



# TRANSPORTATION INFRASTRUCTURE

Solutions overview



Progress through performance  
A **Low & Bonar** solution

# The future of transportation and infrastructure



**Transportation** is one of the key sectors of civil infrastructure and faces a series of unique challenges as global mobility and trade continues to increase in the face of pressure to reduce the environmental impact of our activity.

The 20th century saw the birth and growth of public transportation with the developments of rail networks and then the increasing shift to private vehicle ownership and the increase in use of air travel.

Projections from the Organisation for Economic Co-operation and Development (OECD) and International Energy Agency (IEA) predict that private vehicle numbers and journeys will more than double between 2015 and 2050. Similarly, air travel is predicted to treble to over 15 trillion passenger kilometres by 2050.

The environmental impact of increased travel demand would be a 70% increase on current figures if mitigation measures are not implemented. Increased fuel efficiency, hybrid vehicles and urban transport policies focusing on public transport are expected to provide some of the reductions required, but the infrastructure to carry the increasing number of passengers will need to be addressed.

In industrialized nations the infrastructure is already in place and the growth figures are not as rapid as in developing nations but the existing infrastructure is already operating beyond capacity and as a result, increasing delays pose their own problems, to the environment and to society. Engineering needs to provide new and innovative solutions to address these issues through road and rail widening and increasing the efficiency while reducing the maintenance demands on existing infrastructure.

Similarly airport infrastructure needs to be improved to provide increased space and mitigate the environmental impact of the increasing volume of air traffic.

In developing nations new modern infrastructure is needed to carry the volumes of traffic generated by increasing urbanization and volumes of global trade; this amounts to the need for millions of kilometres of new or improved road and rail infrastructure between the urban centres and innovative means of increasing the capacity of existing urban roads and airports to carry higher volumes of traffic.

The volume of new infrastructure work and the need to increase capacity on existing routes is compounded by the need to reduce the environmental impact of both the work and the increasing volume of traffic. Future infrastructure demands need our projects to demonstrate not only cost and time savings but also to reduce the whole life carbon footprint of projects by a minimum of 50%, and many nations are beginning to include these requirements within all new procurement documentation.

**” At Low & Bonar, we are proud that our geosynthetics have a long history in road, rail and airport work. And that the necessary cost, time and environmental savings required for the sustainability of our infrastructure have been delivered time and again on all these projects in all areas of geosynthetic application.**

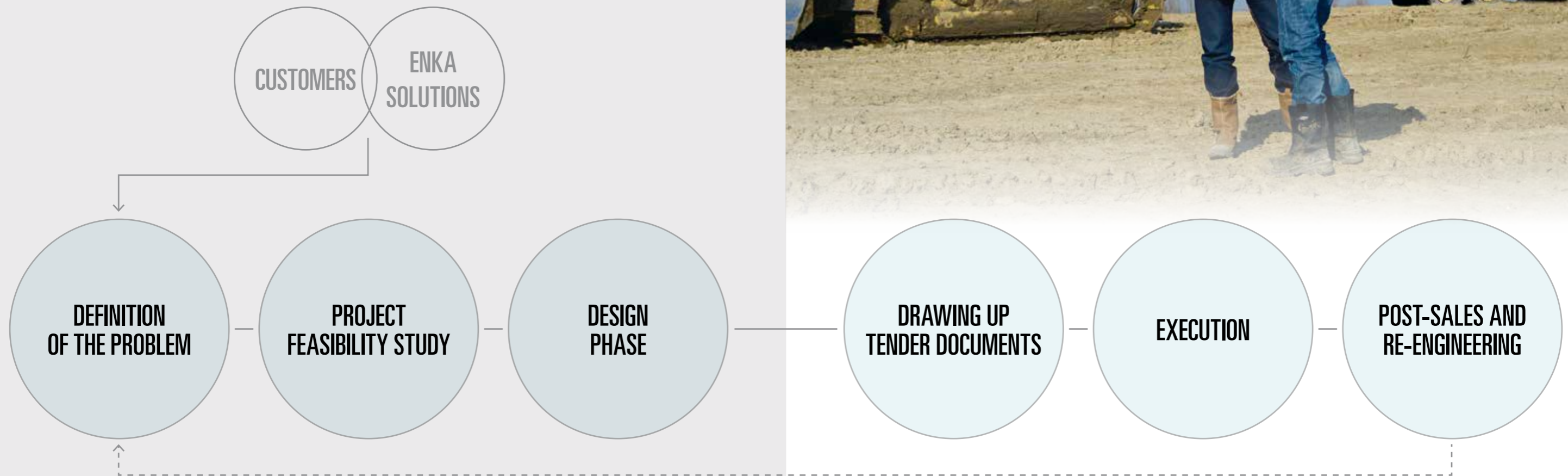
## Index

The future of transportation and infrastructure	3
Our project approach	4
Our solutions for all your transportation infrastructure needs	6
<b>Applications</b>	
1. Roads and working platforms	8
2. Asphalt reinforcement	10
3. Reinforced soil structures	12
4. Railway support	14
5. Edge drainage	16
6. Drainage for earth retaining structures and bridge abutments	18
7. Embankments on weak soils and areas prone to subsidence	20
8. Vibration damping	22
9. Erosion control	24
10. Improved durability of concrete	26
<b>References</b>	
Earthquake-proof embankments Mediterranean Bypass, Morocco	30
Soil Consolidation Marmaray City Train station, Republic of Turkey	32
Railway viaduct SEA High Speed railway, France	34
Enka Solutions product overview	36
Our areas of expertise	37
Enka Solutions values	38



# ENKA SOLUTIONS PROJECT APPROACH

We monitor and supervise your project from the initial definition of the problem all the way through to the post-sales phase. Our specialist engineers will provide the appropriate type of support required for each individual step of your project.



From our many years of **international experience**, our specialists have accumulated the necessary expertise **to provide all the support you need** with regard to defining a problem and to gathering the necessary data that will lead to the creation of the appropriate framework.

We provide **advice and contribute possible solutions** for specific problems or applications. If desired, we can also provide training on specific topics associated with the use of geosynthetics in civil engineering.

In this phase we work out the best possible solution in conjunction with the customer. We provide **tailored advice** by means of calculations for the **all-round solution** and delivering drawings, sketches and models. An optimal mix of products is sought for the specific situation, including the relevant cost calculations.

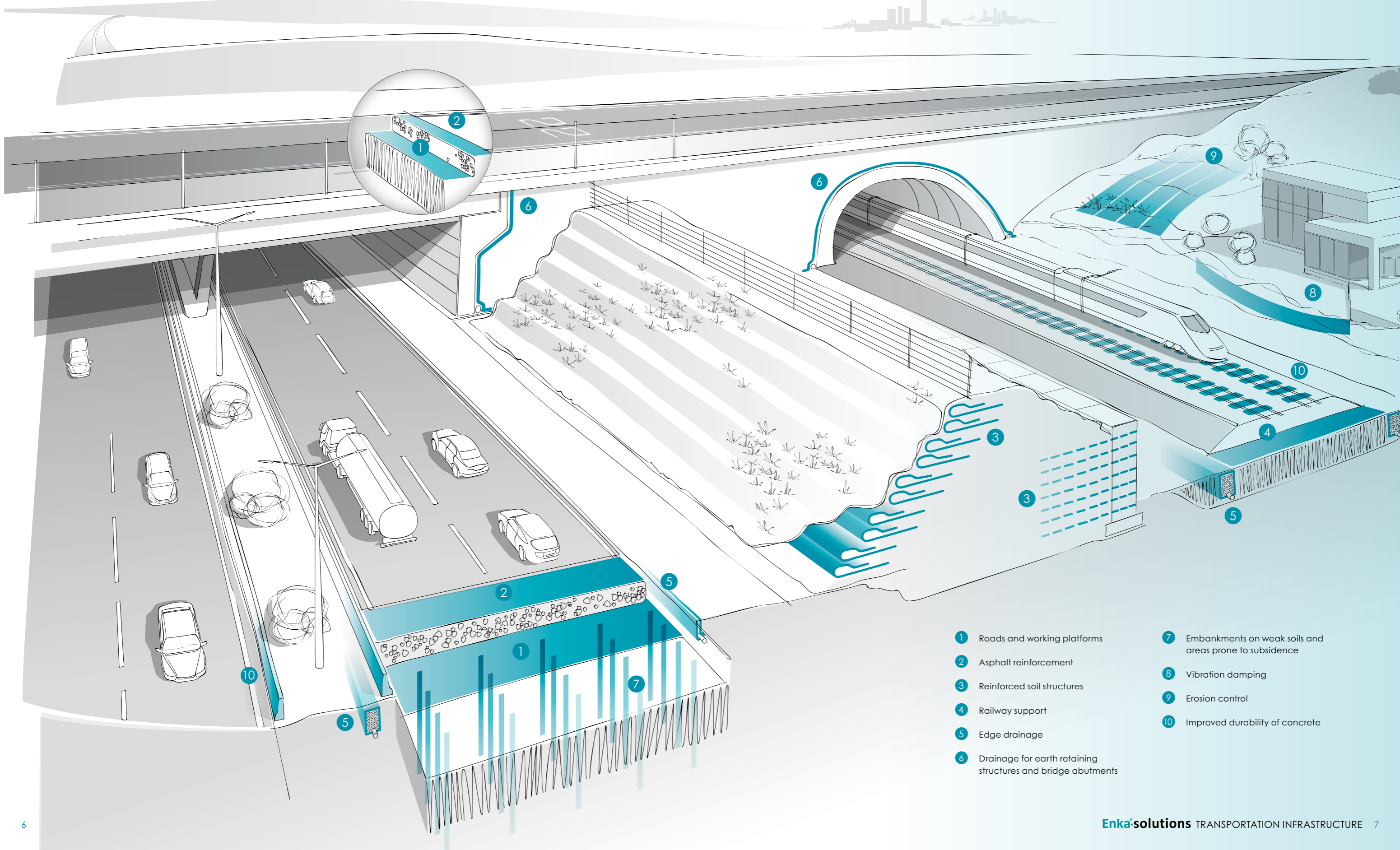
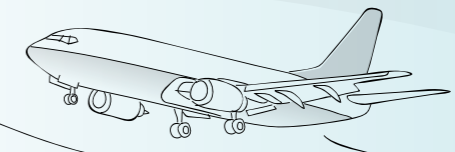
We can either deliver **standardised specification documents and drawings**, or draw up a set of **project-specific installation instructions**.

We prepare for the **execution of the project** by providing clear installation instructions. If desired, we can also organise **project-specific installation training sessions**. Our customers can also rely on on-site support.

Once the project has been completed, we will be happy to assist our customers with any future challenges. We make use of the expertise gained during the execution of specific projects to further streamline our solutions and develop new products.



