Proceedings of the PhD Workshop –

organized by the Pál Vásárhelyi Doctoral School on Civil Engineering and Earth Sciences in the framework of ***TÁMOP-4.2.2/B-10/1-2010-0009***

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MAGYARORSZÁG MEGÚJUL

A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósult meg.

1. A brief description of the Pál Vásárhelyi Doctoral School on Civil Engineering and Earth Sciences

The doctoral school was established in 1993 in a form of two doctoral programs, to rise new generations for research and development in the field of the theoretical and practical aspects of civil engineering and earth sciences. Its focus includes research in structural mechanics, building materials, geology, geotechnics, architectural engineering, highway and railway constructions, hydraulic and water resources, sanitary and environmental systems, geodesy, surveying, geoinformatics and photogrammetry, biomechanics ...etc. The school integrates the research activities pursued in 10 different departments in the Faculty of Civil Engineering, Budapest University of Technology and Economics. The scientific activities in the school are conducted in three main groups, (i) structural engineering; (ii) infrastructural engineering; and (iii) geoinformatical engineering. Since 1993 more than 100 students have successfully defended their PhD theses and have been awarded with the degree. As far as the scientific outcome is concerned, the members, supervisors and students of the school have published several hundreds of high ranking journal papers and the cumulative impact factor goes beyond 400.

2. Research and development projects supported by TÁMOP-4.2.2/B-10/1-2010-0009

The research fields of the faculty cover very broad fields in the civil engineering and geoinformatical researches. PhD-Students and young researchers are always in the frontier of the current investigations, so we divided the objected researches into the classical subdivisions of the research, namely (I) structural engineering, (infrastructure engineering, and (iii) geoinformatical engineering

In the talent care aspects of the TAMOP project the faculty awarded extended grants for 13 of its PhD Students, as well 4-4 doctoral candidate and post-doc researchers were employed

2.1 Research in the field of Structural Engineering

The emphasized objectives of the research of wide topics of the structural engineering discipline are included in the project with the following subdivided fields:

- As local ductility of steel structures gets more and more important in the current structures, the analysis of this behaviour, creating an effective numerical material model, backed by laboratory experiments is planned
- Buckling restrained braced (BRB) frames are analysed for their capacity parameters with global non-linear dynamics
- Design of composite structures based on numerical simulation with emphasis on shear connections.
- Development and generalization of the „constrained finite strip" method for the stability analysis of thin walled steel structures
- Application of polymer concretes and their temperature-dependence
- Engineering geological and geostatistical analysis of the new metro stations in Budapest
- Early age shrinkage cracking and sensibility analysis of different concretes

- Strength and behaviour of building materials in and after fire
- Analysis of the geotechnics of municipal solid waste landfills
- Biomechanics of the human eye

2.2 Research in the field of Infrastructural Engineering

The emphasized objectives of the research of wide topics of the infrastructural engineering discipline are included in the project with the following subdivided fields:

- Analysis and modelling of fluctuations in shallow lakes caused by the wind
- Analysis of interaction of reed-water interface zones in shallow lakes
- Short-time hydrodynamic forecasting for lakes with 3D-modelling
- Determination of the diffuse pollution and water quality of roof runoff precipitations in urban areas
- Research and development of water purification technology, particularly for arsenic and ammonium-exempt
- Analysis and quantitative evaluation of ecosystem services

As it can be seen from the list, the objectives are the detailed analysis of the hydrodynamics of lakes and water management research in urban and rural areas

2.3 Research in the field of Geoinformatical Engineering

The emphasized objectives of the research of wide topics of the geoinformatical engineering discipline are included in the project with the following subdivided fields:

- Application of the measurements with the torsional pendulum of Eötvös in geodesy
- Analysis of the application of RFID system for geoinformatical problems
- Geodesic application of modern mathematical and computational methods with emphasis on differential evolutionary algorithms

3. Papers

In the frame of the project „Talent care and cultivation in the scientific workshops of BME" the Doctoral School grants financial aid to its several talented PhD-Students, PhD-candidates and post-doc researchers to achieve the pledged scientific result through their research. In this section we have chosen two PhD-Students, one PhD-candidate and one post-doc researcher to present their research.

The selected papers are:

Zsófia Derts (PhD Student): Quantitative evaluation of ecosystem services: problems and possibilities experienced in the Tisza Valley case study

Zita Ultmann (PhD Student): Linearity analysis of the Eötvös-tensor

Olivér Fenyvesi (PhD candidate): Early age shrinkage cracking of concretes

Gabriella Varga (post-doc researcher): Degradation Dependent Stability Issues of Landfills

Quantitative evaluation of ecosystem services: problems and possibilities experienced in the Tisza Valley case study

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Abstract

The Tisza Valley is risked by extremities related to water resources that are aggravated by direct and indirect anthropogenic effects and climate change. The long term planning of land use based on the maximization of the natural capital would be a possible way to manage these risks. The integrated hydrological model of the WateRisk decision support system developed at our Department contributes to the technical initiation of this concept, and, the environmental economic post-processing module of the same software is able to demonstrate the long term change of several ecosystem services. As an outcome of the background research for the WateRisk project, in this article, the results, limits and further possibilities about the determination of the natural capital of the Tisza Valley study areas are presented.

Introduction

The Tisza Valley is characterized by water resources extremities in space and time (flood, excess water and drought ([6], [11]), which induces serious – and probably increasing – social and ecological risks. The solution to this issue (adaptation to the altering conditions and/or the moderation of the risk factors) requires an integrated management of water resources, land use and natural circumstances. A possible approach to related decision making is the economic comparison of the total economic value (TEV, [3], [8]) of the water resources policy-land use scenarios, by means of hydrological and hydro-dynamic modeling tools.

The economic benefit of ecosystems is defined through natural capital and ecosystem services: physical and biological stocks and flows that contribute to human well-being ([1], [2], [9], etc.). The fact that certain ecosystem services dominate a given landscape facilitates their valuation. At the same time some services are hardly definable numerically, some others are barely referable to changes in water resources or to financial values, which make research more difficult. Costanza ([1]) produced the global range of natural capital for different ecosystems, on the other hand in case of given study areas it is fundamental that the valuation of ecosystem services the calculations be executed by taking into account the local circumstances.

Methodology

The method of the research is based on a multi-criteria analysis of the alternatives of water resources management and land use in order to mitigate the risks of the Tisza Valley related water resources and in order to optimize the composition of natural capital by the following phases.

The areas were chosen on the inactive floodplain of the Tisza Valley by hydro-dynamic modeling. The former ecosystem services of which the reference period was the 18-19th century were assessed in a qualitative way by means of contemporary maps [5]) and ethnographical literature. The actual ecosystem services were identified after the study of a land use data base ([4]), by taking into account of high priority the risks related to water resources extremities. In the course of the definition of land use alternatives, two main approaches were taken into consideration: (i) the continuing preference of provisioning services, (ii) an environmentally optimal land use with regard to the long term interests of the society. Finally the probable ecosystem services of each alternative were evaluated partly qualitatively and partly quantitatively.

Results

The chosen study areas

The study areas are localized in the Tisza Valley: on the inactive floodplain which was regularly covered by water before the 19th century river regulations. The 36 study areas cover a total area of approximately 1500 km^2 from Tiszabecs to Szeged.

