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THE INFLUENCE OF THE THICKNESS OF THE SLAB AND CONCRETE GRADE ON COMPOSITE FLOORS

BY

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Abstract. A modern flooring system is the ComFloor Composite Floor Deck from Corus. This type of floor has many advantages involving cost, weight, construction speed, but also disadvantages regarding vibrations induced by human activity. The vibration behaviour of this system was analysed taking into consideration two parameters: the thickness of the slab and the grade of the concrete. Two sets of models were made, one with composite beams and one with steel beams. The purpose was to make a comparison between these two types of flooring systems. Results showed a good improvement created by the composite action of the beams and usefull information regarding the two parameters considered.

Key words: ultra shallow floor beam; vibrations; parametric study; frequency.

1. Introduction

Modern floors with steel frames and concrete slabs (composite flooring systems) extend across spans almost twice as wide as what used to be practiced a few decades ago. These floor slabs use metal decking, which spans between main beams or secondary beams. Concrete is then poured onto the decking to make up the composite system.

Composite flooring systems are widely used for floors in offices, shopping centres and airport terminals due to their advantages. These advantages are the following:

a) the steel decking acts as a permanent shuttering which eliminates the need for slab propping while the concrete develops strength; this leads to simple and rapid construction;

b) the composite action reduces the overall depth of the structure;

c) it provides a good fire resistance without any additional fire protection;

d) the system is light and can be cut to awkward shapes;

e) the overall weight of the system is reduced;

f) the demands on cranage are low;

g) fast construction because there is no propping and no time is needed for curing of the concrete.

The use of this type of structure can lead to a serviceability problem due to vibrations produced by people walking. Also aerobics, dancing and other rhythmic human activities have caused annoying vibrations in a number of buildings in recent years. Although the human activity criteria for vibration have been known for many years, it has only recently become practical to apply such criteria to the design of floor structures. The reason for this is that the problem is complex – the loading is complex and the response complicated, involving a large number of modes of vibrations. The loading is repetitive in the cases of aerobic facilities, dancing rooms but in other cases the loading is very complex because human walking is very variable and difficult to predict.

2. Objectives and Goal of Work

In this paper the dynamic behaviour of a composite flooring system is investigated. Two types of systems are modelled: one that has steel beams and one with composite beams. On each of them a parametric study has been performed. The dynamic particularities of the systems are investigated by using Autodesk Robot Structural Analysis. Also the improvement created by the composite action of the beams is analysed.

The parameters taken into consideration are

a) the thickness of the slab;

b) the grade of the concrete.

3. Modelling the Floor Systems

The floor systems have in common a composite slab supported by steel beams in the first model, and composite beams in the second. The floor model has fixed supports from columns. The composite slab consists of steel decking with concrete topping. The steel decking considered is the ComFloor® 210 deep composite profile from Corus. The original SlimFlor long span steel deck, ComFlor® 210 has the capability to span up to 6 m in unpropped construction. The deck material is Corus Galvatite, hot dip zinc coated steel EN 10326-S350GD+Z275. Guaranteed minimum yield stress 350 N/mm^2. Minimum zinc coating mass 275 g/m^2 total both sides. The difference from the other composite floors is that the steel decking is supported by the bottom flange of the beams as shown in Fig. 1.

The composite slab has been modelled in Autodesk Robot Structural Analysis, as an orthotropic slab: slab composed with a trapezoidal plate as shown in Fig. 3 *a*. Also the type of steel and concrete is chosen according to the case. Meshing the slab has been done by using the Coons method with rectangles in rectangular contour as shown in Fig. 3 *b*. The size of the finite elements is chosen by dividing the floor into 20 divisions on both directions [1].

