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ANALYTICAL MODELING OF COMPOSITE SLAB BEHAVIOR OF DIFFERENT PROFILED SHEETS UNDER BENDING LOAD

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Abstract

This study concerns the determination of the main geometric characteristics of the slab and the profiled sheet according to the imposed loading, the length of the slab, and the thickness of the profiled sheet. Using the five equations providing the conditions of the deflection, the bending moment, the shear force, and the longitudinal shear at the service limit state and the ultimate limit state for the slab and the profiled sheet, a program in Matlab was developed to solve the five inequalities. The resolution of this system of equations offers an infinite number of possible results. Only logical values are taken into consideration. A logical value corresponds to a standardized dimension.

Keywords: Composite Slab; Profiled Sheet; Stresses; Analytical Model; Deflection.

1. INTRODUCTION

Compared to past years, nowadays technology is being introduced in force in the construction of new structures to improve their efficiency in terms of safety, economy, and aesthetics. New construction materials will be reliable tools to achieve structures with the highest strength/weight ratio. In an attempt to increase the performance of such structures, the combination of two materials with different mechanical characteristics is the most common way to have a structure that is strong enough [1-4]. The composite slab is a structure in which profiled steel (or composite) sheets are used as permanent formwork to support the weight of the concrete [5-7], the reinforcement and the construction loads. Subsequently, the profiled sheets are structurally combined with the hardened concrete and act as all or part of the tensile reinforcement of the finished floor.

In many studies, the profiled FRP sheet was used to perform the reinforcement of the composite slabs and avoid cracking in the lower part of the slab [8, 9].

This study concerns the determination of the main geometric characteristics of the slab and the profiled sheet according to the imposed loading, the length of the slab, and the

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thickness of the profiled sheet. Using the five equations providing the conditions of the deflection, the bending moment, the shear force, and the longitudinal shear at the service limit state and the ultimate limit state for the slab and the profiled sheet, a program in Matlab was developed to solve the five inequalities. The resolution of this system of equations offers an infinite number of possible results. Only logical values are taken into consideration. A logical value corresponds to a standardized dimension.

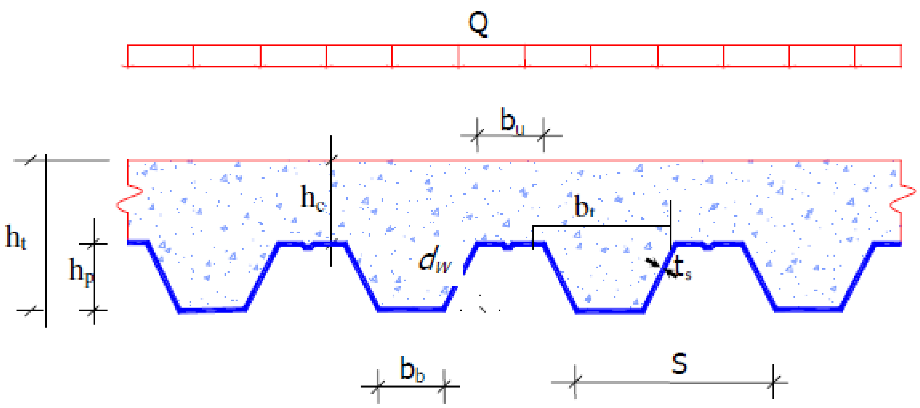

Fig 1: Geometry of composite slab

2. DIMENSIONING OF PROFILED SHEET SECTIONS

2.1 Verification of composite profiled sheets used as formwork according to the Euro Code

- **Ultimate Limit State:**

At the ultimate limit state, the condition verifying the bending moment is expressed by:

$$M_{sd} \leq M_{Rd} \tag{1}$$

- **Service Limit State:**

At the service limit state, the condition verifying the deflection is ensured by the condition:

$$w_{act} \leq w_{all} = \frac{l}{300} \tag{2}$$

2.2 Verification of the composite slab

- **Ultimate Limit State:**

The same is done for the composite slab, where the condition verifying the bending moment at the ultimate limit state is given by:

