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Investigations on the Mechanical Properties of Hot-Rolled and Cold-Formed Steels subjected to high temperature

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ABSTRACT

Large quantities of hot-rolled and cold-formed hollow sections (Q235), Q345 steel (Q345 or Q420), and other steel components are used in building construction. In the event of fire, steel buildings are exposed to higher temperatures. Determine whether the building can be rescued, repaired, or quickly repurposed after the fire by undertaking an exhaustive analysis of its remaining functionality" Cold-formed Q235 steels with various degrees of cold working were compared to mechanical properties of hot-rolled Q235, Q345, and Q420 steels. Cooling methods included air and water once a variety of temperatures had been reached in the samples. Measurements of stress and strain of post-fire materials were made by conducting tensile coupons tests There are elastic moduli, yield strengths, and ultimate strengths. There was also a look at the heating and cooling processes. Studies show that steel's mechanical characteristics change significantly when heated to temperatures beyond 700 degrees Celsius. Different cooling techniques had a substantial impact, but cyclic heating and cooling had no effect at all. Research on the impact of various cooling procedures on the post-fire mechanical features of hot-rolled and cold-formed steels studied can now be done because of improved prediction models that take these parameters into account.

1. Introduction

These hot-rolled steel sections are often utilized in the construction of buildings as load-bearing components. Steel beams, columns, and joints are often made of Q235 or Q345 steel in China's residential and industrial projects, while Q420 steel is frequently used in the country's skyscrapers. In high-rise and large-span construction projects, Q235 cold-formed hollow sections of various forms (squares, rectangles, or circles) are often used because to their cheap cost and simple manufacturing proces. In the event of a fire, steel buildings are unavoidably subjected to temperatures that would be unthinkable for any other material. Steel structures, in contrast to reinforced concrete buildings, have poor fire resistance, i.e., their performance degrades rapidly when heated. Thus, steel structure fire design is of critical importance. To better understand the high-temperature performance of different types of steel, several investigations have been carried out.

As the temperature rose, steels' strength and stiffness decreased dramatically, according to grades and kinds [1–9]. Design guides like the British Standard (BS) 5950-8 [10] and the European Committee 3 (“EC3”) provided suggestions in line with this finding. Despite this, building structures are often constructed with safety in mind and have a high degree of redundancy built in (e.g., large-span steel structures exhibit high degree of statically indeterminacy). Due to internal force redistribution, whole buildings may not collapse despite the dramatic drop in steel's performance in a fire. Before a building is destroyed, rebuilt, or repurposed after a fire, it must be thoroughly assessed to determine its remaining performance for the purpose of preventing structural collapse. Steel constructions' post-fire performance is heavily reliant on their mechanical qualities.

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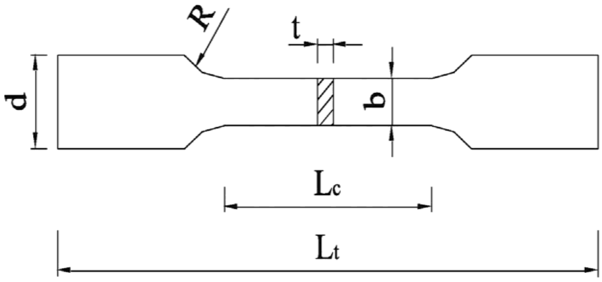
Steels' post-fire mechanical characteristics are now the subject of research in Europe, the United States, Australia, and China, but the study is still in its early phases. The mechanical properties of S355 cold-formed steels were studied in experiments done by researchers Outline and MacLaine [12].The likes of Qiang and others

2.Experimentalinvestigation

2.1Testmaterialsandspecimens"



Hot-rolled steel plates with the grades 235, 345, and 420 were used for the longitudinally oriented cuts in these samples. To meet the standards of GB/T 700 and 1591, steel sheets were used in the building of this facility Grades Q235 denote the nominal yield strength of 235, 345, 345, or 420 N/mm2 for these steels. We cut CFS-F and CFS-C slices from a specimen of 800 x 800 x 20 mm cold-formed square hollow sections (Q235 SHS). The GB/T 6725-2008 standard governs the manufacturing of parts in China. In my opinion, CFS-C has a greater capacity for cold operation than CFS-F does.

Figures 1, Table 1 and Figure 2 are formed and measured in line with GB/T 228.1-2010 and GB/T 4338-2010. There were three measurements made of each specimen's diameter using vernier calipers. These steels' mechanical properties are based on average measurements of their dimensions.