Qualitative assessment of ecosystem services

Former land use

Before the 19th century river regulation, water exchange between the river and its floodplains provided a large scale of benefits ([10]) resulting a high value of natural capital (Table 1).

Provisioning services	Regulating and supporting services	Habitat services	Cultural and spiritual services
Fish	Microclimate regulation	Genetic diversity	Folk art inspiration
Fruits	Equalization of flood and drought		
Crops	Water cycling		
Livestock	Nutrient cycling		
Surface water			

Table 1 Former ecosystem services of the Tisza floodplains regularly covered by water

Actual land use

On the course of the identification of present ecosystem services, land use as well as its suitability took part of the important factors. According to the CORINE land cover data base ([4]), the proportion of croplands exceeds 70% which means that nowadays the provisioning services – and, within this group intensive agriculture – dominate the study areas. Regulating and supporting services are present in a smaller proportion, which is demonstrated by the fact that 58% of the total of croplands are exposed to high drought risk, 93% to flood and 92% to excess water[1], and these risks affect the most of areas together.

Future land use scenarios

The future land use possibilities were compared along two different scenarios suiting to the IPCC SRES[2].

The continuation of the actual land use fits the scenario A2. In this case, the ecosystem services will be of the same types than actually but they will probably available in a limited way.

Compared to the continuation of the present land use, the approach of scenario B2 offers an alternative way with the preference of the local realization of economic, social and ecological sustainability, which can be demonstrated by a land use corresponding to the following requirements:

- preference of the alternative providing the highest level of natural capital in a way that,

1 The study of the risk of flood, excess water and drought is based on the GIS layer of [21] p39.

2 For the description of the scenarios please visit http://www.ipcc.ch/publications_and_data/ar4/wg2/en/figure-2-5.html.

- the provisioning services necessary for the inhabitants are conserved otherwise the other types of services are preferred;
- infrastructural and urban damages are minimized, and,
- risks and benefits are equally taken into consideration.

In this case the areas of deeper altitude – with adapted vegetation – would be regularly covered by water and agricultural activities would be placed at areas of higher altitude. This solution would lead to a diverse land cover combined with water surfaces with an increased proportion of woodlands, allowing variable supporting and regulating functions.

After the qualitative presentation of the ecosystem services related to the different land use scenarios, the quantification results of some of the services of the sustainable land cover of the scenario B2 will be presented in details for the study areas.

Quantitative assessment of ecosystem services

Flood regulation, mitigation of damages

As a result of model simulations, 36 areas have been found with a reservoir capacity between 20 and 230 million cubic meters and water surface between 13 and 88 km^2, providing a summarized reservoir volume of 2.5 milliard cubic meters.

As part a whole system, these areas would be able to mitigate flood damages of at least 1 meter on average for the total Hungarian section of the Tisza River, which is equal to a decrease of damage costs by several milliard Forints each year. As a result of its application the sum of the main investment and operation costs and the reduced damage costs would probably be lower than the actual average of damage and defense costs.

Water quality regulation

The water conducted to behind the dykes would significantly slow down compared to its velocity in the main river bed hence a part of the suspended solids would settle in the study areas with the connected particulate phosphorus particles ([7]). This way 2.8 tons of suspended solids would settle on average on each hectare of the same study areas containing about 3 kg of particulate phosphorus (PP), of which process the economic value was estimated as the saved cost of phosphorus removal in wastewater treatment. Based on these results, it can be drawn that by only taken into account the operational costs of phosphorus removal, the regular water coverage would contribute to the social benefit of nutrient cycling by even 30 000 Ft by year on average on each hectare of the study areas.

The benefit of woodlands

Provisioning and supporting-regulating services are related to woodlands at once: by a professional operation: provision of fiber, carbon dioxide fixation and climate regulation. As a preliminary estimation at a woodland proportion of 25% the social benefit of carbon sequestration would reach 7500–15000 Ft per year per hectare on average for the total of the study areas.

Conclusion

Achievements up to now

On the course of the research it became evident that (i) the actual land use is not suitable to the hydrological risk factors and to the environmental circumstances and hence not sustainable in the long term, and, (ii) by taking into account only the aspects of land use or water resources policy the risks and the potentials of the areas cannot be adequately managed. The main goal of our research was therefore to initiate a possible way of complex decision making of land use and water resources management by the valuing of ecosystem services of different alternatives and the comparison of their potential natural capital.

The research work based on hydrological and hydro-dynamic modeling lead partly to numerical and partly to ideal results for the study areas. According to our current knowledge, the adequate involvement of the areas of the inactive floodplain to the flood regulation, the mitigation of drought and to the increase of biodiversity would be a possible way for the next few decades. To this end, a professionally designed land use should be implemented which would be terraced in altitude: with a higher proportion of woodlands and wetlands it would mitigate the extremities in water resources without damages.

To summarize, the social benefits of easily calculable ecosystem services potentially provided by the study areas can reach a magnitude of a few hundred thousand Forints per hectare each year.

All statements above refer to the study areas chosen in the inactive floodplains along the whole Hungarian section of the Tisza Valley.

Further research goals

For the continuation of our research the following aims are set:
involvement of further components of ecosystem services;
definition of a water resource index related to the natural capital;
detailed comparative analysis for certain study areas with the planning of land use at the level of simulation cells;
description of the optimal land use in the long term for certain study areas.

According to our experiences with the methodology based on hydrological and hydro-dynamic modeling presented above the total economic value (TEV) is impossible to be determined due to (i) the nature of ecosystem services (some of them can hardly be related numerically to the changes in water resources), and to (ii) the fact that the possibility of financial expression of several services is limited.

The application of this methodology is also limited by the size of the study area. The cell-scale planning of the land cover and the storage and flows of water together with the simulation of changes in water resources can take months for each study area for a researcher.

Acknowledgement

The work reported in the paper has been developed in the framework of the project „Talent care and cultivation in the scientific workshops of BME" project. This project is supported by the grant ***TÁMOP - 4.2.2.B-10/1--2010-0009*** . The research has been completed at the Department of Sanitary and Environmental Engineering and has been supported by the WateRisk project.

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Linearity analysis of the Eötvös-tensor

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Abstract

Assuming the linear trend of the elements of the Eötvös-tensor between adjoining network points is an important demand for different determination methods in geodesy (e.g. interpolation of the deflection of the vertical, geoid computations, and interpolation of the gravity values or the vertical gradients of gravity). To study the linearity of gravity gradients, torsion balance measurements were made both at the field and in a laboratory. The results of the computations emphasizes that the linearity of the gravity gradients mainly depends on the amplitude of gradients and generally the given point density of the earlier torsion balance network is not enough for geodetic purposes.

Introduction

In the last century thousands of torsion balance measurements were made for geophysical purposes in Hungary, but these measurements are still not used for geodetic purposes. During our former researches a suspicion arised about the nonlinearity of the gravity gradients between the adjacent torsion balance stations. The question is whether the point density of these measurements is enough or not to satisfy the linear changing requirements of gravity gradients which are an important demand of the geodetic applications?

