Analytical prediction for the capacity of old-new concrete interfaces

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Abstract

The ANSYS computer program has been used to examine the behaviour of the interface between old and new concrete in a column strengthened by the addition of a concrete jacket. The friction, the cohesion and the thickness of the jacket are the three parameters that have been examined. Friction and cohesion are considered as the parameters that influence the strength at the interface. The maximum shear strength at the interface is given by the equation $T_{lim} = \mu P + c$, where: *μ is the frictional coefficient, P is the contact normal pressure and c is the contact cohesion.* Initially, a smooth contact, where the friction and the cohesion are very small, has been examined. Then a rough contact surface was used. Finally, a column that has been strengthened with thicker concrete jacket has been investigated. After all of the above have been examined and with an adequate knowledge of the influence of the three parameters on the strength of the old-new concrete interface, an estimation of the appropriate attachment condition at the interface has been made in order to make the composite element behave as if it were monolithic. To achieve this, suitable coefficients of friction and cohesion have been determined.

1 Introduction

In this paper, the magnitude of the sliding shear stress and the frictional stress developed at the old-new concrete interface of columns strengthen by the addition of a concrete jacket is investigated for different interface conditions. To this end, the Finite Element Analysis Computer Program, ANSYS, has been used [2]. The work has relevance with respect to existing vulnerable structures that have suffered, or could suffer, damage due to inadequate strength and could be repaired or upgraded by enhancing the ductility or capacity of critical columns.

2 Geometry and material properties

In this project, a reinforced concrete column strengthened with concrete jacket has been examined. The cross-section dimensions of the original column were 250X250 mm and the height was 1.8 m. The longitudinal reinforcement bars are 4Φ14 of steel grade S220 and the concrete cover was 25 mm. In addition, there were Φ8/200 stirrups of steel grade S220. The thickness of the jacket used was 75 mm and the height was 1.4 m. The longitudinal reinforcement bars of the jacket were 4Φ20 of steel grade S500 and there were Φ10/100 stirrups of steel grade S220. The concrete cover was again 25 mm. Figure 1 presents the details of the column strengthened with the jacket, the loading conditions and the cross-sectional details.

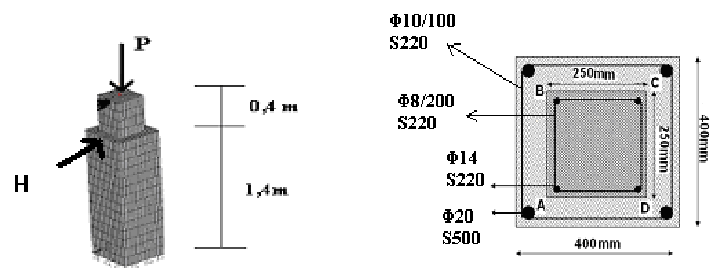

Figure 1: The column strengthened with jacket and the cross-section

The concrete strength of the column and the jacket, taking into account the effectiveness of confinement [1],was considered to equal 20.0 MPa. The ultimate compressive strain of the confined concrete was considered to equal 8 ‰.

3 Analytical work

The column and the jacket were considered to have a fixed base. A constant vertical compressive load, P, resulting from a compressive pressure equal to 10.72 MPa, was applied to the top of the column. In addition, an increasing horizontal load, H, was applied on the top of the column (at 1,40m height), parallel to sides AD and BC of the column, as shown in figure 1.

In modelling the specimen, three different types of finite element were used. Solid elements were used for the concrete; link elements were used for the steel and contact elements were used for the interface. A total number of 6336 elements have been used of which 3984 were solid elements, 1232 were link elements and 1120 were contact elements. A solid element is a three dimensional element capable of cracking in tension and crushing in compression. Eight nodes define this element. Each node has three degrees of freedom. These are translations in the nodal x, y and z directions respectively. A link element is a three-dimensional spar element. It is a uniaxial intensity-compaction element with three degrees of freedom at each node. These are translations in the nodal x, y and z directions respectively. There are two types of contact element. The first is a target surface that models the surface of new concrete. It is a two dimension linear element with four degrees of freedom at each node (UX, UY, UZ and TEMP). The second is a contact surface and models the surface of old concrete. It has the same properties as the target element.

