Performance of composite unprotected steel Beam-deck floor exposed to high temperature (fire flame)

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Abstract:-

An experimental program was conducted to determine the residual of composite Steel Beams-Reinforced Concrete (SB-RC) deck floors fabricated from a rolled steel beam topped with a reinforced concrete slab, exposed to high temperatures (fire flame) of 300, 500, and 700ºC for 1 hour, and then allowed to cool down by leaving them in the lab condition to return to the ambient temperature. The burning results showed that, by exposing them to a fire flame of up to 300ºC, no serious permanent deflection occurred. It was also noticed that the specimen recovered 93% of 19.2 mm of the deflection caused by burning. The recovered deflection of burned composite SB-RC deck floor at 500ºC was 40% of 77.9 mm of the deflection caused by burning with a residual deflection of 46.4 mm. The greatest deterioration occurred when exposed to 700ºC, at this temperature, a higher unrecoverable permanent deflection was recorded (160.3 mm) of the maximum measured burning deflection (173.8mm), indicating that the percent recovered deflection was 8%. Then, all composite SB-RC deck floors were loaded until failure to determine the percent decrease in their ultimate capacity. The results were compared with the behavior of composite SB-RC deck floor without burning (reference specimen).

Keywords: Ambient temperature, Burning, Cooling, Fire flame.

1. Introduction

The behavior of the composite unprotected SB-RC deck floor has been extensively studied over the years due to the involvement of different type of accidents and terrorism. In the past, the behavior of the structure under fire has also been studied experimentally **[6]**, **[14]** and **[15]**. More recently, with the rapid development of commercial finite element scientific programs, theoretical methods have been used **[5]**, **[10]** and **[13]**. Material properties of steel and concrete at raised temperatures are extensively unique in relation to those at encompassing temperature. By and large, with increasing temperatures, the quality and solidness of the materials reduces while their flexibility increases **[3]**, **[9]** and **[12]**.

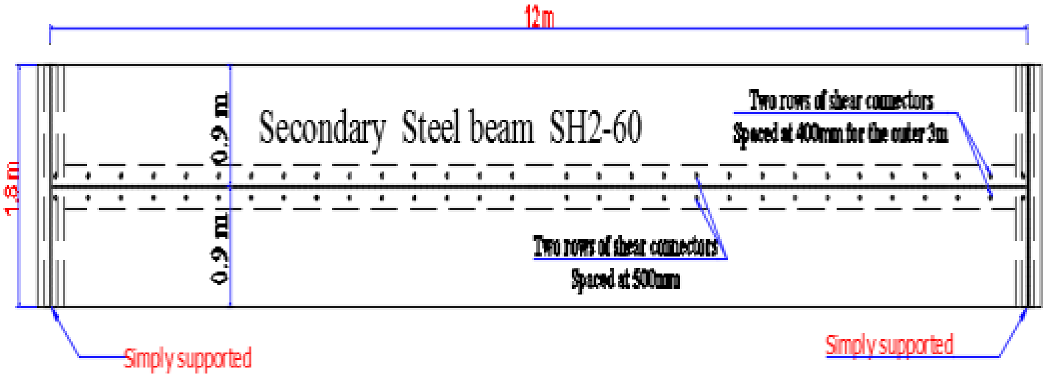
In this study, a comparison was made by testing unprotected composite SB-RC deck floors each has been exposed to a different burning temperature of 300, 500, 700 ºC to find its performance and the residual reversibility of this type of composite structures.

2. Fabrication of composite SB-RC deck floor models

A composite SB-RC deck floor of 12 m and 14.4 m span length and width, respectively, simply supported boundary condition at each edge corner was selected and designed. The structural analysis depends on live load application according to ASCE, requiring nine secondary steel beams of SH2-60 (Russian rolled sections) spaced at 1.8 m and welded to two main beams of HS3-70 with an additional bottom steel plate and 120 mm reinforced concrete deck floor. One of the internal secondary steel beams was selected with a portion of reinforced concrete deck floor specified by a half beam spacing center on all sides. The designed steel beam, concrete deck, stiffeners, and shear connectors are illustrated in **Fig. 1**.

The composite prototype designed SB-RC deck floor of 12 m simple span was converted to a composite deck floor model by using a scale down factor of 1/4, therefore, the model span and deck floor width will be 3 m and 0.45 m, respectively **Fig. 2**.

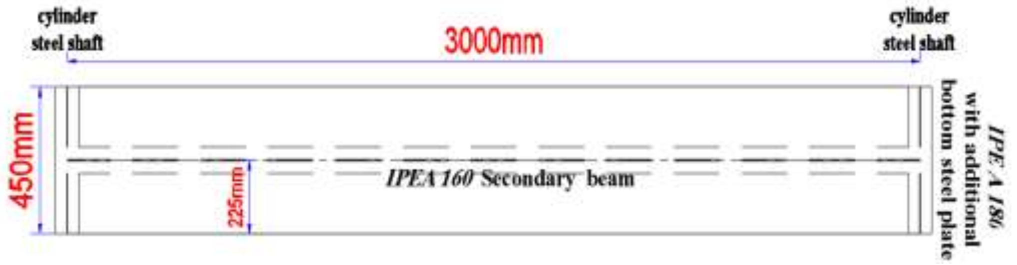
A rolled steel section of IPEA 160 was used to model the secondary steel beam **(SB)**. An additional steel plate of 70 mm width and 5 mm thickness was welded to the lower flange of another rolled steel section of IPE A 180, which used to model the portions of two main beams **(MB)**, stiffeners dimensions, and concrete deck floor thickness were also scaled down by using the same factor of 1/4 **[8]**.