Mathematical background of the linearity analysis

One of the most important task in the geodesy is to determine the most accurate shape of the Earth in which the deflection of the vertical plays a very important role. If difference of deflection of the vertical wants to be determined by an interpolation method based on the curvature gradients W_Δ and W_{xy} measured by torsion balance in α_{ik} azimuth between the points P_i and P_k, the

$$\int_{n_i}^{n_k} \frac{\partial^2 W}{\partial n \partial s} dn \tag{1}$$

integral should be computed, where

$$\frac{\partial^2 W}{\partial n \partial s} = \frac{\partial^2 W}{\partial x \partial y} \cos 2\alpha_{ik} + \frac{1}{2}\left(\frac{\partial^2 W}{\partial y^2} - \frac{\partial^2 W}{\partial x^2}\right) \sin 2\alpha_{ik} = \\ = \frac{1}{2} W_\Delta \sin 2\alpha_{ik} + W_{xy} \cos 2\alpha_{ik} \quad , \tag{2}$$

n_{ik} is the distance between P_i and P_k, and s is perpendicular direction to n ([5]).

If the P_i and P_k points are quite close to each other, then the change of the second derivative of the potential W_{ns}, can be considered as linear, and the integral (1) can be approximated with the following formula:

$$\int_{n_i}^{n_k} \frac{\partial^2 W}{\partial n \partial s} dn = \frac{1}{2}\left[\left(\frac{\partial^2 W}{\partial n \partial s}\right)_i + \left(\frac{\partial^2 W}{\partial n \partial s}\right)_k\right] n_{ik} \ . \tag{3}$$

The change of the N–S and E–W components of deflection of the vertical $\Delta\xi_{ki}$ and $\Delta\eta_{ki}$ can be determined using the following simplification between the points P_i and P_k

$$\frac{1}{2}\left[\left(\Delta W_{ns}\right)_i+\left(\Delta W_{ns}\right)_k\right] n_{ik}=g\left(\Delta\xi_{ki}\sin\alpha_{ik}-\Delta\eta_{ki}\cos\alpha_{ik}\right) \tag{4}$$

where

$$\Delta W_{ns}=\frac{1}{2}\left(W_\Delta-U_\Delta\right)\sin 2\alpha_{ik}+\left(W_{xy}-U_{xy}\right)\cos 2\alpha_{ik} \quad , \tag{5}$$

the U_Δ and U_{xy} are the normal values of the W_Δ and W_{xy} curvature gradients measured by the torsion balance ([5]).

The accuracy of the interpolated deflection of vertical primarily depends on the linear or nonlinear changing of the curvature gradients W_Δ and W_{xy} between the adjacent points.

The same situation is in the following interpolation methods: gravity g, gravity anomaly Δg or vertical gradient W_{zz} based on the horizontal and curvature gradients of gravity measured by torsion balance ([5], [6], [7], [9]).

Test area

In the last century approximately 60000 torsion balance measurements were made in Hungary ([2]). Among others on the Csepel Island 238 measurements were made in the year 1950 for geophysical purposes. For the linearity test 7 torsion balance stations were selected, the average distances between these points are about 1.5 km. To study the linearity of gravity gradients new torsion balance measurements were made with higher point density (distances between these new points are 150 m). As a preliminary conclusion of our former studies carried out on this area shows that between these points the linearity assumption of the Eötvös tensor is not correct.

Therefore another investigations was required ([3], [4]). The new test measurements were made in the Geodynamical Laboratory of Lorand Eötvös Geophysical institute in the Mátyás cave. The location plan of the Geodynamical Laboratory can be seen on Fig. 1. The Hungarian gravity basepoint marked by the No. 82 can be found in the biggest hall of the cave, and the 14 gravity microbase network points are in the passageway between the entrance and the gravity basepoint. The distances between the microbase network points are only a few meters. Gravity values and the elements of the full Eötvös tensor are known on each points ([1]). There are unusually huge gravity gradients along the network line because of the tall bluffy cliff at the entrance of the cave.

New torsion balance measurements were made on the microbase points in 2008-2009 by a refurbished AUTERBAL instrument ([8]). Later to study the fine structure of the gravity gradients the torsion balance stations are refined around the point 82/1, in N-S and E-W direction (see on Fig. 1). This ultra-fine network contains 9 points in N-S and 3 points in E-W direction, including the point 82/1. Distances between points are only 30 cm.

The Mátyás cave is particularly good place for precise measurements because of the constant temperature and constant calmness.

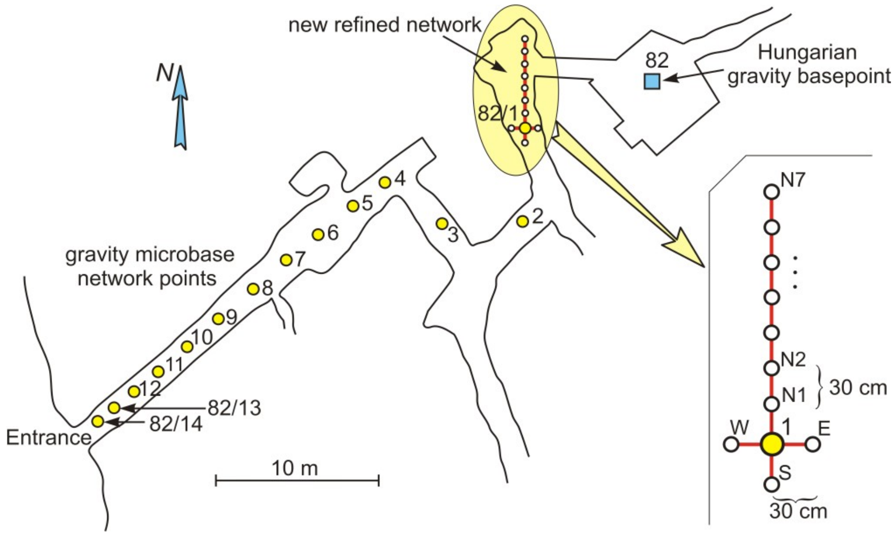

Fig. 1. The torsion balance microbase and the refined network points in the Mátyás cave

Analysis of the precise measurements

The results of measurements on the Hungarian gravity basepoint and microbase network can be seen on Fig. 2. Uncommon huge changing of gravity gradients were noticeable between points, the values can reach up to 1000 E (1E = 1 Eötvös Unit = 10^{-9} $1/s^2$) within a few meters. Based on the behavior of gradients on Fig. 2 it can be established that the changing is not linear, the variation of the gravity gradients may contain further components with higher frequency. Further refined measurements were carried out to study the fine structure of the gravity gradients around the torsion balance station 82/1 in N-S and E-W direction. Distances between points are 30 cm (see on Fig. 1).