2.2 *Testequipmentandprocedure*

There were just two stages in the whole experiment. An first heating and cooling process brought the specimens up to predefined high temperatures. Phase two saw the specimens undergo a tensile coupon test at room temperature. An electric heater with a temperature control provided heat (Fig. 3). "Because of this, a closed-loop control system was developed by the thermocouple that measured the furnace's air temperature and sent this information to the control system. The specimens in this study were subjected to a total of 10 temperature increases (100°C, 200°C, 300°C, 400°C, and 420°C):

A temperature range between 500°C and 1000°C. CFS-F and CFS-C specimens could only be heated to a maximum of 300 °C for the experiment."These four temperatures are well within the range of engineering requirements, When there is a fire, the maximum temperature that steel members may be subjected to during the fire is 800 °C, However, some nearby residents may be exposed to temperatures of up to 1000 °C or higher. To obtain the goal temperature, the furnace temperature was raised by 50°C every 15 minutes for 10 minutes. A last 20 minutes were spent maintaining the temperature at a five-degree Celsius per minute pace. This heating procedure guarantees that the samples are heated evenly and that the actual temperature does not rise over a predefined threshold. Heater time may be ignored, according to this theory. The next stage was to remove the specimens from the furnace and allow them to cool down. An experiment was carried out to compare the natural extinguishing process with the use of water and air cooling techniques. As a way to mimic how fire extinguishers destroy fires, the water chilling approach was used to cool down the specimens. Figure 4 depicts the whole heating–cooling procedure. Adopting this amount of water for the experiment

Figure:1.ShapesofthehotrolledQ235,Q345,and Q420steelspecimens.

Table1: All three hot-rolled steel specimens have the same dimensions, namely Q235, Q345, and Q420 (mm).

Specimens	t	b	d	R	L_c	L_t
Q235/Q345	7.5	15	30	15	80	220
Q420	7.0	20	30	15	80	200

On the basis of how much water was sprayed on the specimen surface, The amount of water sprayed on the members was found to be comparable to the amount of water sprayed on the members during actual fire suppression. This was the conclusion reached. Water jet flux and firefighting parameters will influence spraying time.

Figure:3.Temperature-controlled electric furnace.

3.Experimentalresults

3.1 Failuremodes

Testing was done on steel specimens that had been exposed to high temperatures, which result in fractures, before they were cooled down. Figure 5 depicts their discovery of the root cause of the problem. Comparative data was gathered from specimens that had not been subjected to high temperatures. No matter the exposure temperature or cooling technique employed to produce ductile failure, cold-formed steels CFS-F and CFS-S, as well as hot-rolled steels Q235, Q345, and Q420, all demonstrated ductile failure with necking. As with CFS-F and S, the ductility was clearly enhanced by increasing exposure temperature. Findings from this research show that hot rolled and cold rolled steel may resist brittle failure after fire exposure, which is good news for the steels' reuse in the aftermath of fires.

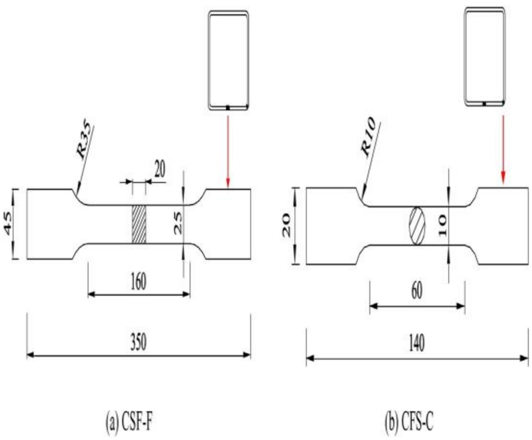
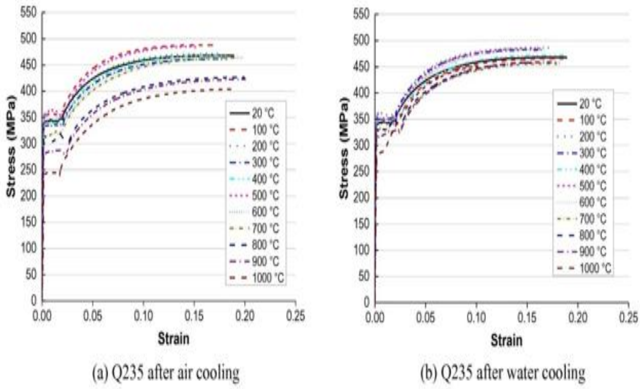


Figure:2.Samplingpositionsanddimensionsofthecold-formedQ235steelspecimens.