4 Results and discussion

In this section, the analytical results for different values of the coefficient of friction and cohesion that simulate the old-new concrete contact conditions at the interface between the initial column and the jacket are presented and discussed.
Initially, three different values for the coefficient of friction, μ, were used. These were 0.5, 2.0 and 10.0 respectively. The cohesion, c, was considered constant and equal to 1.0 MPa. Results are presented in figure 2.

Figure 2: Maximum concrete strain and top displacement against horizontal load for differing values of μ and a constant c equal to 1MPa.

Secondly, The coefficient of friction was considered constant and equal to 0.5 while different values for the cohesion were applied. These were 0.0 MPa, 1.0 MPa and 2.0 MPa respectively. Results are presented in figure 3.

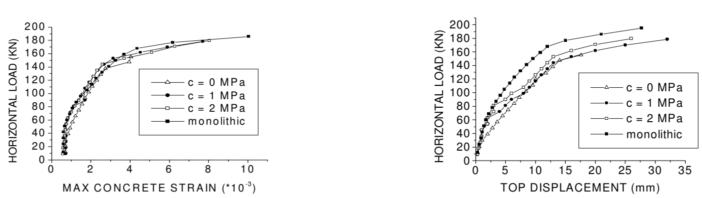

Figure 3: Maximum concrete strains and top displacements for different values of c and a constant μ equal to 0.5.

As can be seen from figures 2 and 3, the increase in the coefficient of friction and in the magnitude of the cohesion results in a reduction in both the maximum concrete strain and the top displacement. However, the influence of the above parameters with respect to the concrete compressive strain appears to be

negligible. Moreover, the influence of the coefficient of friction is more significant than that of the cohesion. In addition, the behaviour of the specimen when the coefficient of friction is high (μ = 10.0) is similar to that of the monolithic specimen.
Table 1 presents the values of the failure horizontal load and the corresponding top displacement for all of the cases examined, together with the relevant values of the jacket and the original column yield stage.

	Ultimate stage		Jacket yield stage		Column yield stage	
Interface conditions μ, c (MPa)	Horiz. load (kN)	Top disp. (mm)	Horiz. load (kN)	Top disp (mm)	Horiz. load (kN)	Top disp. (mm)
μ = 0.5, c = 0	155.4	17.6	141.9	13.6	150.2	15.7
μ = 0.5, c = 1	180.0	31.8	147.9	14.2	144.2	13.1
μ = 0.5, c = 2	180.0	26.0	152.7	13.6	143.0	12.1
μ = 2, c = 1	180.0	20.0	160.5	13.0	146.9	11.1
μ = 10, c = 1	182.0	19.7	166.0	12.7	129.0	7.6
Monolithic	180.0	18.0	166.9	12.1	131.8	7.5

Table 1: Horizontal load and top displacement at ultimate and yield stages.

It is worth noting that, only in the case with most poor interface contact conditions (μ = 0.5 and c = 0.0 MPa) the failure load was found lower than that corresponding to a monolithic column. This was due to a premature failure at the interface. This is also the reason why the steel of the initial column does not yield earlier than that of the jacket. In all of the other cases that were examined, it was found that the maximum horizontal load was not influenced by the interface conditions.

