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# RAPPORT

Jürgen König

# The Effect of Density on Charring and Loss of Bending Strength in Fire

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*Paper presented at CIB-W18, Meeting 25, Åhus, August 1992*

Trätek

INSTITUTET FÖR TRÄTEKNISK FORSKNING

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# THE EFFECT OF DENSITY ON CHARRING AND LOSS OF BENDING STRENGTH IN FIRE

by
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## SUMMARY

The influence of density on charring of timber exposed to standard fire is studied, evaluating test results by Norén. It was found that both the effective and measured charring rates vary about 10 % in the density interval between 290 and 420 kg/m$^2$, representing characteristic densities of strength classes C14 to C40 in prEN 338, Draft 1991. It was found that there was no influence of density on the loss of bending strength.

## INTRODUCTION

In the CIB-code /1/ the charring rate has been given as being inversely proportional to density. According to this the influence of density on charring is considerably greater than reported by Schaffer /2/ for some North American species. In a recent study by White et. al. /3/ the influence of some parameters, among them density and moisture content are studied. For European spruce the influence of density is reported to be in the same order of magnitude as given in /2/, but the charring rate itself is overestimated in comparison to values which are accepted in Europe.

## FIRE TESTS BY NORÉN

In an experimental investigation, the effect of knots on the loss of load capacity of light wooden members exposed to fire was determined by Norén /4/. In the tests light members of Swedish spruce of the dimension 45x120 mm$^2$ were exposed to standard fire according to ISO 834 on four sides in a small furnace. Test series of specimens with knots and of specimens fairly free from knots were compared. Using a method of matching, load capacity at normal temperature of each specimen was predicted. The load levels during the fire tests, denoted as load ratios, were one third and one sixth respectively of the ultimate load at normal temperature. The results obtained showed that the failure times were fairly independent of the existence of knots, with a slight tendency for timber with knots to exhibit longer failure times. Since this influence is very small it can be disregarded in design practice.

In the following the influence of density is shown using the test results in /4/.

The ratio $A_r/A_0$ versus oven dry density $\rho_{0u}$ is shown in Figure 1, where $A_r$ is the residual area of the cross section at failure , and $A_0$ is the area prior to the test. It can be seen that density does not influence the total amount of charring that leads to failure. Since the load ratio is the same within each series, the conclusion can be made that neither does density exert any influence on the loss of bending strength of the residual cross section.

A considerable scatter of failure time in each series which allows to study how the charring rates are influenced by density. The plots of failure time versus density are shown in Figure 2. We can see that failure time increases with increasing density. Thus the charring rate

decreases with increasing density as shown in Figure 3, where the rate of charring is expressed as the charred area $A_{char}$ divided by failure time
where

$$A_{char} = A_0 - A_r$$

With the assumption that the bending strength of the effective residual cross section is the same as under normal conditions, effective charring rates $\beta_{ef}$ have been calculated which lead to failure loads equal to the test loads. The results are shown in Figure 4. It is obvious that the effective rate of charring decreases with increasing density.

From the figures it can be seen that there exists considerable scatter of the results. Comparing the two test series with the load ratios 0,33 and 0,167 respectively, we can see that the charring rate is about 20% larger in the latter. One reason is that the charring rates shown in the diagrams are mean values. Since the failure times were very short - the mean values were about 10 and 15 minutes respectively - the mean charring rate is more affected by the initially low charring rate in the first series. Another reason for this result can be insufficient accuracy of the measurements of the charred sections. In the second series a digitizer was used which gives better accuracy.

In design practice characteristic densities of timber in the most used strength classes are between 290 and 420 kg/m$^3$. These densities refer to a temperature of 20 °C and a relative humidity of 65 %, i.e. the oven dry density is between 325 and 470 kg/m$^2$. These limits correspond to strength classes C14 and C40 according to prEN 338, Draft 1991. Using the regression lines in Figures 3 and 4 we can calculate the ratios of charring rates of the two density limits:

| Load ratio | $\beta_{ef,470}$ / $\beta_{ef,325}$ | $(A_{char,470} / t)/(A_{char,325} / t)$ |
|---|---|---|
| 0,33 | 0,90 | 0,87 |
| 0,167 | 0,92 | 0,94 |

The values for both effective and measured charring are of the same order of magnitude. Since the effective charring rate is the integrated effect of charring and loss of strength, the two values differ less than the two values belonging to the measured charring. In both cases the charring rate is about 10% smaller at the upper limit of this interval of density than at its lower limit.

