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2ND INTERNATIONAL SYMPOSIUM GEOSYNTHETICS AND SUSTAINABILITY – MARCH 18, 2026 DELFT UNIVERSITY OF TECHNOLOGY (TU DELFT)

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Huesker Synthetic BV, Rosmalen

WELCOME

Dear GEObuild readers,

In a world increasingly focused on sustainability, the construction sector is stepping up with innovative, eco-friendly materials and solutions. For NGO-IGS Netherlands, sustainability is a central theme – both nationally and internationally. To contribute to this development, we recently organised the second International Symposium on Geosynthetics & Sustainability. In this edition, you will find several articles related to this event.

We look back with great appreciation on the 2nd International Symposium Geosynthetics and Sustainability, held at TU Delft on 18 March 2026. A key highlight of the symposium was the keynote lecture by George R. Koerner, who travelled to Delft to mark the launch of the IGS Geosynthetics Handbook. This comprehensive publication provides an extensive overview of geosynthetic materials, their applications, design considerations, and installation practices across projects in geotechnical, hydraulic and environmental engineering.

The symposium offered a valuable platform for knowledge exchange, with a strong focus on sustainability and Life Cycle Assessment (LCA). Leading experts from around the world shared state-of-the-art research and practical applications, demonstrating the growing importance of geosynthetics in sustainable engineering. Hosting the event at TU Delft also strengthened the connection with education and young professionals, while the hybrid format enabled broad international participation. In this edition, we present the first two articles based on the symposium lectures:

Wim Voskamp, Rijk Gerritsen and George R. Koerner – 2nd International Symposium Geosynthetics and Sustainability

George R. Koerner – Introduction and Description of the IGS Geosynthetics Handbook

Additional contributions from other speakers will follow in upcoming editions of GEObuild.

The presentations and articles clearly demonstrate that geosynthetics play a significant role in advancing sustainability within the civil engineering sector. Their application can substantially reduce CO_2 emissions and the use of primary raw materials, while enabling climate-adaptive and resilient solutions. Examples include improvements in flood protection, sustainable infrastructure, water storage during drought, and systems for managing extreme rainfall. These applications result to smarter designs, increased robustness, lower environmental impact, and reduced construction and maintenance costs.

Together, we must take meaningful steps to reduce environmental impact and integrate geosynthetics into a sustainable future. This is a shared challenge - and opportunity - to our geotechnical sector.

We hope you enjoy and get inspired by this edition.
Be smart. Be sustainable.

Rijk Gerritsen
Editor-in-chief GeoBuild Magazine

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2ND INTERNATIONAL SYMPOSIUM GEOSYNTHETICS AND SUSTAINABILITY

Introduction

The symposium took place on Wednesday, March 18, 2026, at Delft University of Technology (TU Delft) in the Netherlands. The event was held both in person and via livestream in one of the main lecture halls at TU Delft (see Figure 1). More than sixty people attended on site, while over one hundred online participants joined from all over the world. Professional audio and video technology was provided by the TU Delft media support team, contributing to a well-organized hybrid event.

The symposium's main objectives were the launch of the IGS Geosynthetics Handbook and to illustrate the role of geosynthetic materials in pioneering sustainability in engineering construction projects.The program of the symposium was as follows:

- IGS Geosynthetics Handbook. "Design principles and installation examples", by George Koerner.
- Sustainability effects of geosynthetics in major infrastructure projects in the Netherlands, by Wim Voskamp.
- Geosynthetics for a sustainable, resilient future in flood protection, by Kent von Maubeuge.
- An overview of the comparative life cycle assessments for roads, prepared for EAGM, by Jürgen Gruber.
- An overview of the comparative life cycle assessments for walls, surface drainage, and hydraulic channels, prepared for EAGM, by Henning Ehrenberg.
- Sustainable use of geosynthetics in roads in Europe, by Marie-Therese Hortmann.
- The design and construction of soil-reinforced structures in the A10 widening project near Amsterdam, by Justus Lagendijk.

Impression of symposium speakers and event organizing NGO board members are given in Figure 2, 3 and 4. The symposium emphasized the urgency of addressing climate change, as this necessitates innovative solutions within civil and hydraulic engineering. Geosynthetics have emerged as a sustainable construction method that can significantly reduce CO_2 emissions (20-90%) and energy consumption (up to 85%) compared to traditional building materials. This symposium, organized by NGO, IGS and EAGM, served as a platform for knowledge exchange on geosynthetic materials and sustainability.

IGS Geosynthetics Handbook

The first part of the symposium focused on the introduction of the IGS Geosynthetics Handbook. IGS took the initiative to publish a handbook describing the application of geosynthetics across various sectors. The design principles and their elaboration are summarized in eight chapters, accompanied by relevant installation guidelines. Written by experts in the field, the handbook provides a solid foundation for anyone wishing to explore this area.

The handbook was compiled by George Koerner, who served as editor. He attended the symposium and gave a keynote lecture on the handbook (see Figure 3). Thanks to the support of the symposium partners, it was possible to present and hand out this state-of-the-art handbook to all participants attending on site in Delft.

The next table provides an overview of the chapters of the IGS Geosynthetics Handbook, together with their typical application in Dutch

Figure 1 – Symposium impression hosted at the TU Delft Civil Engineering department, with physical attendance and parallel online streaming.

Figure 2 – Symposium speakers and NGO board, from left to right: Rijk Gerritsen, Kent von Maubeuge, Jürgen Gruber, Justus Lagendijk, Henning Ehrenberg, George Koerner, Marie-Therese Hortmann, Dick Janse, and Wim Voskamp.

SUMMARY

NGO-IGS Netherlands looks back with great appreciation on the 2nd International Symposium 'Geosynthetics and Sustainability', held at TU Delft in the Netherlands. An important part of the symposium was the keynote lecture by George Koerner, who travelled to Delft in person to mark the launch of the IGS Geosynthetics Handbook. This new handbook provides an extensive overview of geosynthetic materials, applications, design considerations, and installation practices across infrastructure. The symposium served as a platform for knowledge exchange on geosynthetics and sustainability, with a specific focus on LCA (Life Cycle Assessment). The program featured a strong line-up of presentations. This article presents the main highlights of the symposium.

