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Elevated temperature resistance of concrete columns with axial loading

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Abstract. The influence of temperature on the material of concrete filled columns (CFCs) under axial loading has been quantitatively studied in this research. CFCs have many various advantages and disadvantages. One of the important inefficiency of classic CFCs design is the practical lack of hooped compression under the operational loads because of the fewer variables of Poisson's rate of concrete compared to steel. This is the reason why the holder tends to break away from the concrete core in elastic stage. It is also suggested to produce concrete filled steel tube columns with an initial compressed concrete core to surpass their design. Elevated temperatures have essentially reduced the strengths of steel tubes and the final capacity of CFCs exposed to fire. Thus, the computation of bearing capacity of concrete filled steel tube columns is studied here. Sometimes, the structures of concrete could be exposed to the high temperatures during altered times, accordingly, outcomes have shown a decrement in compressive-strength, then an increase with the reduction of this content. In addition, the moisture content at the minimal strength is declined with temperature rising. According to Finite Element (FE), the column performance assessment is carried out according to the axial load carrying capacities and the improvement of ductility and strength because of limitations. Self-stress could significantly develop the ultimate stiffness and capacity of concrete columns. In addition, the design equations for the ultimate capacity of concrete columns have been offered and the predictions satisfactorily agree with the numerical results. The proposed based model (FE model of PEC column) 65% aligns with the concrete exposed to high temperature. Therefore, computed solutions have represented a better perception of structural and thermal responses of CFC in fire.

Keywords: elevated temperatures; finite element technique; concrete-filled columns; mathematical model

1. Introduction

Typically, CFC is used in construction around the world, particularly in high-rise constructions with inclined grid of columns, for example, in Eastern and South-East Asia located in high seismic activity areas. CFCs have developed bearing capacity and caused a big deformability because of the hooped compression produced by steel holder of concrete material (Naghipour *et al.* 2020, Shariati *et al.* 2020b, Shariati *et al.* 2020c, Shariati *et al.* 2020d, Shariati *et al.* 2020f). CFCs are widely applied to resist against the heavy load (s) in high-rise constructions. Concrete column is accepted as an important result that remarkably raises the stiffness and strength of hollow steel, and essentially develops its fire resistance. Concrete material is totally encased by steel tube, thereby showing an improved ductility. Additionally, steel tube performs as a longitudinal permanent formwork and reinforcement for the filled concrete that highly reduce projects' costs & time. Steel tube also represents the quasi-plastic nature of destruction, even using high strength concrete (Armaghani *et al.* 2020, Shariati et el. 2020a, Shariati *et al.* 2020g). Building resistance across earthquake is essentially raised due to the use of such columns in building frames. Recently, CFC is commonly used in modern buildings such as the retrofit of existing structures (Mahdi Shariati 2019b). In this study, a numerical method is offered to completely represent the structural behavior of bolted shear connectors in CFST in failed load transfer regions because of concrete crushing adjusted to a triaxial stress state with more cracks close to connector region (Shariati *et al.* 2020e). This analytical method has been delineated according to the numerical study that uses a concrete constitutive model as Concrete Damaged Plasticity (CDP). Various non-linear relationships for concrete have been examined in this numerical study based on the relationships in standard EN1992-1-1:2004, and by (Phung-Van *et al.* 2015) with diverse fictitious crack width for estimation the fracture behavior of concrete. Despite few studies in CFC usage in concrete composite structures and steel (Wang *et al.* 2004) has presented a numerical outcome of CFC and tested 12 specimens to analyze the axial-flexural interactions of concrete filled carbon columns with/without CFC reinforcing bars. Recent research has shown that the behavior of CFC strips make CFST short-columns[1]

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[1]Behavior of Concrete-Filled Columns

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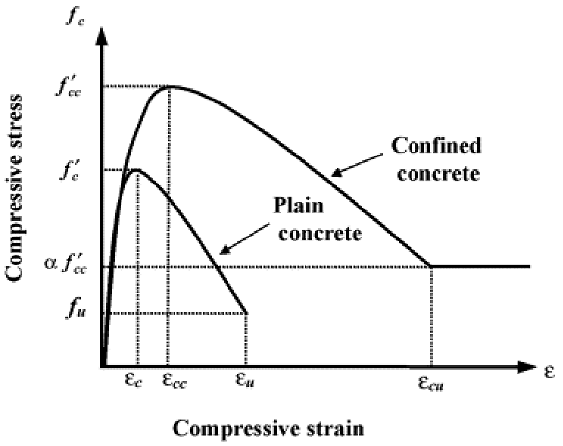

