IGCS BULLETIN

From the Editors' Desk





This issue brings to you once more news about a successfully conducted Winter School in March with 30 participants from India and Germany learning and sharing their experiences about topics on urban water. One of the student groups looked into Adyar River Restoration project, and a summary of the interesting results from that study is presented here.

IGCS also conducted a workshop to launch a one-year research project on issues relating to peri-urban Chennai, to understand the dynamics and processes of

change in such places in India. Coinciding with this, we are happy to welcome several research fellows and students from Germany who are investigating specific topics to contribute to our research portfolio.

The feature article on Finite Element modelling of the interface between soil and geogrid is a result from Felix Jacobs' research visit, a collaboration between RWTH Aachen and IGCS/IITM.

Thanking you, **B** S Murty and **Christoph Woiwode Editors**



VOL 4: ISSUE 2 \diamond April 2015

Contents		
IGCS NEWS	2	
PROJECT REPORT: Adyar River Restoration	7	
FEATURE:	11	
Finite Element modelling of the in- terface behaviour between soil and		

Fi geogrid in large scale biaxial com-





Prof. B. S. Murty

Prof. Chr. Woiwode

IGCS NEWS

Winter School 2015

"Sustainable Water Management in Urban Areas"

IGCS organized successfully the 2015 Winter School on "Sustainable Water Management in Urban Areas" from 3rd to 14th March 2015 in IIT Madras. The course was open to Master and Ph.D. Students in academic fields related to engineering, environmental and social sciences, many of them specializing in the area of sustainable development. Thirty students (15 Indian and 15 German) from different universities in India and Germany attended the School. It was inaugurated by Dr. Paul Appasamy, earlier Director of Madras School of Economics. He had also delivered the Key Note address on sustainable urban water manage-





tersheds, Conflict resolution, Water Markets, Fate of micro-pollutants etc. The programme included field visits to Sewage Treatment Plant at Nesapakkam (owned and operated by Chennai Metropolitan Water Supply and Sewerage Board, CMWSSB), Water Reuse and Recycle System at Daimler, Chennai and a Culture-cum-Field trip to Auroville and Pondicherry. Officials from the Central Groundwater Board, Government of India, Chennai Regional Office have arranged field trips and participants had an opportunity to see the rainwater harvesting projects.

ment, with particular reference to Chennai city. Lectures were delivered on wide ranging topics related to urban water management, by faculty drawn from IIT Madras, other academic and research organizations and the Industry. These included: Sustainable urban water management, Sustainable water and land use management in peri-urban areas, Sustainable waste management, Ecological restoration of urban water bodies, Urban water infrastructure and health, Adapting to climate change in urbanizing wa-





Participants of the IGCS Winter School 2015

Upcoming Event: IGCS Conference

Indo-German Conference on Sustainability "Exploring planetary boundaries and their challenges and opportunities", 5-6 December 2015, Indo-German Centre for Sustainability (IGCS), IIT Madras

The pressures of development are seen in all aspects of resource and environment management today. In order to cope with the various issues it is necessary to explore methods and technologies that not just result in advancement of society, but also make such advancement sustainable.

The focus areas of the centre are sustainable technologies for water management, energy management, waste management and land use. This conference proposes to bring together researchers in academia and industry, and policy makers in India and Germany to exchange research findings, discuss and deliberate on these issues, and identify future course of action towards sustainability. The organisers invite research papers and poster presentations in the focus areas and personal participation in the conference.

The conference organisers invite paper contributions from India and Germany (see website for listed areas). The submissions must be in the form of PDF documents formatted as extended abstract of the work in a maximum of 600 words (including tables and figures).

