Behavior of Concrete Beam Encasing Castellated Steel Section with Different Shear Stud Interactions

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Abstract

This study's objective is to investigate the behavior of concrete-encased castellated steel sections with varying pore sizes. There two different types of Shear Stud Interactions: Partial (P) and Full (F). When shear connectors with F are used, stud connections combine the concrete and steel components. Four Composite beams that are simply supported were tested in settings of two-point loading. By encasing concrete in castellated steel beams, four instances were produced. The maximum pressure support capability of the structures was evaluated. Castellated beams are among the many features that are assessed when two different kinds of contact occur. in keeping with the test's findings. The F interaction that the sample experienced when utilizing caused the final load percentages to rise by around 6.4%. The percentages of mid-deflection and horizontal displacement are reduced as well by 10% and 6.7%, respectively, as compared to the same sample when P interaction is used. Furthermore, at complete interaction, the sample with the same aperture showed a larger final load.

Keywords

Shear Stud , Full Interactions , horizontal displacement, Partial Interactions, mid-deflection.

1.Introduction

Beams of steel that have had their webs cut off in zigzag or other patterns after being cast in a rolling mill. After that, one of the parts created by this type of cutting is twisted and welded to another section[1]. welded points at the contact gap between apertures on the post web. "Castellated Beam" describes the holes in the web that are made when parts of the original beam are welded, chopped, and turning. The castellation indicates that the structure is "built like a castle, having battlements or regular holes in the walls, like a castle" [2]. This type of beam can have octahedral, circular, or hexagonal apertures, depending on the split manufacturing process. Because of its increased slenderness, the web becomes weaker due to its greater depth. The flange bears the external loads, and the primary cause of the compressive stress tolerance is the conveying shear in a web that arises from geometric composition. A corrugated shape can thereby maintain a big flange and narrower web [3]. Pipelines, internet cables, electrical cables, gas lines and ducts for heating and cooling systems may all be installed through web apertures [4]. Beams might be web-flanged, rectangular, square, circular (solid or hollow), or Castellated. The material selection also affects the behavior of the structure of the beams [5]. The impacts of shapes and materials that make up beams have therefore been the attention of researchers and construction engineers in an effort to get the highest strength possible [6].To improve the chemical and mechanical characteristics of the member, a cementation material known as RPC can be applied as an overlay or added to reinforced concrete [7].Castellated steel bars could not be used because the cost of making them by hand was too high and the production process could not be automated. Over time, however, many in the building industry and scientists came to recognize the potential benefits of automation. All types of castellated beams have become popular and are utilized worldwide [8–11].The structural performance Various web openings for composite castellated beams sections was examined by the author. The author intended to ascertain The highest capacity to bear loads and deflect by altering the stud interaction. When compared to composite beams that employ P interaction, the results showed that those that use F interaction had the best carrying capacity and the least degree of deflection.

2. Experimental Section

2.1 Fabricated Beams with Castellation

The web is cut in a regular, alternating zigzag pattern to divide a conventional hot rolled wide flange I-section into two equal parts. The castellated beams are then created by moving the two sections and welding them together. The castellated beam's strength and stiffness are changed in comparison to the original I-section beams as a result of the constructing process, which also causes the beam's depth to grow.

2.2 Dimensions and specifications of test specimens

The standard rolled-up part is MB200*100*21.3.As per the **ASTM E8/E8M-15a** [12] standard, the root section of four castellated steel beams was made of Continental Steel. **Table 1** lists the names and descriptions of the artificial specimens that were utilized in this investigation. The detailed designations of the examined specimens are also given, as seen in **Figure 1**.

Table 1 Specimen Classifications.

Specimen No.	Designation of the specimen	Description
1	NSCHF35	Concrete beams encasing castellated steel sections with normal strength concrete, opening hexagonal, and F interaction.
2	NSCHF70	Concrete Beams Encasing Castellated Steel Sections with normal strength concrete, opening hexagonal, and F interaction.
3	NSCHP35	Concrete beams encasing castellated steel sections with normal strength concrete, opening hexagonal and P interaction.
4	NSCHP70	Concrete beams encasing castellated steel sections with normal strength concrete, opening hexagonal and P interaction.

