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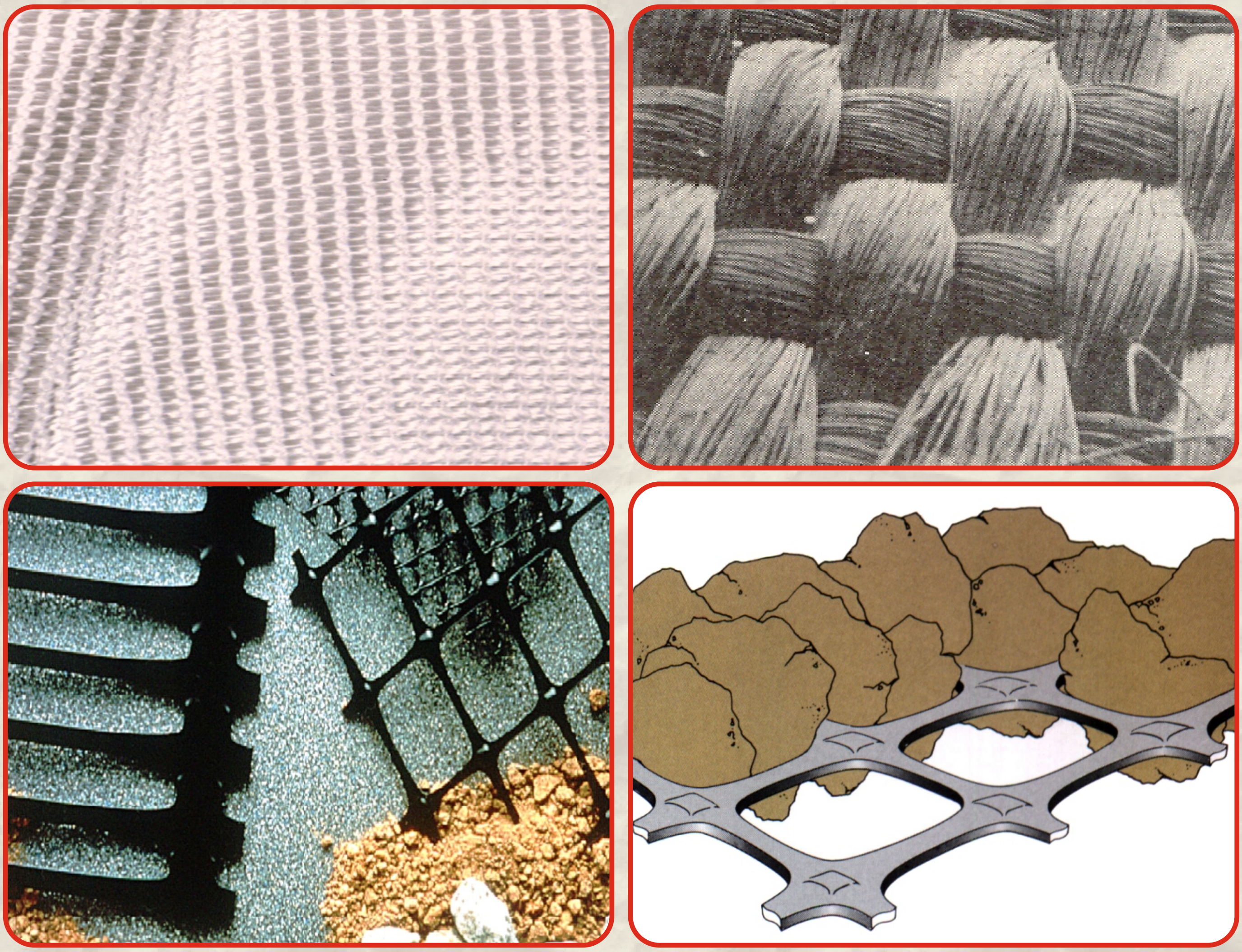
IGS INDIA

# Indian Journal of Geosynthetics and Ground Improvement

Half Yearly Technical Journal of Indian Chapter of International Geosynthetics Society



# ABOUT JOURNAL

Geosynthetics are now being increasingly used the world over for every conceivable application in civil engineering, namely, construction of dam embankments, canals, approach roads, runways, railway embankments, retaining walls, slope protection works, drainage works, river training works, seepage control, etc. due to their inherent qualities. Its use in India though is picking up, is not any where close to recognitions. This is due to limited awareness of the utilities of this material and developments having take place in its use.

The aim of the journal is to provide latest information in regard to developments taking place in the relevant field of geosynthetics so as to improve communication and understanding regarding such products, among the designers, manufacturers and users and especially between the textile and civil engineering communities.

The Journal has both print and online versions. Being peer-reviewed, the journal publishes original research reports, review papers and communications screened by national and international researchers who are experts in their respective fields.

The original manuscripts that enhance the level of research and contribute new developments to the geosynthetics sector are encouraged. The work belonging to the fields of Geosynthetics are invited. The manuscripts must be unpublished and should not have been submitted for publication elsewhere. There are no **Publication Charges**.

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# INDIAN JOURNAL OF GEOSYNTHETICS AND GROUND IMPROVEMENT

***Volume 11, No. 1*** ***January 2022***

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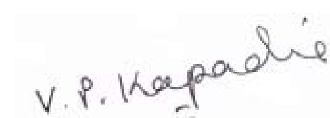
# FROM THE PRESIDENT DESK

Climate change has posed a serious challenge in the field of water management. Dams being the most important means of water management, their safety and longevity have become a matter of concern in the wake of extreme events. India's food security badly depends of water storage potential and therefore Dams are of utmost important in Indian context. The same way many countries of the world are struggling to attain or maintain their food security who recognize the importance of dams.

In construction of new dams, geosynthetics are amply used. In repairs of existing dams, usage of geosynthetics is gaining ground with passage of time as geosynthetics are techno-economically much more viable than other alternatives but at the same time they provide long lasting solutions. Saving of large quantity of natural material and thereby serving the cause of environment is an added advantage. Ease of applying them under water makes them a preferred option. Usage of geosynthetics in construction and rehabilitation of dams have actually gifted newer concepts of viewing the problems and designing the solutions therefor. This entire issue of the journal focusses on case studies on dam restoration or rehabilitation. Authors of papers published in this volume have shared their first-hand experiences to make a point for furthering the applications of geosynthetics in dam engineering. All the papers shed light on so many possibilities for developing innovative applications of geosynthetics.

Several people have been working for the cause of improving the infrastructure and making cost saving and providing environment-friendly solutions whose efforts are of showcased, the world can be better for living. The objective of this journal is to disseminate the experiences of such technocrats and the C.B.I.P. and I.G.S., India are instrumental in its publication which is a matter of pleasure to me as the President of the I.G.S., India and Vice President of the C.B.I.P. I hope, this volume would be providing an insight to the dam engineers whose role is going to be very crucial in coming years.




**Vivek P. Kapadia**
*President*
Indian Chapter of
International Geosynthetics Society

# FROM THE EDITOR'S DESK

Greetings from IGS India, New Delhi.

I wish to thank all the office bearers and members of the Indian National Group of Geosyntheitic and IGS for their support and guidance in completing one more successful year of service to the Geosynethetics fraternity,

The International Geosynthetics Society (IGS) is a learned society dedicated to the scientific and engineering development of geotextiles, geomembranes, related products, and associated technologies. The core purpose of the IGS is to provide the understanding and promote the appropriate use of geosynthetic technology throughout the world.

Geosynthetics beneficially improve the sustainability of infrastructure. They extend road service lives, reduce the dependence on aggregates, conserve water resources, minimize land disturbance, control soil erosion, protect groundwater, etc.

Geosynthetics Society (IGS) is a valuable investment for anyone interested in the engineering and geosynthetics industry. In addition to outstanding international representation, the IGS delivers services and ideas to maximize revenues and brand awareness through conferences, education sessions, case studies and other global platforms. The IGS keeps you informed on industry issues and offers you the combined experience of professionals and educators across the world who gladly share their knowledge and expertise of geosynthetics.

IGS India is grateful to authors of the various papers for their contributions included in this issue. Through this journal our attempt is to provide useful information to our readers on geosynthetic which would help them in better understanding and update their knowledge on the State of the art technology and material in this field. We are sure these papers will be of interest to the readers.

We request all the readers for contributing technical papers, case studies, and technical news, etc., which would be of interest to others, for publishing in the subsequent issues of the journal

I believe that IGS India Members to become active ambassadors of the society and geosynthetics industry by delivering our message to others - **Geosynthetics and related technology can pave the way our paths forward by bringing sustainability into the construction industry.** Your active participation can make difference!

**A.K. Dinkar**
*Member Secretary*
Indian Chapter of
International Geosynthetics Society

# IMPERVIOUS ASPHALT MEMBRANES FOR AGING CONCRETE DAMS

**Yue Zhu[1], Shan Feng[1] and Weibiao Wang[1]**

**ABSTRACT**

*Concrete dams have a long history to be widely constructed as this type of dams possess adequate safety in good geological foundation conditions. However, aging of concrete dams with time has become one of serious engineering problems due to weathering, lowering and raising of the reservoir level, and freezing-thawing of cycles. The stability of concrete dams generally maintains, however, the imperviousness of the upstream faces of concrete dams are gradually deteriorated with time and some leakages occur. The rehabilitation of the upstream faces is usually to use spray coating materials and the coating is easily to be peeled off when the faces have become porous due to aging. The paper presents the advantages of asphalt membranes with prefabricated concrete slabs anchored on the concrete faces of concrete dams. The detailed design and a case study are also presented.*

## 1. CONCRETE DAMS IN CHINA

Two-thirds of built large dams are concrete dams in China. Concrete dams have many advantages compared with other types of dams. However, aging has become one of serious problems for concrete dams with time. Concrete dams are continuously subjected to physical and chemical changes due to weathering. After years' aging the dam behaviors have been deteriorated with time. Especially, the upstream faces of the dams have gradually lost the imperviousness and some leakage may occur. In such cases, maintenance and repair have become necessary to keep the operation.

Most of concrete dams in China have been built after the 1949. According to the statistics for 109 large and medium-sized concrete dams, 67 of them had existed over 40 years till 2010, and the oldest was nearly 70 years. It is difficult to accurately give an aging period of each typical dam, however, the imperviousness of the upstream faces of concrete dams start to be gradually deteriorated with time and some leakages may occur after 30 years of operation. At present, the rehabilitation of the upstream faces is usually to use spray coating materials and the coating is easily to be peeled off when the faces have become porous due to aging.

## 2. FACTORS AFFECTING THE IMPERVIOUSNESS OF CONCRETE DAMS

The factors affecting the imperviousness of the upstream faces of concrete dams are mainly the aging.

### 2.1 Freezing-thawing of Cycles and Frost Heave

Freezing-thawing of cycles and frost heave of the upstream faces of concrete dams are a kind of physical damage. In the process of temperature change from positive to negative, the water volume expands about 9%. When water stays in large voids and turns into ice, the frost heave stress is produced. The ice forces the unfrozen water in the deep voids to generate osmotic pressure. When the combined stress of the frost heave stress and osmotic pressure is larger than the allowable fatigue stress of concrete, damage will occur.

### 2.2 Surface Carbonization

The surface carbonization of concrete dams is a chemical damage. $CO_2$ in the air penetrates pores of unsaturated water, reacts with $Ca(OH)_2$ that is the cement hydration product, and produce $CaCO_3$. The carbonization results in two detriments. On the one hand, the alkalinity of concrete is reduced from the surface to the center and cause the surface layer of concrete to fall off. On the other hand, the carbonization consumes a part of the cement binder and may cause cracks or small holes due to volume shrinkage.

### 2.3 Leakage Corrosion

$Ca(OH)_2$, a cement hydration product in concrete dams, is continuously lost along with pressure water leakage. When it starts to react with $CO_2$ at the leakage outlet to produce $CaCO_3$, a sign that indicates the concrete dams have been damaged by dissolution. The dissolution is a complex physical and chemical reaction process. The compressive and tensile strength of concrete will be reduced by 38.5% and 66.4%, respectively, when $Ca(OH)_2$ has been dissolved (by CaO content) up to 25%. Simultaneously, the void content increases, the imperviousness decreases, and the water absorption increases by 90%. When CaO in the concrete has been

1. Xi'an University of Technology, Xi'an, China

dissolved up to 33% the concrete becomes loose due to the significant strength decrease.

## 3. REHABILITATION OF UPSTREAM FACES OF CONCRETE DAMS

It is necessary to control the damages of the imperviousness of upstream faces of concrete dams to keep the dams in a good performance. The rehabilitation of upstream faces of concrete dams is usually to use spray coating materials and the coating is easily to be peeled off when the faces have become porous due to aging.

Asphalt concrete is impervious, corrosion-resistance, anti-aging material and presents viscoelastic behavior. It has been widely used as water barrier in dams and dikes [1,2]. Asphalt membranes used for rehabilitating the watertightness of upstream faces of concrete dams can be traced back to 1966 for the Agger Dam in Germany. The 40 m high Agger dam was built in 1929 and the upstream face had been aged with time. The upstream face was rehabilitated by anchoring prefabricated reinforcement concrete slabs of 28 cm in thickness and filling asphalt concrete of 12 cm in thickness between the upstream face of concrete dam and the slabs.

Asphalt concrete (impervious membrane) between the prefabricated concrete slabs and upstream face of concrete dams is protected by the slabs from sunshine, air, reservoir water level fluctuations, and weathering. The aging is dramatically reduced and hence the durability of the asphalt membrane is ensured.

### 3.1 Thickness of Asphalt Membrane

Asphalt membrane has a high impervious gradient and a low permeability coefficient of below $10^{-9}$ ~ $10^{-10}$ cm/s. In order to ensure the workability and imperviousness of asphalt membrane, there should be more free bitumen in the asphalt membrane. The void content of the membrane is commonly less than 1%. Figure 1 shows the seepage versus the thickness of asphalt membrane. It can be seen that when the thickness of asphalt membrane is bigger than 3~4 cm, the seepage is dramatically reduced and can be neglected. When the thickness is bigger than 6 cm, there is no significant effect on the imperviousness of the asphalt membrane. The asphalt membrane with a thickness of 4 cm has been used for the upstream face of the Shangyoujiang concrete dam, Jiangxi Province, China, for more than 70 years and performed well. Test results indicate that the shear rheological rate of asphalt membrane increases with the increase of temperature and thickness of asphalt membrane. The thickness of asphalt membrane should be between 5~10 cm considering the factors such as the construction quality assurance, unevenness of the dam face, maximum aggregate size of asphalt membrane, convenience for construction.

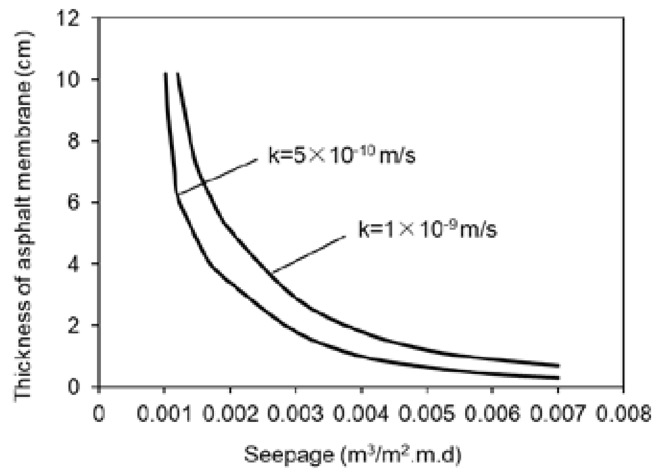



**Fig. 1** : Thickness of asphalt membrane versus seepage with different coefficients of permeability.

### 3.2 Prefabricated Concrete Slabs

The functions of the prefabricated reinforcement concrete slabs for asphalt membrane are: (a) to be as formworks for asphalt mixture filling; (b) to prevent the asphalt membrane from losing stability due to rheology; (c) to prevent the asphalt membrane from being damaged by floating debris impacts.

The thickness of the prefabricated concrete slabs is in the range of 6-12 cm. The height and length of the slab depend on several factors such as construction equipment, technical level, convenience for installation, filling of asphalt mixture and minimization of joints of slabs. According to the practices in China, the height of slabs is in the range of 30~100 cm while the length is in the range of 100~200 cm. Figure 2 shows a typical structure of the slab.

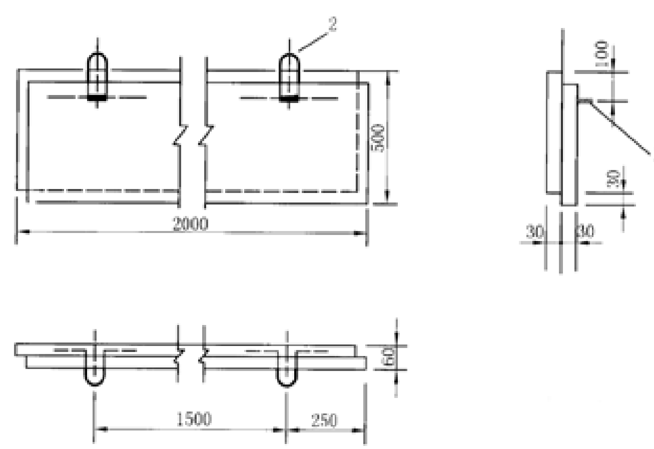
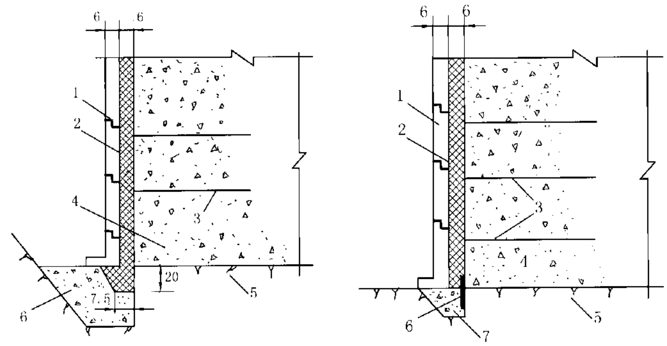



**Fig. 2** : Typical structure of prefabricated reinforcement concrete slab.1: fixed ring; 2: hanging ring. Unit: mm

The slabs are fixed on the dam face by anchored reinforcement bars. The space between bars on the concrete face and diameter of the bars as well as the length of the bar in the concrete are determined according to the stability requirements of the slabs and the lateral rheological pressure of the asphalt membrane. The bar diameter is in the range of 16~20 mm and the anchoring length of the bars in the concrete is in the range of 40~150 cm.

### 3.3 Connection of Asphalt Membrane and Perimeter Structure

There are two types of connection structures of asphalt membrane and foundation and abutment slope. One is to set cut-off groove. The width of the bottom of the groove should be larger than the thickness of the asphalt membrane, commonly 1.5 times of the thickness of the asphalt membrane. Asphalt mixture should be filled in the groove to extend the contact length. The groove bottom at the abutment slopes is designed in a slope but not steeper than 8V:1H. Other is to set water stop in the concrete base. Asphalt membrane is directly seated on the rock foundation or concrete base. One end of the water stop is embedded in the concrete base, the other end is embedded into the asphalt membrane. Figure 3 shows typical connections of asphalt membrane and rock foundation.



(a) Cut-off groove (b) Water-stop

**Fig. 3** : Connection of asphalt membrane and rock foundation. 1: Prefabricated reinforcement slabs; 2: asphalt membrane; 3: reinforcement bar; 4: concrete dam; 5: rock foundation; 6: concrete base or water-stop; 7: concrete base. Unit: cm.

