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Mechanical properties of G550 cold-formed steel under transient and steady state conditions

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A R T I C L E I N F O

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A B S T R A C T

Material properties at elevated temperatures are the important factors in the fire safety design and numerical analysis of cold-formed steel structures. Most of the previous research on material properties at high temperatures has adopted the steady state test method. However, the transient state test method is more realistic for actual fire conditions. This paper presents a detailed experimental investigation of G550 steel with a thickness of 1 mm under both transient and steady state test methods. The test results obtained from transient and steady state methods are discussed, and the results show that the steady state method is not equivalent to the transient state method for G550 steel. The steady state test results of G550 may result in an overestimate of the fire resistance of cold-formed steel structures. In addition, the test results were also compared with those obtained from other researchers and the current design rules. The comparison shows that the yield strength predicted by BS5950 agrees well the transient state test results of G550 and is conservative for the steady state test results. However, BS5950, AS4100, and Eurocode 3 provide nonconservative predictions in other cases. Finally, a unified equation for the reduction factors, including the yield strength, elastic modulus, and ultimate strength of G550 at elevated temperatures, is proposed by the numerical fitting technique. A stress–strain expression of G550 at elevated temperatures is also given based on the Ramberg–Osgood model. The proposed equations are in good agreement with test results and meet the requirements for engineering.

1. Introduction

Cold-formed steel structures originate from traditional timber structures and have been used extensively in low-rise residential, industrial, and commercial buildings. In recent years, a growing number of mid-rise buildings have been framed with cold-formed steel as the primary load bearing structural components. The corresponding fire safety problems concerning cold-formed steel mid-rise buildings are becoming increasingly conspicuous. This paper focuses mainly on the mechanical properties of cold-formed steel at elevated temperatures because mechanical properties are considered the primary factor that affects the performance of steel structures during fires.

The mechanical properties at elevated temperatures recommended by Eurocode 3 [1], AS4100 [2], and BS5950 [3] are based on investigations of hot-rolled steel. Compared with hot rolled steel, cold-formed steel has a higher section factor and thermal conductivity. At the same time, the strengthening effect of the cold-forming [1] process of cold-formed steel is progressively reduced at high temperatures. Hence, the loss of mechanical properties in cold-formed steel is greater than in hot rolled steel at elevated temperatures [4], and the current design rules are unreasonable.

Both steady and transient state test methods are currently used to investigate the mechanical behavior of steel at elevated temperatures. The steady state test method is based on a constant temperature under increasing static loading, and the transient state test method is based on temperature variations under a constant load. The steady state tests are easier to perform than the transient state tests because of the lower requirements of experimental conditions. In addition, the steady state tests give the stress–strain curve directly whereas the transient state tests give the temperature–strain curve, which must be converted to a stress–strain curve. Approximate values of the mechanical properties cannot be avoided in the process of conversion. However, the transient state test method is more realistic because it simulates real fire conditions.

Most of the previous research on mechanical properties at elevated temperatures adopted the steady state test method [5–11]. However, the steady state test results are not very satisfying and differ among each other, probably because of the inadequacy of test facilities and differences in the chemical composition of cold formed steels. The test results obtained by Lee [5], Ranawaka [6,7], and Heva [8] show a clear oscillation in the elastic phrase of stress–strain curves. The oscillation could easily lead to errors in the determination of the elastic modulus. Chen and Young [9,10] conducted steady state

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