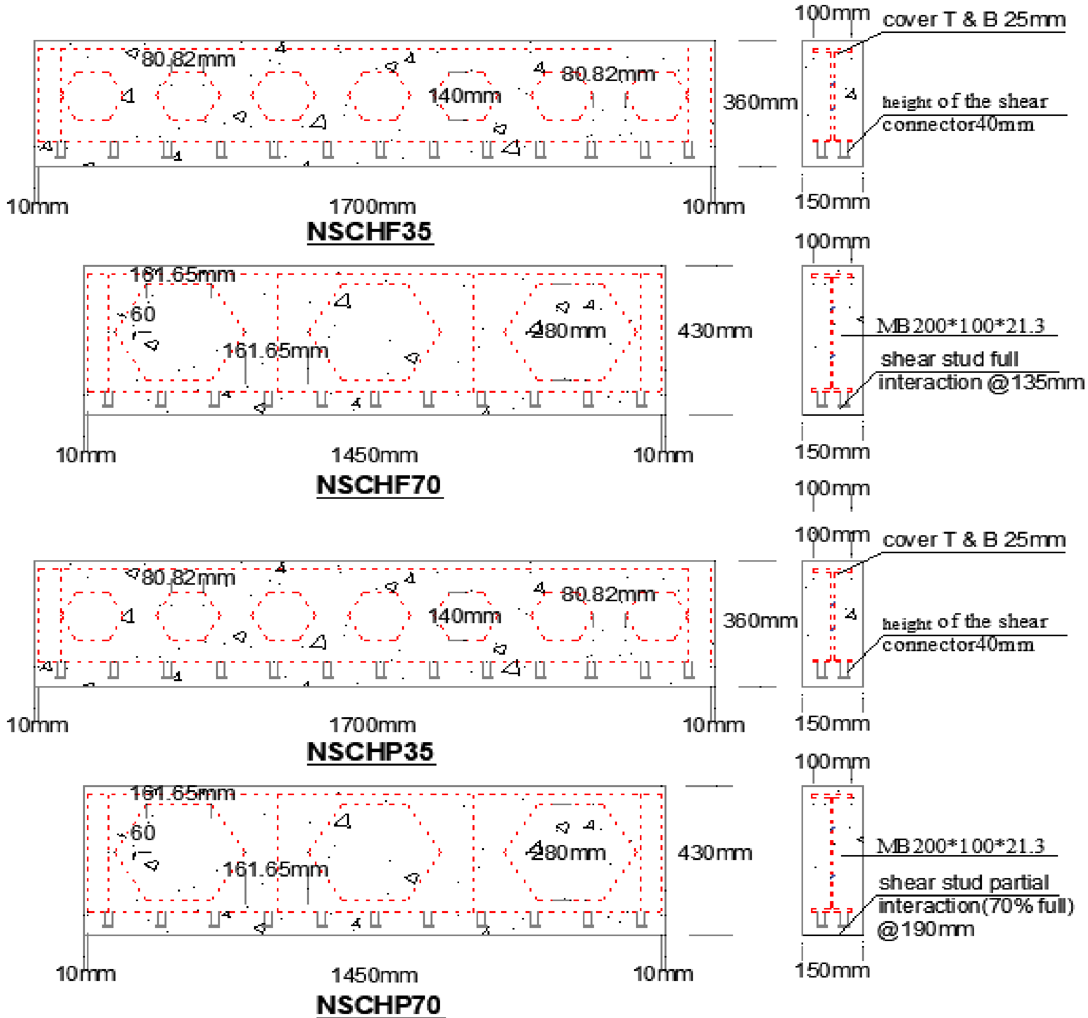

Figure 1 Dimensions and Specifications of Composite Castellated Beam.

