

GCCM TECHNOLOGY FOR IRRIGATION CANAL REHABILITATION: TWO CASE STUDIES

TECHNOLOGIE GCCM POUR LA RÉHABILITATION DES CANAUX D'IRRIGATION : DEUX ÉTUDES DE CAS

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ABSTRACT

Ageing irrigation infrastructure, combined with intensifying climate pressures, is driving demand for rapid, cost-effective rehabilitation solutions that reduce water losses and extend asset service life. This paper examines the application of Geosynthetic Cementitious Composite Mat (GCCM) technology - specifically the CCX-MTM product conforming to ASTM D8364 Type II classification - as a practical alternative to conventional precast or cast-in-place concrete for irrigation canal lining and rehabilitation.

Two international case studies are presented. The first concerns the Tiszafüred II. Secondary Canal in Hungary, operated by the Middle Tisza District Water Directorate (KOTIVIZIG). In February 2022, a pilot section of this canal - part of a system originally constructed between 1937 and 1940 - was rehabilitated using CCX-MTM GCCM. The installation was completed in two working days under near-freezing winter conditions, within the narrow maintenance window available outside the irrigation season, and the canal was returned to service within one week. The case study documents construction methodology, cold-weather installation procedures, jointing techniques, and lessons learned for future large-scale adoption.

The second case study concerns the Henry Miller Reclamation District No. 2132 (HMRD) in Dos Palos, California, USA. In October 2023, approximately 2,600 m² of CCX-MTM were installed to rehabilitate a deteriorated concrete-lined irrigation canal serving ~190 km² of farmland. Installation was completed in just over three days, and post-installation seepage monitoring recorded a 96% reduction in water loss. The canal was returned to service within 24 hours of final hydration.

Comparison of the two projects demonstrates that GCCM technology delivers consistent performance across contrasting climatic environments, institutional contexts, and infrastructure conditions. Key conclusions include: installation speed significantly within available maintenance windows; seepage reduction performance consistent with established benchmarks; suitability for self-installation by district operational personnel; and applicability across a wide range of canal rehabilitation scenarios. The paper argues that GCCM solutions represent a viable and scalable response to the global challenge of irrigation infrastructure deterioration under accelerating climate stress.

Keywords: GCCM, Geosynthetic Cementitious Composite Mat, canal rehabilitation, irrigation infrastructure, water loss reduction, CCX-M, seepage control, climate resilience.

RESUME

Le vieillissement des infrastructures d'irrigation, combiné à l'intensification des pressions climatiques, stimule la demande croissante pour des solutions de réhabilitation rapides et rentables de réduire les

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perdes d'eau et de prolonger la durée de vie des ouvrages. Cet article examine l'application de la technologie des tapis composites cimentaires géosynthétiques (GCCM) - plus précisément le produit CCX-M™ conforme à la classification ASTM D8364 Type II - comme alternative pratique au béton conventionnel (préfabriqué ou coulé sur place) pour le revêtement et la réhabilitation des canaux d'irrigation.

Deux études de cas internationales sont présentées. La première concerne le canal secondaire Tiszafüred II en Hongrie, géré par la Direction des eaux du district de la Tisza moyenne (KOTIVIZIG). En février 2022, une section pilote de ce canal - faisant partie d'un système initialement construit entre 1937 et 1940 - a été réhabilitée à l'aide du CCX-M™ GCCM. L'installation a été réalisée en deux jours ouvrables dans des conditions hivernales proches du point de congélation, durant la courte période de maintenance disponible en dehors de la saison d'irrigation, et le canal a été remis en service en l'espace d'une semaine. L'étude de cas documente la méthodologie de construction, les procédures d'installation par temps froid, les techniques d'assemblage, et les leçons apprises pour une adoption future à grande échelle.