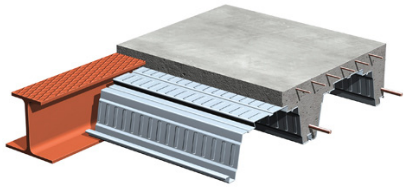
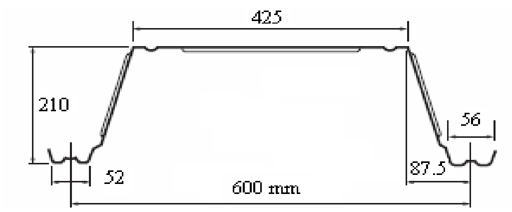


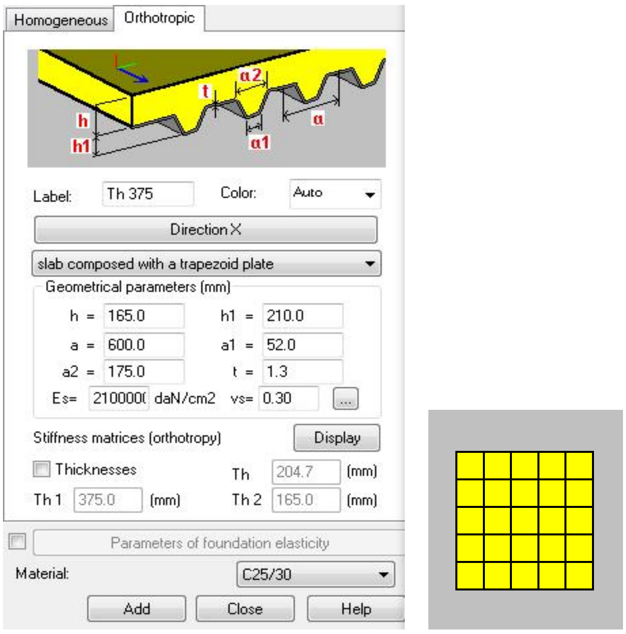
Fig. 1 –ComFloor® 210 deep composite profile from Corus [7].

The section properties of the ComFloor 210 profile are shown in Fig. 2.



design thickness: 1.22 mm
profile weight: 0.16 kN/m
area of steel: 2,009 mm^2/m
moment of inertia: 816 cm^4/m

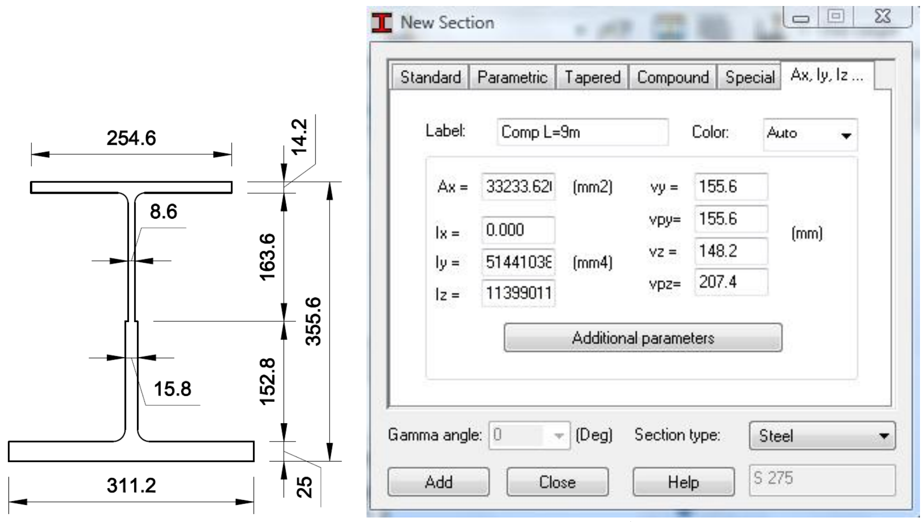
Fig. 2 – Section properties of the ComFloor 210 profile [7].



a *b*

Fig. 3 – Slab modeling in Robot (*a*); finite element types: rectangles in rectangular contour (*b*) [1].

The steel beams considered are universal beams, but having asymmetric sections. The main reason is that the steel deck can be supported by the bottom flange without the need of welding a shelf plate to the underside of the beam. The asymmetric beam considered for the study is presented in Fig. 4 *a*, and the steel grade is S275. The composite beams are modelled in the program by using the section definer. A user-defined section is created by defining the mechanical characteristics of the composite beam [2], [5], [6], as shown in Fig. 4 *b*. These characteristics were computed by taking into consideration the effective width of the slab [3], [4].



a *b*

Fig. 4 – Geometric properties for the asymmetric beam (*a*); modelling in Robot (*b*) [1].