3.2 "Stress–strainrelationships"

"Figure 6 displayed in the graph are the stress–strain correlations that were discovered in this experiment after a fire (each curve plotted is one of three curves derived from the specimens in a group). Following their oxidation, these steels' mechanical characteristics were examined using these curves. Both at ambient temperature and after cooling from high temperatures, yields achieved a consistent level regardless of kind of fire or cooling method. Hot rolled steel Q235,Q345, and Q420 stress–strain curves were constant at 700°C."Since the steels had been exposed to such high temperatures, cooling procedures had a substantial impact on the residual yield strength of those steels. Recovering more of their initial yield strength was achieved by water-cooled steel specimens than air-cooled ones. It is because of the quenching action of water cooling, which is like cooling. There's some evidence that steels that have been subjected to fire cannon quenching at temperatures higher than 700 degrees Celsius maintain more of their yield strengths. As a result, cold-formed steel's ultimate strength decreased marginally. These steels can withstand temperatures as high as 800°C without losing any of their ultimate strength, unlike hot-rolled steel, which begins to lose its strength at temperatures over 300°C far earlier than with CFS-F and CFS-C.



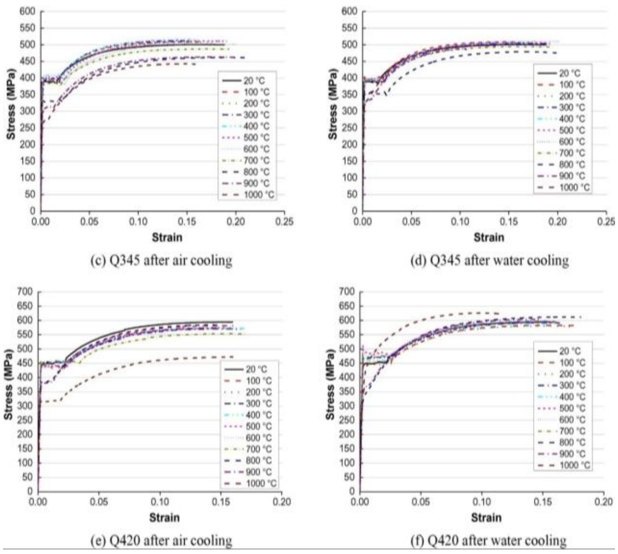


Figure:6Stress–straincurvesafterexposuretovariousfiretemperatures.

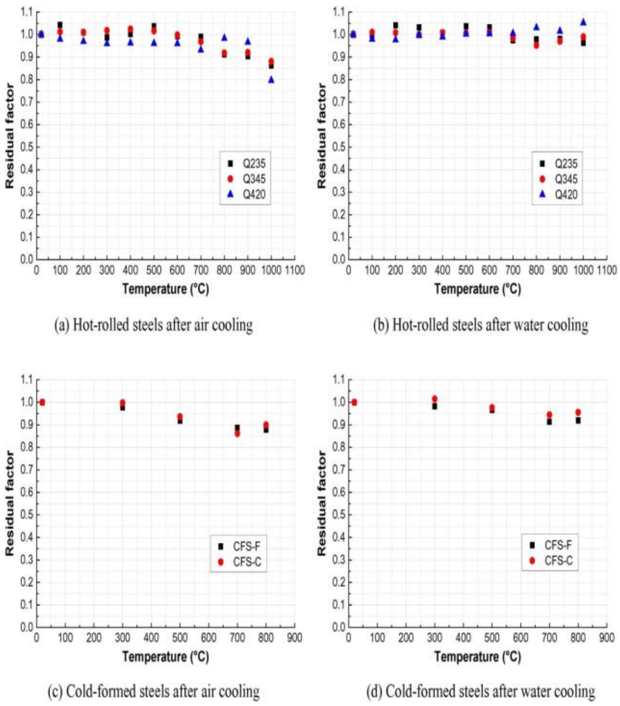


Figure: 10. Post-fireultimate strengthresidual factors."

4.Conclusion

The level and corner portions of Q235 preparations cut from square empty segments have excellent post-fire mechanical qualities, it was determined. Air or water splashing was used to cool the steel to the ambient temperature of 1000 °C (or 800-800 °C for cold-shaped steel). Mechanical data, including as stress-strain bends and flexible moduli, were investigated after ductile samples were submitted to pressure coin testing.

When it came to residual strength and ductility, cooling techniques had a significant influence. There were no significant differences between hot-rolled water-cooled steels and air-cooled steels when it comes to yield, ultimate strength, and ductility. Strength gains were the only thing found in cold-formed steels. As previously noted, current design guidelines and extant literature do not give acceptable suggestions for the re-use of the common steels evaluated in this research. Thus, post-fire elastic moduli may now be properly predicted using new prediction equations that account for the impacts of different cooling processes. The steels tested had good yield and ultimate strengths. Using the predictive equations presented in this study, steel structures' post-fire performance and safety of re-use may be accurately assessed.

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