La deuxième étude de cas concerne le district d'aménagement hydraulique Henry Miller No. 2132 (HMRD) à Dos Palos, en Californie, aux États-Unis. En octobre 2023, environ 2 600 m² de CCX-M™ ont été installés pour réhabiliter un canal d'irrigation revêtu en béton détérioré desservant environ 190 km² de terres agricoles. L'installation a été achevée en un peu plus de trois jours, et la surveillance des infiltrations après l'installation a enregistré une réduction de 96% des pertes d'eau. Le canal a été remis en service dans l'intervalle de 24 heures suivant l'hydratation finale.

La comparaison de ces deux projets démontre que la technologie GCCM offre des performances constantes malgré la diversité des environnements climatiques, des contextes institutionnels et de l'état des infrastructures. Les principales conclusions incluent : une rapidité d'installation compatible avec les périodes de maintenance disponibles; des performances de réduction des infiltrations conformes aux références établies; une facilité de pose par le personnel opérationnel du district; et une applicabilité à un large éventail de scénarios de réhabilitation de canaux. Le document soutient que les solutions GCCM représentent une réponse viable et évolutive au défi mondial de la détérioration des infrastructures d'irrigation face à l'intensification du stress climatique.

Mots-clés: GCCM; Tapis composites cimentaires géosynthétiques; Réhabilitation du canal; Infrastructure d'irrigation; Réduction de la perte d'eau, CCX-M; Contrôle des infiltrations; Résistance climatique.

1. INTRODUCTION

The global irrigation sector is under increasing pressure. Climate change is intensifying the frequency and severity of droughts, altering precipitation patterns, and raising evapotranspiration rates, all of which demand more efficient management of available water resources. At the same time, a substantial proportion of irrigation infrastructure worldwide is ageing, with many systems designed and constructed decades ago now exhibiting structural deterioration, seepage losses, and reduced hydraulic efficiency. Canal seepage represents one of the most significant sources of non-beneficial water loss in irrigation systems. Studies conducted by the United States Bureau of Reclamation (USBR) over a 25-year monitoring programme indicate that concrete linings over geomembranes achieve approximately 95% effectiveness in reducing seepage through canals (USBR, 2019). In the absence of adequate lining, conveyance losses of 30% to 40% are common across both earthen and deteriorated concrete-lined systems. In regions where water resources are scarce or highly contested, such losses represent a critical challenge to food security and agricultural viability.

Geosynthetic Cementitious Composite Mats (GCCMs) represent an emerging class of engineered materials that combine the hydraulic barrier properties of geomembranes with the structural robustness of cement-based composites. Standardised under ASTM D8364 and subject to European Technical Assessment (ETA) frameworks in the European Union, GCCMs offer a factory-manufactured, flexible,

and rapidly deployable alternative to cast-in-place concrete and precast for canal lining and hydraulic structure rehabilitation.

