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Design of block walls reinforced by geosynthetics.

R.M. FAURE, Cetu, BRON, France
G. HEMOND, Solem Expertises, Genève, Suisse
G. SEVE, CETE Méditerranée, Nice, France

ABSTRACT : We present here a new code for the design of block walls with geosynthetics as this kind of wall is more and more used. The height of these walls can reach more than 12 meters and in this case the help of a code is compulsory. This code is built following the rules of the experimental norm XP G 38064. It presents an easy to use front end that allows parametric calculus for the best choice of a design. Some aspects of duration of geosynthetics are given.

1. THE UPRAISAL OF BLOCK WALLS.

Block walls are more and more common and numerous. From small walls to high walls the user can choose a great number of different blocks. The description of different systems (blocks with geosynthetics) shows how different features can be taken in account in calculation.

On figure 1 a general scheme shows the main features of this kind of wall. A foot strip of reinforced concrete is the base on which the first row of block is carefully settled. As blocks are not very heavy the following rows are easily built. Geosynthetics layers are only gripped between two rows of blocks. To avoid motion blocks usually have lugs and the position of them allows two or three definite dip angles for the face of the wall. An other criteria for the choice of a block is the area of contact between the blocks as to minimise the stresses on the interface. So, better blocks are these with a large contact surface.

The criteria for a better choice of the whole structure are not obvious. Blocks made with concrete in full volume, i.e. without holes, are more interesting for high walls and give a better protection against chocks, as for walls by rivers or for steep riverbanks.

On figure 2 , a drawing shows a concrete block with voids that will be filled with soil and used for walls up to 8 meters high. On figure 3 a more interesting block made in extruded concrete allows high walls. At the end of the text, figure 8 presents four views of walls. This figure tries to show some possibilities of using different kinds of blocks for a wall. Lot of shapes can be built, visual aspect may be very good with an accurate choice of cement and gravel and the easy building is not the last advantage of that kind of retaining wall. With blocks with well designed lugs, block walls can be also used in seismic areas. Mori & al (1999) show trials with a 1G shaking table for the evaluation of the behaviour of block walls under seismic solicitations.

2. THE NORMATIVE ASPECTS.

Following the EC norms, the experimental norm XP G 38064 gives us the basis of the calculus.

For this kind of wall the use of limit state in the soil for the calculation of active pressure is not adapted, because the soil is a reinforced material and failure lines can vary regarding the density of reinforcement or the solicitation. So the design of such a block wall needs a failure approach and the determination of :

- The external stability, considering the block wall and its reinforcements as a massive wall.
- The global stability, very important in case of a wall on a slope, where large failures must be considered.
- The internal stability : the ability of the wall to stand up. This internal stability checks the choice of geosynthetics, the number and the position of the layers of geosynthetics, and the choice of the kind of the concrete blocks. For this purpose, the characteristics of soil, geosynthetics and the behaviour of geosynthetics inside the soil are needed. For geosynthetics, usual pull out tests give these parameters.

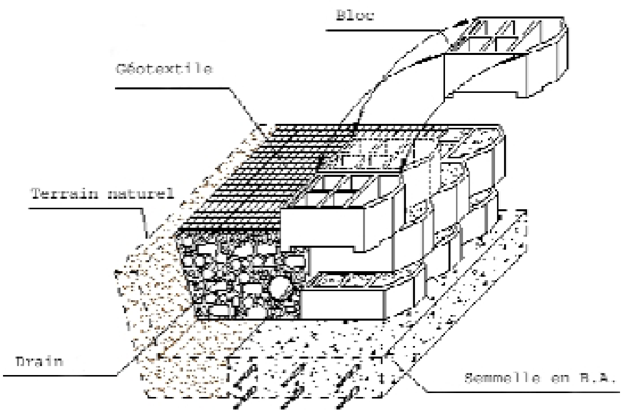

Figure 1 : General scheme for retaining wall made of blocks

For the internal stability, failure curves are determined through each interface between blocks, in a circular way where the centres are, as for usual slope stability calculus, on an orthogonal grid. But failures curves are also generated as non circular curves using an algorithm with smooth cubic splines.

In both cases the failure curve is extended with a straight line between the blocks of the retaining wall. The friction, between the blocks is evaluated and added to the forces balance, and the user can see the influence on the stability of the wall itself.