(a) Specimen of one secondary beams (Top View)

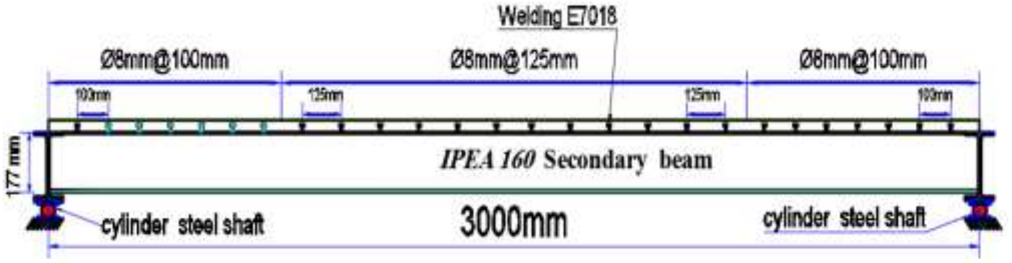
(b) Specimen of one secondary beams (Side View)

Fig. 1 The chosen beams cross-section of full scale designed composite SB-RC Deck floor



(a) Plane of composite SB-RC deck floor

(b) Profile of composite SB-RC deck floor



(c) Distribution of shear connectors

Fig. 2 Composite SB-RC deck floor model

An additional distributed load of 5.1 kN/m^2 was used to induce stresses in the scaled-down secondary steel beam similar to that of the full-scale prototype due to its self-weight (SW) and the permanent dead loads (PDL).

The experimental program was executed by fabricating four simply supported composite SB-RC deck floors. Assemblage of the specimen components (beams, stiffeners, and shear connectors) was performed by welding the individual components together using a fillet weld-type E70XX. Then, the steel sheet of 0.18 mm thickness was fixed to simulate the corrugated sheets formwork required to pour concrete deck of a 35 MPa compressive strength at 28 days (100 mm diameter cylinders and 200 mm height) after assembly of one layer of the deck reinforcing bars of 4 mm diameter spaced at 100 mm in two directions; the resultant structure yielded stress and ultimate strength of 623 and 789MPa, respectively.

Steady-state test method was performed to evaluate the steel beam tensile strength **[4]**. Coupon specimens were tested at the ambient lab temperature after exposing them to fire flam of 300, 500, and 700°C, followed by cooling to the ambient temperature. The results are listed in **Table 1**. According to Eurocode **[7]**, the recommended reduction factor for effective yield strengths at 300, 500, and 700°C measured by transient-state test method were 1.0, 0.78, and 0.23, respectively. This deviation with the test results can be attributed to the difference in the test methods.

Table. 1 Mechanical properties of rolled steel I-beam *IPEA 160*.

	(transient-state test method) ●	**(Steady-state test method)**			
Burning temperature	Reduction factor for effective yield strength %	Yield Stress (MPa)	Residual Yield stress of (burned/ unburned) %	Ultimate Strength (MPa)	Residual ultimate strength of (burned/ unburned) %
un-burned	100	360	100	440	100
300˚C	100	328	91	418	95
500˚C	78	252	70	304	69
700˚C	23	76	21	89	20

● The recommended reduction value according to **Eurocode 3**: Part **1-2 [7].**

3. Test set-up

Two stages of experimental tests were performed, as follows:

1. **Exposure to fire flam:** Three specimens were exposed to high temperature of 300, 500, and 700°C simultaneously with a uniformly constant equivalent dead load, followed by gradually cool-

ing by leaving the specimens at the lab condition.

The furnace was manufactured by using a 3 mm thick steel plate similar to two L-shapes with closed ends to burn one composite SB-RC deck floor at a time with its control specimens **Fig. 3; Plate 1**, the inner clear space was 500 mm height, 750 mm width, and 3000 mm length, appropriate with the specimen dimensions, to keep sufficient space underneath the deck floor so as to reach the fire flame from the methane fire sources (nozzle) to the composite SB-RC deck floor. The nozzles were positioned five in each bottom side of the furnace to simulate underneath fire disaster of the composite SB-RC deck floor.

2. **Load application test:** To find the residual ultimate load capacity, all specimens were loaded until failure by applying a distributing load on the entire specimen surface **Fig. 4.** The results were compared with those of unburned specimen.

