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ScienceDirect

Procedia Engineering 171 (2017) 176 – 184

Procedia Engineering

www.elsevier.com/locate/procedia

Sustainable Civil Engineering Structures and Construction Materials, SCESCM 2016

Full height rectangular opening castellated steel beam partially encased in reinforced mortar

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Abstract

This paper discusses analysis and test results of full height rectangular opening castellated steel beams without encasing and with partially encasing using reinforced mortar. Each contains two types of beam span namely short span beams to study the shear failure mechanism and long span beams to study the flexural failure mechanism. Test results show that the beams without encasing have lower load capacity than the original section due to Vierendeel truss mechanism. On the other hand the application of partially reinforced mortar encasing in the long span beam can avoid the Vierendeel truss mechanism and increases the yield moment capacity around 3.5 times of original steel section yield moment. However the short span one failed in brittle shear mechanism due to diagonal crushing in the mortar and then followed by Vierendeel truss mechanism so that the flexural strength could not be achieved. Shear strength of the full height rectangular opening castellated steel beam partially encased in reinforced mortar is larger than the calculated conventional reinforced concrete shear capacity but is less than the steel web shear capacity. It is recommended that the shear strength is calculated using diagonal strut mechanism of the mortar to give more appropriate shear strength prediction.

Peer-review under responsibility of the organizing committee of SCESCM 2016.

Keywords: beam, castellated, encased, flexural, shear, Vierendeel mechanism

1. Introduction

The most common pattern or shape of the hole in the web of castellated steel beams that has been known quite sometimes ago is hexagonal [1]. The main objectives of making castellated steel beam are to increase the steel section

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Peer-review under responsibility of the organizing committee of SCESCM 2016.
doi:10.1016/j.proeng.2017.01.324

flexural stiffness and strength without increasing the steel self weight [2]. These advantages can safe some cost especially in mass production of long span beams [3]. If shear stress becomes dominant in the castellated beam, it is required to give stiffeners around the holes to increase the shear capacity [4]. Stress analysis of castellated steel beam can be calculated based on Vierendeel truss theory [1,2].

Steel encased in reinforced concrete method is used to avoid the steel from buckling that can be used for beams [5,6], columns [7,8], both columns and beams [9, 10, 11], or coupling beams [12,13]. There are two types of encased method namely fully encased and partially encased. In the fully encased method the whole steel section is covered by the reinforced concrete so that the top and the bottom flanges are not in the outermost position. In this case maximum strain developed in the steel is less than the one in the concrete. On the contrary, in partially encased method only the web is covered by the reinforced concrete, therefore maximum strain will develop in steel flanges that makes the application of the steel section can be more optimum.

This research was carried out to further optimize the application of steel in the partially encased method, that is by using new rectangular hole pattern castellated steel beam to be encased in reinforced mortar. The new hole pattern is designed to make full height rectangular opening castellated steel beam, see Figure 1.

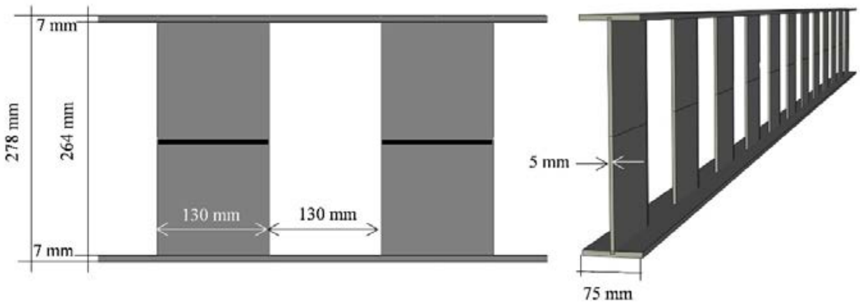

Figure 1. Full height rectangular opening castellated steel beams

2. Research Method

Two groups of specimens were made and analysed in this research. The first group was the full height rectangular opening castellated steel beams without encasing shown in Figure 1 that contains two beam specimens namely short span beam to study shear strength and long span beam to study flexural strength, see Figure 2. Two point loadings method was used in the tested beams which were supported using hinge at one end and roll at the other end. The full height rectangular opening castellated steel beam was made from IWF 150x75x5x7 section that had original section height h = 150 mm, width of flange b_f = 75 mm, flange thickness t_f = 7 mm, web thickness t_w = 5 mm, and the yield strength f_{ysec} = 278 MPa. Using this data it can be found that the original steel section has yield moment of 24 kNm. In the full height rectangular opening castellated steel beams the vertical and the horizontal cutting pattern made the width of hole in the web to be B = 130 mm, the height of hole d = 264 mm, and the height of castellated beam h = 278 mm or almost as twice as its original height of 150 mm as has been shown in Figure 1.

The second group of specimens was the same full height rectangular opening castellated steel beams mentioned above but were then partially encased in reinforced mortar as shown in Figure 3. Encasing process was carried out by firstly adding transversal and longitudinal reinforcements in the full height rectangular opening castellated steel beams. Two D16 reinforcing bars having yield strength f_{yD} = 412 MPa were used for the top and the bottom longitudinal reinforcement, while P8 reinforcing bar having yield strength f_{yP} = 408 MPa was used for the transversal reinforcement. It is noted that equal longitudinal reinforcement at the top and at the bottom flanges was used to maintain the steel ductile behaviour. Transversal reinforcement in the short span beam contains two steel hoops while the long span beam contains only one steel hoop. This transversal reinforcement was put at each edge of the web holes. Once the steel reinforcement has been added, the both sides of the web were then poured with flow mortar. The mix design of flow mortar for encasing material had the composition of water = 313 kg/m^3, cement = 781 kg/m^3, sand = 1172 kg/m^3, and super plasticizer = 5.45 l/m^3, that made the compressive strength of this flow mortar f'_m = 53 MPa.