Utilization of Numerical Techniques to Predict The Thermal Behavior of Wood Column Subjected to Fire Part B: Analysis of Column Temperature and Fire Resistance

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Abstract. Mathematical models of Part A [1] are used to calculate the temperatures, deformations and fire resistance of rectangular, hexagonal, octagonal and I-cross section columns for the purpose of Part B. In this paper the comparison among the configurations of the column has been carried out to predict the temperature history for the column elements for preventing the spread of fire and prolonging the structural time collapse. The columns are varied in section size, among them are the rectangular, hexagonal, octagonal and I-cross section column of Keruing timber. The developed mathematical models defined the failure point as the point which the column can no longer support the applied load. From the comparison, the I-cross section column is the worst configuration than the other configuration.

Introduction

The designer needs to obtain the suitable type, shape and size of column to enable it to withstand the applied load at elevated temperature. There are wide ranges of parameters to analyze for wood columns, but in this paper we will discuss the effect of different boundary conditions, and configurations on temperature history, the fire resistance for wood column and its charring area. The cross sectional area for each configuration is 361 cm^2. The applied load for each column is taken less than half the stress of Keruing timber multiplied by its cross-section. This is done to prolong the failure time and study the effect of fire in formulating char. [2]

Temperature History and Fire Resistance for Rectangular Column. The objective of this research study is to analyze different column configuration and to find out the best cross- section capable of sustaining fire. The rectangular cross-section is commonly used in constructions. The selected length to width ratio is 3: 2 and column cross section dimension is 233x155 mm. The applied axial load, the meshing and the selected elements are the same as used in the square column simulation [1]. The temperature history for the selected elements is shown in Fig 1. From this figure, the behavior of the rectangular column is similar to that of the square column. However, the temperature history of the rectangular column is higher than the square column, especially at the interior elements. The failure time for square and rectangular is 30 and 32 minutes respectively. The reason of this little difference in fire resistance is that the width of the rectangular column is 155 mm and the square side length is 190 mm [1].

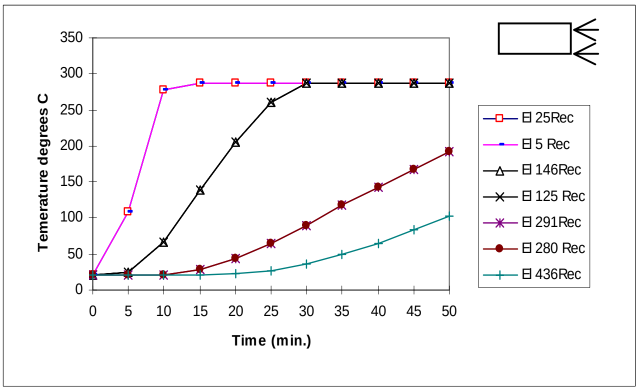

Fig.1: Temperature variation of elements on rectangular cross-section of (Malaysian Keruing Timber)

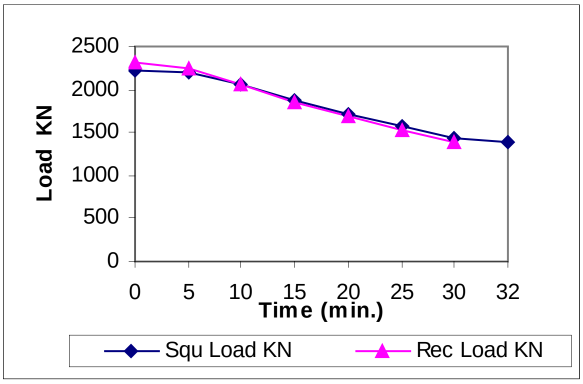

Fig.2: Comparison of fire resistance for square and rectangular cross section.