## 4. CASE STUDY

There are ten concrete dams using asphalt membrane on the upstream face of the dams in the literature [3] (Table 1). This paper is to introduce the Luowan Dam using the asphalt membrane for rehabilitating the upstream face of the dam as a case study.

Luowan concrete gravity dam is located in the northwest of Nanchang City, Jiangxi Province, China. It was built in the 1970s with a height of 47m. The upstream face was obviously uneven with voids and pits due to the poor construction quality at that time. There were many vertical and horizontal cracks on the upstream face of the dam after 30 years' operation. The upstream face had to be rehabilitated and asphalt membrane was selected. The thickness of the asphalt membrane is 10 cm considering the uneven upstream face. Prefabricated reinforcement concrete slabs with a size of 60 cm × 200 cm and a thickness of 6 cm were fixed on the upstream face by anchored bars. The asphalt membrane was 3300m$^2$.

### 4.1 Materials of Asphalt Membrane

The mixed bitumen was initially used with two types of B100 and B10. The ratio of the two types of bitumen was

**Table 1** : Asphalt membrane used on the upstream faces of concrete dams in China.

| No | Name | Year | Dam type | Dam height (m) | Impervious area (m$^2$) | Thickness of membrane (cm) | Thickness of Slab (cm) |
|---|---|---|---|---|---|---|---|
| 1 | Shangyoujiang | 1957 | Gravity | 68.5 | 2100 | 4 | 7.5[b] |
| 2 | Agger[a] | 1966 | Gravity | 40 | 6000 | 12 | 28 |
| 3 | Fengtan | 1977 | Hollow, arch | 112.5 | | 5 | |
| 4 | Hunanzhen | 1978 | Trapezoid buttress | 128 | 6343 | 7 | 4 |
| 5 | Biliuhe | 1981 | Gravity | 53.5 | 2140 | 10 | 10 |
| 6 | Baishan | 1981 | Hollow, arch | 149.5 | 800 | 10 | 6 |
| 7 | Fengshuba | 1973 | Wide joint | 95.3 | 3196 | 6 | |
| 8 | Kengkou | 1986 | RCC | 56.8 | 3100 | 6 | 6 |
| 9 | Huanren | 1989 | Buttress | 78.5 | 6700 | 10 | 6 |
| 10 | Fengman | 1990 | Gravity | 90.5 | 16000 | 10 | 6 |

a Germany. b Wood was used for the slabs.

determined by tests and was 60(B100):40(B10). The property of the mixed bitumen is shown in Table 2.

**Table 2** : Property of mixed bitumen.

| Ratio (B100:B10) | Penetration (25°C (100g,5s) (0.1 mm) | Softening point (°C) | Ductility (25°C) (cm) |
|---|---|---|---|
| 60:40 | 30 | 60 | 60 |

Crushed limestone aggregates were used for the coarse aggregates and the maximum aggregate size was 15 mm. River sand was used for fine aggregates. Limestone powder was used for the filler. Different mixes were tested on workability, density, void content, permeability, compression behavior, long-term shear rheology and other behaviors. Suitable mix was suggested for construction and is shown in Table 3.

**Table 3** : Suggested asphalt mix for impervious membrane on the Luowan Dam.

| | Coarse aggregate (<15mm) | River sand (<5mm) | Filler (<0.075 mm) | Mixed bitumen |
|---|---|---|---|---|
| Mix proportion (%) | 31 | 31 | 21 | 17 |

A high bitumen quality of B70 was available during constructing the asphalt membrane on the Luowan Dam and the bitumen was used to replace the mix bitumen of B100 and B10. Accordingly, the mix proportion was adjusted by testing for the asphalt membrane and is shown in Table 4.

**Table 4** : Mix proportion of asphalt membrane using B70

| | Coarse aggregate (<15mm) | River sand (<5mm) | Filler (<0.075 mm) | Bitumen (B70) |
|---|---|---|---|---|
| Mix proportion (%) | 34 | 34 | 18 | 14 |

### 4.2 Construction

The thickness of the asphalt membrane is 10 cm. The size of the prefabricated slabs is 60 cm × 200 cm, with a thickness of 6 cm. The bitumen was dehydrated and heated by a thermal insulation pot with double layers. The dehydration temperature of B10 was 200°C and 140°C for B100 and B70. The dehydration time for the three types of bitumen was about 4 hours. The heating was controlled after the bitumen had been dehydrated totally so that the temperature for B10 would be controlled at 180±5°C, and at 160±5°C for B100 and B70. The bitumen was weighed and put into other thermal insulation pot at the designed ratio of B100:B10=60:40 by weight. The temperature of the mixed bitumen was controlled at 170±5°C.

According to the mix proportion, the coarse aggregate and river sand were weighed. The weight of the coarse aggregate and river sand was about 0.2 $m^3$, heated to 200°C in the dryer, while the filler was heated to 50°C on a steel plate. The mixed aggregates and the filler were put in the mixer and mixed for 20s. The mixed bitumen or B70 bitumen was put into the mixer and mixed for 60s. The hot asphalt mixture was controlled at 160±5°C.

The upstream face of the dam face had been cleaned and dried and the prefabricated slabs had been fixed before the asphalt mixture was filled between the both. The longitudinal and transverse cracks on the dam face were manually chiseled and filled with bituminous mastic, and then pasted with polyester membrane. The positions of the anchored bars were marked on the dam face according to the arrangement of the prefabricated slabs. The holes for the fixed bars were drilled with the depth of 60~80 cm from the dam face. Cement mortar was filled in the holes and the anchored bars with diameter 16 mm were inserted to ensure the cement mortar full of the holes.

The hot asphalt mixture was unloaded into the thermal insulation tank on the four-wheel vehicle and transported to the dam top. The tank was hoisted by a truck crane on the dam top to vertically transport to the spot on the dam upstream face. When the tank was at the right place, the bottom door of the thermal insulation tank was opened and the asphalt mixture flowed into the cavity between the dam face and the prefabricating slabs. Figure 4 shows the filling of asphalt mixture into the cavity between the slab and dam face. The asphalt mixture was tamped by iron rod manually with a depth 30 cm of layer and the temperature of the asphalt mixture was controlled over 140°C.

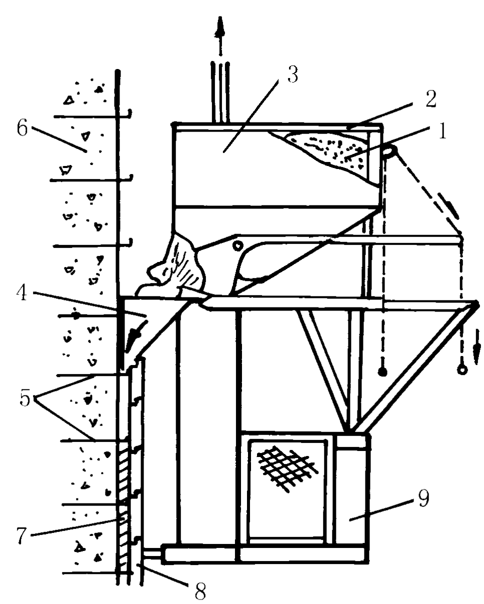



**Fig. 4** : Asphalt mixture filling into the cavity between the slab and dam face. 1: asphalt mixture; 2: isolated layer; 3: tank; 4: funnel; 5; reinforcement bars; 6: dam; 7: asphalt membrane; 8: mobile hanging basket.

### 4.3 Performance

The construction of the asphalt membrane for the Luowan Dam was started in the middle of January 2002 and completed at the end of March. The height of the dam face was covered by the asphalt membrane was 24 m and the area was 3300 $m^2$. No leakage has been detected through the asphalt membrane in the observation gallery and the dam has performed well up till now.

## 5. CONCLUSIONS

Aging of concrete dams is an irreversible process. Especially, the upstream face is subjected to freezing-thawing of cycles, frost heave, and carbonation in operation. Dam performance may be seriously affected when the imperviousness of the upstream face is deteriorated with time.

There are many ways to rehabilitate the upstream face of concrete dams. However, the asphalt membrane presents the most reliable and cost-efficient alternative. All the concrete dams with the asphalt membrane have performed well. There are many concrete dams in China faced aging and imperviousness deteriorating of upstream faces. The asphalt membrane alternative is competitive technically and reliably and one of good solutions.

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# CALENDAR OF UPCOMING EVENTS

| Sl. No. | Event Name | Place | Date |
|---|---|---|---|
| 1 | NGO (IGS Netherlands) Virtual Lecture: Geosynthetic solutions in impressive projects | Virtual | March 8, 2022 |
| 2 | TC-Barriers Webinar: Geosynthetic Clay Liners for Dams and Dykes by Kent P. von Maubeuge | Virtual | March 17, 2022 |
| 3 | TC-Barriers Webinar [REPEAT SESSION]: Geosynthetic Clay Liners for Dams and Dykes by Kent P. von Maubeuge | Virtual | March 23, 2022 |
| 4 | 13th Rencontres Géosynthétiques 2022 (2022 Geosynthetics Meetings) | Palais des Congrès in Saint-Malo | April 05 - 07, 2022 |
| 5 | GeoANZ #1 – Advances in Geosynthetics | Brisbane, Queensland | June 07 - 09, 2022 |
| 6 | International Conference on “Innovative Solutions for Geotechnical Problems” in Honour of Prof. Erol Guler (ISGPEG2022) | Istanbul - Turkey | June 22-23, 2022 |
| 7 | EuroGeo 7 – 7th European Geosynthetics Congress | Warsaw, Poland | September 4-7, 2022 |
| 8 | GeoAsia 7 – 7th Asian Regional Conference on Geosynthetics and IGS ACC Young Engineers Conference (GeoAsia7) | Taipei, Taiwan | October 31 – November 4 2022 |
| 9 | GeoAfrica 4 – 4th African Regional Conference on Geosynthetics | Cairo, Egypt | February 20-23, 2023 |
| 10 | 12th International Conference on Geosynthetics: 12 ICG | Rome, Italy | September17-21, 2023 |

# STRATEGY FOR REHABILITATION AND STRENGTHENING OF DAM - A CASE STUDY OF TEMGHAR DAM

**R. D. Mohite[1], P.S. Kolhe[2] and S.V. Pradakshine[3]**

**ABSTRACT**

*Dams contribute to development of civilization and help in meeting drinking water, irrigation and hydropower requirement and also for protection from catastrophic floods. To serve these purpose successfully throughout life span of dam, these dams needs proper maintenance and repairs to be done. The study represents strategy for rehabilitation of Temghar dam. Temghar dam has been constructed across Mutha River near Pune district of Maharashtra during the period March 1997- May 2010. Temghar dam is located on upstream of Khadakwasla dam, from where drinking water is supplied to Pune city and also severs for irrigation. Construction of temghar dam was completed in year 2010. Leakages in dam were observed from the time of construction in increasing trend with increase in reservoir storage level. Since Temghar dam was located on u/s of Khadakwasla dam, which was located on u/s of Pune city, it had high hazard potential in case of any mishap. So there was need for immediate action to be taken to reduce leakages and to look for safety of dam. Water Resources Department immediately started taking action for repair work of dam and started Grouting of dam body. Repair work of Temghar dam mainly includes Grouting of dam body and polypropylene fibre reinforcement shotcrete treatment to U/S side of dam. In year 2016 to 2019, 65% of Grouting work is completed and in season 2018-19, 10 % of shotcrete work is completed. As a result of this repair work of dam Water Resources Department got success in reducing 90% of leakage to Temghar Dam.*

## 1. INTRODUCTION

### 1.1 About Temghar Dam

Temghar dam has been constructed across Mutha River near Pune district of Maharashtra during the period March 1997- May 2010. Temghar project mainly caters to Domestic water supply to Pune city and irrigation of 1000 Ha agriculture land through K.T. weirs. Hydro power is also contemplated at the foot of the dam. The total utilization of 3.708 T.M.C. is planned for this project which is accommodated within 599 T.M.C. of Krishna water allocated to Maharashtra.

Temghar dam is a stone masonry dam with 5 m thick colgrout masonry (1:3) septum on u/s face, at bottom of thickness 3 m and on downstream side as a triangular toe from foundation up to RL 667 m where the stresses were more than 120 T/m$^2$. Total length of the dam is 1075 m and maximum height is 86.6 m. It comprises 72 m long spillway portion in the centre from RD 528 to 600 m and non overflow portion on either flank. The dam top RL is 711.40m and Full Reservoir Level is at RL 706.50 m. Gross capacity at FRL is 108 Mcum i.e. 3.71 TMC.

### 1.2 Salient Feature

| Sr. No | Particulars | Details |
|---|---|---|
| 1. | Source/Name of River | Mutha River |
| 2. | Location:<br>State<br>Region<br>District<br>Taluka<br>Village<br>Toposheet No.<br>Latitude<br>Longitude | <br>Maharashtra<br>Western Maharashtra<br>Pune<br>Mulshi<br>Temghar<br>47 F/7, 47 F/11<br>18$^o$ 27' 0" (N)<br>73$^o$ 32' 0" (E) |
| 3 | Controlling Levels<br>River Bed Level<br>M.D.D.L.<br>F.S.L.<br>H.F.L.<br>T.B.L. | In Mtr<br>641.56<br>661.40<br>706.50<br>710.12<br>711.40 |
| 4. | Command Area(on d/s of dam to back water of Khadakwasla Project)<br>1.Gross command area<br>2.Culturable command area<br>3.Irrigable command area | <br><br><br>2000 Ha./4940 Acres<br>1600 Ha./3952 Acres<br>1000 Ha./2470Acres |

1. Chief Engineer,Water Resourses Department, Pune
2. Superintending Engineer, Pune Irrigation Project Circle, Pune
3. Executive Engineer, Bhama Askhed Dam Division, Pune

## 2. ISSUES: DELAY IN CONSTRUCTION, ARTIFICIAL SAND, POOR QUALITY, LEAKAGE, DENSITY ETC.

The construction of Temghar Dam was started in March 1997. As per schedule, construction period was 44 months and work was expected to be completed by November 2000. However due to increase in quantities and cropping up of extra items during execution extension for completion was granted. The construction of dam was going in full swing from March 1997 to December 2001. However work was totally stopped by the forest department in January 2002 due to the 4.5 ha of forest land coming under submergence. After receiving the due permission from forest department, construction was again restarted in April 2009 and completed in 2010.

The upstream septum of 5m width is provided of colgrout masonry to prevent leakage. Also on downstream colgrout masonry zone is provided at toe portion up to RL 667m. From the leakage and visual inspection, it is evident that particularly left flank portion and half of the central gorge portion work has been executed very badly. Upstream surface undulations and uneven slopes speak of bad workmanship. Cement slurry accumulated on upstream surface, percolated from the shuttering for colgrout masonry reveals that cement grout is not able to occupy the space between the stones due to improper packing between the stages of masonry. Large cavities show the improper laying of stones, single drum mixer was used instead of double drum mixer which is not able to create colloidal state of the mix. Also use of improper grading of artificial sand used seems to be responsible for forming inhomogeneous masonry. Crushed sand was used for construction of colgrout masonry. Due to angular surfaces in the crushed sand together with high fineness modulus of the sand might have resulted in non colloidal state of colgrout slurry during construction and may have caused segregation of sand and cement. This may be one of the reasons for inadequate strength of colgrout mortar and high seepage. Leakages in Temghar dam were observed at the time of construction which increased with increase in reservoir storage level.

Following table shows how leakage increased year by year.

| Sr. No | Year of Construction | Max. total seepage in lps | Remarks |
|---|---|---|---|
| 1 | June 2000 | -- | |
| 2 | 2001-02 | 72 | |
| 3 | 2002-03 | 58 | |
| 4 | 2003-04 | 47 | |
| 5 | 2004-05 | 68 | |
| 6 | 2005-06 | 90 | |
| 7 | 2006-07 | 395 | |
| 8 | 2007-08 | 430 | |
| 9 | 2008-09 | 524 | |
| 10 | 2009-10 | 508 | Construction upto FRL |
| 11 | 2010-11 | 526 | |
| 12 | 2011-12 | 602 | Grouting done in 2012 |
| 13 | 2012-13 | 307 | Leakages observed after Grouting done in 2012 |
| 14 | 2013-14 | 402 | Leakages observed in monsoon season of 2013 |
| 15 | 2014-15 | 385 | |
| 16 | 2015-16 | 1174 | |
| 17 | 2016-17 | 2581 | |
| 18 | 2017-18 | 1039 | Leakage reduced from 2587 to 1039 lps after grouting of 2000 M.T. grout |
| 19 | 2018-19 | 413.80 | Leakage reduced from 2587 lps to 413.80 lps around 80 % after grouting of 18000 M.T. |
| 20 | 2018-19 | 265.80 | Leakage reduced from 413.80 lps to 265.80 lps around 90 % after grouting of 25430M.T. and 4210 Sqm (About 10%) of Shotcrete |

## 3. POTENTIAL HAZARD

Temghar dam is located on upstream of Khadakwasla dam, from where drinking water is supplied to Pune city by a pipe line and lake water is also released into Khadakwasla RB canal to irrigate drought prone area in the East. Water stored in Temghar dam is planned to be released back into the river for its use from Khadakwasla dam. Since Temghar dam was located on u/s of Khadakwasla dam, which was located on u/s of Pune city, it had high hazard potential in case of any mishap. Leakages from masonry induce leaching of free lime in cement rendering loss of strength of masonry and also loss of water and creating fear amongst the people residing on downstream.

## 4. REHABILITATION & STRENGTHENING STRATEGY

### 4.1 Findings of Ranade Committee Report:

To suggest the remedial measures for this leakages Government of Maharashtra decided to constitute an Expert committee for study and recommendations. So Temghar Dam Expert Committee (TDEC) was constituted vide Executive Director, Maharashtra Krishna Valley Development Corporation, Pune's order no.1901 of 2014 issued under no.6549, date 27.8.2014 to examine causes of seepage through Temghar Dam and exploring possible measures to reduce it and to access structural stability of dam as well as to suggest the remedial measures for its rehabilitation.

Temghar Dam Expert Committee (TDEC) studied behavior of the Temghar dam by carrying out field inspection and reviewed record related to dam construction & quality control aspects. TDEC held discussions with the present site officials to know developments in seepage from the dam and seepage control measures tried by them. It was observed that most of the seepage was coming out in the form of jets at many places from dam body on the LB. In that comparison, seepage from gorge and RB was much less. Seepage was also coming from some monolith joints and foundation drains. TDEC felt need to improve the crude unscientific methods of measurement of seepage followed by the field officers at site. It was felt necessary to find out percentage of dissolved salts from seepage water & lake water, to know loss of dissolved solids from dam masonry. Appropriate suggestions were given to the project staff in that matter. Study of ‘Tomography’ was carried out for the assessment of presence of saturated zones in the dam masonry on LB. Some in-situ masonry samples also were tested for its density and crushing strength and finally TDEC has given their opinion about remedial measures to reduce seepage.

#### 4.1.1 *Short Term Remedial Measures*.

- U/s surface treatment
- Dam Body grouting
- Foundation curtain grouting
- Cleaning of porous block
- Repairing monolith joint

#### 4.1.2 *Long Term Measures*

- Strengthening by post tensioning cables
- Strengthening by Earth backing
- Providing additional drainage gallery
- Masonry or concrete backing
- Buttressing

### 4.2 Repair Work-important Items

Short term measures such as grouting, providing Shotcrete treatment to upstream face of dam, completing remaining curtain grouting and dam body grouting, Rimming / drilling of porous drains to improve their functioning etc. are needed to be addressed immediately.