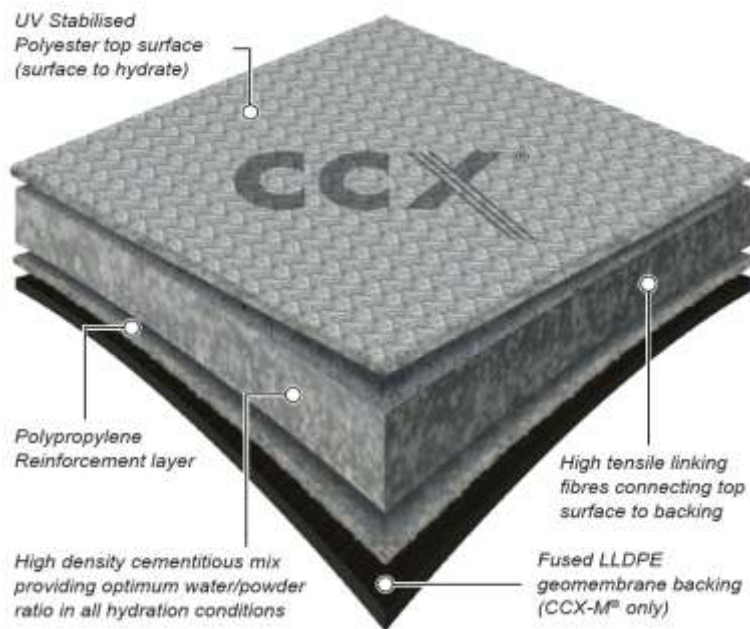


Figure 1. Cross section of a typical GCCM

This paper presents two international case studies demonstrating GCCM application in irrigation infrastructure rehabilitation: the Tiszafüred II. Secondary Canal in Hungary (2022), and the Henry Miller Reclamation District No. 2132 canal project in California, USA (2023). While these projects differ substantially in scale, climate, and institutional context, both demonstrate the technology's capacity to deliver rapid installation, measurable seepage reduction, and long-term structural performance. Together, they illustrate the broad applicability of GCCM solutions across contrasting environments and conditions.

2. GCCM TECHNOLOGY: DEFINITION, STANDARDS, AND PERFORMANCE

A Geosynthetic Cementitious Composite Mat (GCCM) is defined under the ASTM D4439-20 standard nomenclature for geosynthetics as: a factory-assembled, cement-impregnated geosynthetic composite material that hardens upon hydration. The product category has been standardised through ASTM D8364 (published in 2021), which sets out the minimum performance characteristics required for GCCM materials, determined through product-specific testing. Products that conform to this standard are classified by type according to their performance characteristics, with Type II GCCMs - such as the CCX-M™ product used in both case studies presented here - offering enhanced structural and hydraulic performance suited to canal and bulk water applications.

In the European Union, GCCMs are subject to European Technical Assessment (ETA) procedures, with the European Assessment Document (EAD) prescribing testing requirements broadly aligned with ASTM D8364. This dual regulatory framework provides a basis for the international application of GCCM materials with consistent quality assurance.

The CCX-M™ product used in both case studies is manufactured by Concrete Canvas Ltd (Wales, UK) and distributed through regional partners. It consists of a dry concrete mix encapsulated between two geotextile layers, with a fused LLDPE geomembrane backing that can be thermally bonded at joints to achieve very low permeability. Key material properties include a compressive strength exceeding 70 MPa (cured), an initial flexural breaking load (at 24 hours from hydration) greater than 2,500 N/m, and

abrasion resistance approximately 3.5 times that of conventional 20 MPa concrete typically used for canal applications. The product has an unhydrated unit weight of approximately 14.5 to 15.5 kg/m², a Manning's roughness coefficient of 0.010 to 0.015, and a design life in excess of 50 years.

A critical operational advantage of GCCMs over cast-in-place concrete is installation speed. The material is supplied in factory rolls, deployed directly onto a prepared and profiled substrate, joined at overlaps, and activated by the application of water. The material is ready to use within 24 hours of hydration, permitting swift return of assets to service. For cold-weather applications, additional measures such as insulating cover during the curing period are required, as demonstrated in the Hungarian case study. Installation does not require specialised contractors or heavy formwork, making it accessible to irrigation districts operating with limited technical resources or tight maintenance windows.

3. CASE STUDY 1: TISZAFÜRED II. SECONDARY CANAL, HUNGARY

3.1 Background and Site Selection

The Tiszafüred Irrigation System is one of the oldest and most extensive irrigation schemes in Eastern Europe, constructed between 1937 and 1940 to serve agricultural land in the Middle Tisza region. Since 2017, the system has been operated by the Middle Tisza District Water Directorate (Közép-Tisza-vidéki Vízügyi Igazgatóság, KÖTIVIZIG). The system includes primary and secondary canals lined with concrete, applied to canal reaches underlain by highly permeable subsoil, to limit seepage losses.

Over more than 80 years of operation, the original concrete lining on numerous sections has experienced varying degrees of deterioration. KÖTIVIZIG, which has developed experience with Concrete Canvas GCCM products (specifically the original CCT product types) at three locations within the Tiszafüred system since previous years, was invited by the manufacturer to participate in a large-scale field trial of the newer CCX-MTM product launched in 2022. The trial was intended to generate practical construction experience and evaluate the performance of the new product under field conditions representative of Hungarian hydraulic engineering practice.

