Earth Reinforcement Practice, Ochiai, Hayashi & Otani (eds) © 1993 Balkema, Rotterdam, ISBN 90 5410 093 1

Discussion leader's report: Testing and materials

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Session 1 is related to a wide and important scope with 36 papers from 17 countries around the world. The review has been organized according the following approach:

.measurement of the material characteristics which are the input of any geosynthetic application and for which Prof Rigo et al have demonstrated the need

.definition of models from these characteristics and from tests to describe elementary or global behaviours of structures

.design in relation with the application as the result of the two previous steps

1 CHARACTERISTICS OF MATERIALS

Characteristics must deal with soil and reinforcements.

1.1 Index tests

The measure can be achieved by index tests to define the properties of the material itself. Karunaratne et al defined through modified ASTM tests the measure of the specific weigth, the thickness, the tensile strength and the opening size of jute geotextiles. Yuan et al defined the mechanical characteristics of polypropylen strips used in their country. Tests were analysed to establish criteria of use as for example the maximum allowable strain and to establish some parameter values.
In reinforcement applications the long term behaviour of materials is necessary to be known for permanent structures. Helwany et al proposed an analytical model to predict the crep behaviour of geotextiles based on creep tests and validated it on tensile tests performed at different rates of strain.

1.2 Performance tests

But in civil engineering applications soil is always one of the constituents and we need performance tests to characterize the interaction between soil and the other materials. Bush et al performed biaxial tensile tests on polyethylen grids. They make clear that if there is no change of tensile strength in comparison with uniaxial tests, strain at failure can be reduced.

1.2.1 Long term behaviour

Blivet et al performed tensile and creep tests on woven, non woven needle-punched geotextiles of polypropylen and polyester under confinement conditions. For some non wovens a higher stiffness can be measured. Concerning the creep of wovens no influence seems to exist.
Also related to long term behaviour durability must be studied for materials used in contact with soils. But it is necessary to examine the durability of the function of the material in the application regarding the damage process that can occur. Anderson et al presented results of a research program on hydrolysis of polyester. After a first step that has allowed the definition of the limits of parameters acting on hydrolysis process they performed tests on polyester yarns at 80°c in acid, neutral and basic solutions. A reduction of tensile strength has been observed for low tenacity yarns. But we have to keep in mind that durability must be evaluated in realistic conditions that will be the third step of their program. Informations about the stress cracking of HDPE are given by Jailloux et al on the base of the

behaviour of notched samples under the testing procedure set up by GRI for geomembranes. Results show that brittle failure can occur at nodes of oriented polyethylen grids with a similar behaviour of non oriented sheets.
Site investigations are necessary to evaluate durability in realistic conditions. Bastic et al gave results of 25 years of observations on corrosion of steel strips in reinforced structures. They identified the parameters acting on corrosion, defined a model and validated it on sites.
In an other way a specific performance test has been achieved by Austin et al to study the resistance to fire of polypropylen grids behind a concrete facing.

1.2.2 Interaction

Another important point concerning the performance of the structure is the knowledge of the soil-reinforcement interaction in reinforced structures. Several papers gave results of shear tests and pull-out tests but no specific conclusion has been withdrawn about the test to perform for design. Garg et al tested thc interaction of sand with aluminium and bamboo strips. They showed the difficulty to interprate pull-out tests. Large pull-out tests were performed by Bouazza et al on polypropylen strips in contact with waste materials showing an apparent coefficient of friction decreasing with the overburden pressures and of low values. Results of pull-out tests in full scale embankments on polypropylen strips in contact with cohesive soils were analysed by Chen. An apparent coefficient of friction was defined in which the part of cohesion can be from 10 to 35 %.
A lot of works dealed with geogrids for which the pull-out behaviour can be more complex: partial friction soil-soil, friction soil-geogrid and contribution of the cross members. Cancelli et al developped a new apparatus to perform shear and pull-out tests. An interesting conclusion of the results they gave on pull-out behaviour of geogrids is the necessity to take into account a residual friction which can be lower in large deformations. Two papers tried to clarify the behaviour of geogrids. Bergado et al have elaborated an anlytical model for the pull-out behaviour of geogrids based on the measure of the skin friction and the bearing capacity of the cross members. Ochiai et al showed the importance of the geogrid elongation during a pull-out test which induces a tensile force distribution in the geogrid. They proposed to use the average total area method based on simple pull-out test (restricted to small normal stresses) to define the allowable shear resistance. Pull-out behaviour of geogrids in contact with volcanic ashes under seismic conditions were studied by Yasuda et al. It appears that the pull-out force measured in these conditions is in the same order or higher than the one measured in static conditions.
Performance tests can also be used to characterize the global behaviour of a material as for example Mito et al have done to study the capability of plastic drains as a countermeasure of liquefaction of soils using shaking tables. From the tests they established charts design.