> 01 July 2015 15 Aug 2015 01 Oct 2015 01 Nov 2015

Important dates:

Submission of Extended Abstract:
Announcement of Acceptance:
Submission of Final manuscript:
Deadline for Registration:

Conference website for further details and updates: http://www.igcs-chennai.org

Workshop "Peri-Urban Dynamics and Sustainability: The case of Sriperumbudur"

On 21 April 2015 IGCS organized this workshop, attended by around 30 participants. The workshop was conducted as part of an IGCS research programme with the Department of Science and Technology to develop a Global Technology Watch on Sustainable Habitats. The aim of the research programme is to conduct exploratory research for the next year in Sriperumbudur Taluk to try to understand drivers of land-use change and industrialisation, in particular, but in the process also to understand their complex linkages with themes such as labour and migration, housing, water and energy demand, waste production, and governance. The goal of this launch workshop was to have a preliminary engagement with researchers, government representatives, professionals and activists who have worked around Sriperumbudur. The expected outcomes were the following:

- Generate discussion and awareness on the various social, economic, environmental and institutional indicators of Sriperumbudur, historically as well as in recent times.
- Envision baseline and future development scenarios for Sriperumbudur in terms of the aforementioned indicators by using the World Cafe Method.



The workshop was divided into two sessions. The forenoon session consisted of introductory remarks and short, informal presentations by researchers on their work on Sriperumbudur followed discussions and questions. The afternoon session comprised of a brainstorming ses-

sion following the World Cafe Method to envision the current and future development scenarios for Sriperumbudur. A short summary of each of these sessions is reported in the following sections.

The morning session began with an introduction by the facilitators, Prof. Sudhir Chella Rajan and Dr. Christoph Woiwode on the research motivation and

agenda. It was followed by presentations on "Understanding Sriperumbudur: Baseline Social and Economic Indicators" by Amala Devi (IGCS, IIT-M) and on "Land use, Spatial Population Trends and basic Hydrology in Sriperumbudur: Preliminary explorations using LANDSAT5, SRTM and Census data" by Siddharth Hande (IGCS, IIT-M).

The IGCS presentations were followed by informal talks by IIT-M research teams who also carry out research in the Sriperumbudur region. Dr. Suresh Babu (Associate Professor, Humanities and Social Sciences Department, IIT-M) and Dr. Binitha Thampi (Associate Professor, Humanities and Social Sciences Department, IIT-M), working on migrant labor in Kerala and Tamil Nadu, explained some of the focuses of their study. Dr. Franziska Steinbruch (IGCS Visiting Professor) briefly described the ongoing and future work in spatial analysis and hydrology.

In the afternoon session a visioning exercise was conducted consisting all the participants divided into four teams to represent Society, Institutions, Economy and the Environment. In several brainstorming and clustering rounds during which the groups were repeatedly reshuffled, the participants worked out a picture of the current situation in each of the four thematic areas. They then extend that to envision a future business-as-usual scenario for Sriperumbudur. Lastly, the objective was to imagine the state of Society, Economy, Institutions and Environment in a future that has paid attention to issues of sustainability This was followed by a plenary discussion of the re-

sults. Several such workshops with various stakeholders will be held to develop different scenarios in the course of the next year.



Research Scholars and Students at IGCS

Currently IGCS boasts of a large number of visiting scholars. In collaboration with Freiburg University, three masters students working on various topics joined IGCS in March. Their guide, Dr. Kirsten Hackenbroch, came for her second research visit and stayed for one month from mid- March to mid-April to continue with her own research about "Global visions and local realities of sustainable urban development - Exploring strategic urban environmental politics and emerging (social) spaces".

Robert John

Sriperumbudur area.

Peri-urban areas are often subject to increasing population and economic growth, overlying jurisdiction and missing land use planning face multiple challenges and are particularly interesting sites for researching sustainable governance. Robert John will therefore investigate the governance mechanism and power relations between different actors active in the field of peri-urban water management, under the supervision of Dr. Kirsten Hackenbroch from the university of Freiburg, Prof. Dr. Christoph Woiwode, visiting Professor at IITM and Prof Chella

Rajan. This in-depth analysis will fo-

cus on one study area that encompasses all major the supervision of Prof. Dr. Christoph Woiwode and stakeholders of peri-urban areas, giving special Prof. Chella Rajan of IIT Madras and Dr. Kirsten attention to aspects of distributional justice and mor- Hackenbroch of Albert-Ludwigs-Universität Freiburg, al responsibility between the actors involved. In the Germany, she is looking at how new actors and initicourse of the research ethnographic observations atives form and organize to influence the transition and qualitative interviews with villagers, the indus- towards a sustainable mobility sector in Chennai. To tries, real estate sector and the political administra- do this, Radina has studied the new Non-Motorized tion, will help to shed light on the current practises Transport Policy of the Corporation of Chennai and is of resource governance in Sriperumbudur.