The site selected for the trial was the Tiszafüred II. Secondary Canal, a primary-order lateral canal of the irrigation system. The canal section between chainage 0+265 and 0+350 was identified, offering a smaller cross-section suitable for the available material quantity and presenting documented seepage problems. The existing concrete lining on this section was removed prior to GCCM installation.

3.2 Construction Methodology

Preparatory works commenced following the close of the irrigation service season. The canal was dewatered, accumulated sediment was removed, and the existing concrete lining elements were demolished and cleared. Due to inadequate width of the left bank spoil bank, local material was used to widen it, and over-excavation of the canal bed was carried out to accommodate a stabilising layer of quarry gravel placed on geotextile. Transverse anchor trenches were excavated at both ends of the pilot section to anchor the terminal edges of the GCCM.

The CCX-MTM material was supplied in 12 rolls, each 25 linear metres long and approx. 50 m² in area, delivered to the adjacent canal warden building and transferred to the installation site using a lifting frame and a JCB backhoe loader. Installation supervision was provided by representatives of the manufacturer, including a structural civil engineer and business development personnel from the UK and Italy.



Figure 2. Installation of geotextile, gravel, and anchor trenches

The canal lining began from the downstream end of the pilot section. Individual roll lengths were cut to the required dimensions on-site and placed within the canal profile, with care taken to conform the material to the bed-slope transition at the toe. The upstream terminal was anchored into the prepared trench and weighted with in-situ concrete, which also formed the transition to the adjacent existing concrete lining. Overlapping joints between adjacent GCCM panels were achieved with a 10 cm overlap. Joint preparation required mechanical removal of cement dust from the lower sheet using a brush, cleaning of the upper sheet with a cloth, and thermal bonding of the geomembrane layer using a hot-air gun, followed by physical compression of the joint. Joints were additionally secured with concrete reinforcing bar stakes and stainless-steel screws.



Figure 3. Hydration process

Installation was carried out within one working day, a total installed area of 570 m² across 87 linear metres of canal. The placed material was covered with black polyethylene sheeting for the night to protect against temperature fluctuation prior to hydration.

Hydration was performed on the second day, applying approximately 7 litres of water per square metre of CCX-M™, corresponding to the material's unit mass of 14.5 to 15.5 kg/m². Water was delivered via a 1 m³ plastic tank and two submersible pumps with a combined output of 2 m³/hour. Following hydration, the entire installed section was again covered with black sheeting for a minimum of 72 hours, as directed by the manufacturer's engineer, to retain the heat of cement hydration and protect the curing material from near-freezing ambient temperatures recorded during the period. A final hydration check and supplementary wetting were performed on the third day, and the protective sheeting was removed couple of days later. Anchor trenches were subsequently backfilled, the spoil bank was graded, and

temporary canal closures were removed. The canal section was returned to service in early March of 2022, in time to meet incoming water demands from fish pond operators served by the system.



Figure 4. Irrigation canal in operation

3.3 Key Observations and Performance

The primary observation from this installation was that the overall construction process for CCX-M™ did not differ substantially from that of the previously used CCT products, though the greater unit mass of CCX-M™ (14.5 to 15.5 kg/m², compared to 7 kg/m² for CCT1) necessitated mechanical handling at all stages. The joint welding process was identified as the rate-limiting activity, with daily output determined by the number of thermal bonds that could be completed per day. At low ambient temperatures, increased heat loss during welding must be compensated for by adjusting nozzle geometry and technique to achieve adequate geomembrane fusion.

The installation demonstrated that GCCM rehabilitation of irrigation canals can be completed within the narrow maintenance window available outside the irrigation season (typically 1 November to 1 March in the Hungarian operational context), while remaining within seasonal weather conditions suitable for the material. The capacity to install over existing or adjacent concrete without the requirement for full demolition in all scenarios was confirmed, and the product was assessed as technically suitable for wider application within the KÖTIVIZIG operational portfolio, subject to continued monitoring of the pilot section.

