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Shear Connectors Behavior Under Elevated Temperature: A review

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Abstract

A composite member is described as a structural steel shape that has been built up or rolled and filled with concrete, covered in reinforced concrete, or structurally attached to a slab of reinforced concrete. The shear connection between the steel beam and the concrete slab is the primary component of the composite beam. In risky situations, like building fires, the performance of composite structures and steel structures is heavily dependent on the execution of connection. Numerous kinds of shear connectors exist and are being utilized in construction engineering rendering to their use. This paper reviews research conducted in the past years on the performance of shear connectors such as (ASTM A325 bolts, channel shear connectors, T, T-mass, and T-Proband shear connectors) exposed to raise heat degree. This research covers the experimental testing of push-out specimens, the behavior of connectors in steel structures, various shapes of shear connectors under elevated temperatures, main failure modes, finite element modeling of shear connectors, design approaches offered by investigators, and various codes. Compared to the size of work available on shear connectors at room temperature, relatively slight research has been done on the conduct of shear connectors (studs) under high temperatures. In addition, this report indicates several topics that need further investigation. Through this article, it was concluded that when temperatures rise, the strength of all shear connectors decreases proportionally regardless of their shape and type. A comparative study showed that the channel connectors are an economical and reliable option to standard shear connectors. Among the findings of some studies is that the effect of temperature on the shear resistance of the head stud connector is significantly above 400℃, whether the test is done at temperature or post-temperature conditions. Also, adding some materials to the concrete mix such as carbon nanotubes will be not effective on the ultimate shear at temperatures less than 400 ℃, but it reduces the spalling and cracking of the concrete. In general, the influence of elevated temperatures on the ultimate shear capacity of the headed stud connector is noticeably clearer when the test is conducted at exposure to a certain temperature compared to post-temperature conditions (the test is conducted after exposure of the specimen to heat and cooling).

Keywords: Composite structures; finite element modeling; High temperature; Load-slip; Push out test

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1. Introduction

Composite structural members are made up of more than one material or more than one shape linked to each other by means of a connector. The materials are most frequently used when steel is used as a beam and concrete is used as a slab in a composite beam. Although steel and concrete have somewhat distinct properties, they work well together; steel works well

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under tension while concrete works well as a slab. In this instance, the concrete slab is predominantly subjected to compressive loads while the steel beam is subjected to tensile stresses, thus using the advantageous properties of each material [1]. Because steel components are often thin and brittle, concrete helps prevent buckling in addition to providing corrosion protection. Gives the structure ductility, and steel gives it thermal insulation at high temperatures. Whatever the shape or type of this conductor, its mission is to transfer and distribute the shear stresses uniformly between the composite parts, so it is called a shear connector.

The importance of these shear connectors is very great due to the task they perform Which lies in the transfer of the applied shear load to the parts of the composite beam and the resistance to longitudinal slip that is created in the inner face between the reinforced concrete part and the steel part. The stiffness and strength of the composite structural members depend largely on the durability and toughness of the connectors [2]. The most dangerous and important conditions to which these members are exposed are fires. Fires are one of the most serious disasters that threaten the safety of buildings and their inhabitants, which requires taking preventive and design measures to reduce the effects of fire or at least increase the time for failure to occur to the building to ensure the safety of the largest possible number of human lives in such circumstances. When a building burns, these members will be greatly affected because they contain weak areas, namely the areas of connection between two parts, whether they are of the same material or of two materials (the two materials are often concrete and steel). The rigidity and durability of shear connectors are greatly affected when visible to high temperatures, and this is reflected in the overall performance of the building [3].

Therefore, it is necessary to study the behavior of shear conductors under the influence of high heat and find ways to reduce the impact of heat and improve the behavior of shear conductors and thus improve the performance of the composite structure in general. Therefore, to reduce fire risks and limit losses, whether human or structural losses, fire safety design is very important to take into consideration for buildings [2]. There is a lot of research that has studied the behavior of many types and shapes of shear connectors under elevated temperatures. In this paper, some previous studies will be reviewed to collect more than one study in one paper; will learn about their behavior under elevated temperatures.

2. Literature review

Numerous writers have examined how shear connectors behave at high temperatures. Many types of connectors that have been studied under the influence of high temperatures will be discussed in the following paragraphs:

2.1 ASTM A325 bolt under high temperature

This research investigated the performance of ASTM A325 bolts under fire conditions under tension loading. Moreover, numerical analysis was conducted to develop the model by using FE to predicate the response of these screws.

In numerical analysis is no need for repeat testing. The diameter of the bolt was 12.7mm which connected two hollow steel sections with dimensions (101.6*101.6mm). These hollow square steel sections were fixed to a tension-testing device held by two bars of diameter 25.4mm. A great-heat strain gauge was fixed to the stem of the verified bolt, in some of the tests. These details are displayed in Fig. 1 (a) and (b).

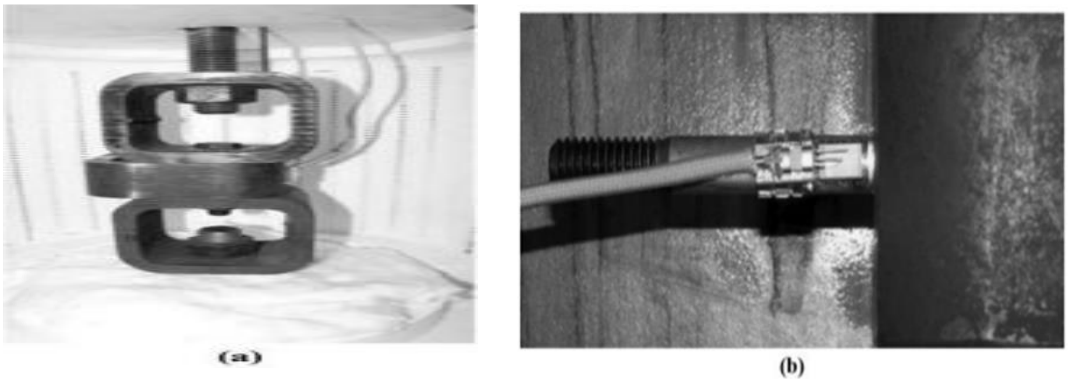

Fig. 1 (a) Collected specimen; (b) the verified bolt [4]

The oven utilized in the research involved two semi-cylinder-shaped rechargeable ceramic furnaces with atriums on the upper and lowest of (2700 W and 240 V). The dimensions of these heaters are shown in Fig. 2. Two thermal wires were inserted in the furnace by the top cap, which was used to close the top of the atriums, to measure the temperature inside the oven. The temperature inside the oven was set and readings were received according to a pre-determined heating regime via a computerized control unit [4].

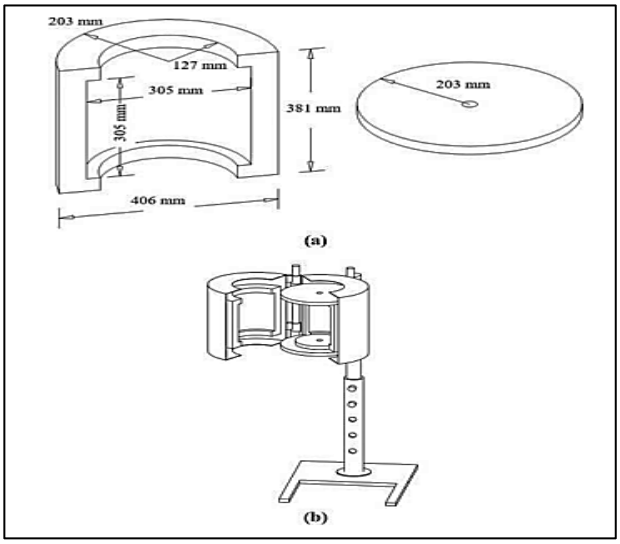

Fig. 2 (a)Power-driven oven components (b) a sketch of the oven and its frame [4]

In this study, a parametric design was adopted to create a finite element model geometry, which enables future research to apply it to any bolt type and different sizes. Fig. 3 shows the 3D finite element model details.