Fire Resistance and Temperature History for Hexagonal cross-section Column. Computer simulation is carried out to analyze the effect of load carrying capacity, temperature history and charring area for a hexagonal cross-section column (Malaysian Keruing timber). The selected elements for analysis are 6, 10, 61, 65, 87, 104, and 136 within the column cross section. Fig. 3 and 5 presents the temperature history of the selected elements at different fire boundaries. The fire resistance of the hexagonal column is shown in Fig. 4 and Table 2 for different fire boundaries. Fig. 5 illustrates the intersection of the two curves of element 65 and 136 because of the element location. (Element 65 is nearer to the center of the column compared to that of element 136). It is very significant that the fire resistance of a two-side fire boundary is highest among the other two.

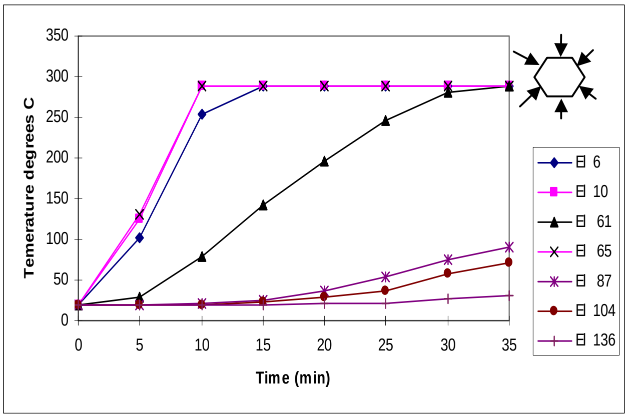

Fig.3: Temperature variation of selected elements on the hexagonal column surrounded with fire from all sides

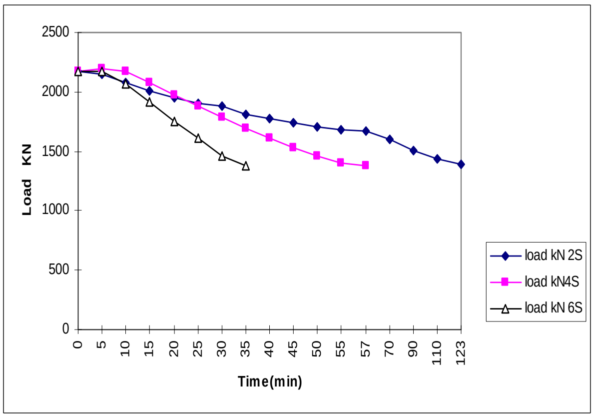

Fig.4: Comparison of fire resistance hexagonal column for different boundaries

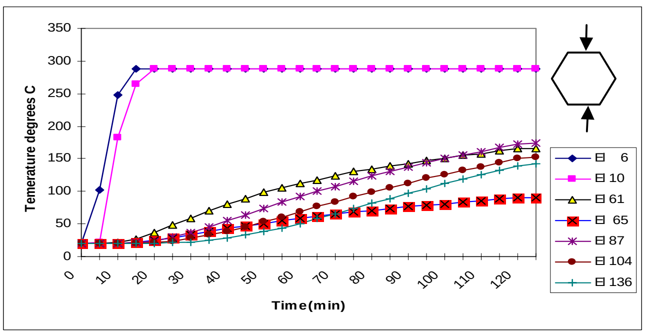

Fig. 5: Temperature variation of selected elements on the hexagonal column surrounded with fire from two sides

Type of boundary	Temperature of column center after 30 min.	Fire resistance time(min)
Fire from two sides	$22\ ^{0}C$	122.5
Fire from four sides	$24\ ^{0}C$	57
Fire from six sides	$26\ ^{0}C$	33.5

Table 2: Comparison of column center temperature and endurance time at different boundary condition for hexagonal column

Temperature History and Fire Resistance for Octagonal Column. The selected elements for octagonal column are 6, 10, 61, 65, 146, 241, 246, and 336. The influences of fire on the selected elements are represented in Fig 6 through Fig 9 with different fire boundary conditions. The fire resistance of the octagonal column is shown in Fig. 9. Table 2 summarizes the failure or endurance time at different fire boundary conditions.

