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A FINITE ELEMENT ANALYSIS OF SHEAR CONNECTORS IMPACT ON SHEAR BEHAVIOR OF CONCRETE-ENCASED COMPOSITE STEEL BEAMS

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DOI: 10.5281/zenodo.1161742

Keywords: Composite Beams, Connector, Shear Stud, Shear Failure, Finite Element Method.

Abstract
Advantages of joint application of two important construction materials in composite concrete-steel structures have made these structures a very popular option. Encasing steel in concrete improves its rigidity and energy absorption while reducing potential local buckling in the concrete-encased steel. Due to insufficient laboratory and analytical data on shear behavior of encased steel, the available code does not contain particular instructions that can be used to prevent fracture caused by shear failure in composite members. The present study, therefore, attempts to examine effects of application of stud shear connectors on behavior of concrete-encased composite steel beams by modeling this element in ABAQUS and analyzing the results. The findings indicate considerable impact of connectors in shear reinforcement of composite beams.

Introduction
The current techniques for outlining fortified cement and steel structures are not satisfactory regarding giving legitimate steel-solid association. Shear pressure is the fundamental type of power - in spite of the fact that by all account not the only power - applied on this association. Shear connectors as weld stud or shear jolts, convolute the examination of the association and in this manner strategies for planning these associations have regularly been created exactly utilizing as a part of vitro investigations. Utilization of shear studs assumes an essential part in counteracting shear disappointment of cement encased composite pillars, especially when the cross area of the steel part has a bigger width since for this situation the traverse of the steel part intently coordinates the aggregate width of the composite profile, prompting expanded spread of shear splits along the upper rib. Shear disappointment for this situation can be best anticipated utilizing shear connectors frequently as studs. Keeping in mind the end goal to appropriately exchange solid steel shear pressure adequate number of studs must be utilized. Along these lines, here we adjusted the dividing between lines of studs associated with the upper spine of the steel bar in composite pillars and examined the effect of this parameter in various cases.

Details of Finite Element Analysis
There are different techniques for modeling concrete in ABAQUS, including plastic damage model that was used here. The model assumes that the main mechanisms involved in the onset of concrete failure are cracking and compressive crushing. Both phenomena result from cracking and spread of cracks. The model largely relies on the stress-relative elongation curve under uniaxial compression as well as stress-relative elongation curve under uniaxial tensile loading both discussed below. Stress-relative elongation curve under uniaxial compression was plotted using H.G. Kwak Model [1] which has been proposed for analysis of reinforced concrete structures using finite element method (FEM).

For nonlinear analysis, steel beam was modeled using elasto-plastic model with elongation hardening often referred to as bilinear model. In addition, elasto-plastic model with strain hardening in bilinear model was used to model steel. Rebar arrangement was model using an embedded model. Separate elements were considered for modeling concrete and steel, complete continuity conditions was satisfied for steel and concrete, and finally contact conditions were applied implicitly by making changes in the structural equations governing concrete behavior. Fig. 1 illustrates a schematic of samples and their profiles.

ISSN: 2349-5197
Impact Factor: 3.765

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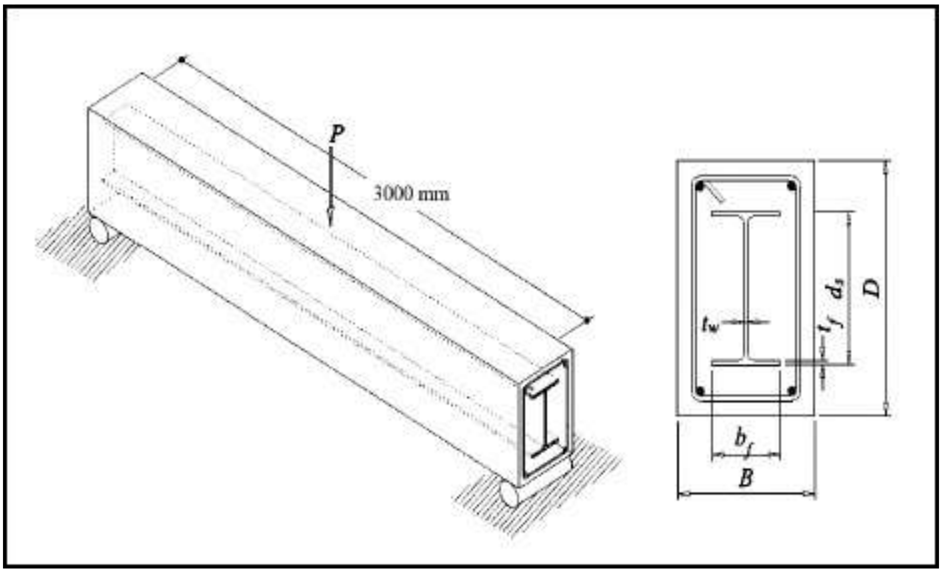