This result is in the same order of magnitude as those given in /2/ and /3/.

## CONCLUSIONS

The influence of density on the charring rate is considerably smaller than given in the CIB-code /1/. Since it is small in the intervall of most used strength classes, it should be disregarded in practical applications.

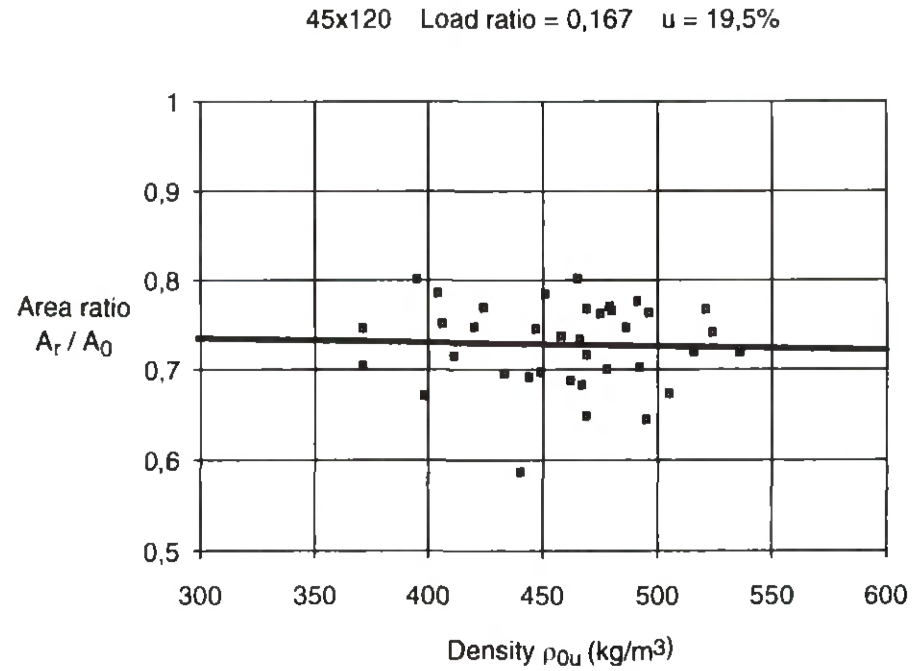
REFERENCES

/1/ CIB Structural Timber Design Code. CIB Publication 66, 1983

/2/ Schaffer, E. L., Charring of selected woods - transverse to grain. Forest Products Laboratory, Madison, 1969.

/3/ White, R. H. & Nordheim, E. V., Charring rate of wood for ASTM E 119 Exposure. Fire Technology, February 1992.

/4/ Norén, J., Failure of structural timber when exposed to fire. 1988 International Conference on Timber Engineering, Seattle.