Considering severity of the problem and hazard potential of the dam it is planned to adopt immediate short term measure before coming monsoon to plug excessive leakages which may lead to potential danger of piping and Long term measures are planned to provide complete solution for leakages as well as strengthening of the dam.

### 4.3 Grouting

It was decided to go for exhaustive grouting. So from dam top to Inspection Gallery, Inspection gallery to foundation gallery, from D/s as well from U/s side the drilling and grouting work was immediately started from April 2017.

Grouting from Upstream face: Grouting the upstream colgrout septum from foundation to dam top is done by drilling 38 mm to 51 mm dia holes having depth at 3 m c/c both ways. Intermediate holes are drilled for water intake test and for grouting if necessary.

Grouting from Downstream face: Grouting of UCR masonry is done by drilling 51 mm to 75 mm dia holes with light weight hydraulic diamond drilling machines (by percussion drilling). These are mounted on continuous support systems anchored firmly on dam top with anchor fasteners for maximum depth to cover all the masonry perpendicular to the downstream sloping face of dam. Primary grouting at 6 m c/c and intermediate secondary grouting at 3 m c/c and tertiary at 1.50 m c/c is adopted.

Dam body grouting is also done from dam top to inspection gallery and from inspection gallery to foundation gallery wherever it was possible by drilling slant holes. Directional grouting it also carried out targeting maximum penetration under low pressure with reservoir empty condition. Stage grouting method is adopted. Grout pressure is given between 1.5 to 3.0 kg / $cm^2$ and grout mix design is given by CWPRS, Pune is as below :

<table>
<tr><th>Sr. No.</th><th colspan="2">1</th><th>2</th></tr>
<tr><td>1</td><td colspan="2">Mix proportion cement+Fly ash +Silica</td><td>80:18:2</td></tr>
<tr><td>2</td><td colspan="2">WC Ratio</td><td>0.65</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">Admixtures (% by weight of cementatious material)</td><td>Powder Form</td><td>2 %</td></tr>
<tr><td>Liquid by volume</td><td rowspan="2">5 ml per kg of cementatious material</td></tr>
<tr><td>Liquid by volume</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Average Compressive Strength Kg/ $cm^2$</td><td>7 Days</td><td>107</td></tr>
<tr><td>28 Days</td><td>222</td></tr>
<tr><td>5</td><td colspan="2">Density (gm/cc)</td><td>1.8</td></tr>
<tr><td>6</td><td colspan="2">Marsh Flow Time (Sec)</td><td>27 to 36</td></tr>
<tr><td>7</td><td colspan="2">Settlement</td><td>Less than 5%</td></tr>
</table>

### 4.4 Shotcrete Treatment to U/S Treatment

As per the various experiments carried out at field with help of CWPRS, it is decided to give polypropylene fibre reinforcement shotcrete treatment to upstream face of the dam. For this purpose following provisions are made for wet shotcrete treatment to upstream surface

- Clean the Upstream surface by chipping with mechanical brakers and Air, water jetting of the chipped surface & expose the masonry.
- Anchor Bars of 25 mm dia. 1.5 m length anchored at 1m x 1m distance.
- To give the strength to shotcrete layer wire mesh of 8 gauge of 100 mm x 100 mm is to be used.
- To create bond between bars and wire mesh, M.S. square plate of 100mm x 100mm size and 5mm thickness is being fixed on outer end by threading.
- Providing first layer of average 50mm thick filler shotcrete and second layer of 50mm thick shotcrete.
- Spraying 2 to 3mm thick cement slurry.

For Temghar dam reccomended shotcrete mixture is of 43 grade portland cement, fly ash, silica, admixtures, polypropylene fibre, 10 MSA coarse aggregates, fine aggregates and water.

Final mix design for Shotcrete given by CWPRS, Pune is obtained from CWPRS, Pune as follows :

| Sr. No. | Constituents | Quantity of Dry ingredients in kg for one cubic meter concrete | |
|---|---|---|---|
| | | First layer | Finishing coat |
| 1 | Cement | 380.00 | 360.00 |
| 2 | Fly Ash | 40.00 | 40.00 |
| 3 | Silica | 20.00 | 20.00 |
| 4 | Coarse aggregate (10mm – 4.75 mm) | 471.2 | 254 |
| 5. | Fine aggregate (Passing 4.75 mm) | 1100 | 1439 |
| 6. | Fibre | 1.17 | 1.17 |
| 7. | Accelerator | 4.7 | 4.7 |
| 8. | SPG (Super plastisizer) | 4.7 | 4.7 |
| 9. | Water | 286 (Tentatively) | 294 (Tentatively) |

As per the recommendation of CWPRS, Pune with reference to Manual for Dam Rehabilitation of Large Dam, CWC, January 2018, it is decided to give shotcrete joint treatment by cutting slot of joint width 50mm and depth 150 mm and fixing 12 mm thick Ethylene propylene diene monomer Geomembrane (EPDM) sheet by adhesive and aluminum strips and filling the formed hole with polyurethane material.

### 4.5 Current Status of Temporary Repair Measures

Work of grouting started in April 2017 and Work of shotcrete is statred in April 2019. Before that leakage observed was 2587 lps and now in 2019 leakage observed are 265.80 lps. Monolith wise quantity of grouting and Shotcrete executed upto June 2019 is as shown in below table :

| Monolith No. | Executed quantity of grouting (MT) | Executed quantity of Shotcrete (Sqm) |
|---|---|---|
| 1 to 13 | 14885.80 | 3075.00 |
| 14 to 17 | 8898.64 | 1135.00 |
| 18 to 27 | 1645.85 | 0.00 |
| Total | 25430.29 | 4210.00 |

Uptill now about 65% of grouting and 10 % shotcrete work is completed and with this work about 90 % of the leakages are reduced. As per the Temghar Dam Expert Committee (TDEC) out of five short term recommendations grouting and Shotcrete that is also in a partial quantities are executed. But with this about 90% of leakages has come down. After the execution of all grouting and shotcrete work as well as remaining measures like Vertical porous hole cleaning, Curtain grouting, repairing monolith joint etc. it can be say that leakage will be reduced within the permissible limits.

### 4.6 Test and Quality Control

To maintain the quality of work there are various teste conducted on the grout, which includes marsh cone test, settlement, pH value, strength and Temperature. To check the flow time marsh cone test is carried out and the permissible flow time should be between 28 to 30 sec. permissible pH value of grout should be between11to13. For assessing colloidal stage of slurry settlement test is taken where in settlement should be below 5 %. Standardize formats are maintained at site in which periodical reports (weekly, fortnightly, monthly and seasonal) about physical progress, cement consumption, mixer registers, field tests, laboratory tests etc. are recorded by engineers at different levels.

## 5. CONCLUSION

At the end of season 2019 ( June 2019 ) about 65% of grouting and 10% of shotcrete work is completed and the leakages are curtailed to 90%. It is planned to complete whole work in coming year & by the end of June-2020 whole work along with all measures is expected to be completed. It is also planned to check the density of post grouting masonry by Nuclear bore hole logging and also test the weak zones by Tomography. After these results it is planned to go for permanent measures like concrete backing of dam as suggested by Temghar Dam Expert Committee.

Figure 1 shows comparison of leakage to Temghar Dam before starting repair work in July 2016 and after completing about 65% of grouting and 10% of shotcrete work at the end of July 2019.

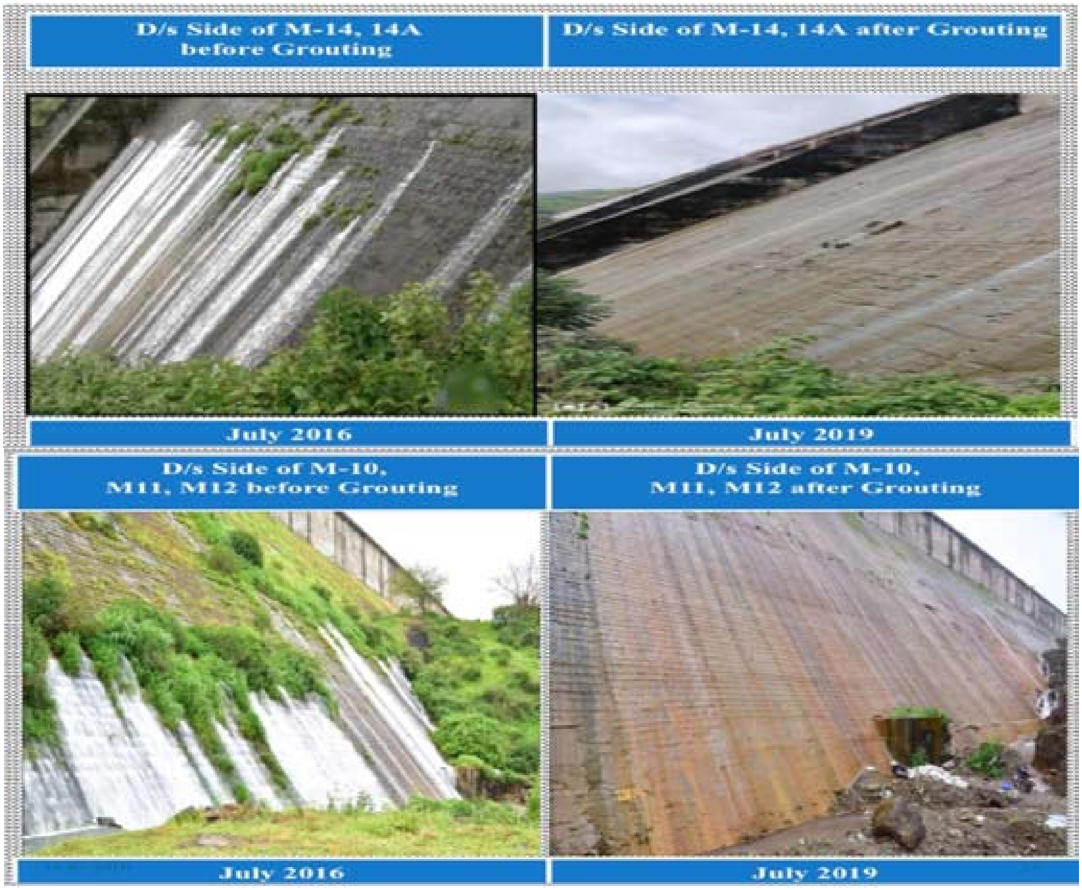


**Fig. 1** : Leakage Comparison before and after repair work.

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# INDIAN EXPERIENCE IN FLEXIBLE GEOMEMBRANE FOR WATERTIGHTNESS OF AGEING DAMS

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**ABSTRACT**

*Watertightness is one of the key issues to ensure safe operation and durability of dams. The installation of geomembranes on the upstream face of large dams is in practice in India since early 2000ies with Kadamparai, a 67 m high masonry dam, that was brought back to its full operational capacity. Since 14 years of installation, the Pumped Storage Hydro Electric Generation station has gained full efficiency and is generating to its full capacity of 400 MW power limiting the leakage within the permissible limit, paving the way for similar installations in other dams. The second project was Servalar dam under DRIP – Dam Rehabilitation and Improvement Project of the Government of India, in 2018. Carpi braved the challenges posed due to erratic weather conditions and successfully installed with the same level of result of the first project. The third one, at Upper Bhavani dam also under DRIP, an 80 m high stone masonry dam providing water to a series of power houses generating over 800 MW; the same geomembrane system is being installed in phases getting completed in 2020. The paper provides details of these projects, focusing on how the geomembrane technology is proven suitable and adaptable to any kind of environment and at the same time provides the most durable solution for watertightness.*

## 1. INTRODUCTION

Water is an integral part of our daily life and essential for rising population, industrialization, urbanization, modernization of agriculture, etc. Since water is one of Earth's most limited resource, conservation of water has become a growing problem around the globe today. Hydraulic structures like dams, canals, tunnels, reservoirs constructed to conserve water must be rehabilitated in the best way to guarantee safety and minimum water losses.

Geomembranes are prefabricated synthetic materials produced in thin flexible sheets, whose function in dams and other hydraulic structures is to construct a water barrier, due to their being practically watertight. In some of the pioneer projects in large dams, the geomembrane installed system was covered. Over time, following the good behaviour of geomembranes already installed, and the improvements achieved in materials' composition and manufacturing procedures, and in design and installation techniques, confidence in these systems increased. At the beginning of 1970ies geomembranes started to be used in exposed position, in new construction as well as in rehabilitation of dams.

The developments in design of materials and of anchorage systems in new installation methodologies based on modern equipment allow constructing safe and long-lasting waterproof systems that can be installed in a short time, reducing costs, and allowing earlier exploitation of the structure, a substantial asset in countries where the need for water and power has become an emergency.

### 1.1 ICOLD Guidelines

The most authoritative international body dealing with dams, ICOLD, the International Commission on Large Dams, has since the end of the 1970ies been addressing the use of geomembrane in dams. Dedicated bulletins have been issued to provide information and guidelines in 1981, 1991 and 2010. The most recent one, Bulletin 135, "Geomembrane Sealing Systems for Dams – Design Principles and Review of Experience", is the world's reference guideline for design, installations and behaviour of geomembrane systems. Bulletin 135 also gives guidance to technical contents of contracts, and the contract guidelines to be met by the bidding contractors.

This paper will be of use to understand how geomembranes with an effective installation technique can be the best repair method for any kind of water leakage problem in dams that need installation in dry as well as in underwater conditions. This paper presents case studies where the Carpi's geomembrane waterproofing system was installed in masonry dams in India.

1. Carpi India, Chennai, India

2. Carpi Tech, Balerna, Switzerland

- Kadamparai masonry dam of Tamil Nadu Electricity Board (TNEB)in the year 2005
- Servalar masonry dam of Tamil Nadu Generation and Distribution Corporation (TANGEDCO) in the year 2017-2018
- Upper Bhavani masonry dam of Tamil Nadu Generation and Distribution Corporation (TANGEDCO) (ongoing).

The paper gives a complete insight into how the three projects were envisaged by the client and the acceptance of the system in each of the projects after a series of attempts put forth by the client prior to adoption of a geomembrane technology.

Each case discussed in this project has a unique background on the benefits attained. Though the objective lies in preserving the structure, the positive results and success attained has done justice to the investment made on rehabilitation.

## 2. EXPERIENCE IN INDIAN SOIL – KADAMPARAI DAM, INDIA

Kadamparai dam in the state of Tamil Nadu in India, owned by Tamil Nadu Electricity Board (TNEB), was constructed in 1983 and is a composite structure consisting of a central stone masonry gravity section and two earthen embankment sections. The masonry section is 67 m high and 478 m long, with a central spillway, a scour vent tower and one inspection gallery.

The dam is used as a forebay reservoir for the Kadamparai pumped-storage plant, which has an installed capacity of 400 MW. The gross storage capacity is 26.85 X $10^6$ $m^3$. As a result of the pumping operation, the water level may vary by about 4 to 5 metre per day.

### 2.1 Seepage History

In the first impoundment in 1984, the maximum measured seepage was 1120 l/minute. Most of the seepage was observed through the shafts inside the gallery and the seepage sources included:

- Distributed seepage entering the masonry facing system, at deteriorated joints between rocks and through cavities that formed in the masonry
- Concentrated seepage at joints between monoliths, Seepage through the foundation rock
- Seepage through the embankment section into or around the gravity section was estimated to be very small.

### 2.2 Remedial Measures

Remedial measures were carried out repeatedly over the years, mostly requiring partial dewatering of the reservoir, with significant impact on operation of the pumped storage scheme and consequent financial losses.

**Table 1** : Remedial measures carried out in Kadamparai dam since first impoundment.

| Period of repair | Remedial measures taken |
|---|---|
| 1990 – 1996 | Packing and pointing was carried out at selective locations on the upstream face where leakage had been identified and vertical drilling and grouting was done |
| 1999 – 2000 | Underwater treatment of the leaking areas was done using chemicals and cement and this reduced the leakage from 4200 to 800 litres per minute |
| 2000 – 2003 | Again packing and pointing was carried out. The seepage in 2003 touched 11,800 litres per minute at El 1140.55 (around 10 metres below Full Reservoir Level) |

### 2.3 Selection of Rehabilitation Method

As all the conventional methods already adopted had failed at Kadamparai, a suitable long-term solution was sought by the client. Reputed institutes like IIT's, Anna University were approached for their expert opinion on this issue and installation of geomembrane on the upstream face was suggested by these institutes. After a detailed analysis of the market, the client TANGEDCO contacted Carpi Tech, a Switzerland based company for the study of the leakage and a proposal to address the problem. Carpi then was with 40 years of experience in the use of geomembrane systems on dams experiencing such large leakage. The client did a cost benefit ratio of the generation loss versus the repair cost and it was concluded to line the exposed masonry face leaving the embankment section. Also, no excavation was planned to expose the foundation level as records indicated the quantum of leakage from the foundation drains were very minimal and the time constraint to excavate already hardened silt deposit.

### 2.4 Beginning of the Repair Works

The contract was awarded to Carpi in July 2004 through an international bidding process. Before the geomembrane works started, Carpi made a detailed study of the dam and suggested basic structural improvement works that included (a) Additional drilling and grouting from the crest, (b) Removal of sediments at the heel of the dam, (c) Stabilizing some part of the masonry face which got withered off.

The design of the waterproofing system avoided extensive civil works for preparation of the upstream surface. After the removal of debris and sediments at heel, the loose and detached stone blocks were repositioned. A specialized treatment was carried out on the lower part of the joint near to the ground level to minimize water infiltration from below the watertight perimeter seal through the 12 construction joints.

The major elements included the anti-puncture geotextile layer of 2000 g/m$^2$, installed on the entire upstream face of the dam to reduce risk of puncture by the very aggressive surface of the stone masonry blocks. The nonwoven needle-punched geotextile made of pure polyester fibre was anchored to the face (Figure 1).

**Fig. 1** : Installation of anti-puncture geotextile and of waterproofing geocomposite.

The main waterproofing liner is a geocomposite, consisting of an impervious flexible SIBELON® geomembrane 2.5 mm thick, formulated with a special compound of polyvinylchloride plasticised with high molecular weight branched plasticisers and heat-bonded during extrusion to a non-woven, needle punched 500 g/m$^2$ geotextile that provides drainage and further anti-puncture protection. The geocomposite is secured to the dam body by a patented fastening system spaced at 5.7 m designed intervals and consists of two stainless-steel components, one anchored to the dam body and the upper one holding the geocomposite in contact to the dam body. These vertical anchorage lines on the upstream face also work as free-flow drainage conduits. A watertight perimeter anchorage completes the system.

The geocomposite sheets were lowered from the dam crest and positioned on the upstream face by crews working from suspended platforms (Figure 1 at bottum). On the masonry face large offsets were observed and at the bottom perimeter seal area a layer of shotcrete was done to allow even adhesion of the stainless-steel element to the dam body.

## 2.5 Monitoring System

The efficiency of the geocomposite system is checked by monitoring the water drained behind the geocomposite. A drainage geonet band conveys the drained water into a special conduit pipe into the gallery. A piezometer was installed inside the gallery which helps to record the quantum of leaked water. An Optical Fibre Cable (OFC) was installed along the bottom periphery of the entire masonry dam to detect if there is any leakage occurring behind the geocomposite. This works by Heat Pulse Method (HPM) wherein the difference of temperature caused by seeping water is signalled and conveyed by the OFC.

## 2.6 Performance and Cost Economics

The entire work was completed in 4 months' time, 6 weeks ahead of the schedule and with a result far better than the expectation of the client. The total area of 17,300 square metres was installed in a record 16 weeks' time. The scope covered design, supply, installation, equipment, quality control, management, commissioning, patent fees and 10 years warranty.