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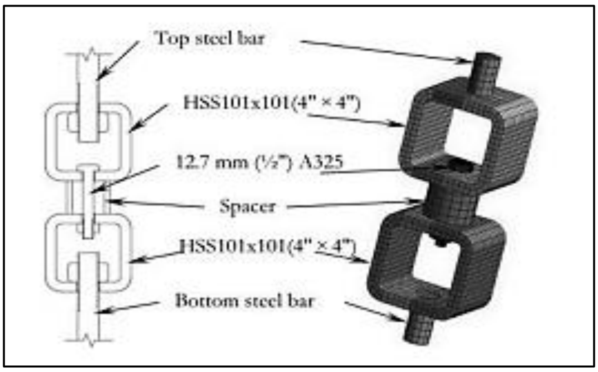

Fig. 3 3D finite element model [4].

2.2`Channel Shear Connector

This research is a numerical study for previous experiential studies utilizing the finite element set ANSYS to ensure the validity of the results of the experimental study. That previous experimental study [5] investigated the behavior of channel shear connectors, which connect a steel I-section and a high-strength concrete section, under cyclic monotonic loading using a push-out test at ambient temperature conditions. After validation, this paper expanded to numerically study the behavior and performance of the FE model at elevated temperatures.

The total number of models in this paper was 50 FE models. To advance the rate of convergence between the experimental results and the numerical results, second-order 3D solid rudiments were used to simulate the push out samples. The ISO standard specification for fire testing (1975 tests) was relied upon when applying thermal procedures as displayed in Fig. 4. As for modeling the push-out specimens and channel shear connectors, whether at normal or high temperatures, reliance was placed on previous research [3], [6], and [7] which deal with related topics from this paper topic.

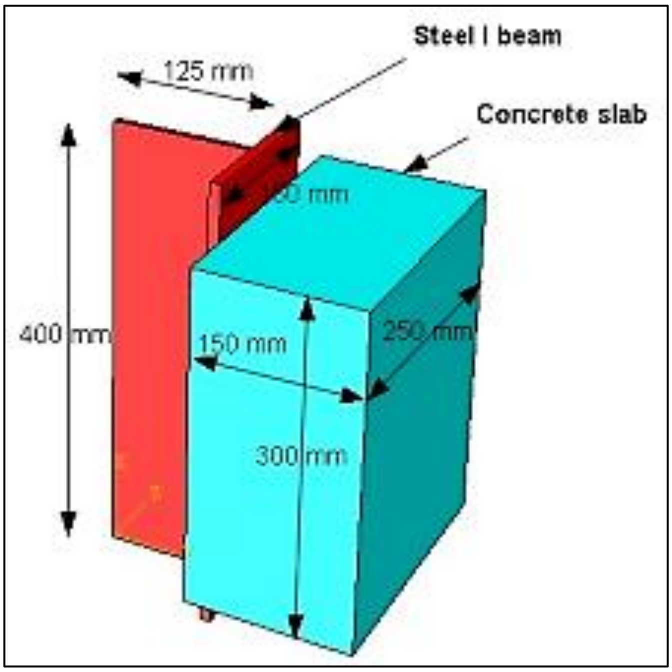

Fig. 4 Push out geometric modeling [2]

Table 1: Geometrical properties SP-1 to SP-6 [2]

Specimen ID	Height (mm)	Length (mm)	Web thickness (mm)	Flange thickness (mm)
Sp-1	75	50	5.0	7.5
Sp-2	75	30	5.0	7.5
Sp-3	100	30	6.0	8.5
Sp-4	100	50	6.0	8.5
Sp-5	60	30	4.0	7.0
Sp-6	60	50	4.0	7.0

Table 2: Mix magnitudes of high strength concrete constituents [2]

Mix No.	Cement (Kg/m^3)	Coarse aggregates (Kg/m^3)	Fine aggregates (Kg/m^3)	Water (Kg/m^3)	Silica fume (Kg/m^3)	SP (%)	W/C	Modulus of elasticity (GPa)	Compressive strength (MPa)
H_1	460	910	825	168	40	0.5	0.37	39	82
H_2	360	940	870	180	-	1	0.50	32	63

The finite element specimen details: -In general, three-dimensional solid elements were used for all parts of the push-out specimens, but the details are different for each element. The concrete and steel parts were both simulated using a 3D element with 8 nodes (C3D8R) and as for the shear connectors, they were modeled using a second-order 3D quadratic brick element with 30 nodes (C3D30R) to obtain more accurate and better marks. A linear 3Dtruss element consisting of two nodes (T3D2) was used to represent the steel reinforcement [2].

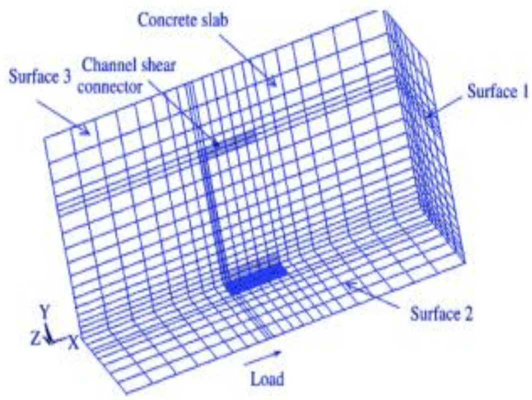

Fig. 5 Finite element network and edge condition of the solid slab model [2]

The thermal analysis and the structural analysis are conducted independently, maintaining the same specimen geometry. Because material properties can vary from member to member and not all materials behave the same way at high temperatures, thermal analysis is thought to be more complex than structural analysis [8]. In the furnaces used for testing, the effects of temperature are represented by a temperature time curve that shows the usual temperature in the event of a fire. The heat exposure provided by ISO834 [9], in which T is the mean temperature (°C) and t is the time (min), is used as the testing basis for pertinent design standards. Shahabi et al. [10] used Software to simulate the flow of temperature in a composite slab and derive the time-temperature curve, which was subsequently precisely confirmed by [10]. The simulation techniques employed in this investigation are comparable to those in [10]. Fig. 6 presents the optimal temperature distribution diagrams for a solid concrete slab, illustrating the layering of the concrete, structural steel beam, and shear connectors. The temperature distributions are distinguished based on time using this technique.

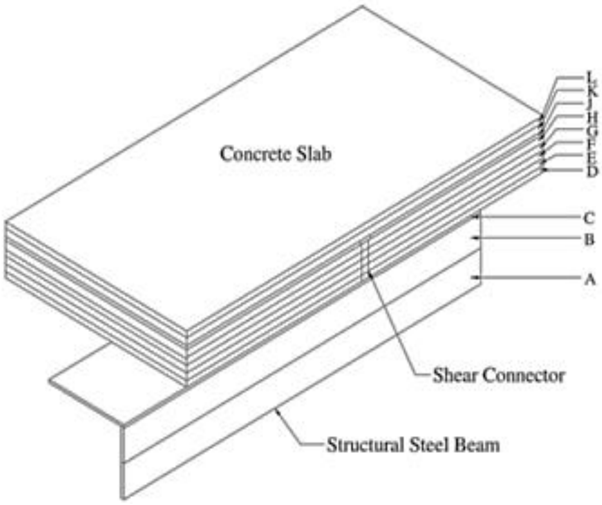

Fig. 6 The diagram of solid slab temperature distribution [2]

Channel connectors' temperature distribution was measured at various intervals of 10, 20, 30, 60, 90, 120, and 180 minutes. The temperature distribution of the layers with respect to time is given in Table 3. To ascertain the load-slip behavior of the shear connectors and investigate the impact of temperature on their performance, all FE push-out tests were modeled. The FE models, which included constant temperature at various time intervals, were altered to investigate the impacts of fire on time variation. There were three increments in the mechanical load levels: 20%, 40%, and 60% of the final load.