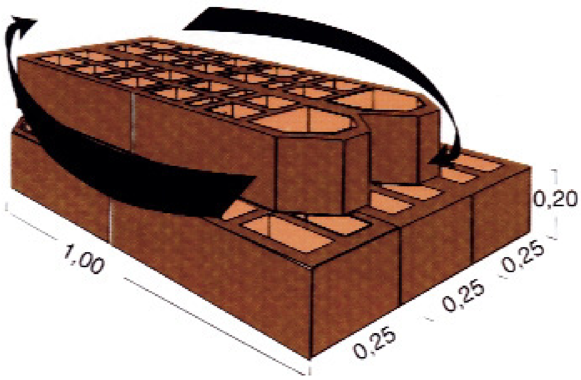

Figure 2 : A block with voids to be filled with soil
The shape of the blocks allows architectural effects.

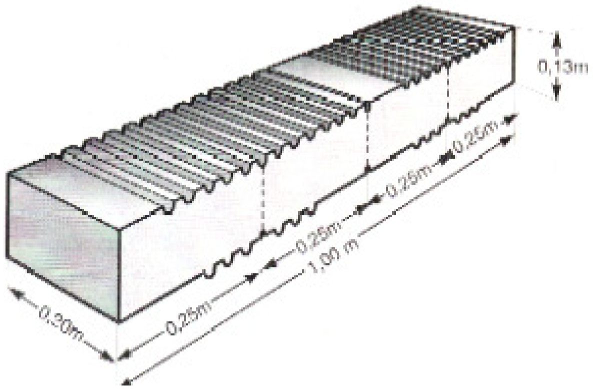

Figure 3 : A concrete block for strong and high walls.
It is very easy to cut this block into smaller blocks.

Shear tests are compulsory to give these parameters. Figure 4 shows a shear test for determining the strength parameters of the behaviour of two blocks.

Figure 4 : Shear tests between blocks.

Full scale experiments give also lot of information. On figure 5, we can see a failure test on two block walls, one with geosynthetics and the other with only the blocks. Designed with usual method for wall, that is with active pressure evaluation, the limit of height was 4.0 meters.
The walls reached 4.2 meters and with the load made of concrete heavy blocks it did not collapse. But the measurement of displacements inside the earth showed a failure mechanism that can be analysed with failure methods.

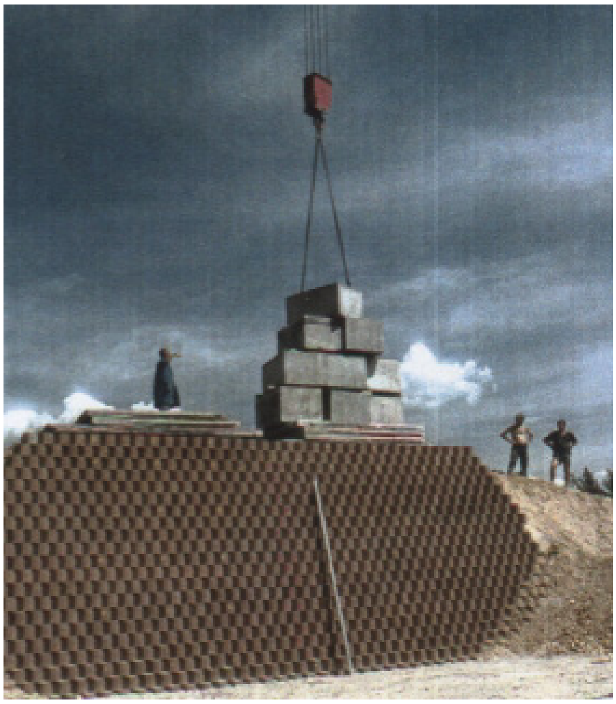

Figure 5 : Failure trial on a block wall.
(photo R.M. Faure)

3. DISPLACEMENTS ASPECTS.

The results of the full scale experiment described above give us useful ideas for code implementation. When a failure surface appears inside the soil the layers of geosynthetics work like passive anchors. The retaining force of each layer depends of the local displacement. On a section, we can describe the field displacement with a grid and linear interpolation between the vertices of the grid where the user give the value of the displacement. To define the displacement that give the stability an iterative schema, like in Cartage code (Delmas et al.,1986), compute step by step the balance of the forces. The given values of the displacement field are used with a factor of 0.1, 0.2, ….,1.0, as to provide 10 steps. (Faure et al, 1988), (Gouria, 1998) These calculus would be very useful because we have more and more questions about the deformation of the works. For high speed railways tracks the stability is widely assumed, but the deformation must be also limited, and this at a design step.