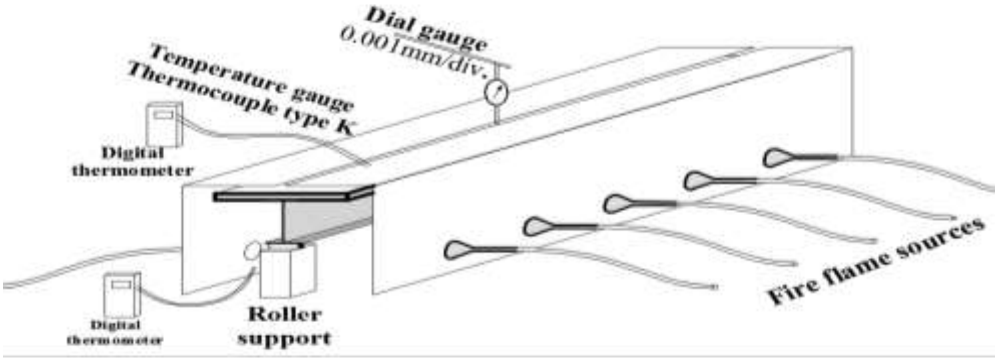


Fig. 3 Furnace schematic shape and burning process

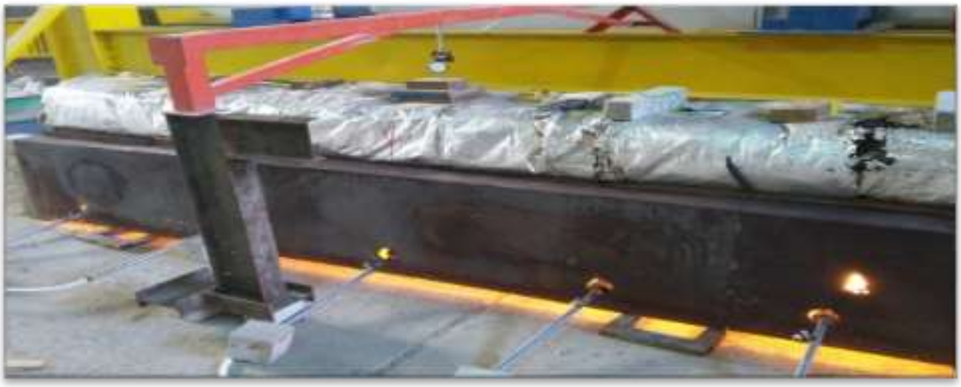


Plate 1 Burning process with applying uniformly distributed load

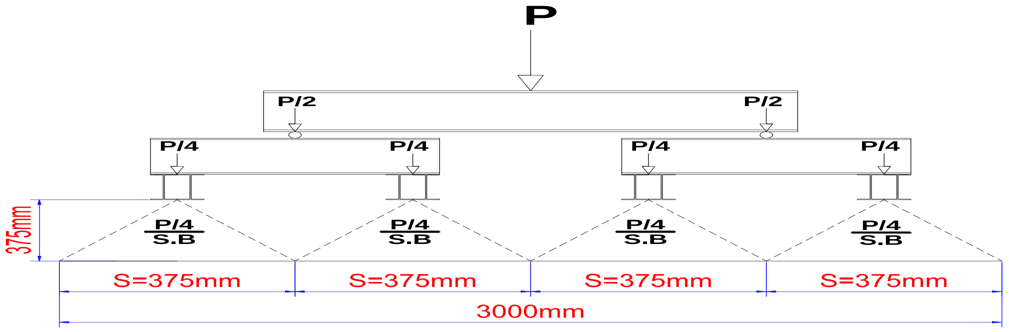


Fig. 4 Distributing applied load on all of the specimen top surface in additinonal to the equivelant distributed load.

4. Experimental results and discussion

4.1. Exposure to high temperature (fire flame)

The burning stage included fixing of the furnace horizontally on a rigid support. Then, the composite SB-RC deck floor was positioned above the idealized, simply supported ends. A dial gauge was placed and the initial readings were recorded after equivalent and uniform dead load was applied (SW and PDL). Then, each specimen was exposed to a burning temperature of 300, 500, or 700˚C for 1 hour each, after reaching the target temperature. The transition period to reach the target temperature was approximately 25, 45, and 70 minutes, respectively. The composite SB-RC deck floors were gradually cooled by left the specimens under ambient lab conditions.

Fig. 5 shows the time history of mid-span deflection through the burning and cooling periods. Obviously, with increasing burning temperature, the deflection increased. At a burning temperature of 300ºC ($SB\text{-}RC_{300}$), the maximum burning deflection was 19.2 mm, and the specimen approximately returned to its original position; the recovered deflection was 93%, i.e., the residual deflection was only 7% **Table. 2**. While exposing specimens to a temperature of 500ºC ($SB\text{-}RC_{500}$), the deflection was about 4 times of that at the burning temperature of 300ºC, reaching 77.9 mm. Consequently, the residual deflection was also higher than that of $SB\text{-}RC_{300}$, the percent recovered deflection was 40%, that is, it was 60% residual deflection or the composite SB-RC deck floor was permanently deformed. The worst case was the burning of the specimen at 700ºC ($SB\text{-}RC_{700}$). At this temperature, the mid-span deflection was extremely high, reaching 9 times greater than that at 300ºC (173.8 mm), while only 8% was recovered on returning to the ambient temperature **Table .2**.

Exposing the composite SB-RC deck floors to high temperatures pass through three periods. The transition period, to reach the target temperature. Through this period, the highest rate of descending was observed due to the exposure to high rate of expanding material; the rate of deflection to the transit time was 0.63, 0.83, and 1.98 mm/min. for the burning temperatures of 300, 500, and 700˚C, respectively. At the end of this period, the maximum measured deflection was 16.2, 37.5, and 138.6 mm for *SB-RC*$_{300}$, *SB-RC*$_{500}$, and *SB-RC*$_{700}$ specimens, respectively **Table. 2**. The second period, it took 1 hour with a constant temperature, the composite *SB-RC*$_{300}$ deck floor exhibited low rate of deflection with time, reaching 0.05 mm/min. or approximately a slight change in the mid-span deflection. In contrast, *SB-RC*$_{500}$ and *SB-RC*$_{700}$ exhibited a significant increase in the deflection with a highest rate of curve descending compared to that of *SB-RC*$_{300}$, it was 0.67 and 0.59 mm/min, respectively. These values indicate that more damages could occur. The fire sources were underneath the specimens; therefore, the heat gain began from the lower parts to the upper ones, which led to the expansion of these parts before the headings. Moreover, the steel thermal conductivity was much higher than that of concrete. This phenomenon provides a high rate of specimen deflection at the first period. But, when all specimen parts reached the target temperature or the heat balance, the deflection rate decreased.