Figure 1 A 3D view of the samples studied and their cross sections

Description of Samples

Application of shear studs plays an important role in preventing shear failure of concrete-encased composite beams, particularly when the cross section of the steel member has a larger width since in this case the span of the steel member closely matches the total width of the composite profile, leading to increased spread of shear cracks along the upper flange. Shear failure in this case can be best prevented using shear connectors often in the form of studs.

In order to properly transfer concrete-steel shear stress sufficient number of studs must be used. Therefore, here we modified the spacing between rows of studs connected to the upper flange of the steel beam in composite beams and investigated the impact of this parameter in different cases. In total 9 models were developed and analyzed in three groups with a large ratio of flange width which increases the probability of shear failure.

The first group includes the models E1, E2, and E3 with the stud spacing 25, 20, and15 cm, respectively. The steel profiles used in this group had a flange width to gross width ratio of 0.6.

The second group includes the models E4, E5, and E6 with the stud spacing 25, 20, and15 cm, respectively. The steel profiles used in this group had a flange width to gross width ratio of 0.7.

The third group consists of the models E7, E8, and E9 again with the stud spacing 25, 20, and15 cm, respectively. The steel profiles used in this group had a flange width to gross width ratio of 0.8.

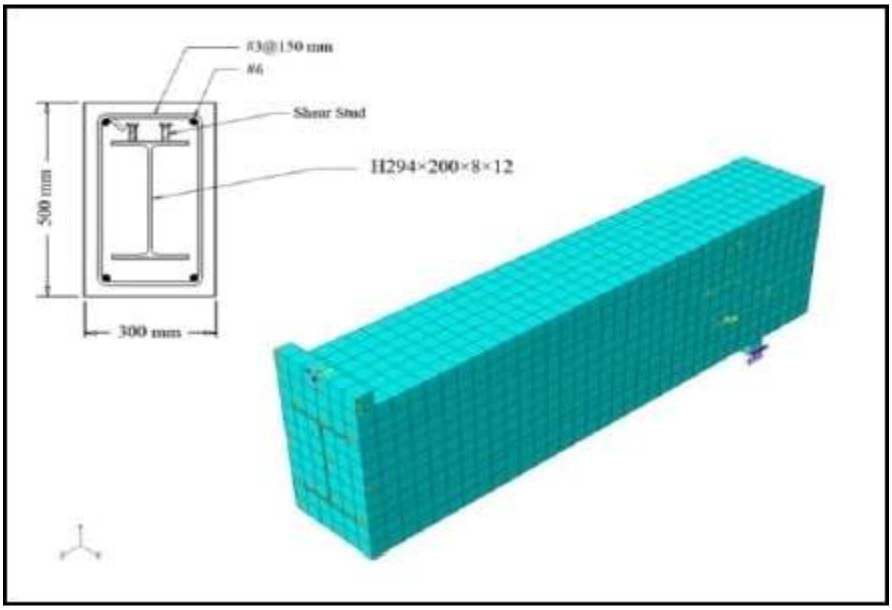

Figure 2 A 3D view of the samples modeled in ABAQUS

In all models, the section of the whole composite beam had a dimension of 300 mm by 500 mm. The longitudinal bars were 19 mm in diameter while the stirrups, spaced at 150 mm, were 10 mm in diameter.

Comparison of Numerical Results

Fig. 3 shows load-deflection curves for E1, E2, and E3. A comparison of these curves indicates that smaller spacing between the studs slightly increases loading capacity of the composite beams. The loading capacity of E2 was increased by 1.26% compared to E1, and by 2.99% in E3 compared to E1.