4.1 Sliding, friction and shear stress distribution around the perimeter of the interface

In figures 4,5 and 6, the distribution of sliding, friction and shear stress around the perimeter of the interface for sections taken at the base, the mid-height and at the top of the jacketed column are shown for all the examined interface conditions. Results for different values of μ of 0.5, 2.0 and 10.0 respectively refer to a value of horizontal load equal to 180 kN, while the different values of c equal to 0.0 MPa, 1.0 MPa and 2.0 MPa respectively refer to a value of horizontal load equal to 155 kN.

c = 1.0 MPa μ = 0,5

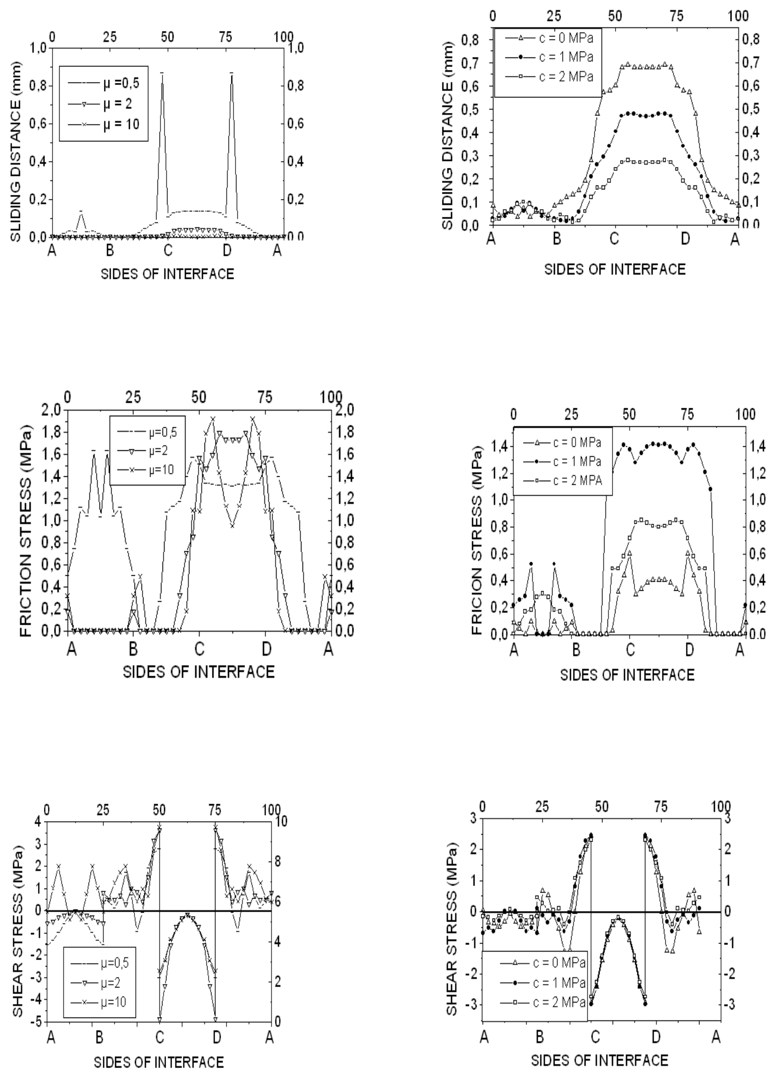

Figure 4: Sliding, friction and shear stress distribution around the interface at the base for different interface conditions.