The final period, when the fire flame turned off, indicated the cooling period. A high rate curve ascending was recorded or, in other words, the composite SB-RC deck floors tended to recover their original positions. At the first 40 min. of the cooling period, *SB-RC*$_{300}$ specimen exhibited higher recovery rate of mid-span deflection. Until about 125 min. of the total time, the composite SB-RC deck floor recovered its original position and continued to rise above its original specimen level before burning for a distance of about 0.3 mm. Because, the lower parts of the composite SB-RC deck floor (lower steel flange and web) dissipated heat faster than the upper ones (upper steel flange, concrete deck floor, and the mass of additional dead load), which led to the shrinkage of these parts while the upper ones continued to expand. Next, a little increase in the deflection was measured with time; the total time needed to dissipate heat and return to the ambient temperature was about 200 min. of the total time, while the residual deflection was 1.4 mm **Table. 2**. This means that the specimen recovered 93% of the deflection caused by heating. Therefore, it can be concluded that composite SB-RC deck floors exposed to fire flame up to 300ºC approximately did not lead to any serious permanent deflection. Specimen *SB-RC*$_{500}$ exhibited a high rate of recovered deflection through this period; this rate subsided after a short period of time. **Fig. 5** shows that, from 200 min. until about 600 min., a little deflection was recovered and the residual deflection was 46.8 mm, indicating that the recovered deflection was only 40%. In contrast, a small amount of the total burned deflection was recovered for specimen $SB\text{-}RC_{700}$ and the residual deflection was 160.3 mm; therefore, the percent recovered burning deflection was 8%. This result reflects the amount of damages that occur when composite SB-RC deck floors are exposed to high temperature of up to 700ºC.

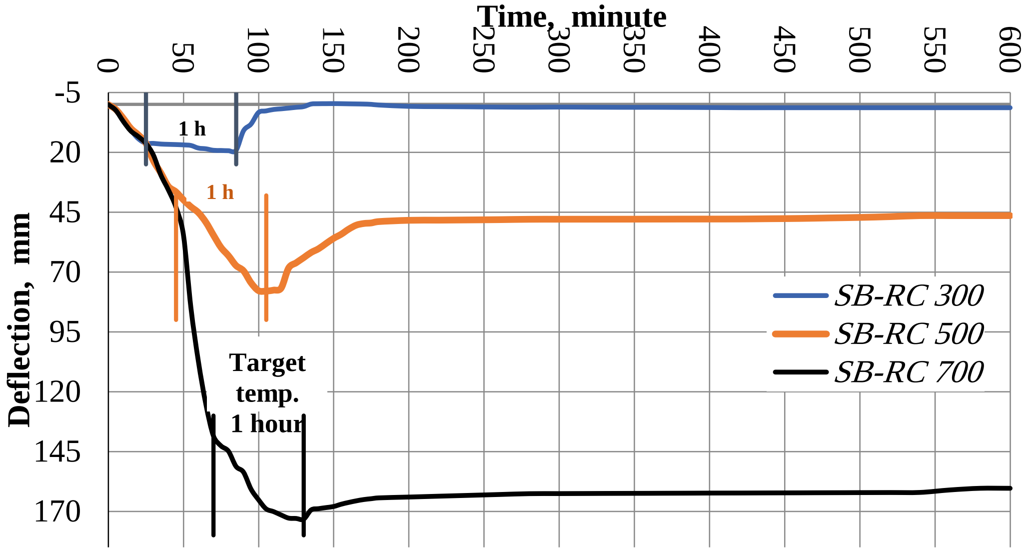


Fig. 5 Mid span deflection-time history of burned composite *SB-RC* deck floors at different temperatures .

Table .2 Mid span deflection at the end of each time period of burning and cooling stage.

Model No.	First period (Transient) Time minutes	Mid span deflection mm	Second period (Target) Time minutes	Mid span deflection mm	Third period (Cooling) Time minutes	Mid span deflection mm	Recovered deflection mm	Recovered deflection %
$SB\text{-}RC_{R}$	-	-	-	-	-	-	-	-
$SB\text{-}RC_{300}$	25	16.2	85	19.2	420	1.4	17.8	93
$SB\text{-}RC_{500}$	45	37.5	105	77.9	520	46.8	31.8	40
$SB\text{-}RC_{700}$	70	138.6	130	173.8	600	160.3	13.5	8

4.2. Load application test

At the end of the first test stage, the equivalent distributed load was removed and composite SB-RC deck floors were transmuted to the load test rig. Thus, the residual deflection of the burning period cannot be conserved to the next test stage.