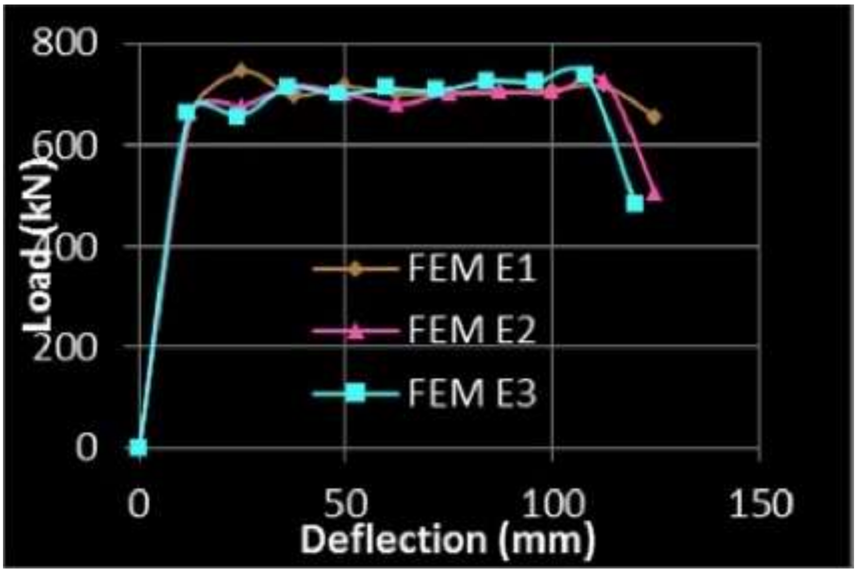

Figure 3 Load-deflection curves for E1, E2, and E3

Fig. 4 shows load-deflection curves for E2, E3, and E4. As seen in this figure, loading capacity of beams increases as the spacing between the studs is reduced. The loading capacity of E5 was increased by 1.48% compared to E4, and by 2.99% in E6 compared to E4.

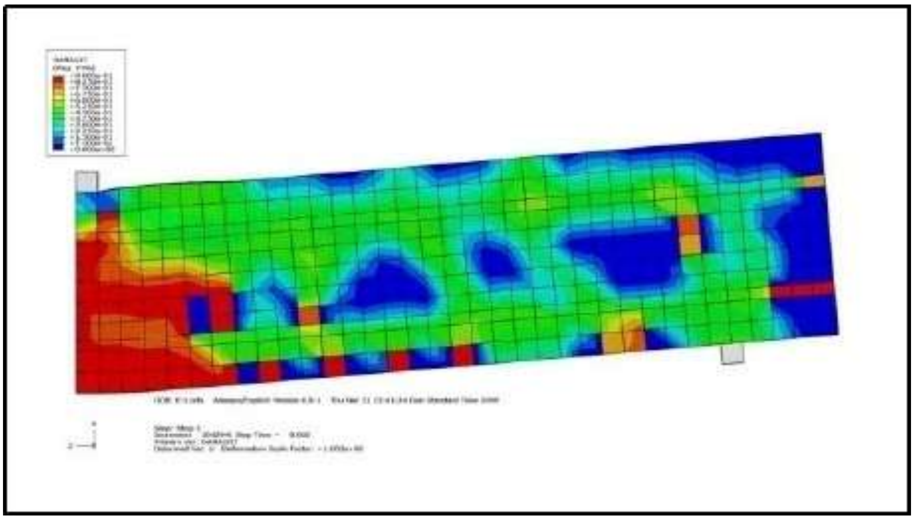

Figure 4 Load-deflection curves for E4, E5, and E6

Fig. 5 shows load-deflection curves for E7, E8, and E9. Again, loading capacity of beams increases as the spacing between the studs is reduced. The loading capacity of E8 was increased by 1.50% compared to E7, and by 2.89% in E9 compared to E7.