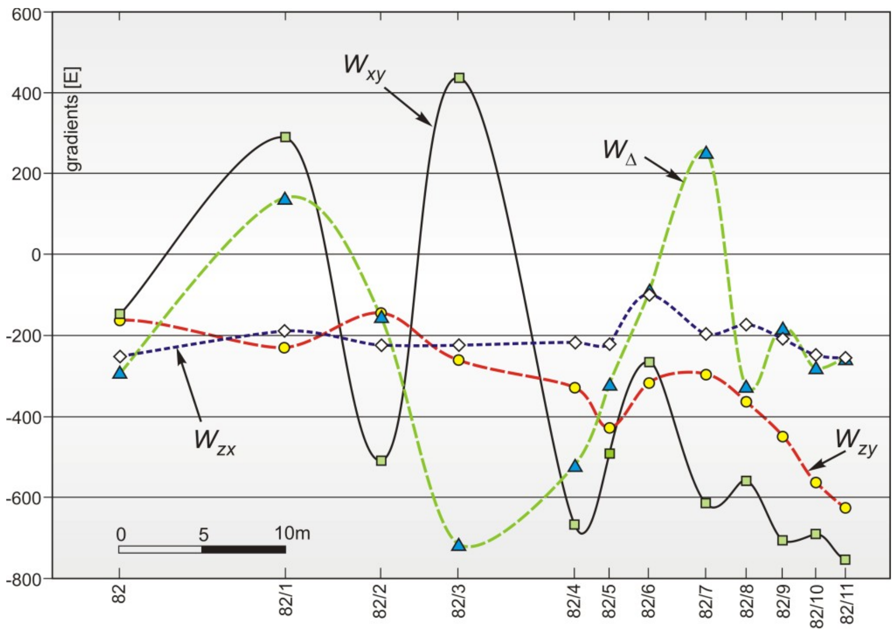

Fig. 2. Gravity gradients on the microbase network points in the Mátyás cave

Changing of the horizontal and curvature gradients in N–S and E–W direction can keep track on the Figs. 3 and 4 respectively. The changing of the horizontal gradients W_{zx} and W_{zy} more or less can be regarded as a linear within 30 cm distance, – as it can be seen on Figs. 3 and 4, although there are exceptions of W_{zy} on the surroundings of point 82/1 and at the N direction of 1.5 m away from this point. At the same time the changing of the curvature gradients W_Δ and W_{xy} within a distance of 30 cm still is not considered to be linear, furthermore these are the two quantities required for the interpolation of the deflection of the vertical and for the determination of the fine structure of the geoid. Especially the changing of W_Δ at the surroundings of point 82/1 calls the attention to the fact, that is not to be trusted in the linearity of the curvature data still within a few dm distances, if the order of magnitude of gravity gradients is so huge as in the Mátyás cave.

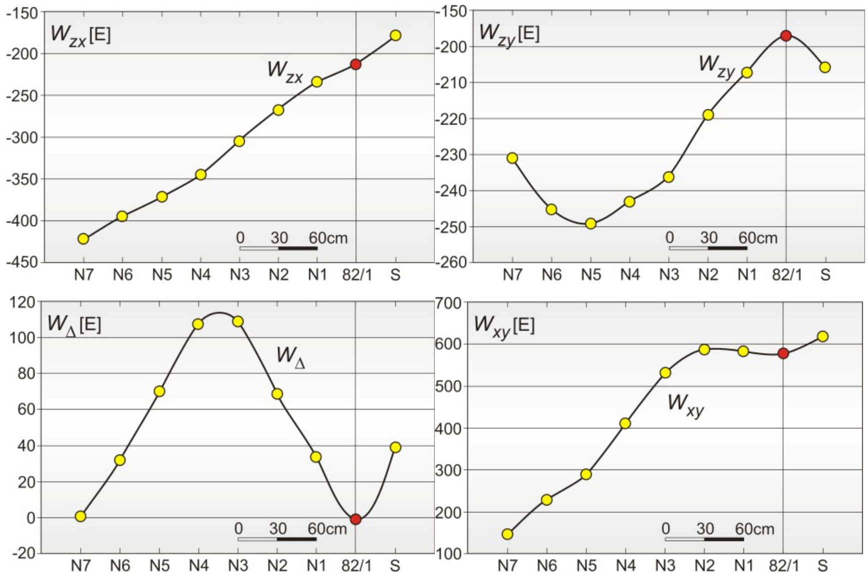

Fig. 3. Gravity gradients on the refined network in N-S direction

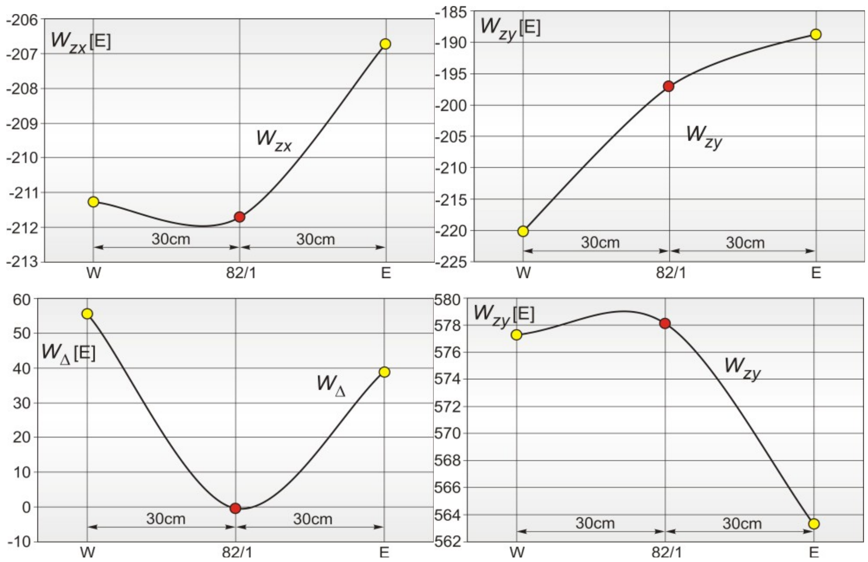

Fig. 4. Gravity gradients on the refined network in E-W direction

Summary

To study the linearity of gravity gradients, torsion balance measurements were made at the gravity microbase network in the gravity laboratory of Loránd Eötvös Geophysical Institute in the Mátyás cave.

The results of our investigations show that the linearity of the gravity gradients mainly depends on the order of the magnitude of gradients, and generally the given point density of the earlier torsion balance stations is not enough for some geodetic purposes.

The analysis of the local geological features is imperative due to their influence on the trend and magnitude of the gradients.

Further investigations are planned to study about the connection between the linearity of gradients and the geological fine structure of rocks near to the surface.

Acknowledgement

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Early age shrinkage cracking of concretes

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Abstract

It is often a problem during the design and construction of concrete and reinforced concrete structures to meet the requirements of crack-free structures, e.g. exposed concretes, hydraulic engineering works, gas-tight, watertight or liquid-tight concretes, basins, water towers, waterproof concretes, and flat roofs. Early age shrinkage cracking tendency has high priority during the construction of several reinforced concrete structures. Crack formation significantly influences durability of concrete. Based on scientific results of this paper the right cement type can be chosen for the mix design of these structures according to the cement parameters, e.g. compressive strength. To measure early age shrinkage cracking tendency of cement types, ring tests were made, measuring cracking time of different mixtures made with different cement types.