Table 3. The temperature of layers at different times [2]

Layer (T) (℃)											
Time (t) (min)	A	B	C	D	E	F	G	H	J	K	L
10	575	505	430	430	355	280	205	130	55	25	10
20	720	625	550	550	475	400	325	250	175	100	25
30	770	705	630	630	555	480	405	330	255	180	105
60	870	780	705	705	630	555	480	405	330	255	180
90	900	825	750	750	675	600	525	450	375	300	225
120	900	860	785	785	710	635	560	485	410	335	260
180	900	900	825	825	750	675	600	525	450	375	300

2.3 Headed Stud Connector with profiled slab

This research's main aims are to make a three-dimensional temperature scope, constant temperature scope along a segment in the surrounding area of the rivet to pretend the behavior of the shear connectors in both compact and profiled slabs at high temperatures for doubly shear tests, moreover to examine the results of temperature on push tests performance. The location of shear connectors is presented in the Fig. 6 [3].

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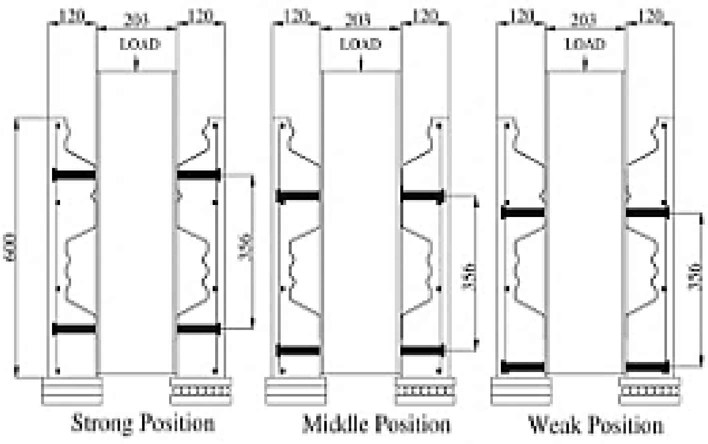

Fig. 6 Location of shear connectors in push test samples [3].

The mechanical performance at ambient and raised temperature is studied, in this paper. Certain temperatures, thermal development, and thermal conductivity are the main possessions that are necessary to do an exact calculation of the temperature allocation. According to the push out tests conducted by [11] and [12] which studied the behavior of shear connectors of a solid and profiled slab at room temperatures, respectively, the FE models were compared. Figs. 7 and 8 show the finite element mesh of solid and profiled steel canvas slabs, respectively. Using the modified RIKS approach, which can be obtained by a series of iterations for each increment for a non-linear structure, a static focused load was delivered to the center of the web. In addition, the load magnitude was considered unidentified and needed to be addressed alongside the loads and displacements. The RIKS approach can employ the arc length along the static equilibrium in load-displacement space to provide correct results in ABAQUS. If the finite element model is unable to converge, the first increments will be modified. Ultimately, the load value is automatically calculated following each increment. Either the maximum load value or the maximum displacement value will be the outcome in the end.

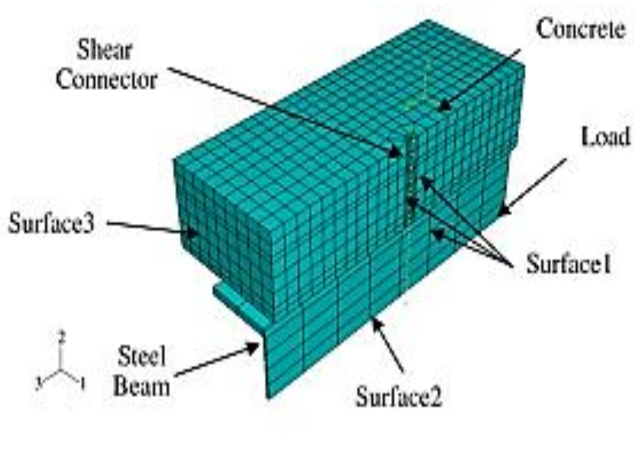

Fig. 7 Finite element network and edge state of the solid slab model [3]

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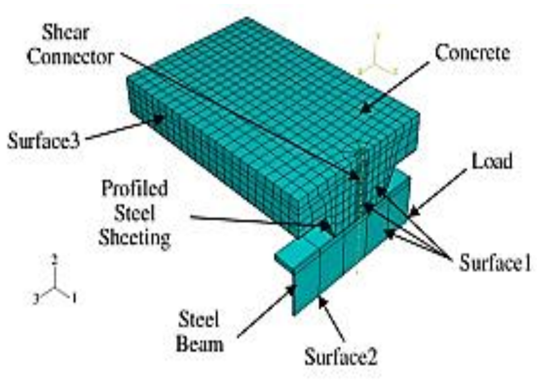

Fig. 8 Finite element network and boundary state of the profiled steel canvas slab model [3]

2.4 T- Shear Connectors Under Elevated Temperature

The conduct of T, T-block, and T- perfobond shear connectors under fire conditions are investigated in this paper for evaluation of the shear resistance, ductility, and collapse modes of the connector at elevated temperatures. The test samples were manufactured built on the standard double shear test in European code 1994-1-1 (2005), extension B[13], with several differences, as one of the concrete slabs was removed as shown in Fig. 9. The purpose of this modification is to apply the thermal achievement to one side of the short beam. The dimensions of the reinforced concrete slab were 600mm wide,650mm long, and 150 or 200mm thick liable on the connector height. The concrete part was reinforced at the upper and lowest with steel bars with a diameter of 10mm, with a spacing of 150mm in both directions, and the concrete cover was also taken near 25mm as specified in Eurocode1994-1-1, annex B [13].

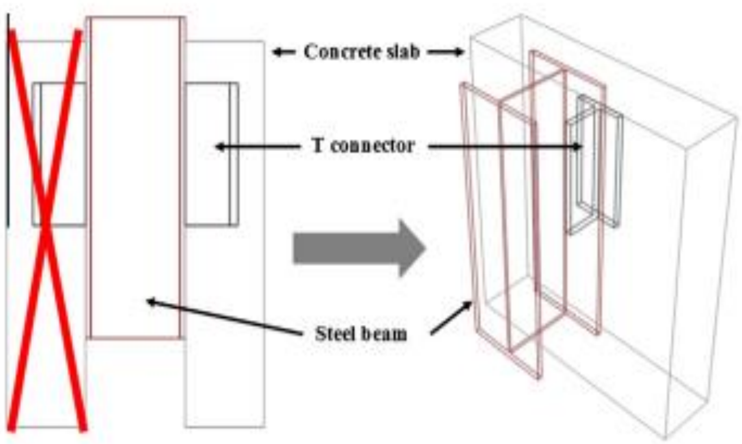

Fig. 9 Test sample for the reformed push-out tests at a great temperature [14]

In accordance with Eurocodes 1994 1-1, annex B, the tests of ambient temperature were loaded in two steps. In the primary phase, a recurring application load between 5% and 30% of the predicted final load-sustain capability was utilized in 25 cycles at a level of 1 kN/s while under weight control[14].