Fig. 1 Equivalent uniaxial stress strain trend for concrete fill column

strength. Accordingly, the lateral deformation of CFC provides impressive restraint against more wrapping of CFC strips (Purba *et al.* 1999, Takawa *et al.* 2000, Michels *et al.* 2014, Pan *et al.* 2017). A new CFC comprising a concrete column wrapped with FRP sheet and partially encased in concrete is offered (Fig. 1). Analytical capacities of CFC concrete columns under axial loading are properly forecasted by some standards. Unlike CFCs, the eccentric axial load behaviour of concrete columns by applying other non-CFC types is empirically studied. According to a related literature, through ABAQUS with a bilinear stress-strain relationship for bolted shear connectors material, (Nguyen-Thoi *et al.* 2018) has investigated force transfer in steel and concrete components of composite columns. After attaining the tensile strength, a descending linear stress-strain relationship has been applied for concrete tensile behavior. More tests that are empirical have been performed in last 40 years on CFT columns behavior adjusted to concentric, seismic and eccentric loadings. Accordingly, the major test parameters were strength of materials, shape of cross-section, type and slenderness of loading. High attention is cast to CFT column behavior fabricated from high-strength materials. A recent research by (Ahmadi *et al.* 2019) have reported from eccentric loading tests on 41 circular CFT columns with f_y=410–435 MPa and 100 MPa, in which load eccentricity and slenderness have essentially influenced the strength of columns. Regarding the meritts and demirtis of two composite column types, (Wang *et al.* 2015) has suggested Steel-reinforced concrete filled column. An emprical-numerical study has been presented by while showig the behavior of composite beams composed of steel beams and overlapped by concrete slabs and testing the application of various bolted shear connectors' type. Shear connectors application has been used to reinforce a bridge in Texas, USA, in which the raise of loading by 75% is possible. A recent research has verified the behavior of headed studs and high strength bolts as shear connectors. Concerinng the purpose of this research, only column tests loaded with equal end eccentricities to be resulted in single curvature bending have been taken. For Table 1, a choice parameter of *Le/D N 6* has been applied to make discrepancy between the long columns and the short columns. An analytical study is performed to understand the behavior of CFC limited encased concrete columns. The influence of slenderness ratio and CFC layers' number on axial load relationship has been verified. On this circumstance, the impact of porosity or moisture content on the compressive strength has been solely studied in literature (Shariati *et al.*). However, concrete structure might be exposed to altered elevated temperature in different time periods (in practical engineering). Furthermore, steel beam could be expanded quicker than concrete material in a radial direction, while the steel tube has not restrained the concrete core. Thus, no division has been existed between the adjacent concrete and steel at this point (Shariati *et al.* 2019g). In contrast, when the applied load reaches the uniaxial strength of concrete, concrete micro cracking is started and propagated. The lateral expansion of concrete reaches its maximum while mobilizing the concrete column and confining the concrete material efficiently. Therefore, final CFC capacity is more than the sum of their components' resistance. Radial stress defined by steel tube on concrete is responsible for more concentrically resistance loaded CFC columns, in which steel beam is under a biaxial stress state and concrete core is subjected to a triaxial stress state (Zhou *et al.* 2019). Those parameters that control the behavior of concrete such as creep strain, compressive and tensile strengths, thermal conductivity and thermal strain and modulus of elasticity are non-linear temperature's functions (Yagiz *et al.* 2012). The mechanical features affecting the fire function of RC members are modulus of elasticity, strain response of constituent materials at elevated temperatures and compressive and tensile strength. Adding that many constitutive methods for compressive and tensile strength for concrete at normal temperature are studied. The laws for concrete material under fire condition are complex while having limited material test data in thermal properties. There are more variations in high temperature test data for other properties of concrete and limited test data for some high temperature properties had done by (Phan-Dao *et al.* 2013). These alterations are majorly because of the test methods' variation, condition of processes, and the environmental parameters following the tests by (Mahdi Shariati 2019a). As a result, there are no reliable constitutive relationships in standards and codes for majority of high temperature features of concrete which carried out by (Mclister *et al.* 2014).

