

## BEHAVIOR OF LONG SPAN OF FINITE ELEMENT MODELING OF COMPOSITE BEAMS UNDER LOADS.

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### Abstract

Composite construction has become a popular construction consisting of composite systems of steel and concrete for use in many buildings and bridges. It has been used mostly in recent years due to its advantages over non-composite construction. Moreover, it takes an important role in the scientific advancement of building and bridge engineering. This is due to the combined properties of the steel beam and reinforced concrete slab with the introduction of a shear connection at the interface that acts as a composite system. In this paper the Abaqus program was used to model the behavior of long span composite beams. Half of the beam was modeled and loaded to failure, because of symmetry in the material, geometry and non-linear behavior.

### الملخص العربي

أصبح البناء المركب بناءً شائعًا يتكون من أنظمة مركبة من الفولاذ والخرسانة للاستخدام في العديد من المباني والجسور. تم استخدامه في الغالب في السنوات الأخيرة بسبب مزاياها على البناء غير المركب. علاوة على ذلك، فإنه يأخذ دورًا مهمًا في التقدم العلمي لهندسة البناء والجسور. ويرجع ذلك إلى الخصائص المدمجة للحزمة الفولاذية والبلاطة الخرسانية المسلحة مع إدخال وصلة القص في الواجهة التي تعمل كنظام مركب. في هذا البحث تم استخدام برنامج ابيكوس لنمذجة سلوك الحزم المركبة طويلة المدى. تم نمذجة نصف الحزمة وتحميلها إلى الفشل، بسبب التناظر في المادة والهندسة والسلوك غير الخطي.

Keywords: Composite beams; Finite element modelling; Behaviour under load ; Long span.

### Introduction

Modeling and analysis of composite steel and concrete structures brings together many challenges facing steel structures and reinforced concrete structures, as well as specific issues due to interaction and load sharing between structural steel and reinforced concrete components [1,2]. Structural engineers involved in the analysis and design of steel and concrete composite structures have to encounter practical difficulties due to procedures that deal directly with the specific behavioral aspects of composite construction are generally not included in the commercial programs available. However, various models have been proposed in the literature so far in an attempt to provide efficient and powerful tools for the analysis of steel and concrete buildings and bridges [3]. Previous studies on the

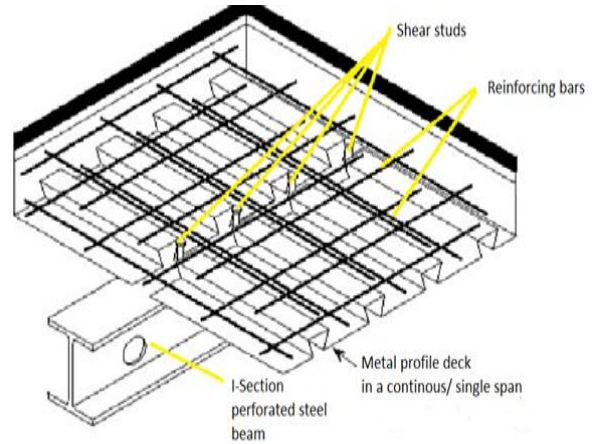
behavior of the composite beam have highlighted that the relative displacement between the steel beam and the reinforced concrete slab (partial reaction) is required to be included in the numerical model to obtain an adequate representation of the composite response [4]. The behavior of the shear connection should be taken into account since its behavior has to be modeled In Eurocode 4 Part 1 [5] (nonlinear global analysis) and Eurocode 4 Part 2 [6] (nonlinear global analysis for bridges). One of the first papers that examined the analysis of composite beams with partial interaction is that by Newmark et al. [7]. The Newmark model couples two types of beams, one for the reinforced concrete slab and the other one for the steel beam by means of a deformable shear connection distributed along their interface. This shear connection allows for longitudinal relative movement between the two

