Comparing the Performance of Different Types of Cooling Methods on Hot Rolled Steel

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Abstract: **Hot-rolled steel is a common material in modern high- rise and long-span structural systems. Despite its structural advantages, its rapid strength deterioration at elevated temperatures makes it vulnerable to fire events. This study aims to evaluate the effectiveness of passive fire-resistant systems in enhancing the fire endurance of hot-rolled steel elements. A series of tensile coupon tests were conducted on uncoated specimens subjected to temperatures ranging from ambient to 1200°C. Cooling was performed using both air and water quenching methods. The mechanical properties, including stress-strain behaviour, yield strength, ultimate strength, elastic modulus, and elongation, were analysed. Results indicate significant performance variations based on cooling method, offering critical insights for fire-resistant design in steel structures.**

Keywords: Hot-rolled steel, Fire resistance, Passive fire protection, post-fire mechanical properties, Cooling methods.

I.INTRODUCTION

Steel structures, especially those composed of hot-rolled sections, are extensively employed in high-rise buildings and long-span frameworks due to their superior strength-to-weight ratio. However, exposure to fire remains a critical threat to their structural integrity. Unlike reinforced concrete, steel loses strength and stiffness rapidly when heated beyond 500°C, leading to possible structural collapse unless adequately protected.

Passive fire protection systems have been developed to mitigate this vulnerability. This research focuses on evaluating fire-resistant performance through experimental tensile testing and assessing post-fire mechanical properties.

II.OBJECTIVES

This study explores to evaluate the post-fire mechanical properties of hot-rolled steel experimentally. Also to assess the effect of cooling methods (air cooling and quenching) on mechanical properties after fire exposure.

The scope of the work includes assessing stress-strain behaviour, yield and ultimate strengths, elastic modulus, and elongation. Tests performed: tensile testing on coupons at various exposure temperatures (200–1200°C).

III.LITERATURE REVIEW

Several studies have explored post-fire properties of uncoated steel sections. Yu et al. (2019) established that hot-rolled steel exhibits significant strength loss beyond 600°C, with residual properties depending heavily on cooling methods. Zhang et al. (2020) demonstrated that ductility can improve with foam cooling even when ultimate strength drops.

Lu et al. (2016) and Wang et al. (2015) noted that while air cooling preserved ductility, water quenching increased strength variability. Despite individual assessments, comparative studies under identical thermal and mechanical conditions are limited. This project addresses that gap.

IV.METHODOLOGY

1.1 Experimental Setup

Tensile specimens conforming to ASTM A370 standards were prepared from 6 mm thick hot-rolled steel plates. The specimens were heated in a furnace up to target temperatures and cooled via air or water.

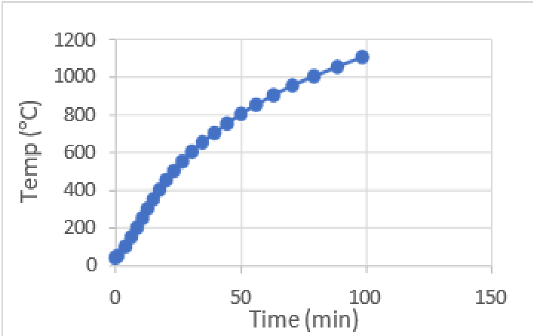

Fig 1: Temp. vs Time graph

1.2 Test Matrix

The study involved heating the specimens to various temperatures and applying two different cooling techniques: air cooling and water quenching. Each condition had 3 replicates.

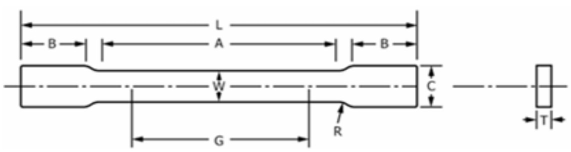

Fig 2 Tensile coupon Dimension

1.3 Measurements

Table 1 Dimension

Property	Sheet-type Specimen (12.5 mm Wide)
Gauge Length (G)	50.0 ± 0.10 mm
Width (W)	12.5 ± 0.25 mm
Thickness (T)	6 mm
Radius of Fillet (R), min	13 mm
Overall Length (L), min	200 mm
Length of Reduced Section (A), min	60 mm
Length of Grip Section (B), min	50 mm
Width of Grip Section (C)	20 mm

Post-exposure tensile testing was performed to extract:

- Yield Strength
- Ultimate Tensile Strength (UTS)
- Elastic Modulus
- Percent Elongation
- Stress-strain curves

V.RESULTS AND DISCUSSION

Initial tests on control (uncoated, unheated) specimens showed average yield strength of ~317 N/mm² and UTS of ~479 N/mm². The following patterns emerged from the heated specimens:

- Uncoated steel showed drastic strength and ductility loss beyond 600°C.
- Air cooling preserved ductility but led to slightly reduced strength.
- Quenching caused hardness increase but also brittleness, especially in samples exposed to high temperatures.

Fig 3 Tensile coupon

VI.CONCLUSION

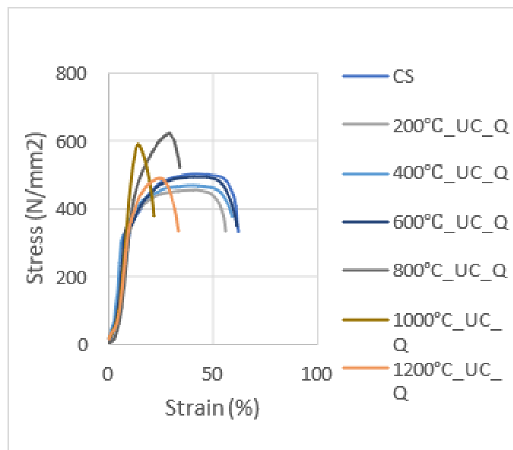

Fig 4 Stress strain curve under Quenching

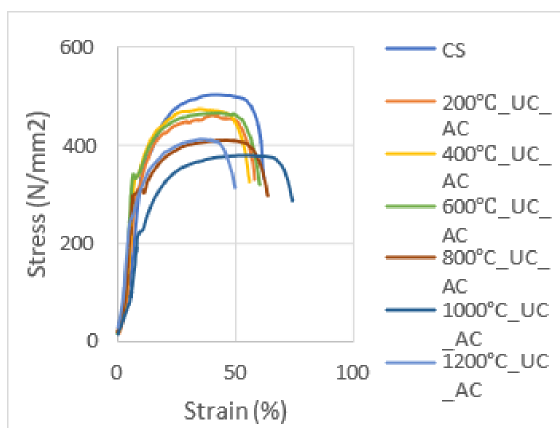

Fig 4 Stress strain curve under Air cooling

Uncoated steel shows significant mechanical property degradation after fire exposure. Cooling methods significantly influence the residual properties—air cooling results in better ductility retention. Further research is suggested using full-scale elements and modelling with software like ABAQUS to validate structural performance.

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