Table 1 Specification of profile steel

Profile steel	f_y (MPa)	E_s (GPa)	ε_y
Steel flange	240	203	1222

2. Methodology

2.1 Finite element model and mesh

Owing to the thin-walled nature of steel beam, shell elements have been used for modelling of steel tube. In this study, the two-node shell elements with reduced integration

Table 2 Parameters of test

Sample of test	CFC substrate	Slenderness ratio l0/L	Column height (cm)	Profile steel slenderness (cm)
C4F2	1	5.6	40	12
C4F5	3	4.3	40	12
C4F3	5	3.7	30	13
C4f5	7	4.8	60	12
C6f9	0	6.4	80	12
C6f6	1	6.9	65	15
C6f2	6	7	70	12
C6f3	3	6.6	90	12
C8f8	0	8.2	100	12

SHELL171 has been facilitated beside the use of steels conforming to Chinese standard Q245 steel. The width and height of steel sections are 125 mm, while the web thickness is 8.5 mm and the flange thickness is 9 mm (Table 1). Concrete mixed proportion has been designed to gain the target strength of 20 MPa based on the regulation for Mix Proportion of Concrete (Schafer *et al.* 1999, Sinaei *et al.* 2011, Jalali *et al.* 2012, Shah *et al.* 2015, Shariati *et al.* 2016, Khorami *et al.* 2017a, Heydari *et al.* 2018, Huang *et al.* 2018, Ismail *et al.* 2018, Ziaei-Nia *et al.* 2018, Luo *et al.* 2019, Milovancevic *et al.* 2019, Sajedi *et al.* 2019, Shariati *et al.* 2019b, Xie *et al.* 2019). The nominal thickness of each layer of CFC is 0.167 mm and the width of each layer of CFC sheet is 100 mm. The ultimate tensile strength is 3471 MPa, elastic modulus of CFC sheet is 255 GPa and tensile strain at fracture is 0.45% (Arabnejad Khanouki *et al.* 2010, Hamidian *et al.* 2011, Shariati *et al.* 2011a, Shariati *et al.* 2011c, Shariati *et al.* 2012a, Shariati *et al.* 2012b, Mohammadhassani *et al.* 2013b, Mohammadhassani *et al.* 2014a, Mohammadhassani *et al.* 2014b, Shah *et al.* 2016a, Shah *et al.* 2016b, Shahabi *et al.* 2016b, Khorramian *et al.* 2017, Mansouri *et al.* 2017, Hosseinpour *et al.* 2018, Paknahad *et al.* 2018, Sadeghipour Chahnasir *et al.* 2018, Shariat *et al.* 2018, Toghroli *et al.* 2018a, Toghroli *et al.* 2018b, Li *et al.* 2019, Trung *et al.* 2019a).

2.2 Material constitutive models

CFT columns include steel materials and concrete. Uniaxial behavior of steel beam could be simulated by an elastic-plastic model with a related flow rule. When the steel beam is adjusted both axial and uniaxial stresses, a von Mises yield criterion (F) is conducted to identify the elastic behavior as follows

$$F=\sqrt{3J2}=\frac{1}{\sqrt{3}}=\sqrt{(\sigma_1-\sigma_2)^2_+(\sigma_2-\sigma_3)^2+\sigma_3-\sigma_2} \quad (1)$$

J_2=second stress invariant of stress deviator tensor

σ_1, σ_2, σ_3=main stresses for steel beams

12 specimens comprising 9 CFC limited particularly encased concrete columns and 3 partially encased concrete materials have been provided for test under finite element software. Sample of models is in the height of 60 cm, 80 cm and 100 cm. Design parameters of specimens including their fabrication process are shown in Fig. 2 and Table 2.