IGS Geosynthetics Handbook	***Typical use in Dutch practice***	***Dutch standards or guidelines***
I. Introduction to Geosynthetics		**EN ISO 10318: 2015** part 1 and 2: Geosynthetics Norms and Definitions.
II. Roads and pavements	In Dutch practice, design and implementation are often channelled through RAW based contracting; technical background on base reinforcement is referenced via NGO/CROW material.	**CUR 175:** Geokunststoffen als funderingswapening in ongebonden funderingslagen. **STOWA 209-02a**: Crane hardstands for installation of wind turbines. **NEN EN 13249: 2018**: Characteristics required for use in the construction of roads and other trafficked areas. **RAW** / Standaard RAW Bepalingen.
III. Subsurface drainage / water storage (in several applications)	Drainage and storage/infiltration systems are often addressed via STOWA guidance and national climate adaptation documents, including use of geotextile filters/wrappings.	Several, often as part of another guideline or standard. For example: **CROW CUR C162: 2022**: Handboek construeren met grond. **KIWA** BRL-richtlijnen voor membranes, BRL K519, K537, K538, K546, K1149. **NEN EN 13252: 2018**, Characteristics required for use in the construction of drainage systems. **RAW** / Standaard RAW Bepalingen. Ondergrondse waterberging en infiltratie (Kennisportaal Klimaatadaptatie).
IV. Erosion and sediment control	In the Netherlands, erosion control with geosynthetics is strongly linked to hydraulic engineering and earth works (embankments).	**CROW-CUR Richtlijn 8:2025:** Design guideline on geotextiles under revetments. **NEN EN 13253: 2018**: Characteristics required for use in the construction of erosion control works. **CUR 115**: Uitvoering van geokunststoffen in de waterbouw. **CROW CUR C162: 2022**: Handboek construeren met grond.
V. Reinforced soil systems	CUR 198 is the primary Dutch design guideline for reinforced soil structures; RWS specifications apply in Rijkswaterstaat projects; CUR 226 is used for basal reinforced pile-supported embankments.	**CROW CUR 198**: Kerende constructies van gewapende grond. **RWS**: Specificaties kerende constructies van gewapende grond. **CROW CUR 226**: Design Guideline Basal Reinforced Piled Embankments. **RWS and ProRail**: Voorschrift Ontwerp-parameters geokunststof wapening. **EN NEN 13251: 2018**: Characteristics required for use in earthworks, foundations and retaining structures. **CROW CUR C162: 2022**: Handboek construeren met grond. **CROW CUR**: Durability of Geosynthetics.
VI. Geosynthetic Barriers and Seepage control systems	Dutch practice places strong emphasis on protocols and certification for design, installation, welding and acceptance of geomembranes, supported by NEN EN product standards.	**CROW 2026**: Handboek Folieconstructies (CROW online knowledge module). **NEN Protocollen geomembranen** UIT 83/84/85 2018. **Kiwa BRL richtlijnen** o.a. BRL K519 / K537 / K538 / K546 / K1149. **NEN EN 13361: 2018**: Characteristics of geosynthetic barriers.
VII. Environmental protection	Environmental protection measures involving geosynthetics are often governed by enforceable certification and inspection frameworks, especially BRL SIKB 7700.	**BRL SIKB 7700** – aanleg of herstel van een vloeistofdichte bodemvoorziening; Vloeistofdichte bodemvoorziening (Informatiepunt Leefomgeving). **VROM 1991/3**: Richtlijnen voor dichte eindafwerking op afval- en reststofbergingen. **VROM 1991/5**: Handleiding voor ontwerp en constructie van eindafdekkingen van afval- en reststofbergingen. **VROM 1991/5**: Richtlijn voor het toepassen van geomembranen ter bescherming van het milieu. **VROM 1993/1**: Richtlijn drainagesystemen en controlesystemen grondwater voor stort- en opslagplaatsen. **VROM 1993/2**: Richtlijn onderafdichtingsconstructies voor stort- en opslagplaatsen.
VIII. Geosynthetics support systems	Quality control according to EN product application standards	**EN NEN 13249 -13257, EN NEN 13265** and **EN NEN 15381.**

Figure 3 – Presentation George Koerner – IGS Geosynthetics Handbook "Design Principles and Installation Examples."

Figure 4 – Wim Voskamp (left) and George Koerner (right) on stage.

practice. For each topic, relevant Dutch standards and guidelines are also included.

Sustainability and ECI in the Netherlands

The second part of the afternoon started with a contribution by Wim Voskamp. He presented an overview of several recently completed projects in which the application of geosynthetics made a significant contribution to reducing CO_2 emissions and overall environmental impact.

The use of geosynthetics in slope reinforcement, retaining walls, and pile-supported geosynthetic-reinforced embankments (also known as paalmatrassen in Dutch), results in a substantial reduction in environmental impact. This is reflected in the low Environmental Cost Indicator (ECI) values. The application of geosynthetics offers clear environmental benefits. These include a reduced use of primary raw materials such as sand, clay, and riprap; significantly less material transport; reduced use of concrete; and the replacement of clay layers by bentonite mats (GCLs) and asphalt reinforcement. In addition, the service life of the structure can be extended through the application of geosynthetics in pile-supported embankments.

In a large TenneT project involving temporary access roads, it was demonstrated that, in addition to reducing the amount of foundation material, it was possible to remove the road and geotextile after completion of the structures. The geotextiles could then be fully recycled after purification and shredding.

Figure 5 – Julianakanaal Westkolk Born application of Geosynthetic Clay Liners (GCLs) as sealing system for the full canal profile with bottom and slopes.

In the Julianakanaal project (Figure 5), it was demonstrated that GCLs can be used on a large scale to seal a full canal bottom and slopes. After installation, the GCLs are covered with stones. The sealing of the canal could have been executed in a traditional way with a natural clay layer of 0.6-0.8 meter, however, in that case, the canal would have needed to be excavated to a greater width and depth. In this project, the use of GCLs minimized groundworks and eliminated the need to mobilize large quantities of natural clay. This reduced transport movements, shortened construction time and avoided long-term disturbance of the main shipping route. These effects turned out to be important sustainability aspects when the construction methods were compared upfront.

In tenders for major central government projects in the Netherlands, environmental costs are explicitly included in the evaluation. For this purpose, the ECI/MKI values must be determined. This is done by calculating the shadow price. In addition to the bid price, the quality of the design is considered within the framework of the Best Price-Quality Ratio evaluation during the tender evaluation. A design is assessed on: Performance, Quality Aspects, and Environmental Costs. A fictitious value of approximately 20% of the standard price is assigned to each category. For each category, the fictitious discount is determined based on an assessment of the proposed design and execution (see Figure 6 and 7). The environmental cost indicator MKI/ECI is used to determine and assess the environmental costs. These fictitious prices are deducted from the tender price, and the bidder with the lowest total price is selected. Recently, the methodology has changed; the shadow price of the environmental impact (the ECI/MKI value) is added to the tender price, after which the fictitious prices for the other categories are deducted. In this process,

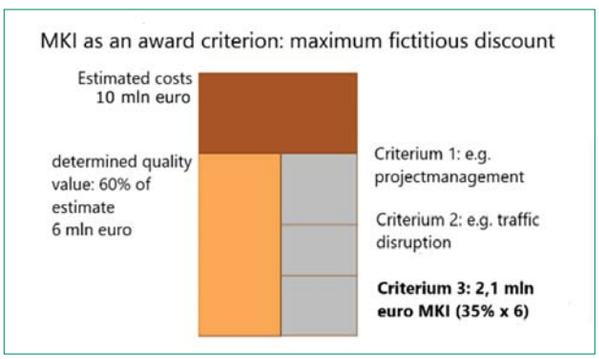

Figure 6 – Example calculation of fictitious discount based on ECI. Source: Molenaar, K. (2024).

