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Review on Flexural Behaviour of Cold Formed Built-up Channel Sections Subjected to Fire was Investigated Experimentally

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ABSTRACT:The great majority of the studies in this area emphasise further the structural behaviour of cold-formed steel members by means of analytical approximation and purely numerical methods. In addition, they generally only take into account the structural behaviour of members with just one profile. On the contrary, this paper reports a series of flexural tests under fire conditions focused on cold-formed galvanised steel beams consisting on compound cold-formed steel profiles which are often used in floors and roofs of warehouses and industrial buildings. The main objective of this research was to assess the failure modes, the critical temperature and the critical time of the studied beams. Other important goals of this research work were also to investigate the influence of the cross-sections, the axial restraint to the thermal elongation of the beam and the rotational stiffness of the beam supports. Finally, the results showed above all that the critical temperature of a cold-formed steel beam might be strongly affected by the axial restraint to the thermal elongation of the beam.

KEYWORDS:Cold-formed ,Steel, Beam, Flexural, Fire, Buckling.

I. INTRODUCTION

The use of cold-formed steel (CFS) profiles in buildings is a solution that is under continuous development, and so it will remain a challenge for the next few years. They are increasingly becoming a popular material in construction because they provide a high strength to weight ratio, they are easy to produce, transport and assemble when compared to heavier hot-rolled steel members. Studies in this area are still few, and mostly of a numerical nature. However, there are some that address the most important phenomena related to these elements at room temperature, including post-buckling resistance (local and distortional buckling), global flexural, torsional and flexural-torsional buckling, shear resistance, bending resistance.

Cold-formed steel behave quite differently from hot-rolled steel members. This is due to the high slenderness of the cross-section's walls (high ratio width/thickness of the wall) and the low torsional stiffness (much lower than the flexural stiffness), and to the fact that in many of these cross-sections, the shear centre does not coincide with the centre of gravity and the great majority of the cross-sections are open and either mono symmetric or completely asymmetric. Consequently, these members may buckle at a stress level lower than the yield point of steel. It is therefore clear that cold-formed steel members are more susceptible to instability (local and global) than hot-rolled ones, and there are still many open questions to investigate. As it is an emerging technology and since a great variety of profiles with different geometric shapes can be easily produced, it is of the almost importance that studies in this field should be undertaken.

When it comes to fire, there are even fewer studies related to the behaviour of cold formed steel elements subject to high temperatures. Fire is another phenomenon which deteriorates its structural behaviour. The high thermal conductivity of steel and the high section factor of these structural members (very thin wall thickness) can lead to a rapid rise in steel temperature in a fire and together with the deterioration of its mechanical properties as a function of temperature may cause serious deformation of structural members and the premature failure of the building, like it happens with the hot-rolled steel structural members. Since the structural behaviour of usual bare steel members under fire conditions may constitute a limiting ultimate limit state condition, investigations into CFS members under fire are required, especially because there are no simplified calculations methods for fire design of CFS structures, unlike for hot-rolled steel members, see EN1993-1.2

II.LITERATURE REVIEW

2.1 Luis et al. (2013) "Experimental analysis on cold-formed steel beams subjected to fire"

In this Paper, the main objective of this research was to assess the failure modes, the critical temperature and the critical time of the studied beams. Other important goals of this research work were also to investigate the influence of the cross-sections, the axial restraint to the thermal elongation of the beam and the rotational stiffness of the beam supports. Finally, the results showed above all that the critical temperature of a cold-formed steel beam might be strongly affected by the axial restraint to the thermal elongation of the beam. The main conclusion of this research work was that critical temperature of a CFS beam might be strongly affected by the axial restraint to the thermal elongation of the beam, even for low values of axial restraint. However, in general it seems that the failure modes become more complicate in CFS beams with complex boundary conditions.

2.2 Luis et al. (2015) "Flexural behaviour of axially and rotationally restrained cold-formed steel beams subjected to fire"

The main purpose of this work was to evaluate the influence of different cross-sections, especially of compound cold-formed steel sections, the axial restraint to the thermal elongation of the beam and the rotational stiffness of the beam supports. From the experimental results, it seems that the critical temperature and consequently the fire resistance of CFS beams should still depend on other parameters, such as, the ratio of the axial stiffness of the surrounding structure to the axial stiffness of the beam, the ratio of the rotational stiffness of the surrounding structure to the rotational stiffness of the beam and one which takes into account the section geometry (if it is an open, closed, single or compound section), among others.

