Determining the Method of Carrying Capacity Formula of Precast Concrete Sandwich wall slab by Finite Element

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Abstract: This article takes the Sandwich wall slab that be connected by reinforcing bar trusses as an example, research the method and steps of calculating the carrying capacity of precast concrete Sandwich wall slab by finite element. this provide a basis for how to use the Sandwich wall slab safely in engineering.

Compose of Sandwich wall slab

Sandwich wall slab is compose of Inner layer,outer layer And heat preservation, connect with steel truss or independent connector

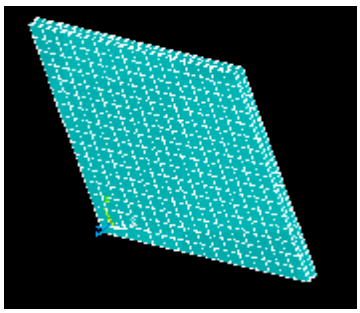
Taking the composite wall slab that is connected by reinforcing bar truss for example , the calculation formula of carrying capacity can be determined refer to the theory of ordinary reinforced concrete member in bending , that is ,the tension is produced when the reinforcing bar is in tension,the concrete and reinforcing bar in the compressive zone produce the pressure jointly, the tension and the pressure constitute the ultimate bending moment.So,according to the actual composition of composite wall slab,using finite element program to calculate the stress of each material of the composite wall slab that is under uniformly distribute load,analyzing the disruption of the compressive concrete ,compressive reinforcement and tensile reinforcement ,then, establish the calculation formula of carrying capacity.

The process of finite element analysis

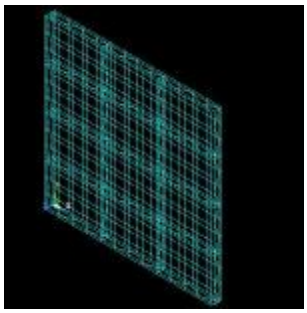
By creating unit, defining the features of the line-unit’s section, defining the material, modeling and so on to constituting the element model of the inner layer and outer layer of wall panel (as shown in figure 1a), the element model of bar-mat reinforcement with reinforcing bar truss member (as shown in figure 1b),and the element model of thermal insulating material that is similar to figure 1b.

Determine ultimate bending moment

There are four kinds of signs that indicate the composite wall slab is disrupted,these signs are :in the compressive zone,the concrete is crushed or the reinforcing bar is yield; the concrete in the tensile region is cracked; the reinforcing bar in the tensile region is yield; the actual maximum deflection is greater than the limit deflection of the member. Making a finite element analysis which according to the constitution of the section of composite wall slab and the detailing requirement of distributed steel, then,analyzing the stress of each material on the basic of the results, therefore which materials will be disrupted first can be estimated,then ,using the strength of this



(a) Element of concrete layer



(b) Element of bar-mat reinforcement and reinforcing bar truss member

Figure 1 Finite element model of Sandwich wall slab

material to calculate the ultimate bending moment of composite wall slab.

In subject researching, according to the actual situation and the detailing requirement, concrete C20 is used, and configurate hot-rolled and ribbed reinforcement whose specification is φR5@100 in the inner and outer concrete layers, there are also some vertical and horizontal reinforcing bar trusses in the composite wall slab, the diameter of chord is φ8,that of web member is φ5,the angle between the web members is 900.There are 15 test specimens with different constitutions of section and different distance between trusses,these test specimens are divided into two groups,the specific situations are as shown in Table 1.

Table 1. The working situations of test specimens (parlyt)

NO.	The thickness of outer layer	The thickness of heat insulation	The thickness of inner layer	The distance c between horizontal trusses	The distance d between vertical trusses
Model 3600×3600					
1	50	100	50	1200	900
8	50	120	50	900	1200
model 4800×4800					
9	60	100	60	1200	600
15	60	110	60	600	600

The result of finite element analysis indicate that the stress of concrete in the compressive zone is the first one that achieve the shear strength, and it causes the section disrupted.So ,increase the load that be used in the finite element calculation,the multiple that the load increased is （f_c/σ_c）,f_c is the design value of concrete's axial compressive strength ,σ_c is the compressive stress of concrete,so the ultimate load under which the composite wall slab is disrupted can be ascertained,and the ultimate bending moment also can be determined.The stress of concrete in the compressive zone and the ultimate load by calculating are shown in Table 2.The ultimate bearing capacity bending moments of composite wall slab are shown in Table 3.

Table 2.The ultimate load that the Sandwich wall slab beared (partly)

NO.	σ_{cmax}(N/mm^2)	f_c(N/mm^2)	Q_{max}(kN/m^2)
1	4.09	9.6	14.08
2	4.23	9.6	13.62
14	2.87	9.6	20.07
15	2.86	9.6	20.14

Table 3. The ultimate bearing capacity bending moments of Sandwich wall slab(partly)

NO.	L(m)	H(m)	lx(m)	ly(m)	Q(kN/m^2	M_{xmax}(kN.m)
1	4.8	4.8	2.4	4.2	14.08	29.80
2	4.8	4.8	2.4	4.2	13.62	28.83
14	3.6	3.6	1.2	3	20.07	21.68
15	3.6	3.6	1.2	3	20.14	21.75

L-width of the composite wall slab H-height of the composite wall slab

Equation for calculating the carrying capacity

According to the principle of the disruption of the concrete that in compressive zone ,and refer to the equation for calculating the carrying capacity of ordinary concrete member in bending,this equation is $M = a_1 f_c bx(h_0 - 0.5x) = a_1 f_c bx g_s h_0$,so,the equation that be used to calculating the theoretical ultimate carrying capacity of composite wall slab is :

$$M = a_1 f_c b h_3 g_s h'$$

Through the formula to calculate the inside lever coefficient and deviation analysis and actual lever coefficient, Deviation rate are shown in Table 4

Table 4.Compared the theoretical value with the finite elemen tactual valu of resisting moment arm coefficient (partly)

NO.	The theoretical value γ_s	The actual value γ_s	The deviation rate
1	0.249	0.259	3.7%
2	0.245	0.25	1.8%
13	0.223	0.227	1.6%
14	0.223	0.226	1.2%
15	0.226	0.227	0.4%
The average deviation rate			3.11%

The average deviation rate is 3.11%,less than 4%,so consider the equation is able to be the equation for calculating the coefficient of internal force arm. Hence,the ultimate flexural capacity of the composite wall slab's section can be obtained from the equation as follows

$$M = a_1 f_c b h_3 h' (0.4253 \frac{h_1 + h_3}{h} - 0.0034 \frac{h_2}{h} - 0.128 \frac{cd}{LH}) \quad (2)$$

h_3—— the width of curb wall panel which is compressed;

h'——the reduced height of section of Sandwich wall slab;

h_2——the insulating layer thickness;

h——the height of section of Sandwich wall slab;

c——the distance of horizontal truss；
d——the distance of vertical truss；
L——the width Sandwich wall slab；
H——the highly Sandwich wall slab。

Conclusions

Determined the equation for calculating the carrying capacity of composite insulation wall slab by using finite element analysis,it is helpful for using the wall slab in engineering more safely .

Acknowledgements

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