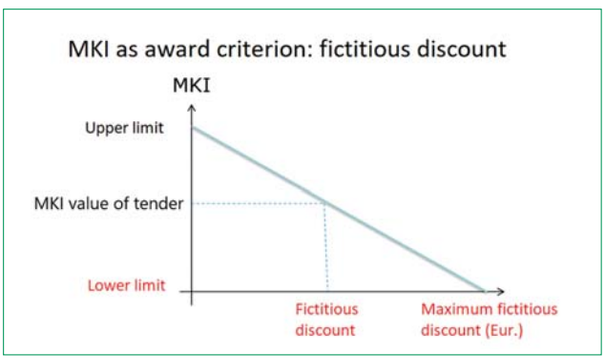

Figure 7 – Example calculation of fictitious discount with linear interpolation between limits. Source: Molenaar, K. (2024).

the effect of sustainability can be further enhanced by applying a weighting factor > 1 to the MKI value.

This method of tendering makes it possible to give environmental costs a significant place in the selection of the design to be executed. This is clearly noticeable in the chosen designs.

Geosynthetics in flood protection

Kent von Maubeuge gave a presentation on Geosynthetics for a sustainable, resilient future in flood protection (see Figure 1). As a result of climate change, rainfall intensity and duration are increasing, leading to greater risks and potential disasters. After an introduction regarding the flood risks, he provided an overview of the measures that must be taken in dike or levee design. The three-zone concept was explained, as described in the German DVWK Guideline "River levees" 210/1986 (or DIN 19712). This concept consists of an impervious barrier on the outer slope, a permeable and stable supporting core, and highly permeable passive wedge for long-term drainage at the foot of the inner slope. The application of geosynthetics and geosynthetic clay liners makes a significant contribution to sustainable design.

Life Cycle Assessment (LCA) studies

The European Association of Geosynthetic Manufacturers (EAGM) commissioned an extensive life cycle assessment study. Several geosynthetics applications were compared with traditional designs, focusing on environmental impact and energy consumption. The results for road applications were presented by Jürgen Gruber. The studies focused on three cases: Filtration (Figure 8), Foundation-stabilized road (Figure 9), and Temporary road (Figure 10).

Henning Ehrenberg presented the results of the study for Landfill construction (Figure 11), Slope retention structures (Figure 12) and Filter function in river construction (Figure 13).

For the cases Filtration (case 1), Foundation-Stabilized road (case 2), Landfill construction (case 3) and Slope retention structures (case 4), a cost comparison was also prepared by a consultancy firm. Figure 14 presents the results. The costs of the entire construction project with geosynthetics are set at 100 % (case B). The costs of the traditional construction methods are shown as percentages relative to case B. The conclusions from this study are as follows:

- Overall, the geosynthetic alternative results in 20% to 90% lower environmental impact compared to the traditional construction alternatives.
- The cumulative energy demand is reduced by 13% to 85% because of the use of geosynthetics.

Figure 8 – Results of the LCA comparison for the case Road filter layer.

Reference **Figure 8 - 13**: Comparative Life Cycle Analysis of Geosynthetics vs. conventional construction materials, by Treeze/ Zurich University and visualized by the EAGM.

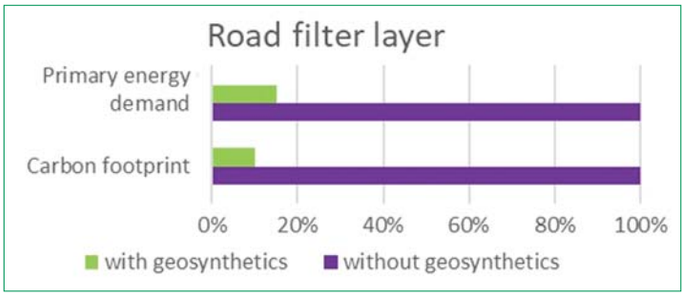

Figure 9 – Results of the LCA comparison for the case Road foundation stabilisation.

Figure 10 – Results of the LCA comparison for the case Temporary road.

Figure 11 – Results of the LCA comparison for the case Landfill construction.

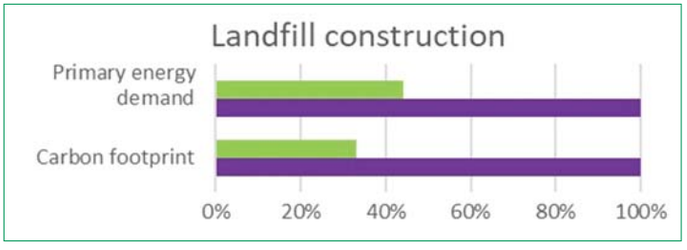

Figure 12 – Results of the LCA comparison for the case Temporary road.

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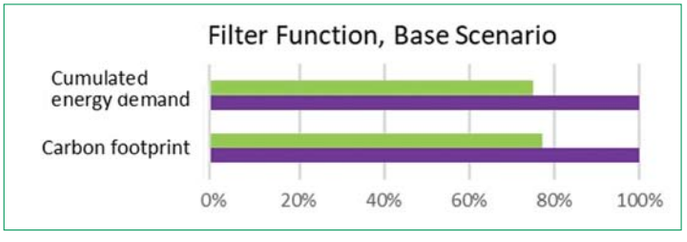
Figure 13 – Results of the LCA comparison for the case Filter function, base scenario.



- Geosynthetic applications significantly reduce the use of natural resources such as gravel, sand, and water.
- In several cases (based on 2021 data), the total construction costs of entire projects were significantly reduced by implementing geosynthetics.

For more details, please refer to the study reports published online at (EAGM, 2026).

Sustainable use of geosynthetics in road construction

Marie-Therese Hortmann gave a presentation on the sustainable use of geosynthetics in roads in Europe. The European Green Deal also affects the construction industry. One of the most important consequences is the introduction of the new Construction Products Regulation 2024/3110. This regulation requires that the declaration of performance and conformity issued by the

producer includes the products environmental sustainability performance over its entire life cycle.

The new regulation will come into force once the harmonized standards have been adapted accordingly. As a result of this and other implementation measures, even greater emphasis is being placed on the environmental effects of the application of the products.