2.3 Craveiro et al. (2016) "Experimental analysis of built-up closed cold-formed steel columns with restrained thermal elongation under fire conditions"

An experimental research on the fire behaviour of compressed cold-formed steel columns with closed built-up cross-sections and restrained thermal elongation is presented. Several parameters were assessed, including the influence of loading level, boundary conditions, restraint to thermal elongation imposed by the surrounding structure and cross-sectional shape. between the initial applied load and the imposed level of restraint to thermal elongation may significantly influence the overall behaviour of CFS columns under fire conditions. If a column could freely expand when subjected to fire, no additional forces (restraining forces) would be generated. However, when some level of restraint exists additional compressive forces are generated, which may lead to premature collapse and consequently to lower critical times and column temperatures. Increasing the level of restraint imposed by the surrounding structure, the magnitude of restraining forces generated in the column also increased and the peak value was reached at much lower temperatures. It seems that increasing the level of restraint may allow column buckling to be controlled by axial restraining forces, whereas at lower levels of restraint buckling is controlled by a temperature increase and consequent degradation of the mechanical properties of steel.

2.4 Muftah et al. (2016) "Experimental investigation of cold-formed steel (CFS) channel material at post elevated temperature."

The two channel sections were used for study of cold formed steel at post elevated temperature. The specimens were passed through two stages of condition. The first condition was heating condition at temperature of 1000oC to 1100oC to simulate the cold formed steel under heating in the furnace. Then the specimens were cooled to ambient condition for a period of time until it achieves ambient temperature. The tensile coupon test was conducted. The cooled specimens were tested for tensile until it fails. In the review, the GDSChemical analysis of metal testing services was used to determine the metal-based properties of CFS. The other parameters like colour, weight reduction was also tested at post elevated temperature. It was concluded from the extensive study that, the material properties like yield strength reduces, elastic modulus suddenly drops and ultimate strength reduces gradually at post elevated temperature.

2.5 SivakumarKesawan and Mahen Mahendran (2017), "Post-fire mechanical properties of cold-formed steel hollow sections."

This paper presents the details of an experimental investigation on the post-fire mechanical properties of cold-formed steel hollow sections. Tensile tests were performed on coupons exposed to elevated temperatures varying from 100 C to 800 C and then cooled down to room temperature. These coupons were cut from cold-formed steel square and rectangular hollow sections with varying thicknesses and grades. The results from this investigation provided post-fire stress-strain curves, yield strengths, ultimate strengths and elastic modulus, and their reduction pattern. They show that the post-fire mechanical properties of cold-formed steel hollow sections are different to those of open cold-formed channel and hot-rolled sections. New predictive equations were proposed to determine the post-fire mechanical property reduction factors. Post-fire mechanical properties were also compared with their elevated temperature mechanical properties to evaluate their strength gain after cooling down. This paper also evaluates various strength enhancement techniques for use with fire damaged cold-formed steel hollow sections. The coupons taken from these sections were heated up to temperatures ranging from 100 to 800 C, and then allowed to cool down. Tensile tests of these coupons were then performed and their stress-strain curves and the post-fire reduction factors of yield and ultimate strengths and elastic modulus were obtained. It was found that the loss of Cold-formed channel sections are screwed to a box section to increase its capacity Cold-formed angle sections are screwed to a box section to increase its capacity Hollow section. The hollow sections were able to retain 74, 66 and 55% of their ambient temperature capacity when exposed to temperatures of 600, 700 and 800 C, respectively. The elastic modulus remained the same even after heating up to 500 C. The steel was able to regain more than 80% of its ambient temperature elastic modulus value after being exposed to 800 C

2.6Tekcham Gishan Singh and KonjengbamDarunkumarSingh (2018), "Post-fire mechanical properties of YSt-310 cold-formed steel tubular sections"

An experimental programme to study the residual mechanical strength of Tata Structura-YSt 310 cold-formed steel square and rectangular tubular sections (conforming to Indian Standard 4923) after being exposed to elevated temperature is described in this paper. First, the coupon specimens extracted from the flat regions are exposed to pre-determined elevated temperature in the range ~ 300–800 °C, and then the residual mechanical properties and hardness value were estimated at ambient temperature after natural air cooling. The results from the experimental programme are reported in this paper in the form of post-fire stress-strain curves and associated basic material properties (eg. elastic modulus, proof stresses, tensile strength, percentage elongation at fracture, Ramberg-Osgood material parameters etc.) as well as surface hardness values. The post-fire yield strength and tensile strength were able to retain at its parent material ambient temperature material strength when the exposed temperature was below 400 °C, but significantly reduced to 59% and 77% respectively when exposed to 800 °C. Two correlations between yield and tensile strengths against hardness value were developed to provide an alternative for determining material strengths, without actually performing tensile coupon test.