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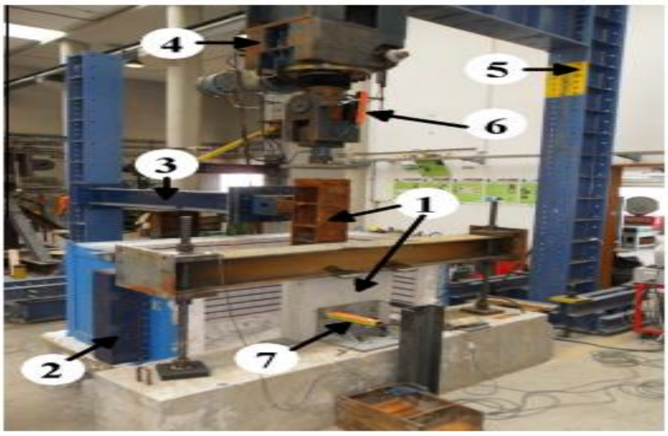

Fig. 10 Test arrangement for reformed push-out tests [14]

The samples were also exposed to a perpendicular load at the second stage, which resulted in shear packing beside the boundary between the concrete slab and the beam flange. This shear loading was limited by displacement and occurred at a ratio of 0.01 mm/s until there was a significant relative displacement between the concrete slab and the short steel beam (anywhere the load in the drop phase was equivalent to at smallest 80% of the crowning load). In a similar manner to the ambient heat tests, to begin with, a recurring loading was implemented over 25 rounds at a velocity of 1 kN/s, encompassing a range from 5% to 30% of the disappointment load achieved from the personal tests conducted at ambient heat degree within this study. Next, the specimens were exposed to heating until reaching the desired temperature, adhering to the boiler rate outlined by the ISO 834 fire arc [15].

As previously stated, the specimens' ultimate shear strength tests had target temperatures of 840, 950, and 1005 C in the oven. These temperatures correspond to 30, 60, and 90 minutes of the ISO 834 fire curve, correspondingly. Ultimately, the samples were laden at a proportion of 0.01 mm/s up to the comparative movement between the small steel beam and the concrete lump was quite considerable, as well as during the ambient heat degree tests when the temperature in the heater touched the necessary level. The furnace was maintained at a steady temperature while this load was applied [14].

2.5 Effect of Carbon Nano-tubes modified concrete on behavior shear connectors

In this study, the performance of shear connectors, which connect composite beams consisting of concrete and steel, when exposed to fires and after exposure to fires, i.e. after cooling, was studied. The push-out test was performed to check the models at ambient temperatures, elevated temperatures, and post high temperature exposure, which was 200, 400, and 600℃, as well as to perform tests after cooling. In this research, concrete with different compressive strengths was used, where ordinary resistance concrete with compressive strength 25 MPa and modified concrete which used carbon nanotubes were used to build composite beams. The standard dimensions of the Reinforced Concrete slab component were modified because of the internal dimensions of the oven which are available in the laboratory.

The dimensions used for concrete slabs are (400 *400 * 200) mm while the standard dimensions are 600 mm in width and long but 150 mm in thickness. According to Australian standards 1554.2 virgins (2003), the weld of the headed stud to the flanges of the I-section steel beam is been. The total specimens tested in this research are twenty-eight, fourteen models are ordinary reinforcement concrete, and the fourteen samples are carbon-nanotubes modified concrete. Wherever the percentage of carbon-nanotubes which added to ordinary concrete was one percent by weight of ordinary concrete. In addition to laboratory tests, the analysis of the Finite elements was utilized to simulate the behavior of shear connectors under normal temperature and fire temperature numerically using the ABAQUS program [16].

Fig 11: Push out test system at fire (a) ordinary concrete (b) carbon nanotube concrete [16]

3. Investigators Results

After the handy and hypothetical investigations conducted by the researchers, the following marks were obtained:

3.1 ASTM A325 bolt under high temperature

A 12.7mm diameter bolt was tested under a constant tension load of 8,896.44 N. The marks displayed that in the first stage of the test, the tension load increases but during the heating stage the tensile load remains constant. The displacement during the tensile loading phase increases steadily and it increases significantly in a linear manner up to temperature 500°C, after which rapid deformation occurs, leading to failure. The first point of a sudden decrease in the tensile load was considered the end point of the test. To confirm this point, the dimensions of the components of each model were measured before and after the test. The models took 40 min to touch a temperature of 600 °C, while a normal fire reaches this fever within 6 minutes. This long time of exposure to such a high temperature led to creep distortions in the results because steel in general shows important creep conduct at temperatures approaching one-third of its tender point, which is approximately 1400°C . The difference between the standard fire and the specimens' temperature is shown in Fig. 12.

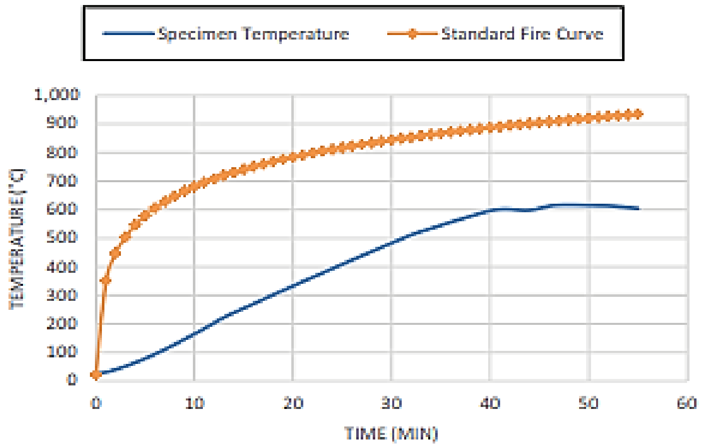

Fig 12. Contrast among a normal fire and the temperature of the heater [4]

Up to a temperature of 500°C, the finite element model and the laboratory investigational model agree closely in results. The FE model does not contain the residual internal stresses and does not reflect the impurities present in the materials used, so some marks of improved stiffness appeared in the FE model. While, at higher temperatures, the FE model did not explanation for creep on the contrary in the experiments. There are three estimated locations of bolt failures at ambient temperatures; 15% under the head of bolt, 20% at the finale of the filament and 65% in the filaments at the nut surface. The major cause for this fiasco is stress attentions due to unexpected geometric changes. At elevated temperatures, alike propensities were renowned [4].

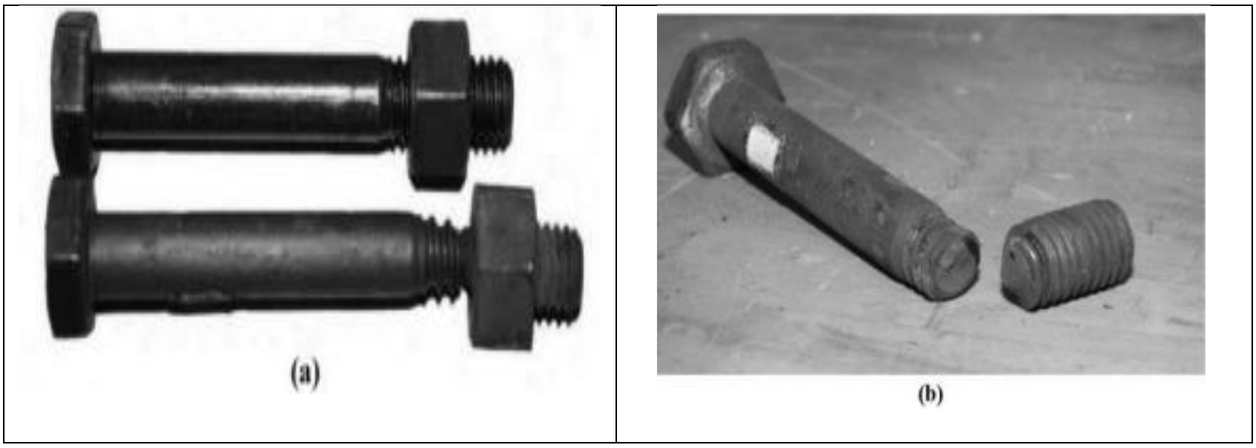

Fig. 13 (a) Bolt contrast; (b) disappointment surface. [4]

3.2 Channel Shear Connector

3.2.1 FE model at ambient temperature

The push-out specimen is failing in two types of failures. One of these failures is channel breakage and the other is concrete devastating/splitting. The type of failure push-out specimens entrenched in HSC in all experimental tests is channel connector fracture. The failure mode that developed in the FE model at ambient temperature is the same failure mode in experimental tests, yielding and fracturing at the web and bottom flange.