Consequently, the Life Cycle Assessment (LCA) of products within construction projects is becoming increasingly important. At present, some EN standards still restrict the use of recycled raw materials in geosynthetics for reinforcement applications, for example EN 13249: 2016-10. Marie-Therese Hortmann illustrated the potential of reducing environmental impact by showing the results of an LCA study, carried out under direction of Prof. F. Heimbecher at FH Münster University of Applied Sciences. The study showed that a CO_2 reduction of approximately 40% can be achieved in the construction of abutments with geosynthetic-reinforced soil (GRS), compared to traditional construction methods.

Soil-reinforced structures Amsterdam

Justus Lagendijk explained the various structures in which geosynthetics were applied in pile-supported embankments, reinforced slopes, and retaining walls in the major A10 highway widening project, south of Amsterdam.

In many cases, traditional construction methods could not be applied due to the limited available space, and soil reinforcement proved to be a suitable solution in various ways. It was used in both temporary and permanent structures. More about this project can be found in GEObuild 2026/1 (Lagendijk, 2026).

Conclusion

This symposium highlighted the urgency of addressing global warming as it makes innovative solutions necessary within civil and hydraulic engineering. Geosynthetics have emerged as a sustainable construction method, significantly reducing CO_2 emissions (20% - 90%) and energy consumption (up to 85%) compared to traditional construction materials. This symposium, hosted by the NGO, IGS and EAGM, served as a platform for knowledge exchange on geosynthetics and sustainability.

A special highlight of the event was the launch of the IGS Geosynthetics Handbook, which was handed out in printed format to participants attending in person. George Koerner marked the launch with a keynote lecture on the handbook.

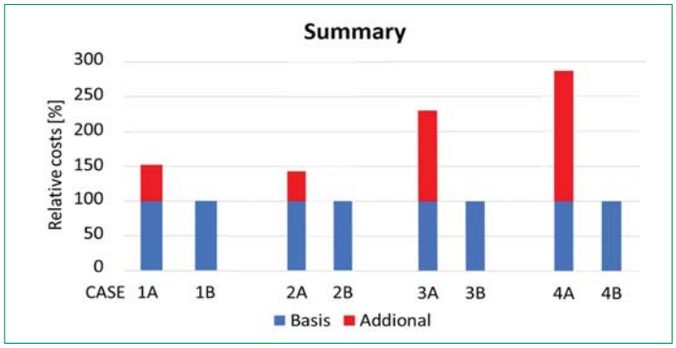


Figure 14 – Results of the comparison of the construction costs of the entire project; cases 1 to 4 with case B the costs of the solution with geosynthetics. Case A is the case with the traditional solution. Source: H. Ehrenberg, 2nd International Symposium, Delft 2026.

Figure 15 – Panel discussion, from left to right: Kent von Maubeuge, Jürgen Gruber, Henning Ehrenberg, Marie-Therese Hortmann, Justus Lagendijk and George Koerner.

During the symposium, multiple presentations were given, connecting and deepening the topic of geosynthetics and sustainability. The symposium concluded with a panel discussion (see Figure 15), during which questions from online participants were also addressed.

The symposium brought together professionals, researchers, and experts with an inspiring program focused on the role of geosynthetics in environmental, civil, and hydraulic engineering. The presentation slides are available on the website of NGO (ngo.nl). The lectures were professionally recorded by the TU Delft media team and were published online on the NGO YouTube channel.

Final words

We would like to thank all participants, both in person and online, for attending and for contributing to a valuable symposium focused on knowledge sharing and discussion. Special thanks for the valued partners of this event, Naue, HUESKER, Solmax, Enviro Quality Control, and Tensar. With their support, it was possible to hand out the IGS Geosynthetics Handbook free of charge to all participants attending in person. We are very grateful for the collaboration with the International Geosynthetics Society (IGS), Delft University of Technology, Deltares, EAGM - European Association of Geosynthetic Product Manufacturers, and KIVI – Royal Institute of Engineers in the organization of this symposium.

The symposium was organized by the board of NGO, consisting of Wim Voskamp, Rijk Gerritsen, Leo Kuljanski, Andries Steerenberg and Dick Janse. Final special thanks for the organization by Lieke van Vliet and Jolanda van Zadelhoff.

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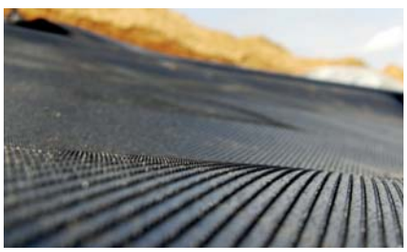

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High-quality nonwovens for separation, filtration or protection

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Innovative applications with high-quality geo-building materials

- Added value with geo-building materials in ground, road and hydraulic engineering projects, such as infrastructure, landfills, flood defences and canals.
- Innovative and sustainable applications with geosynthetic clay liners, geomembranes, geogrids (reinforced soil structures, base course stabilisation/reinforcement), erosion and drainage mats, filter and separation nonwovens.
- Proven solutions that can be adapted to challenging conditions such as subsurface settlement, limited space or construction time.
- Support from initial feasibility, design with calculations and drawings, supply of materials and installation.

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George R. Koerner
Geosynthetic Institute (GSI)

INTRODUCTION AND DESCRIPTION OF THE IGS GEOSYNTHETICS HANDBOOK

Introduction

The IGS Geosynthetics Handbook is a one-stop technical reference guide suitable for all levels of experience in geosynthetics. The handbook offers a concise yet comprehensive summary of the fundamental applications of geosynthetics and is an essential reference guide for students, instructors, and civil engineering professionals. This new reference manual was created by the IGS and drafted by some of the industry's top practitioners. The Geosynthetics handbook showcases their utilization.

Geosynthetics have emerged as some of the most versatile and cost-effective construction materials in the field of geotechnical engineering. Their application has rapidly expanded across nearly all areas of this discipline. The IGS Handbook presents geosynthetics from a practical perspective rather than a purely design-focused one. It is intended to serve as a general reference for those involved in the construction of facilities or structures that incorporate geosynthetics. This handbook was distributed to everyone at the symposium in a printed format and was comprehensively covered during George Koerner's opening presentation.

It is important to note that the International Geosynthetics Society (IGS) supported the development of this handbook, emphasizing a collaborative effort rather than a single-author approach. The handbook reflects the vision of the current IGS President, Sam Allen, of TRI Environmental Inc. IGS aimed for a concise, generic handbook applicable to a wide range of manufactured products.