2.7 Viorel et al. (2018). "Behaviour of thin-walled cold-formed steel members in eccentric compression."

For the study of cold-formed steel structures five different types of plastic mechanisms for members in compression with different eccentricities were identified and examined on the basis of FE numerical simulations. In consideration with influence of buckling mode, the failure mode of the compressed bar and the buckling behaviour of examined columns was investigated. The analysis was carried out using CUFSM code based on Finite Strip Method as well as FE analysis. For two cases (positive and negative eccentricities) the FSM and FE results were verified using an analytical numerical method. From the study conducted it was found that, for all positive eccentricities a typical distortional buckling takes place. For the smallest negative eccentricities, a local distortional buckling mode was observed. For larger negative eccentricities the local buckling takes place.

2.8 Chong et al.(2020) "Experimental investigation of post-fire mechanical properties of Q235 cold-formed steel."

This paper presents an experimental investigation on post-fire mechanical properties of cold-formed steels. The test specimens were cut from flat portion and corners of cold-formed channel sections, which were exposed to temperatures ranging from ambient temperature to 800C, and then cooled with water and air. The specimens are of grade Q235, with section thicknesses of 1 mm and 2 mm. The stress-strain curves and mechanical properties of the specimens were obtained from tensile coupon tests.it should be noted that the yield strength increased after exposed to high temperatures and cooled with both cooling methods, but increased more with water cooling. Under air cooling condition, ultimate strengths of all flat and corner specimens almost remained the same. However, the ultimate strengths increased significantly after being water cooled from exposed temperatures beyond 600 C.

2.9 Yang et al. (2020) "Experimental study on fire resistance of cold-formed steel built-up box columns"

In this paper, a full-scale experimental investigation on fire responses of sixteen axially loaded cold-formed steel built up box columns was conducted. As a benchmark, the load-bearing capacity of the columns at ambient temperature was tested first. The effects of heating rate, load ratio, and temperature distribution pattern on the fire responses of the columns were investigated in the fire tests. Non-uniform distribution of temperature along the height of the column influenced not only the location of the failure region of the specimens but also yielded higher member critical temperatures. When the columns were subjected to elevated temperature, creep deformations were observed to be more significant when lower load ratios were applied, which was attributed to longer exposure time and higher surrounding temperature.

2.10 Chen et al. "High-temperature steady-state experiments on G550 cold-formed steel during heating and cooling stages."

Most previous investigations on the high-temperature material properties of cold-formed steel (CFS) focused on the heating stage of steel, corresponding to the growth and fully developed phases of a compartment fire. The influence of the cooling stage of steel, which corresponds to the decay phase of a compartment fire, has not been properly considered. This study conducted 88 steady-state tests on G550 CFS at elevated temperatures and investigated the material properties during the heating and cooling stages. The results show that the prediction of the time dependent load-bearing capacity of CFS structures under compartment fires might become non-conservative if the material properties of the G550 CFS during the cooling stage are replaced with those during the heating stage. For instance, when the tensile temperature is less than 500C and the peak temperature is greater than or equal to 600C, the yield strength reduction factors of G550 CFS during the cooling stage are significantly lower than those during the heating stage under the same tensile temperature.) The distribution of the yield strength (ultimate strength) reduction factors of G550 CFS during the cooling stage is affected by the peak and tensile temperatures and displays two branches. One branch is for a peak temperature not less than 600 C and tensile temperatures less than or equal 500 C. The second branch is for the other peak and tensile temperatures. For each branch, the yield strength and ultimate strength reduction factors of G550 CFS during the cooling stage are similar under the condition of the same tensile temperature and different peak temperatures. However, the differences in the yield strength and ultimate strength reduction factors between the two branches become significant under the condition of the same tensile temperature and different peak temperatures

III.CONCLUSION

1) The results showed above all that the critical temperature of a cold-formed steel beam might be strongly affected by the axial restraint to the thermal elongation of the beam.
2) The critical temperature of a cold-formed steel beam might be strongly affected by the stiffness of the surrounding structure depending on the relation between its stiffness and the stiffness of the beam.
3) The increase in the non-dimensional axial restraint ratio and column load levels lead to a decrease in critical temperatures.
4) There is scope to carry out research studies on flexural behaviour of cold formed built-up channel section subjected to fire.

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