Chloe Hill is originally from Australia and after com-

From left: Robert, Chloe, Kirsten, Radina

pleting a Bachelor of Environmental Science in Tas-Robert John holds a Bachelor degree in "Philosophy mania she decided to look abroad to discover some and Economics" and is currently undertaking his of the interactions between governance, develop-M.Sc. in "Environmental Governance" at the Al- ment and the environment. Following this Chloe bert Ludwigs University of Freiburg. He stays at the lived in Copenhagen where she continued her stud-IGSC from March 2015 to May 2015 to conduct a les and worked as a tour guide while experiencing research project on the topic of sustainable govern- well developed infrastructure and best practice enviance of water resources in urban fringes within the ronmental governance. Chloe is currently undertaking a M.Sc. in Environmental Governance at Albert-

> Ludwigs-Universität in Freiburg, Germany. She has recently undertaken an internship in the Philippines where she helped promote solar and geothermal powered public transport and sustainable policy. For her Master Thesis Chloe will be researching the impact of rapid urbanisation on the social resilience of peri-urban Chennai."

> Radina Vassileva is currently pursuing a M.Sc. in Environmental Governance at the Albert-Ludwigs-Universität Freiburg, Germany. For her Master Thesis, Radina

joined the IGCS from March-May 2015 to conduct research on the topic "Green mobility aspirations". Under

meeting with various stakeholders at the Corporation as well as NGOs and civil society.

April 2015



currently a Master student min and Christoph Woiwode. in Urban and Regional Planning at TU Berlin. He is is staying at IITM from March-July 2015 and is involved in the

emerging cross-disciplinary research project of the IGCS about sustainable peri-urban development in Chennai. The objective of his research is to understand the driving forces of urbanization in Chennai's peri-urban region Sriperumbudur, a highly dynamic industrial area along the Chennai-Bangalore Highway. As the availability of suitable land is one of the crucial factors for peri-urban industrialization, the first focus is to study the process of land conversion from agricultural to industrial and commercial use. The motivations of farmers to dispose of their land, as well as the forces and constraints that agricultural production faces in metropolitan Chennai are analyzed in his fieldwork. Assuming that peri-urban transformation (re)produces uneven social and political landscapes, the second focus of the study is to reveal processes of marginalization and to assess strategies of the poor for secure livelihoods. The results shall contribute to a growing knowledge base

Tobias Kuttler holds a bache- that eventually allows envisioning a socially more lor degree in Geography and inclusive development of peri-urban Chennai. Tobias European Ethnology and is is mentored by Profs. Chella Rajan, Solomon Benja-

> Benedikt Bader holds a masters degree in environmental engineering at the RWTH Aachen. He graduated in February 2015 and started his Ph.D. position at the Department of Engineering Geology and Hydrogeology (LIH) at RWTH Aachen in



March 2015. His ongoing research project is based on an agent-based modeling approach linked with ontology and geo-information based database. Goal of his research project is to model and determine the impact of human activities on the water resources in megacities. The project is supervised by Prof. Dr. Azzam (RWTH Aachen), Prof. Dr. K. P. Sudheer (IIT Madras) and Dr. F. Steinbruch (IGCS). Funded by a DAAD doctoral grant, Mr. Benedikt Bader will stay from April 2015 for a period of nearly 1 year. His fieldwork in Chennai is mainly focused on the district of Velachery and Perungudi.