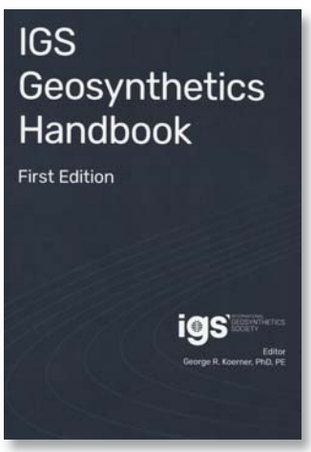


Figure 1 – Cover of the IGS Geosynthetics Handbook.

Figure 2 – Authors of the various chapters IGS Geosynthetics Handbook.

Table 1 – Overview chapters and authors of the IGS Geosynthetics Handbook.

Chapter	*IGS Geosynthetics Handbook*	*Author*
1	Introduction to Geosynthetics	George R. Koerner
2	Geosynthetics in roads and pavements	Eli Cuelho
3	Geosynthetics in subsurface drainage	Barry Christopher
4	Geosynthetics in erosion and sediment control	Joel Sprague and Jay Sprague
5	Geosynthetics in reinforced soil systems	Chris Lawson
6	Geosynthetics in barriers and seepage control systems	Kent von Maubeuge
7	Geosynthetics in environmental protection (waste containment)	R. Kerry Rowe
8	Geosynthetics support systems	George R. Koerner

It should be noted that this handbook is a living document, anticipated to undergo many revisions in the future.

The handbook editor, Dr. George Koerner, would like to express gratitude to the chapter authors for their expertise in their assigned chapters. We value their unique contributions, insight and timely submissions.

1. Introduction to Geosynthetics (George R. Koerner)

The introductory chapter is authored by Dr. George Koerner, Director of the Geosynthetic Institute (GSI). With over 350 technical papers published during his 40-year association with polymers used in below-ground construction Dr. Koerner serves as editor. He holds a Ph.D. in Geotechnical Engineering from Drexel University, is a registered professional engineer, and is a certified quality auditor.

The global geosynthetics market was valued at approximately USD 17 billion in 2025 and is projected to reach USD 21 billion by 2033, growing at a compound annual growth rate (CAGR) of 9.5% from 2026 to 2033. Key application areas driving growth in geosynthetics usage include roads, landfills, and erosion control.

There is an increasing demand for eco-friendly geosynthetic products that promote sustainability alongside durability. Additionally, government regulations and standards are influencing market dynamics and product development. The market is expected to continue its growth beyond 2033, driven by investments in infrastructure and environmental considerations.

The selection of geosynthetic products for specific applications primarily depends on the functional requirements of the project. In some cases, a combination of geosynthetic products may be utilized if the project has multiple objectives. The first chapter briefly introduces various Types of geosynthetics and aligns them with the Functions they provide, as illustrated in Table 2.

2. Roads and Pavements (Eli Cuelho)

The second chapter is authored by Dr. Eli Cuelho,

SUMMARY

The IGS Geosynthetics Handbook is a one-stop technical reference guide suitable for all levels of experience in geosynthetics. The handbook offers a concise yet comprehensive summary of the fundamental applications of geosynthetics and is an essential reference guide for students, instructors, and civil engineering professionals. This new reference manual was created by the International Geosynthetic Society (IGS) and drafted by some of the top industry's practitioners. Geosynthetics have proven to be among the most versatile and cost-effective construction materials available, and their use has expanded rapidly into nearly all areas of civil engineering. This handbook showcases their utilization.

Function/Geosynthetic	GTX	GGR	GST	GCE	GN	GBR-P & GM	GBR-B & GM	GBR-C & GCL	GCCM	GP	GMA & EC-TRM	GF	GCO	GSY or AP
1. Filtration or Permeability	X										X		X	X
2. Drainage	X				X					X	X	X	X	X
3. Separation	X	X					X		X		X	X	X	X
4. Barrier	X					X	X	X	X				X	X
5. Reinforcement	X	X	X	X					X		X		X	X
6. Stress Relief	X	X					X				X	X	X	X
7. Protection	X						X		X		X		X	X
8. Stabilization	X	X	X	X							X		X	X
9. Erosion Control	X								X		X		X	X
10. Insulation	X										X		X	X
11. Absorption and Adsorption	X						X	X	X		X		X	X
12. Resistance versus Conductivity	X					X				X			X	X
13. Appertenances and Connection													X	X

GTX – geotextile
GST – geostrip
GN – geonet
GBR-C & GCL – geosynthetic clay liner
GP – geopipe
GF – geofoam
AP – appurtenances
GGR – geogrid
GCE – geocell
GBR-P &GM – geomembrane
GCCM – geosynthetic cementitious composite mat
GMA & EC-TRM – geomat
GCO – geocomposite

who has over 30 years of experience in geosynthetic research and testing. His expertise encompasses a variety of topics, including geotechnical engineering, geosynthetic design, full-scale testing of roadway applications, and pavement maintenance. Dr. Cuelho also develops new test procedures for geosynthetics used in pavement and reinforcement applications and serves as the chair of the Transportation Research Board (TRB) Geosynthetics Committee for the Federal Highway Administration (FHWA).

This chapter covers the extensive benefits of geosynthetics in both unpaved and paved roads. It discusses their functions and specific applications, including preventing intermixing between dissimilar layers (separation), road construction on soft ground, stabilization and reinforcement of unbound aggregate layers, moisture control, and asphalt interlayers.

To effectively measure roadway performance when geosynthetics are used, performance indicators are defined, and field tests are conducted to assess long-term performance through periodic inspections and maintenance assessments. Comparison of performance data, such as the traffic benefit ratio, base course reduction factor, layer coefficient ratio, and modulus improvement factor against established benchmarks, is frequently

Figure 3 – Road application with composite geosynthetic material combining separation and stabilization/ reinforcement functions Highway Ontario, Canada (reference Terrafix).

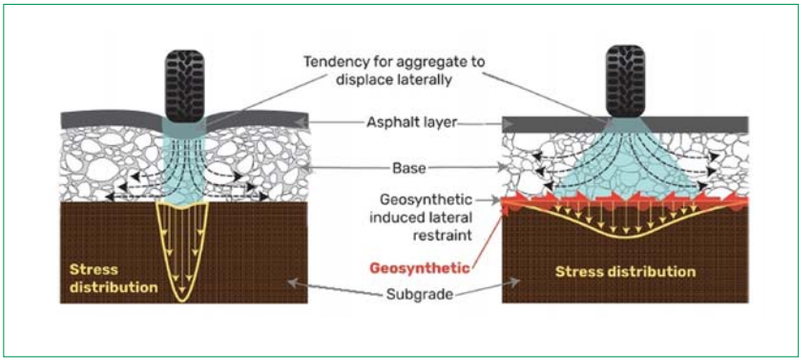


Figure 4 – Stabilization of soft ground using geosynthetics (reference Zornberg, 2017).

encountered in this chapter. All these performance measurement techniques are discussed in detail, supported by illustrated case histories from both field and full-scale laboratory analyses.