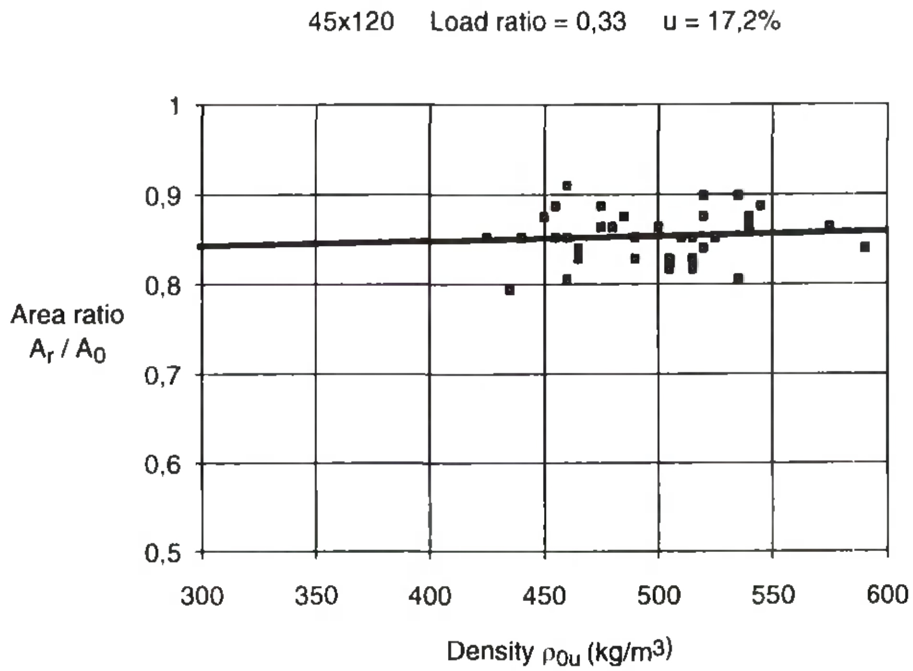
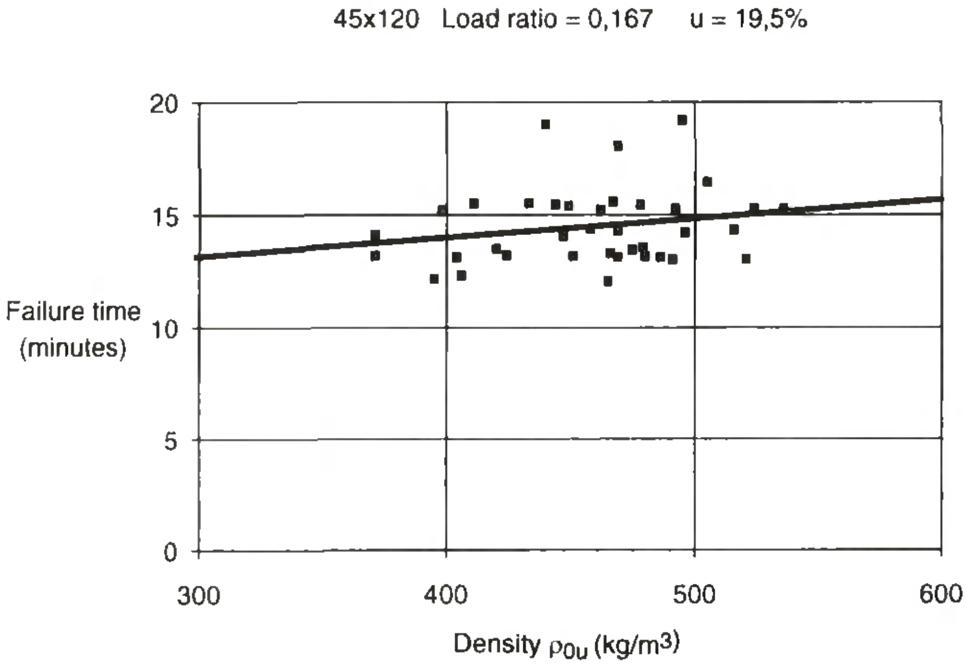