<u>c = 1.0 MPa</u> <u>μ = 0.5</u>

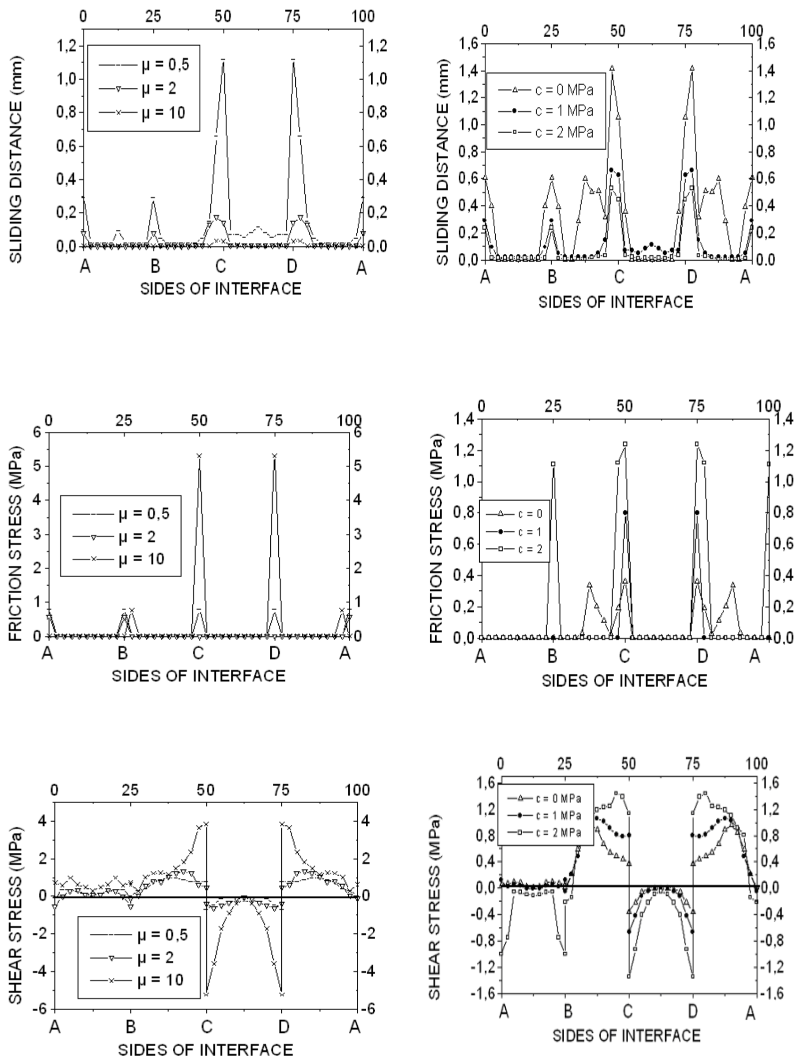

Figure 5: Sliding, friction and shear stress distribution around the interface at the mid-height for different interface conditions

<u>c = 1.0 MPa</u> <u>μ = 0.5</u>

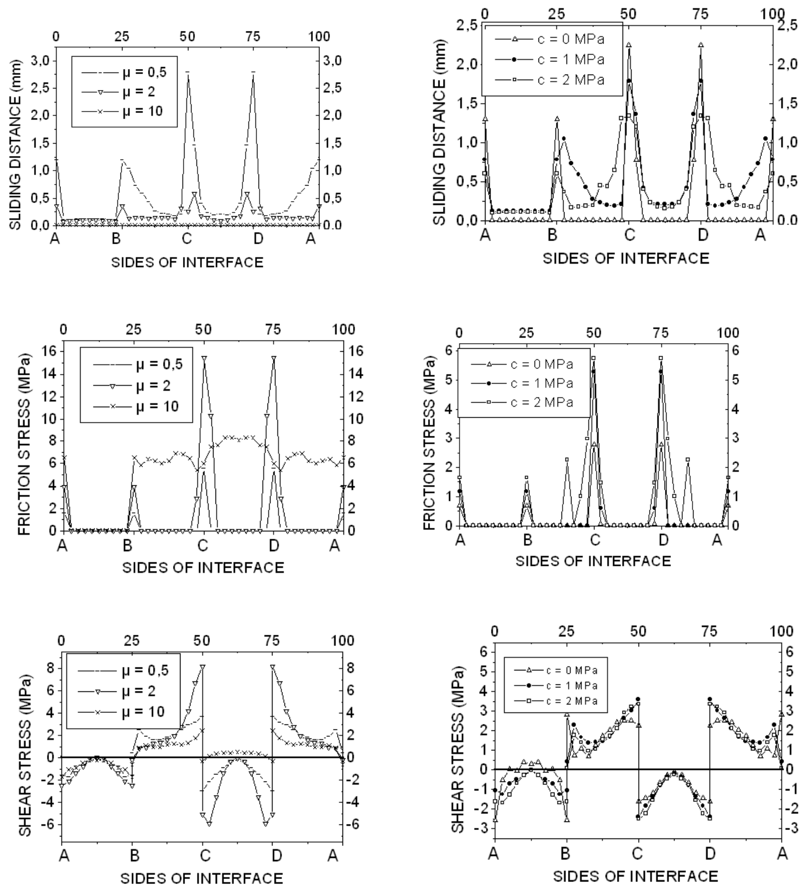

Figure 6: Sliding, friction and shear stress distribution around the interface at the top of the jacket for different interface conditions.