Introduction

In concrete, mortar and cement paste shrinkage takes place from the very beginning of the life of the material. In early age volume change can be both swelling and shrinking, but later *shrinkage* will relevant, which is caused by water movement in the porous and rigid body. During the hydration of cement (in the first 2-8 hours), while the cement paste is plastic, it undergoes a volumetric contraction (*plastic shrinkage*), while in cement paste as in any other fine-grained suspension, water content is moving toward the external surface of the specimen. After compaction and subsidence of particles due to its surface tension water is absorbed from the capillary pores towards the external surface and evaporated (due to this deformation it is called capillary shrinkage too). Volume reduction of the outer layer is inhibited by the inner part of the material, and this can result map-like wide cracks, so-called mapping (the same as fine mud forms cracks even after drying) [3]. During the hydration of cement paste also a volume change occurs (*autogenous shrinkage*), due to the hydration products (cement stone) volume is less than the volume of the raw materials (cement + water). However, the extent of hydration prior to setting is small, and once a certain stiffness of the system has developed, the contraction induced by the loss of water by hydration is greatly restrained [5]. Withdrawal of water from concrete, mortar or cement paste stored in unsaturated air causes *drying shrinkage*. A part of this drying shrinkage is irreversible and should be distinguished from the reversible moisture movement caused by alternating storage under wet and dry condition [5, 2]. Plastic, autogenous and drying shrinkage together are called early age shrinkage.

Influencing factors of early age shrinkage in mix design:

- cement content of the paste
- specific surface area of cement
- fine aggregate content (under 0.125 mm particle size)
- specific surface area of fine aggregate
- water-cement ratio
- total aggregate content
- type of aggregate
- water absorption capacity/water content of aggregate
- applied admixtures
- compacting rate of paste
- porosity

- other added components e.g. fibres.

Shrinkage of concrete depends on the temperature of concrete and its surroundings, on relative humidity and on the velocity of air movement as well as the curing and composition of the concrete [5].

Drying shrinkage related to most important mix parameters of concrete was investigated by *Grube*,[2]. He found that the most important influencing parameters to shrinkage are: cement content, type of cement, and water content (*Fig. 1.*).

To fulfil the requirements of crack-free structures is often a problem during the design and construction of concrete and reinforced concrete structures, e.g. exposed concretes, hydraulic engineering works, gas-tight, watertight or liquid-tight concretes. Crack formation is also disadvantageous in the point of view durability.

Time has a two-fold effect from this point of view: the strength increases, thereby reducing the cracking tendency, but on the other hand, the stress induced by shrinkage also increases. If stress reaches the tensile strength of concrete, cracks appear on the structure or specimen (*Fig. 2.*) [5].

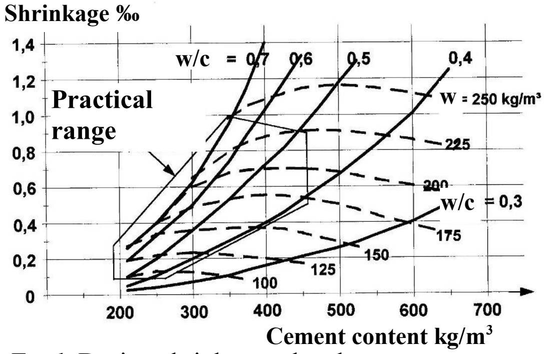

Fig.1. Drying shrinkage related to cement content and water-cement ratio [2]

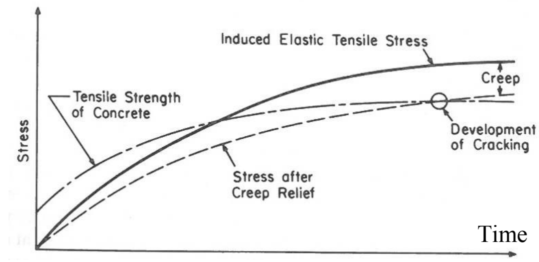

Fig. 2. Relationship between tensile strength and shrinkage induced tensile stress [5]

Crack formation has significant influence on durability of concrete. The constructors have to know the causes of crack formation, and to reduce their affects.

Experimental studies

Investigating early age shrinkage cracking tendency of different cement types, the variable parameter was the *cement* type. Beside the crack tendency compressive strength of standard cement mortar mixtures were determined according to the standard MSZ EN 196-1:2005 with the same cement samples cement stone mixtures were made with two w/c ratios: 0.34 and 0.44 and their compressive and flexural tensile strength were tested at the age of 2,7 and 28 days according to the standard MSZ EN 196-1:2005 [4]. The most important test methods are summarized in *Tab. 1*

Cement stone ring specimens were tested with the same cross-section 40×40 mm as the prisms, which were made for the compressive strength test. The outer diameter of the ring specimen was 240 mm, and the inner diameter was 160 mm. The cement paste was worked in around a stiff steel core, so early age shrinkage tensile stresses are induced in the ring specimen. If the tensile stresses got higher as the tensile strength of the cement stone, a crack was formed on it (Fig. 3-5.). Crack tendency was indicated with the time of cracking. The longer the time is needed for crack formation, the lower the early age shrinkage cracking tendency is.

Measured property	Type of specimen	Duration/age	Specimen/ mixture	Method
Fresh cement paste body density	Prism 40×40×160 mm	15 minutes age	3 specimen	Mass weight
Consistency	-	10 minutes age	-	Flow table test
Compressive strength	Prism 40×40×160 mm	2, 7, and 28 days age	3 specimen	Compression test
Flexural tensile strength	Prism 40×40×160 mm	2, 7 and 28 days age	3 specimen	Flexural tensile test
Early age shrinkage cracking tendency	Cement stone ring, ø240/160×40 mm	Until cracking	3 specimen	Crack time

Tab. 1. The most important applied test methods during the research programme

The experiment has to be carried out in a climate of 65 % relative humidity and 20°C, which parameters were measured during the tests. If the temperature or the relative humidity changes during the tests, results can be failed and the experiment has to be repeated.

During the research programme 42 cement pastes were investigated, which means 126 pieces of ring specimens and further 756 pieces of other types of specimen were tested. On every ring specimen crack time was measured.

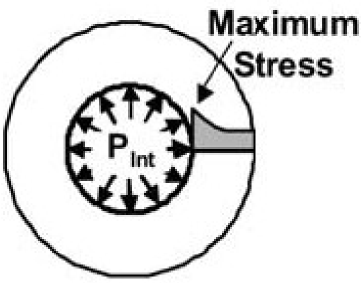

Fig.3. Stress formation in the cement stone ring specimen according to Banthia and Gupta ([1])

Fig.4. A crack on a ring specimen

Fig.5. Cement stone ring specimens during the test

Scientific results

The relationship between the early age shrinkage cracking tendency and the early age compressive strength (at the age of 2 and 7 days) of the cement pastes is almost linear (*Fig. 6-9.*). The higher is the compressive strength the lower is the cracking time, which indicates higher early age shrinkage cracking tendency. This is caused by the higher hydration rate of cements with higher strength, which causes higher autogenous shrinkage. Beside this, fineness of cement influences also the drying shrinkage of cement paste. Finer cement has higher compressive strength. Finer cement has higher specific surface, so it can absorb more mixing water on the surface of cement particles which increases drying shrinkage. So higher fineness of cement particles causes higher early age shrinkage cracking tendency of cement pastes/stones.