components while preventing vertical separation between them. Based on comparisons with experimental results were made [8], they concluded that their model was best suited for depicting damage in composite members as it was found to be highly sensitive to higher modes of flexural vibrations. The vertical deflections for different values of parameters (shear connection stiffness), (normal elastic modulus to shear elastic modulus ratio), (span-to-depth ratio) were calculated and compared with those obtained using the Newmark model [9]. These comparisons illustrated that shear deformations are more important for high levels of shear connection stiffness, for beams with high E/G ratios and for short beams with small span-to-depth ratios. An extensive parametric study based on approximately 200 realistic simply supported and continuous composite bridge arrangements was presented by Ranzi and Zona [10] presented. This parametric study was conducted using a lock-free finite element model assuming linear elastic materials and considering the time-dependent behavior of concrete. It was found that there are not slight differences between the Newmark models and the EB-T models, especially for the relatively low values of a dimensionless parameter measuring the importance of the shear stiffness compared to the flexural stiffness of the steel beam.

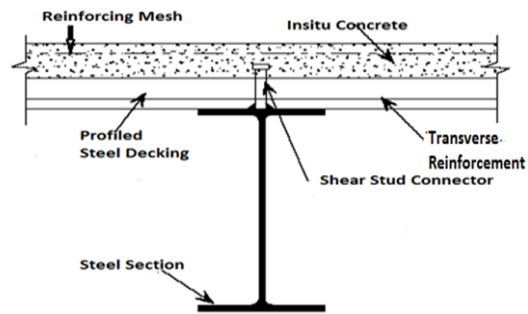
The use of composite construction is returned for more than a century in the USA during the event of the 1906 San Francisco earthquake that caused the destruction of many building and fires. Through investigations conducted after that event, it was found that buildings constructed of encased columns performed well against the impact of both seismic loading and fire. The result of this discovery led to experiments with construction that used steel beams or encased columns with concrete or masonry in more than one story building that was in the San Francisco Bay and lasted until the 1940s [11]. The use of composite system has been become common in many places such as USA and UK due to their benefits of fire resistance. The early design of composite system had very small amount of transverse reinforcement and the design calculation did not take into account the effect of the encasement [11]. Since then, the composite construction method has been applied in many civil engineering departments. The main reason behind choosing this system is significant reduction in construction time by means of rapid construction compared to normal construction method. Moreover, the use of profiled sheet decking which serves as formwork and reinforcement at the bottom of the concrete slab is more economical than other methods. The composite construction method gives lighter and longer spans by using steel and concrete composite system than concrete reinforcement or steel structural without concrete. Also, composite constructions are more robust and stiffer system than conventional methods. Composite beam system can be defined as the interaction of concrete slab and steel beam that are assembled into a single form to use the material properties advantages of both concrete and steel.

The combination of steel beam and concrete slab gives a result in one system of monolithic which lead to better stiffness and strength than if all steel or concrete was used as a single component.

Figure 1 shows the construction of a typical composite beam and Figure 2 shows the component of a composite beam.



**Fig. 1** View of a steel and concrete composite construction



**Fig. 2** Element of composite beam

Shear stud connections are used in the composite beam to cause the interaction between the concrete slab and the steel beam which is one of the reasons behind the shear stud connection to resist the force that comes from the horizontal axis. Most of the shear stud connections are welded to the steel beam through steel decking sheets if profiled sheets are used. Concrete slab increases with the steel beam capacity, so the moment capacity is twice at the composite beam system. Some differences that belong to the characteristic of the material properties of the concrete and steel were founded [12]. The behaviour of the shear stud connection is mainly to design two things that are slip at the interface between concrete and steel and the shear force transmitted [13].

## Definition of objectives

The objectives are to investigate different models of composite beams as well as study the relationship between deflections against different loads.

### The interface between the steel and concrete

Getting very realistic models is a bit difficult, but there are some simplifications taken into account when creating the models. The Poisson's ratio for the steel was chosen 0.3 and the elastic module for steel was selected as 210000MPa. The upper and lower part of the steel section flange are assumed to have the same strength. Moreover, the shear stud is designed as a wire conductor . The coefficient of friction between the beam flange with the concrete slab was chosen as 0.3.