Visit of HE Mr. Vijay Gokhale to RWTH Aachen University

On May 6, 2015 HE Mr. Vijay Gokhale, Ambassor of the Republic of India in Berlin, visited RWTH Aachen University. He met with the rector's delegate to India/Centre Coordindator of IGCS in Germany, Prof. Dr. Rafig Azzam, and the acting head of International Relations office, Dr. Dieter Janssen. Future academic cooperation with India and exchange of ideas on Indo-German Centre for Sustainability were among the topics discussed during the afternoon.



Project Report

(Winter School, March 2015)

Adyar River Restoration

Project Team: Bibhishana Bhuyan (IIPS, Mumbai, India), Kriste Makareviciute (Kiel University,Germany), Malini Rajendran (IISc, Bangalore, India), Raicy M C (Anna University, Chennai, India), Thirumurugan M (Anna University, Chennai, India), Tobias Baumeister (RWTH Aachen, Germany)

Introduction

These are excerpts from the project report prepared by one of the groups during the IGCS Winter School in March 2015 (see report in this issue).

The increasing supply for rapidly increasing population and decreasing trend of rain fall pattern has caused the scarcity of natural groundwater resources which reduced the quantity of utilizable water. The pollution of surface water resources have become a major problem nowadays due to urbanization, industrialization, unhealthy agricultural practices and increased population. About 60 % of the rivers in India are polluted and a major cause of river pollution in India is the untreated sewage.

Chennai, Tamil Nadu and to formulate plans towards preservation of ecological and natural resources such as flora and fauna, water ways, water bodies, preserving and eco balancing inter alia, with a view to minimizing and mitigating pollution.

The study area forms a part of the Adyar river basin. The area lies within the latitudes 79.97 to 80.32 and longitudes of 13.11 to 12.89 in decimal degree. The land elevation varies from 10 m to 0 m gradual slope towards the eastern side.

Basic information about Adyar River

Adyar river, originating near the Chembarambakkam Lake in Chengalpattu district, is one of the two rivers which winds through Chennai, Tamil Nadu, India, and joins the Bay of Bengal at the Adyar Estuary. The 42.5-kilometre long river contributes to the estuarine ecosystem of Chennai. The estuary attracts a

Objective of the study and study area

The present proposal focuses to restore one of such highly contaminated river named Adyar, located in



Figure 1: Map locating the study area in Chennai

about 300 acres was made a protected wildlife re- industrial effluents carrying heavy metals and about serve in 1987. Despite the high pollution levels, 8.1 mld of domestic sewage are allowed to flow into boating and fishing take place in this river. Most of Adyar river (Gowri and Ramachandran 2001). The the waste from the city is drained into this river and sand bar nearby Adyar river mouth also prevents the Cooum.

in its upper reaches and 0.5 m in its lower reaches. of highly contaminated sewage into the river instead Bed width ranges from 10.5 to 200 m. The average of the healthy discharge of sewage at a water depth annual flow in the Adyar river is 89.43. The total an- of more than 20 m in the ocean to facilitate better nual discharge of the river into the Bay of Bengal is diffusion and dispersion (Gowri and Ramachandran, about 190 to 940 Mm³ during normal seasons 2001, Beder, 1989). Consumption of fish thriving in whereas the discharge increases 7 to 33 times more polluted coastal waters also will deteriorate the huthan the annual average during the North East mon- man health. The fishing community has reported few soon season between September to December. types of dermatological problems due to coastal pol-Tanks at Chembarapakkam are characterized by less lution in Chennai. permeable soil and it causes surplus flood at middle and the tail parts of the river during extreme mon- The average water chemistry of the Adyar river is soon. The river collects surplus water from about 200 53.89 to 454.11 t/d of suspended solids, 0.06 to tanks and lakes, small streams and the rainwater 19.64 t/d of ammonia, 15.95 to 123.24 t/d of nitrate drains in the city, with a combined catchment area of and 0.4 to 17.86 t/d of phosphate, 0.004 to 0.09 kg/d 860 Km2.