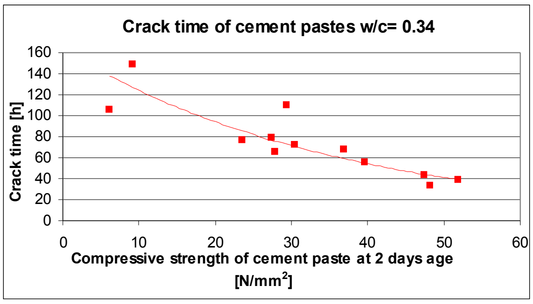

Fig. 6. Relationship between crack time of the cement paste rings and the compressive strength of the cement paste prisms at the age of 2 days (average of three specimens, w/c = 0.34)

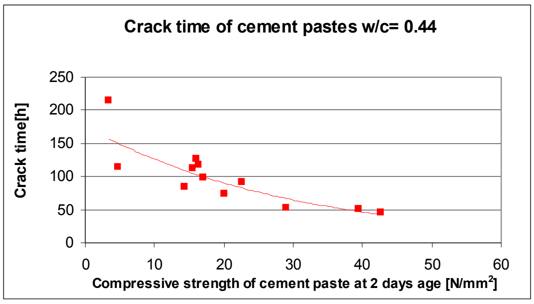

Fig. 7. Relationship between crack time of the cement paste rings and the compressive strength of the cement paste prisms at the age of 2 days (average of three specimens, w/c = 0.44)

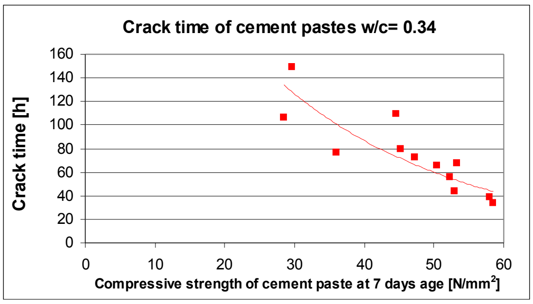

Fig. 8. Relationship between crack time of the cement paste rings and the compressive strength of the cement paste prisms at the age of 7 days (average of three specimens, w/c = 0.34)

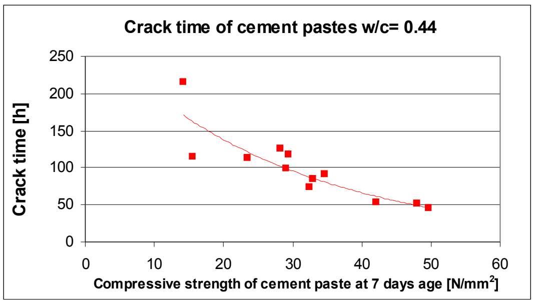

Fig. 9. Relationship between crack time of the cement paste rings and the compressive strength of the cement paste prisms at the age of 7 days (average of three specimens, w/c = 0.44)

Fineness and hydration rate of cement also influences the compressive strength of standard cement mortar. So there is a relationship between compressive strength of cement mortar and early age shrinkage cracking tendency of cement stone too. The relationship between the early age shrinkage cracking tendency of the cement pastes and the compressive strength of the standard cement mortar (at the age 28 days) is linear (*Fig. 10-11.*).

Conclusions

During concrete mix design the applied cement type is a determining parameter, which depends on many environmental parameters (weather conditions, temperature, applied technologies, strength, deformations, etc.). Based on the presented scientific results it is easier to choose the optimal cement type for normal concretes from the point of view of early age shrinkage cracking tendency.

To measure early age shrinkage cracking tendency of cement types, ring tests were made with cement pastes (two w/c ratio were applied: 0.34 and 0.44). The variable parameter of different mixtures was the cement type. Cracking time was measured, which indicated early age shrinkage cracking tendency of the sample. The longer is the cracking time the lower is the early age shrinkage cracking tendency.

During the scientific research program it was found, that early age compressive strength of cement paste has a decisive influence on the early age shrinkage cracking tendency of the material. The higher is the compressive strength of the cement paste the higher is the crack time of the ring test, which is caused by the higher specific surface area of the high strength cement types. Strengthening rate of cement pastes enhances also autogenous shrinkage, so it increases early age shrinkage cracking tendency too.

Due to the compressive strength of standard cement mortar is related to strengthening rate of the cement, there can be found a relationship between early age shrinkage cracking tendency of the cement type and the standard compressive strength of cement mortar too. The higher is the compressive strength of the standard cement mortar the higher is the crack time of the ring test on the cement pastes. This means cement types, which have higher compressive strength, have higher early age shrinkage cracking tendency too. It was found that for construction of concrete structures with low early age shrinkage cracking tendency, low-fineness and low-strength cement types should be used.

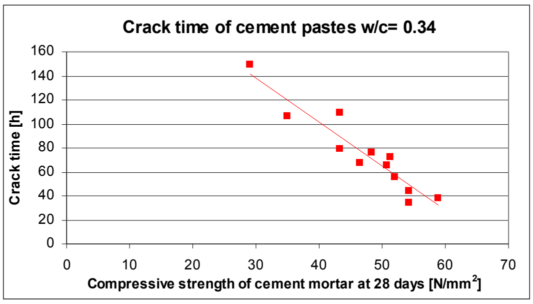

Fig. 10. Relationship between crack time of the cement paste rings (average of three specimens, w/c = 0.34) and the compressive strength of the cement mortar prisms at the age of 28 days (average of three specimens, w/c = 0.50)

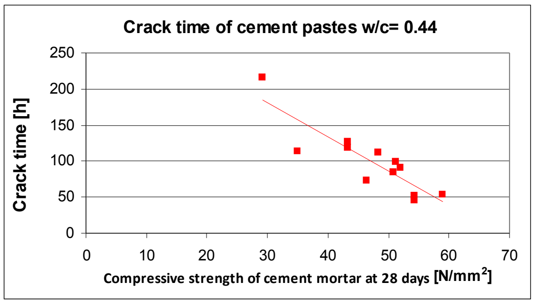

Fig. 11. Relationship between crack time of the cement paste rings (average of three specimens, w/c = 0.44) and the compressive strength of the cement mortar prisms at the age of 28 days (average of three specimens, w/c = 0.50)

Acknowledgement

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Degradation Dependent Stability Issues of Landfills

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Abstract

Urbanization, economic growth, and the continuing improvement in living standards have all contributed to the increase of municipal solid waste. More waste coupled with increasing prices of land forced engineers to design higher and steeper landfills for better utilization. Changes in the size of landfills result in increased sheer strength (5). In the analysis of long term behaviour of landfills, slope stability analysis plays a major role because the gas and leachate pipes, and the monitoring and lining systems can easily get damaged. My research focuses on determining soil mechanics parameters of Hungarian waste bodies with regards to their degradation phase.

Introduction

Environment protection and conservation are very important in the 21st century [6]. This is even more important in waste management design and construction where deposition of heterogeneous waste must be achieved in a way that minimizes its environmental impact. Therefore positioning and construction of landfills, their day-to-day maintenance as wells as their utilization are all very important in Hungary, the European Union, and all over the world. The heterogeneity of waste body makes it difficult for engineers to model its behaviour [3]. Age, unit weight, classification and compaction methods all influence mechanical behaviour of municipal solid waste (MSW) [8]. Nevertheless, detailed knowledge of waste properties is needed to predict the change of MSW shear properties over time.

Bioreactor Process Overview and the Phases of Waste Decomposition

Acceleration of the degradation of MSW is the primary function of the bioreactor landfill. This is achieved by enhanced biomechanical processes that transform and stabilize the decomposable organic waste. This reduces the standard 30- to 100-year degradation time of conventional landfills to 5 to 10 years. In bioreactor landfills the time needed for total consolidation decreases while the amount and the quality of biogas increases. With the accelerated degradation and consolidation the amount of waste that can be deposited is growing which has significant financial impact. The above advantages shift waste management to bioreactor landfill operation all over the world. A bioreactor landfill can be classified as anaerobic, aerobic or hybrid [7]. In order to achieve optimal moisture levels moisture is added to waste in anaerobic bioreactor landfills. A municipal solid waste landfill can be treated as a huge anaerobic bioreactor with degradable organic patterns.