### Parameter study

This paper focuses on how different lengths of the span (6m and 9m) affect the behavior of the beam specifically under the bending moment. The steel section used in this paper is symmetric. Different steel sections are selected for different spans, but the dimensions of the concrete is constant in all sections. The boundary conditions chosen for this model are developed from a previous project and the composite beam is simply supported. The height of the steel section, the strength of the steel beams and different types of the steel section such as  $f_y=25, f_y=335$  are investigated. Abaqus/CAE is used to conduct finite element analysis of these beams, and the aim to analyse the effect of the aforementioned parameters on the behavior of the composite beam under the bending moment.

### Modelling structural

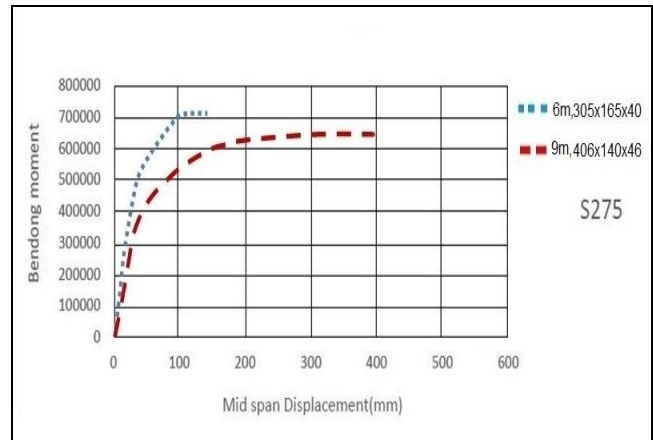
For the 6m span, UKB305x165x40 is selected as a steel section with a depth of 303.4mm. For the 9m span, UKB406x140x46 is selected as a steel section with a depth of 403.2 mm. The studs are spaced between two studs per row, with a spacing of 300 mm between each pair.

Table 1 shows the details of each composite beam.

**Table 1: Details of the composite beam.**

Span	Spacing Stud	Beam section	Beam depth(mm)	Steel Strength
6m	2 stud per row 300mm	UKB305x165x40	303.4	$F_y=275$
9m	2 stud per row 300mm	UKB406x140x46	403.2	$F_y=275$

Figure 3 shows the results of finite element analysis.



**Fig. 3** shows the results of finite element analysis.

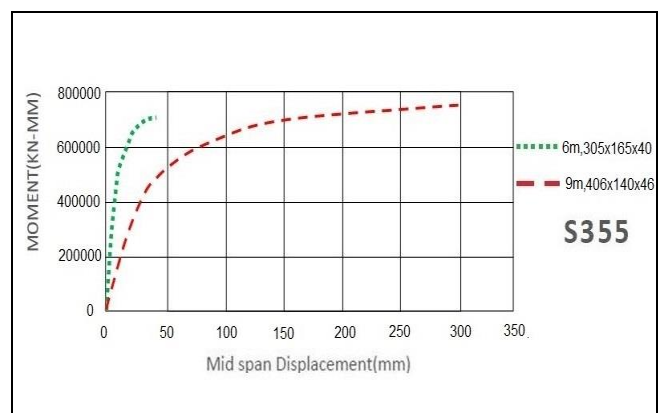
In this part, the steel section of two different spans similar to the previous one has been selected. The only parameter that has been changed is the strength of the steel from 275 to 355.

Table 2 shows the details of each composite beam.

**Table 2: Details of the composite beam.**

Span	Spacing Stud	Beam section	Beam depth(mm)	Steel Strength
6m	2 stud per row 300mm	UKB305x165x40	303.4	$F_y=355$
9m	2 stud per row 300mm	UKB406x140x46	403.2	$F_y=355$

Figure 4 shows the results of finite element analysis.



**Fig. 4** shows the results of finite element analysis.

In this section, the strength of the steel used is  $f_y = 275$  and other parameters remain constant.

