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The performance of composite steel in the elements of a post-fire steel bridge

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Abstract. The steel structure is commonly acknowledged able to return to its original strength condition. It is yet unknown whether composite structure may return to its initial condition. Test specimen on the present study consists of 8 units, each of them divided into four stud-connector bold (SP) composites beams and four UNP connector (SF) composite beams. Each of the specimen has control value by SP/020 and SF/020, and other six specimens with combustion of SP/400, SP/550, SP/700 and SF/400, SF/500, SF/700, within condition of point load for about 12 kN. The study intends to investigate composite girder of post-fire bridge element towards duration and heat temperature factors and effect of beam performance towards stud-connector and UNP connector composites. The results draw several conclusions; The process of composite combustion shows that the failure on composite steel beam specimen is due to the load, burning duration and temperature which results in residual deflection. Deflection test reveals the effect of temperature, load, and duration do not give significant impact to load capacity of post-combustion beam structure.

1. Introduction

Response of steel structure which was exposed to fire is affected by heat, mechanical and deformation characteristics. Heat characteristic determines the profile temperature of fire-exposed steel section while mechanical characteristic manages the loss of strength and stiffness as time function. Deformation characteristic determines deformation area of steel section that was exposed to fire [1]. IWF beams burning is part of structural bridge element which points out progressive collapses on steel beam due to temperature effect and burning duration and the first-mid span of load during the fire. Therefore, beam structure performance during the fire is affected by these three factors; aside from deformation capacity reduction and ductility. However, these three factors do not have great impact on the peak-load capacity of post-fire beams, unless it had suffered high residual deformation or buckling due to the burning process. In apparent, to a certain degree, it can be marked by residual deflection limitation, bridge element which is girder of load gravitation buffer on the bridge that remained to be applied after the fire [2].

Aims of the study are as follows:

- Recognize the performance of post-fire composite steel bridge element beam towards the temperature, duration and load.
- Acknowledge the decline of deformation capacity and ductility in the aftermath of fire damage.

- Understand the effect and performance comparison of composite steel element beams by employing stud connector and UNP connector.

2. Literature review
A number of study results proved that under a high temperature, structure performance is suffering a very significant decline. In the 600°C temperature, stiffness and bending capacity of beam suffered a decrease and the achieved maximum stress was far below the material melting point [3]. Temperature effect towards material property decline is “high temperature led to a significant decline in melting point and steel material elasticity modulus” [1].

3. Methodology
The experiments that will be performed generally are: material test to identify steel and concrete material characteristics for composite steel beam, composite beam burning test with lateral load, and composite steel structure test before and after the fire damage. The tested specimens consist of two group specimens where four of them utilizing stud connector (SP) and another four specimens by utilizing UNP connector (SF). The following steps will be carried out in this study as follows:

- Tensile Test of steel profile specimen
- Concrete Compressive Test
- Composite beam specimen burning which the elaboration is described in the following table.

Table 1. Type of composite beam specimen and composite beam burning.

Specimen		Burning Target		
		Temperature (^{O}C)	Gravitation Load (kN)	Duration (Minute)
Stud Connector	SP/020	-	-	-
	SP/550	550	17	120
	SP/700	700	17	120
	SP/900	900	17	120
UNP Connector	SF/020	-	-	-
	SF/550	550	17	120
	SF/700	700	17	120
	SF/900	900	17	120

- The test employs *Universal Testing Machine* (UTM) to compare each of the results with the burning test result of controlled specimen.

3.1. Material experiment
Material test involves steel tensile test and concrete compressive test to discover the stress and strain of composite beam. The sample of steel tensile test refers to ASTM standard E8/E8-09 as the following figure 1.

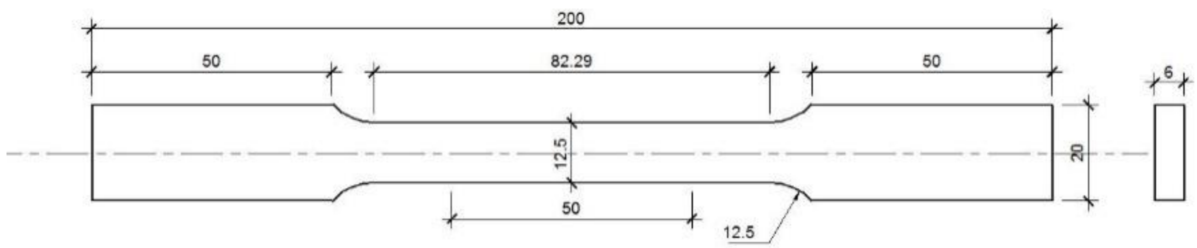

Figure 1. Tensile test specimen ASTM E8/E8M-09 [4].