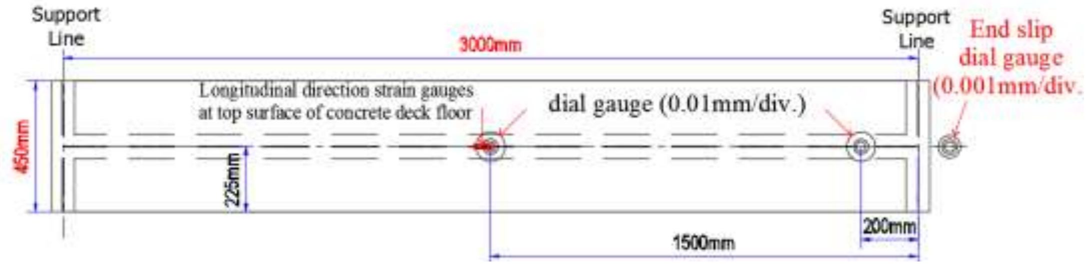
To find the behavior and the residual ultimate capacity of the composite SB-RC deck floors exposed to different burning temperatures, specimens were uniformly loaded along with an equivalent uniform load applied during the burning stage. For this purpose, mid-span deflection and the relative displacement between the concrete deck floor and the steel I-beam were measured by using sensitive dial gauges of 0.01 and 0.001 mm/div., respectively. Electrical resistance foil strain gauges of 6 and 60 mm lengths were used to measure the lower flange strain and top concrete strains at mid span, respectively **Fig. 6**

4.2.1. Load versus deflection

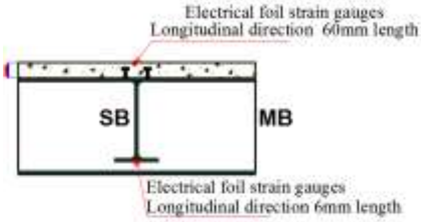
Table. 3 and **Fig. 7** show the effect of fire flame on the serviceability of the composite SB-RC deck floors with respect to specimen's deflection.

The unburned specimen $SB\text{-}RC_R$ showed a linear behavior until the loading of 59 kN/m^2 at a companion deflection of 17.0 mm. The burned specimens at 300, 500, and 700°C loss their linear behavior at a loading of 48, 22, and 11 kN/m^2, respectively. After this limit of loading, the curves descended.

According to the AISC **[1]**, the permissible deflection limit was L/240 (12.5 mm). Therefore, this value of deflection and its companion load was used for comparison as an end service limit of the linear behavior for the unburned and burned specimens **Table. 3** Consequently, the applied load at this specified limit for the unburned specimen was 47 kN/m^2, while it was 38, 19, and 10 kN/m^2 for the burned composite SB-RC deck floors at 300, 500, and 700°C, respectively.



(a) Top view



(b) Side view

Fig. 6 Location of dial gauges and electrical resistance foil strain gauges

These results indicate that the reduction in serviceability limit or the initial specimen stiffness values were 19, 60, and 79%, respectively, as compared to those of the unburned specimen. An increase in the straight portion of the load-deflection curve indicates a high specimen serviceability; in contrast, decreasing value reflected product deterioration due to the burning process. It can be seen that, as the burning temperature increased, the straight region decreased, for the burned specimen at 700°C (*$SB\text{-}RC_{700}$*) the straight region was very small, i.e., the elastic behavior was approximately marginal, where the applied load at the end of this region limit was about 11 kN/m^2 (including the equivalent SW and PDL) after that, the specimen exhibited an excessive increase in the deflection as compared to a small increase in the resisting applied load

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Table. 3 Load and deflection at linear service portion limit.

Model No.	Linear portion (Service) ●		Burned Service load / unburned (reference) ● %	Load at end of linear behavior (kN/m^2)
	Deflection at L/240 ● (mm)	Load (kN/m^2)		

SB-RC_R	12.5	47	100	59
SB-RC₃₀₀	12.5	38	81	48
SB-RC₅₀₀	12.5	19	40	22
SB-RC₇₀₀	12.5	10	21	11

- ***Note: Control deflection according to ASCE [2] L/240 = 12.5mm***

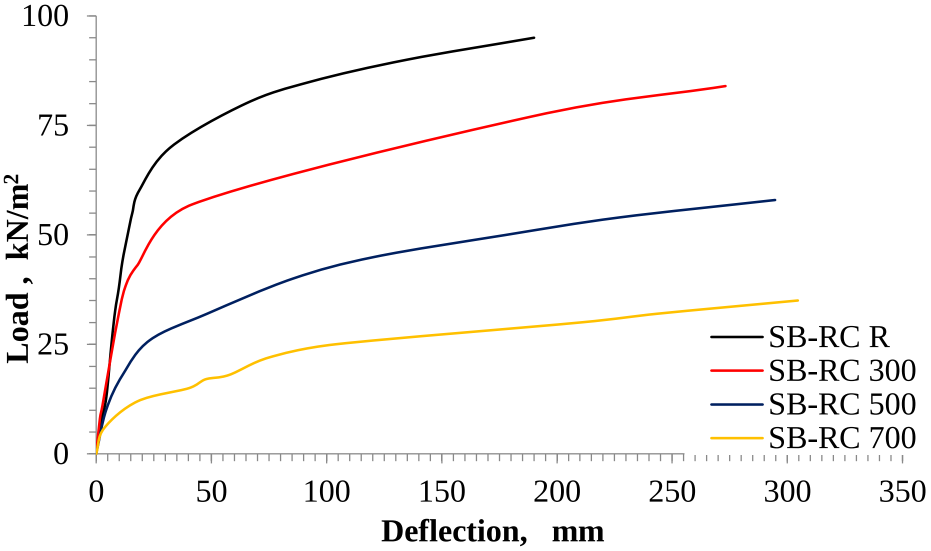


Fig. 7 Load versus mid span deflection of unburned and burned composite SB-RC deck floors at different temperatures

4.2.2. Load versus bottom steel flange strain

During the burning stage, thermal strain of the composite SB-RC deck floors could not be measured due to the high temperature of the fire flame.