Present Scenario

Nearly 98.2% of Chennai's land area is used for industrial, residential and commercial purposes. A number of refineries, thermal power plants, chemical, rubber and fertilizer industries are located along the Chennai coastal zone. More than half of all industrial and municipal wastes are directly discharged into estuar-

wide variety of birds. The estuary covering an area of ies and coastal marine waters. About 0.775 mld of tidal flushing. The fish growth is reducing in the The river has varying depth of approximately 0.75 m coastal waters of Chennai due to the direct discharge

> of cadmium, 0.15 to 1.29 kg/d of lead and 3.03 to 17.58 kg/d of zinc is transported by Adyar river to the coast (Gowri et al 2008). The suspended solids was higher in Adyar river which is due to the relief of the drainage basin, climate condition, flow rate and salinity gradient (Milliman 1980: Markofsky et al., 1986). The mass transport of ammonia, nitrate and phosphate in the river prevails the denitrification due to discharge of domestic sewage and industrial effluents.

Fable 1: Source	of contaminant	and its affects	on human	beings
-----------------	----------------	-----------------	----------	--------

Major pollutants	Point sources	Nonpoint sources	Health effects
Nitrate, Phosphate, Ammonia, Cadmium, Lead and Zinc	Dumping of municipal sewage sludge, dredged spoils, industrial wastes, Municipal and industrial effluents, (Pharmaceuticals)	Urban runoff, septic tank leakage, groundwater transport, erosion and contamination soils, atmospheric deposition (Kotti et al., 2005), human sources (Oil spills, marine mining	It affects organs like liver, cardiovascular system and kidney. Pathological changes in brain tissues, lesions of the skin and appendages, Anorexia, etc.

Table 2 shows a number of measures that can be effected to restore the river. Here the focus will be on ecological river restoration.

Table 2: Measures to restore the river

-	
SI	Tasks
1	Strengthening of policies
2	Mobilization of community
3	Construction of check dams across the river
	at suitable location
4	Increasing the river water flow
5	Increasing the river water volume
6	Remedial measures for flash floods
7	Boating and fishing
8	Development of a sustainable ecosystem
	and ecological landscape
9	Awareness programs

With a rapid urban development, there is increasingly less green area left to provide refuge for wildlife and recreational areas for the inhabitants. Therefore, we propose the creation of a green belt surrounding the Adyar river and a buffer zone around it limiting the establishment of new settlements (fig.2).

A green belt should include all the available land around the river, where there are still no buildings. Slums, however, should be removed, and their inhabitants resettled to a location with more appropriate conditions. Where possible, communities residing along the river should contribute and sustain a green land in their property.

The buffer zone should be included in the city master plan as an area where no further new buildings are allowed. Rain harvesting, sewage collection and treatment implementation should be emphasised in this area.

Ecological restoration – case study

We chose a small area of the river to understand the problems and propose solutions for restoration in a small scale. Here, the area around the river is limited; walls and dikes are unavoidable restoration measures to prevent floods. Our aim is to both protect the city from floods and to restore the ecosystem providing a diversity of habitats for aquatic life.



Figure 2: Green belt (green) in restoration area, and buffer zone (transparent yellow) surrounding the river.

Naturally in flat terrain rivers have small valleys with the sustained restoration in the Adyar river are listed gradual increase of the slope in the banks. Surround- as follows:

ed with houses, Adyar is "squeezed" in between two banks. Therefore, in ideal situation, the river bed should be widened and the slope of bank lowered. This is a good measure in the north bank where there is some land available. Here the slope should be planted with local vegetation – flood and drought resistant grasses, shrubs and trees to provide a habitat resembling the most natural conditions.

Where the slope is steeper, additional measures should be taken to manage it sustainably (figure 3). Live stakes of willow could be used to support the slope and prevent erosion. Some plants, as vertiver grass, have very long roots and are perfect in slope fixation (figure 3). When the slope is vegetated, it requires less maintenance and is more resistant to erosion during floods.