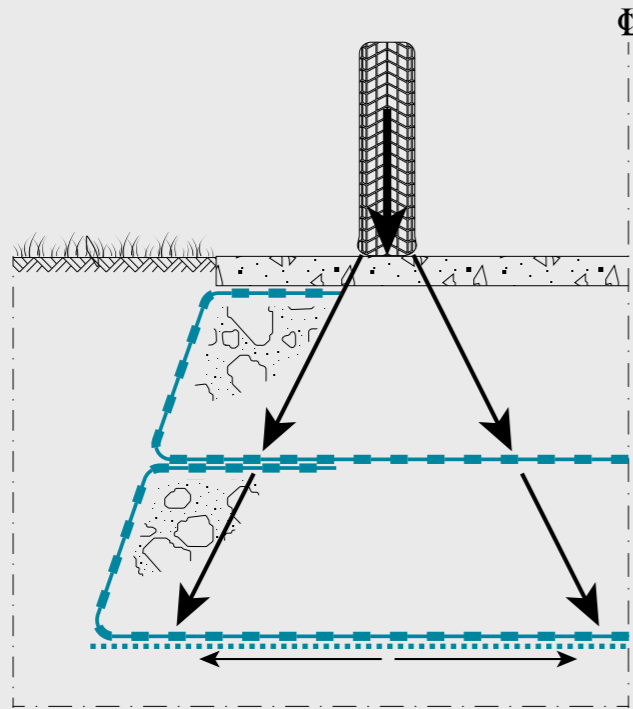
# Our solutions for all your transportation infrastructure needs



- 1 Roads and working platforms
- 2 Asphalt reinforcement
- 3 Reinforced soil structures
- 4 Railway support
- 5 Edge drainage
- 6 Drainage for earth retaining structures and bridge abutments
- 7 Embankments on weak soils and areas prone to subsidence
- 8 Vibration damping
- 9 Erosion control
- 10 Improved durability of concrete

# 1. Roads and working platforms

Stability of the soil on which infrastructure is to be built, is a first and foremost criterion. We provide solutions for **reinforcing foundations and subbases over weak soils.**



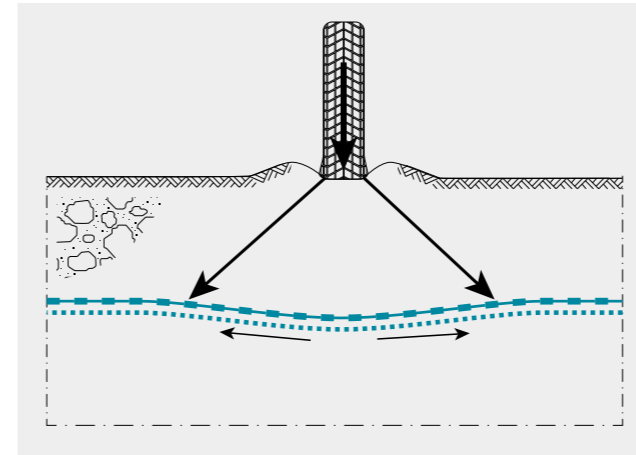
Depending on the local soil parameters, long-term reinforcement can be obtained by single layers of geosynthetics, or in case of extremely weak soils by a wraparound system. Our design team will advise on the optimal solution with the Enka Solutions range of geosynthetics.

**For roads, railways or airports** built over variable depths of poor subgrade material it is possible to utilize geosynthetics to reinforce the subbase material in order to reduce the amount of granular material necessary to produce **a stable surface or to significantly increase the maintenance** interval and surface durability. Our biaxial geogrids or woven reinforcements provide the reinforcement necessary to **reduce rutting depth** on unsurfaced roads or **minimize deformation** of permanent surfaces.

Nonwovens or geocomposite materials can be used to **ensure the segregation of the subgrade and subbase** and to prevent the pumping of fine soil particles. Recommended solutions for constructions of roads and railways are always **based on specific project needs.**

FUNCTIONS:

- Filtration
- Reinforcement of foundations
- Separation
- Subbase stabilization

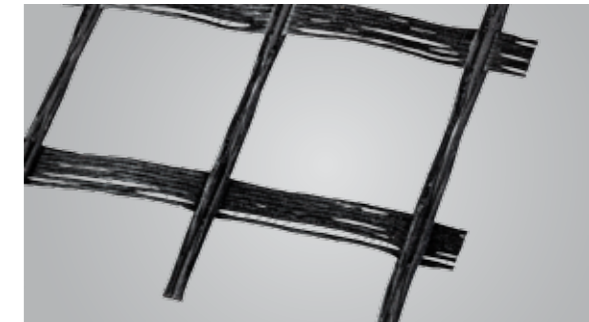


Rutting on unpaved roads is effectively minimized with geosynthetics reinforcing the subbase and separating the subbase and subgrade.

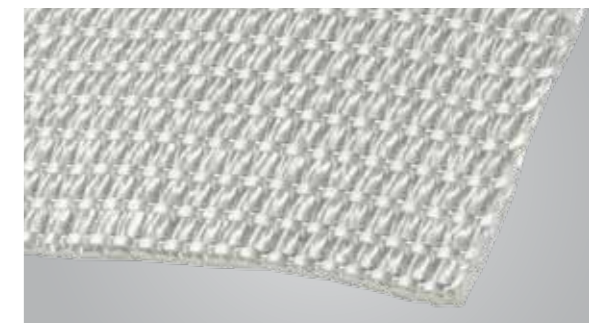
- Relevant products:
- Enka®-Tex wovens
  - Enka®-Tex nonwovens
  - Enkagrid® MAX
  - Enkagrid® G and M
  - Enkagrid® MAX C
  - Enkagrid® PLUS G and M
  - Enkagrid® TRC
  - Enka®-Force G and M



Enkagrid® MAX



Enkagrid® G

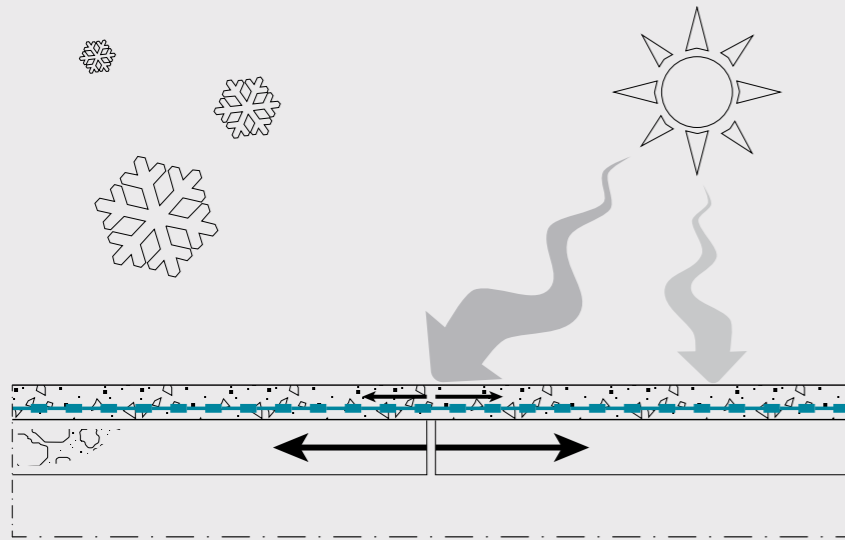


Enka®-Force G



## 2. Asphalt reinforcement

Asphalt surfacing provides a durable, low-noise, permeable road surface but unfortunately it can be prone to **cracking and wear due to external forces** including traffic load, movement of the subgrade material and seasonal temperature fluctuations. The cracking and wear of the surface has an impact on ride comfort and safety, with the maintenance required adding significantly to whole life costs and carbon footprint.



Reflective cracking of the base layer induced by thermal effects will be reduced by using Enkagrid or Enka-Tex for asphalt reinforcement.

**Asphalt reinforcement** is proven to extend fatigue life and increase the maintenance intervals of asphalt pavements.

**Asphalt reinforcement** works in three distinct ways. First, it **reinforces asphalt** by giving it the tensile strength needed to significantly delay the occurrence of cracks and maintain granular interlock after cracking has occurred.

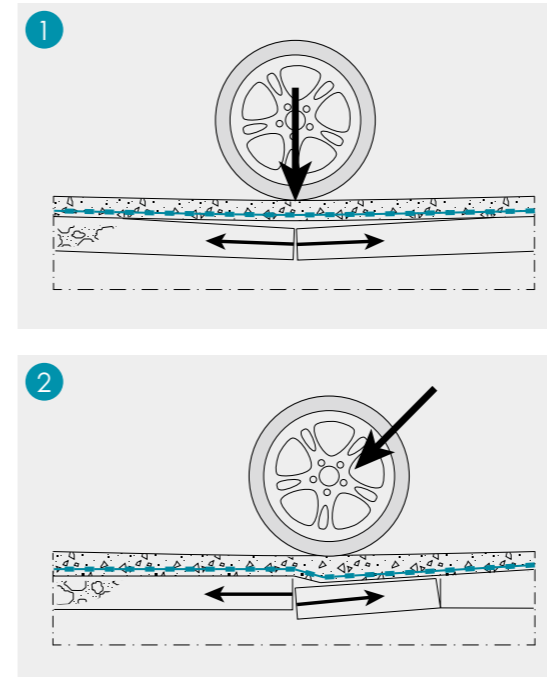
Secondly, it **reduces the effect of stress** and prevents reflective cracks

from propagating up from the high stresses at the bottom of the pavement or down from the surface.

Last but not least, it works as an **impermeable barrier within the asphalt layer** that directs the flow of rainwater to the road edge drainage, preventing infiltration into the subbase and the resultant freeze/thaw damage, loss of bearing capacity and pothole development.

FUNCTIONS:

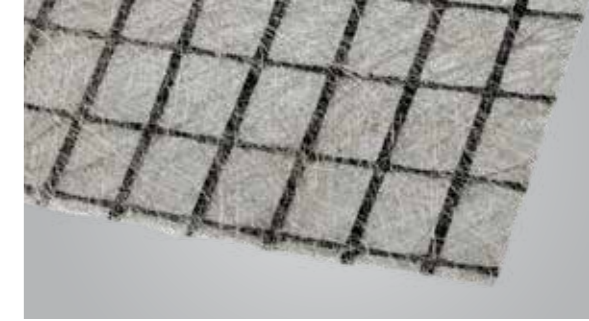
- Reinforcement of asphalt layers
- Repair of asphalt layers
- Water tightening / sealing of asphalt layers
- Reducing maintenance



The cracking and wear of the surface caused by bending ① and shear ② has impacts on ride comfort and safety. Enkagrid contributes to lowering the maintenance cost of highways and roads by reducing these effects.