4. A PRODUCTIVE TOOL.

Nixes et Trolls 5.0 is a code with a friendly user front end that gives many possibilities for slope calculation. It is developed from the first Nixes et Trolls code that appeared in 1973. (Faure & al, 1976). Nixes et Trolls 5.0 can take in account and combine all kind of retaining systems that are soil nailing, active anchors, piles and block walls. On a profile the designer can use five different designs of each retaining system, and combine them with simple mouse clicks on the screen of the choices. (figure 6). As all kinds of concrete blocks, all kinds of geosynthetics, all kinds of nails are carefully described in permanent files, the designer can quickly obtain the best design for his wall. In a close future Nixes et Trolls will be linked with a data-base, and so it will be a knowledge tank about stability and the use of all kind of retaining system (nails, anchors, concrete blocks and geosynthetics).

For block walls, the code can give the influence of the kind of block on the stability, when the user tries several kinds of blocks in the design of the wall. As recommended in the experimental norm, failures are generated from each interface between blocks and the shear strength between two blocks is obtain from parameters determined in shear tests on two blocks. Figure 7 shows the main screen of Nixes et Trolls

Nixes et Trolls 5.0 is a huge code and its dissemination is not very easy for maintenance reasons. New WEB technologies give us a good alternative with WEB services, but it is necessary to split the code in small parts that can be used inside WEB servers, and all the front-ends have to be redefined. We hope to be able to give soon, to any user the opportunity of using, on line by Internet, this code.

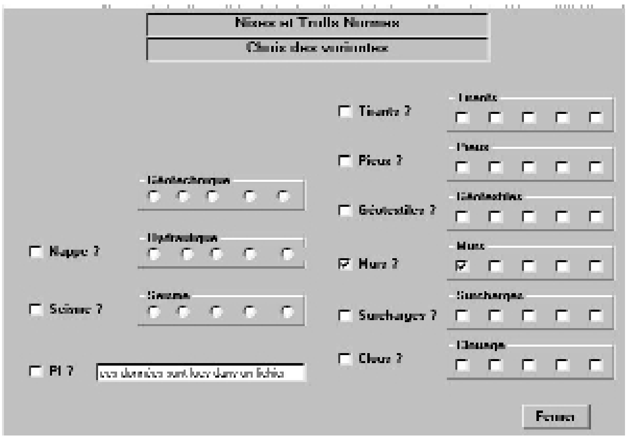

Figure 6 : The control screen for the selection of the calculus elements.