After the steel beams, the composite beams and the composite slab are modelled in the program, the floor model can be created. Two sets of five models each are considered: one for steel beams, one for composite beams, each having different aspect ratios. These models have the following aspect ratios: 1 : 1 (6 × 6 m), 1 : 1.5 (6 × 9 m), 1 : 2 (6 × 12 m), 1 : 2.5 (6 × 15 m) and 1 : 3 (6 × × 18 m). The loads considered are the self weight of the system and an uniformly surface distributed load equal to 200 daN/m^2. The models with the aspect ratios equal to 1 : 2.5 and 1 : 3 have the same beam section and are hypothetical. These models are accepted for comparing the results.

4. Results

As a continuous structure, a floor slab has infinite number of modes of vibration (degrees of freedom) but only the first few modes contain almost all the vibration energy of the floor. The first mode (fundamental mode) has the lowest natural frequency and the largest movement. Frequently, lowering the frequency of this mode alone lowers the overall floor vibration to an acceptable level.

4.1. The Influence of Changing the Thickness of the Slab

The first parametric study is to check the behaviour of the systems by changing the thickness of the slab. The considered thicknesses are 275 mm, 300 mm, 330 mm and 375 mm and the concrete grade is C25/30. The slab is simply supported. The analysis has been performed for all aspect ratios. The obtained results are presented in Table 1 and Fig. 5. The charts are for the 1st mode of vibration.

4.2. The Influence of Changing the Grade of the Concrete

The second parametric study is investigating the behaviour of the system by changing the grade of the concrete in the slab. The grades considered are C16/20, C25/30, C35/45 and C45/55 and the thickness of the slab is 375 mm and it is considered to be simply supported. The results are presented in Table 2 and Fig. 6 as charts for the 1st mode of vibration.

Table 1

The Influence of Changing of the Thickness of the Slab

	Th = 275 mm		Th = 275 mm		Th = 300 mm		Th = 300 mm	
	Steel beams		Composite beams		Steel beams		Composite beams	
Aspect ratio	*f*, [Hz]	*T*, [sec]	*f*, [Hz]	*T*, [sec]	*f*, [Hz]	*T*, [sec]	*f*, [Hz]	*T*, (sec)
1:1	8.44	0.12	8.76	0.11	9.46	0.11	9.83	0.1
1:1.5	6.56	0.15	7.17	0.14	6.8	0.15	7.52	0.13
1:2	4.61	0.22	5.41	0.18	4.58	0.22	5.41	0.18
1:2.5	3.19	0.31	3.9	0.26	3.12	0.32	3.82	0.26
1:3	2.28	0.44	2.85	0.35	2.22	0.45	2.77	0.36

	Th = 330 mm		Th = 330 mm		Th = 375 mm		Th = 375 mm	
	Steel beams		Composite beams		Steel beams		Composite beams	
Aspect ratio	*f*, [Hz]	*T*, [sec]	*f*, [Hz]	*T*, [sec]	*f*, [Hz]	*T*, [sec]	*f*, [Hz]	*T*, [sec]
1:1	10.75	0.09	11.22	0.09	12.54	0.08	13.25	0.08
1:1.5	7.09	0.14	7.93	0.13	7.54	0.13	8.49	0.12
1:2	4.58	0.22	5.43	0.18	4.7	0.21	5.51	0.18
1:2.5	3.08	0.32	3.76	0.27	3.13	0.32	3.75	0.27
1:3	2.19	0.46	2.71	0.37	2.22	0.45	2.68	0.37

Table 2
The Influence of the Concrete Grade

	C16/20		C16/20		C25/30		C25/30	
	Steel beams		Composite beams		Steel beams		Composite beams	
Aspect ratio	*f*, [Hz]	*T*, [sec]	*f*, [Hz]	*T*, [sec]	*f*, [Hz]	*T*, [sec]	*f*, [Hz]	*T*, [sec]
1:1	12.27	0.08	12.95	0.08	12.54	0.08	13.25	0.08
1:1.5	7.44	0.13	8.36	0.12	7.54	0.13	8.49	0.12
1:2	4.65	0.22	5.46	0.18	4.7	0.21	5.51	0.18
1:2.5	3.1	0.32	3.72	0.27	3.13	0.32	3.75	0.27
1:3	2.2	0.45	2.67	0.38	2.22	0.45	2.68	0.37