Relevant products:

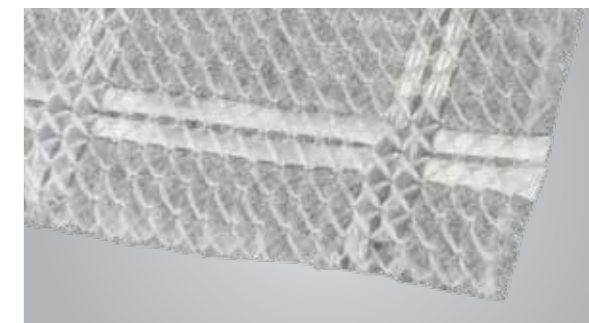
- Enka®-Tex nonwovens
- Enkagrid® PLUS G and M
- Enkagrid® TRC



Enkagrid® TRC



Enka®-Tex nonwoven

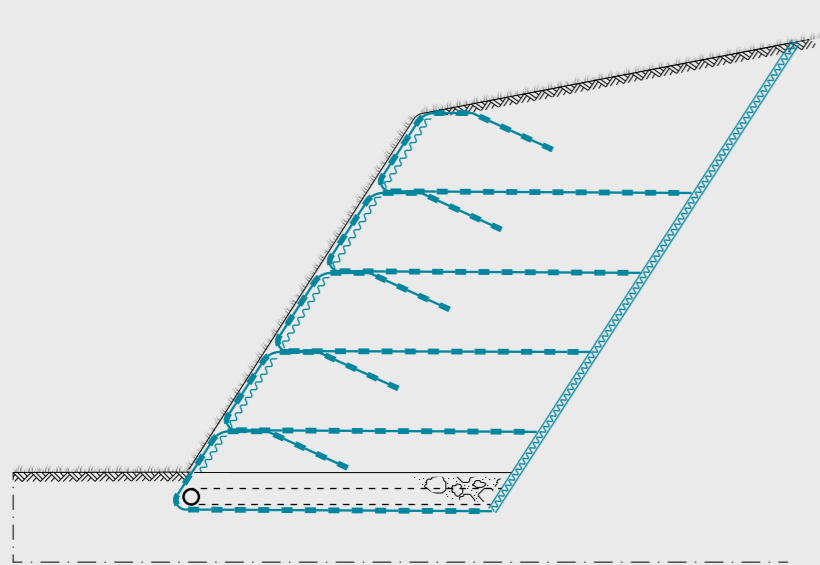


Enkagrid® PLUS G



### 3. Reinforced soil structures

Whether widening existing road or rail corridors to increase capacity, stabilizing existing embankments in both cut and fill or creating new infrastructure, the need to **minimize the land space needed** for the works and **reduce the need for removal of in situ materials and import new materials** is key to delivering **cost-effective and sustainable** schemes.



Enkagrid G and PRO are used to provide internal stability for the soil mass within reinforced steep slopes. Micro stability of the facing soils and vegetation support can be provided with Enkamat or HF wovens with the vegetation established to ensure the finished structures blend into the environment.

**Reinforced soil slopes**, noise and sight bunds, walls and bridge abutments are proven techniques which enable construction at a much greater rate than traditional techniques, with **significant cost savings and environmental benefits**. For slopes up to 1:1, layering of reinforcement can enable the reuse of site-won materials whilst erosion control mats enable the establishment of vegetation and offer **long-term prevention of surface erosion**. Steeper slopes up to 70° from the horizontal can be built with layered reinforcement and either a wraparound or integral mesh facing, reusing site won fill and enabling the establishment of surface vegetation or installation of stone facings. Steeply sloping vegetated bunds are often used alongside infrastructure

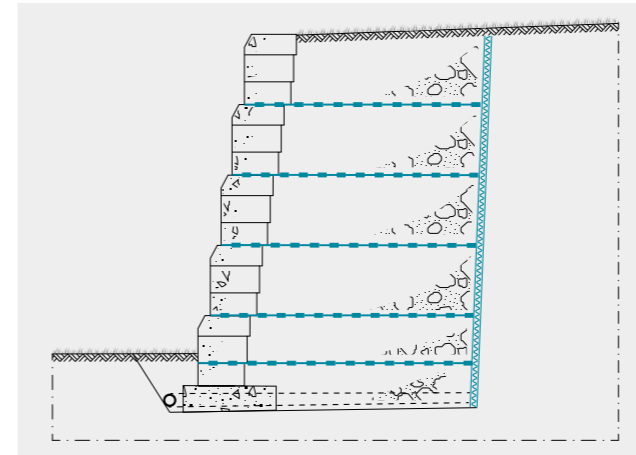
projects in urban environments to **minimize the visual and noise disruption posed by the traffic**; the use of steep slopes instead of rigid barriers enables reuse of surplus site won fill materials reducing exportation to landfills whilst the face angle and vegetation provide better noise absorption and dispersal than rigid faces.

For walls and bridge abutments the same layering of reinforcement combined with steel mesh facing, modular concrete blocks or thin concrete panels can be used to build vertical faces whilst **the designs can accommodate high surcharges** including bridge bank seats or vehicular parapet walls. Conventional solutions such as gabions, mass concrete, concrete

cantilever, crib or piled walls all work by passively resisting the soil's self-weight. The distinct advantage of reinforced soil solutions is that they are **internally stabilized** with the reinforcement's tensile strength being mobilized by the self-weight of the soil and surcharge loads

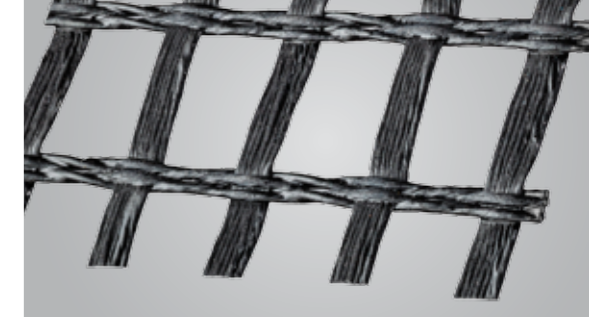
**FUNCTIONS:**

- Reinforcement of steep slopes and earth wall structures
- Drainage of retaining walls or embankments
- Erosion control to slope faces
- Vegetation support



Blockwalls are an economical and esthetical alternative to traditional mass concrete and steel shaped retaining structures. Additional to the Enkagrid reinforcement, Enkadrain secures the dry constant soil parameters to further increase the stability of the structure.

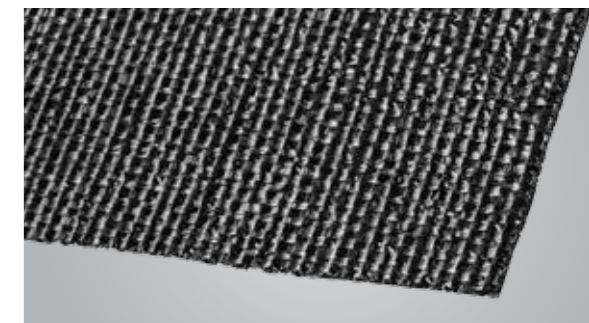
- Relevant products:
- Enkagrid® PRO
  - Enkagrid® G and M
  - Enkagrid® PLUS G and M
  - Enka®-Tex wovens
  - Enka®-Force G and M
  - Enkamat®
  - Enkamat® J
  - Enkamat® W
  - Enkadrain®



Enkagrid® G



Enkagrid® PRO

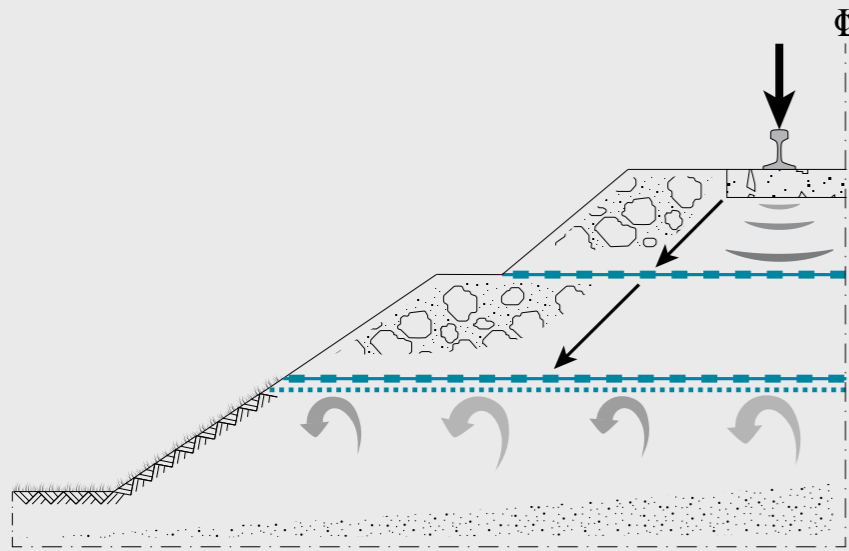


Enka®-Tex woven



## 4. Railway support

Passage of train wheels on a railway track causes a dynamic vertical load on the sleepers and ballast. This pumping action can cause subsoil to be pumped upwards into the ballast foundation, with the subsequent reduction of its bearing capacity.



The pumping effect of dynamic loads is strongly reduced with the use of Enka-Tex. Where local soil demands further reinforcing measurements, Enkagrid will improve the load distribution capacity and, with its interlocking effect, stiffen the soil at grid level creating a soil-geogrid composite.

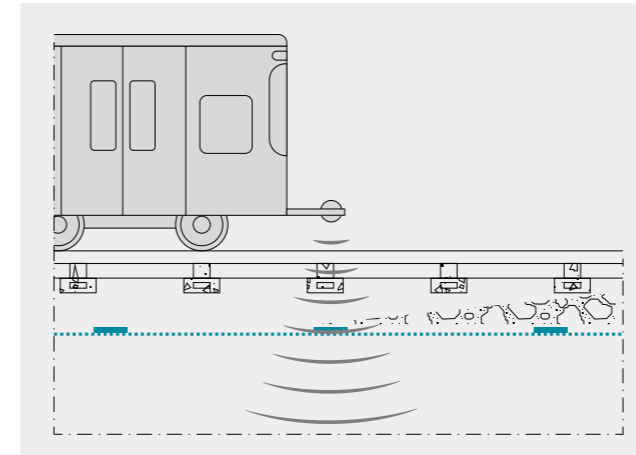
Historically the solution to this has been systematic maintenance work which required raising of the rails and topping up of the ballast, leading over time to a gradual sideways creep of rail embankments.