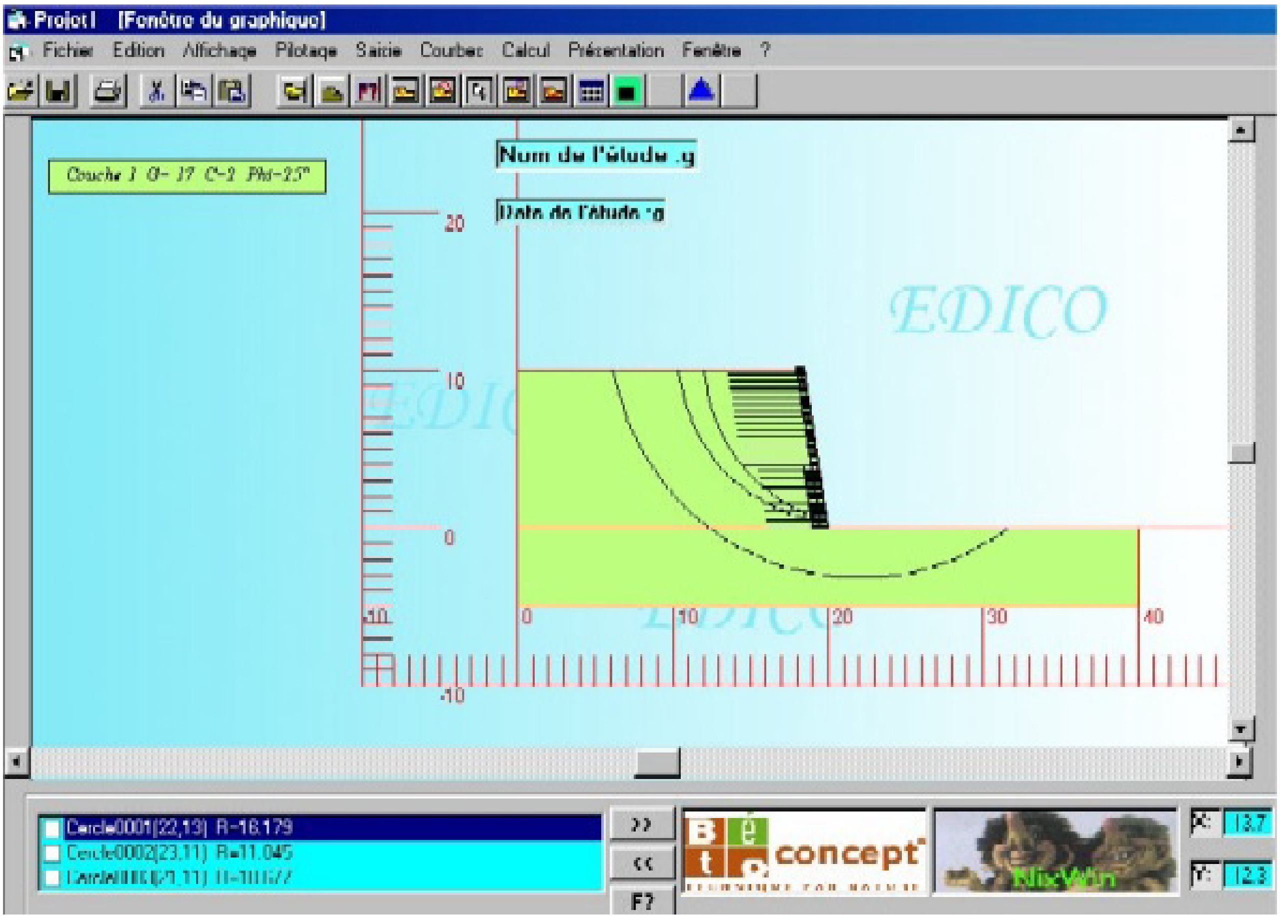

Figure 7 : Main screen of Nixes et Trolls V5.0

5. SOME REMINDER OF CHEMISTRY.

For speaking about the durability of that kind of construction, with geosynthetics, some remarks based on chemistry are presented here.

The use of unweaved geosynthetics began with polyesters compounded of polyesters fibres obtained by a polycondensation reaction. All these fibres are terminated by hydroxyl's (- OH). One of the main characteristics of these hydroxyl's is to react easily with alkaline elements that are numerous in fresh concrete. This is generally the basis of the risk of destruction of the geosynthetics, but in the case of walls built with blocks of concrete, the blocks are mature and dry. Even with rainfalls the small quantity of alkaline element transported by water is not sufficient for the destruction of unwoven layer.

As to avoid any risk, geosynthetics fabricants since several years have changed polyesters by polyolefins, such are polypropylene or polyethylene, that have not OH ends and are not able to present saponification reactions. (RILEM, 1988) (Rollin and Rigo, 1991)

For walls built with concrete blocks there is now a great choice of geosynthetics layers, in term of strength and behaviour. This is why we have developed in Nixes et Trolls modules able to take in account deformation or strains.

6. CONCLUSION

The design of a block wall is very complex as lot of features (blocks, geosynthetics, complementary retaining system as active anchors or piles) can be used at the same time in the design. The use of a computer code is now compulsory.

But the skill of the engineer remains most determinant from the first visit on the site to the last screen of the design.

Figure 9 : Some examples of blocks retaining walls :
top left in Lebanon, height 14m, top right near Mende (France) height 8m
bottom left near Pagano (Italy) height 9.5m, bottom right near Pegomas (France) height 5.2m

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