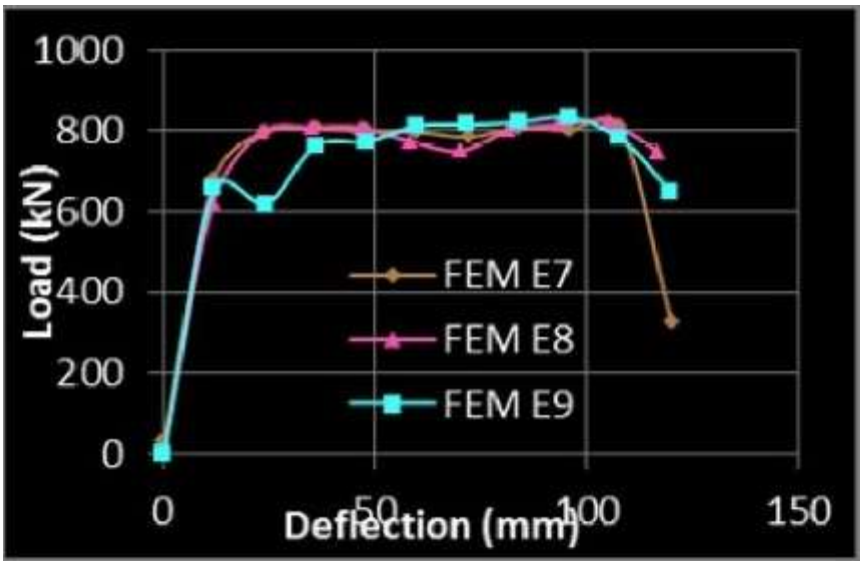

Figure 5 Load-deflection curves for E7, E8, and E9

Figures 6 through 8 depict damage contours for E1 to E3. The ratio of flange width is 0.6 in these models.

A comparison of these contours clearly demonstrates reduced horizontal damage as a result of reduced spacing between the studs.

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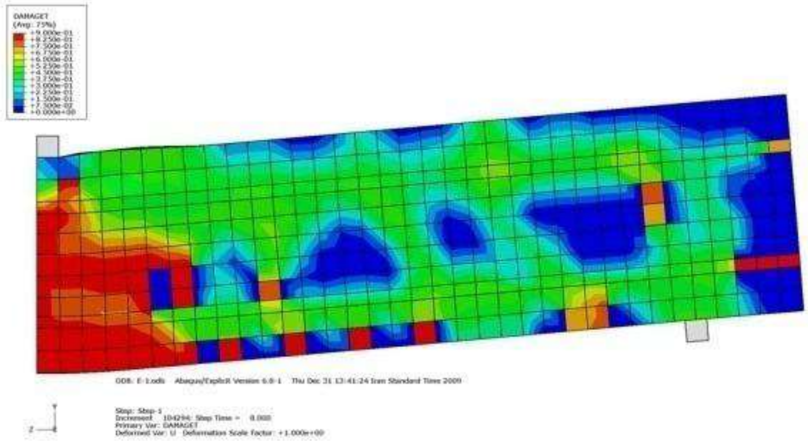