**Our nonwoven geotextiles resist the upward passage of fine soil particles** helping maintain the bearing capacity and free draining qualities of the ballast. Grids may also be incorporated for ballast or subballast reinforcement to improve bearing capacity over weaker subgrades or to prevent deformation of the ballast.

Additionally the geosynthetics can be manufactured to include a metallic element at regular intervals in the cross machine direction to facilitate nondestructive monitoring of trackbed deformation through the use of electromagnetic detection to assist in systematic maintenance and increase track safety through early detection of subbase movement.

### FUNCTIONS:

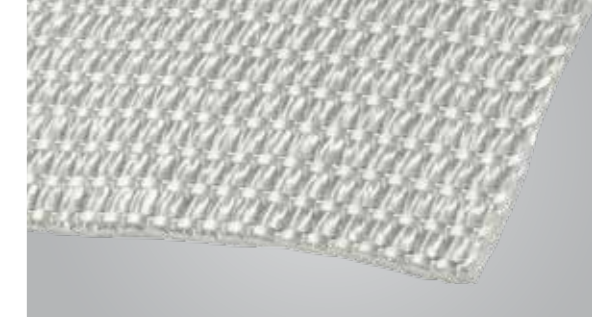
- Separation of ballast and subgrade
- Reduction of the pumping effects on railway tracks
- Ballast and subballast reinforcement
- Reducing maintenance
- Trackbed motion sensing



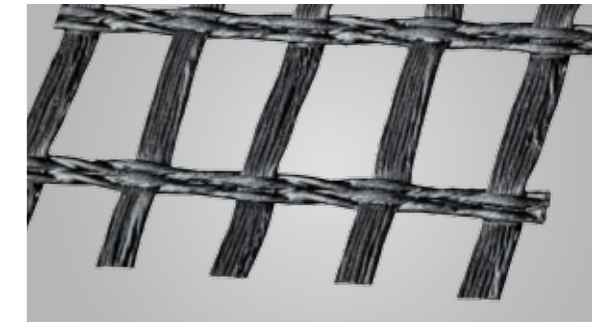
Enka-D-Tect allows for electromagnetic detection of subbase movement and facilitates nondestructive monitoring of the trackbed.

### Relevant products:

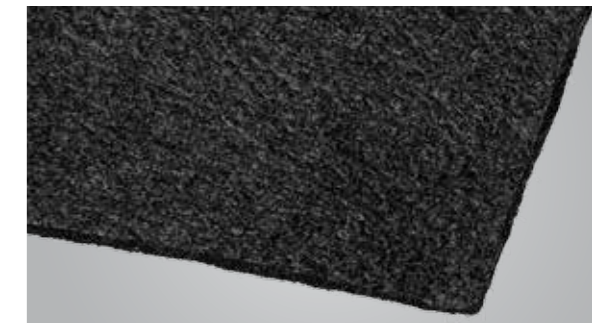
- Enka®-Tex wovens
- Enka®-Tex nonwovens
- Enka®-Force G and M
- Enkagrid® G and M
- Enkagrid® PLUS G and M
- Enkagrid® MAX and MAX C
- Enka®-D-Tect
- Enkagrid® PLUS MC



Enka®-Force G



Enkagrid® G



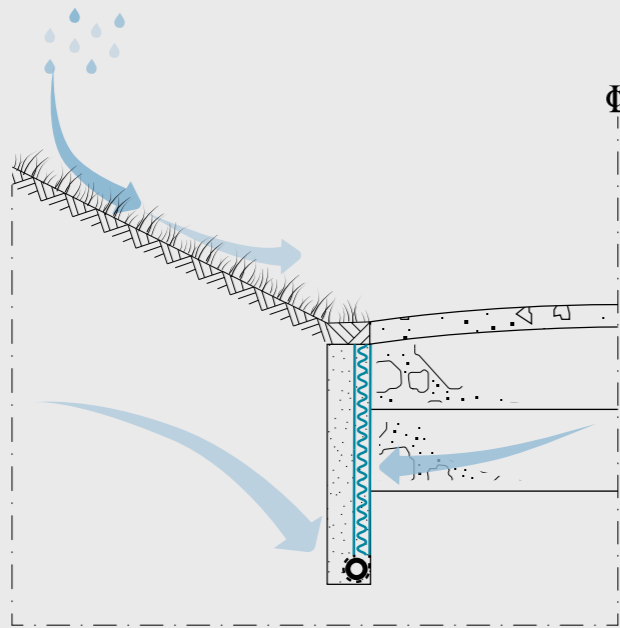
Enka®-Tex nonwoven





## 5. Edge drainage

Water in soil embankments and cuttings **increases pore pressure and reduces the soil's strength** which can have disastrous effects on the structure as a whole. Enka-Tex or Enkadrain Findrain will effectively **protect the structure from damage** caused by the presence of moisture/pore water, thereby greatly increasing the life of the road, as well as reducing maintenance costs.



Vertical interception of groundwater flows by Enkadrain Findrain. Enkadrain Findrain includes a filter and drainage core and eliminates the need for granular fill.

**Effective drainage** at the edge of the trafficked platform and at the top and bottom of slopes and structures is essential in **ensuring long-term stability**.

The conventional solution with French drains involves significant quantities of selected granular material of various gradings to allow the passage of water but prevent the granular fill from silting up, reducing its drainage capacity. Enka-Tex can alternatively be used as a filter layer around a French drain or pipe drain to prevent the siltation of the drain.

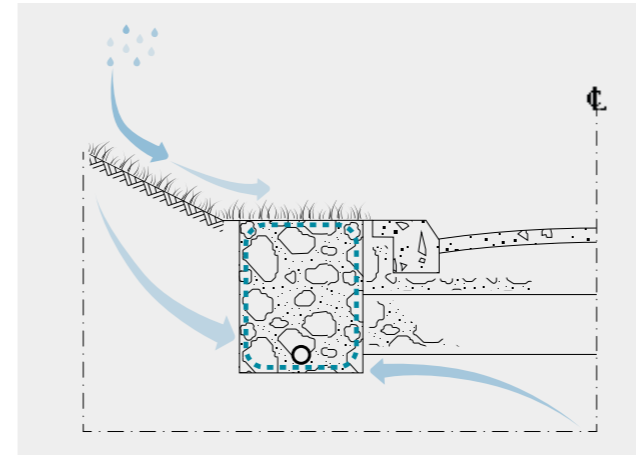
Alternatively for a complete solution Enkadrain Findrain, consisting of a composite drainage core, filter

layer and perforated pipe, acts as a **vertical interceptor of groundwater flows** and as a transporter of this water horizontally to outlets. It is typically nine times more effective than conventional granular fills, i.e. French drains.

Enkadrain Findrain provides **long-life drainage of sub-surface water** and/or run-off from grassed areas. In road construction, Enkadrain Findrain is used to collect water from embankments, cuttings, slopes, verges and road formations. In the latter, Enkadrain Findrain removes sub-surface water quickly, which is of great benefit in **maintaining the formation of the subbase and retaining its bearing capacity**.

### FUNCTIONS:

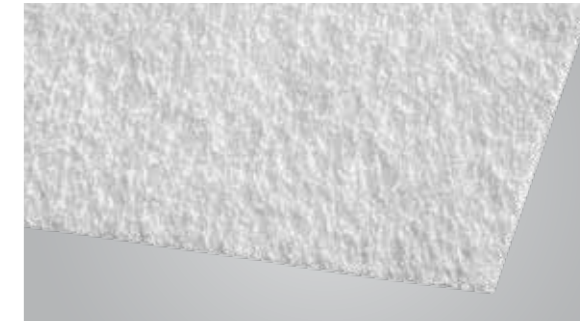
- Drainage with use of prefabricated screens
- Filtration
- Separation
- Improving slope stability



Enka-Tex is used as a filter for French drains, reducing the need for granular fill and preventing the backfill from silting up.



Enkadrain® Findrain



Enka®-Tex nonwoven

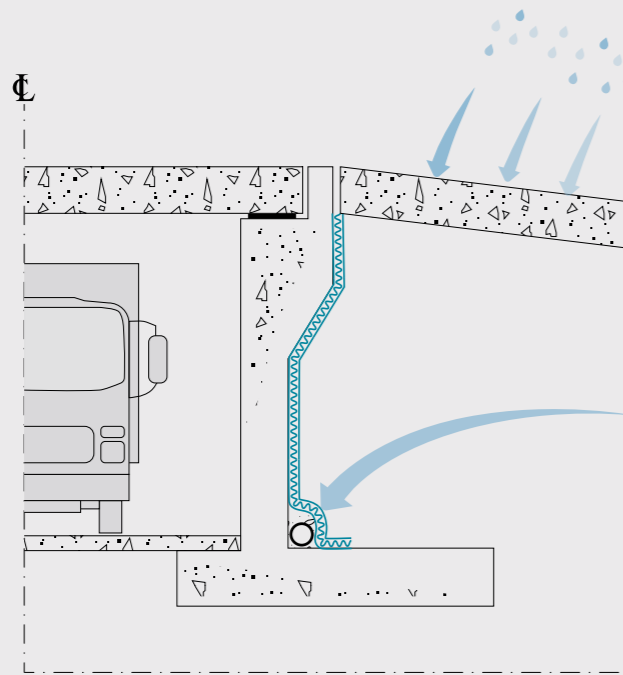
Relevant products:

- Enka®-Tex wovens
- Enka®-Tex nonwovens
- Enkadrain® Findrain



## 6. Drainage for earth retaining structures and bridge abutments

Water buildup behind conventional retaining structures and bridge abutments can increase the applied loading and movements on the rear of the structure and may require thicker structures to resist the loading.



Pressure caused by water buildup is relieved by Enkadrain. Additionally, the use of Enkadrain with one or two filter layers decreases humidity in the concrete.

This pressure is normally dealt with by the introduction of a granular fill or mineral layer behind the structure. This can be expensive and may cause sustainability issues as well as an increase of the construction time required to finish the project. **Long-term performance of granular fill** may also be affected by the intrusion of fine grained soil particles carried by the water from the backfill material.

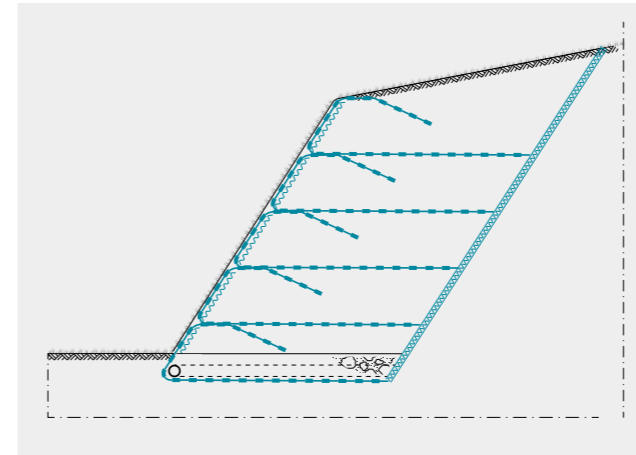
An increase in water volume during construction may cause delays in construction time as this will need to be managed to avoid damage to the temporary works.