Pohland et. al. describe five distinct phases of waste decomposition [6].:

- Phase I (lag phase). It is an acclimation period in which moisture starts accumulating and aerobic bacteria begins to consume the oxygen trapped in freshly deposited solid waste.
- Phase II (transition phase). This is the first anaerobic phase where total volatile acid (TVA) reaches a detectable level and chemical oxygen demand (COD) increases.
- Phase III (acid formation phase). The second anaerobic phase is characterized by microbial conversion of biodegradable organic content and the activity of acidogenic bacteria increases.

- Phase IV (Methane fermentation phase). In this phase intermediate acids are consumed by methanogenic bacteria and converted into methane and carbon dioxide.
- Phase V (Maturation phase). A marked drop in landfill gas production, stable concentrations of leachate constituents, and the continued relatively slow degradation of recalcitrant organic matter characterize this phase.

Laboratory tests

In order to analyze long term behaviour of landfills it is a common practice to compare the results of field evaluations and laboratory tests with the results of computer-based modeling. Comparing the models applied in recent studies brings up numerous issues [4]. Studying landfill behaviour in a laboratory setting is a difficult task because the material to be analyzed is heterogeneous, and the largest diameter of particles is, depending on the landfill management technique, may go as high as 0.1 meter to 1 meter. Therefore, the number of places where such laboratory tests can be performed are very limited.

I have defined shear strength parameters for MSW samples of different degradation phases. 15 tests have been performed in a purpose-built, oversize (500 x 500 x 400 mm) direct shear test equipment provided by the laboratory of Department of Geotechnics at the Budapest University of Technology.

Results of direct shear tests

With the advancement of degradation internal friction of waste greatly decreases, while the cohesion of waste decreases less significantly, which may result in stability problems for landfills. Table 1 shows a summary of my results based on 15 samples from the same site in 5 different degradation phases.

Figure 1 shows the internal friction angle and cohesion in different degradation phases. Values change in an extended interval, which can be explained by the heterogeneous nature of municipal solid waste [2]. My results are in line with data from other similar studies [1].

Based on laboratory tests I have drawn up shear strength envelopes for waste with different density, composition, and degradation phase (Figure 2). This envelope helps to determine the safety factor of a landfill for the entire degradation process and the geometry of landfilling can be modified to take the current safety factor value into account. Using this table long-term stability of landfills can be calculated, stability problems can be avoided, which produces financial benefits as well. Based on these equations shear strength of waste can be calculated if the degradation phase is known.

Phase	**1**			**2**			**3**			**4**			**5**		
Sample	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**
φ(°)	34,86	35,99	35,42	26,78	28,4	22,92	23,08	22,35	23,46	21,49	21,74	21,92	21,09	20,32	19,77
c (kPa)	4,31	25,74	26,15	15,17	4,4	22,13	12,68	10,59	15,67	12,28	9,87	11,29	5,47	3,69	3,44

Table 1 Internal friction angle and cohesion in different degradation phases

Numerical results and performance analysis

Numerical tests were used to confirm that the degree of decomposition affects the stability of landfills [7]. I have compared literature recommendations with results coming from laboratory tests performed on Hungarian solid waste. My model divides the waste body into five layers according to the degree of decomposition.

I used PLAXIS and GEOSLOPE program in my simulations then I compared their results. I have found that the factor of safety decreased significantly with the advancement of degradation.

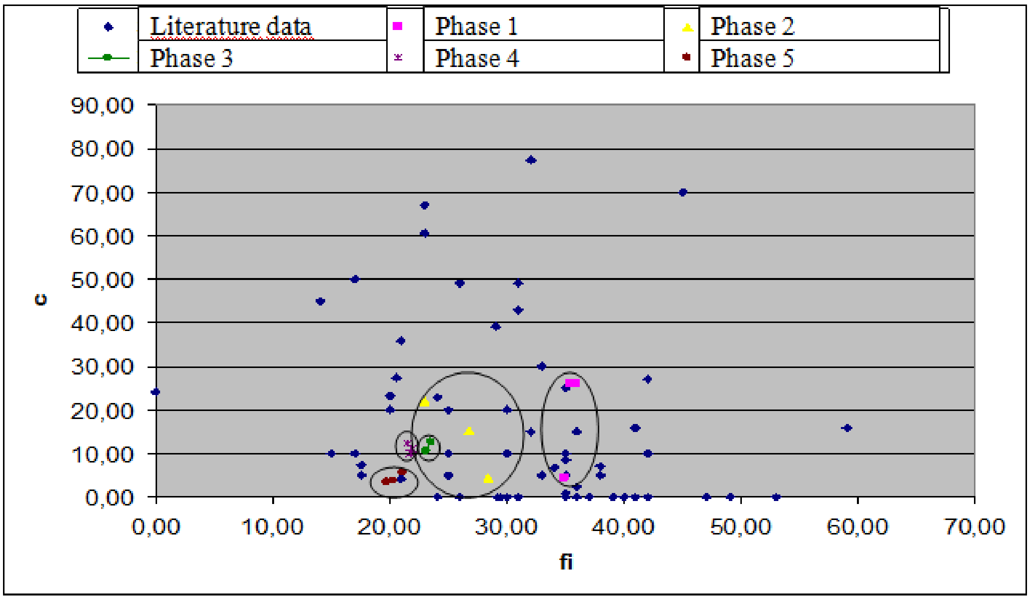

Fig. 1 Internal friction angle and cohesion of MSW for different degradation phases