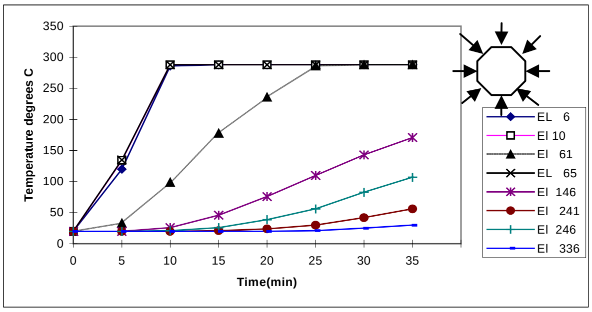

Fig.6:Temperature variation of selected elements on the eight sides column surrounded with fire from all sides

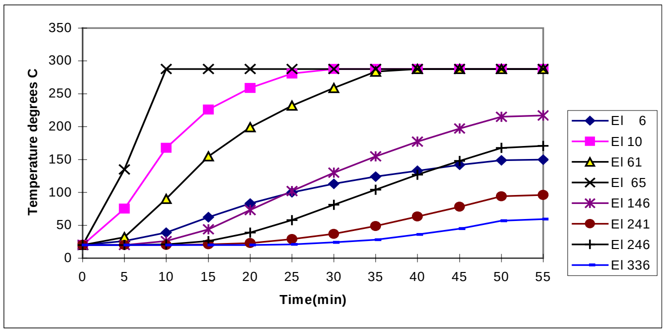

Fig.7: Temperature variation of selected elements on the octagonal column surrounded with fire from six sides

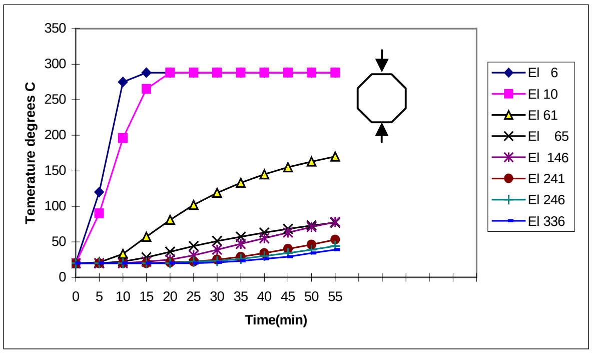

Fig.8: Temperature variation of selected elements on the octagonal column with fire from two sides

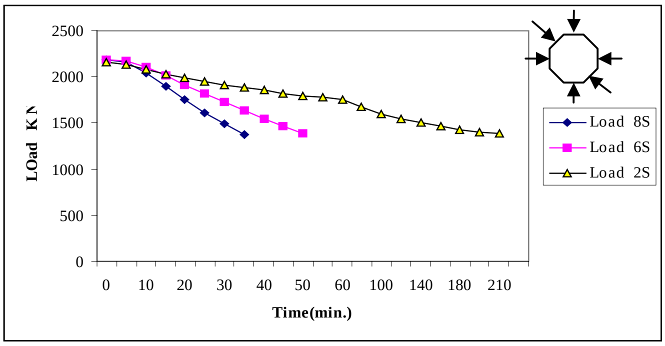

Fig.9: Comparison of fire resistance for octagonal column at different boundaries

Type of boundary	Temperature of column center after 30 minutes.	Fire resistance endurance time (minutes)
Fire from eight sides	25°C	35
Fire from six sides	24°C	51
Fire from two sides	22°C	210

Table 2 : Column center temperature and endurance time comparison at different boundary conditions for octagonal column (Malaysia Keruing timber; applied axial load 1380 kN)

Fire Resistance and Temperature History for I-cross section Column. The temperature history for each selected element in the I- cross-section column is illustrated in Fig.10. It is observed, the temperature history for each element is relatively high compared to the preceding cross-sections. The fire resistance of the I-cross section column is shown in Fig 11, the column failed after 17.5 minutes. This failure time is the worst among all configurations selected in this study.