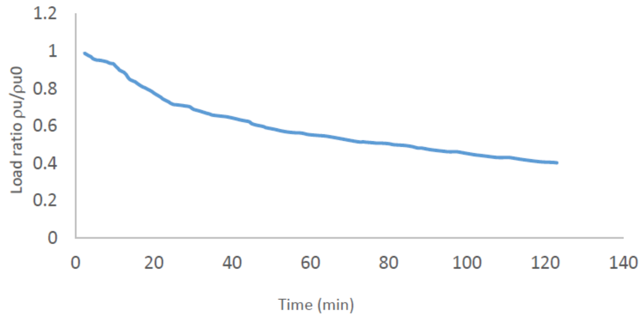

Fig. 2 The load ratio of CFC column with *b/ts* ratio of 60 seconds at various exposure periods to standard fire

For monitoring the evaluation of columns' axial, two Linear *v* displacement transducers are located on the axial load at the beneath of model system (Fig. 3).

2.3 Load-axial displacement behavior

Fig. 10 shows the variations of applied axial load *(P)* with a measured axial displacement *(δv)* for the tested columns. The results have illustrated that for specimens of a particular *D/t* rate, axial stiffness is declined by raising the eccentricity with a decline which is more pronounced for the specimens with higher eccentricity (*e/D*=0.4) (Shariati *et al.* 2020d, Shariati *et al.* 2020h, Shariati *et al.* 2020i). This possibly corresponds to more concrete cracking occurred for the specimens because of the tensile stresses in cross-section from the tests' starting, unlike the specimens with lower *e/D* values. This resembles the behavior that is observed earlier for short CF-SWST columns. The impact of CFC sheet layers' number has been described by the load curves of test models. The load-displacement trend of tests is linear in the initial stage, meaning that test models are in elastic stage. By keeping on the increasing of axial load, the result shows slight discrepancy. By raising the number of CFC sheet layers, stiffness and bearing capacity of columns are also increased. Indeed, CFC columns have better ductility and deformation capacity (Ismail *et al.* 2018, Sadeghipour Chahnasir *et al.* 2018, Shariat *et al.* 2018, Toghroli *et al.* 2018a, Toghroli *et al.* 2018b, Chen *et al.* 2019, Davoodnabi *et al.* 2019, Katebi *et al.* 2019, Li *et al.* 2019, Luo *et al.* 2019, Milovancevic *et al.* 2019, Safa *et al.* 2019, Shariati *et al.* 2019b, Shariati *et al.* 2019c, Shariati *et al.* 2019d, Shariati *et al.* 2019e, Suhatril *et al.* 2019, Trung *et al.* 2019a, Trung *et al.* 2019b, Xie *et al.* 2019). Thus, stiffness is declined by raising the slenderness rate. The columns' axial load with higher slenderness rate is dropped quickly after the peak load, while compared to the columns with lower slenderness rate. It shows better deformation ability for the columns with lower slenderness rate, thus there will be a significant increase by decreasing the axial load ratio (Arabnejad Khanouki *et al.* 2011, Daie *et al.* 2011, Hamidian *et al.* 2011, Shariati *et al.* 2011a, Shariati *et al.* 2011b, Shariati *et al.* 2011c, Sinaei *et al.* 2011, Jalali *et al.* 2012, Shariati *et al.* 2012a, Shariati *et al.* 2012b, Shariati *et al.* 2012c, Sinaei *et al.* 2012, Mohammadhassani *et al.* 2013a, Mohammadhassani *et al.* 2013b, Shariati *et al.* 2013, Mohammadhassani *et al.* 2014a, Mohammadhassani *et al.*