Figure 1 Ratio of residual and initial area versus density



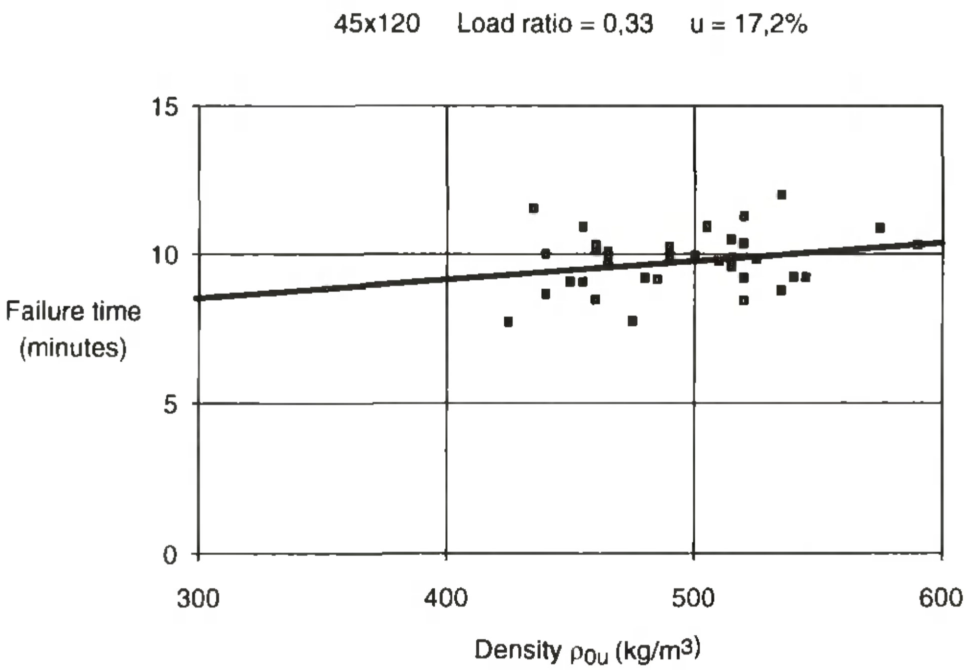
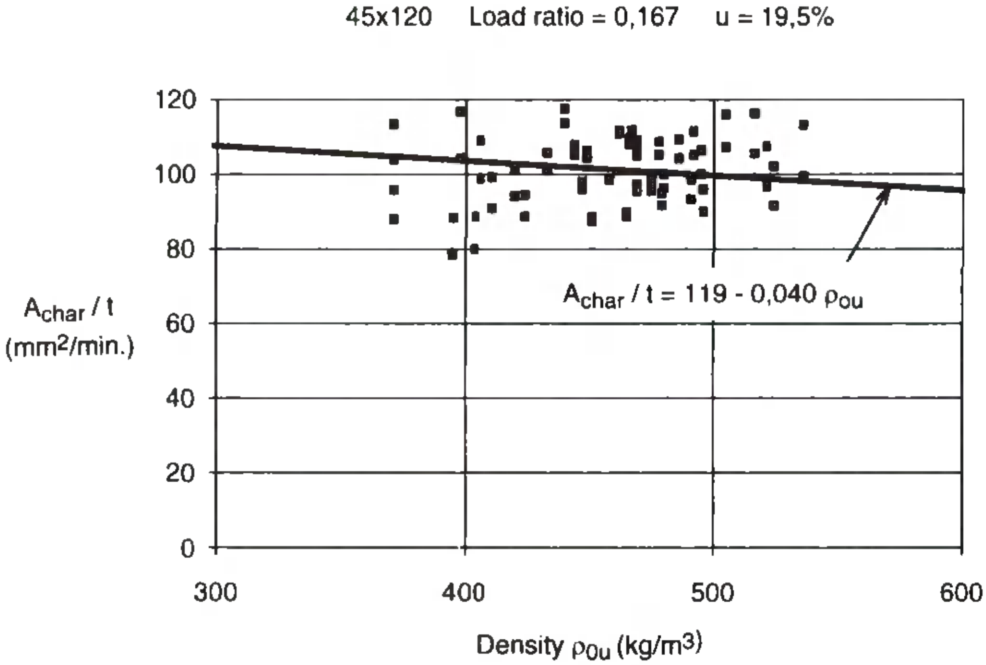