Linear coefficient of thermal expansion (α) of the structural materials ranged from 11 to 12 (x 10^{-6}/°C) for structural steel and 8 to 12 (x 10^{-6}/°C) for concrete. The two materials had approximately the same values. Accordingly, thermal strain $\in_{therm.}$ could be calculated as:

$$\in_{therm.} = \alpha \cdot \Delta t \quad \ldots. \; 4.1$$

$$\in_{therm.} = 11 \times 10^{-6} \cdot \Delta t$$

Therefore, the generated thermal strain at the burning stage theoretically reached 3300, 5500, and 7700 microstrain at the burning temperatures of 300, 500, and 700°C, respectively. While **[7]** gives an estimation of warm thermal of 4618, 8258, and 12218 microstrain, respectively, which can be calculated from the equation, as follows:

$$\varepsilon_{th}(\theta) = -2.416 \times 10^{-4} + 1.5 \times 10^{-5}\theta + 0.4 \times 10^{-8}\,\theta_a^2 \quad \text{for } 20^\circ\text{C} \le \theta < 750^\circ\text{C} \qquad \ldots.\ 4.2$$

All composite SB-RC deck floors are simply supported by using steel rollers. In other words, no internal stresses are generated. Furthermore, visible permanent curvature was observed in composite SB-RC deck floors, which was burned at 500°C; and it was more apparent at 700°C at the end of the burning stage, which led to plastic deformation, as accorded by the measured residual deflection.

Electrical foil strain gauge of 6-mm length was used to measure the longitudinal strain at mid-span, bottom surface of the lower steel flange during the load test stage.

According to **Eurocode (EC3) [7]**, the recommended modulus of elasticity reduction factors at 300, 500, and 700°C were measured by transient-state test method, and the tested yield stresses that were found by steady-state test method **Table. 4**, the yield strain depending on these values can be calculated. By comparing the calculated value of strain with the measured maximum strain value of the straight line for load strain curves **Fig. 8**, which give the percent ratio **Table .4** Most of these ratios are close to the theoretical ones assumed from yield strain values. Despite the use of two different test methods for calculating and measuring the strain, the deviation was acceptable.

Fig. 8 shows the strain versus applied load of composite SB-RC deck floors burned at different temperatures. It can be seen that, the strain increased with the burning temperature, that is, the curve flattened with the increase in the burning temperature. The linear portion of the curve that was adopted as a reference for comparison (servisibilty limit), decreased with an increase in the burning temperature. Depending on the service limit specified for the linear curve portion, the increase in the generated strain rate compared to the unburned composite SB-RC deck floor was 165, 379, and 758% at the burning temperatutes of 300, 500, and 700°C, respectively **Table.5**

Table .4 Measured and calculated strain of secondary steel beam at the end of linear behavior.

Burning temperature	Modulus of elasticity reduction factor	Reduced Modulus of elasticity (GPa)	Tested yield stress (MPa)	Calculated Yield strain • • (mm/mm)	Measured Strain at end of linear portion• • • (mm/mm)	Measured / calculated strain %
$SB\text{-}RC_{R}$	1.0	200	360	0.0018	0.00170	94
$SB\text{-}RC_{300}$	0.80 •	160 •	328	0.00205	0.00202	98
$SB\text{-}RC_{500}$	0.60 •	120 •	252	0.0021	0.00220	105
$SB\text{-}RC_{700}$	0.13 •	26 •	76	0.0029	0.00260	90

- According to **Eurocode (EC3) [7].**

• • $\in = \sigma / E$

• • • Measured Strain at end of linear portion of load-strain curves **Fig. 8**

Table .5 Measured longitudinal bottom steel flange strain at service limit

Burning temperature	Load at service limit of (L/240) deflection (mm/mm) (kN/m^2)	Measured Strain at service limit of (L/240) deflection (mm/mm)	Generated strain rate ratio of burned/unburned (reference specimen) %
$SB\text{-}RC_{R}$	47	0.00124	100
$SB\text{-}RC_{300}$	38	0.00166	165
$SB\text{-}RC_{500}$	19	0.00190	379
$SB\text{-}RC_{700}$	10	0.00200	758

Note: Generated strain rate ratio, is the ratio of generated strain to the companion load

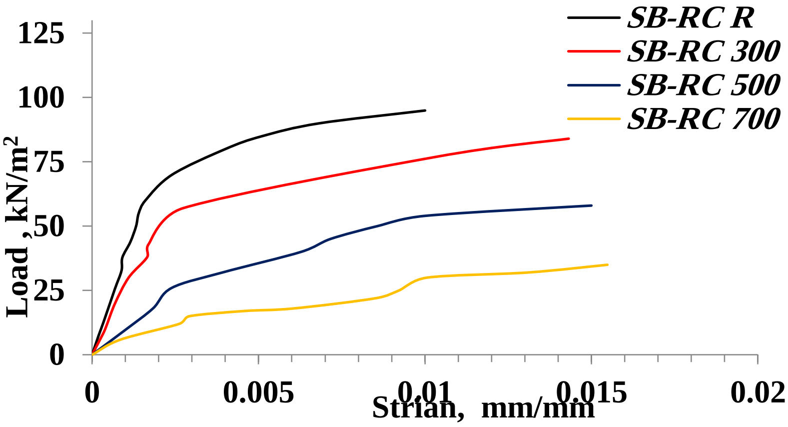


Fig. 8 Load versus bottom steel flange strain of composite SB-RC deck floors at different burning temperatures

4.2.3. Load versus top concrete deck strain

Despite the exposure to high temperature and concrete deterioration, the longitudinal top concrete deck strain was measured for the specimens were burned up to 500°C. **Fig. 9** shows the longitudinal strain of composite SB-RC deck floors were exposed to different temperatures. It can be seen that, as the burning temperature increased, the generated strain increased due to the deterioration and defects occurring in material strength of concrete and the used rolled steel. Depending on the strain companions to the specified service load limit **Table. 6**, the longitudinal generated strain rate percent of increase in strain was 161% and 506% at the burning temperatures of 300 and 500°C, respectively. All specimens reached the nominal ultimate strain of 3000 microstrain.