The use of Enkadrain geocomposite drainage layers instead of a granular fill offers a variety of benefits.

- **A drainage core with a consistent 95% void** which has a filter material that prevents the intrusion of fine soil particles from the backfill
- It allows for a uniform **movement of water in all directions** through the drainage layer
- It creates an **air layer between soil and wall** to decrease humidity in the concrete
- **Speed of installation** will reduce the construction time required

FUNCTIONS:

- **Drainage with use of prefabricated screens**
- **Filtration**
- **Separation**
- **Protection**



Enkadrain secures the stability of the earth retaining structure, by draining off destabilizing water flows.

Relevant products:

Enkadrain®  
Enkadrain® Wide



Enkadrain® ST



Enkadrain® Wide

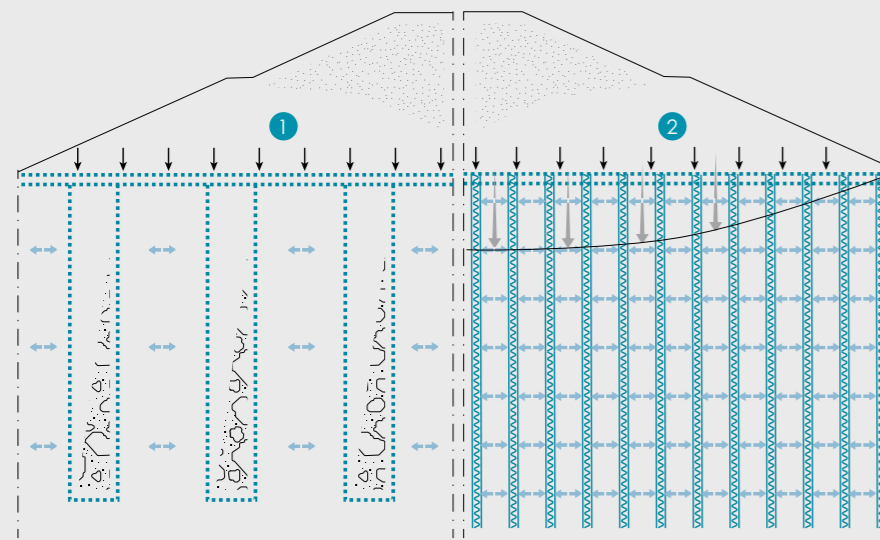


Enkadrain® B10



# 7. Embankments on weak soils and areas prone to subsidence

**Soft foundation soils or potential cavities** under road or railway embankments can cause differential settlements and long-drawn-out consolidation, critical deformations or even insufficient global stability which may lead to deformations in the road or railway structure, stability failures or pose a risk of catastrophic failure. In order to minimize these problems, **preventive measures may be necessary.**



Consolidation of soft soils is accelerated by using Enka-Tube ① or Colbondrain ②. The additional high strength Enka-Force acts as load distributor and membrane layer.

Allowing for consolidation can be a long process (> 25 years) in weak saturated soils under embankments, so to release water and therefore reduce pore water pressure, we must look to shorten the drainage path of the water held in the soil. **Accelerated consolidation is achieved by the use of prefabricated vertical drains (PVD)** to create shorter drainage pathways for groundwater.

Colbondrain prefabricated vertical drain is a geocomposite that resists tears under load during installation to maintain its integrity and therefore **maintain the drainage pathway.** The outer filter fabrics are bonded to the core structure over its entire surface to form a homogeneous geocomposite product.

To drain off the saturated weak subsoil, increase the global stability immediately and get smaller and more even settlements the system of geosynthetic-encased columns (GEC) is another proven method. Due to the seamless finishing of Enka-Tube the undesirable **mixing of the gravel material with surrounding weak soil is prevented.**

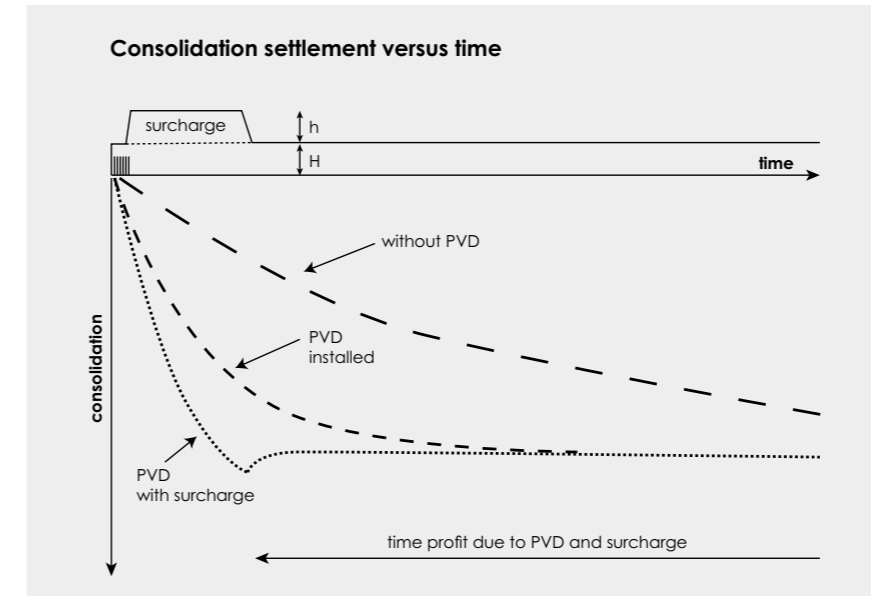
Both applications are recommended to be combined with high-strength woven geotextiles as load distributor layers. Furthermore, in case of a sudden deformation of the subsurface due to cavities, the geosynthetic layer acts as membrane layer and mitigates against the risk of catastrophic failure.

- ① Stone columns are traditionally used to improve bearing capacity and reduce settlements but their degree of vertical support is limited by the passive earth pressure of the surrounding soft soil whilst bulging can substantially increase the quantity of stone required. Geosynthetic Encased Columns (GEC's) resist this bulging and ensure the columns transfer loads vertically with the lateral support being provided through the reinforcement.
- ② Prefabricated vertical drains (PVD) are used to shorten the horizontal drainage path in low permeability soils enabling full consolidation to be achieved in months rather than years.

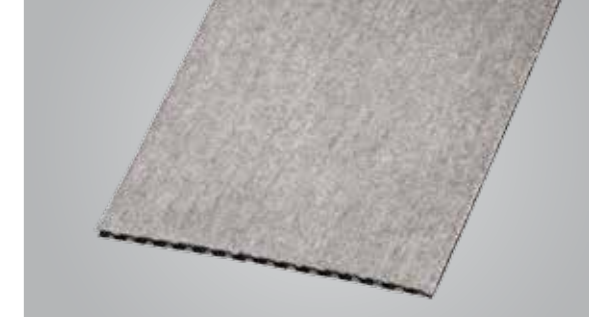
**FUNCTIONS:**

- **Accelerating consolidation**
- **Increasing bearing capacity**
- **Improving embankment stability**

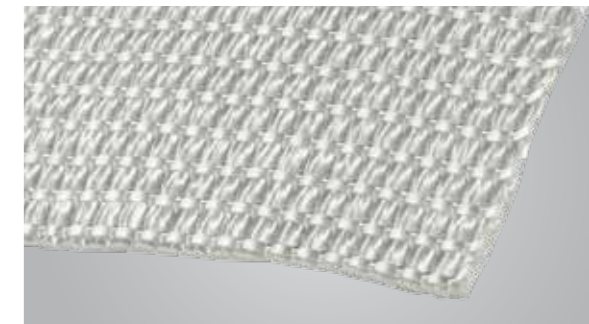
Full consolidation of weak soils can be achieved in months rather than years when using Colbondrain prefabricated vertical drains (PVD).



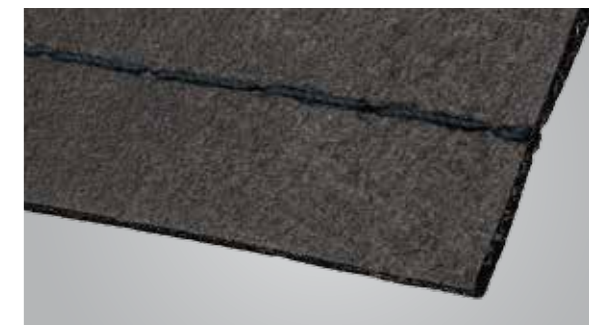
Relevant products:  
Colbondrain®  
Enka®-Tube  
Enka®-Force G and M  
Enkadrain® Wide



Colbondrain®



Enka®-Force G

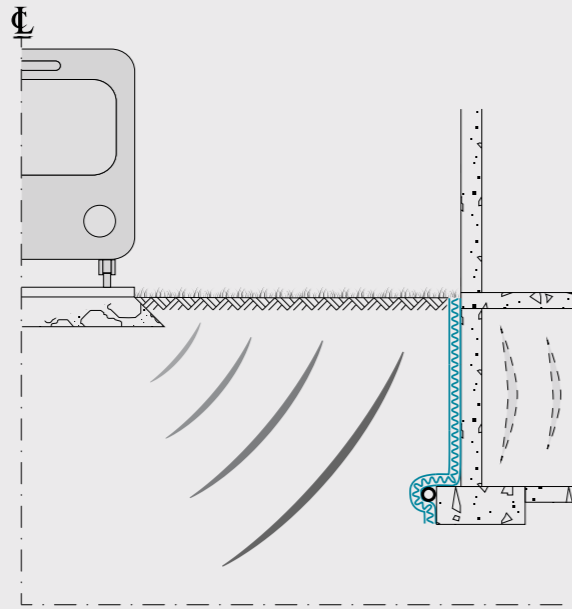


Enkadrain® Wide



## 8. Vibration damping

Road traffic, trains, trams and construction traffic, whether above ground or underground create vibrations that are **transmitted through soil and concrete to adjacent structures**. In densely populated urban areas this can have an **impact on the health and well-being of residents** as well as affecting the value of their property. Routes of new infrastructure must be carefully selected or even moved to reduce these types of impact.