3. Subsurface Drainage / Water Storage (Barry Christopher)

The third chapter focuses on basic subsurface drainage principles and illustrates how geosynthetics effectively transport liquids from one location to another. It is authored by Dr. Barry Christopher, who has published over 150 technical papers and contributed to the FHWA guidelines. Dr. Christopher was the first chair of ASTM committee D35 on Geosynthetics. Since 1994, Christopher has worked as a self-employed consultant, transitioning to that role full time after serving as a principal engineer at STS Consultants and later as vice president at Polyfelt Americas.

This chapter highlights geosynthetics used as drainage layers, prefabricated vertical drains and water collection systems. Geosynthetics enhance the performance of all types of subsurface drainage systems. Effective subgrade dewatering requires a highly porous drainage medium to accept seepage, along with a properly graded filter to retain fine-grained particulates. Geosynthetics are commonly employed to resolve subsurface drainage issues in applications such as roads, parking lots, sports fields, retaining walls, golf courses, landfills, and landscaping. The chapter discusses the advantages of geosynthetics over conventional soil drains, which include:

- Cost Efficiency: Reduced installation and maintenance costs compared to traditional methods.
- Durability: Longer lifespan, minimizing replacement expenses over time.
- Sustainability: Often made from recycled materials, promoting environmental sustainability.
- Performance: Superior drainage capabilities, enhancing water management efficiency.
- Installation Speed: Quicker installation, reducing labour costs and project timelines.
- Reduced Soil Disturbance: Minimizes soil disruption, preserving the surrounding ecosystem.

Dr. Christopher also covers design considerations for subsurface drainage applications, discussing specific requirements for structural drainage, landmass dewatering and consolidation, underground detention systems, and bioengineering applications. The chapter highlights problems associated with conventional construction methods, including slope instability and poor drainage in marginal soils. It emphasizes the increasing comparison of geosynthetic materials versus traditional construction solutions when addressing various engineering challenges.

4. Erosion and Sediment Control (Joel Sprague)

This chapter, authored by Mr. Joel Sprague, a senior engineer at TRI/Environmental and Sprague & Sprague Consulting Engineers, focuses on the role of geosynthetics in enhancing erosion and sediment control technologies at TRI's extensive R&D centre in Greenville, SC, USA.

Geosynthetics provide structural support to vegetated systems, preventing soil movement due to wind and precipitation, while aiding in water management to minimize erosion risk. Mr. Sprague differentiates between temporary rolled erosion control products and long-term turf reinforcement mats, discussing both index and performance testing in laboratory and field settings. He provides design guidelines for slopes and channels and presents installation guidance for both rolled erosion control products (RECP) and high-performance turf reinforcement mats (HP-TRMs). Drawing on years of experience from numerous field sites, this guidance is critical for successful installations.

The chapter concludes with examples of geosynthetic systems used in various erosion control applications. These systems include engineered synthetic turf (EST), cellular confinement systems (CCS), anchored geosynthetic systems (AGS), geosynthetic cementitious composite mats (GCCM), fabric-formed concrete revetments (FFCR), and geotextile-encapsulated sand elements (e.g., mattresses, bags, tubes, and geocontainers). These solutions reduce the need for extensive earthworks and maintenance, offering cost-effective solutions to persistent geotechnical issues.

5. Reinforced Soil Systems (Chris Lawson)

Mr. Cristopher Lawson was Technical Director of TenCate Geosynthetics Group Asia. TenCate, nowadays Solmax is a global leader in the geotextile industry. TenCate specializes in developing leading edge technology used for development and management of geosynthetics. Mr. Lawson has been instrumental in leading TenCate to offer solutions for building sites, transportation, energy, water and environmental infrastructure. Chris received his engineering degrees from the University of New South Wales. He has worked in the field of geosynthetics for 40 years in Australia, Europe, North America and Asia. During this period, Mr. Lawson has served several international organizations developing standards and codes of practices for geosynthetics and geosynthetics structures. He is the author of over 50 technical papers on geosynthetics, geotechnical engineering, mining and hydraulic and coastal engineering.

In this chapter, Mr. Lawson examines reinforced soil systems, breaking it down into sections on embankments, slopes, and retaining walls (Figure 8). He describes how geosynthetic reinforcement enhances soil stability and performance by improving load distribution, reducing stress on

Figure 5 – Highway edge drain (reference National Highway Institute).

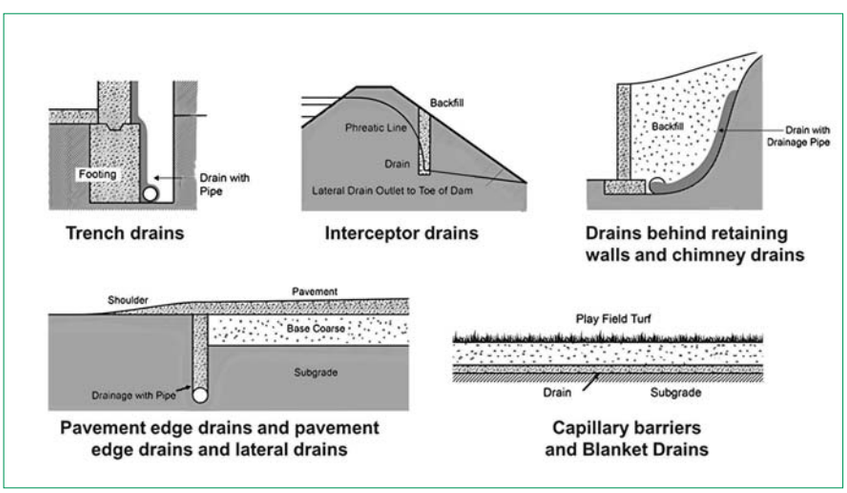


Figure 6 – Uses of geosynthetic drains in road constructions, embankments and walls (reference FHWA-NHI-132013).

underlying soil layers, increasing overall strength and stability, minimizing settlement and deformation in weak soils, enhancing drainage, and providing cost-effective solutions through reduced material usage and simplified construction processes. This chapter is particularly enriched with case histories and design examples.

6. Geosynthetic Barriers and Seepage Control Systems (Kent von Maubeuge)

Mr. Kent von Maubeuge wrote the chapter on seepage control systems. He has been involved in the geosynthetics industry for more than 40 years with Naue in Germany, where he has held multiple roles including Communications Director and Senior Product Manager. Over several decades, Mr. von Maubeuge has been a strong advocate for geosynthetics. He has served actively with various engineering professional associations and standards bodies, such as DIN, CEN, ISO, the Geosynthetic Institute and ASTM International. He has also served on the IGS Council, helped establish the IGS Technical Committee on Barrier Systems, and contributed numerous papers and lectures to technical conferences and professional societies around the world. For more than 20 years, he has lectured in engineering at the University of Applied Sciences in Ostwestfalen-Lippe and for the past 10 years he has also lectured at the University of Applied Sciences in Bielefeld.

