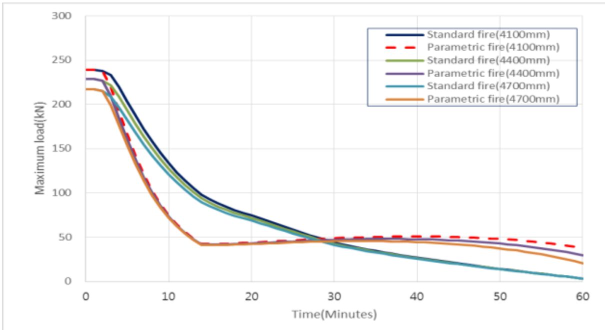


Figure 10. Comparisons of the maximum loads at various lengths

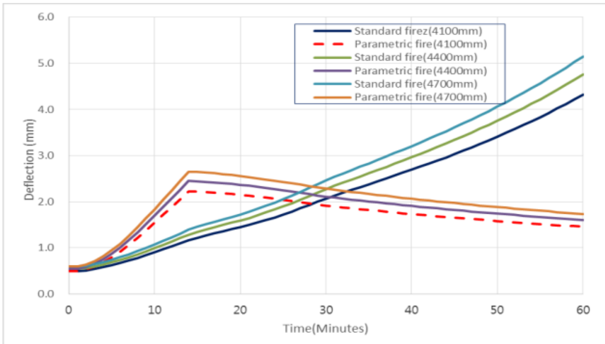


Figure 11. Comparisons of the deflections at various lengths

In a standard fire, the structural stability is shown to be worse, for the parametric fire curve can be down after the consumption of the combustible materials within the compartment.

Acknowledgement

This research was supported by a grant (code 20AUDP -B100356-06) from an Urban-Architectural Research Program funded by Ministry of Land, Infrastructure and Transport of Korean government.

IV. CONCLUSION

Steel framed buildings and structures are increased gradually due to their structural and economical benefit in construction market. However, the fire safety requirements have been strengthen due to their inherent weakness to high temperatures. In this study, to cetify and clearify the structural stability of the beam designed by the ordianry grade structural steel, SS400 and SM 400 the performance based fire engineering design method was applied and the followings are derived.

1) Parametric fire curve is derived from a real situation of compartment and it is more rational than the standard fire curve.

2) Surface temperature history curves of SS 400, SM 400 were derived and the result was almost the same.

3) Maximum loads and deflection were calculated and the parametric fire curve was regarded as more rational than standard fire curve

4) As the lengths of the beam is longer, the structural stability is worse and differences in lengths are compared.

REFERENCES

[1] I. K. Kwon, "Analytic Evaluation of Fire Performance according to Boundary Conditions and Lengths for Steel Columns built with SM 520 and SM 570 AT high Temperatures", *Materials Research Innovations*, Vol.151, No. 8, pp. 486-489, 2015. I. K, Kwon, I. H. Chang, "Development of the Fire Engineering Techniques of Structural Steels", RIST, *Research Institute of Industrial Science & Technology*, 2001.

[2] K. J. LaMalva, "Developments in Structural Fire Protection Design- a US Perspective", New ASCE/SEI7 Standard, *The Structural Engineer*, pp.25-29, 2018.

[3] ASCE, "Structural fire engineering, ASCE Manuals and reports on engineering practice No.138", Reston, USA, 2018.

[4] AISC, "Specification for Structural Steel Buildings", 2016.

[5] ASCE, "Structural fire engineering", ASCE Manuals and reports on engineering practice No.138, 2018

[6] Buchanan, A.H., Abu, A.K. "Structural design for fire safety", 2017.

[7] CEN, "Eurocode 1: Actions on structures-Part 1-2: General actions- Actions on structures exposed to fire", 2002.

[8] Fire research Group, "Development of Standard for the Performance Based Fire Design and Guideline", *Korea Institute of Civil Engineering and Building Technology*, Hwasung, Korea, 2018.

[9] D.C. Jang, S.H. Jang "Steel Structure Design", Gumisukwan, 2016.