Figure 2 Failure times at same load ratios versus density



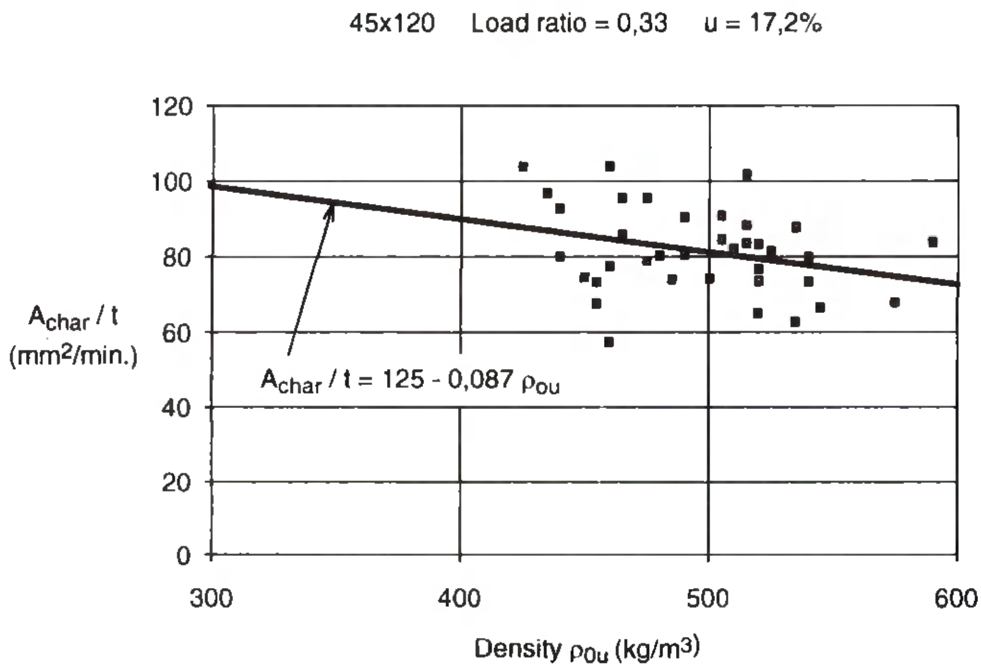
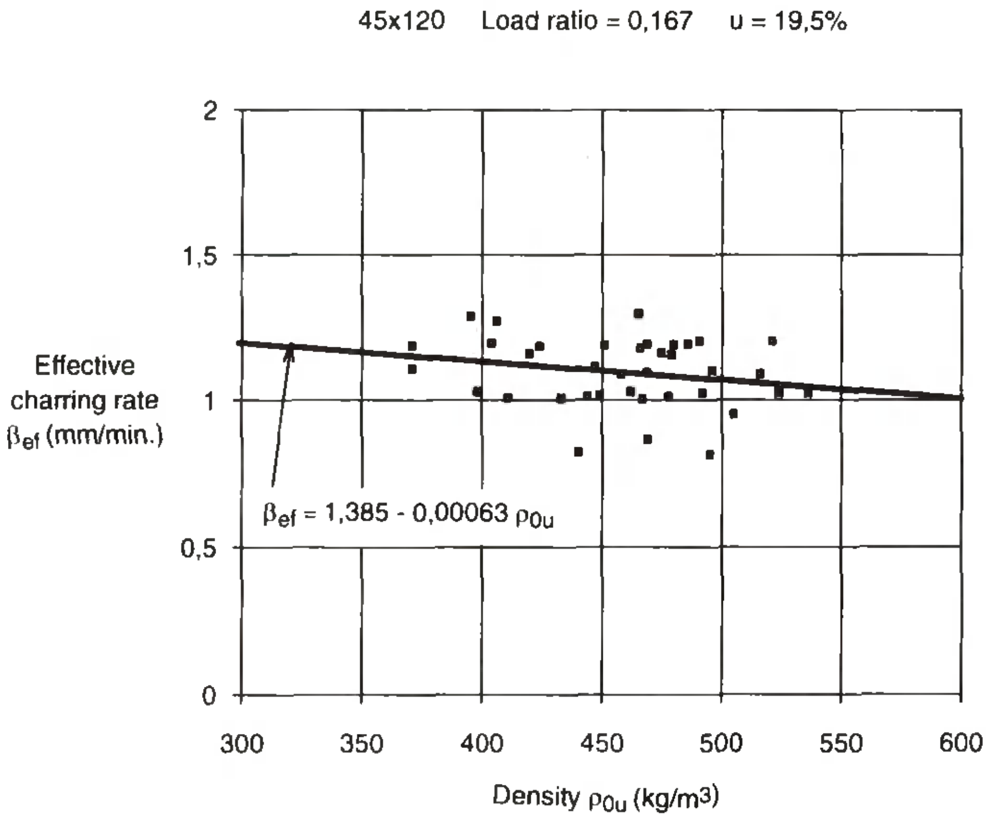