It can be seen from figures 5 and 6 that the sliding distance, the friction and the shear stress take their highest values along edges C and D.

4.2 Sliding, friction and shear stress distribution along the height of the column

Since maximum values of sliding, friction and shear stress occur at the edges C and D of the column, the distribution of these quantities along the height of the column (at edges C and D) have been examined and the results are presented in figure 7.

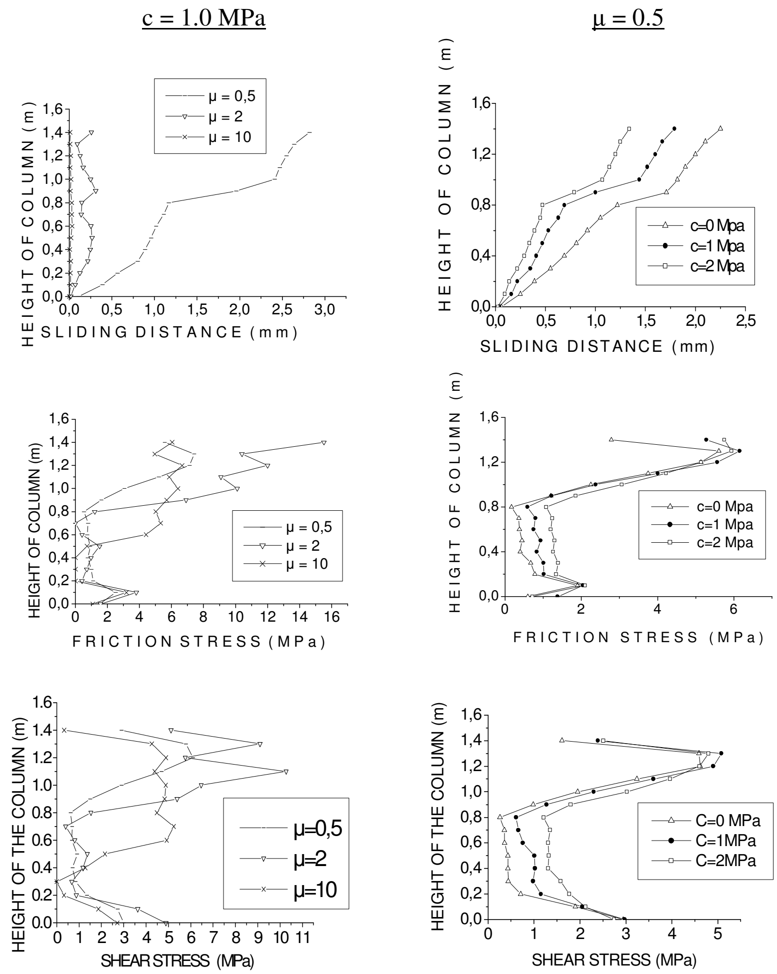

Figure 7: Interface sliding, friction and shear stress distribution along the height of the column at the side CD and edge C (or D), for different cohesion and friction interface conditions.

It can be seen that the highest values of the interface sliding and frictional stresses are observed near the top of the jacket. It can also be seen that sliding is larger when the coefficient of friction and the cohesion have small values and a reduction in friction stress is observed as the cohesion decreases.