The client has confirmed "the results that the leakage of the order of 30,000 litres/minute has been reduced to 100 litres/minute. The overall cost has been kept within the announced limits and the entire work was completed ahead of the time allowing earlier generation of power house".

## 2.7 Results after 15 Years of Operation

The result of the geocomposite installation at Kadamparai dam in 2018/2019 is still sound with the leakage still around the same levels. The first geomembrane project has more than satisfied the client in terms of the results, and since its installation the dam is now filled up to the FRL (Full Reservoir Level) thereby allowing full generation power of 400 MW, which was not possible before geomembrane works as the dam was operated at nearly 10 metre below FRL

**Fig. 2** : Upstream face of the dam before and after geomembrane installation.

Carpi was awarded the India Power Award for the year 2008 for this project in recognition for "Excellence in Water & Energy Management"

**Fig. 3** : Drainage gallery before and after geomembrane installation

**Fig. 4** : Kadamparai dam after installation of the geomembrane system

## 3. SERVALAR DAM (UNDER WORLD BANK FUNDED DRIP)

Servalar dam is a masonry dam constructed in the year 1984 for the purpose of drinking water, irrigation and power generation and owned by Tamil Nadu Generation Distribution and Corporation Ltd (TANGEDCO). This is one of the two reservoirs that supplies water to the entire districts of Tirunelveli and Tuticorin, in the state of Tamil Nadu. The dam is constructed across the Thamirabarani river (one of the perennial rivers in Tamil Nadu). The dam has an installed power capacity of 20 MW. The operation of the power house is as per water demand on the downstream side of the dam monitored by Public Works Department (PWD). The storage capacity of the dam is 35 million cubic metres.

### 3.1 Problems in the Dam

The major problem in Servalar dam is the high seepage collected inside the gallery through the vertical shafts and the extremely wet downstream side. The left flank of the dam experienced heavy seepage (Figure 5) when compared to that to the right flank, while a complete wet and oozing downstream side is visibly seen and goes unmeasured. The problem is attributed majorly to the poor quality of construction. The leakage which has been continuing for many years now has resulted in many of the drainage shafts getting choked, and heavy calcination was observed both inside the gallery as well on the downstream side of the dam.

Earlier attempts by the maintenance wing of TANGEDCO (Generation Team) consisted of racking/packing with cement mortar, racking/packing with chemical epoxy/ mortar, grouting and joint chemical treatment. The attempts to control the seepage did not give a permanent solution and instead the leakage continued to rise every year. With the available data and observation, the water oozing out from the downstream side should be more than 5,000 l/minute(approximately) from the left and spillway blocks.

Fig. 5 : Heavy seepage on left flank.

Any kind of repair works on hydraulic structures with chemical or cementitious material or ceramic material has a limited life time and durability, forcing the clients to go in for permanent long-term solution. Geomembrane waterproofing systems have proven to be a long-term solution in the field: an exposed geomembrane system installed at Lago Nero dam in the Italian Alps, in 2020 will be have a 40 years' history with no maintenance. Thus, the need for a geomembrane waterproofing system arose.

The total leakage measured in the vertical shafts before geomembrane works is around 1,200 l/minute taken by Carpi in 2017 December (before geomembrane works) and the critically leaking shafts are provided in table below.

Total leakage recorded in vertical shafts before geomembrane installation is 1025 litres/minute.

The last recorded leakage by DRIP in 2014, before the remediation works, was 743 l/minute and a complete wet downstream side (which is unmeasured – which can be approximated as around 6,000 l/minute). Most of the vertical drain shafts were choked. This continued leakage resulted in bulging of the entire dam on the left flank downstream which posed a serious risk to the dam.

### 3.2 Remedial Measures

Every 2/3 years attempts to control leakage were undertaken by the client TANGEDCO which consisted of racking/packing and pointing with cement mortar and chemical mortar/epoxy, grouting and joint chemical treatment, and all such methods could not get a long-lasting solution. In between 2007 and 2010, TANGEDCO had done repairs with epoxy pointing at a cost of 40 million Indian rupees and within years the leakage started to increase.

### 3.3 Selection of Rehabilitation Method

A detailed study of the problem at Servalar Dam was made and the most sophisticated design was adopted to install the SIBELON® geomembrane system. With the introduction of DRIP (Dam Rehabilitation and Improvement Project) Team in Tamil Nadu, this work of rehabilitation of Servalar dam was covered. Under the DRIP initiative, a preliminary proposal was submitted by Carpi Tech B.V, Amsterdam, Balerna Branch. Goal of the rehabilitation works was to reduce leakage at the dam, with the ultimate goal to make the dam watertight. The system proposed by Carpi for Servalar dam had to create a continuous water barrier by means of a flexible SIBELON® composite liner (=geocomposite), consisting of a watertight geomembrane heat-bonded during extrusion to an anti-puncture geotextile. The 10,200 $m^2$ upstream face was proposed to be waterproofed in the dry condition for the left flank and spillway portion.

The contract was awarded to Carpi in November 2016, and the scope of works consisted of desilting near the dam face to install the geomembrane lining down to the foundation of the dam, filling of cavities, if any observed on the upstream face of the dam, racking/packing and pointing, drilling and cement grouting in critical sections to fill the porous sections and design / supply / installation

**Table 2** : Leakage recorded in vertical shafts before geomembrane installation.

| Vertical Shaft | Leakage recorded | | Vertical Shaft | Leakage recorded | | Vertical Shaft | Leakage recorded | | Vertical Shaft | Leakage recorded |
|---|---|---|---|---|---|---|---|---|---|---|
| | litres/min | | | litres/min | | | litres/min | | | litres/min |
| 11 | 28 | | 15 | 600 | | 25 | 215 | | 40 | 6.25 |
| 13 | 20 | | 18 | 24 | | 32 | 25 | | 43 | 5 |
| 14 | 40 | | 20 | 49 | | 37 | 13 | | | |

of a SIBELON® geomembrane system at the left flank and spillway

### 3.4 Preparatory Works

Loose and weak zones were identified using hydro-jetting method whereby water applied at high pressure around 150 bar is used to clear off the loose materials in the mortar joints. The weak ones withered off and racking and packing and pointing were carried out to fill the racked mortar joints. Wherever large superficial cavities and honey combs were found, they were filled with mortar and proper curing and packing was done.

### 3.5 Geomembrane Waterproofing Components

A very thick geotextile of 2000 g/m$^2$ was initially laid over the entire upstream face of the stone masonry dam to protect the geocomposite from puncture as well as to provide some drainage capability. The waterproofing liner is a flexible synthetic geocomposite, SIBELON® CNT 3750, consisting of a 2.5 mm thick SIBELON® geomembrane heat-bonded during extrusion to a non-woven, needle punched 500 g/m$^2$ polypropylene geotextile. Each sheet has a length such as to cover the dam section where it is placed.

Face anchorage of the SIBELON® CNT geocomposite to the dam is obtained by the Carpi patented system of stainless-steel tensioning profiles allowing continuous linear fastening and pre-tensioning of the geocomposite. The tensioning profiles are placed at 5.70 m spacing and waterproofed with a cover strip of SIBELON® C 3250 geomembrane (the same material composing the SIBELON® CNT 3750 geocomposite, but without geotextile) 2.5 mm thick. All welding of the waterproofing geocomposite and geomembrane cover strips has been done by the “hot air” method, using manual one-track welding gun.

Submerged perimeter seals (at heel and around the inlet gates - scourvent and power vent) are made with 80x8 mm flat stainless-steel profiles tied to the dam with anchor rods embedded in chemical phials. Even compression is achieved with 80x3 mm EPDM rubber gaskets, and stainless-steel splice plates. In the areas where the seals are made the surface is regularized by a layer of mortar. The perimeter seal at crest is made with 50 x 3 mm flat stainless-steel batten strips tied to the dam with mechanical anchors. In the area where the seal is made the surface is regularized by a layer of mortar. And around the crest of the spillway gates with 80X8 mm flat water tight seals.

### 3.6 Drainage System

The drainage system was divided into 6 separate compartments: 4 upper compartments collecting water drained from the upstream face, and 2 lower compartments collecting water coming from the area between the primary and secondary bottom perimeter seals. Drained water is discharged into the gallery by 10 transverse pipes, 6 pipes discharging in the upper gallery and 4 pipes discharging in the lower gallery acting also as a ventilation conduit.

### 3.7 Results and Comparison

The entire work was completed on 14$^{th}$of October 2018 and an inspection of the gallery was done on 15$^{th}$ of October jointly with the client and Carpi. Leakage from shaft reduced from 1,200 litres/minute to 1.31 litres/minute. The downstream face is now completely dry with water level almost close to FRL. The recorded leakage through the vertical shafts is1.31 litres/minute on 09.11.2018 at water level 257.14 m.

**Table 3** : Leakage recorded in vertical shafts after geomembrane installation.

| Vertical Shaft No. | Leakage recorded in litres/minute |
|---|---|
| Vertical Shaft 14 | 0.00 |
| Vertical Shaft 15 | 0.00 |
| Vertical Shaft 20 | 0.00 |
| Vertical Shaft 25 | 0.00 |
| Vertical Shaft 32 | 0.00 |
| Vertical Shaft 37 | 0.05 |
| Vertical Shaft 40 | 0.98 |
| Vertical Shaft 43 | 0.28 |
| Total leakage recorded | 1.31 |

### 3.8 Conclusion

The installation of the exposed SIBELON® geocomposite, mechanically anchored and drained, has more than confirmed the expectations of TANEGDCO when it selected the system as a rehabilitation measure to provide efficient seepage control. Seepage that was in the order of 7,000 litres/minute has been reduced to around 20 litres/minute. A geomembrane system, adequately designed and installed, has once again proved to be advantageous and hence is a preferred alternative to traditional repair systems in Indian soil, in terms of technical and financial effectiveness.

The rehabilitation of Servalar dam using an exposed geomembrane is the second project of its kind in India and the first in DRIP projects and has been proved to be an effective way of reducing seepage in dams and hydraulic structures. The foundation gallery which was flooded before geomembrane works is now accessible and has significantly reduced the impact of uplift pressure on the gravity dam.

### 3.9 Results

**Fig. 6** : Downstream side before and after geomembrane installation.

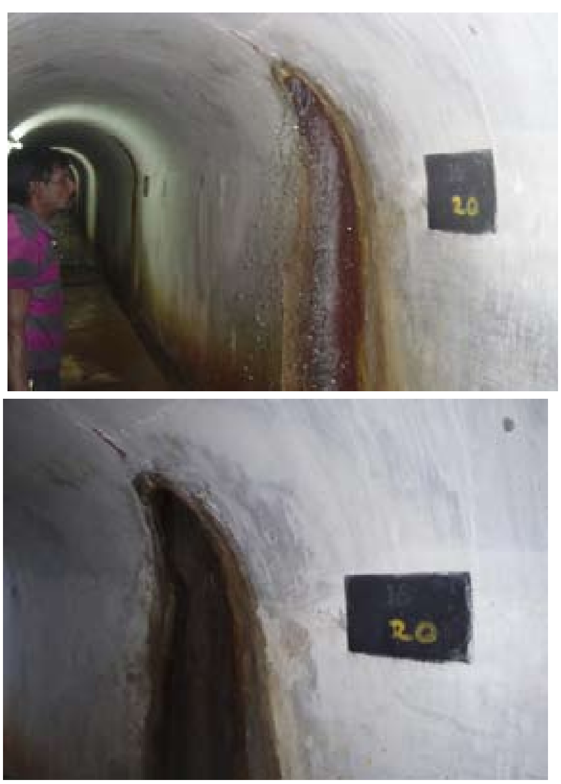

**Fig. 7** : Vertical shaft leakage before and after geomembrane installation

The results achieved is yet another proof of effective and professional design of geomembrane waterproofing system on large dams. A dam which was leaking at a rate of > 6,000 litres/minute is now reduced to just < 2 litres/minute on the left and spillway section.

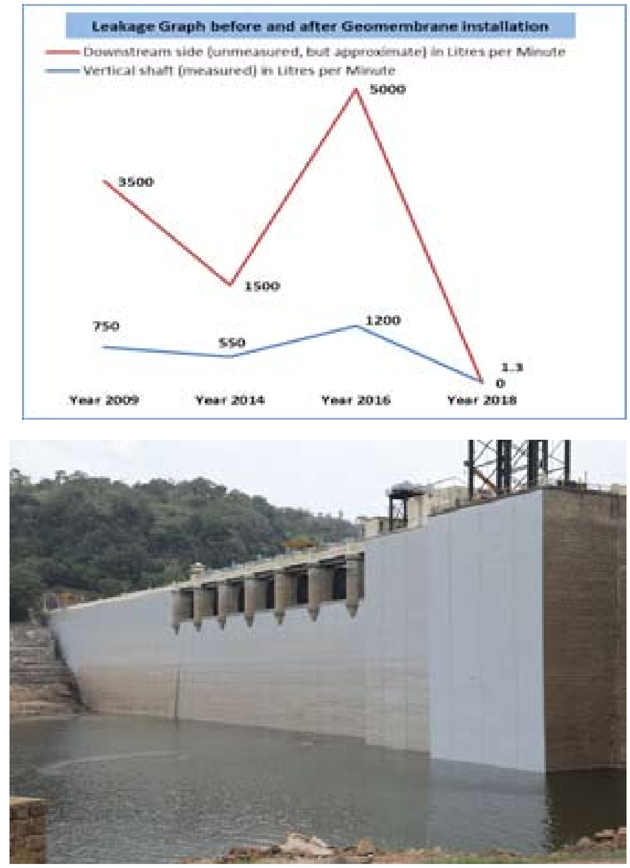


**Fig. 8** : Leakage pattern before and after geomembrane installation. At right, Servalar dam after geomembrane installation

## 4. UPPER BHAVANI DAM, (UNDER DRIP - ONGOING)

Upper Bhavani dam, a stone masonry dam of 80 m height, located in the Nilgiris District, Tamil Nadu (India) is the third project in India for Carpi and the second project in the DRIP program (Dam Rehabilitation and Improvement Project). The dam, constructed in the year 1965, started leaking badly since the early 2000ies. Leakage started increasing thereafter and especially the region surrounding the spillway started leaking very badly. Around 8,000 l/minute has been recorded as the leakage from the two shafts surrounding the spillway alone. Various repair attempts were made between 2003 and 2010 and the dam has been declared as the most distressed dam in spite of the conventional repair works carried out, which again did not provide good results. Ultimately it was decided to install a geomembrane waterproofing system citing the previous success stories of the Kadamparai and

Servalar projects. The project is being executed in two phases out of which 20% of geomembrane installation has been completed in the first phase between April and June 2019. The next phase will commence by February 2020 once the monsoon ends by December 2019. Despite the challenges of extreme cold weather and location of the dam in a deep reserved forest, the balance work has been planned to get completed in second phase between Jan and June 2020. The water from the Upper Bhavani dam acts as the main source for a series of cascaded power houses with a total power generation capacity of > 600 MW. Thus, saving water is of utmost importance for the client TANGEDCO

**Fig. 9** : Leakage in vertical shaft of drainage gallery at left. At right, geomembrane lined on the upstream face of the dam as of June 2019

## 5. CONCLUSIONS

Geomembrane systems effectively restore watertightness in all types of leaking dams and joints, with little or no impact on operation of the dam, adhering to the demanding environmental conditions. They provide water tight barriers in all types of dams. Their elongation capabilities allow resisting movements that would destroy other types of water barriers. In all the installation done so far, it is to be noted that meticulous planning and designing has always played the key role in success of the project. With > 160 installation on dams all over the world, every installation confirms to the guidelines stipulated by ICOLD and thereby achieving the goal in each and every project.

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# STRENGTHENING MASONRY DAMS BY MEANS OF DOWNSTREAM BACKFILLS

**P.Lignier[1] and S.Delmas[1]**


## ABSTRACT

*Many old masonry dams suffer from a lack of safety margin due to their ageing or the new criteria related to the latest regulations and standards. An easy way to strengthen a masonry dam is to put in place a backfill against its downstream face, which brings a beneficial force opposite to the water thrust. This article presents the 30 years' experience of the strengthening of masonry dams in France by means of downstream backfills.*

*For the backfill material, it is recommended using a non-cohesive rocky material – 0/400 mm - with a friction angle comprised of approximately and 40°. It allows on the one hand to reduce the downstream slope of the backfill in comparison with soil material and on the other hand to obtain a higher beneficial force in comparison with blocky rock material. The main difficulty is to assess this beneficial force brought by the rocky backfill. A simple method to calculate this force is presented in this article. This method which can be applied for any geometry gives results close to FEM calculations, and is always on the safe side.*


## 1. INTRODUCTION

### 1.1 Masonry Dams in France

72 masonry dams - more than 15 m high - have been built in France for 350 years. The oldest one – still in use - is Saint-Férréol dam built in 1672. Masonry dams represented the majority of the dams built in France during the 19th century and the beginning of the 20th century.

From the 1850s, the profiles of the masonry dams became thinner – with a slope equal to 1vertical for 0,6 or 0,7 horizontal- to optimize the masonry volume until the failures of Bouzey dam in 1895. These accidents highlighted the role of the water pressure in the masonry and in the foundation.

From the beginning of the 20th century, the profiles of the dams were thicker and the dams progressively drained.

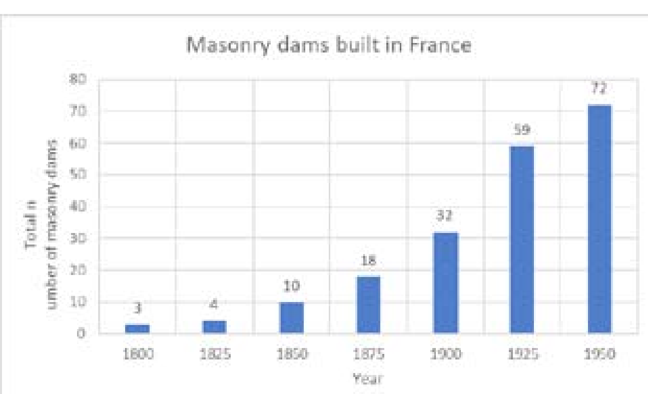


**Fig. 1** : Total number of masonry dams in France versus time

From our experience, the old masonry dams suffer from the following main pathologies:

– Watertightness defect of the masonry (80% of French masonry dams)
– High permeability or water pressure in foundation (45 % of French masonry dams)
– Global instability (insufficient safety margin) (25 % of French masonry dams)

The following remedial works were carried out so far:

– Improvement of the watertightness of the masonry (80% of French masonry dams)
– Grouting and drainage of the foundation (45 % of French masonry dams)
– Strengthening by anchors (10 % of French masonry dams)
– Strengthening by downstream backfill (13 % of French masonry dams)

Following French masonry dams strengthened by a downstream backfill may be mentioned:

**Table 1**. French masonry dam strengthened by downstream backfill in the last 35 years

| | Dam height | Dam slope | Backfill slope |
|---|---|---|---|
| Joux | 30 m | 0.84h/1v | 1,4h/1v |
| Ternay | 41 m | 0.7h/1v | 1,4h/1v |
| Vérut | 21 m | 0.75h/1v | 1,5h/1v |
| La Gimond | 19 m | 0.8h/1v | 1,8h/1v |
| Pas-de-Riot | 36 m | 0.73h/1v | 1,7h/1v |
| Dardennes | 37.5 m | 0.84h/1v | 1,5h/1v |

See references [1], [2] & [3]

1. Tractebel Engineering S.A, France

## 2. THE PRINCIPLES OF A STRENGTHENING BY MEANS OF DOWNSTREAM BACKFILL

### 2.1 Main Constraints

Two opposite constraints govern the design of a strengthening by means of a downstream backfill.