4. CASE STUDY 2: HENRY MILLER RECLAMATION DISTRICT NO. 2132, CALIFORNIA, USA

4.1 Background and Context

The Henry Miller Reclamation District No. 2132 (HMRD) is an irrigation district located in Dos Palos, California, in the San Joaquin Valley, one of the most agriculturally productive regions of the United States. The district serves more than 90 registered water users across ~190 km³ of farmland through a network comprising more than 117 km of main irrigation canals and 182 km of lateral canals. The majority of these canals are earthen or compacted unlined channels; reducing seepage losses is identified as a top operational priority.

The canal selected for rehabilitation was an approximately 439m section previously lined with conventional concrete. Over time, differential ground movement had caused widespread cracking of the concrete lining, leading to water losses exceeding 30% during conveyance. The district evaluated multiple lining options before specifying CCX-M™ GCCM as a value-added alternative to a combination of plastic membrane and shotcrete, on the basis of installation simplicity, cost-effectiveness, performance characteristics, and the capacity for self-installation by district personnel.

4.2 Installation Procedure

Installation was carried out in October 2023 by a crew from Concrete Canvas USA, in collaboration with HMRD staff. Prior to GCCM placement, the existing cracked concrete lining was removed, the canal profile was re-excavated and compacted, and anchor trenches of approximately 150 mm x 150 mm were constructed along both banks of the canal.

The CCX-M™ material was supplied on rolls measuring 25 m x 1.9 m. Individual sections approximately 8.2 m in length were unspooled from the roll, sufficient to line the canal invert and extend into the anchor trenches on each bank. As successive sections were deployed, overlapping joints were pegged at 150 mm centres and thermally bonded to achieve the lowest achievable permeability - appropriate for an installation intended primarily to mitigate canal seepage and conserve water. At the inlet and outlet of the canal section, existing concrete collars were present; the GCCM was anchored to these using 6 mm diameter anchor bolts on 500 mm centres with washers. At the close of each working day, all deployed material was pegged, thermally bonded, and hydrated with water to prevent partial unintended curing from overnight dew or rainfall.



Figure 5. GCCM installation

Approximately 2,600 m² of CCX-M™ were installed in just over three working days - reported as less than half the duration that would have been required for conventional concrete construction methods. The canal was returned to service less than 24 hours after the final hydration.

4.3 Performance Assessment

One week following completion of installation, both ends of the rehabilitated canal section were closed and seepage was measured over a four-day monitoring period. The results indicated a 96% reduction in seepage compared to the pre-rehabilitation condition, a performance outcome consistent with the USBR's long-term study findings for concrete-over-geomembrane lining systems (USBR, 2019). The district manager expressed high satisfaction with the results.



Figure 6. GCCM lined canal in operation, Henry Miller Reclamation District

The project demonstrated several additional operational advantages of CCX-M™ in the California context. The material's resistance to high UV exposure, extreme temperature variation, and burrowing animal damage - the leading cause of canal failures in the western United States - was noted as particularly relevant for HMRD's operational environment. The reduced logistical footprint of the material significantly reduced transportation and handling requirements. Following the success of the installation, the district indicated its intention to consider CCX-M™ for rehabilitation of additional canal sections within its network.

5. COMPARATIVE ANALYSIS AND DISCUSSION

The two case studies presented in this paper differ substantially in scale, climate, institutional context, and pre-existing infrastructure conditions. However, both demonstrate consistent themes with respect to the application of CCX-M™ GCCM technology for irrigation canal rehabilitation.

In terms of installation performance, both projects achieved rapid completion within constrained operational windows. In Hungary, 570 m² were installed within just one working day in winter conditions, with the canal returned to service within approximately one week of commencement; in California, approximately 2,600 m² were installed in just over three days, with the canal returned to service within 24 hours of the final hydration. Both outcomes reflect the material's principal operational advantage: the capacity to deploy GCCM within the narrow maintenance periods available between irrigation seasons, without the extended curing periods associated with cast-in-place concrete.