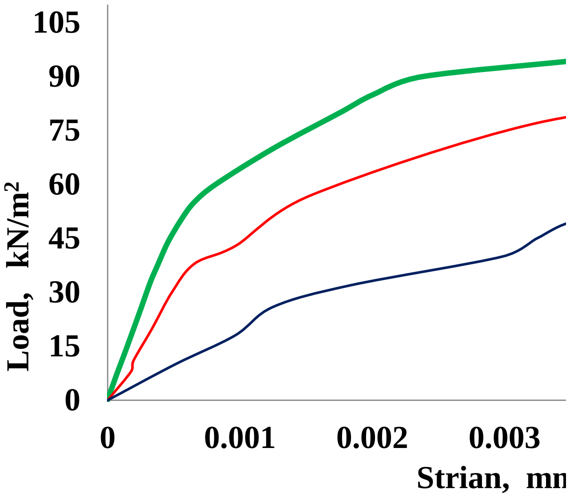


Fig. 9 Load versus longitudinal top concrete strain composite SB-RC deck floors at different burning temperatures

Table. 6 Measured longitudinal top concrete deck strain at service limit

Burning temperature	Load at service limit of (L/240) deflection (mm/mm) (kN/m^2)	Measured strain at service limit of (L/240) deflection (mm/mm)	Generated strain rate ratio of burned/unburned (reference specimen) %
$S\text{-}SB\text{-}RC_{R}$	47	0.0005	100
$S\text{-}SB\text{-}RC_{300}$	38	0.00065	161
$S\text{-}SB\text{-}RC_{500}$	19	0.00102	506
$S\text{-}SB\text{-}RC_{700}$	10	-	-

Note: Generated strain rate ratio, is the ratio of generated strain to the companion load

Ultimate load capacity and mode of failure

The residual ultimate strength was the final limit of comparison beyond the validation and the serviceability of the structural element. **Table.**7 shows the effect of high temperature on the ultimate load capacity. The residual strength decreased as the burning temperature increased. For the burned composite deck floors at 300, 500, and 700°C, the corresponding values were 88, 61, and 37% as compared to the unburned specimen, respectively. It can be concluded from the above results that the composite SB-RC deck floors can carry load even when exposed to high temperature reaching up to 500 and 700°C; however, its serviceability was demonstrated by excessive deformation and elongation of the steel beams. **Table. 7** summarizes the modes of failure of the tested composite deck floors, after the load test stage was finished.

Failure of reference composite SB-RC deck floor ($SB\text{-}RC_{R}$) passed through different stages, started with the apparent mid-span deflection **Plate 2-a**. Due to the uniform equivalent applied load, led to the development of cracks on both concrete deck sides which can only be observed **Plate 2-b**, even when the top concrete strain reached the nominal ultimate value of 3000 microstrain, the propagation of cracks or crashing could not be specified. With increasing load, the bottom steel flange reached yield stress, thereafter, excessive deflection was measured and the composite SB-RC deck floor could not resist any further applied load. Top concrete cracks and damages were observed after removing the uniform equivalent applied load **Plate 2-c.**

Plates 3 through **5** show the failure of burned composite SB-RC deck floors, showcasing the same behavior as that of $SB\text{-}RC_{R}$, but these specimens were pre-damaged as a result of the burning stage. Obviously, as the burning temperature increases, the damage of concrete as well as steel beam increases. This could have affected the ultimate load resistance and the failure of these specimens. Despite the structural composition of specimens and the applied load on all topping concrete deck, longitudinal top cracks were detected, followed by lateral crushing of concrete deck as in $SB\text{-}RC_{300}$ specimen (**Plate 3-c**).

Table .7 Load at ultimate state and mode of failure.

Model No.	**Ultimate Load (kN/m^2)**	**Residual strength %**	**Mode of failure**
$S\text{-}SB\text{-}RC_{R}$	95	100	Concrete deck : Crushing Steel beam : Yield
$S\text{-}SB\text{-}RC_{300}$	84	88	Concrete deck : Crushing Steel beam : Yield
$S\text{-}SB\text{-}RC_{500}$	58	61	Concrete deck : Crushing Steel beam : Yield
$S\text{-}SB\text{-}RC_{700}$	35	37	Concrete deck : Crushing Steel beam : Yield