$$M_{sd} \leq M_{Rd} \tag{3}$$

The condition verifying longitudinal shear is ensured by the condition:

$$V_u \leq V_l \tag{4}$$

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For the shear force, we must check the condition:

$$V_u \leq V_r \quad (5)$$

- **Service Limit State:**

At the service limit state, the condition verifying the deflection is ensured by:

$$w_{act} \leq w_{all} = {}^{l}/_{300} \quad (6)$$

3. CALCULATION OF LONGITUDINAL SHEAR BETWEEN THE CONCRETE SLAB AND THE SHEET METAL

3.1 Analytical Method for the Determination of Shear Force

The horizontal section, composite slabs with profiled sheets admit a failure due to the action of the bending moment and the shear forces. To express the shear forces or the bending moments responsible for this failure, the theory of the resistance of materials is used. For this reason, the elementary cell given by the following figure is considered.

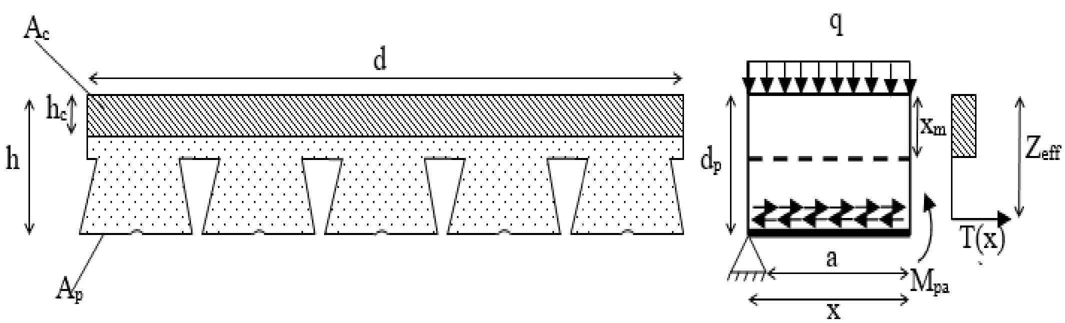

Fig 2: Forces distribution in the horizontal section of the elementary section

The expression for the shear force is as follows:

$$V_l(x) = \frac{Q \times z}{\gamma \times \left(E_c I_{c.eff} + E_p I_{p.eff}\right)} M_0 \left(1 + \left(\frac{2}{\lambda^2 x(l-x)}\right) \times \left(\frac{ch(0.5\lambda l) + ch\left(\lambda(0.5l - x)\right)}{ch(0.5\lambda l)}\right)\right)$$

Table 1: Mechanical properties materials

Materials	Type	fi	E(N/mm2)	γ(kg/m3)	γi
Concrete	C25	30	30000	2350/2400	1.50
Profiled Sheet	Fe360	235	200000	7850	1.15
Steel (Reinforcement)	S275	275	210000	7850	1.10

Table 2: Geometry of the three proposed sheets

S1				S2				S3			
hp(m)	S(m)	Bt(m)	Bb(m)	hp(m)	S(m)	Bt(m)	Bb(m)	hp(m)	S(m)	Bt(m)	Bb(m)
0.05	0.018	0.016	0.014	0.065	0.020	0.018	0.016	0.08	0.022	0.02	0.018

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3.2 Variation of shear force

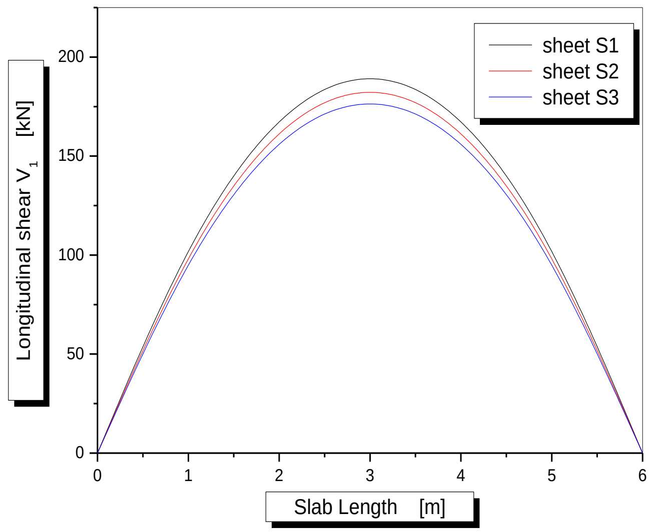

Fig 3: Variation of longitudinal shear depending on slab's length for different profile dimension