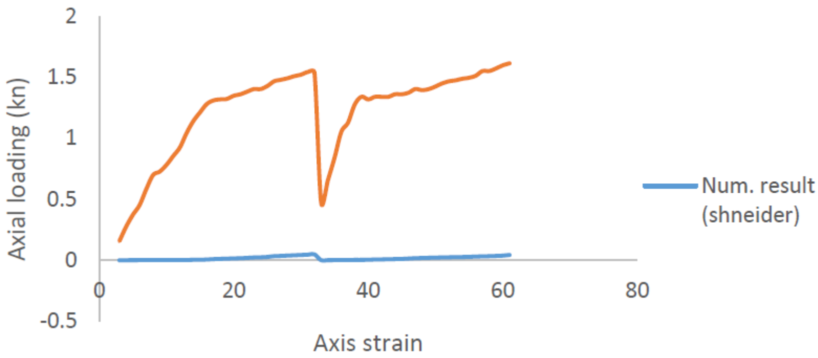

Fig. 3 Verification of developed model

Table 3 the impact of temperature of concrete

Temperature (°C)	Water loss (g/cm^3)	Drying time (h)			
		Sr=95%	*Sr*=50%	*Sr*=35%	*Sr*=0%
25	63.4	7	23	81	300
109	179.9	3.5	8	88	27
158	186.7	8.5	3.3	6	60
206	172.8	1.3	0.5	8.8	8.5
260	167.8	2.15	0.7	3.3	6.5

2014b, Shariati *et al.* 2014b, Toghroli *et al.* 2014, Khorramian *et al.* 2015, Shah *et al.* 2015, Shao *et al.* 2015, Shariati *et al.* 2015, Khanouki *et al.* 2016, Safa *et al.* 2016, Shah *et al.* 2016a, Shah *et al.* 2016b, Shah *et al.* 2016c, Shahabi *et al.* 2016a, Shahabi *et al.* 2016b, Shariati *et al.* 2016, Tahmasbi *et al.* 2016, Khorami *et al.* 2017a, Khorami *et al.* 2017b, Khorramian *et al.* 2017, Shariati *et al.* 2017, Toghroli *et al.* 2017, Heydari and Shariati 2018, Hosseinpour *et al.* 2018, Nasrollahi *et al.* 2018, Nosrati *et al.* 2018, Paknahad *et al.* 2018, Shao *et al.* 2018, Shariati *et al.* 2018, Wei *et al.* 2018, Zandi *et al.* 2018, Ziaei-Nia *et al.* 2018, Sajedi and Shariati 2019, Shao *et al.* 2019, Shi *et al.* 2019a, Shi *et al.* 2019b). There is an important impact of axial load on column fire-resistance, say when the rate of load is 0.72, an obtained fire intensity is 20 min (Fig. 2), also when the rate of axial load is fallen down to 0.61, the fire resistance raises to 40 min. According to Fig. 2, a sharp falling down of column strength is occurred due to the steel losing its strength at high temperatures. After 35 min, the column strength is steadily reduced by raising the time, thus the load is majorly resisted by concrete.

2.3.1 Load distribution

A rectangular CFC column (400×500 mm) with slenderness of 10 mm and a *b/t* ratio has been tested to study the axial load in steel components. Concrete column with the strength of 40 MPa has been adjusted to fill the steel beam with the strength of 200 MPa. The axial loads resisted by steel tube, concrete and CFC column as a function of axial load at the fire exposure for 20 min are shown (Fig. 3). At time of fire exposure, outcomes have shown that steel is produced and its value is stable in applied load. Concrete core shares an important part of final load. The contribution rate for concrete and steel as a time of fire exposure are shown in Fig. 3. The effect of concrete cover on the bond behavior at elevated temperatures has been provided according to the response of beam to high temperatures. Typically, degradation of bond strength could be resulted in more central deflection of beam because of bond deterioration.