- Mandatory treatment of industrial wastewater before draining into the river;
- Imposition of heavy fines on the firms who break the rules;
- No future construction activities in the green belt;
- Regular examination of water quality in the river;
- Pollution control in the upstream area;
- Imply creation and recapturing of green areas in planning process;
- De-siltation/de-sedimentation in a regular interval:
- Motivating stakeholders for smooth management;
- Inviting corporate firms for beautification and of the recreational parks.

Conclusion

Chennai city has become the sewage canal, deterio- wirenet system for easier plastic removal, will ensure rating the water quality, estuarine eco-system and the smooth operation of the riverine ecco-system. eventually causing floods during monsoons due to heavy siltation on its river bed and affecting the economy of Chennai City. Amazing river revitalization work has been undertaken along the river in the last year. The restoration of Adyar river should follow the principles of sustainability. The river bank has to be restored using environment friendly measures, where possible. Communities should participate in river restoration and benefit from improved conditions. The domestic waste and unwanted desilted material could be turned into economically beneficial activity. The recommendations for

The Adyar river, once the lifeblood for the growth of Periodical survey of water quality and level, desilting,

Selected References

- Beder S (1989) Engineering Sydney's sewerage pollution: Public relations assisted technology. Curr Aff Bull 66:27–31.
- Gowri VS, Ramachandran S, Ramesh R, Pramiladevi I.R.R, Krishnaveni K (2008) Application of GIS in the study of mass transport of pollutants by Advar and Cooum Rivers in Chennai, Tamilnadu. Environ Monit Assess (2008) 138:41-49.
- Kennish M J (1994) Practical handbook of marine science. 2nd ed. CRC Press, Boca Raton, USA



Figure 3: Measures for bank erosion prevention. Left - when the slope is not steep, centre - where erosion is strong, right – vertiver plant and it's deep root (Adapted from USDA NRCS, 1996).

FEATURE

Finite Element modelling of the interface behaviour between soil and geogrid in large scale biaxial compression tests

Felix Jacobs*, Prof. Martin Ziegler*, Prof. K. Rajagopal**

*Chair of Geotechnical Engineering, RWTH Aachen University, Germany, jacobs@geotechnik.rwth-aachen.de *Geotechnical Engineering Division, Indian Institute of Technology Madras, Chennai, India

Introduction to geogrid reinforced soil

Geosynthetics, synthetic materials used in geotechnical engineering structures, play an important role in the development of construction methods that are more sustainable than classic methods. This was approved, amongst others, by a study under supervision of the Swiss Federal Institute of Technology (ETH) that investigated four cases of application of geosynthetics in direct comparison with classic construction methods concerning their environmental performance. Result was that geosynthetics supported structures caused significantly lower climate change impacts and lower acidification, eutrophication, and cumulative energy demands in all investigated cases. In the case of application of geogrids (polymer grids) for a slope retention (similar as shown in Fig. 1), the geogrid reinforced soil wall caused on an average only 24 % of the environmental impact caused by a conventional steelreinforced concrete wall (EAGM study, 2011).

Fig. 1 shows a typical application of geogrid reinforced soil for walls. These geogrid reinforced soil walls are being constructed near Redhills, North West of Chennai, and will support embankments of a sixlane bypass road. In these walls, horizontal layers of geogrids with a vertical spacing of 60 cm have the tasks to first take up occurring tensile forces and second hold back the facing of the wall. In the illustrated case, the facing consisted of small concrete blocks

with the geogrid layers in between every third block layer, being connected only through surface friction. In addition to these two tasks of the reinforcement, there is another important effect caused by geogrid reinforcement. Through the intense interaction between soil and reinforcement, the geogrids induce a higher general stress state within the soil, which confines it and thereby enables the soil to withstand higher loads itself.



Fig. 1. Construction of geogrid reinforced soil walls for a bypass road near Redhills, Chennai.

Having discussed some of the technical and ecological advantages of constructions using geosynthetics (geosynthetics structures are also financially a good option which is not discussed here due to restricted space), the question arises as to why geosynthetics in general and geogrids as soil reinforcement in particular are not used in all applicable constructions.