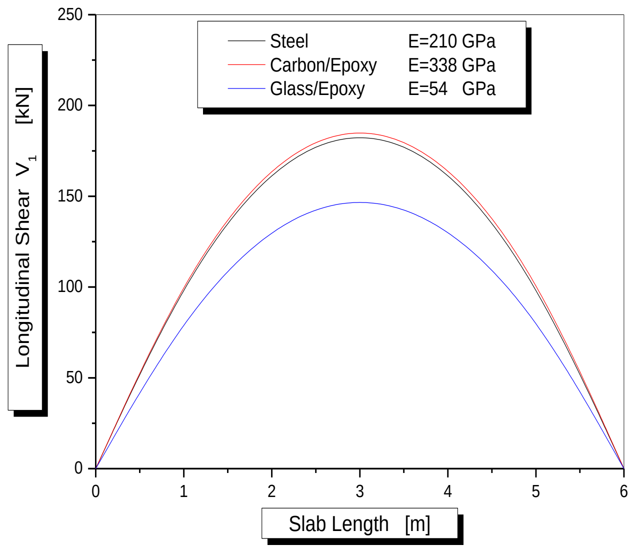

Fig 4: Variation of longitudinal shear depending on slab's length for different materials

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4. CALCULATION OF THE DEFLECTION OF THE MIXED SLAB

4.1 Analytical method for the determination of deflection

By analogy with the theory of beam bending, the relationship between bending moment and deflection in a composite slab.

The expression for the max arrow is as follows:

$$w_{max} = \frac{5Ql^4}{384E_{eff}I_{eff}} + \frac{Q}{\lambda^4 D}\left(\frac{1}{ch(0.5\lambda l)} + \frac{\lambda^2 l^2}{8} - 1\right)$$

4.2 Variation of the deflection of the composite slab

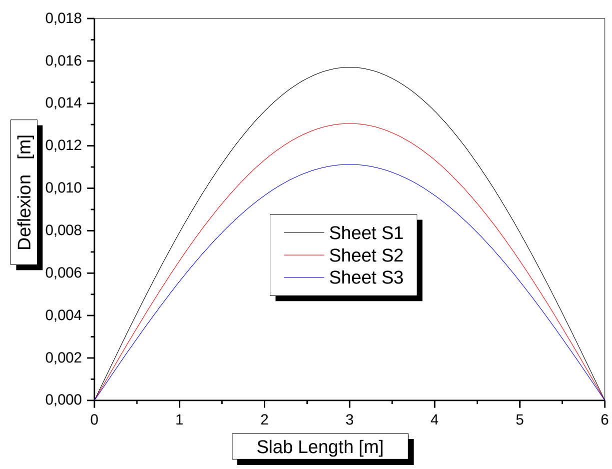

Fig 5: Variation of deflection depending on slab's length for different profile dimension

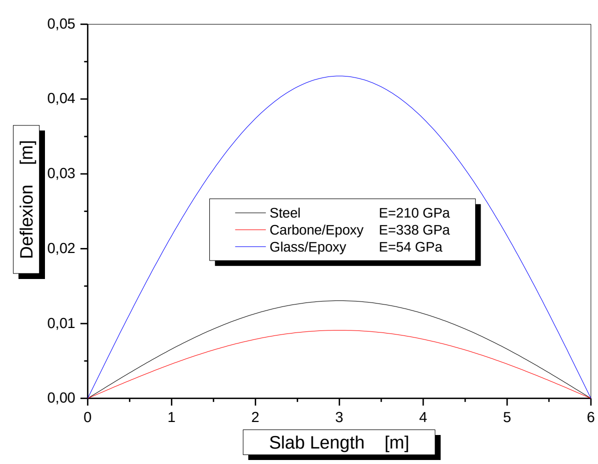

Fig 6: Variation of deflection depending on slab's length for different materials