When the concrete specimens are dried in oven in a similar hydration degree temperature, water losing need to be theoretically similar. However, the ultimate water loss is increased by temperature (see Table 3). The reason for this could be because of the various evaporation temperatures of water in concrete texture. Water is presented in 3 conditions in concrete: capillary water (CW), physically bonded water (PBW) and chemically bonded water (CBW). Accordingly, CW is liquid water residing in capillary pores including micrometer dimensions and bounded by capillary menisci. The behavior of CW resembles free bulk water beyond the solid surface force ranges (Arabnejad Khanouki *et al.* 2010, Daie *et al.* 2011, Hamidian *et al.* 2011, Shariati *et al.* 2011a, Shariati *et al.* 2011b, Shariati *et al.* 2011c, Sinaei *et al.* 2011, Jalali *et al.* 2012, Shariati *et al.* 2012b, Shariati *et al.* 2012c, Sinaei *et al.* 2012, Mohammadhassani *et al.* 2013a, Mohammadhassani *et al.* 2013b, Shariati *et al.* 2013, Mohammadhassani *et al.* 2014a, Shariati *et al.* 2014a, Toghroli *et al.* 2014, Khorramian *et al.* 2015, Shah *et al.* 2015, Shariati *et al.* 2015, Shah *et al.* 2016a, Shah *et al.* 2016b, Shah *et al.* 2016c, Shahabi *et al.* 2016a, Shahabi *et al.* 2016b, Tahmasbi *et al.* 2016, Khorami *et al.* 2017a, Khorami *et al.* 2017b, Khorramian *et al.* 2017, Mansouri *et al.* 2017, Toghroli *et al.* 2017, Heydari and Shariati 2018, Hosseinpour *et al.* 2018, Ismail *et al.* 2018, Nasrollahi *et al.* 2018, Paknahad *et al.* 2018, Sadeghipour Chahnasir *et al.* 2018, Shariat *et al.* 2018, Shariati *et al.* 2018, Toghroli *et al.* 2018a, Toghroli *et al.* 2018b, Wei *et al.* 2018, Davoodnabi *et al.* 2019, Katebi *et al.* 2019, Li *et al.* 2019, Luo *et al.* 2019, Milovancevic *et al.* 2019, Safa *et al.* 2019, Sajedi and Shariati 2019, Shariati *et al.* 2019d, Shariati *et al.* 2019e, Shariati *et al.* 2019f, Suhatril *et al.* 2019, Safa *et*

Table 4 Porosity features of concrete in the elevated temperatures

Temperature (℃)	Porosity (%)			Temperature (C) void ratio (%) diameter (nm)	
	Micro pores (N_2 absorption)	Capillary pores (*MP*)	Air voids (MIP)	N2 absorption	MIP
30	0.87	2.75	2.85	0.24	3.31
56	0.86	3.02	3.02	0.27	3.31
108	0.84	3.36	3.36	0.40	3.31
162	0.71	3.92	3.92	0.61	3.67
210	0.67	4.38	4.38	0.90	4.27
240	0.58	4.91	4.91	1.80	7.27

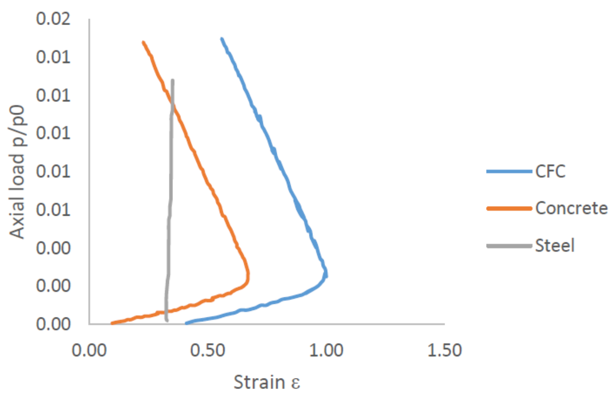

Fig. 4 Axial load in beams and concrete in CFC column subjected to 10 min fire exposure

