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Control works on the tottering walls of the northern side of Calitri castle, Southern Italy

E. Scire & V. De Nicola
BAAAAS of Salerno and Avellino, Italy

M. Candela
Structural Consulting Soprintendenza of Salerno and Avellino, Italy

G. Urciuoli, F. Rozza & E. Del Guercio
Avellino, Italy

ABSTRACT: A very tottering block of wall of 500 mc, closed to the hill, was sigled out. It was built against the vertical Northern side of the hill, for an height of 15 meters; but it was separated from the stable slope by a natural joint, that after the fall of a part of the wall it was possible to see. Control works to stabilize the Northern side of the hill are briefly described.

1 PREMISE

The ancient center of the town of Calitri is seated on the top of a hill, bounded by steep slopes. Only the Southern side of the hill is built; the houses are tightly interconnected with a network of underground cavities, often crossing the whole hill as far as the Northern side that is almost vertical. On this side the bastions of Calitri Castle are sit too. The hill is formed by cemented sands and its substratum is represented by a very thick formation of Varicolored clays, including Pliocenic clays.
The earthquake of November 23, 1980 produced heavy damages to the old buildings and some slope instabilities consisting in falls of cemented sands and a large reactivated flow in the Varicolored clay formation.
The hill allowed for an inhabited settlement on the south face on the condition that the inhabitants excavated a series of underground passage which almost always had their ending precisely in the slope in consideretion and which therefore have a foundamental role in the building and thus necessitate intervention.
Given the dangerous nature of the site (see fig. 1) the solution adopted had to take into consideretion a reasonable operating safety during the execution of retrafitting work. For this reason the classic use of scaffolding was not possible. Taking as a starting point the morphology of the site, thanks to the presence of the indicated caves and underground passages, several places were identified on the south side of the hill from which to start a network (of nails) which anchors the tottering wall of the north face to the hill behind. All this without exposing the workers to unacceptable risks.
It is to be noted that the availability of the site was obtained thanks to the coordination of the operation carried out by the planning office of Soprintendenza, made up by Architets N. Scire' and V. De Nicola and building surveyor A. Quagliariello.

2 RETROFITTING

The actual working conditions in the site have permitted the use of large diameter stell bars for the reinforcing of the nails in the place of the previously envisaged strands. Thus facilitating the location of the packer or of similar mechanisms indispensable for the execution of the cementation of the nails.
Furthermore the use of the bars offer the possibility of being able to count

Figure 1.View of thr bastion after the collapse

on the important contribution of the shear stength of the same bars as well as notably reducing the problems of corrosion given that the reinforcing cross section adopted is superior to that which is strictly necessary.
The following calculations have been carried out according to the hypothesis that the wedge is in a condition of ultimate equilibrium or rather with a unitary safety coefficient.For this reason the micropiles at the foot of the wedge and the diffused nails, have been planned in such a way as to satisfy the foreseen requirements of the Italian Law,guaranteeing the increase of the safety coefficient to the prescribed value even in the presence of seismic movement.
The behaviour assumed by the wedge is that of a rigid body making it necessary to use injection for the realization of the nails ensuring the monolithicity of the wall.
In the following consideretion it is to be supposed that wedge A could be subject to possible sliding action along the existing and visible plane of discontinuity ,inclined at 77' to the orizontal,which undoubtedly makes up a preferential sliding surface. Other planes will obviously have higher safety coefficients.The planned intervention ensures the stability of wedge A with regard to sliding in whichever direction in the plane of discontinuity(plane of separation of wedge A from the stable slope).
As far as geological and geothecnical evaluation are concerned on the basis of tests carried out in situ thefollowing parameters were obtained,cohesion =0.28 Kg/cm^2,friction angle 32'.
The possibility of appending new loads on the reinforced wall is not envisaged.Possible kinematics of the wedge considered as a rigid body are analyzed according to three Cartesian axes that are indicated in fig.2:
a)The possibility of sliding along the axis t1 is undoubtedly the most probable and is tied to the possibility of the foundation of the wall giving way,mobilizing the entire mass above; for this reason the plane envisages the retrofitting of the foundation with micropiles.Widely diffused nails in the body of the wedge are also envisaged in order to raise the sliding coefficient in the direction t1 to the minimum prescribed by rulings in force;
b)sliding along the direction t2 (horizontal)has been calculated and contrasted with very strong internal and external friction and is to be considered mechanically unnacceptable;

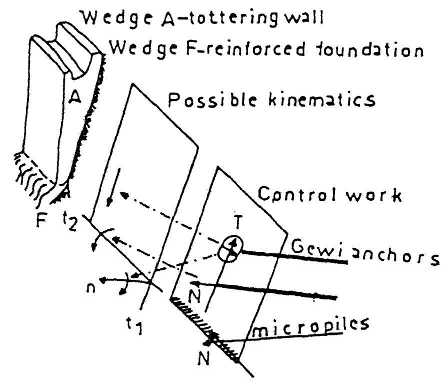

Figure 2.Possible kinematics

c)sliding along the direction n is mechanically unnacceptable in so much as it would entile negative work of the weight of the whole itself;
d)rotation around the axis t1 and t2 is a possible kinematic and for this