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5. RESULTS AND DISCUSSIONS

5.1 Variation of sheet metal dimensions under an imposed load Q=2.0 kN/m^2

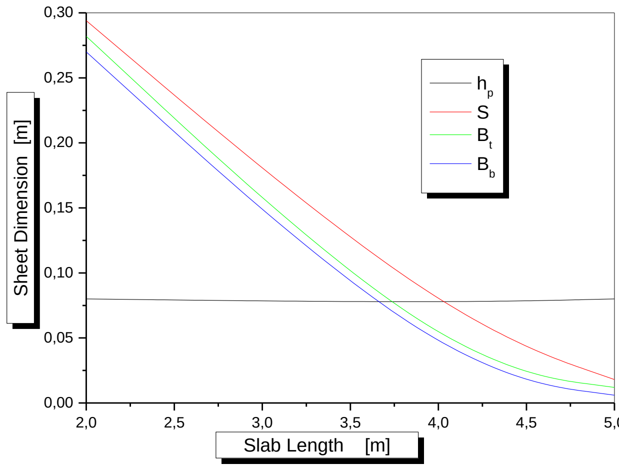

Fig 7: Variation of sheet dimension on slab's length for different metal dimension

This graph represents the variation of dimensions as a function of length for a load Q = 2 kN/m^2, we notice a decrease in dimensions (S, B_t & B_b) following the increase in the length of the beam which is logical, because the decrease in dimensions gives us a large contact surface between the slab and the sheet which allows us to have better adhesion.

5.2 Variation of dimensions depending on the sheet material (S, B_b &B_t)

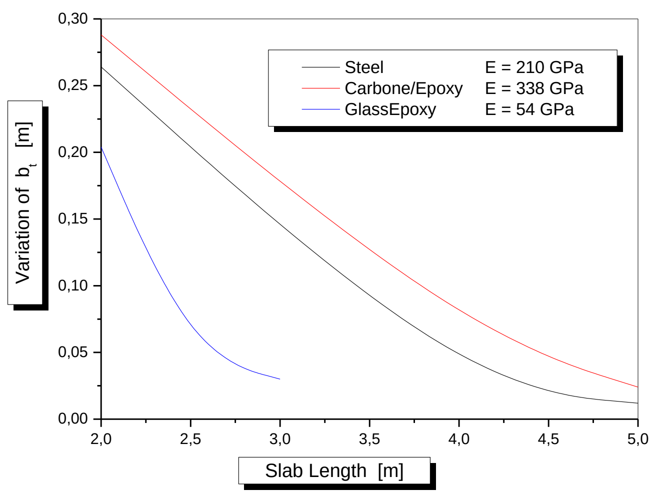

Fig 8: Variation of sheet dimension (*B_t*) on slab's length for different materials

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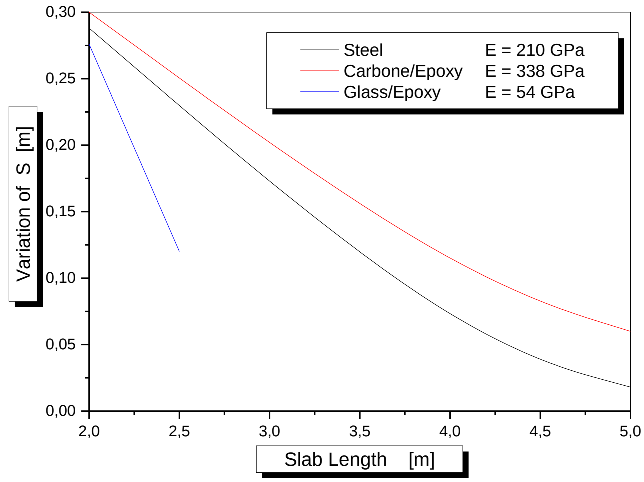