Note: The ultimate load includes the equivalent SW and PDL

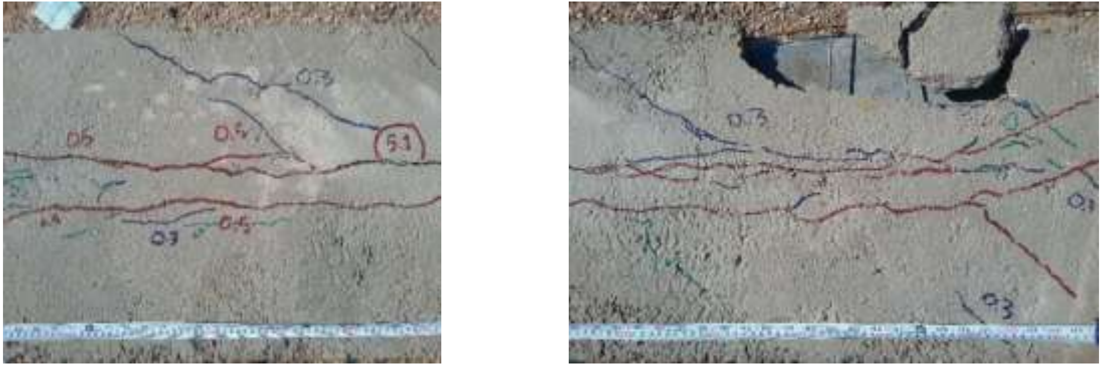
There are several limit states or conditions for which a structure can be considered unusable and a failure, for example, when members or the entire structure reach a particular yield, when the ultimate strength exceeded a specified maximum deflection limit, when the members fracture, or collapse occurs.

(a) Excessive deflection of SB-RC_R just before failure

(b) Flexural cracks side view **(c)** Flexural cracks top view

Plate 2. Failure of reference composite SB-RC deck floor (SB-RC_R)

(a) Excessive deflection of SB-RC_{300} just before failure



(b) Flexural cracks top view **(c)** Lateral crushing of concrete deck

Plate. 3 Failure of burned composite SB-RC deck floor SB-RC_{300}) after loading stage

(a) Excessive deflection of SB-RC$_{500}$ just before failure

(b) Flexural cracks top view **(c)**Longitudinal concrete deck cracks

Plate 4. Failure of burned composite SB-RC deck floor (SB-RC$_{500}$) after loading stage

(a) Excessive deflection of SB-RC$_{700}$ just before failure

(b) Flexural cracks top view **(c)** Lateral crushing of concrete deck

Plate 5. Failure of burned composite SB-RC deck floor (SB-RC$_{700}$) after loading stage

Conclusions

1. Composite SB-RC deck floor exposed to fire flame up to 300ºC did not result in any serious permanent deflection. Specimen *SB-RC*$_{300}$ recovered 93% of 19.2 mm of the deflection induced by burning at 300ºC; the residual deflection was only 1.4 mm. The most defects happened during the period of temperature increase until the specified temperature was reached. The total time needed to dissipate heat and get back to the ambient temperature was about 200 min.
2. Burning composite SB-RC deck floor at 500ºC for 1 hour recovered 40% of 77.9 mm of the deflection, and the residual deflection was 46.4 mm. The defects continued through the burning process until reaching the cooling period.
3. Exposing composite SB-RC deck floor to 700ºC led to the biggest deterioration reflected by the measured deflection of 173.8 mm. The unrecovered burning deflection was 160.3 mm, indicating the percent of recovered deflection to be only 8%.
4. The reduction in service limit depending on the maximum linearity behavior of the load-deflection curves of burned to unburned composite SB-RC deck floors were 19, 63, and 81% at the burning temperatures of 300, 500, and 700°C, respectively. These results indicate that as the burning temperature increased the linearity behavior of load-deflection decreases or the curve flattens.
5. The residual ultimate strength capacity decreased as the burning temperature increased. For the burned composite deck floors at 300, 500, and 700°C, the corresponding values were 88, 61, and 37%, as compared to the unburned specimen, respectively.
6. Excessive deflection was monitored with yielding steel beams and concrete deterioration, but the total collapse of the burned composite SB-RC deck floors was not observed and they could carry load even when exposed to high temperature of up to 500 or even 700°C.
7. All composite SB-RC deck floors failed by yielding of steel beams and top concrete crushing.

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أداء مركب من الحديد غير المحمي وسطح السقف المعرض إلى ارتفاع في درجة الحرارة (لهب النار)

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الخلاصة:-

وقد أجري برنامج عملي لتحديد المتبقي من هطول أسطح السقوف المركبة من الجسور الحديدية (SB-RC) المصنوعة من الحديد المدلفن يعلوها سقف من الخرسانة المسلحة، تتعرض لدرجات حرارة عالية (لهب حريق) من 300 و500 الى 700 درجة مئوية لمدة ساعة واحدة، ثم يسمح لتبريد من خلال تركها في حالة المختبر للعودة إلى درجة الحرارة المحيطة. وأظهرت نتائج الحرق أنه من خلال تعريضها الى لهب النار بدرجة تصل إلى 300 مئوية، لم يحدث أي هطول خطير دائم. كما لوحظ أن العينة أعادت 93٪ من 19.2 مم من الهطول الناجم عن الحرق. وكان الهطول المسترد من سطح السقف المركب SB-RC المحترق عند 500 درجة مئوية 40٪ من 77.9 مم من الهطول الناجم عن الحرق مع هطول متبقي قدره 46.4 مم. وقد حدث أكبر تدهور عند تعرضه إلى 700 درجة مئوية، وعند هذه الدرجة، تم تسجيل هطول دائم غير قابل للرجوع (160.3 مم) من أقصى هطول حرق تم قياسه (173.8 مم)، مما يشير إلى أن النسبة المئوية للهطول التي تم استردادها 8٪. بعد ذلك، تم تحميل جميع أسطح السقوف المركبة SB-RC حتى الفشل في تحديد نسبة الانخفاض في قدرتها النهائية. وتمت مقارنة النتائج مع سلوك سطح السقف المركب SB-RC بدون حرق (العينة المرجعية).

الكلمات المفتاحية : درجة الحرارة المحيطة، حرق، تبريد، لهب النار.