al. 2020). Accordingly, while heated, this water would initially be evaporated from concrete. Also, PBW adsorbed water bonded to the solid surface by adhesive forces and evaporated while adequately is heated. Typically, CBW is applied in hydration procedure while transferred into a hydration product. Under 105, CBW wouldn't be decomposed. CBW could be released into the pores if heated adequately (Table 4). All CW and PBW is released at 105 (Arabnejad Khanouki *et al.* 2011, Shariati *et al.* 2012a, Rezaei *et al.* 2014, Shariati *et al.* 2014a, Shah *et al.* 2016c, Shariati *et al.* 2016, Shariati *et al.* 2017, Nosrati *et al.* 2018, Zandi *et al.* 2018, Ziaei-Nia *et al.* 2018, Chen *et al.* 2019, Mansouri *et al.* 2019, Safa *et al.* 2019, Shariati *et al.* 2019a, Shariati *et al.* 2019b, Shariati *et al.* 2019d, Shariati *et al.* 2019e, Shariati *et al.* 2019f, Trung *et al.* 2019a, Xie *et al.* 2019, Safa *et al.* 2020, Shariati *et al.* 2020d, Shariati *et al.* 2020h, Shariati *et al.* 2020i), thus this temperature (105) is taken as a reference temperature. Respectively, the outer layer of CW and PBW can be just evaporated at 40. The final water loss gap between the evaporation at 105°C and 40°C might be occurred by the inner layer of PBW that is difficult to evaporate at 40 (see Table 4). In a heating more than 105, concrete basic component ($Ca(OH)^2$ and hydrate phase of C-S-H ettringite) would be disintegrated that induce the collapse of micro-pores related to CBW which is difficult to release. According to table 3, water losing is between 105-150, 150-200, and 200-250 are much smaller than the water lossing between 40-105. When the fully saturated concrete model tests were exposed to the elevated temperatures, the drying time is changed to attain the target saturation (Daie *et al.* 2011, Khorramian *et al.* 2015, Shahabi *et al.* 2016a, Tahmasbi *et al.* 2016, Khorami *et al.* 2017b, Khorramian *et al.* 2017, Toghroli *et al.* 2017, Hosseinpour *et al.* 2018, Nasrollahi *et al.* 2018, Paknahad *et al.* 2018, Shariat *et al.* 2018, Shariati *et al.* 2018, Toghroli *et al.* 2018a, Toghroli *et al.* 2018b, Wei *et al.* 2018, Davoodnabi *et al.* 2019, Katebi *et al.* 2019, Li *et al.* 2019, Shariati *et al.* 2019d, Shariati *et al.* 2019f, Suhatril *et al.* 2019). By rising the drying time, the moisture content was initially declined fast. Later this decrement was slowed down up to the complete drying of specimen. The ultimate drying time was sharply declined by temperature raising (Table 3).

2.3.2 Failure mode

According to Fig. 4, by reaching of load to about 85% of maximal load, concrete cracking is occurred, thus the crack is spread toward the bottom and top ends of column. In addition, the column's axial deformation is quickly increased (Fig. 5). There is a good alignment between the optimum displacements computed by MATLAB and ABAQUS in the blast cases having higher level of displacement axial load. The gap between the peak displacements prediction is as high as 17% in the case of 35 KN axial load and transverse loading with a peak pressure of 32.8 MPa. In addition, an impulse of 22.8 MPa-ms show the outcomes attained from ABAQUS are reasonably accurate.

3. Result and discussion

Concerns regarding a disposal, degradability, and recycling of synthetic fibres used in composite materials have highlighted the need for eco-friendly materials. This article focuses on fabrication and characterization of fibre metal laminate (FML) reinforced with carbon, flax, and sugar palm fibres in order to reduce the environmental impact without compromising the strength requirements. Out of autoclave (OOA) manufacturing processes including hand lay-up and hot compression molding were employed to fabricate FML. Tensile, compressive, inter-laminar shear strength (ILSS), and fatigue properties of fabricated FML were studied. The results have indicated that tensile properties and compressive strength for flax based FML (CFC) was superior and 23% higher than CSC while 5% higher than hybrid CFC configuration. CFSSFC outperformed CFC and CSC in the inter-laminar shear

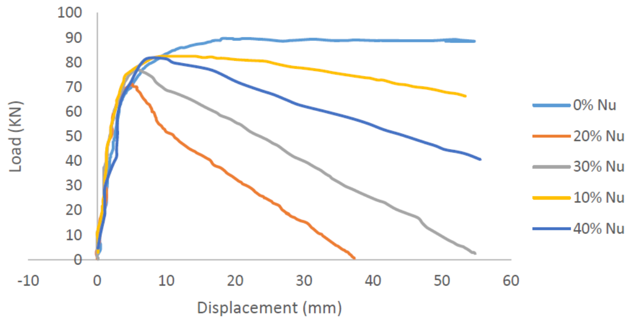

Fig. 5 Steel and concrete contribution- fire exposure displacement

strength by showing 6.5% and 25% increment in magnitude. In case of fatigue, CFC showed excellent fatigue resistance by withstanding high fatigue loads and lasted up to 10 4 cycles before failure (Fig. 5). Delamination between the metal/composite plies was observed in fractured samples under all the mechanical loads.