Figure 3 Rate of charred cross sectional area versus density



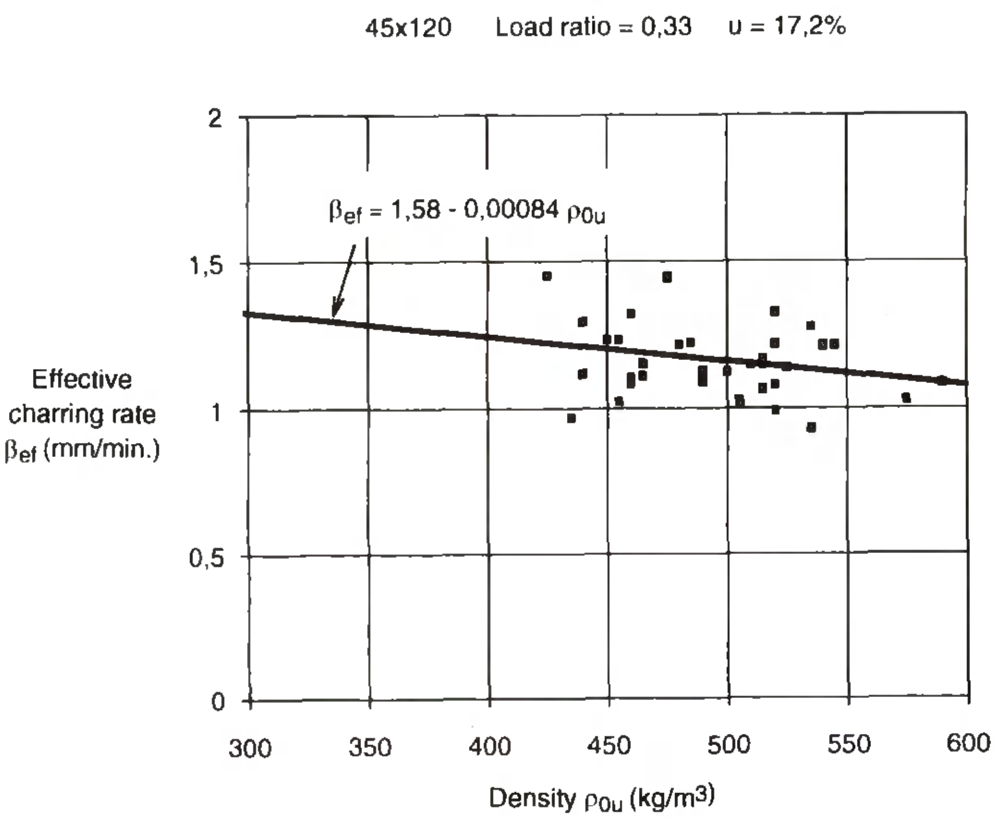




Figure 4 Effective charring rate versus density under the assumption that the bending strength of the residual cross section is not influenced by fire

# SAMMANFATTNING

Brandförsök genomförda av Norén utvärderades med avseende på densitetens inverkan på förkolningshastigheten. Det konstaterades att både den effektiva och den uppmätta förkolningshastigheten varierar ungefär 10 % i densitetsintervallet mellan 290 och 420 kg/m$^2$ vilket representerar karakteristiska densiteter i hållfasthetsklasserna C 14 till C 40 enligt prEN 338, förslag 1991. Försöken visade att densiteten inte påverkade minskningen av det kvarvarande tvärsnittet.

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