Mr. von Maubeuge's chapter on geosynthetic barriers in seepage control systems focuses specifically on applications for ponds, reservoirs, canals, levees, and dams (Figure 9 and 10). He emphasizes the importance of installation quality and provides detailed design considerations for geomembranes and geosynthetic clay liners (GCLs). Key topics covered include:

– Manufacturing Quality Control
– Quality Assurance Testing
– Transportation and Storage Quality Control
– On-site Verification and Field Testing
– Installation Quality Control and Construction Quality Control
– Documentation and Record-Keeping

Mr. von Maubeuge concludes with a checklist for successful installations, contrasting it with case histories of failures due to overlooked protocols. This practical overview serves as a guide to current best practices in installation and construction.

7. Environmental Protection (Kerry Rowe)

Dr. Rowe is University Distinguished Professor and Canada Research Chair at Queen's University, Canada. He holds two bachelor's degrees and a doctorate from the University of Sydney. His advances to research and development in the

Figure 7 – Embankment erosion control with Turf Reinforcement Mat (TRM).

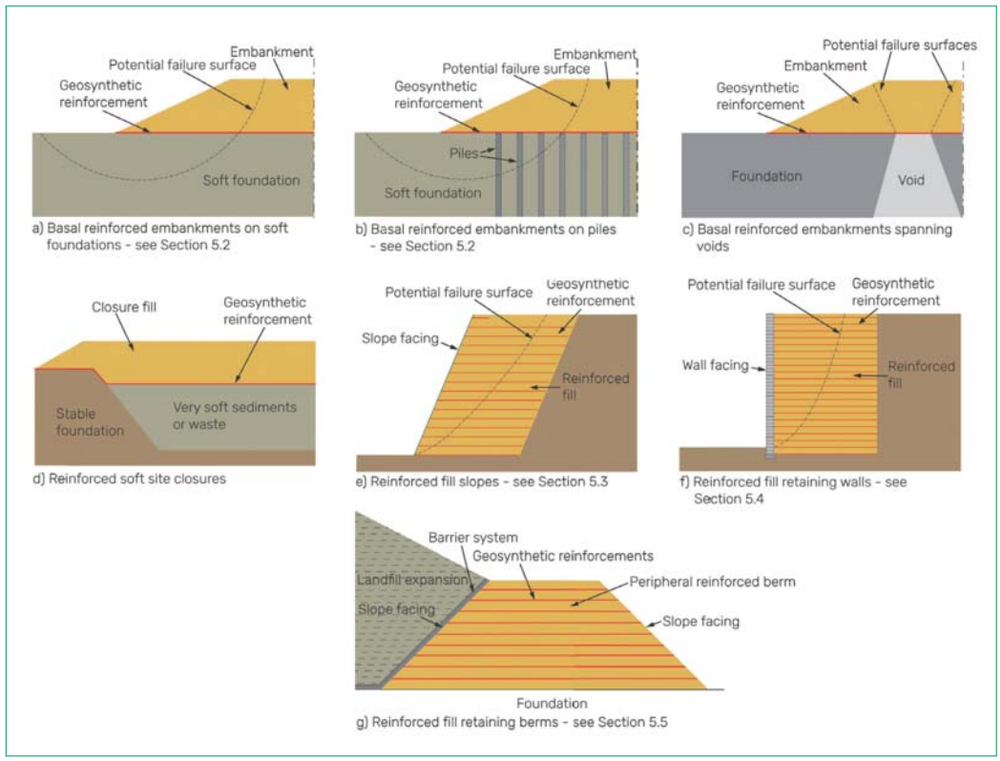


Figure 8 – Reinforced soil applications using geosynthetic reinforcement (geogrids)

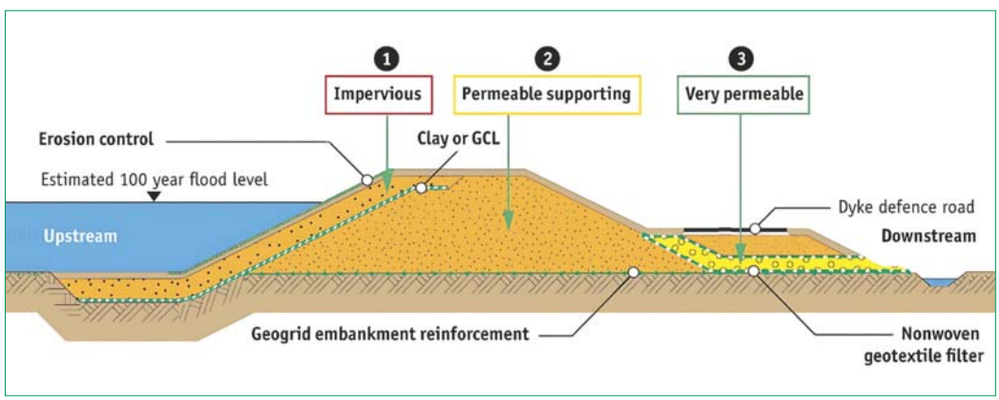


Figure 9 – Cross section of a 3-zone river levee implementing geosynthetics (reference Naue).

Figure 10 – Installation of a geosynthetic clay liner and a leakage collection geosynthetic drainage mat, as well as the cover soil placement in a power water reservoir Thuringen (reference Naue).