2 MODELS

All these interaction parameters have to be used in models to predict for example the interaction behaviour. Two papers present a validation of models which can be used. Gourc et al performed pull-out tests in centrifuge on extensible and inextensible reinforcements. It is confirmed that the extensibility of the reinforcement has an influence on the pull-out behaviour and on the soil deformations. Results were analysed with finite elements method and the analytical formulation of the french displacement method. It appears possible to modelize the pull-out behaviour of geotextiles with the friction parameters determined from shear tests. Mitachi et al present a similar analytical approach taking into account the extensibility of the reinforcement and an elasto-plastic interaction behaviour. They came to the same conclusion as the previous authors and proposed a design method for the length anchorage.
The ways to define and to validate models using the previous parameters can be laboratoty tests and/or field observations. Baykal et al tested the reinforcement of sand with wovens, non wovens in triaxial cells. They showed the importance to take into account the stress-path to have a good representativity of the tests. Moroto performed compression tests on sand reinforced with paper showing the increasing of stiffness of the reinforced soil. A specific apparatus called Automated Plane Strain Reinforcement is described by Wittle et al to study the

stresses in reinforcements. They established the method to analyse results and predict the pull-out force of a planar reinforcement. Springmann et al analysed the requirements to modelize reinforced structures in centrifuge and explained how they have solved the reduction of the instrumentation on the models to measure strains.

For the field observations the instrumentation is of a great importance. Radeniya related the necessity to calibrate the instrumentation in the field conditions as for example strains gages on grids in embankments subjected to temperatures from 30°c to -20°c. Mc Gown et al gave a description of what must be an instrumentation in reinforcement applications to measure load, strains and temperature.
Most of the papers dealed with discrete reinforcements. A random one is also possible as with the Texsol. Hyde et al compared the two types on models. With a random distribution of reinforcements it is possible to increase the global stiffness of the reinforced soil and to reduce the lateral earth pressures. In the same way Akagi et al show that it is possible to improve continuous yarns reinforced sand by adding a small amount of cement for erosion control purposes.
The knowledge of the materials characteristics and of the structure must also go on with the developpment of new construction technics. Datye described new technics of low cost using natural and synthetic materials, geocells...
Concerning the finite elements modelling Sawicki et al used a visco-elastic behaviour of reinforced soil based on the mechanical properties of the constituents, their geometrical arrangement and volume fractions to analyse the long term behaviour. Kulczykowski applied the elasto-plastic theory to a full scale reinforced retaining wall loaded on top until failure and found a relative good agreement. Nakai also used an elasto-plastic analysis to calibrate triaxial compression tests on a reinforced sand. The surface roughness, the stiffness and the density of reinforcements are of a great importance. Otani et al described an originel FE analysis showing the necessity for geogrid reinforced structures to take into account the dilatancy of the interaction.

3 DESIGN

Legrand et al described the program they established for the applications in which specification of geotextiles is more or less empirical. The originality of this program lies in the association of a geotextile data and the possible selection of the geotextile in agreement with the specifications. Voskamp analysed the geogrid reinforcement and how to define the allowable tensile strength looking to all safety factors. Charts were drawn to design the pull-out force and the anchorage length from a specific experimental program.
At the last step or the first the quality of the design and the products govern the behaviour of the structure. In this way the Endorsement Certificate System established in Hong Kong for products to be used in permanent reinforced structures and presented by Man et al is really interesting. It is based on national certificates, durability, insurance quality of the producer, specifications of use.

4 CONCLUSION

As a final conclusion, considering an application, if we correctly gather the puzzle of the products, the testing methods, the models and the design we construct a permanent civil engineering structure.

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