Figure 6 Tensile damage contour for E11

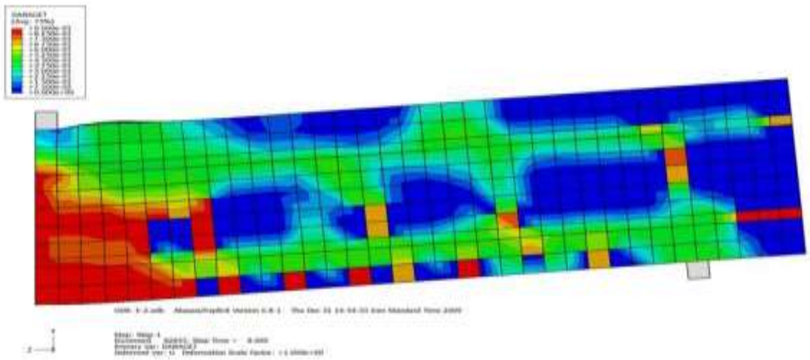

Figure 7 Tensile damage contour for E2

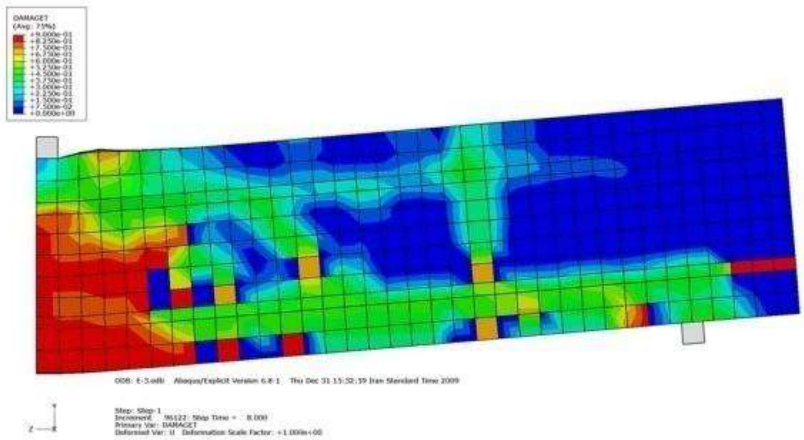

Figure 8 Tensile damage contour for E3

Figures 9 through 11 show damage contours for E4 to E6. The ratio of flange width is 0.7 in these models. As seen in these figures, beams become less damaged as studs are placed at smaller spacing.