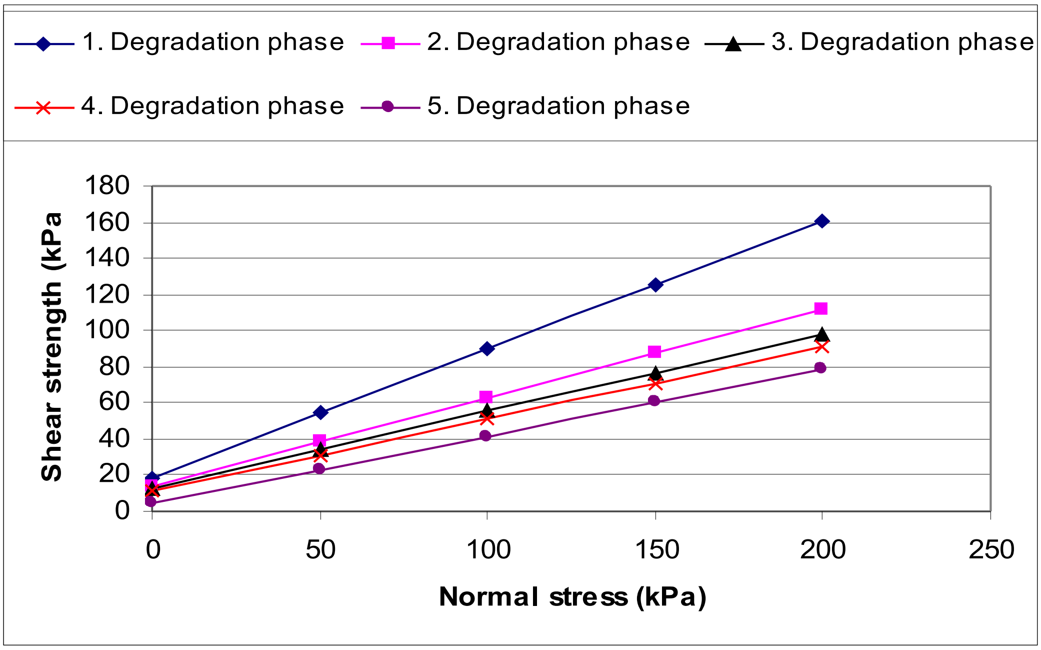

Fig. 2 Shear strength envelope of MSW at different degradation phases

The results show (Figure 3) that the factors of safety computed from literature recommendation parameters are close to the 2nd or 3rd degree decomposition parameters determined by my simulations. With the advancement of decomposition, the factor of safety may be smaller than the results coming from literature recommended parameters, which may compromise the stability of landfill.

Accordingly, I propose that the stability of bioreactors should be determined with shear strength parameters defined as a function of degradation (and time). Commonly applied fresh waste- or average-based parameters may generate unjustifiably high safety factors, which may result in unexpected stability problems. Literature recommendations should be treated uniquely in every landfill with careful considerations.

Numerical simulations also have been performed to prove that the geometry of landfilling has a major impact on slope stability. In order to achieve the highest stability I recommend deposition strategies that respect the degradation phase of waste.

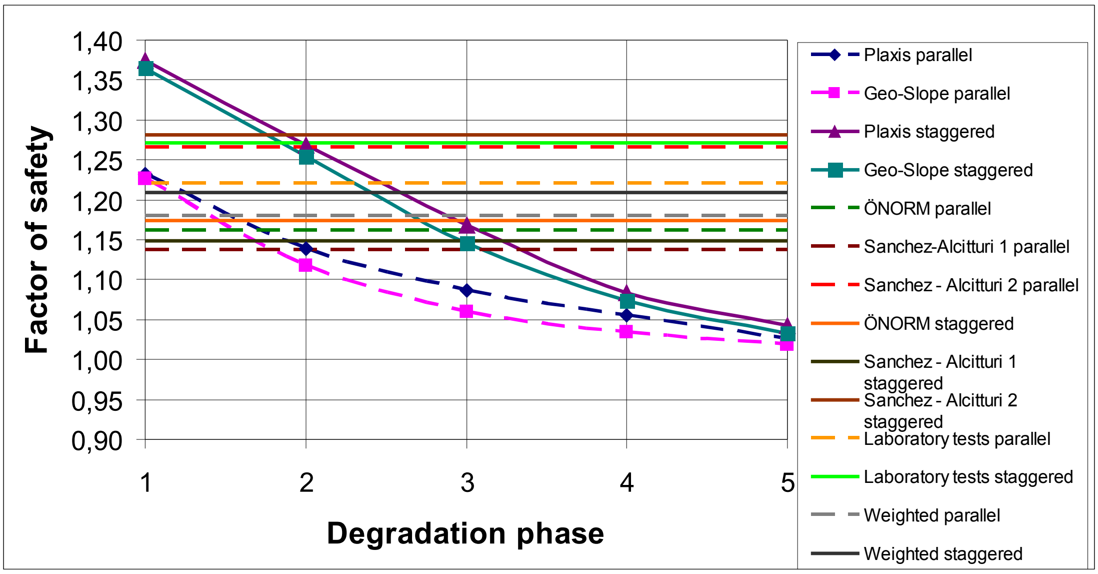

Fig. 3 Factor of safety in case of different recommendations as a function of degradation

My model divided the waste body into five layers and two different geometries were simulated: parallel and staggered. I have used PLAXIS and GEOSLOPE program in my simulations then compared their results. I have found that the geometry of landfilling has a major impact on slope stability.

In case of aslope landfilling technique the slope became unstable already in the first phase, while stability of the totally filled up landfill was sufficient. I conclude that stability calculations are very important in deposition procedure design, otherwise unexpected failures may happen. Based on my comparisons I conclude that the safety factor is higher in the staggered geometry in all stages of degradation. In the final stage when the whole waste body reaches the last degradation phase and waste structure under examination is uniform, the staggered landfill still showed a slightly higher safety factor. It shows that the geometry of landfilling technique plays a major role in its stability. I recommend the usage of staggered geometry for landfills.

I have performed our simulations both with PLAXIS and GEOSLOPE. The results of the two sets of simulations are very close despite their different approaches (Figure 4). It shows the reliability of the generated geotechnical model.

Conclusions

It is very important to formalize design guidelines suited for local conditions, evaluate the conditions of waste bodies in the country, and define their shear strength parameters. I have created a geotechnical model to determine the time (degree of degradation) dependent stability of bioreactor landfills. The model is suited for:

- examining and optimizing the deposition strategy
- predicting the time dependent changes of
    1. stability,
    2. potentially instable waste body ,
    3. surface settlement.
- creating a monitoring strategy and related alarm levels.

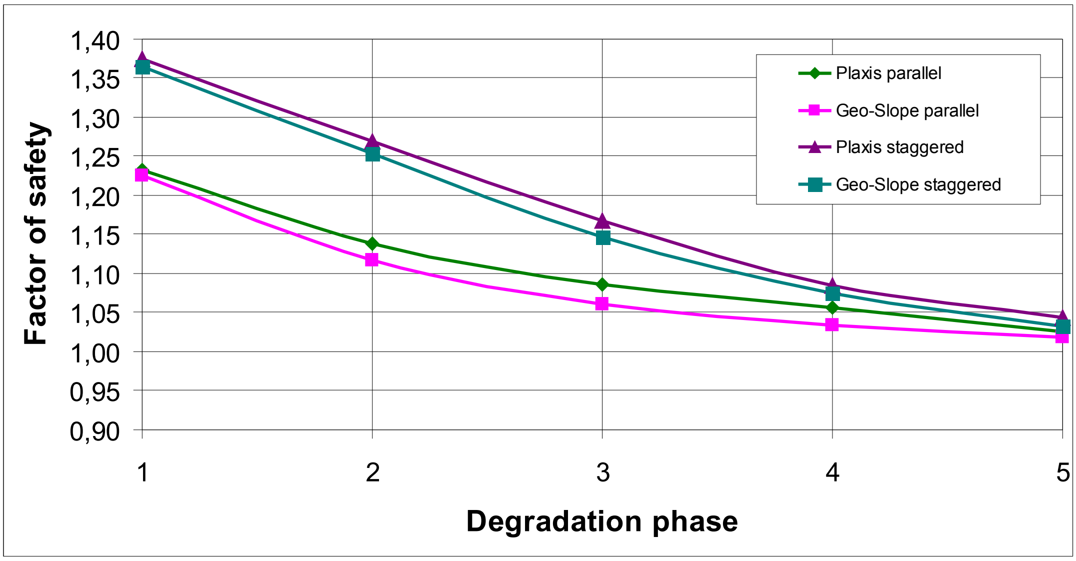

Fig. 4 Factor of safety in case of different geometry of landfilling as a function of degradation

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