On the one hand it is often advantageous – for lack of space or from economical point of view – to design a backfill with a steep slope. On the other hand, the beneficial thrust is reduced when the material used for the backfill presents a high friction angle. The higher is the friction angle, the lower is the beneficial thrust.

It is thus recommended opting for an economical compromise using rocky material with a maximum diameter of 400 mm.

### 2.2 Rockfill Characteristics

Usually, a rocky material with a friction angle of approximately 40° is selected. As this friction angle is difficult to measure, it is recommended using rocky material with a continuous grading curve, with a maximum diameter of 400 mm. The percentage of fines – below 80 µm - can reach 8 to 10 %. This kind of material is easy to find and often cheap.

To ensure the stability of the backfill, the material shall be permeable – $k > 10^{-3}$ m/s. The maximum percentage of fines is dictated by the global permeability of the material. Permeability tests – as Matsuo tests – shall be performed to check that fines % above 5% can be authorized.

The backfill does need to be too compacted so as not to increase too much the friction angle. Usually two passes of roller are enough for compaction. The material in vicinity of the downstream face of the backfill shall be compacted with more energy to ensure the stability of the slope – skin effect.

### 2.3 Typical Cross-section

The typical cross-section is presented in Figure 2.

A transition layer – sand - is put between the backfill and the downstream dam face to improve the transmission of the beneficial thrust to the dam.

## 3. ASSESSMENT OF THE BENEFICIAL THRUST

It is difficult to assess the beneficial thrust brought by a backfill as the common formula used for retaining walls cannot be applied. Indeed, active or passive earth pressure formulae cannot be applied as the displacement of the dam is too small. Moreover, the formula used for estimating backfill pressure at rest – as Jaky's formula for coefficient of lateral pressure at rest : $K_o = (1 - \sin \varphi)$ – cannot be used as it is valid for a semi-infinite horizontal backfill. The geometries of the dam and its backfill are too complex.

A new method inspired by the Coulomb's wedge method is proposed by the authors.

### 3.1 Coulomb's Wedge Method

At a certain level, let's consider the equilibrium of a rockfill wedge defined by a downstream inclined plane. The weight ($\vec{P}$) of this wedge can be broken down into two reactive forces:

- A force $\overrightarrow{(A)}$ acting on the downstream face of the dam – the beneficial thrust

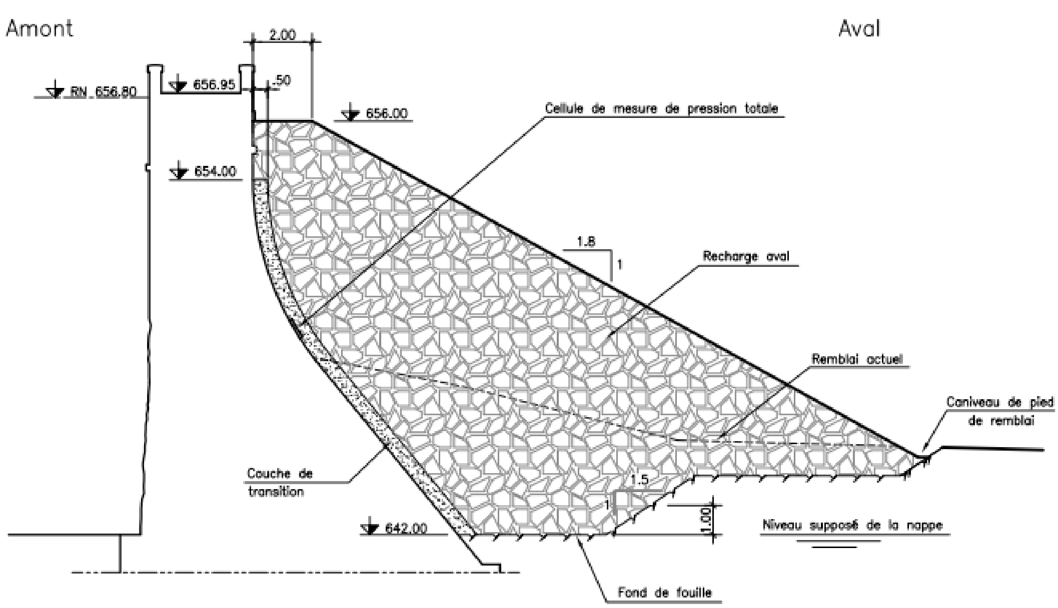


**Fig. 2** : Typical cross-section

- A force ($\vec{R}$) applied on the remaining part of the backfill by the wedge.

Préciser les points d'application de ces forces

Against a moving wall, the backfill thrust is given by a Coulomb's wedge defined by an inclined plane at 45°+ φ/2 – φ being the effective friction angle of the backfill material.

To obtain a unique breakdown of the forces, it is necessary to make the following assumptions on the directions of the forces:

- The direction of the force $(\vec{A})$ is inclined of ϕ/2 to the perpendicular to the dam downstream face

- The direction of the force ($\vec{R}$) is inclined of φ to the perpendicular to the wedge downstream plane.

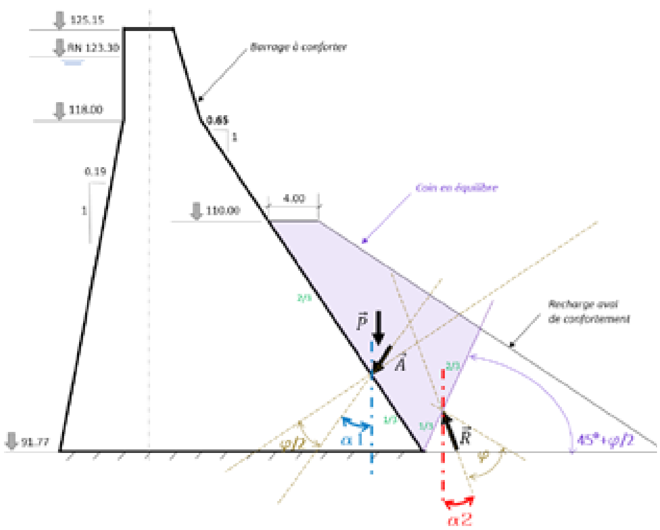


**Figure 3** : Breakdown of the forces applied on the Coulomb's wedge

The following beneficial thrust is obtained:

$$A = P /(\cos(\alpha 1)\,(1 + tg(\alpha 1)/tg(\alpha 2))$$

with

$\alpha_1 = \beta - \varphi/2$ ( β angle of the downstream dam face with horizontal)

$\alpha_2 = 45 - \varphi/2$

If we assume less friction between the remaining part of the backfill and the Coulomb's wedge - the force ($R$) becomes closer to the perpendicular to the downstream wedge plane - $\alpha 2$ is increasing – the horizontal thrust A increases.

If we assume less friction between the Coulomb's wedge and the downstream dam face – $\alpha 1$ is increasing – the horizontal thrust A increases.

As intuitively felt, the more the friction, the less the beneficial thrust. The force A assessed as above appears to be the minimum theoretical thrust.

### 3.2 Comparison with FE Method and Jaky's Formula

In order to validate this new method, comparisons with FEM calculations have been carried out for some dams. The differences are small.

The detailed calculation performed for Dardennes masonry dam is provided as an example.

Dardennes dam is a 37.5 m high masonry dam which was built in 1912. The behavior of the strengthened dam was assessed with a non-linear Finite Elements Model.

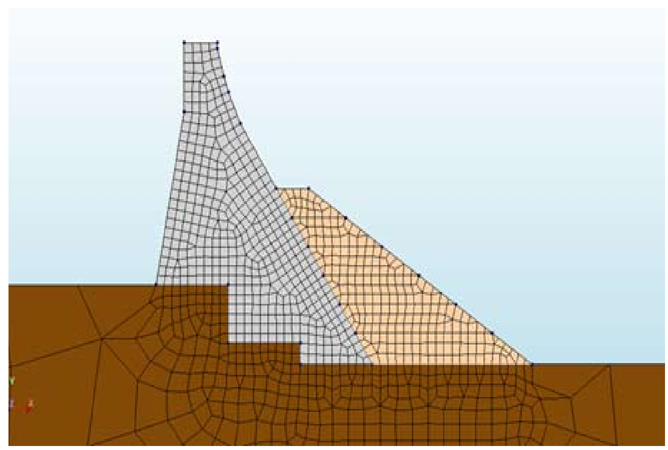

**Figure 4** : FE model (Dam in grey – Backfill in orange)

The beneficial thrust was estimated by both methods with the following assumptions:

- Backfill friction angle: 40 °
- Friction angle between the dam and the foundation: 45 °

The main results are summarised in the table below.

**Table 2** : Dardennes masonry dam - Beneficial thrust calculated by both methods

| | Horizontal thrust | Vertical thrust | Total thrust |
|---|---|---|---|
| EF method | 0.72 MN/m | 0.91 MN/m | 1,16 MN/m |
| Coulomb's wedge method | 0.71 MN/m | 0.94 MN/m | 1,18 MN/m |
| Difference | 2% | 4 % | 2% |

For the same dam, the Jaky's formula for lateral earth pressure at rest has been also used. A coefficient of lateral earth pressure $K_0$ of 0,36 is obtained, to be compared with the coefficient calculated with Coulomb's wedge method of 0,24 . The thrust force for Coulomb's wedge method has been assessed to be equal to $\frac{1}{2}.K_0 \gamma.h^2$ with γ the backfill unit weight and h the backfill height. The Jaky's formula - $K_o = (1 - \sin \varphi)$ - is far too optimistic by 50%.

### 3.3 Comparison with Site Measurements

Six Total pressure cells measuring the total pressure applied by the backfill on the dam were installed on Pas-de-Riot dam which was reinforced with a downstream backfill in 2018.

The first measurements show backfill pressures approximately 30 % above the value calculated with the Coulomb's wedge method.

These first results shall be taken with care as they are very sensitive to various parameters difficult to control, such as the exact inclination of the cells.

## 4. CONCLUSION

The objective of this article was to present the French experience on the strengthening of masonry dam by means of downstream backfills. Six French old dams were successfully reinforced with this technique in the last 35 years. Intuitively, the downstream backfill brings a beneficial force opposite to the upstream water thrust. As the geometry of the downstream dam face and of the backfill is complex, the classical formula for retaining walls cannot not be used.

A simple method using Coulomb's wedge theory has been developed to assess the beneficial thrust brought by the rocky backfill. This method gives values theoretically on the safe side. Comparisons with more complex FE models showed that this method is robust.

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# DEPLOYMENT OF A FIBRE OPTIC LEAKS AND SEEPAGES DETECTION SYSTEM BELOW A WATERPROOFING GEOMEMBRANE ON UPPER BHAVANI DAM

**C. Guidoux[1], R. Beguin[1], P. Pinettes[1], J. Subramanian[2], V. Subramanian[2], F. Tronel[3] and J.R. Courivaud[4]**

**ABSTRACT**

*Although geomembranes represent a very safe solution for old dams waterproofing, they may remain sensitive to damages from mechanical impacts of any type. In order to reduce this vulnerability, development of low-cost technologies that enable operators to immediately detect and locate leaks as soon as they appear are requested. A competitive technology available to achieve this goal is fibre optics distributed temperature monitoring that enable to infer the presence of leakages from the temperature variations all along a fiber optic path with a very high resolution (up to 0.2 m). This type of measurement is acknowledged as particularly adapted to applications that require dense arrays of measurements or extended monitoring zones, such as dam faces or water reservoir faces.*

*The ability of fibre optics to actually detect and locate leaks below geomembranes has been experimentally demonstrated in 2018 using heated fibre optics cables. The results gathered from this experiment were used to design an industrial leakage detection system dedicated to the surveillance of the geomembrane. This system is currently being installed on the Upper Bhavani Dam, in India. The present paper deals with the design and the on-going deployment of this system.*

## 1. INTRODUCTION

### 1.1 Waterproofing using Geomembranes

Waterproofing old dams is often a very interesting alternative to reinforcing or repairing them, as it significantly lengthens their lifespan for rather limited an investment, in particular when compared to the cost of structural reinforcements. In the same perspective, watertight membranes are obviously a key element for the performance of water reservoirs that are located on non-watertight soils.

It is therefore of utmost economic interest to improve the effectiveness of today waterproofing techniques.

Although geomembranes (GM) and geocomposites represent a very safe solution (strict quality control during the production in factory, high resistance, high deformability able to adapt to various movements such as settlements or seismic displacements), they may remain, when uncovered, sensitive to damages from mechanical impacts of any type. The possibility that water can by-pass the area lined with GM cannot besides be totally ruled out.

In order to reduce this vulnerability, development of low-cost technologies that enable operators to immediately detect and locate leaks as soon as they appear are requested, as they would enable to immediately repair when necessary.

### 1.2 Fibre optic-based surveillance system

Although fibre optics are generally known only as excellent telecom cables, they can be used as competitive thermal or strain sensors : when properly instrumented at one of their extremities, they enable to measure the temperature or the strain all along their path with very high a precision (0.1°C in temperature, and up to a few microstrains in strain) and very high a resolution (up to 0.1 m, depending on the implemented optical technology) – go for instance at http://geophyconsult.com/faq/faq.html for an introduction to Fibre Optics Monitoring (FOM) and to the physical processes behind, as well as to the way this technique is used to monitor infrastructures.

This type of measurement is acknowledged as particularly adapted to applications that require dense arrays of measurements or extended monitoring zones, such as dam faces or water reservoir faces.

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3. Carpi, CARPI Tech S.A., Balerna, Switzerland

4. EDF, Le Bourget du Lac, France

It is likely to be used to detect leaks on dams or water reservoirs that are waterproofed with GMs that are positioned on their upstream face. The principle of measurement is rather simple, provided that we assume that (1) a drainage geonet is installed on top of the surface to waterproof, (2) a fibre optics cable is pulled over the drainage geonet, over several back and forth horizontal lines covering the surface to monitor (see Figure 1); and (3) the fibre optics cables include electric wires in which an electric currents are regularly forced to flow, so as to generate successive heat pulses all along the fibre optics cables. In case of seepage or leak, water coming out from the seepage or leak is then drained downwards within the drainage geonet until it intersects the nearest horizontal fibre optics line, where it speeds up the cooling of the heat pulse. The amplitude of the momentary generated heat pulse is thus reduced at all locations which are intersected by seepage or leak flows, with respect to all other locations (see Figure 1). The detection of such anomalies with thermal measurements carried out all along the fibre optics cable that intersects the leak flows is known as the « Heat Pulse Method » (Perzlmaier et al., 2006 or Read et al., 2014).

## 2 EXPERIMENTAL DEMONSTRATION

### 2.1 Experimental Setup

The ability of fibre optics to actually detect and locate leaks below was experimentally demonstrated in 2018 (Guidoux, 2019), using a 1:1 dyke of about 22 m length, 3 m height, which closes a 14 m wide concrete reservoir (see Figure 2).

A drainage geonet has been installed on top of the upstream face of the dyke and a fibre optics cable has been pulled through the drainage geonet over two back and forth horizontal lines, so as to properly cover the face of the structure to monitor (see Figure 3 and Figure 4). The deepest horizontal line is called “Bottom” line, it is located about 85 cm above the bottom of the reservoir (ground zero or G0). The other one is called “Top” line, it is located about 110 cm above G0.

**Fig. 2** : EDF experimental setup in action (© EDF).

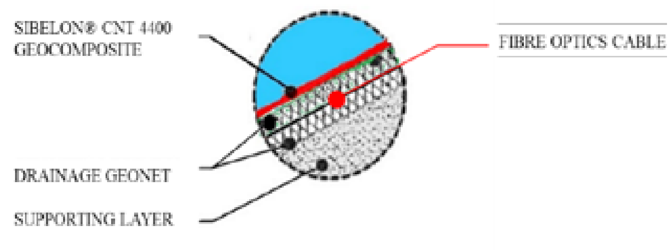


**Fig. 3** : Cross section of the position of the fibre optics cable within the sandwich composed of the GM and the upstream face of the structure.

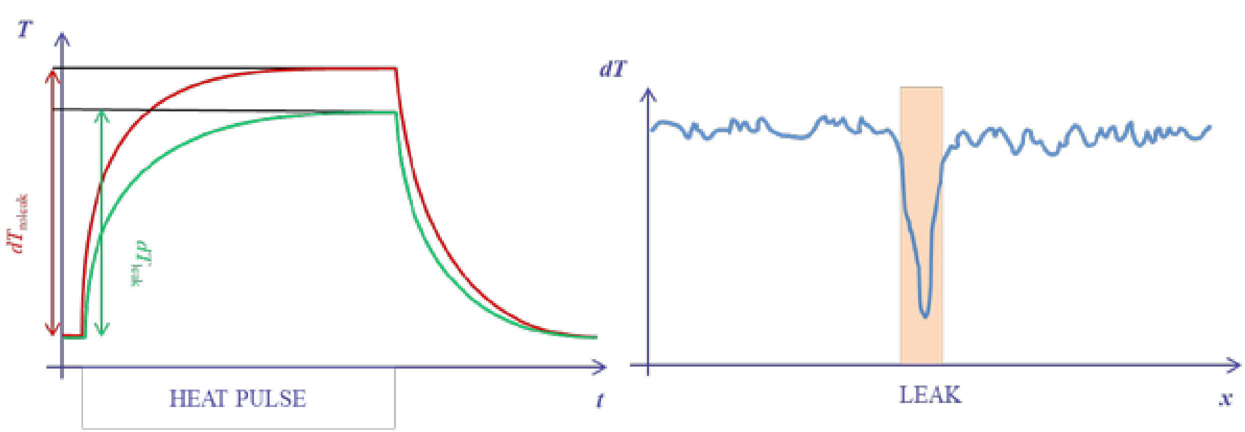


**Fig. 1** : Principle of detection according to the Heat Pulse Method (Perzlmaier et al., 2006). Left: generated heat pulse, with a low amplitude where it is intersected by leak flows (green situation) and a high amplitude elsewhere (red situation). Right: difference of temperature measured all along the fibre optics horizontal line just before and at the of the generation of the heat pulse, with the thermal signature of a leak at the middle of the line.

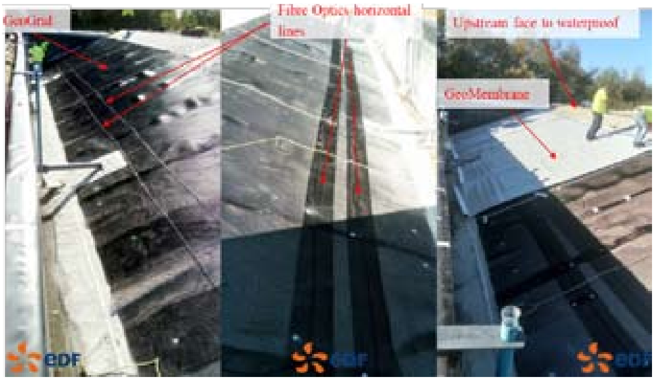


**Fig. 4** : Cross section of the position of the fibre optics cable within the sandwich composed of the GM and the upstream face of the structure

On top of the drainage geonet, a standard CARPI geocomposite type SIBELON® 4400, consisting of a 3.0 mm thick plasticised Polyvinychloride (PVC) geomembrane heat-bonded during fabrication to a 500 g×m$^2$ non-woven, needle punched polypropylene geotextile, has been installed according to CARPI standard installation procedures.