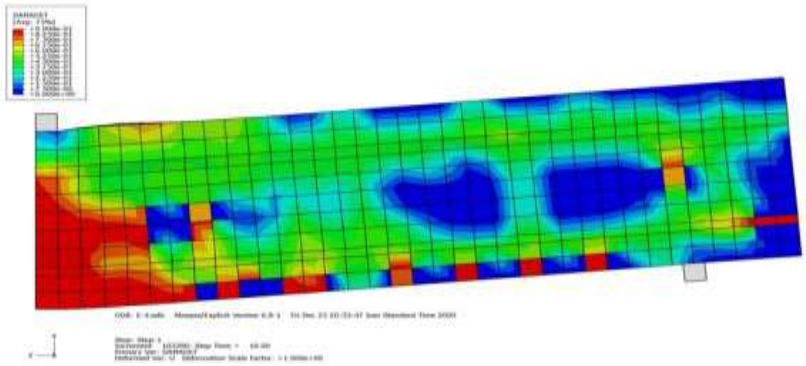

Figure 9 Tensile damage contour for E4

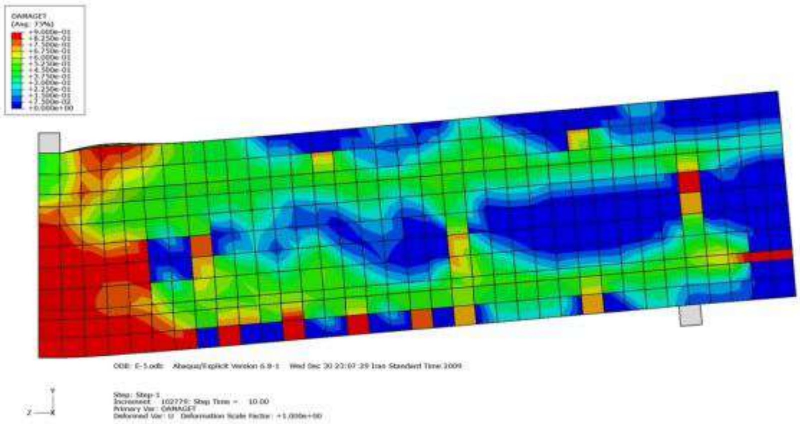

Figure 10 Tensile damage contour for E5

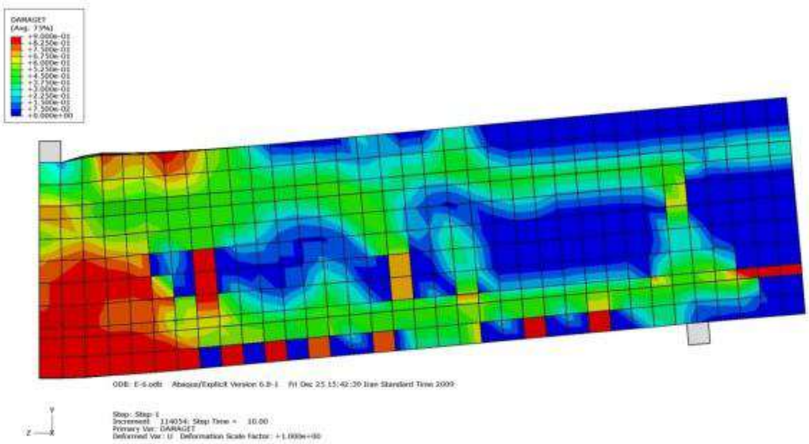

Figure 11 Tensile damage contour for E6

Figures 12 through 14 illustrate damage contours for E7 to E9. The ratio of flange width is 0.8 in these models. Again, smaller stud spacing has led to reduced number of shear crack. However, the cracks on the concrete surface are more intense compared to the other two groups because of the large flange width ratio.