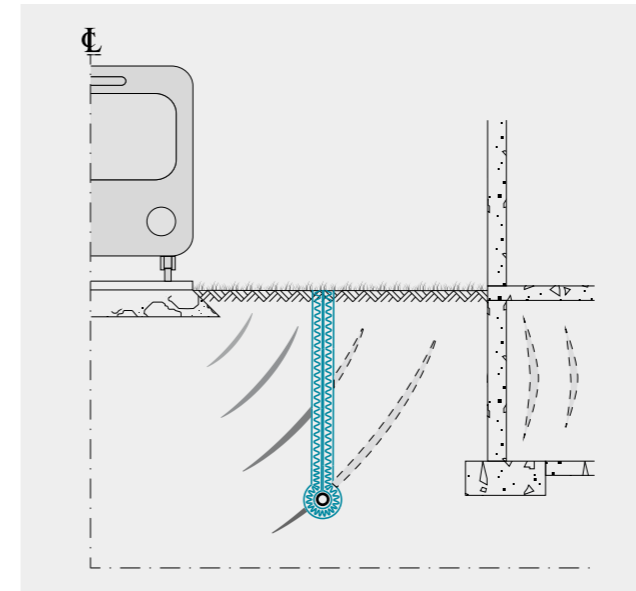
Enkadrain vibration damper directly installed on the building, with additional drainage and protection function, constructed and designed simultaneously with the building or after complaints due to large vibration emission.

The increasingly close proximity of adjacent structures necessitated by increasing urbanization coupled with the presence of sources of vibration including rail, tram and road transport and mixed industrial-residential areas has introduced the need for **innovative and cost effective vibration damping solutions**. Multifunctional geocomposites with cavity-rich polyamide cores coupled with impervious PVC, coated filter or fleece layers onto the sides are one potential solution.

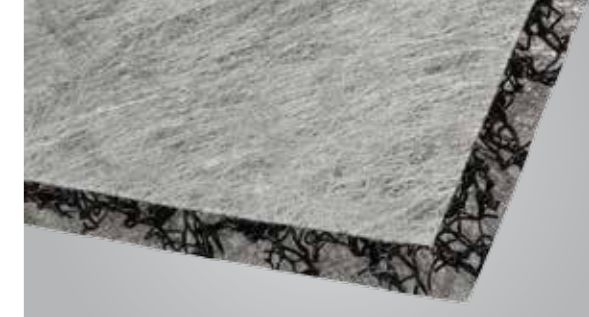
With Enkadrain ST and Enkadrain CK the transmission of horizontal vibration to vertical parts of the building can be reduced. The geocomposite layer can be **affixed directly to the building foundation or used as an absorbent layer** between the source of vibration and the building.

FUNCTIONS:

- Vibration damping
- Vertical drainage
- Lost shuttering when working with in-situ concrete



When appropriate, Enkadrain vibration damper can be installed at any position between the source of the vibration and the building that needs protection.



Enkadrain® ST



Enkadrain® CK

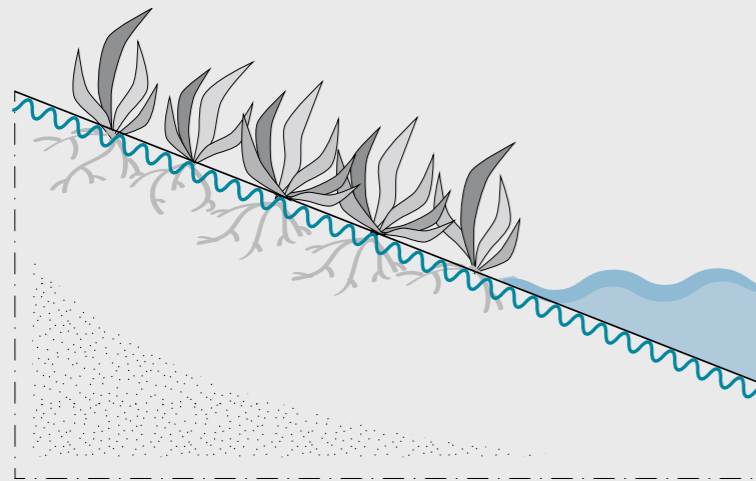
Relevant products:

Enkadrain® ST  
Enkadrain® CK



## 9. Erosion control

The face of a slope and its geometry can be **critical to long-term performance**, and any change to its angle or shape may even lead to failure. Surface erosion is usually a progressive mode of failure with minor pitting of an unprotected soil surface progressing to the formation of runnels which concentrate run-off flow and lead to deeper channels forming an eventual loss of stability.



This failure can lead to delays whilst clearance and repairs are undertaken and could also lead to failure of structures on top of the slope.

**The natural defence against either water or wind erosion is the root matrix of grasses, plants and trees** which serve to hold the soil together. This is only possible after a period of growth time and the slope face will remain unprotected until then.

Our range of Enkamat erosion control products protect the slope immediately after construction by

creating an **artificial root matrix** on the face of the slope, **by protecting the surface from inundation and by locally encapsulating the soil**. The open nature of Enkamat with over 90% voids and high filament density ensures encapsulation of the topsoil. It permits hand seeding, planting or hydroseeding to establish vegetation without impeding root growth or passage of moisture.

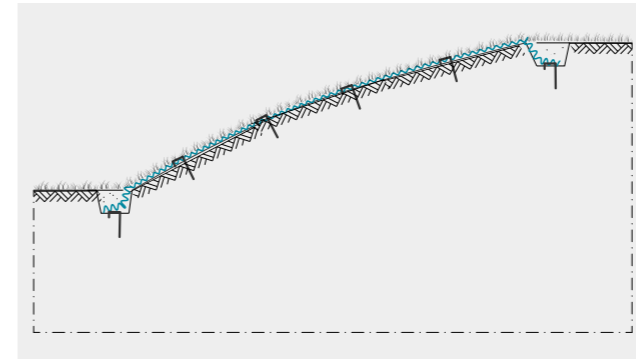
Enka-Net woven materials protect soil surfaces from direct rainfall and **prevent soil from washing out** of the slope face prior to vegetation taking hold.

The three dimensional Enkamat erosion prevention mats provide immediate protection, allow for fast growth of vegetation and offer a long-term strong foothold for vegetation root systems. Protection is permanent and maintenance is not required. Enkamat types are available for protection of dry slopes as well as for water banks.

Armater is an open three dimensional matrix of nonwoven material which, when pegged to a slope surface, physically encapsulates individual cells of topsoil or granular material at the slope surface, intercepting and preventing the continuation of any runnels and **permitting the flow of surface water without allowing the soil to be transported**.

FUNCTIONS:

- Permanent surface stabilization
- Support of vegetation
- Prevention of splash, runnel and gully erosion



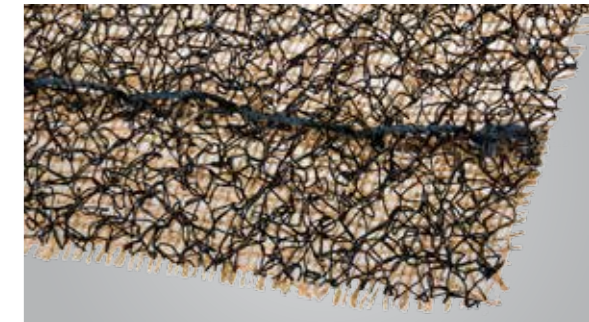
Enkamat is secured in trenches at the slope's toe and shoulder, and is pinned at regular intervals to maintain contact with the underlying soil.

Relevant products:

- Enkamat®
- Enkamat® J
- Enka®-Net
- Armater®



Enkamat®



Enkamat® J

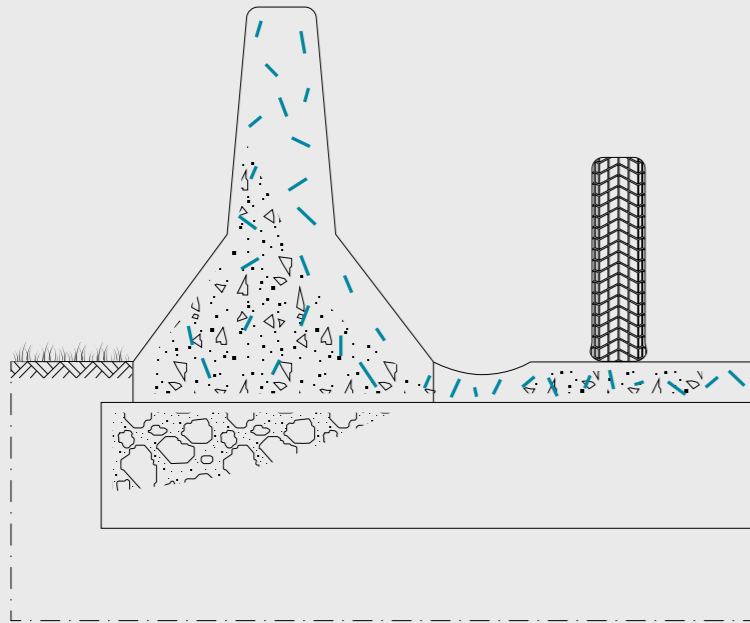


Armater®



# 10. Improved durability of concrete

**Concrete** is the preferred solution for **durable impact-resistant** traffic barriers along the median of major roads and on the parapets above steep embankment slopes or retaining walls. The structures are usually precast or slipformed in situ and contain **high quantities of reinforcing steel** to resist vehicular impact.



Adfil synthetic fibres added to concrete barriers and pavement improve impact and abrasion resistance and freeze-thaw resistance which both increase the lifetime of the concrete.

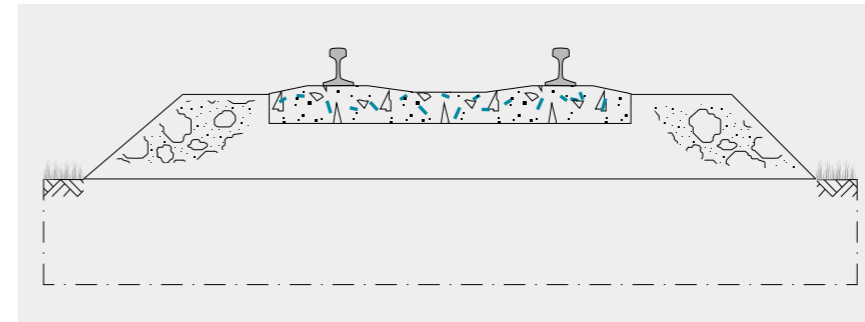
**Concrete** is also used extensively for road decks and carriageway surfacing as an alternative to asphalt-bound surfaces and is the preferred material for precast rail sleepers.

The addition of **synthetic macro and micro fibres** into the concrete in these applications **can eliminate the need for steel reinforcement** which leads to a reduction in cost, faster construction time and lower environmental impact.