Fig. 2. Laboratory device for large-scale biaxial compression testing of geogrid reinforced soil at RWTH Aachen University and sketch of the specimen (Jacobs & Ziegler, 2015).

Problem statement

Geogrids in soil cause an advanced composite material, known as geogrid reinforced soil. While the two separate materials, tensile products and soils, have been investigated thoroughly for decades or centuries, respectively, the complex combined behaviour is so far not fully understood. Therefore, most design approaches are based on mainly empirical investigations, lacking realistic mechanical models. Due to their empirical character, those approaches lead to too conservative designs, as measurements at existing structures show (see e.g. Bräu and Floss, 2000; Herle, 2006).

The main item in question still concerns the interaction between the two materials, soil and geogrid, i.e. the load transfer mechanisms (Ziegler, 2013; Bathurst, 2014).

Experimental investigation

At RWTH Aachen University, a sophisticated laboratory device (Fig. 2) has been developed in recent years to carry out biaxial compression tests with geogrid reinforced soil (see Ruiken, 2013). The large dimensions of the device allow to use real-sized ge-

ogrid samples and thereby to investigate non-scaled interaction mechanisms. With the device's transparent side wall, this non-scaled soil-geogrid interaction can be observed and many more stress and deformation state variables can be measured with redundant instrumentation.

Developed interaction model

The obtained holistic test data has been used to develop an analytical interaction model that, besides frictional load transfer, explicitly takes into account bearing load transfer caused by the transverse geogrid elements. An existing interaction model for the description of geogrid pullout (Jacobs et al., 2014) had served as basis for the development of this advanced model of interaction within a biaxial loading situation (see Fig. 3).

With the advanced model and a special test series carried out with modified geogrid samples for model calibration (see Jacobs, 2013), functions for the interface strength and stiffness have been developed. These functions can serve as input for an interface element in finite element software.



Fig. 3. Results from a biaxial compression test with two geogrid layers (left) and developed model for description of interaction behaviour between geogrid and soil (right).



Fig. 4. Stress-strain behaviour of biaxial compression tests and corresponding simulation results.

Finite Element model

A 2D plane strain finite element model has been formulated at the Geotechnical Engineering Division at IIT Madras for simulating the global material behaviour. Simulation results in Fig. 4 show the resulting global vertical stress σ_1 vs. global vertical strain ε_1 for unreinforced tests and one geogrid reinforced test.

All simulated stress-strain curves are in good agreement with the observed laboratory results. However, the reaction of the geogrid reinforced soil sample could only be modelled adequately by using unrealistic and very conservative values for the interface description. This emphasises the mentioned need for an alternative interface description.

Conclusions and summary

To promote sustainable construction using geogrid reinforced soil as modern composite material, experimental investigations were carried out with largescale biaxial compression tests at RWTH Aachen University. The comprehensive test results allowed for the development of a model, in cooperation with the Geotechnical Engineering Division of IIT Madras, for describing the complex interaction between the geogrid and soil, and allowed for the calibration of a common finite element model for simulation of the material behaviour. Implementation of the developed interaction model as interface into the finite element simulation is expected to improve modelling and design of geogrid reinforced soil structures.

References

- Bathurst, R.J. (2014): Challenges and recent progress in the analysis, design and modelling of geosynthetic reinforced soil walls, *Proc. 10th Intern. Conf. on Geosynthetics - Giroud Lecture*, Berlin, Germany.
- Bräu, G. and Floss, R. (2000). Geotextile structures used for the reconstruction of the motorway Munich – Salzburg, *Proc.EuroGeo 2000*, Bologna, Italy, 15218.
- EAGM study: Stucki M, Büsser S, Itten R, Frischknecht R. and Wallbaum H. (2011). Comparative life cycle assessment of geosynthetics versus conventional construction materials. ESU-services Ltd. Uster, ETH Zürich, Switzerland. Commissioned by the European Association for Geosynthetic Manufacturers (EAGM).