In order to simulate seepages, at abscissa 12 m from the right rim of the dyke, a pipe has been inserted into the drainage geonet down to about 25 cm above the "Top" line, so as to enable water injections at a controlled rate in the drainage geonet, below the GM. And in order to simulate leaks, at abscissa 8.2 m from the right rim of the dyke, a 10 cm long vertical cut has been made through the GM about 25 cm above the "Top" line. The puncture has been covered by a removable plastic strip, so that the activity of the leak can be controlled (Guidoux, 2019).

In addition to those elements, 3 pipes have been installed at the bottom of the drainage geonet and linked to pumps working at a bigger pumping rate than the rate of the water which is injected (either via the pipe or via the puncture). The aim of these additional pumps was to ensure that the bottom of the drainage geonet remained properly drained during the test so that the space between the upstream face of the structure and the GM never got drowned.

The reservoir level and the pressure of the water at the bottom of the drainage geonet below the GM were permanently monitored with standard pressure gages.

The heat pulses were generated by a tailor-made electric device enabling to inject a few Amperes over 100 to 270 V in 4 or 6 electric wires of 0.5 mm$^2$ section, depending on the targeted elevation of temperature. The generated thermal anomaly ranged between 20 and 30°C, for an injected power ranging from 6 to 9 W×m$^{-1}$. The total length of the electric and optical circuits were equal to 114.2 m.

The optical fibres were standard Multi Mode fibres of 50 µm diameter. They were measured with a classical Raman interrogator which enabled to measure the temperature every 5 min with a spatial resolution 12.5 cm and a relative precision in temperature of the order of 10$^{-1}$°C.

During the installation phase, a detailed table of correspondence between the marks printed on the fibre optics cable and their actual location on site was established, so that the optical lengths delivered by the opto-electronics interrogator could be converted into precise locations on the experimental setup.

### 2.2 Detection Results

Successive seepages of 10 l×m$^{-1}$, 5 l×m$^{-1}$, 1 l×m$^{-1}$ and finally 0.5 l×m$^{-1}$ have been tested. The results are given Figure 5 for the "Top" line. Clearly, all the seepages above 1 l×m$^{-1}$ have been detected and located, while the seepage of 0.5 l×m$^{-1}$ has been of the order of the detection threshold.

In the same respect, one can note that the horizontal extension of the detection parameter anomalies were bigger on the "Bottom" line than on the "Top" line. Again, this was normal, as the water flow associated with the seepages naturally spread as it went further down from where it had been initiated.

The ability of the system to detect the leak generated by the puncture made in the GM at x = 8.2 m has also been tested, with various values of injected current ($P_{inj}$ = 6 W×m$^{-1}$ and $P_{inj}$ = 9 W×m$^{-1}$) and of various water levels in the reservoir (1.5 m above G0 and 2 m above G0). Figure 6 clearly show that the leak has been detected and located in all the tested configurations, on both lines.

The water flow associated with the leak has not been measured precisely, as it has turned out not to be able to prime the pump dedicated to the draining of the drainage geonet . However indirect estimates of this water flow lead to a water flow of the order of 0.5 l×m$^{-1}$.

Assuming a security margin of 100%, we can thus assert that the system turned out to detect and locate seepages and leaks that were as low as 1 l×m$^{-1}$.

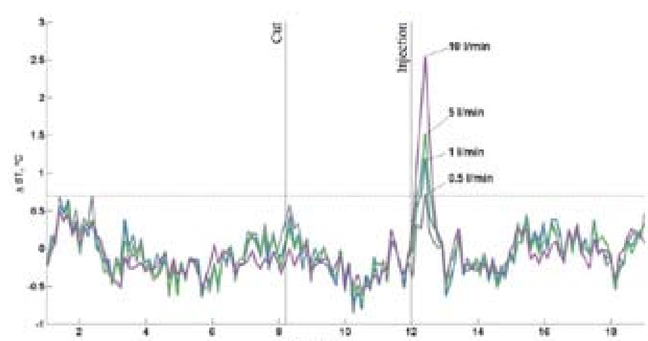


**Fig. 5** : Detection parameter during the seepage tests for the Top line. In purple seepage of 10 l×m$^{-1}$, in light green seepage of 5 l×m$^{-1}$, in dark green seepage 1 l×m$^{-1}$ and in brown/grey seepage of 0.5 l×m$^{-1}$. The first vertical line represents the abscissa at which the puncture simulating the leaks is located, while the second vertical line represents the abscissa at which the water injected below the geomembrane to simulate the seepages is located. The horizontal line represents the threshold above which anomalies can be considered as potential leaks or seepages.

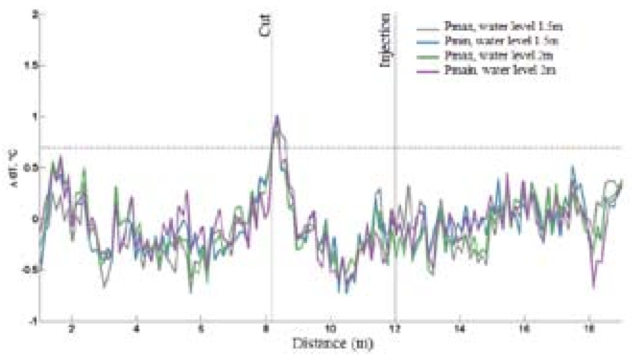


**Fig. 6** : Detection parameter on the Top line during the leak tests for various values of injected current and various water levels in the reservoir. In grey/brown current $P_{inj}$ = 9 W×m$^{-1}$ and reservoir level = 1.5 m above G0 ; in blue $P_{inj}$ = 6 W×m$^{-1}$ and reservoir level = 1.5 m above G0 ; in green Pinj = 9 W×m$^{-1}$ and reservoir level = 2 m above G0 and in purple $P_{inj}$ = 6 W×m$^{-1}$ and reservoir level = 2 m above G0 . The first vertical line represents the abscissa at which the puncture simulating the leaks is located, while the second vertical line represents the abscissa at which the water injected below the geomembrane to simulate the seepages is located. The horizontal line represents the threshold above which anomalies can be considered as potential leaks or seepages.

### 2.3 Intensity of Ddetection vs Flow Rate

In order to deduce the water flow associated with the seepage or leak generated below the geomembrane, geophyConsult and EDF have imagined a new parameter, called the intensity of detection level, that could be directly calculated from the detection parameter defined above each time a detection occured. Figure 7 shows that this parameter – as expected – is drastically influenced if not directly proportional to the water flow associated with the seepage or leak.

The geophyConsult and EDF intensity of detection parameter is therefore a very good candidate for estimating the water flows associated with the detected seepages or leaks.

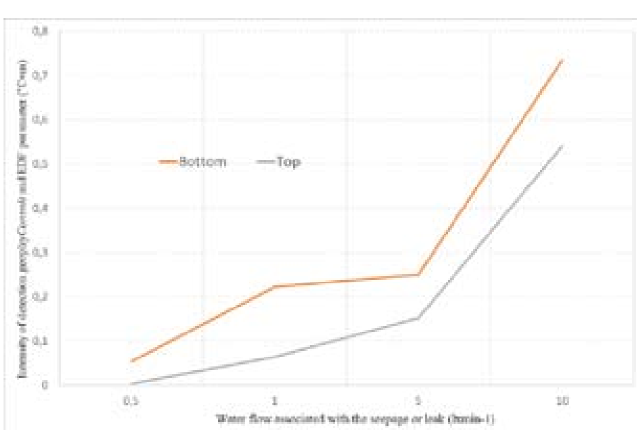


**Fig. 7** : Representation of the parameter called “Intensity of detection”, as defined by geophy Consult and EDF, and calculated for the detections on “Top” (grey) and “Bottom” (orange) cables as a function of the water flow associated with the seepages or leaks that generated the detections.

## 3. INSTALLATION ON THE UPPER BHAVANI DAM

The carried out tests showed that seepages or leaks as low as 1 l×min$^{-1}$ can be detected and located with a precision of the order of a few tens of centimeters with horizontal fibre optics cables properly installed on the upstream face of a hydraulic structures water proofed by a GM, provided the space between the GM and the structure face is properly drained at its bottom and provided the fibre cables are properly instrumented. Associated with a system that automatically detects all flows that are bigger than a given threshold (to be fixed by the structure owner), they thus can be used as a powerful and economic tool to instantly detect and locate leaks below GM. Associated with the calculation of the geophyConsult and EDF intensity of detection parameter, they can also estimate the water flow associated with the detected seepage or leak. The detection sensitivity of 1 l×min$^{-1}$ turns out to be sufficient for industrial applications. In fact, it corresponds to the targeted performance of GMs on actual dams, dykes or water reservoirs.

Heating up to 10 W×m$^{-1}$ hundreds of meters of electric cables is easily feasible with standard power generators. The investment costs of such a system are besides very low compared to the total cost of a waterproofing operation of a dam, dyke or water reservoir. The proposed solution is thus a priori relevant for waterproofing operations of dams or water reservoirs of width of the order of a few hundreds of meters and of height of the order of 50 to 100 m.

The deployment of the proposed solution has been initiated on several dams around the world, starting with the Upper Bhavani dam, in India.

### 3.1 The Upper Bhavani Dam

The Upper Bhavani Dam is a masonry dam located in the Nilgiris District (Tamil Nadu State, India), on which an upstream face lining with a Carpi Sibelon geomembrane is foreseen on the entire upstream face.

The dam was considered a distressed dam in 2005 and several repair attempts were made but none could provide a long lasting permanent solution and the client decided to go in for installation of Geomembrane waterproofing system on the upstream face similar to the one in their own Kadamparai dam installed in 2004-05 where the leakage was brought down from nearly 35,000 l×min$^{-1}$ to nearly 100 l×min$^{-1}$ and is still in service. The leakage currently was recorded in Upper Bhavani at 8000 l×min$^{-1}$ at 8 meter below the Full reservoir level. Being a large dam with exposed area of around 20,000 sqm, the client expressed interest to have a surveillance system to monitor the efficiency of the geomembrane system and hence the decision to go in for optical fiber based measuring system.

**Fig. 8** : Overview of the dam with nearly 20% of the upstream face installed with Geomembrane system & Optical Fiber Cable.

## 3.2 Design

The main objective of the surveillance system is to detect and localize defects below the geomembrane, on the entire length of the dam. In order to do so, the leakage detection system has been designed with:

- 4 fibre optic cable loops located under the GM. The lowest measurement lines are located above the drainage gallery;
- 8 waterproof optical connection boxes under the GM (red boxes on Figure 9). These boxes are mandatory because the works has been planned on two or three years, therefore the cables have to be cut into pieces before the installation on each work area, then they have to be spliced in order to restore the optical continuity of each measurement line;
- 4 or more optical connection boxes and one heat command rack at the crest of the dam, housed in 4 concrete shelters (blue boxes on Figure 9);
- 1 measurement device;
- 1 power supply for the measurement device and the heat command rack.

The cables will be heated at approximately 6 W×m$^{-1}$, using an electrical supply of 5kW (220V) available for the command box. According to the methodology validated during 2018 tests (Guidoux 2019), the measurements will be performed:

- before the impoundment of the dam (reference);
- each year or in case of increasing leakages measured in the drainage gallery.

## 3.3 Installation

The installation started in May 2019 and carried on till mid June 2019 when monsoon started and the work is now extended to the next season. In the current situation, the entire installation of geomembrane has been planned in two phases. The entire dam has been divided into 4 segments (Top Left, Top Right, Bottom Left and Bottom Right). While the Top Left (20%) has been completed in the year 2019 between May 2019 and mid June 2019, the remaining portion is planned for installation between March 2020 and mid June 2020. Wherever the cables are required to be positioned, the following sequence of works are being carried out.

The installation of the cables progresses as described below:

- upstream face preparation
- installation of the cable protection geonet
- installation of the cables on the vertical paths between the crest and the location of the boundary between work phases, with preserved extra length at the top and the bottom


**Fig. 9** : Shelter for Optical connections on the crest

- fixation of the cable every 2 meters (Figure 10)
- reading of metric inscription on the cables in order to identify any measurement point on the cable
- installation of the geomembrane
- quality controls (optical continuity, integrity of the cables)
- pulling of the upper cable ends into their shelter
- protection of the lower end of each cable until the next work phase

### 3.4 Future Works

In the second season programmed to begin in March 2020, the optical fiber cables will be positioned in the vertical section between the crest and the position where the cable takes a horizontal path. Wherever there is a break in between two seasons of work a special connection box will be provided to ensure connectivity between the two sections of the cables.

### 3.5 Cost

The entire scope of work is designed and getting installed well within the contractual price as stated in the agreement. The success of this project in Upper Bhavani is largely attributed to the meticulous design and planning of the fiber optic system in such large dams.


**Fig. 10** : From Left to right, Fiber Optic cable positioned above the geotextile, geogrid protecting the fiber cable and an external protective pipe covering the exposed optical fiber cable at the crest

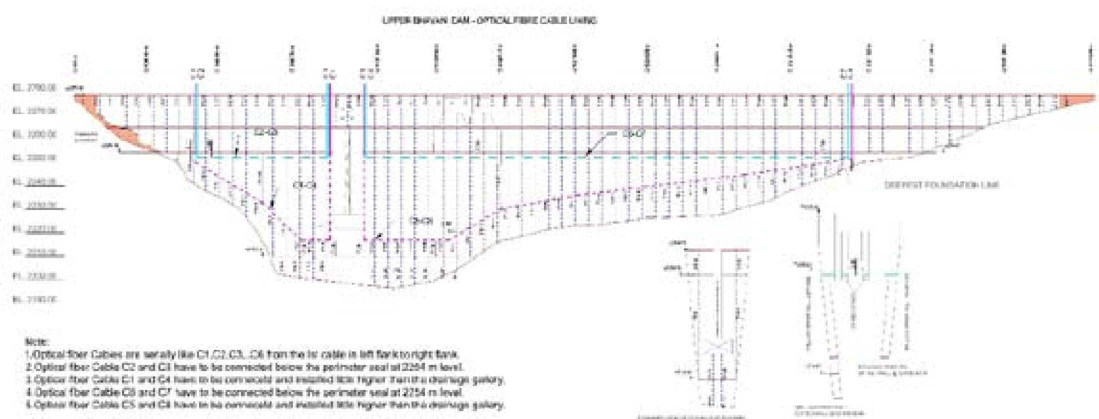


**Fig. 11** : Position of the Optical Fiber Cable along the entire periphery of the dam

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Read, T., Bour O., Selker J.S., Bense V.F., Borgne T., Hochreutener R., Lavenant N. 2014. Active-Distributed Temperature Sensing to continuously quantify vertical flow in boreholes, *Water Resour. Res*., 50, 3706–3713, doi:10.1002/2014WR015273.

Schäfer, P., Perzlmaier S., Conrad M., Strobl T. and Aufleger M. 2003. *ICOLD Montréal Q82*.

# INTERNATIONAL GEOSYNTHETICS SOCIETY

The International Geosynthetics Society (IGS) was founded in Paris, on 10 November 1983, by a group of geotechnical engineers and textile specialists. The Society brings together individual and corporate members from all parts of the world, who are involved in the design, manufacture, sale, use or testing of geotextiles, geomembranes, related products and associated technologies, or who teach or conduct research about such products.

**The IGS is dedicated to the scientific and engineering development of geotextiles, geomembranes, related products and associated technologies. IGS has 47 chapters, over 3,000 individual members and 161 corporate members.**

The aims of the IGS are:

- to collect and disseminate knowledge on all matters relevant to geotextiles, geomembranes and related products, e.g. by promoting seminars, conferences, etc.
- to promote advancement of the state of the art of geotextiles, geomembranes and related products and of their applications, e.g. by encouraging, through its members, the harmonization of test methods, equipment and criteria.
- to improve communication and understanding regarding such products, e.g. between designers, manufacturers and users and especially between the textile and civil engineering communities

The IGS is registered in the USA as a non-profit organization. It is managed by five Officers and a Council made up of 10 to 16 elected members and a maximum of 5 additional co-opted members. These Officers and Council members are responsible to the General Assembly of members which elects them and decides on the main orientations of the Society.

## IGS CHAPTERS

The IGS Chapters are the premier vehicle through which the IGS reaches out to and influences the marketplace and the industry. Chapter activities range from the organization of major conferences and exhibits such as the 10th International Conference on Geosynthetics in September 2014 in Berlin, Germany and its predecessors in Guaruja, Yokohama, Nice and Atlanta to the presentation of focused seminars at universities, government offices and companies. Chapters create the opportunity for the chapter (and IGS) membership to reach out, to teach and to communicate and they are the catalyst for many advances in geosynthetics. Participation in an IGS chapter brings researchers, contractors, engineers and designers together in an environment which directly grows the practice by informing and influencing those who are not familiar with our discipline.

## MEMBERSHIP

Membership of IGS is primarily organised through national Chapters. Most individual members (94%) belong to the IGS through Chapters. Chapter participation allows members to be informed about, and participate in, local and regional activities in addition to providing access to the resources of the IGS.

IGS Offers the following categories of membership:

### Individual

Individual member benefits are extended to each and every individual member of the IGS including Chapter Members. Additional chapter benefits are provided to Individual Members who join the IGS through a chapter.

Individual Member Benefits include:

- a membership card
- an IGS lapel pin
- on-line access to the *IGS Membership Directory*
- the IGS News newsletter, published three times a year
- on-line access to the 19 IGS Mini Lecture Series for the use of the membership
- information on test methods and standards
- discount rates:
    - for any document published in the future by IGS
    - at all international, regional or national conferences organized by the IGS or under its auspices
- preferential treatment at conferences organized by the IGS or under its auspices

- possibility of being granted an IGS award
- Free access to the *Geosynthetics International* journal, now published electronically.
- Free access to the *Geotextiles and Geomembranes* journal, now published electronically.

**Corporate**

Corporate Membership Benefits include:

- a membership card
- an IGS lapel pin
- on-line access to the *IGS Membership Directory*
- the IGS News newsletter, published three times a year
- on-line access to the 19 IGS Mini Lecture Series for the use of the membership
- information on test methods and standards
- discount rates:
  - for any document published in the future by IGS
  - at all international, regional or national conferences organized by the IGS or under its auspices
- preferential treatment at conferences organized by the IGS or under its auspices
- possibility of being granted an IGS award
- free access to the *Geosynthetics International* journal, now published electronically.
- free access to the *Geotextiles and Geomembranes* journal, now published electronically.
- **advertisement in the *IGS Member Directory* and on the IGS Website**
- **IGS Corporate Membership Plaque**
- **Company Profile in the IGS News**
- **right of using the IGS logo at exhibitions and in promotional literature**
- **priority (by seniority of membership within the IGS) at all exhibits organized by the IGS or under its "auspices"**
- **opportunity to join IGS committees in order to discuss topics of common interest.**

**Student**

Student Membership Benefits include:

- Electronic access to the IGS News, published 3 times a year
- Special Student discounts at all IGS sponsored/supported conferences, seminars etc.
- Listing in a special student members category in the IGS Directory
- Eligibility for awards (and in particular the IGS Young Member Award).

## List of IGS Chapters

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# INDIAN CHAPTER OF IGS

In the year 1985, Central Board of Irrigation and Power, (CBIP) as part of its technology forecasting activities identified geosynthetics as an important area relevant to India's need for infrastructure development, including roads. After approval of IGS Council for the formation of Indian Chapter in October 1988, the Indian Chapter of IGS was got registered under Societies Registration Act 1860 of India in June 1992 as the Committee for International Geotextile Society (India), with its Secretariat at Central Board of Irrigation and Power. The Chapter has since been renamed as International Geosynthetics Society (India), in view of the parent body having changed its name from International Geotextiles Society to International Geosynthetics Society.