Additionally, the fibres serve to reduce the laitance of the concrete, improve freeze-thaw resistance and **significantly improve durability** in terms of impact absorption and abrasion resistance, subsequently reducing cracking and surface spalling. This **improves traffic safety and reduces the need for maintenance and replacement.**

**FUNCTIONS:**

- Reducing plastic shrinkage
- Enhancing residual flexural strength
- Improving freeze-thaw resistance
- Increasing impact and abrasion resistance
- Improving chemical resistance
- Reducing the need for maintenance and replacements of cracked sleepers, barriers, etc...
- Minimizing steel reinforcement



The addition of micro synthetic fibres to concrete used for precast train sleepers improves impact and abrasion resistance while adding macro fibres increases flexural strength.



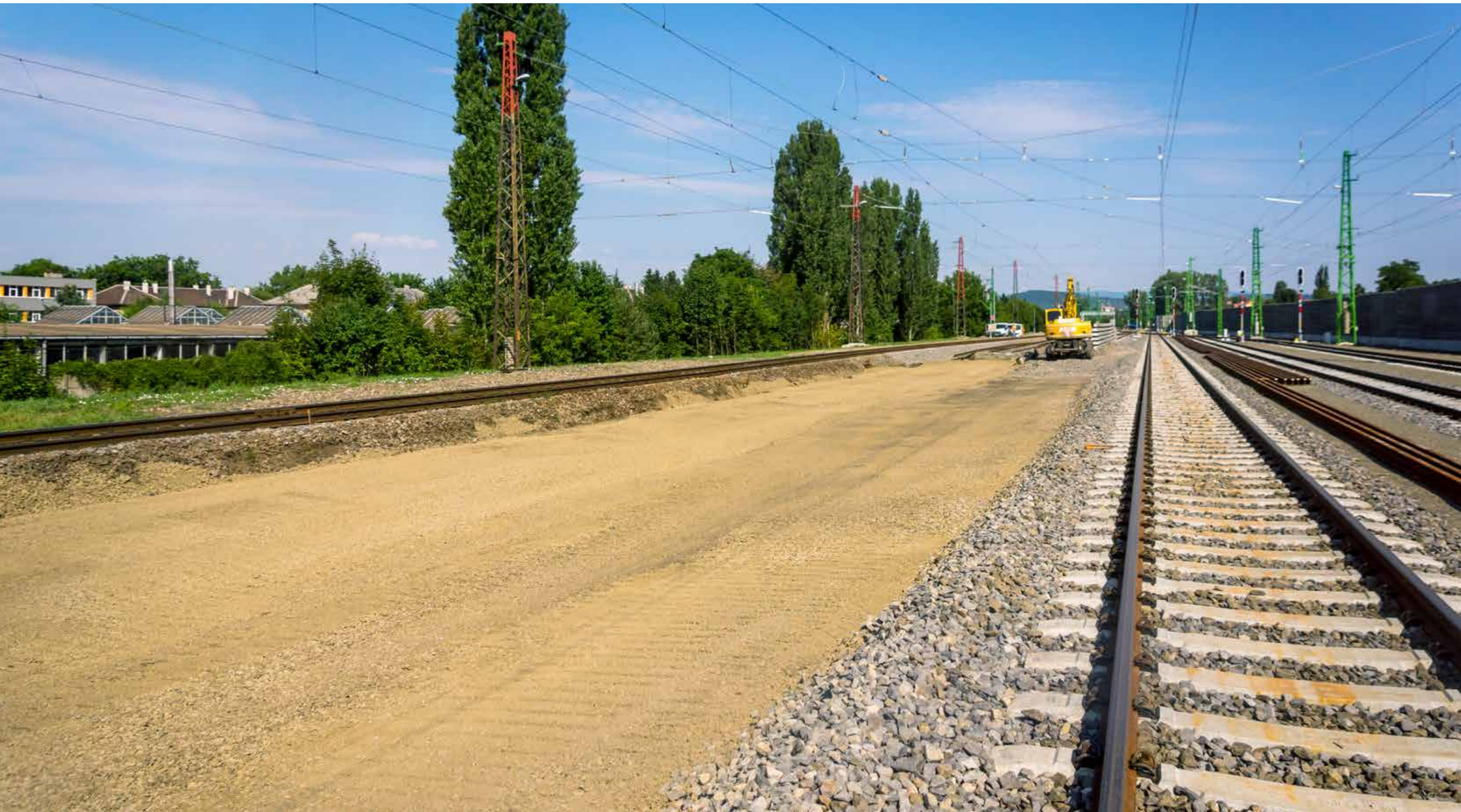
Adfil Durus® macro fibre



Adfil micro fibre

Relevant products:  
Adfil Durus® macro fibre  
Adfil micro fibres





# Earthquake-proof embankments Mediterranean Bypass, Morocco

The construction of the Mediterranean Bypass was a major infrastructure project in the northern part of Morocco and of vital importance for the development of the region. The bypass crosses the Rif region which is known for its high seismic activity and many earthquakes.

### Challenge

Seismicity is considered to be one of the primary causes of instability of embankments, slopes and mountainsides and demands the selection of highly flexible support technique with high inertia to withstand its effects. Moreover, the load applied by the structure on the slope should be as low as possible.

### Solution

The use of earth walls reinforced with Enkagrid PRO geogrids fulfilled these two requirements. In this instance the design called for 35 earth walls with a maximum height of 31 m on Pk 4. All walls have an inclination of 1H/2V and their facing consists of 1m x 1m x 1m gabions filled on site, a nonwoven geotextile ensuring separation and filtration functions between gabions and embankment

materials. The drainage composite Enkadrain Wide was also installed to ensure the drainage of the excavated embankments behind the walls.

### Benefits of the solution

To ensure the earth walls are earthquake-proof, the wall constructions were designed in accordance with the French design standard NF P 94-270 which follows the European regulation Eurocodes. Eurocodes establish a semi-probabilistic approach to safety while applying the principles of limit state calculation with partial factors for the justification of the reinforcing elements. In brief, the effects of loads on internal and external stability are determined through combinations of different permanent or temporary loads in different seismicity or accident-related scenarios, to ensure stability

under the most challenging circumstances.

### Installation benefits

Due to its large nominal aperture size (50 mm x 120 mm), Enkagrid PRO can be installed in all weather conditions, particularly in windy conditions, which was often the case in this coastal environment.

### Result

The project's context (e.g. presence of a house at the toe of the wall PK4) and walls geometry (heights up to 31 m) led to demanding requirements on long term behaviour of the reinforcing material: Enkagrid PRO geogrid offers a postconstruction elongation (from  $t_0 = 10$  h to  $t = 120$  years) limited to 1%. This means that the geogrid elongation during the wall service life will not exceed 1%.



Levelling/compaction of the filling, gabions being used as well as temporary formwork, Enka-Tex pending layer on the gabions



Harsh conditions require an Enkadrain with high tensile strength and puncture resistance



Enkagrid layers pending the levelling and compaction of soil layer



Enkagrid retaining solution minimised the load on top of the existing slopes

PROJECT OWNER  
• Kingdom of Morocco

PRODUCTS  
• Enkagrid® PRO 40 to 180  
• Enkadrain® 5004C/T110PP  
• Enka®-Tex NW 25

FUNCTIONS  
• Reinforcement, drainage and separation

CONTRACTORS  
• Arab Contractors  
• Houar  
• El Hajji  
• LRN  
• Seprob

VOLUME  
• Geogrid: 800,000 m<sup>2</sup>  
• Drainage: 70,000 m<sup>2</sup>  
• Geotextile: 100,000 m<sup>2</sup>



# Soil Consolidation Marmaray City Train station, Republic of Turkey

Marmaray suburban rail is an essential project for Istanbul, connecting Europe with Asia under the Bosphorus and running in the heart of the city. It is crucial to connect the city's metro network over two continents; in the future it will also connect the suburbs of Istanbul with the heart of the city.

### Challenge

It is a real civil engineering challenge to shore up and stabilize weaker soils in a short time frame to allow early construction on them. Using Prefabricated Vertical Drains (PVD's) is a cost efficient solution to reach this goal and to stabilize soft soils even in 30-40 m depths.

Applying PVD's, a path is formed for excess pore-water created by the overburden. Water is drained off to the surface resulting in a stable subgrade on which construction can take place.

### Solution

Installation of Colbondrain CX 1000 vertical drain in a 1.2 m raster with an average depth of 15 m to speed up soil consolidation.

After soil measurements and investigation had been performed, the calculated 1.2 m installation raster and average 15 m installation depth resulted in a calculated 0.9 m settlement in a 6 months time frame instead of years.

### Benefits of the solution

Applying PVD's as a solution not just allowed the contractor to dramatically reduce construction time, but also delivered a significant cost savings compared to other possible civil engineering solutions for stabilizing soft soils in such depths, like piling or even replacing the complete soil.

Colbondrain with its patented core and unique production method of thermally bonding the filter at the entire surface makes a thoroughly tough and durable geocomposite with excellent drainage capacities. Colbondrain's high tensile strength allows faster construction and the thermally bonded filter provides a tear off free - safer - installation.

### Installation benefits

Colbondrain is easy to handle with a roll length of 280 m and is suitable for use in all soil types.

Its unique production method and its high tensile strength allows usage with all installation rig types.

### Result

Expensive and time consuming traditional methods with intensive truck and machinery demand could be replaced by installing Colbondrain CX1000. A stable sub-grade has been created for the railway superstructure in a short time, which will serve the millions of travellers in the upcoming decades.



Typical installation rig for Colbondrain CX1000



Colbondrain CX1000 - at work

PROJECT OWNER  
• City of Istanbul

PRODUCTS  
• Colbondrain CX 1000

FUNCTIONS  
• Vertical drainage for accelerated soil consolidation

CONTRACTORS  
• ALTERNATİF ZEMİN MEKANİĞİ

VOLUME  
• 500,000 lm

# Railway viaduct SEA High Speed railway, France

The construction of the South Europe Atlantic (SEA) High Speed railway is one of the major railway infrastructure projects in Europe. This viaduct, located close to Poitiers, is one of the most significant civil engineering works where Enkadrain TPL was used to ensure vertical drainage of abutments.

### Challenge

Water can cause major disturbances in civil engineering works, both under construction and throughout the service life. Usually, the concrete structures are not designed to resist the water pressure, therefore, additional pressure can lead to collapse.

The drainage system has to fulfil the following requirements:

- provide the appropriate discharge capacity under the maximum earth pressure of the project
- resist the tensile load due to the compaction of the backfill

### Solution

Replacing gravel, Enkadrain TPL/1s, one of our premium products for over 25 years, offers effective solutions in vertical drainage for bridge abutments, retaining walls, concrete foundations of buildings, tunnels etc...

The product is based on a three dimensional geospacer combined with a filter geotextile. The geospacer is consisting of polyamide monofilaments, offering 95% of void. Enkadrain TPL/1s is an authorized product for the French railway authorities (SNCF) and has technical agreement for vertical building applications approved by APAVE.