2.3 Connectors for Shear Studs

A smooth shear stud connection has been changed to have a 13 mm upper head diameter, a 40 mm overall height, and an 8 mm diameter. The height-to-diameter ratio is 5, as specified in the **BS 5400-5**[13]. **Table 2** shows the mechanical properties and specifications of the shear rivet connection.

Table 2 Shear Connectors Geometry and Mechanical Properties.

Actual bar diameter (mm)	Actual Head Stud diameter (mm)	Height of the shear connector (mm)	Thickness of Head Stud (mm)	Modulus of Elasticity	Yield Strength f_y (MPa)	Ultimate Strength f_u (MPa)
8	13	40	8	205000	280	400

2.4 Materials

Standardized testing efficiently determines a material's qualities in compliance with ASTM and IQS standards. This study looks at Type I Portland cement, which is widely used. If kept dry, it will be protected from several types of weather. According to the test results, the chosen cement complies with Iraqi standards **(NO.5/1984)** [14] and **ASTM-C150-17** [15]. In this study, leverage The maximum particle size of natural sand, which is utilized as a fine aggregate in the concrete mix for all forms, is 4.75 mm following the necessary evaluation. The results show that the graded fine aggregate conforms to the Iraqi standard zone standards (IQS) **No.45/1984**[16]. **ASTM C128-15** [17]. Concrete mixes with a maximum particle size of 12.5 mm were made by crushing the local gravel in accordance with Iraqi regulations. Before being wrapped in plastic, every piece of crushed gravel is carefully cleaned and kept dry for a long time in compliance with Iraqi specifications (IQS) **No. 45/1984** [16]. All concrete specimens used in this investigation were mixed and cured using potable tap water.

2.5 Concrete Mix Design and Procedure

In this study, One kind of concrete was utilized. These mixes are Normal Strength Concrete (NSC). **Mohammed** [18] recommended the proportions and method for mixing of NSC.

2.5.1NSC

Table 3 lists the mix ratios for the normal strength concrete used in this experiment.

Table 3 Properties of NSC[18].

Combine notation	w/c	Cement kg/m^3	Water liter/m3	Fine Aggregatek g/m^3	Aggregate kg/m^3
NSC	0.45	350	180	600	1200

Before starting the NSC mixing procedure, It was enough to keep the mixer dry yet clean. Sand and gravel were initially added to the mixer. One-third of the mixing water was then added, and the mixture was left for a minute to hydrate. After combining and mixing the cement for 30 seconds, one-third of the water is added and stirred for one minute. The remaining water is added after another minute of careful stirring, making a total mixing time of one and a half minutes. Just mix for four minutes.

3. Testing of Control Specimens

The specimens were subjected to a universal compression machine at the structural laboratory with a 3000 kN capability of the organization. For each mixture, we employ an average of three specimens. if the Compression strength 25Mpa [19], Modulus of rupture 3.25Mpa[20], Splitting tensile strength 2.5Mpa [21] and Modulus of Elasticity 26.6Gpa[22].

4. The results of the test

Each specimen is subjected to four-point stresses until it fails. The initial fracture stresses, ultimate load, maximum deflection at midpoint, and horizontal displacement at the end of each specimen are provided in **Table 4**.

Table 4 Ultimate Load, First Fracture Load, Horizontal Displacement, and Deflection at Midpoint.