The activities of the Society are governed by General Body and Executive Board.

### Executive Board of Indian Chapter of IGS 2020-2022

The Executive Board of the IGS (India) consists of President, elected by the General Body, two Vice-Presidents and 16 members. The Secretary and Director (WR) of the CBIP are the as the Ex-Officio Member Secretary and Treasurer, respectively, of the Society.

### The present Executive Board is as under:

***President***

- **Mr. Vivek P. Kapadia,** *Secretary to Government of Gujarat and Director*, SSNNL

***Vice-Presidents***

- **Dr. R. Chitra,** *Director,* Central Soil & Materials Research Station
- **Dr. Jimmy Thomas,** Geotechnical Consultant

***Immediate Past President***

- **Mr. M. Venkataraman,** *Chief Executive Officer,* Geosynthetics Technology Advisory Services LLP and Guest Professor, Department of Civil Engineering IIT Gandhinagar

***Hon. Members***

- **Dr. G.V. Rao,** *Former Professor,* Department of Civil Engineering, IIT Delhi and Guest Professor, Department of Civil Engineering, IIT Gandhinagar
- **Dr. K. Rajagopal,** *Professor,* Department of Civil Engineering IIT Madras

***Member Secretary***

- **Mr. A.K. Dinkar,** *Secretary,* Central Board of Irrigation & Power

***Treasurer***

- **Dr. G.P. Patel**, *Director (WR),* Central Board of Irrigation & Power

### Past Presidents

The presidents of the society in the past were:

- Dr. R.K. Katti, Director, UNEECS Pvt. Ltd. and Former Professor, IIT Bombay
- Mr. H.V. Eswaraiah, Technical Director, Karnataka, Power Corporation Ltd.
- Dr. G.V. Rao, Professor, Department of Civil Engineering, IIT Delhi
- Dr. D.G. Kadade, Chief Advisor, Jaiprakash Industries Ltd.
- Dr. K. Rajagopal, Professor, Department of Civil Engineering, IIT Madras

### Indian Representation on IGS Council

- Dr. K. Rajagopal, Professor, Department of Civil Engineering, IIT Madras
- Dr. G.V. Rao, Former Professor, Department of Civil Engineering, IIT Delhi
- Mr. M. Venkataraman, Geotechnical and Geosynthetic Consultant
- Mr. Vivek P. Kapadia, Secretary to Government of Gujarat and Director, SSNNL

## IGS Student Award Winners from India

The IGS has established Student Paper Award to disseminate knowledge and to improve communication and understanding of geotextiles, geomembranes and associated technologies among young geotechnical and geoenvironmental student engineers around the world. The IGS student award consists of US$1,000 to be used to cover travel expenses of each winner to attend a regional conference.

Following from India have been honoured with IGS Student Paper Award:

- Dr. J.P. Sampath Kumar, National Institute of Fashion Technology, Hyderabad
- Dr. K. Ramu, JNTU College of Engineering, Kakinada
- Mrs. S. Jayalekshmi, National Institute of Technology, Tiruchirappalli
- Dr. Mahuya Ghosh, IIT Delhi
- Dr. S. Rajesh, Department of Civil Engineering, IIT Kanpur
- Mr. Suresh Kumar S., Department of Textile Technology, Dr. B.R. Ambedkar National Institute of Technology, Jalandhar

## Publications/Proceedings on Geosynthetics

In addition to the proceedings of the events on Geosynthetics, following publications have been brought out since 1985:

1. Workshop on Geomembranes and Geofabrics (1985)
2. International Workshop on Geotextile (1989)
3. Use of Geosynthetics – Indian Experiences and Potential – A State of Art Report (1989)
4. Use of Geotextile in Water Resources Projects - Case Studies (1992)
5. Role of Geosynthetics in Water Resources Projects (1993)
6. Monograph on Particulate Approach to Analysis of Stone Columns with & without Geosynthetics Encasing (1993)
7. 2nd International Workshop on Geotextiles (1994)
8. Directory of Geotextiles in India (1994)
9. An Introduction to Geotextiles and Related Products in Civil Engineering Applications (1994)
10. Proceedings of Workshops on Engineering with Geosynthetics (1995)
11. Ground Improvement with Geosynthetics (1995)
12. Geosynthetics in Dam Engineering (1995)
13. Erosion Control with Geosynthetics (1995)
14. Proceedings of International Seminar & Techno Meet on “Environmental Geotechnology & Geosynthetics” (1996)
15. Proceedings of First Asian Regional Conference “Geosynthetics Asia’1997”
16. Directory of Geosynthetics in India (1997)
17. Bibliography – The Indian Contribution to Geosynthetics (1997)
18. Waste Containment with Geosynthetics (1998)
19. Geosynthetic Applications in Civil Engineering- A Short Course (1999)
20. Case Histories of Geosynthetics in Infrastructure Projects (2003)
21. Geosynthetics – Recent Developments (Commemorative Volume) (2006)
22. Geosynthetics in India – Present and Future (2006)
23. Applications of Geosynthetics – Present and Future (2007)
24. Directory of Geosynthetics in India (2008)
25. Geosynthetics India’08

26. Geosynthetics India' 2011
27. Geosynthetic Reinforced Soil Structures - Design & Construction (2012)
28. Applications of Geosynthetics in Infrastructure Projects (2013)
29. Applications of Geosynthetics in Railway Track Structures (2013)
30. Silver Jubilee Celebration (2013)
31. Directory of Geosynthetics in India (2013)
32. Applications of Geosynthetics in Infrastructure Projects (2014)
33. Geosynthetics India 2014
34. Three Decades of Geosynthetics in India – A Commemorative Volume (2015)
35. History of Geosynthetics in India - Case Studies (2016)
36. Proceedings of 6th Asian Regional Conference on Geosynthetics (2016)
37. Coir Geotextiles (Coir Bhoovastra) for Sustainable Infrastructure (2016)
38. Proceedings of the Geosynthetics Applications for Erossion Control and Costal Protection (2018)
39. Geosynthetics Testing – A Laboratory Manual (2019)

**Indian Journal of Geosynthetics and Ground Improvement**

The Indian Chapter of IGS has taken the initiative to publish Indian Journal of Geosynthetics and Ground Improvement (IJGGI), on half yearly basis (January – June and July-December), since January 2012.The aim of the journal is to provide latest information in regard to developments taking place in the relevant field of geosynthetics so as to improve communication and understanding regarding such products, among the designers,manufacturers and users and especially between the textile and civil engineering communities.The Journal has both print and online versions.

**Events Organised/Supported**

1. Workshop on Geomembrane and Geofabrics, September 1985, New Delhi
2. Workshop on Reinforced Soil, August 1986
3. International Workshops on Geotextiles, November 1989, Bangalore
4. National Workshop on Role of Geosynthetics in Water Resources Projects, January 1992, New Delhi
5. Workshop on Geotextile Application in Civil Engineering, January 1993, Chandigarh
6. International Short Course on Soil Reinforcement, March 1993, New Delhi
7. Short Course on Recent Developments in Design of Embankments on Soft Soils, Nov./Dec. 1993, New Delhi
8. 2nd International Workshop on Geotextiles, January 1994, New Delhi
9. Short Course on Recent Developments in the Design of Embankments on Soft Soils, January 1994, Kolkata
10. Workshop on Role of Geosynthetics in Hill Area Development, November 1994, Guwahati
11. Workshop on Engineering with Geosynthetics, December 1994, Hyderabad
12. Short Course on Recent Developments in the Design of Embankments on Soft Soils, May 1995, New Delhi
13. Seminar on Geosynthetic Materials and their Application, August 1995, New Delhi
14. Short Course on Recent Developments in the Design of Embankments on Soft Soils, October 1995, New Delhi
15. Short Course on "Ground Improvement with Geosynthetics", October 1995, New Delhi
16. Workshop on "Environmental Geotechnology", December 1995, New Delhi
17. Workshop on "Role of Geosynthetics in Hill Area Development", February 1996, Gangtok
18. Workshop on "Engineering with Geosynthetics", March 1996, Visakhapatnam

19. Workshop on “Ground Improvement with Geosynthetics”, March 1996, Kakinada
20. Workshop on “Engineering with Geosynthetics”, May 1996, Chandigarh
21. International Seminar & Technomeet on “Environmental Geotechnology with Geosynthetics”, July 1996, New Delhi
22. Seminar on “Fields of Application of Gabion Structures”, September 1997, New Delhi
23. First Asian Regional Conference “Geosynthetics Asia’1997”, November 1997, Bangalore
24. Short Course on “Waste Containment with Geosynthetics”, February 1998, New Delhi
25. Symposium on “Rehabilitation of Dams”, November 1998, New Delhi
26. Training Course on “Geosynthetics and their Civil Engineering Applications”, September 1999, Mumbai
27. Seminar on “Coir Geotextiles-Environmental Perspectives”, November 2000, New Delhi
28. Second National Seminar on “Coir Geotextiles – Environmental Perspectives”, April 2001, Guwahati, Assam
29. National Seminar on “Application of Jute Geotextiles in Civil Engineering”, May 2001, New Delhi
30. International Course on “Geosynthetics in Civil Engineering”, September 2001, Kathmandu, Nepal
31. Workshop on “Applications of Geosynthetics in Infrastructure Projects”, November 2003, New Delhi
32. Geosynthetics India 2004 – “Geotechnical Engineering Practice with Geosynthetics”, October 2004, New Delhi
33. Introductory Course on Geosynthetics, November 2006, New Delhi
34. International Seminar on “Geosynthetics in India – Present and Future” (in Commemoration of Two Decades of Geosynthetics in India), November 2006, New Delhi
35. Workshop on “Retaining Structures with Geosynthetics”, December 2006, Chennai
36. Special Session on “Applications of Geosynthetics” during 6th International R&D Conference, February 2007, Lucknow (U.P.)
37. Workshop on “Applications of Geosynthetics – Present and Future”, September 2007, Ahmedabad (Gujarat)
38. International Seminar “Geosynthetics India’08” and Introductory Course on “Geosynthetics”, November 2008, Hyderabad
39. Special Session on “Applications of Geosynthetics” during 7th International R&D Conference, February 2009, Bhubaneswar (Orissa)
40. Seminar on “Applications of Geosynthetics”, July 2010, New Delhi
41. International Seminar on “Applications of Geosynthetics”, November 2010, New Delhi
42. Geosynthetics India’ 2011, September 2011, IIT Madras
43. Seminar on “Slope Stabilization Challenges in Infrastructure Projects”, October 2011, New Delhi
44. GEOINFRA 2012 – A Convergence of Stakeholders of Geosynthetics, August 2012, Hyderabad
45. Seminar on “Ground Control and Improvement”, September 2012, New Delhi
46. Workshop on “Geosynthetic Reinforced Soil Structures - Design & Construction”, October 2012, New Delhi
47. Seminar on “Landfill Design with Geomembrane”, November 2012, New Delhi
48. Seminar on “Slope Stabilization Challenges in Infrastructure Projects”, November 2012, New Delhi
49. Seminar on “Applications of Geosynthetics in Infrastructure Projects”, June 2013, Bhopal
50. Seminar on “Applications of Geosynthetics in Railway Track Structures”, September 2013, New Delhi
51. Silver Jubilee Celebration, October 2013, New Delhi
52. Seminar on “Applications of Geosynthetics in Infrastructure Projects”, July 2014, Agra
53. Geosynthetics India 2014, October 2014, New Delhi

54. Seminar on Geotextiles: A Big Untapped Potential, September 2015, New Delhi
55. Three Decades of Geosynthetics in India – International Symposium Geosynthetics - The Road Ahead, November 2015, New Delhi, India
56. North Eastern Regional Seminar on “Applications of Geosynthetics in Infrastructure Projects”, June 2016, Guwahati
57. Workshop on “Applications of Geosynthetics in Infrastructure Projects”, June 2016, Thiruvananthapuram
58. Training Course on Geosynthethics, November 2016, New Delhi
59. Workshop on Coastal Protection, November 2016, New Delhi
60. 6th Asian Regional Conference on Geosynthethics, November 2016, New Delhi
61. Training Course on "Geosynthetic Reinforced Soil Structures", February 2017, New Delhi
62. Training Course on “Applications of Geosynthetics”, December 2017, Dharwad (Karnataka)
63. Workshop on “Design and Construction of Pavements using Geosynthetics”, January 2018, New Delhi
64. IGS Educate the Educators Program, February 2018, IIT Madras
65. Training Course on “Applications of Geosynthetics”, February 2018, Trichy (Tamil Nadu)
66. Training Course on Design and Construction of Pavements with Geosynthetics and Geosyntheics Reinforced Soil Slopes and Walls, 15 June 2018, New Delhi
67. Seminar on Slope Stabilization Challenges in Infrastructure Projects, 21-22 June 2018, New Delhi
68. Training Programme on “Applications of Geosynthetics in Dams & Hydraulic Structures”, August 2018, Bhopal
69. Training Course on “Slope Stabilization Challenges in Infrastructure Projects”, October 2018, Dehradun
70. Seminar on “Geosynthetics Applications for Erosion Control and Coastal Protection”, October 2018, Bhubaneswar
71. Workshop on Natural Hazard Mitigation with Geosynthetics, January. 2019, Thiruvananthapuram, (Kerala)
72. Symposium of International Association for Computer Methods and Advances in Geomechanics (IACMAG) – Special Session of Indian Chapter of IGS, March 2019, IIT Gandhinagar
73. Seminar on Geosynthetics for Highway Infrastructure with Marginal Materials and Difficult Soils, September 2019, Jaipur
74. Workshop on Testing and Evaluation of Geosynthetics, September 2019, Jaipur
75. Workshop on Best Practices for Implementation of Geosynthetic Reinforced Soil Walls. January 2020, Jaipur
76. Webinar on Challenges in Developing Codes of Practice for Geosynthetics for Durable Infrastructure Development, 14 September 2020
77. Webinar on Challenges in Geosynthetic and Geotechnical Testing, 15 September 2020
78. Virtual Training Sessions on Erosion Control, 28 July 2021
79. Virtual Training Programme on the Failure of Reinforced Soil Walls: Lessons and Remedies, 29 September, 2021

## 50TH ANNIVERSARY CELEBRATION OF GEOTECNIA JOURNAL

the 50th Anniversary celebration of the Geotecnia Journal was held at the Laboratório Nacional de Engenharia Civil on 20th and 21st September 2021, organised by Sociedade Portuguesa de Geotecnia (SPG) in collaboration with Associação Brasileira de Mecânica dos Solos e Engenharia Geotécnica (ABMS) and Sociedad Española de Mecánica del Suelo y Ingeniería Geotécnica (SEMSIG).

The technical programme, was supported by the special volume nº152 (2021) of the Geotecnia Journal available in open access in July 2021 (https://impactum-journals.uc.pt/geotecnia), in addition to the opening and closing sessions and the presentation of the "Úlpio Nascimento" Awards for the biennia 2012-13, 2014-15, 2016-17, 2018-19.

The opening session included the speeches by Carlos Pina, from the Laboratório Nacional de Engenharia Civil, Alexandre Pinto, SPG President, Fernado Schnaid, ABMS President, Fernando Pardo de Santayana, SEMSIG President and Associate Editor of the Geotecnia Journal, and António Gomes Correia, Editor of the Geotecnia Journal and Alberto Sayão, Associate Editor of the Geotecnia Journal.

The opening session was followed by a presentation of António Gomes Correia about the important moments of the 50 years of Geotecnia Journal. The succeeding presentations covered 19 topics (7 by Portuguese authors, 7 by Spanish authors and 5 by Brazilian authors) with emphasis on the characterisation of geomaterials, from soils to rocks, new developments in rock mechanics, geosynthetics, reinforced soils, bentonite barriers for nuclear waste, dams, underground works – hydropower plants, excavations, geothermal, geotechnics in transports, tunnels, landslides, "machine learning" and regulations. These presentations were made by key speakers from Portugal (António Gomes Correia, António Viana da Fonseca, Celso Lima, Emanuel Maranha das Neves, José Vieira de Lemos, Luís Joaquim Leal Lemos, Luís Lamas and Manuel Matos Fernandes), Spain (Antonio Gens, César Sagaseta Millán, Eduardo Alonso Pérez de Ágreda, Fernando Pardo de Santayana, Jose Estaire, Rubén Galindo and Santiago Peña Fernández) and from Brazil (Alberto Sayão, Anna Laura Nunes, Ennio Marques Palmeira, Fernando Schnaid, Gregório Araújo, Joaquim Pimenta de Ávila and Maria das Graças Gardoni).

The closing session included the speeches of the Presidents of SPG, ABMS and SEMSIG and the Editors of the Geotecnia Journal.

It should be noted that this commemorative ceremony of the 50th anniversary of the Geotecnia Journal was the first face-to-face event held in the auditorium of the Laboratório Nacional de Engª Civil after the beginning of the pandemic situation, although also with remote participation. It went according to what had been planned, both in terms of punctuality and quality of the presentations (with the respective discussions when time allowed).

Attendance exceeded expectations for a Portuguese and Spanish-speaking event. On the first day, there were 60 in-person participants and 262 in remote participation, making a total of 322 participants and on the second day, 35 in-person participants and 201 in remote participation, making a total of 236 participants.

Financial support was also provided by 23 companies, without which it would not have been possible to publish, in colour, the special volume no. 152 of the Geotechnics Journal, with a total of 628 pages.

## RESOUNDING SUCCESS FOR CANALS WORKSHOP


Hundreds of geosynthetics professionals from around the world tuned in to the IGS's virtual workshop series on canals.

The three-day event organized by the IGS Technical Committee on Hydraulics (TC-H) with support from the International Commission on Irrigation and Drainage (ICID), welcomed speakers addressing the theme 'Improving the performance of canals with geosynthetics'. These included J.P. Giroud, Nathalie Touze, Hervé Plusquellec and Pietro Rimoldi.

The workshop series used Egypt's current massive canal upgrade program as a focus, and was delighted to have in attendance the country's Minister of Water Resources and Irrigation, Dr Mohamed Abdel Aty.

Egypt is currently retrofitting 10,000km of canals to boost efficiency and preserve its ability to be self-sufficient for food. This is especially important considering climate change and the projected rise of water scarcity in the region. The Egyptian Ministry of Water Resources and Irrigation gave a presentation during the symposium, explaining the issue and how it was being tackled with massive government investment.

The workshop series attracted high praise from a range of participants, including geosynthetics consultant Boyd Ramsey. He said the symposium was "an important contribution to the world and our industry", adding: "The organizers should be proud of their accomplishments and contributions and know that they are well appreciated."

Fellow participant and geosynthetics consultant Tom Sangster acknowledged the hard work needed to stage such an event, adding: "Congratulations to the organizers – as a technical event the webinars were a great success and a major contribution to the debate on the benefits of using geosynthetics for canal linings versus other materials."

TC-H chairman Eric Blond, who coordinated and staged the workshop series, said: "The event was a huge success – more than 200 people attended each day from every continent, attracting mostly designers and owners/regulators, as well as suppliers.

"Many attendees congratulated us for the quality of the event and for being able to reach our target audience.

"We are also extremely grateful for the enthusiastic involvement of the Egyptian Ministry of Water Resources and Irrigation and the attendance of His Excellency Dr. Abdel Aty, an impressive member of the Egyptian government who is devoted to finding an enduring solution to water management infrastructure issues in the country. We appreciate his time and attention during the symposium."