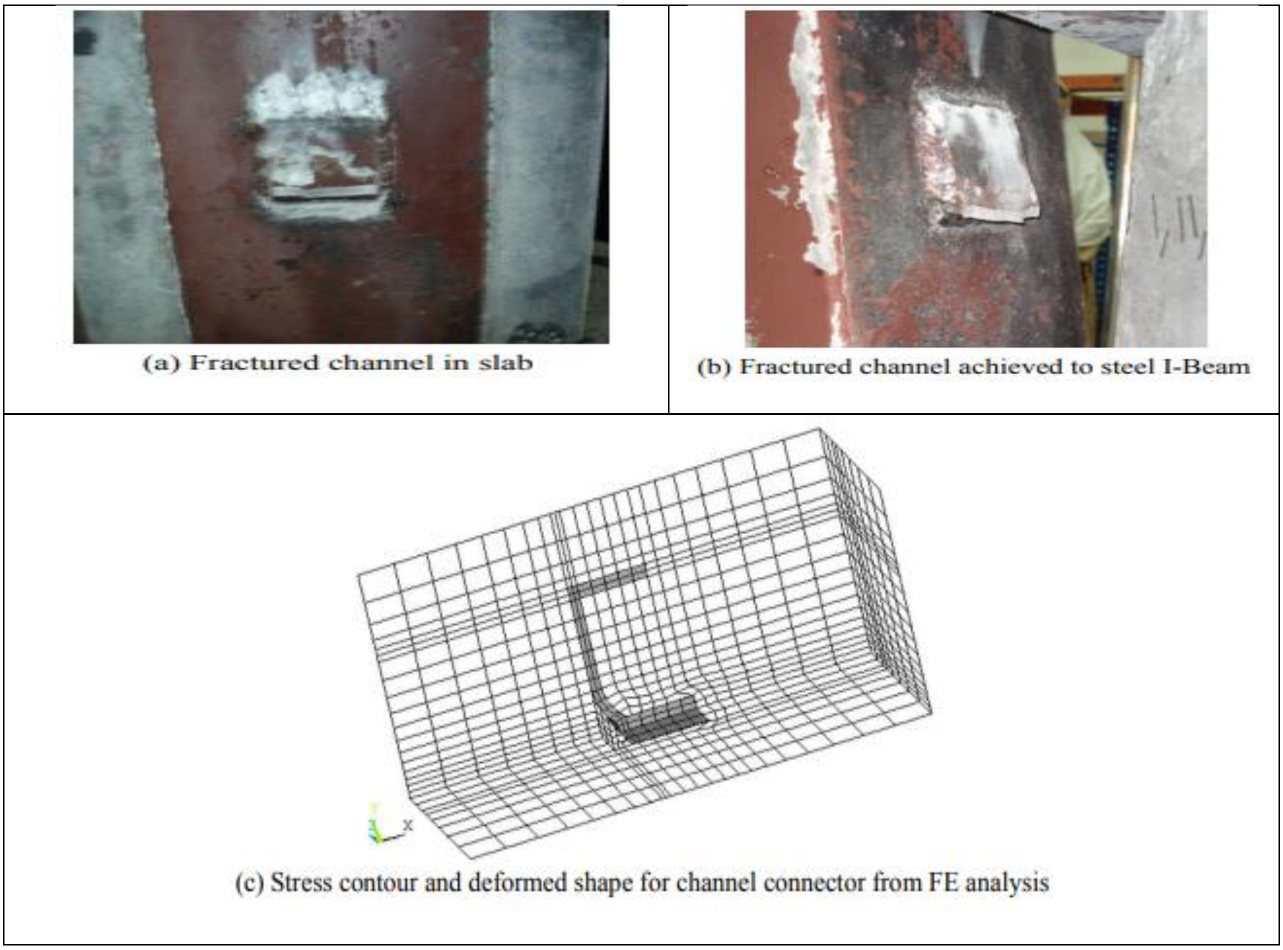

Fig 14: Comparison of failure of channel connector during experiments (Shariati et al. 2012) and FE modeling [2].

The maximum load per channel connector was noted at 170 kN in the experimental test of push-out specimens (SP-1). While in the FE analysis, the maximum load for the same specimen was 160 kN. Experimental and numerical testing gave the same ultimate load which is 160 kN in the SP-2. All cases showed that there is perfect agreement between the results of the tests and the FE study. These results prove the efficiency of the finite element model in the nonlinear range up to failure.

3.2.2 FE model elevated temperature

The lower layers of the FE model exposed greater stress concentration under elevated temperatures due to thermal load applications. This led to fail the connectors in a turnover in its place of shearing-off mode. Shear and flexural stress are generated in the channel connector, while high compressive pressure occurs in the concrete element near the connector. The shear connectors failed faster due to developed temperature profiles and thin concrete slab width [2].

3.3 Headed Stud Connector with profiled slab

3.3.1 Solid slab

The results of the FE analysis gave a critical load of 131 kN which was higher than the experimental results by 5%. These results indicate that the FE results and tentative investigation are in good covenant. Through the stress distribution outlines, it was proven that the specimen's ability to temperature decrease; the higher the applied load is, as shown in Fig. 15 [17].

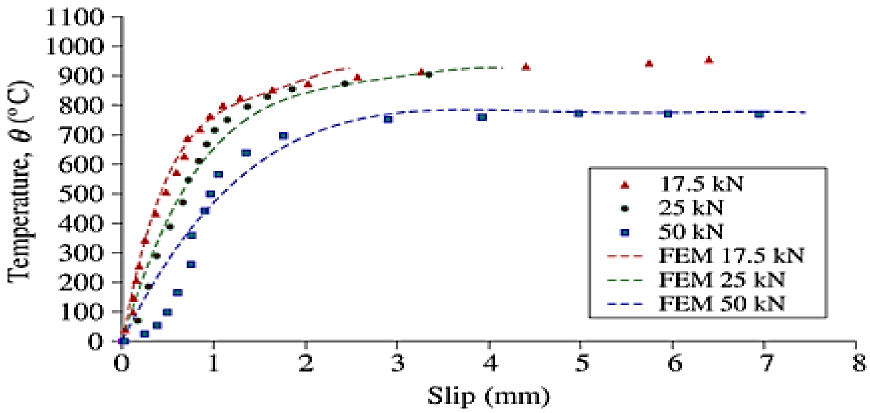

Fig. 15 Slip according to fever [3]