	C35/45		C35/45		C45/55		C45/55	
	Steel beams		Composite beams		Steel beams		Composite beams	
Aspect ratio	*f*, [Hz]	*T*, [sec]	*f*, [Hz]	*T*, [sec]	*f*, [Hz]	*T*, [sec]	*f*, [Hz]	*T*, [sec]
1:1	12.91	0.08	13.68	0.07	13.15	0.08	13.94	0.07
1:1.5	7.68	0.13	8.65	0.12	7.77	0.13	8.76	0.11
1:2	4.76	0.21	5.58	0.18	4.81	0.21	5.62	0.18
1:2.5	3.17	0.32	3.78	0.26	3.2	0.31	3.81	0.26
1:3	2.25	0.44	2.71	0.37	2.27	0.44	2.72	0.37

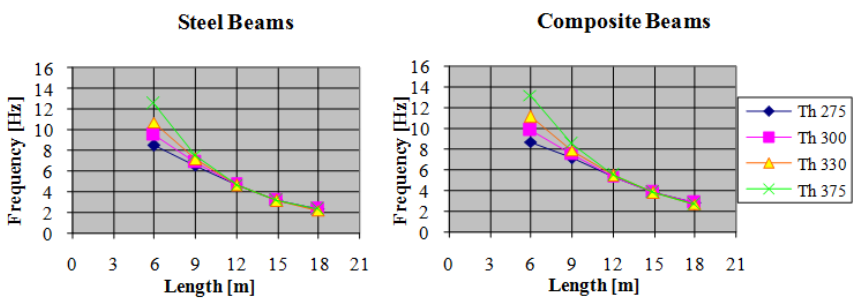


Fig. 5 – The influence of changing the thickness of the slab.

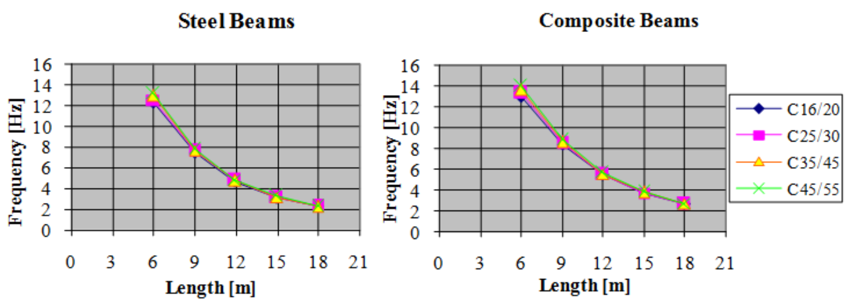


Fig. 6 – The influence of changing the grade of the concrete.

4. Conclusions

One of the goals of this paper was to show ways of improvement of the dynamic behaviour of composite flooring systems. The obtained results showed that a good improvement can be made for slabs having small aspect ratios (1:1, 1:1.5, 1:2) by increasing the thickness of the slab. The parametric study involving the grade of the concrete showed little improvement for all cases.

The second goals was to outline the improvement made by the composite action of the beams on the dynamic behaviour of the floor system. In the case of the concrete grade an improvement of 21.4% was shown and in the case of the thickness of the slab the improvement was even greater, increasing the frequency by 25%.

These results show the potential of this type of system. Further research will be made taking into consideration other parameters involving the aspect ratio of the slab, the end conditions, the beam section and the steel deck profile.

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INFLUENȚA GROSIMII PLĂCII ŞI A CLASEI BETONULUI ASUPRA SISTEMELOR DE PLANŞEE COMPOZITE

(Rezumat)

Unul dintre tipurile moderne de planşee compozite este sistemul de planşeu compozit ComFloor de la firma Corus. Acest tip de planşeu are mai multe avantaje, printre care costul, greutatea sistemului, timpul de execuție dar şi dezavantaje cum ar fi vibrațiile produse de activitatea oamenilor. Comportarea dinamică a acestui sistem a fost analizată luând în considerare doi parametri: grosimea planşeului şi clasa betonului. Două seturi de modele au fost create, unul având grinzi compozite şi celălalt grinzi metalice. Scopul acestora a fost de a face o comparație între cele două tipuri de planşee. Rezultatele au arătat o îmbunătățire adusă de comportarea compozită a grinzilor şi au fost obținute informații utile referitoare la parametrii menționați.