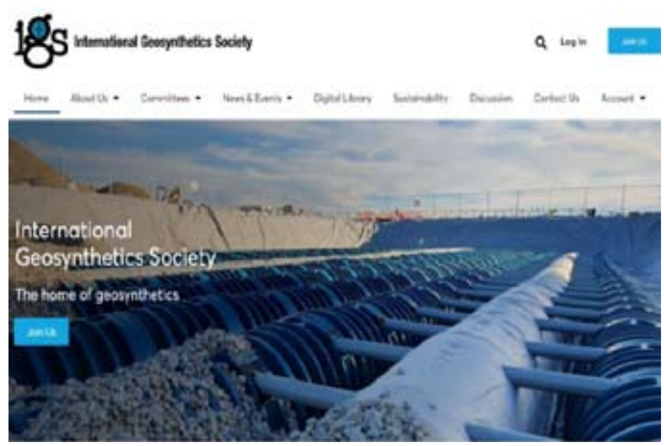
The series was the latest in one of many collaborative events between the IGS and ICID. Following the workshops, the TC-H hosted a special session at the ICID annual conference in Marrakech, Morocco, and is due to contribute to ICID's next annual conference in Adelaide, Australia, in October 2022, where the TC-H has a full day dedicated to geosynthetic technologies.

Mr Blond added: "The IGS is hugely grateful for the continued cooperation of ICID and its President Dr. Ragab Ragab. Together we can develop solutions to mitigate the global water crisis with the help of geosynthetics technologies, one unmissable educational event at a time."

## IGS'S NEW WEBSITE NOW LIVE!

The society is excited to announce the launch of its brand new website.

A refreshed design, member-exclusive functionality and more interactive elements are just some of the fresh features. These include the members-only IGS Online Forum where you can discuss all things geosynthetics with colleagues from around the world and an interactive Chapter map with key information at your fingertips. Members can also easily access and manage their accounts online.




Plus, the Digital Library has more prominence with the latest information, education and media resources accessible all in one place.

Sam Allen, IGS Communications Committee chairman said: "Our team has been working hard on creating a more intuitive website for our users packed with all the content they would expect plus a host of new resources. I'm delighted with the outcome and hope our members enjoy exploring their new website."

IGS President Chungsik Yoo said: "The IGS is a forward-looking society always looking to evolve in positive ways. Our new website is another step on that journey to create an improved essential information and education resource for our members, stakeholders and wider public."

Tell us what you think about your new website – email IGS Secretariat Manager Elise Oatman at igssec@geosyntheticssociety.org with your feedback.

## DID YOU KNOW?... GEOSYNTHETICS HELP SAVE LIVES BY PREVENTING THE DEVASTATING EFFECTS OF LANDSLIDES

The phenomenon of landslides is as old as the hills and can happen anywhere in the world, with potentially deadly and costly consequences.

Landslides are the result of natural processes, typically when rainwater infiltrates soil from above or when groundwater levels rise from below. Landslides may result when weather erodes land, or surface vegetation is lost, for example due to drought. Extreme weather events due to a warming climate mean that landslides are expected to become increasingly frequent and more severe.

Human activities can also increase the likelihood or magnitude of landslides. For example:

- Construction can lead to excessive loading on the ground beneath it.
- Inappropriate earthworks such as the creation of artificially steep slopes may reduce the ground's stability.
- Mine blasting or the removal of deep roots through deforestation can compromise the stability of a slope.

Fortunately, geosynthetics offer a cost-effective, low-impact, and low-maintenance way to prevent landslides and safeguard lives and property.

Geosynthetics can be used to improve drainage, mitigate erosion, and reinforce soils to prevent collapse.

Even in ancient times, people used fibrous natural materials to improve the mechanical performance of soil. Nowadays, more stable and durable products are available that combine strength with limited deformation, and interact well with the surrounding soil material, while resisting degradation.

Engineers can prevent landslides in a number of ways using geosynthetics:

- By performing a barrier function and/or a filter function which prevents the effects of water seepage.
- Using geosynthetics to reinforce the soil, thus making stable even very steep slopes.
- Holding topsoil in place, preventing slippage.
- Allowing excess rainwater to safely drain, without washing the soil away.
- Applying geosynthetics to slope surfaces to encourage the growth of new vegetation, stabilizing slopes through natural means.
- In-filling geosynthetics with soil to provide anchorage to the root structures growing through, thereby increasing their erosion resistance under significant hydraulic stresses.

Clearly, geosynthetics have a significant contribution to make in averting the devastating effects of landslides and land erosion. Their wide use in these applications not only saves time and money but lives and livelihoods.

## EXTRA EVENTS FOR IGS YOUNG MEMBERS

Quizzes, competitions and career-boosting initiatives are in the pipeline for the next generation of geosynthetics experts.

IGS Young Members

The IGS Young Members Committee (YMC) recently agreed a series of exciting activities aimed at strengthening the network and helping students achieve their ambitions.

The YMC is gearing up for the its Young Members Papers Competition at the 12th International Conference on Geosynthetics in Rome in September 2023. Participants have just two months left to submit their abstracts by February 28, 2022. The 10 finalists will have their conference registration fees waived and there is prize money for the top three presentations. There will also be an exclusive interview with the winner on the IGS website. Click here for competition details and to enter.

Widening opportunities for learning has received a boost thanks to funding from the IGS Foundation for the

IGS job shadowing program. The scheme – which has seen pilot initiatives in IGS Australasia and IGS Brazil – offers students the chance to spend a day in-person or chat virtually with one of the IGS corporate member companies. It is an opportunity for participants to gain real-world experience, career advice and grow their network.

Guidelines for the program are currently being developed for chapters, with a global launch planned for summer 2022.

Real world insight continues with the 'My Engineer Life…' interviews on the IGS website. The articles share the career choices and challenges experienced by a host of civil engineering undergraduates, post-grads, research and PhD students from around the world. The series is always looking for new subjects; simply email youngengineers@geosyntheticssociety.org if you know someone who would like to be featured – including yourself. You can catch up on previous interviews by clicking here and entering 'My Engineer Life…' in the search bar.

And that's not all. The YMC is also looking at:

- Developing a set of guidelines for setting up IGS Young Member groups, especially for countries with IGS young members but without an IGS chapter needed to organize events. The guidelines will have some flexibility to allow YM groups to scale regardless of numbers.
- Launching a photo competition in summer 2022 open to IGS and non-IGS young engineers. The YMC would love to see original photos illustrating the application of geosynthetics. There will be prize money for the top three images and special prizes for the best submission from an IGS Young Member and IGS Student Member.
- Hosting the first YMC Geosynthetics Quiz, a social, team-based quiz night focused on geosynthetics.

YMC chairman Dawie Marx said: "The YMC is always striving to provide and develop useful, inspiring and fun initiatives. We'd encourage our members to take part in our latest announcements, and to get in touch if there are activities you'd like us to implement. The YMC is for everyone, wherever they are, so we're always looking to develop programs and events that best serve our members."

Never miss the latest announcements, news and events from the YMC by visiting here.

## XXXI ITALIAN NATIONAL CONFERENCE ON GEOSYNTHETICS – BARI 2021

The XXXI Italian National Conference on Geosynthetics was held on 7 October 2021 in Bari alongside the large construction fair SAIE 2021. The event held for the first time in Bari gave excellent results both in terms of the number of registered participants and the quality of the presented papers. Moreover, the context of the SAIE Exhibition (the international reference point for the world of construction in Italy) enhanced the importance and impact of geosynthetics presentations. This year the theme of the Conference was "Sustainability, Environmental aspects and Climate changes".


The conference was organised by the Italian Geotechnical Association (AGI) and the Italian Chapter of the International Geosynthetics Society (AGI-IGS), in partnership with SAIE 2021 and SENAF.

Nicola Moraci (President of AGI), Daniele Cazzuffi (President of AGI-IGS) and Leonardo Damiani (Chair of the Civil, Environmental, Land, Building Engineering and Chemistry Department – Polytechnic of Bari) opened the conference that was divided, as usual, into two sessions.

The morning session coordinated by Daniele Cazzuffi focused on 'Sustainability and environmental aspects'. The first two contributions covered the sustainable use of geosynthetics in landfills; the keynote lecture of Stefania Bilardi and Nicola Moraci on "The use of geosynthetics in the sustainable design of controlled landfill". Daniele Cazzuffi and Piergiorgio Recalcati presented the second lecture on the "Increase of the available volume in landfills using reinforced embankments". Two additional contributions dealt with the role of geotechnical engineering and geosynthetics in the management of contaminated sediments: Claudia Vitone on the theme "From characterization to sustainable reuse of contaminated sediments: the role of geotechnical engineering in the mar Piccolo of Taranto" and Alberto Simini on the "Capping of contaminated sediments with active geocomposites". Finally, the lecture of Domenico Gaudio on "Seismic design of geosynthetic-reinforced earth retaining walls following a performance-based approach" closed the morning session of the conference.

Nicola Moraci coordinated the afternoon session with four lectures focused on 'Sustainability and Climate changes'. The first two lectures dealt with the rules governing the environmental impacts of geosynthetics with the lecture of Alessandro Manzardo on “Made Green Italy to support environmental superiority of geotextiles and related products” and the lecture of Francesco Fontana on the “Environmental impact of geosynthetics: International researches and activity”. The last two presentations focused on specific applications of geosynthetics; the first one on “Geotextiles and their sustainable applications in alpine environment” from the authors A. Senese, B. De Felice, R. Ambrosini e G. Diolaiuti; the second one was the lecture of Pietro Rimoldi on the “Design of the bank protection against erosion of watercourses as a function of climate change”.

At the end of each session, a fruitful and interesting discussion on the different topics took place.

Proceedings were edited by Daniele Cazzuffi, Nicola Moraci, and Claudio Soccodato. The volume (more than 100 pages) is in Italian with English abstracts and it is available at a cost by contacting Pàtron Editore at advertising@patroneditore.com.

The next XXXII Italian National Conference on Geosynthetics will be held on 20 October 2022 in Bologna alongside the large construction fair SAIE 2022.

## CALL FOR CANDIDATES FOR IGS COUNCIL, PRESIDENT AND VICE PRESIDENT: TERM 2022 TO 2026


The IGS, in accordance with its bylaws, will hold elections in 2022. IGS Members will have the opportunity to elect nine Council Members, a President and Vice President. Each of the elected members will serve a four-year term, beginning on 3 September 2022.

The Council is the governing body of the IGS, responsible for the management of the Society in accordance with the bylaws, objectives and policies.

The IGS encourages any IGS Member who is interested in furthering the IGS Mission to consider standing for election. Council Members are required to attend all IGS Council Meetings during their tenure. The IGS Council normally meets once a year for a two-day period in conjunction with a major IGS event. IGS Council Members are expected to travel to these meetings and actively participate in discussions. Such meetings may take place in any world region, on rotation. Meetings may also be virtual. Council Members are also expected to take part in Committees established by the Council.

The elected IGS Council members whose terms of office conclude in 2022 are:

- Ian Fraser, United Kingdom (Treasurer)
- Edoardo Zannoni, South Africa (Secretary)
- Takeshi Katsumi, Japan
- Pietro Rimoldi, Italy
- Sam Allen, USA
- Dimiter Alexiew, Germany
- Jie Han, USA
- Jacques Cote, Canada
- Preston Kendall, Australia

Council Members may be elected for a maximum of two consecutive terms: Ian Fraser, Edoardo Zannoni, Takeshi Katsumi and Pietro Rimoldi are therefore not eligible for re-election to a Council Member seat. All other serving Council members may stand for re-election.

In addition to nine IGS Council seats, nominations are open for the positions of President and Vice-President. Both serve on Council, with the President as Chair. Any member of the IGS, including those who have served two consecutive terms on Council, may stand for the offices of President or Vice President.

### Nomination & Election Schedule

Only IGS Members are eligible for election. Candidates are required to attend IGS Council meetings, which may be virtual or physical. These are typically held twice a year. Meetings of the IGS Council are generally held in conjunction with international and regional IGS conferences.

### Call for Nominees and How to Apply

The call for candidates has officially opened and will also be shared in the January edition of the IGS Newsletter 2022, and on the IGS website. The call for nominations will close on 1 March 2022.

All IGS Members are encouraged to consider running for Council. Candidates should nominate themselves; there is no requirement for a proposer or seconder. Candidates for the positions of President and Vice President should clearly state they are standing for these positions. Please submit the following:

- your membership number (for verification purposes only)
- your country of residence. There is no restriction on the number of candidates from any country region
- a personal statement of no more than 200 words (350 words for President and Vice President). This may include a link to an online profile
- a photograph of yourself

All documents should be sent by email only to IGS Secretariat Manager at IGSsec@GeosyntheticsSociety.org on or before 1 March 2022. All documents should be editable – no pdfs please. Please use the email address you have registered with the IGS for your membership.

**Announcement of Nominees: March 2022**

The IGS will announce the eligible candidates in the March edition of the IGS Newsletter 2022, as well as on the IGS website. This will include candidates' country of residence, supporting statement and photograph.

**Voting: 18 April to 18 June 2022**

Voting instructions will be sent via email to each eligible Individual IGS Member and each designated representative from the IGS Corporate Membership. Each member may vote once and all voting will be done electronically. Please make sure you have submitted an accurate email contact to the IGS, which you can update by logging in to the IGS website.

Announcement of Successful Candidates: 1 July 2022

Successful candidates will be announced via the website on 1 July 2022.

The first meeting of the new IGS Council is expected to take place at the EuroGeo7 Conference in Warsaw, Poland, September 2022.

## AUSTRALASIAN CHAPTER LAUNCHES NEW CONFERENCE


Hosted by the Australasian chapter of the IGS, known as ACigs, the three-day event gathers eminent speakers and masterclasses themed around the topic of 'Advances in Geosynthetics'.

The conference, which aims to be a biennial event, was a natural development following many successful ACigs education and outreach activities over the last few years including 30-plus webinars, Educate the Educator events and more.

Running June 7-9 at Brisbane Convention & Exhibition Centre, the program begins with three masterclasses on advances in design and construction with geosynthetics for:

- Hydraulic structures and environmental containment
- Retaining structures, slopes and roadways
- Mine tailings and closure applications

Keynote talks on the other days are set to cover topics including geo-environmental applications, reinforcement and stabilization, geosynthetics for mining, and sustainability, durability and innovation. There will also be a conference dinner and site tours.

Speakers include John Cowland, Boyd Ramsey, and Professors Craig Benson, Malek Bouazza, Timothy Stark and Jorge Zornberg.

Abstracts are also welcome with a deadline recently extended to February 28, at 5pm AEDT. Selected papers will be programmed for presentation in 20-minute slots giving a more informal structure to these sessions, encouraging greater involvement and a wider range of topics.

Ten student scholarships have been made available for ACigs members to attend GEOANZ#1 for free thanks to a donation from the IGS Foundation (IGSF), a charitable body set up to support the IGS's educational aims. Apply here by March 31 if you qualify.

Chapter President Siamak Paulson said: "We're incredibly excited to bring this new conference to members and the wider IGS and geosynthetics community. It's important to be aware and maintain knowledge of developments and trends in the industry – that is how we improve and innovate – and this event is an ideal opportunity to learn about current challenges and solutions.

"We're also delighted to be able to offer 10 student scholarships to members and we thank the IGSF for making this possible.

"While the conference is in the Australia/New Zealand region, we have invited distinguished speakers from overseas and are expecting participation from many surrounding countries such as Papua New Guinea and South East Asia. Also, we have so far received several abstracts from overseas presenters from Europe and the US who are expected to attend the conference.

"We aim to stage GEOANZ every two years and hope our inaugural event will be a lively and informative start to a key fixture in the IGS calendar."

# INDIAN CHAPTER OF INTERNATIONAL GEOSYNTHETICS SOCIETY

## EXECUTIVE BOARD 2020-2022

# INDIAN JOURNAL OF GEOSYNTHETICS AND GROUND IMPROVEMENT

## GUIDELINES FOR AUTHORS

**This journal** aims to provide a snapshot of the latest research and advances in the field of **Geosynthetics**. The journal addresses what is new, significant and practicable. **Indian Journal of Geosynthetics and Ground Improvement** is published twice a year (January-June and July-December) by IndianJournals.Com, New Delhi. The Journal has both print and online versions. Being peer-reviewed, the journal publishes original research reports, review papers and communications screened by national and international researchers who are experts in their respective fields.

The original manuscripts that enhance the level of research and contribute new developments to the geosynthetics sector are encouraged. The work belonging to the fields of Geosynthetics are invited. **The journal is expected to help** researchers, technologist and policy makers in the key sector of Geosynthetics to improve communication and understanding regarding geotextiles, geomembranes and related products among designers, manufacturers and users The manuscripts must be unpublished and should not have been submitted for publication elsewhere. There are no **Publication Charges**.

### 1. Guidelines for the preparation of manuscripts for publishing in "Indian Journal of Geosynthetics and Ground Improvement"

The authors should submit their manuscript in MS-Word (2003/2007) in single column, double line spacing. The manuscript should be organized to have Title page, Abstract, Introduction, Material & Methods, Results & Discussion, Conclusion, and Acknowledgement. The manuscript should not exceed 16 pages in double line spacing.

### Submission of Manuscript:

The manuscript must be submitted in doc and pdf to the Editor as an email attachment to **sunil@cbip.org.** The author(s) should send a signed declaration form mentioning that, the matter embodied in the manuscript is original and copyrighted material used during the preparation of the manuscript has been duly acknowledged. The declaration should also carry consent of all the authors for its submission to **Indian Journal of Geosynthetics and Ground Improvement**. It is the responsibility of corresponding author to secure requisite permission from his or her employer that all papers submitted are understood to have received clearance(s) for publication. The authors shall also assign the copyright of the manuscript to the Indian Chapter of International Geosynthetics Society.

### Peer Review Policy:

Review System: Every article is processed by a masked peer review of double blind or by three referees and edited accordingly before publication. The criteria used for the acceptance of article are: **contemporary relevance, updated literature, logical analysis, relevance to the global problem, sound methodology, contribution to knowledge and fairly good English**. Selection of articles will be purely based on the experts' views and opinion. Authors will be communicated within Two months from the date of receipt of the manuscript. The editorial office will endeavor to assist where necessary with English language editing but authors are hereby requested to seek local editing assistance as far as possible before submission. Papers with immediate relevance would be considered for early publication. The possible expectations will be in the case of occasional invited papers and editorials, or where a partial or entire issue is devoted to a special theme under the guidance of a Guest Editor.

**The Editor-in-Chief may be reached at: sunil@cbip.org**


## THEME

Advances in Geosynthetics

## SUB-THEMES

- Tailings and mine waste applications
- Reinforced soil slopes and walls
- Sustainability and green technology
- Innovative uses and new product development
- Road and pavement stabilisation
- Landfill barrier systems
- Embankment basal reinforcement
- Seismic and natural disaster resilience
- Railway stabilisation
- Coastal and river protection
- Durability and long-term performance
- Soil-geosynthetic interaction
- Hydraulic and stormwater structures
- Filtration, drainage and erosion control

## TERMS FOR SUBMISSIONS

All abstract submissions will be subject to review. Authors should ensure that the following criteria are met in their abstract submission:

- Successful presenting authors will be required to pay at least a single day registration
- No funding is available to support presenters
- The topic is relevant and important to the chosen theme or sub theme
- Subject matter is original or innovative

**Abstracts must conform to the requirements as outlined:**

- Abstracts must be 300 – 500 words
- Abstracts must be submitted in the template format
- Submissions for oral presentations close in 28 January 2022

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