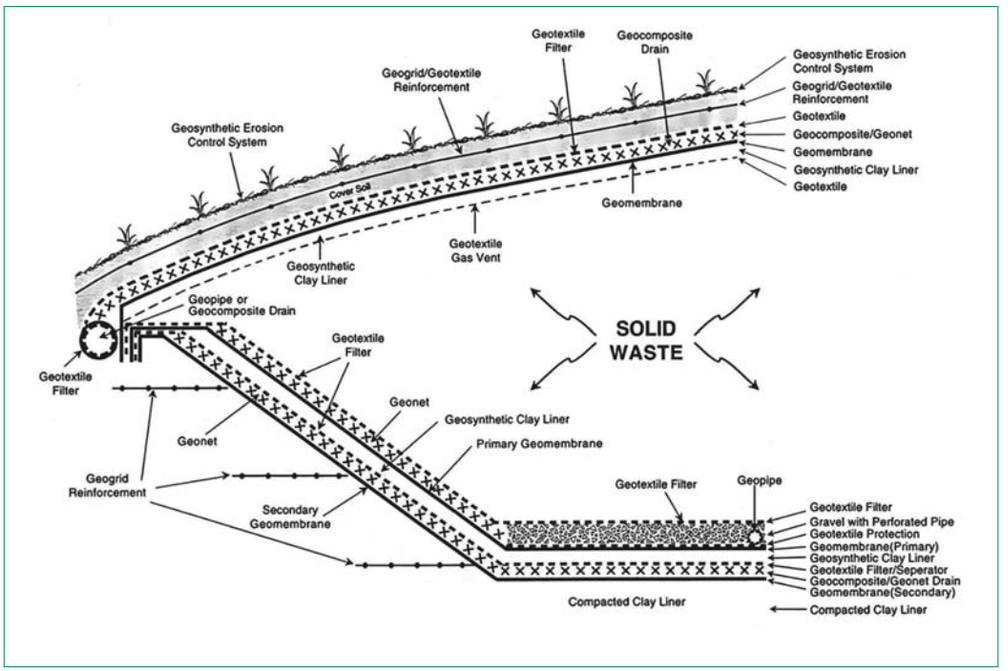


Figure 11 – Geosynthetic materials in landfills, including geosynthetic clay liners, geomembranes, drainage, filters, reinforcement and erosion control (reference Koerner, 2016).

geosynthetic arena have been award-winning. A pioneer and author in the fields of geoenvironmental engineering and geosynthetics, Dr. Rowe is one of the most highly cited geotechnical engineers in the world and is in demand as a keynote lecturer and advisor worldwide. He has more than 440 refereed journal papers, three books, 20 book chapters, and 360 full conference papers to his credit.

Dr. Rowe discusses waste containment via geosynthetics in the environmental protection chapter. He highlights key terms and conditions, such as leachate, advection, dispersion, and diffusion, while emphasizing the importance of groundwater protection. The chapter outlines five essential lessons for successful waste containment:

- The consequences of failure.
- Leachate collection and "nature's revenge."
- The necessity of understanding the system and working with nature.
- The significance of diffusion.
- The critical role of geomembranes, even in the absence of leakage.

It also addresses overarching design questions, such as:

- The geotechnical and hydrogeologic conditions of the proposed site.
- The nature of the material being contained.
- Acceptable levels of leakage or fluid escape.
- The required design life of the containment system.
- Potential environmental changes during the system's lifespan.
- Possible failure points and unintended consequences.

The chapter provides detailed sections on landfills (Figure 11), mining, industrial effluent impoundment lagoons, remediation sites, examining vapor barriers, cutoff walls, spill containment, and liners for contaminated soil.

8. Geosynthetics Support Systems (George Koerner)

Dr. Koerner concludes the document with a comprehensive chapter that highlights stakeholders, manufacturing standards, practices, guides, test methods, specifications, and regulations.
The intent of the IGS handbook is to record and expand on the functions and applicability of geosynthetics in an archival format for posterity. It emphasizes the "Quality System Approach" for all projects involving geosynthetics, which includes:

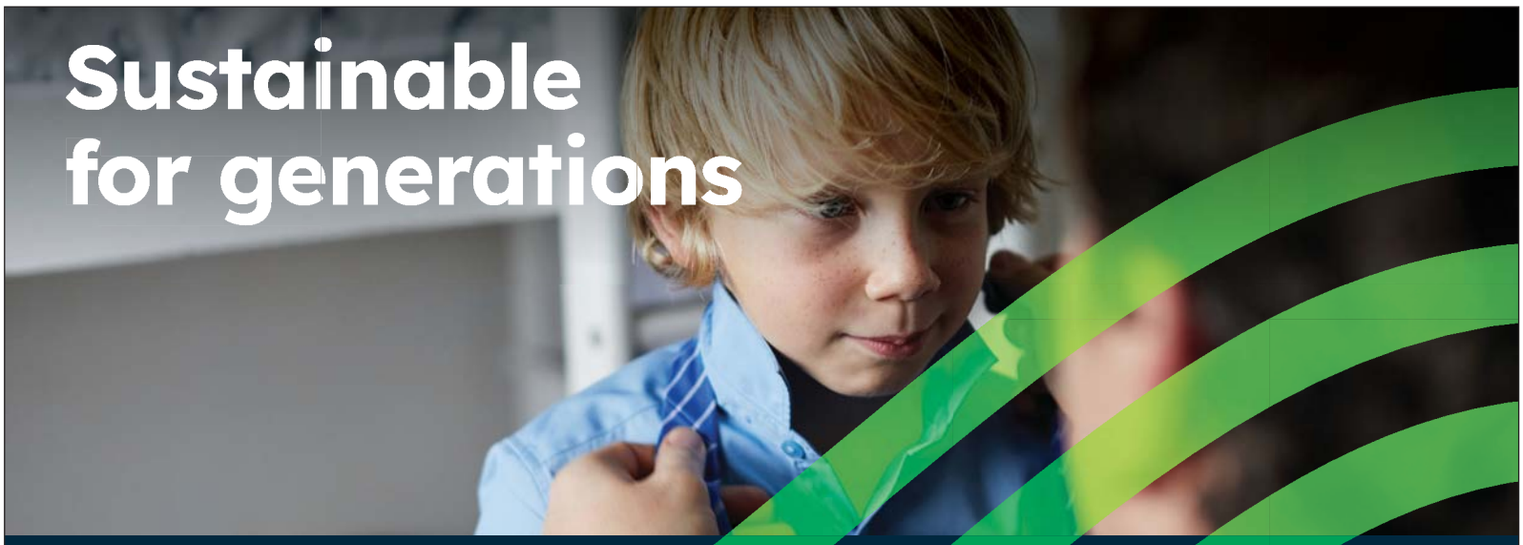
- Good design
- Quality materials
- Accredited testing
- Certified installation
- Quality assurance
- Performance testing prior to commissioning
- Ongoing operation and maintenance

Implementing such a quality system leads to facilities with excellent performance that the public can embrace. Furthermore, it allows for innovation while holding stakeholders accountable. This structured approach improves organizational effectiveness, reduces operational costs, and enhances customer satisfaction. Key benefits include waste minimization, risk reduction, improved efficiency, and enhanced product quality through continuous improvement and standardization.

Final words

The IGS Geosynthetic Handbook, drafted by some of the industry's leading practitioners, serves as a one-stop technical reference suitable for all levels of experience in geosynthetics. It offers a concise yet comprehensive summary of the fundamental applications of geosynthetics, making it an essential reference guide for students, instructors, and civil engineering professionals.

More information on the IGS Geosynthetic Handbook can be found on www.geosyntheticssociety.org/membership-account/shop-igs-geosynthetics-handbook/ or follow the QR-code to the IGS-website. ●



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