Sample Designation	Initial Cracking Load (kN)	Ultimate Load (kN)	Max Deflection at Mid (mm)	Max Horizontal Displacement (mm)
NSCHF35	170	500	18	4.2
NSCHF70	140	450	22	4.34
NSCHP35	200	470	20	4.5
NSCHP70	130	440	24	6.15

5. Results and Discussion

5.1 Load – Deflection at Midspan

The specimens' deflection in reaction to standing loads is measured. **Figure 2** shows the load-deflection curves created for the tested specimens at each loading step till failure. The NSCHF35 specimen is composed of ordinary strength concrete. It interacts fully with the composite beam and has several stud shear connections. The midspan deflection is 18 mm, and the maximum load is 500 kN. The specimen NSCHF70 features a 22 mm mid-span deflection and a 450 kN load capacity. The NSCHP35 specimen, made of normal strength concrete, had a mid-span deflection of 20 mm and a strength capability of 440 kN. The specimen NSCHP70 has an ultimate load capacity of 440 kN because to the greater deflection generated by the P interaction. If the midspan deflection is 24 mm.

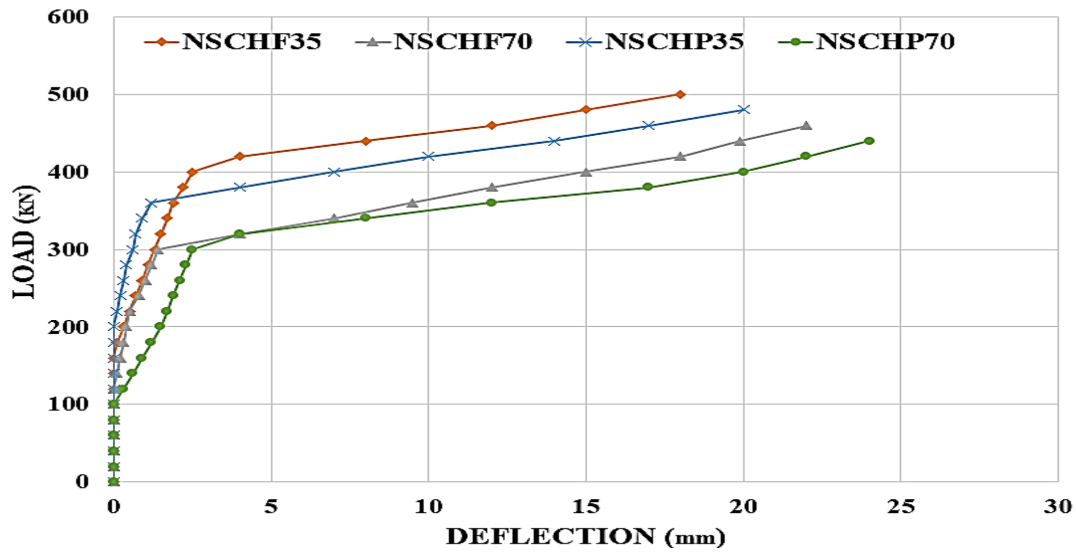

Figure 2 Load-Deflection Curves.

5.2 Load – Horizontal Displacement

Even with the specified number of shear stud connections, the interface surface undergoes horizontal displacement when two dissimilar materials, such as steel and concrete, are combined. **Figure 3** depicts the horizontal displacement behavior for each specimen. The horizontal displacement distribution has a reversed sign and is symmetric about the origin (mid-span). The horizontal displacement measurement ranges between 4.2 and 6.15 mm depending on whether there is total or partial contact.