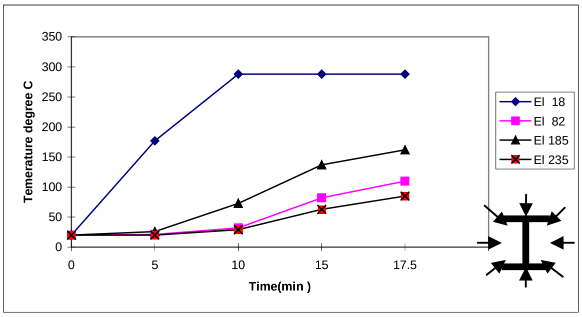

Fig.10 : Temperature variation of selected elements on the I-cross section column surrounded with fire from all sides (Malaysian Keruing timber)

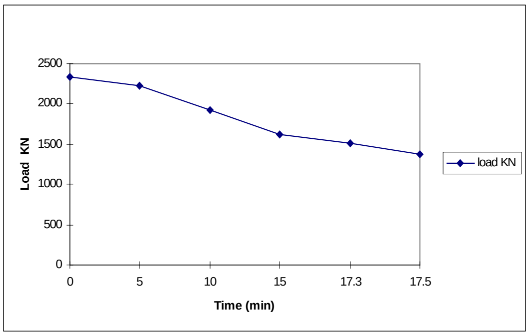

Fig.11: Fire resistance for I-cross section column for (Malaysian Keruing timber)

Comparison of Columns Center Temperature and Fire Resistance for Different Column Cross Sections Surrounded with Fire from All Sides. The temperature results for different configurations of the column centers are shown in Fig 12. The highest column center temperature is I-cross section column. The thickness of the I-section web and flanges column is much thinner than the other columns. The heat will be transferred faster in the thin web and flanges and the element temperature of the column center is raised very fast. The fire resistance is presented in Fig 13 at the applied axial load 1380 kN. The comparisons of endurance time are tabulated in Table 3. The results indicate the best configuration is the circular cross section, which can sustain fire the longest among the others. On the other hand, the worst is the I-cross section column. From Table 3 the least circumference is the circular and the largest, the I-cross-section. Each column has the same cross-section area. The least circumference (i.e. for circular) has the least exposure to fire. That is why it can sustain fire longest among the others

Type of cross section	Endurance time(failure)	Circumference mm
I-cross section column	17.5	1243
Rectangular column	30	810
Square column	32	760
Hexagonal column	33.5	702
Octagonal column	35	690
Circular column	36	673

Table 3: Comparison of fire resistance and the circumference of different configurations

Type of cross section	Charred Area mm^2	Uncharred Area mm^2	Fail time (mii)
I-cross section	17719	18381	23.6
Square	25029	5296	68
Hexagonal	23740	12360	72
Octagonal	23696	12404	73.3
Circular	23692	12408	74.3

Table 4: Comparison of charred area of column and its failure time for different configurations