- Herle, V (2006). Long-term performance of rein- Jacobs, F., Ziegler, M., Vollmert, L. and Ehrenberg, H. forced soil structures. Proc.13. Danube-Europ. Conf. on Geotechnical Engineering, Ljublana, Slovenia.
- Jacobs, F. (2013). Investigation of geogrid reinforced Ruiken, soil using biaxial compression tests. 5th iYGEC -Proc. 5th Intern. Young Geotechnical Engineers' Conf., Paris 2013 / ed. by Yu-Jun Cui ...- Amsterdam: IOS Press, 2013, p. 318-321 (Advances in soil Ziegler, M. (2013). Interaction of soil reinforcement mechanics and geotechnical engineering; 2).
- Jacobs, F. & Ziegler, M. (2015). Investigation of global stress-strain and interaction behavior of geogrid reinforced soil with biaxial compression tests. 15th Asian Regional Conf. on Soil Mechanics and Geotechnical Engineering - Geosynthetic Session, 15ARC, Fukuoka, Japan (in press).

- (2014). Explicit Design of Geogrids with a Nonlinear Interface Model. Proc. 10th Intern. Conf. on Geosynthetics, Berlin, Germany.
- A., 2013. Zum Spannungs-Dehnungsverhalten des Verbundbaustoffs "geogitterbewehrter Boden". Ph.D. Thesis, RWTH Aachen University, Germany, language: German.
- as key issue for ground reinforcement, Proc. 15th European Conference on Soil Mechanics and Geotechnical Engeneering (XV ECSMGE)/ ed. by Andreas Anagnostopoulos et al., Amsterdam, IOS Press, 2013, Vol. 4, 155-164, ISBN 978-1-61499-198-4

Conference Participation

Dr. Christoph Woiwode was invited as a keynote speaker to the International Conference on 'Climate Change and the Developing World' in Kottayam in Kerala, India, from 21st to 25th January 2015. Sponsored by UGC, the Conference was organized by CMS College in association with the Department of Ecology, Church of South India Synod and Nilackal Ecological Commission. The involvement of important religious institutions set this conference apart from most such events about climate change. It provided a space for a truly cross-disciplinary interaction of scientists with social activists, religious and spiritual leaders. The themes of the various sessions ranged from "The Science of Climate Change" to "Religious Response to Ecological Challenges". One highlight was the "Interfaith Summit for WASH (Water, Sanitation, Hygiene)" with representatives from Hindu and Christian faith. Christoph's paper, "Climate Change

responsive Urban Planning: discovering the significance of interiority for sustainable urban development", is published in the proceedings of the conference. edited by Mini Chacko at al. (ISBN9788192599168).



Upcoming Event

Indo-German Expert Meeting on "Subsurface Rainwater Storage in Dry Areas", May 11, 2015

The meeting is hosted by the Environmental Resources and Water Engineering Division (ERWE) of the Civil Engineering Department at IIT Madras, organized by Visiting Professor of the Indo-German Centre for Sustainability, Franziska Steinbruch and Prof. Balaji Narasimhan of ERWE with support by Dr. B. Gowtham of the Madras Presidency College.

About 20 experts from universities in Chennai, the Technical University of Mining and Technology Freiberg, Germany and from respective Chennai-based Government organizations will be attending this meeting to discuss new methods of subsurface rainwater harvesting, and experiences and challenges with subsurface rainwater storage structures in the context of the pertinent rainfall pattern of the Chennai region as well as salt water intrusions. Prospects for the application of new subsurface rainwater harvesting at field site scale shall be explored. The meeting will be followed by a field visit to Lower Korattalaiyar - Araniar River Basin, north of the City of Chennai.

Interested students from IIT Madras may attend the expert meeting upon prior registration.



Website <u>www.igcs-chennai.org</u>

The IGCS Bulletin appears quarterly in the months of January/April/July/October. Please contribute news items or features at least 15 days in advance of publication.