### Benefits of the solution

- Enkadrain TPL/1s is a lightweight, durable, flexible and quick to install product
- It presents high level hydraulic performances, uniform in all directions including on a long-term perspective
- The structure of its drainage core is not sensitive to the filter intrusion phenomenon, the space between contact points core/filter being very small compared to other types of drainage structures

- It creates an air layer between the construction and soil and therefore reduces the risk of humidity in the wall

### Installation benefits

Enkadrain is easy to handle. Cutting can be managed with scissors or cutter. Due to its flexibility, it can be applied with precision even in corners or pinch points. Enkadrain includes fleece overlaps to avoid loss of material. Connection is made by nailing or gluing with a speed ratio estimated from 25 to 30 m<sup>2</sup> per hour. No additional gravel material is needed, not even for junction with the pipe.

### Result

Enkadrain TPL/1s ensures the vertical drainage to avoid any water pressure behind abutments of this highly sensitive structure. It is a complete drainage system from the bottom to the top of the wall.



Overview of the abutment



At the bottom, Enkadrain is covering the pipe, no need of additional gravel material



No loss due to overlapping: Enkadrain is provided with 10 cm overlap of fleeces



Enkadrain is a very flexible product for all conditions of use

PROJECT OWNER  
• Cosea

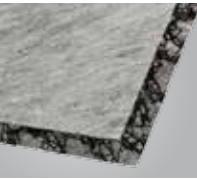
PRODUCTS  
• Enkadrain® TPL/1s

FUNCTIONS  
• Drainage and filtration

CONTRACTORS  
• Dodin-Campenon  
• Bernard (Vinci group)

VOLUME  
• 10,000 m<sup>2</sup> (for viaduct and annex works)

# Enka Solutions product overview



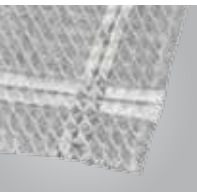
## Enkadrain®

Consistent and excellent long-term performance is a key feature of the Enkadrain drainage mat. Each variant has a drainage core bonded to a synthetic nonwoven geotextile layer or is sandwiched between two such layers. Enkadrain provides solutions for groundwater issues for civil engineering and building projects, both during construction and in service. With an extensive portfolio of product types, Enkadrain is suitable for many different applications.



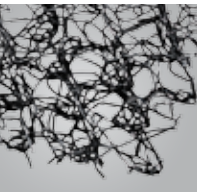
## Enkagrid®

The Enkagrid product range comprises a large portfolio of rigid and flexible geogrids, their common values being the optimum soil-grid interaction delivered for each application in any soil type and their outstanding mechanical long-term durability. Enkagrid types are uni-axial or bi-axial, manufactured from either laser welded strips or woven coated yarns. When soil reinforcement or stabilization is required, our wide choice of readily available products will meet individual project needs.



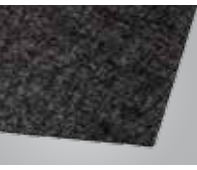
## Enkagrid® PLUS

Enkagrid PLUS is a high performance knitted geocomposite for reinforcement of asphalt and soil. Manufactured from high tenacity yarns and a nonwoven geotextile, this geogrid increases the tensile strength of asphalt layers and reduces the formation of cracks. Enkagrid PLUS also provides an excellent solution for soil reinforcement, combining reinforcement, separation and filtration in one product. Both solutions contribute to a significantly longer service life of asphalt layers and road and railway foundations.



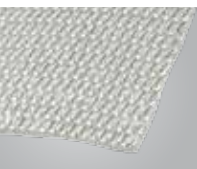
## Enkammat®

Enkammat is a flexible three-dimensional mat for immediate, permanent erosion protection on many different slope types. Its unique structure creates an artificial root structure that prevents soil erosion from steep slopes, river banks, landfill containments and other vulnerable areas. Enkammat has excellent soil retention, providing the perfect conditions for vegetative root systems to develop. Embedded with soil, it forms an integrated and fully vegetated system to control erosion.



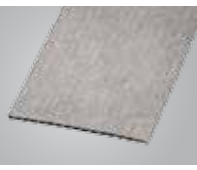
## Enka®-Tex

Enka-Tex is Enka-Solutions' complete range of nonwoven and woven geotextiles. The nonwoven geotextiles are needle punched and can be thermally bonded. The Enka-Tex product range is extensive, each type having specific properties of tensile strength, weight or flow capacity. Enka-Tex is ideal for projects where erosion control, filtration, protection, drainage, stress relief, reinforcement or separation are called for.



## Enka®-Force

The high modulus multifilament yarns used in the production of Enka-Force fabrics offer excellent creep characteristics, making them the perfect choice for use in soil reinforcement applications. The range has been specifically designed to exhibit high strength at low elongation. Typical areas of application include reinforced soil walls, embankments on weak soil and load transfer platforms.



## Colbondrain®

When the sub-grade of a construction site is too weak to bear normal construction activity, Colbondrain will speed up consolidation considerably. Colbondrain is a tough and durable prefabricated vertical drain (PVD), designed to extract pore water from soils to achieve 90% consolidation within six months. Thanks to its high performance Colbondrain is often the chosen PVD for major, technically demanding projects.

# Our areas of expertise

Our solutions offering provides answers for many different geotechnical challenges. They can be applied to what we consider our 'areas of expertise'.

## AREAS OF EXPERTISE

### TRANSPORTATION INFRASTRUCTURE

Our geosynthetic solutions support rails and roads throughout the world.

### COAST AND RIVERBANK PROTECTION

Geosynthetics are effective in protecting coasts and water embankments against the influence of hydraulic loadings.

### ENVIRONMENT

Our geosynthetic solutions help to create parks, playgrounds, ponds and canals to improve our residential, commercial or industrial areas.

### LANDFILLS

Landfills are a common way of managing our disposal of regular waste. To ensure landfills will not cause any environmental harm, leachate and methane gas may not reach our environment.

### GROUNDWORK CONSTRUCTION

When designing and constructing industrial, commercial or public buildings, special attention is required for foundation and drainage issues.

### TUNNELING AND MINING

Enka Solutions' offer for concrete lining protection, railway support, rock wall covering, soil stabilization, tunnel wall drainage and protection and vibration control are amongst the best in the world.



## Three fundamental values are at the core of Enka Solutions: expertise, reliability and responsibility



### Expertise

We began creating our knowledge and expertise base on our products and the industry way back in the 1950's, which means that today we have a multitude of project references worldwide. Coupled with extensive research conducted internally and externally with renowned universities and specialist organisations, our Research, Development and Innovation Team is constantly working in conjunction with clients all over the world to develop new solutions to add to our range of products and applications. In addition to this, our team of experienced engineers, who provide support across all market segments, ensures that numerous innovative solutions come to fruition. We see expertise both as the foundation of our business and as an ongoing process.

### Reliability

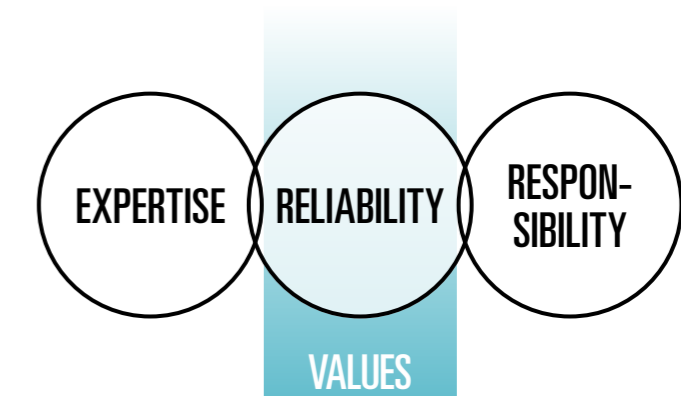
It's our daily mission to be a reliable partner for our customers in order for them to grow their business in a sustainable way. Reliability covers a range of different areas and ensures peace of mind for our partners. As well as our wide, high quality product range, we offer technical and marketing support for all market segments. All our processes are ISO 9001 certified and every single product is tested by our highly qualified laboratory staff. Furthermore, we hold specific product certifications in many different countries (e.g. Asqual, NorGeoSPec, Benor, HPQ, and BBA). Delivering what we promise is part of our nature.

### Responsibility

We take our responsibilities seriously. This is why you can also rely on our solutions being sustainable. We not only examine the full product lifecycle and its impact on the environment to make continual improvements in terms of environment, nature and soil, but also ensure that we meet all legal requirements. We train and advise clients and stakeholders, and contribute to the establishment of new standards to help propel our entire industry forward into the future. It will therefore come as no surprise that safety is also a high priority for Enka Solutions. Safety is inherent to all our solutions and products, as part of our responsibility to care for both the people who use them on building sites, and our employees.

**Enka®solutions**  
ENGINEERING NATURE

These values that are the core of Enka Solutions are reflected in our statement 'Engineering Nature', because not only is engineering in our nature, but we also see ourselves as **engineers delivering reliable solutions that respect nature.**





The Enka Solutions product range is manufactured by Low & Bonar who is a global leader in high performance materials selling in more than 60 countries worldwide and manufacturing in Europe, North America and China. Low & Bonar designs and manufactures components which add value to, and improve the performance of, its customers' products by engineering a wide range of polymers using in-house manufacturing technologies to

create yarn, fibres, geosynthetics, industrial and coated fabrics and composite materials. These materials contribute to a more sustainable world and higher quality of life. Low & Bonar is listed on the London Stock Exchange.

The quality systems of Low & Bonar facilities have been approved to the ISO 9001 Quality Management System Standard. Certificates are available on request.

#### CONTACT US FOR A FREE SAMPLE KIT OR TO DISCUSS YOUR SPECIFIC REQUIREMENTS

Belgium T +32 52 457 487  
 Czech Republic T +420 518 329 113  
 China T +86 21 6057 7287  
 France T +33 1 57 63 67 40  
 Germany T +49 6022 812020  
 Hungary T +36 49 886 200

Netherlands T +31 85 744 1300  
 Slovakia T +421 37 6556010  
 United Kingdom T +44 1482 863777  
 USA T +1 828 665 5050  
 Or contact your local distributor  
[www.enkasolutions.com](http://www.enkasolutions.com) / [info@enkasolutions.com](mailto:info@enkasolutions.com)

#### Disclaimer

All information and product specifications provided in this document are accurate at the time of publication. As the Low & Bonar Group follows a policy of continuous development the provided information and product specifications may change at any time without notice and must not be relied upon unless expressly confirmed by a relevant member of the Low & Bonar Group upon request. No liability is undertaken for results obtained by usage of the products and information.

© 2016 Low & Bonar / SO-ENG-TR-08/2016