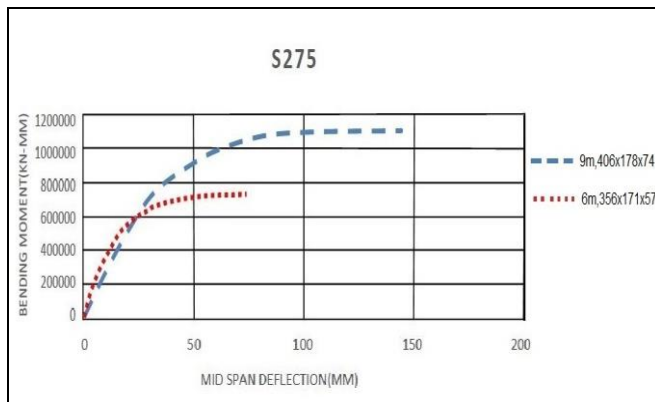
For the 6m span, UKB356x171x57 is selected as a steel section with a depth of 358mm. For the 9m span, UKB406x178x74 is selected as a steel section with a depth of 412.8mm. The studs are spaced between two studs per row, with a spacing of 300 mm between each pair.

Table 3 shows the details of each composite beam.

**Table 3: Details of the composite beam.**

Span	Spacing Stud	Beam section	Beam depth(mm)	Steel Strength
6m	2 stud per row 300mm	UKB356x171x57	358	Fy=275
9m	2 stud per row 300mm	UKB406x178x74	412.8	Fy=275

Figure 5 shows the results of finite element analysis.



**Fig. 5** shows the results of finite element analysis.

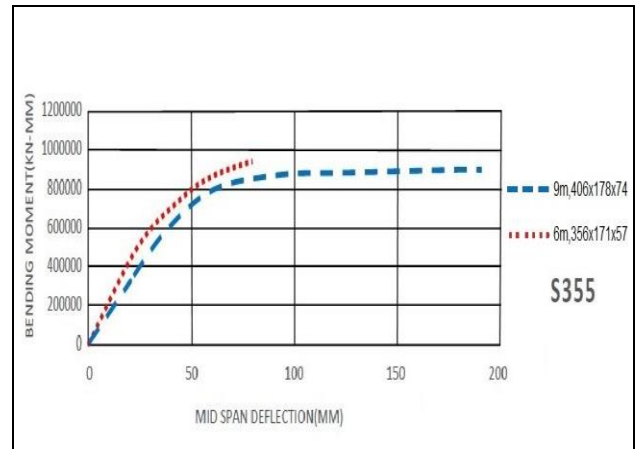
In this part, the steel section of two different spans similar to the previous one has been selected. The only parameter that has been changed is the strength of the steel from 275 to 355.

Table shows 4 the details of each composite beam.

**Table 4: Details of the composite beam.**

Span	Spacing Stud	Beam section	Beam depth(mm)	Steel Strength
6m	2 stud per row 300mm	UKB356x171x57	358	Fy=355
9m	2 stud per row 300mm	UKB406x178x74	412.8	Fy=355

Figure 6 shows the results of finite element analysis.



**Fig. 6** shows the results of finite element analysis.

## Conclusion

This paper provided a comprehensive numerical investigation into the structural behavior of composite beams simply supported by high strength materials and shear connectors. The results of a finite element analysis of the behaviour of composite beams under the bending moment using Abaqus/cae. In this model, the steel beam was designed as a shell element, the concrete slab was designed as a solid element and shear connector studs were designed as wire connectors. Various graphs were made to display the results of the finite element analysis. In most cases, the composite beam was applied to a load concentrated in the middle of the span.

Composite beam with full shear interaction have greater bending capacity. However, it is important to note that strength of the beam steel may also increase the bending capacity of the composite beam. It has been observed that the use of stronger concrete in the model leads to an increase in the bending capacity of the composite beam, and also reduces the deflection in both the elastic and plastic areas. It is found that for composite beams under full shear connection, the moment capacities will be readily increased if the yield strengths of the steel sections are increased without increasing their self-weights. It is also demonstrated that the use of the software allows accurate prediction on the moment capacities of composite beams using a wide range of steel and concrete materials.

Two different spans were selected 6 m and 9 m. The different steel strengths used were 275 and 355. The bending capacity of the composite beam increases greatly with the increase in the height of the steel section. With the increase in the span length, the bending capacity of the composite beam decreases.

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