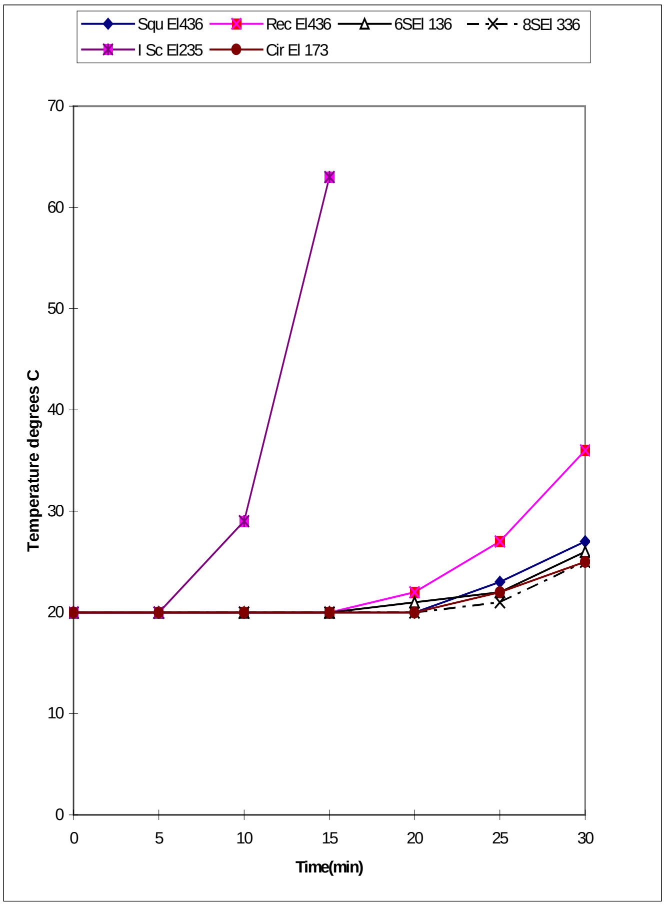

Fig.12: Temperature variation for different column configuration at the column center (Malaysian Keruing timber)

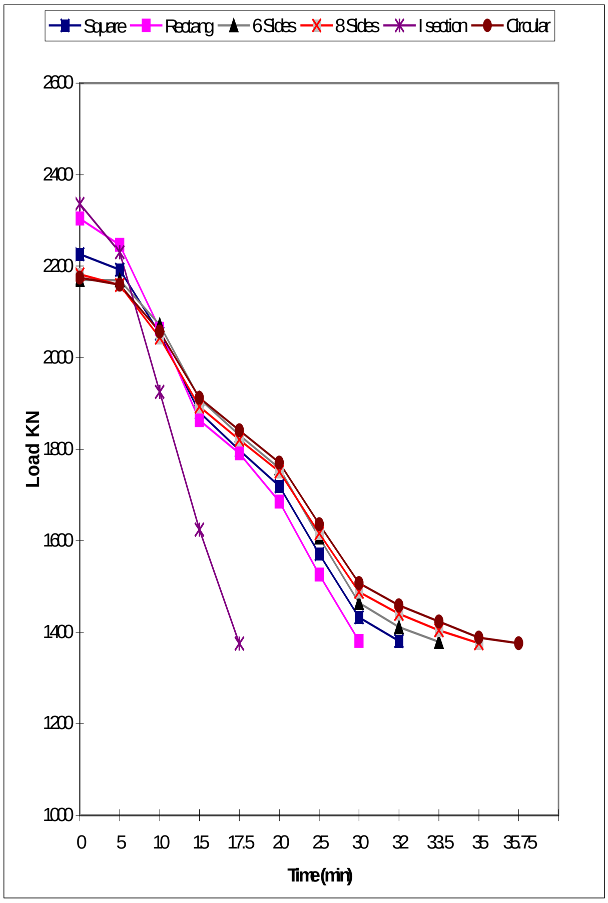

Fig. 13: Fire resistance for different column configuration at the column center (Malaysian Keruing timber)

Charring Area Comparison for Different Configuration. The comparison of the charred area for various cross-sections is tabulated in Table 4 under the same applied axial load of 667 kN each. The table indicates that the least charred area is the I-cross section, though this cross-section failed first among the others. For the rest of the other cross sections, their failure time is longer because heat is allowed to be conducted through the column. The longer the heat is conducted through the column, the more the chance of char being formulated. Therefore, charring area alone is not enough to predict the column's endurance time. However, it can give an approximate indication for the column's fire resistance. Besides that, the temperature history of the elements as indicated in the charring figures, T.T.Lie (1977) [3], can also give approximate indication for the column's fire resistance.

Conclusion

In this paper, a very comprehensive analysis has been done for both of the temperature history and fire resistance for different column configuration. This analysis is applied for rectangular, hexagonal, octagonal and I-cross sections of wood columns. In order to enhance, increase or promote the fire resistance for the column wood component, a sensitivity analysis will be carried out in the following research paper, Part C [4].

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