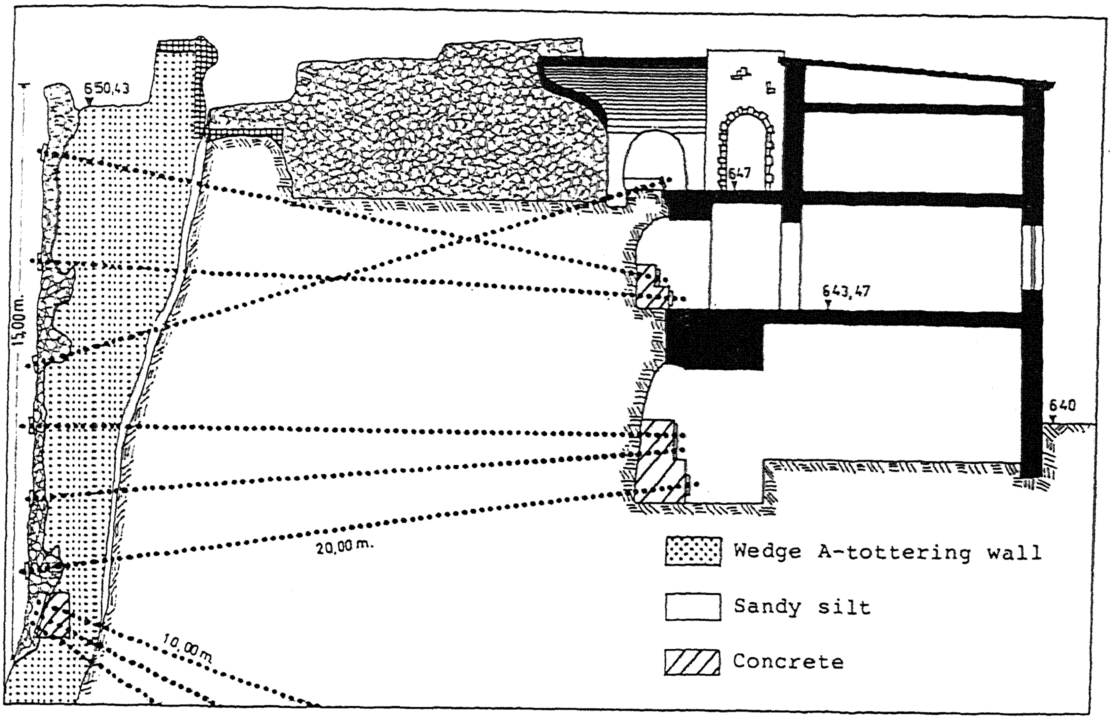

Figure 3.Cross section of the control works

reason in the present plane 50 widely diffused nails in various positions in the wedge are envisaged,such nails are made up of GEWI bars of 52 mm cross section ;
e)the rotation around axis n is also possible kinematic because the wedge is not symmetrical.The above mentioned nails are opposed to such a motion because of their shear strength.
The stabilizing intervention has been planned in a such a way as to raise the safety coefficient calculated the laws in force that is to say 1.3 for the sliding and 2.5 for the ultimate load on the foundations.
It is considered that the natural joints,in a conditions of incipient movement,have a dilating behavior and tend to put the nails placed perpendicularly to the sliding surface in traction;in this way the normal tension on such surface increases and with it the friction resistance.
In order to use the traction resistance of the bars to the pull they have been anchored to the external paramenter of the wall with steel plate ;otherwise the force of the traction applied to each bar would have been limited to the pull-out tension with regard to the ground;In so much as the micropile crosses the tottering wedge for a thickness of about 2 m
If the joint succeed in dilatig sufficiently because it moves a friction resistence,increased by the normal force on the bars will be mobilized on the surface on which the joint slides; if this is not sufficient to guarantee the stability of the wedge,the lateral resistance of the micropiles calculated according to the Broms theory enters into consideretion.
In the case in question it is preferable to apply the Viggiani theory, for the calculation of the ultimate horizontal load of the piles in landsliding motions.

3 MONITORING

The control of working safety was carried out using a monitoring sistem made up of three directional inclinometers commanded by a P.C. and connected to a central alarm system.

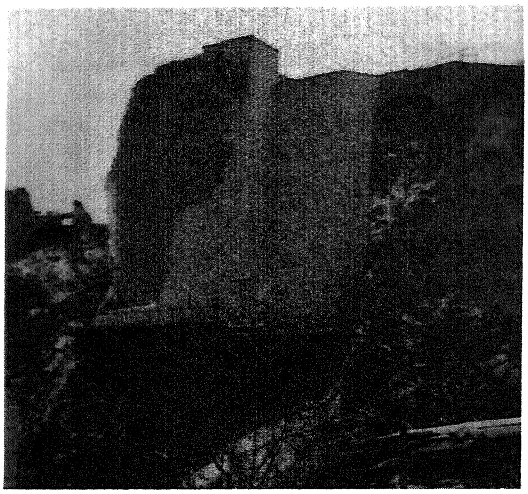

Figure 4:View of the reinforced bastion (on the left)and the rebuilded one (on the right)

The threshold point for the alarm was established for a rotation of the tottering wall of 0.5' .
During the work only ciclic rotations of a few tenths of degree were recorded because of temperature variations

4 CONCLUSIONS

Control works on the tottering walls of the northern side of the Calitri Castle are a relevant example of stabilization,in which tension bars are used in the best way;infact for every possible type of movements tension bars can go in action;also in the direction at rigth angle to the slide for the dilatable behaviour of the joints,along which slide could have occur .
After the realization of control works no factor precluding the reconstrution can be evidenced;in this way the ancient center of Calitri is ready to rebuilding of the houses.

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