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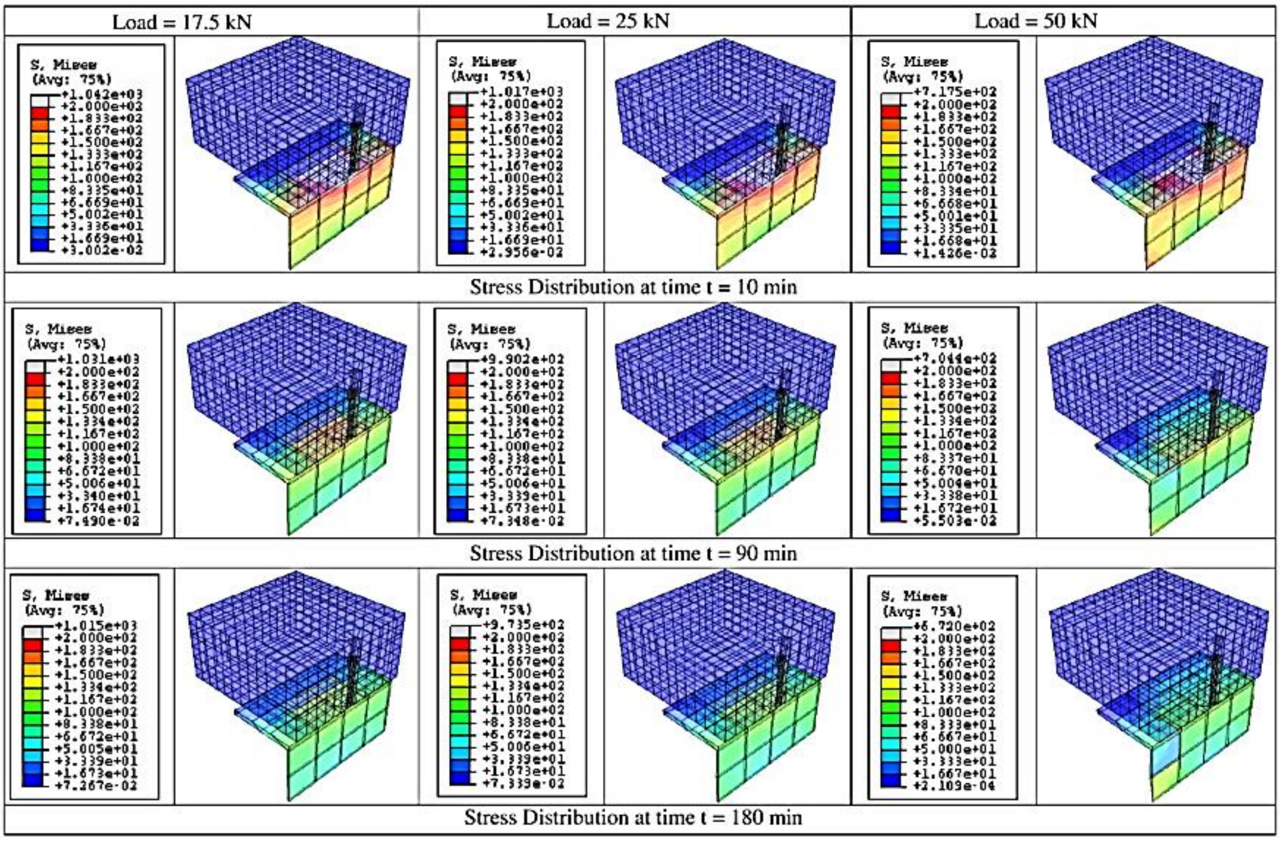

Fig. 16 Stress supply for variable loading according to time [3]

3.3.2 Parametric studies: - Solid slab

The experimental tests conducted by [12] are compared with the finite element model for solid slabs. The compressive strength of concrete in experimental specimens was 35 MPa. The results of the FE model showed that the maximum load is 113 kN with a slip of 9mm which is higher than the experimental results, which is 102 kN maximum load and 6 mm slip. The disappointment style of the shear connectors in this study is like to that defined by [18] and [12]. Moreover, the consequence of temperature variations on the shear connector was studied by creating another FE model. It was concluded that the shear connector strength and ultimate load decreased with increasing temperature. Profiled slab: -

The experimental study conducted by [11] is compared with the FE model for the profiled steel sheeting slab. The compressive strength of the concrete element was 35.5 MPa. The results of the analysis of this model indicated that the FE model marks and the trial result are in good covenant as shown in Fig. 17. The FE model results gave a maximum load of 84kN and 1.3mm slip while the experimental result had a maximum load of 83kN and 1.9 mm slip. The dominant failure mode was concrete deforming in both experimental tests and the finite element model, where the concrete crumpled and fractured before the shear connectors broke near the weld strap. The concrete failure caused a primary rupture in the middle of the slab alongside the channel of the profiled slab.

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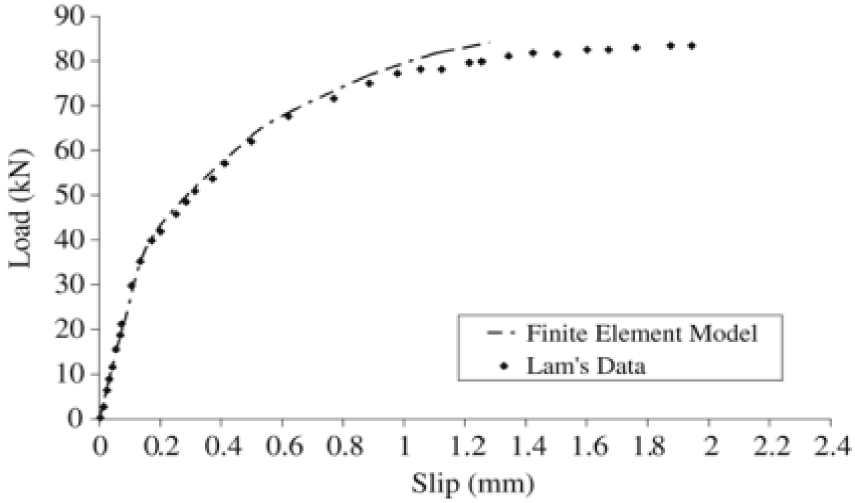

Fig. 17 Contrast between trial push test and finite element model for profiled canvas slab. [3]

Because of the solidity of the profiled steel canvas, the stresses and deformation in the concrete and shear connector were lower, as shown in Fig. 18. In addition, the result of heat changes on the shear connector was studied by analysis of another FE model. The result of that analysis indicated that the resistance of the shear connector is inversely proportional to the temperature changes, as shown in Fig. 19. Compared to the solid slab, the ultimate load reduction with increment in temperature is much less in the profiled slab