With respect to seepage performance, the California project recorded a 96% reduction in seepage through direct measurement, consistent with established benchmarks for concrete-over-geomembrane systems. While a direct post-installation seepage measurement was not reported for the Hungarian pilot section, the hydraulic barrier function of the CCX-M™ product - verified through its conformance with ASTM D8364 and ETA product standards — is consistent with expectations of substantial seepage reduction. The Hungarian case additionally highlights the potential to rehabilitate canals with existing deteriorated concrete lining by installing GCCM directly over or adjacent to the original structure, reducing demolition requirements and construction time.

The two case studies also differ in the nature of the jointing method applied. In California, thermal bonding was selected to achieve minimum permeability, appropriate where seepage prevention is the primary objective. In other projects documented by CCUSA - including the North Sterling Irrigation District in Colorado - mechanical screw jointing was used where controlled seepage is acceptable or desirable to prevent hydrostatic pressure build-up. This flexibility in jointing approach allows GCCM technology to be adapted to site-specific hydraulic and geotechnical conditions.



Figure 7. Different type of jointing methods

From an institutional perspective, both projects illustrate the capacity of GCCM technology to be deployed by or in close collaboration with the operational organisations responsible for the infrastructure, without reliance on highly specialised contractors. In Hungary, the KÖTIVIZIG section engineering team performed the majority of the installation with manufacturer support; in California, HMRD similarly identified the capacity for self-installation as a significant cost and logistical advantage. This characteristic is of particular relevance to irrigation districts and water authorities in regions with limited access to specialist hydraulic engineering contractors.

Taken together, these case studies demonstrate that GCCM technology offers a practical and scalable response to the challenge of irrigation infrastructure rehabilitation across a wide range of conditions. The technology is applicable to both targeted pilot interventions, as in Hungary, and to larger-scale systematic rehabilitation programmes. Its performance across contrasting climatic environments - from Hungarian winter conditions with near-freezing temperatures to the high UV and heat load of California's San Joaquin Valley - confirms the material's environmental durability across a broad operational envelope.

6. CONCLUSIONS

This paper has presented two international case studies of Geosynthetic Cementitious Composite Mat (GCCM) technology applied to the rehabilitation of irrigation canal infrastructure: the Tiszafüred II. Secondary Canal in Hungary (2022) and the Henry Miller Reclamation District No. 2132 canal in California, USA (2023). The following conclusions are drawn: GCCM technology, specifically the CCX-M product conforming to ASTM D8364 Type II classification, offers a technically robust and operationally practical alternative to conventional cast-in-place concrete for irrigation canal rehabilitation. Its composite structure of cement matrix, geotextile reinforcement, and geomembrane backing provides simultaneous structural, erosion protection, and hydraulic barrier functions in a single-application system.

Installation speed is a critical operational advantage. Both case studies demonstrated that significant canal rehabilitation works can be completed within the narrow maintenance windows available between irrigation seasons, without the extended curing periods and specialised formwork associated with conventional concrete construction. Seepage reduction performance is substantial and consistent with established benchmarks. The California project recorded a 96% reduction in seepage through direct post-installation monitoring, consistent with long-term USBR findings for composite lining systems.

The technology is adaptable across a wide range of climatic, geotechnical, and institutional conditions. Performance has been demonstrated in both cold-weather European operational environments and high-UV, high-temperature conditions in California. The material can be installed over existing deteriorated concrete linings where appropriate, reducing demolition requirements and enabling rehabilitation within tighter time and budget constraints. The capacity for installation by operational irrigation district personnel, without reliance on highly specialised contractors, is an important advantage for adoption in contexts where technical contracting resources are limited or where cost reduction is a priority. Future work should include systematic post-installation monitoring of long-term seepage performance and structural integrity across a broader range of GCCM installations in irrigation contexts, to build the evidence base supporting wider adoption within national and international irrigation rehabilitation programmes. The Hungarian pilot section offers an opportunity for continued monitoring over a multi-year period.

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