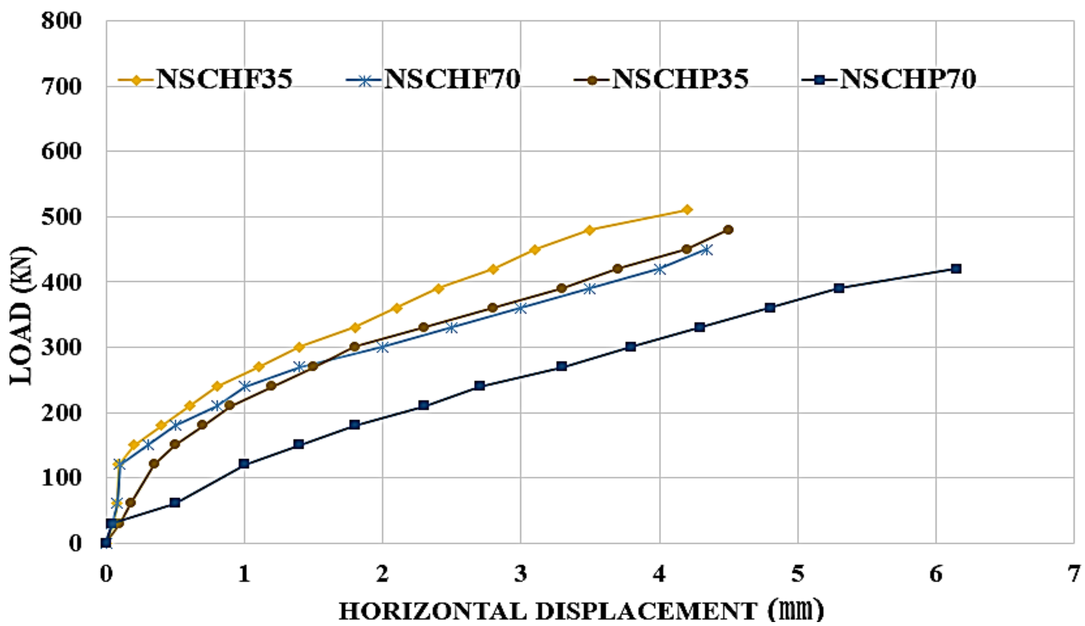

Figure 3 Load-Horizontal Displacement Curves.

6. The Failure Mode and the Crack Style

Cracks begin to appear and propagate when the applied load during a flexural test creates tension in the tensile region that is greater than the modulus of rupture. This is because the horizontal displacement prevents the concrete and steel components from fitting together and increases the deflection. **Figure 4** This shows how fractures spread and how failure mechanisms occur in all composite castellated beams. There were no severed headed stud shear connections or pull-out failures of the concrete beam during testing at the maximum weights for any specimen. Specifically, NSCHF35. The fractures during the failure stage are primarily parallel to the thickness of the beam and vertical. They go downward towards the base of the beam from the point of stress application. The applied stress causes each segment of the composite castellated beam to bend, and flexural failure results from concrete fractures. Compared to NSCHF35, the specimen NSCHF70 exhibits more fractures upon failure because of the big holes. Because the hole is larger in specimen NSCHF35 than in specimen NSCHF70, there are fewer cracks. because of the opening's tiny size and the usage of concrete with great strength. The NSCHP35 and NSCHP70 samples are identical to the ram samples NSCHF35 and NSCHF70 in terms of section and concrete type; however, the connection connections are different. The bearing strength decreases as the distance between the connections increases, if the shear connections are effective in reducing the shear force.