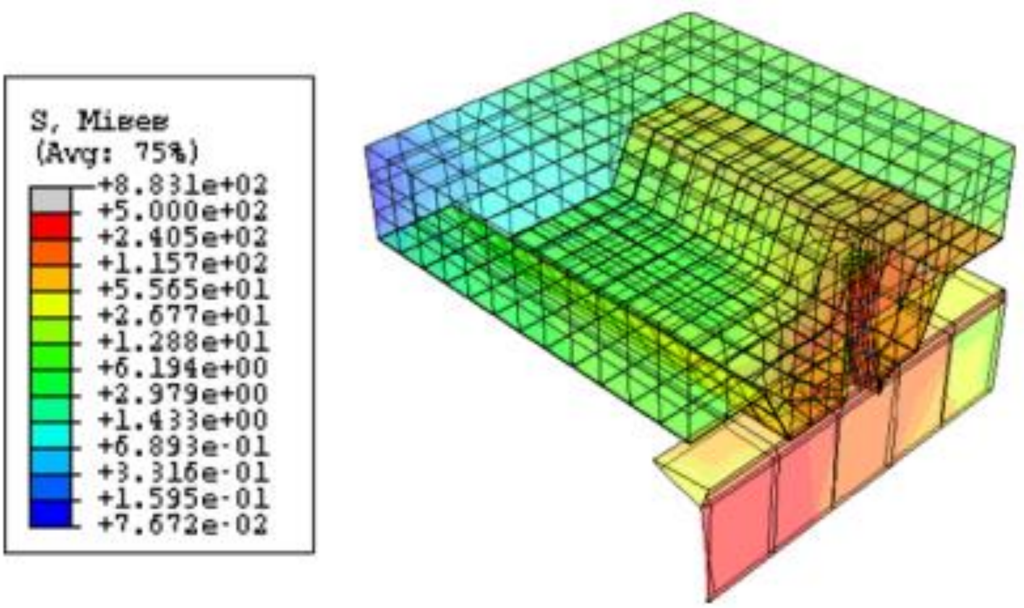

Fig. 18 Stress outlines and distortion form for profiled steel sheeting slab [3]

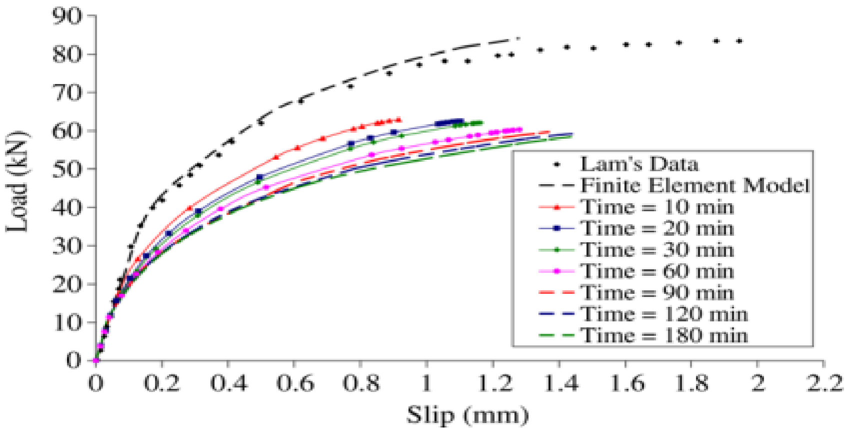

Fig 19: Contrast of push test by fever changes consistent with time [3].

3.4 T-Shear connectors under elevated temperature

3.4.1- Ambient temperature

From the results of tests at ambient temperature, it was found that the linker characteristic resistance increased by 55% when the thickness of the slab was increased from 150 to 200mm. In addition, the connector load-carrying ability was developed with growth in the amount of connector bores. However, through the results of tests under normal temperatures, it was shown that the T-shaped connections give significantly greater changes in uplift magnitude compared to the samples in which the perforated T-shaped connector was used. These results occurred because of the presence of the number of holes and the presence of reinforcement bars in these bores. Therefore, the performance and strength of this type of connector (which contains holes) are controlled by the dimensions of the flange and do not depend heavily on the size of the web or the number of holes in it [14].

3.4.2 Elevated temperature

3.4.2.1 Temperature distribution

After 60 min of heating the connection T_0h_0re_100tall, the mean temperature on the top of this specimen was 148 ℃ (θs3, θs4, θs5, θs6, θs7, θs8, θs9 and θs10) and on the bottom about 448 ℃ (θs1 and θs2) as shown in Fig. 20.

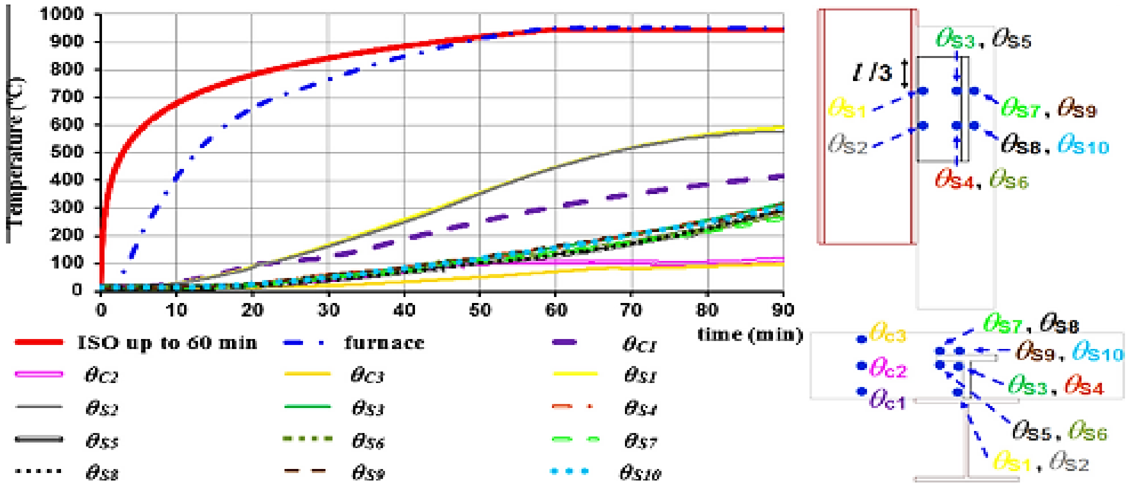

Fig. 20 Growth of heat degree with time for the tested sample T_0h_0re_100tall [14]

Same in Fig. 21 for the connector T_ block _ 100tall_In, the mean fever on the lowest of the linking was 439 ℃ (θs1, θs3 and θs5) and on the highest about 235C (θs2, θs4 and θs6) after 60 min of heating.

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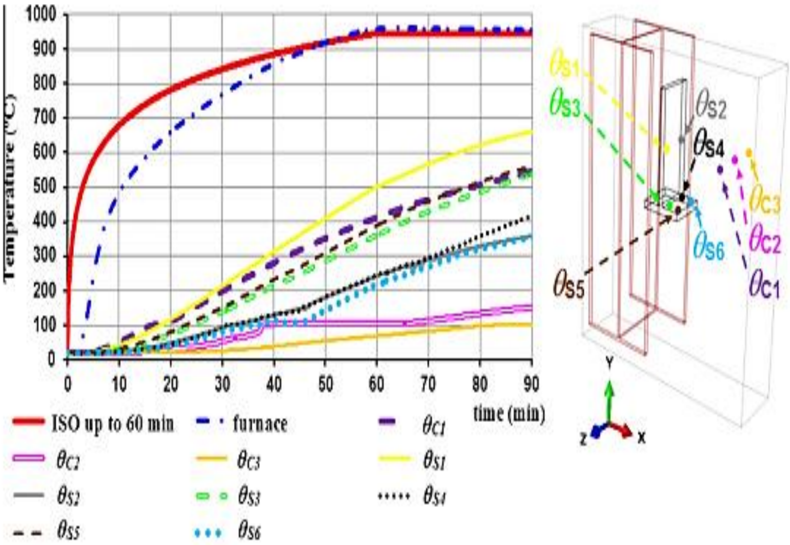

Fig. 21 Development of heat degree with time for the sample T_block_100tall_In at heat close to 950 ℃ [14]

3.4.2.2 Discount of the shear resistance

The impedance plus toughness of the connections reduced with high temperatures. In addition, it was observed that the influence of the number of bores and the existence of strengthening bars in the bores were fewer important in the samples than at room temperature. For example, the toughness of the sample T_P_1h_0re_100tall was 55, 48, and 39 kN/mm at temperatures 840,950 and 1005 ℃ , respectively. It is important to emphasize that the shear resistance of connectors reduces further with growing connector height at high temperatures as shown in Fig. 22.