3.2. Specimen model of test object

Model prototype and dimension of bridge composite beam is displayed in figure 2 below. By using laboratory scale of 1:3, the comparison between specimen model and prototype structure is presented as follows:

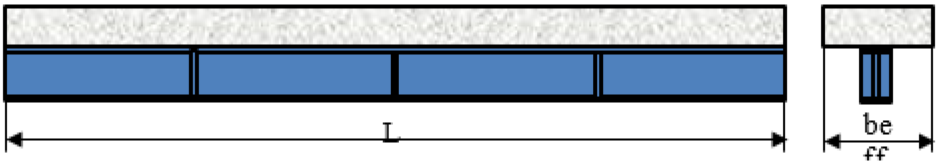

Figure 2. Beam test object.

Table 2. Specimen comparison toward prototype.

	Dimension Iwf (mm)					Concrete Dimension (mm)		Bentang Gelagar L (mm)
	H	**B**	**t_w**	**t_f**	**t_s**	**b_e**	**t_c**	
Prototype	200	100	5,5	8		1250	200	9000
Specimen	95	50	5	4		300	70	3000

3.3. Fire test

Fire test used by ASTM E119 Standard Methods of Fire Test of Building Construction and Materials [5]. Fire test was performed in Building Science Laboratory of Research and Development Center at Ministry of Public Work and Housing Residential, by using the fire furnace as it can be seen in figure 3 and 4 below.

Figure 3. Fire furnace.

Figure 4. Specimen incineration/burning.

During the burning process, an observation is executed within 5 minutes' interval then measures the deflection of load and furnace temperature until the result is obtained. This process will unveil the relation between deformation and burning temperature. Thus, the decline of composite beam and its relation to reduction of steel and concrete elasticity modulus can be revealed.

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4. Results and data analysis

4.1. Fire test result of composite beam

Table 3. The result test of composite beam fire.

	Specimen	Average Temperature (^{O}C)	Load (kN)	Residual Deflection (mm)	Duration (minutes)	Notes
Stud Connector	SP/020		-	-	-	Specimen control
	SP/400	374,316	12	46	120	-
	SP/550	521,092	15	150	120	-
	SP/700	649,414	12	330	120	-
UNP Connector	SF/020		-	-	-	Specimen control
	SF/400	375,80	12	40	120	-
	SF/550	517,116	12	95	120	-
	SF/700		-	-	-	Unfinished Specimen

The result of composite beam fire test indicates that as the temperature escalates, the deflection on specimen also elevates. The initial planning of the present study intends to burden the specimen with concrete load by 17 kN. Based on the observation result, SP/550 had suffered an extreme residual deflection therefore the load is reduced to 12 kN. Load impact to the temperature was also extremely high which causing the specimen SP/700 became collapse. Hence, SF/700 did not undergo the fire test. Following up this occurrence, SP/900 and SF/900 are not burnt in temperature of 900°C and the specimen's name is modified in accordance on the table 3. The experiment then reduces the fire temperature to prevent the failure as it is displayed in the table 3. The comparison between SP specimen and SF specimen shows that SF specimen has better performance influence rather than SP specimen. It is shown physically for SF specimen where composite behavior operates better while it accepted the load and high temperature.

4.2. Steel material testing result

Table 4. The result test of steel material structure.

Profile Steel	**Temp. 020℃**	**Temp. 400℃**	**Temp. 550℃**
Maximum Load, kg	1646,748	1545,632	1476,664
Tensile strength, N/mm^2	376,39	353,28	337,52
Yield Strength, N/mm^2	250,325	234,954	225,728
Elongation, %	33,88	33,93	32,48
Concrete-steel	**Temp. 020℃**	**Temp. 400℃**	**Temp. 550℃**
Maximum Load, kg	1014,2817	980,298	940,628
Tensile strength, N/mm^2	397,76	384,40	368,74
Yield Strength, N/mm^2	252,304	246,86	239,85
Elongation, %	32,03	32,10	32,25

Material testing of structural steel and concrete-steel of each fire temperature can be seen from the tensile test result based on ASTM E8/E8M-09 standard in figure 1 [4]**.**

5. Conclusion

Several conclusions can be gathered from the executed experiment results as follows:

- All the specimens which undergoing the fire burning below 550°C temperatures, their composite structure occurred to be still in a proper load capacity.
- Steel burning process demonstrates a collapse in steel beam which is affected by temperature, fire duration and its initial load.

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- Steel beam does not suffer a collapse while it experienced post-fire residual deflection nor did it suffer lateral buckling or torque buckling.

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