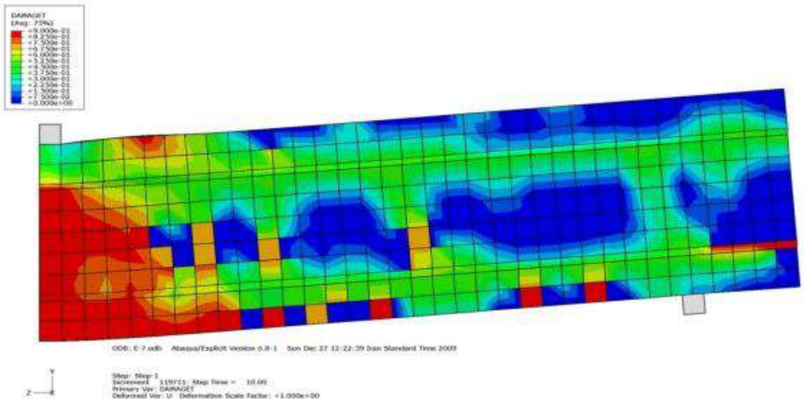

Figure 12 Tensile damage contour for E7

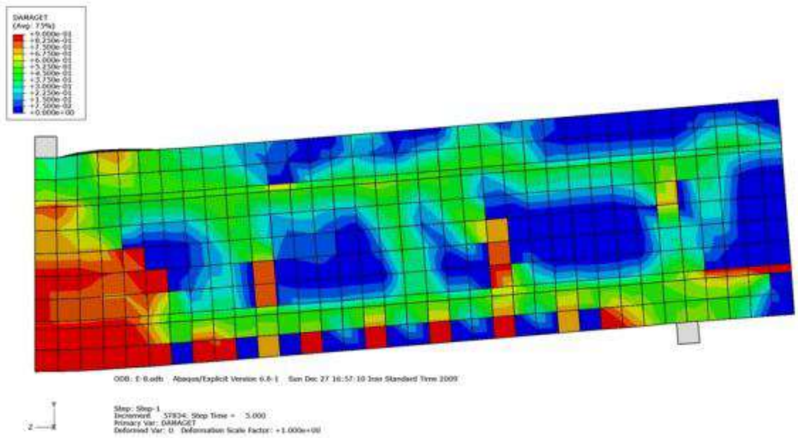

Figure 13 Tensile damage contour for E8

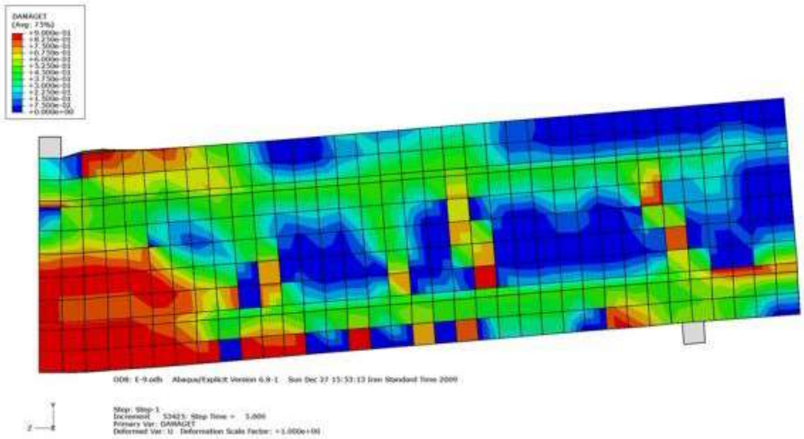

Figure 14 Tensile damage contour for E9

Table I shows shear quality and flexural quality of the models with various stud separating ascertained by FEM. What's more, sorts of breaks were anticipated in light of the perceptions from the harm shapes and relative plastic twisting. Iranian Code for Design and Construction of Steel Structures contains conditions required for outlining shear connectors in composite bars. Results acquired from connector configuration in view of this Code nearly coordinate those found by FEM. To outline connectors utilizing the Code, one should first ascertain the aggregate even shear that must be endured sooner or later between the most extreme bowing minute and the purpose of zero twisting minute. The aggregate flat shear is the littler of the two esteems got from (1) and (2) underneath:

$$V_h = (0.85*f_c* A_c)/2 + (f_y* A_s')/2 \quad (1)$$

$$V_h = f_y* As/ 2 \quad (2)$$

Table I Strength and type of failure in composite beams with different stud spacing

Model	**Model Strength**		**Stud spacing**	**Type of Failure**
	V(KN)	**V(KN)**		
	Models with flange width ratio = 0.6 (bf=180 mm)			
E1	**536.4**	**357.6**	**250**	**Shear**
E2	**543.2**	**362.1**	**200**	**Flexural**
E3	**552.5**	**368.3**	**150**	**Flexural**
Models with flange width ratio = 0.7 (bf=210 mm)				
E4	**576.1**	**384.1**	**250**	**Shear**
E5	**584.7**	**389.8**	**200**	**Flexural**
E6	**590.4**	**393.6**	**150**	**Flexural**
Models with flange width ratio = 0.8 (bf=240 mm)				
E7	**608.3**	**405.5**	**250**	**Shear**
E8	**617.4**	**411.6**	**200**	**Flexural**
E9	**625.9**	**417.3**	**150**	**Flexural**

As indicated by our counts, Equation (1) is the condition that decides even shear in all models. Since the cross segment region of the compressive solid (Ac) is the same for all models, the level shear acquired for all models breaks even with 407.8 kN. Once the extent of the flat power applied on the connectors are computed, the greatest reasonable level shear compel (q) is resolved in view of the kind of connectors and utilizing a table exhibited in the Code. Given the sort of connectors utilized here, the greatest permissible level shear is 28 kN for every connector. In the wake of ascertaining the flat shear and most extreme opposing power, number of required connectors can be figured at either side of the greatest flexural minute. At long last, the dividing of 20.6 cm between the studs is acquired by the conditions given in the Code. Consequences of our FEM investigation likewise demonstrated that in models with stud dividing bigger than 20 cm, disappointment is of shear write while in models with stud separating under 20 cm shear harm is generally controlled.

Results

In view of the perceptions of the type of splits in the exploratory examples and firmly coordinating esteems acquired from FEM displaying, it can be contended that solid encased composite steel pillars encounter two types of disappointment: shear disappointment and flexural disappointment. Shear disappointment is caused by profound breaks along the rib of the steel profile which result in unexpected load drop before the pillar accomplishes its definitive limit, despite the fact that the steel in the examples enables the composite bars to stand bigger loads previously achieving extreme limit.

Confirmations got from examination and investigation demonstrate that shear studs on the surface of steel spines can strikingly anticipate break caused by shear disappointment in composite shafts with substantial rib width proportions, in spite of the fact that studs have additionally positive effects in lessening shear splits caused by twisting.

In this examination of the powerful part of connectors in controlling shear disappointment, it was watched that littler dividing between the studs lessened force of plastic harm along the rib of steel bars, especially in composite shafts with bigger spine width proportions which encounter more extensive spread of breaks and hence can profit more from the connectors. Also, diminished stud dispersing marginally expanded stacking limit in the models considered here.

Directions for Future Research

Shear connectors assume a vital part in avoiding shear disappointment in composite shafts. It is in this way recommended future examinations should concentrate on the effects of various kinds of shear connectors on conduct of composite shafts keeping in mind the end goal to upgrade shear quality of these auxiliary individuals..

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