The axial load trends of samples describe the effect of CFC layers' number on load displacement relationship of concrete (Fig. 5). The load trend of test models is linear in the initial phase, thus test specimens are undergoing the elastic stage. By the raise of axial load, the axial load displacement relationship shows a steady discrepancy. By raising the number of CFC sheet layers, stiffness bearing and capacity of columns have been also increased. The influence of slenderness rate on axial load displacement curves of composite columns is illustrated (Fig. 5). By raising the slenderness rate, the slope of arising part of curves between displacement and axial load is declined. It is also demonstrated that it has favorable deformation ability for the concrete columns with a smaller slenderness rate. Also, the bearing capacity for axial load is increased by the slenderness rate decrement (Fig. 5).

$$DI = \frac{\Delta u}{\Delta y} \tag{2}$$

Where Δu is the final curve for the failure load as the 47% of optimum loading and displacement at the plummet part of curves between the axial load and displacement. Δy is well known as a provided displacement. The effect of various parameters on the axial capacity for tests is shown (Table 3 and Fig. 4). To verify the compressive strength ($fc'c$) of FRP confined concrete, Yan and Libo (2011) have proposed an equation.

$$f_C = f_{Cj} + 2.0 f_{IU}$$
$$f_M = \frac{2 f_{frP}}{\sqrt{h^2+b^2}} \tag{4}$$

t_{frp}=thickness of CFC sheets;

f'_{co}=compressive strength of concrete,

An equation of axial load capacity (N_u) of particularly encased concrete columns is yield by EC4 (2004)

$$N_a = A_a f_a + 0.77 A_C f_C + A_S f_C \tag{5}$$

f_c=and longitudinal reinforcing steel

f_a=the yield strength of steel

f_c=the compressive strength of concrete

A_c=the cross-sectional area of profile concrete

A_s=the cross-sectional area of longitudinal reinforcing steel of column

Based on the above test data analysis, a method is proposed.

$$N_{u^{FR_1}Z} = 9(A_a f_a + 0.85 A_C f'_{CC}) \tag{6}$$

φ=buckling factor of column (Chinese Standard GB50017-2017)

f_{cc}=strength of confined concrete

Eq. (6) as the compare of test and calculated results for the axial load and bearing capacity of columns are illustrated in Table 5, providing an appropriate alignment between both conclusions. Eq. (6) could be relatively estimated for estimation of axial bearing capacity. Sensitive analyzing is typically done for prediction of out-come (as outputs), providing the very area of input parameters. In this research, the objective of sensitive analysis is to investigate the changes in output parameter(s) for the yield sets of input parameters and understand interdependent relationship between the parameters. Accordingly, one input parameter has been altered and other input parameters concurrently are kept constant.

4. Conclusions

As a result, the evolution of compressive strength while being dried at elevated temperatures has been experimentally analyzed. Thus,

- By raising the elevated temperature subjected to specimens, the proportion of final load-bearing capacity plunged has an explicit incline, so the ductility of specimens is enhanced. The primary compressive stiffness is evidently declined by the raise of temperature to 800°C
- The behavior of concrete columns could be numerically surpassed because of CFC confining in lateral direction.
- The axial load displacement of columns is increased in the raise of CFC sheet layers' number, but decreased by the slenderness ratio increment. CFC confining has enhanced the axial bearing capacity of column. Whereas, the capacity of columns and material has not been ever increased by raising the CFC sheet layers' number.
- A simplified formula is provided for estimation the axial load displacement of CFC encased concrete columns' materials. A good alignment is between the prediction proportions and numerical results.
- During the axial loading process for CFC, concrete compressive strength is decreased at first and increased later by moisture content decrement. The minimal strength might happen at a proper moisture content. The moisture content with a minimized compressive strength is highly delineated by the temperature and commonly decreased by a temperature raising. Thus, by the raise of heating, concrete compressive strength with the same moisture content is decreased.

• The influence of thermal treatment on the evolution of concrete strength comes from the two competitive impacts: stiffening influence of capillary pressure and decreasing impact of micro cracks, both related to the moisture content and porosity.
• The formulas for prediction of final strength of SRCFSST stub columns in ambient exposed to high temperature are provided and followed by the well coincidence of test results and computed results.
• Provided stress increment has a minimum influence on concrete strength, pointing out that the strength enhancement ratio of concrete column limited by steel beam is under debate.

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