Fig 9: Variation of sheet dimension (*S*) on slab's length for different materials

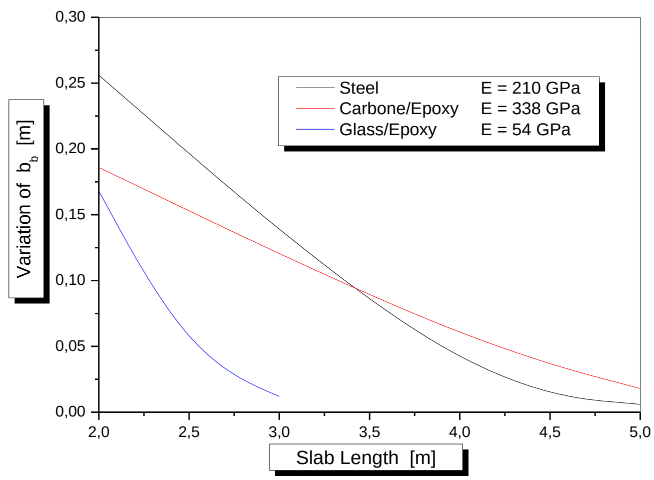

Fig 10: Variation of sheet dimension (B_b) on slab's length for different materials

These graphs represent the variation of the dimensions of the sheet according to the length of the slab, for the three graphs we note that the dimensions (S, B_t & B_b) vary according to the material used for each sheet, and the dimensions of the sheet in (Glass - Epoxy) are lower than that of the sheet in (Steel) and in (Carbon-Epoxy) which is logical, because the rigidity (Glass - Epoxy) is low to that of (Steel) and of (Carbon-Epoxy).

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5.3 Maximum load depending on the length of the slab

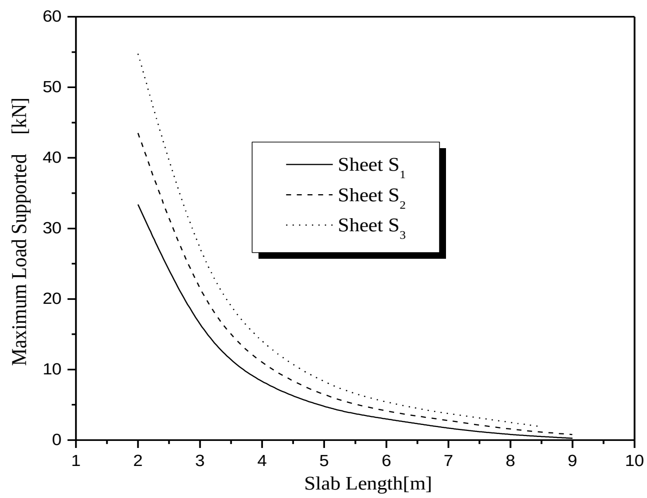

Fig 11: Variation of maximum load on slab's length for different profiled sheets

This graph shows the effect of the type of profiled sheet on the evolution of the maximum load, it is clear that the load is very important for short lengths of the slab. This load is reduced for fairly long lengths. For the S1 profiled sheet, the maximum load is less important, because the latter does not sufficiently resist the applied loads.

6. CONCLUSION

In this work, an analysis was carried out concerning the dimensioning of composite slabs. Depending on the imposed loads, the spacing between the ribs, the thickness of the sheet as well as the lower and upper width of the sheet was determined. Our analytical method is based on the determination of the longitudinal shear forces and the deflection. Using training in the ultimate limit state and the service limit state, it was possible to propose the suitable conditions allowing a standardized pre-dimensioning of the profiled sheet. Finally, it can be said that this work constitutes a good research base allowing a dimensioning of composite slabs according to the standards. The replacement of steel profiled sheets by others in composite is a promising research axis that still requires more research.

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