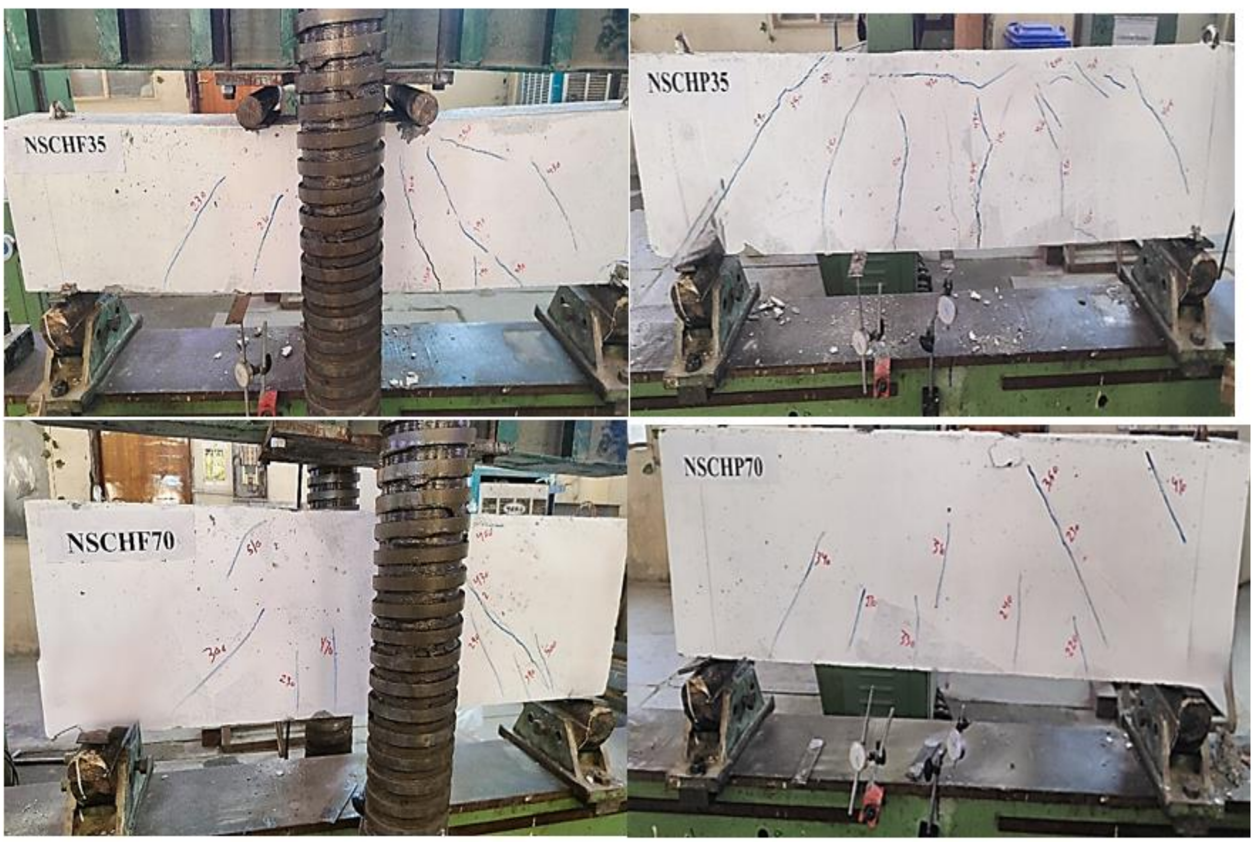

Figure 4 Composite Castellated Beam after Failure.

7. Discussions

Experiments with various parameters in this study have yielded the following observations based on test results and findings: **Table 5** compares specimens by interaction (F and P), with F interaction, reducing deflection, and diminishing horizontal displacement.

Table 5 Effect of Type of Concrete on Ultimate Load, Deflection, and Horizontal Displacement in Composite Castellated Beams

the specimen	Ultimate load (kN)	% Increases in ultimate load	Midpoint deflection maximum (mm)	% Decrease in deflection	Maximum horizontal displacement (mm)	% Decrease in horizontal displacement
NSCHP35	470	-------	20	-------	4.5	-------
NSCHF35	500	6.4	18	10	4.2	6.7
NSCHP70	440	-------	24	-------	6.15	-------
NSCHF70	450	2.3	22	8.3	4.25	30.89

8. Conclusions

The shear stud interaction is one of the primary elements affecting the division's sectional characteristics. The experimental analysis of the concrete beam around the castellated steel section yielded the following results.

1. A comprehensive contact leads to a larger ultimate load, and an increase in the number of shear stud connectors decreases the transfer of shear flow over the contact surfaces of the shear connections. A cohesive structure was produced by the interaction of the concrete and the shear stud at the base of the steel castellated beam.
2. The test results show that the F interaction hexagonal aperture sample uses NSC to boost load-bearing capacity while minimizing horizontal displacement and deflection. The percentage of load-bearing capability increases by about 6.4%. In addition, the midpoint displacement decreased by around 10% in comparison to the same sample with a hexagonal hole of the same size and P interaction. Additionally, decrease horizontal displacement by around 6.7%.

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