4.3 Influence of jacket thickness

In the following figure, figure 8, the influence of the thickness of the jacket and the magnitude of the interface sliding, friction and shear stress at the corners of sides C and D are examined. The maximum concrete strain and the top displacement against the horizontal load for two jacket thickness of 75 and 100 mm respectively are plotted for interface conditions of c = 1.0 MPa and μ = 0.5.

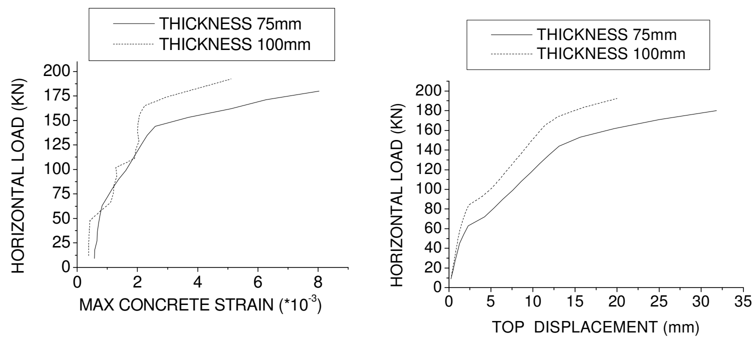

Figure 8: Maximum concrete strain and top displacement against horizontal load for different jacket thickness

Figures 9 and 10 present the interface sliding, the friction stress and the shear stress along the height of the column.

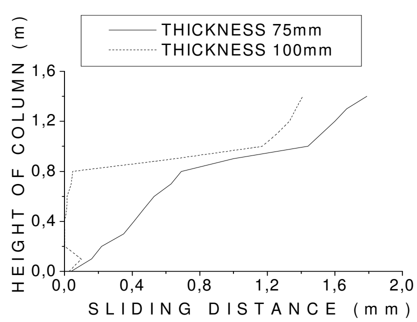

Figure 9: Influence of the jacket thickness on the interface sliding along the height of the column.

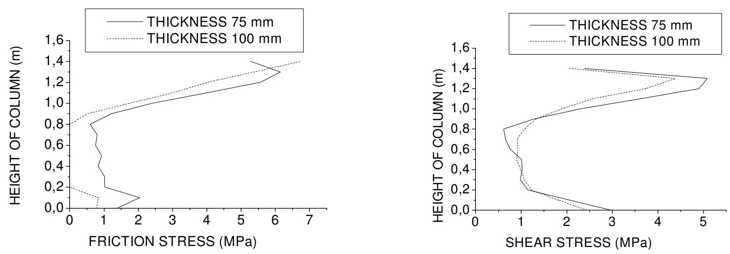

Figure 10: Influence of the jacket thickness on the interface friction and shear stress, along the height of the column.

From figures 9 and 10, it can be seen that the magnitude of the interface sliding, shear and friction stresses reduce when the thickness of the jacket is increased. The above influence is of greater importance as far as the interface sliding is concerned.

5 Conclusions

From the analytical results of the present work the following conclusions can be drawn:

a) Friction and cohesion at the old-new concrete interface influences the behaviour of a jacketed concrete column. However, the influence is not so important, especially with respect to the magnitude of the concrete strain,

b) Friction appears to play a more important role than cohesion,

c) High values for the coefficient of friction (for example, $\mu > 5$) correspond to an almost monolithic behaviour,

d) The magnitude of sliding at the interface becomes very high at the top of the jacket particularly when the friction coefficient is low (for example, $\mu = 0.5$),

e) The maximum value of sliding is concentrated at the corners of the initial column at the opposite side of the applied horizontal load,

f) Increasing the thickness of the jacket reduces sliding.

6 Acknowledgements

The authors acknowledge with thanks the support provided by Dr. Jon Moseley for his help during the preperation of this manuscript.

7 References

[1] Comité Euro-International du Beton , “CEB/FIP Model Code 1990”, Thomas Telford (ed.), London ,1993.

[2] ANSYS, User’s Manual, The Element Library, ANSYS Element Reference, ANSYS Release 6.1, SAP IP, Inc..