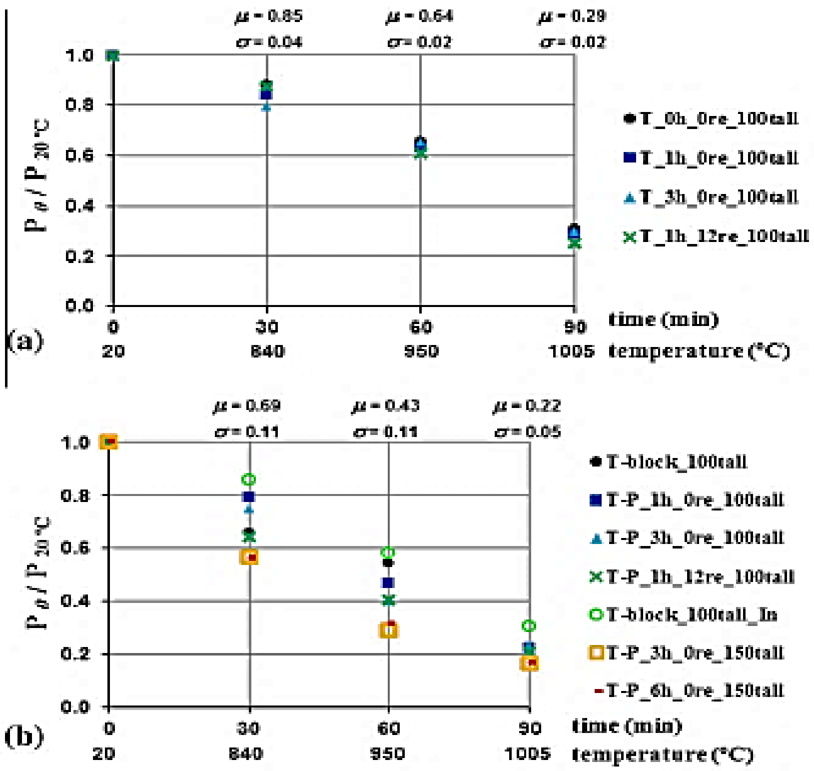

Fig. 22 Comparative values of the vital load-sustain capability of the patterns with T (a), T-block, or T-Proband (b) connector at high temperatures [14].

3.4.2.3 Influence of amount of holes

From Fig. 23, it can be found that the number of holes is directly proportional to the shear opposition of the patterns for almost all stages of heat degree. Yet, the development of shear resistance due to hollows in the connectors was typically greater at ambient temperature than at high temperatures.

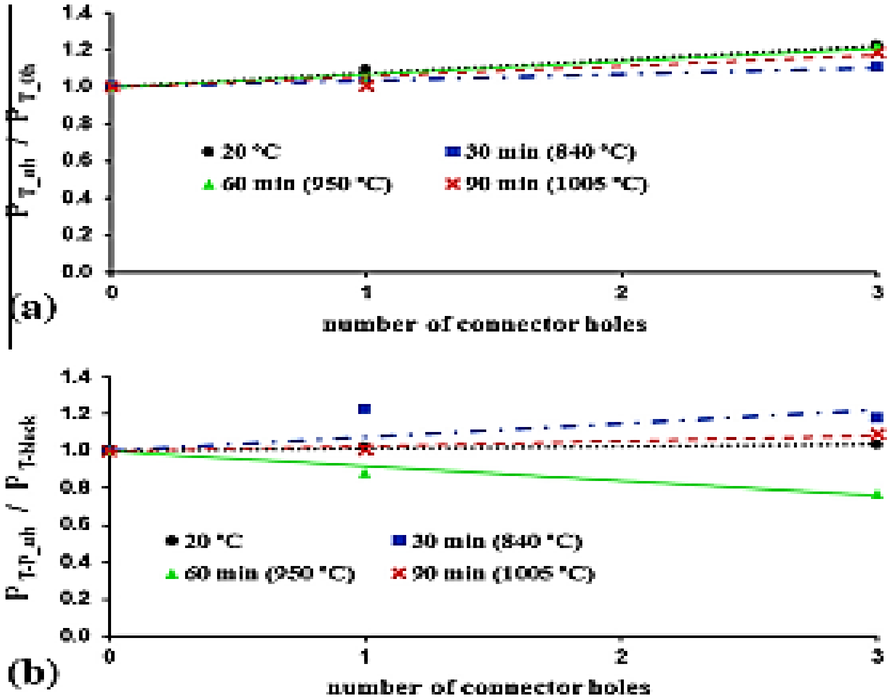

Fig. 23 Influence of the numeral of bores on the maximum load-sustain capability of the patterns with T (a) or T-Proband (b) link at diverse times of the ISO 834 fire arc [14]

3.5 Effect of Carbon Nano-tubes modified concrete on behavior shear connectors

The findings of push out test in this research showed that the ultimate shear capacity and stiffness of the headed stud shear connector decreases as the temperature rises. As a general result, the shear resistance of all models at fire exposure is lower than that at beyond fire exposure as shown in Table 4. As for the effect of carbon nanotubes observed that it's not effective on ultimate shear at temperatures lower than 400 ℃ but it is decreasing concrete spalling and cracking compared with concrete without CNT.

In general, the failure mode of all composite beams in this paper was shear failure of headed stud shear connectors whether the concrete used was ordinary concrete or concrete modified with carbon nanotubes at all temperatures that used. In addition to this result, it is observed that for the Standard concrete-steel composite beam, beyond 400°C, there is a considerable rise in both the total slip and the average slip in 25 cycles. Nonetheless, the temperature has very little effect on the change in slip at ambient to 400°C. In contrast, the average slip in 25 cycles for the CNT-modified concrete-steel composite beam increases significantly from 400°C. Thus, it can be said that until the temperature rose to 400°C or more, the additional CNT material had no effect. However, the numerical analysis gave results in good agreement with that of laboratory experimental tests [16].

Table 4: The percentages of shear resistance reduction of headed stud under different temperature conditions [16]

Composite types	Shear Resistance of headed stud (kN)						
	Ultimate resisting load				Reduction (%)		
	At temperature (℃)						
	ambient	200	400	600	200	400	600
Ordinary concrete and steel	253	206	170	101	19	32	60
CNT modified concrete and steel	244	205	171	115	16	30	53
	Post temperature (℃)						
	ambient	200	400	600	200	400	600
Ordinary concrete and steel	-	240	247	207	5	2	18
CNT modified concrete and steel	-	236	213	210	3	13	13.9

4. Conclusion

1. The properties of connectors, whatever their type, are greatly affected by high temperatures.
2. The higher the temperatures, the greater the reduction in shear resistance of the connector.
3. The height of the T-shaped connector affects the behavior of the connector, whether under high or ambient temperatures, as the greater the height of the connector, the greater the decrease in shear resistance.
4. The solid slab gives a higher bearing capacity than the profiled slab at ambient temperature.
5. At high temperatures, the profiled steel sheeting in the profiled slab protects the concrete slab from high temperatures, as it supports 60% of the ultimate load.
6. The presence of pits in the T-shaped shear connectors enhances the shear resistance of the connector at ambient temperature, and its effect decreases as the temperature increases.
7. The shear resistance capacity of the headed stud is less affected in post-temperature conditions compared with in (at temperature) conditions.
8. Carbon nanotubes in concrete are effective on ultimate shear at temperatures above 400℃, but at temperatures less than 400℃ , it causes spalling and cracking in concrete.
9. A certain material should be used to reduce of temperature effect on connectors.

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