# LONG-TERM PERFORMANCE OF PET GEOGRIDS WITH LLDPE COATING IN ALKALINE CONDITIONS: EXHUMATION FINDINGS POST LIME AND CEMENT STABILIZATION

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**Abstract.** *The increasing demand for sustainable construction practices and cost minimization has spurred interest in using locally available soil for reinforced fill structures. However, cohesive soils on-site often require stabilization treatments to enhance volume stability, strength, compressibility, permeability, and durability. These treatments can induce chemical reactions that dry the soil and alter the clay's surface mineralogy, impacting the pH level. Soils with a pH consistently above 9 is deemed not suitable for conventional PET geogrids due to hydrolysis susceptibility. This research examines the performance of PET geogrids with polyethylene-sheathed tendons in alkaline environments. Through experimental laboratory analyses and exhumation campaigns to assess the real-world conditions and prolonged exposure effects on these geogrids and geostrips, the study presents some considerations on the effects of a specific geogrid structure and coating.*

## 1 INTRODUCTION

In the construction industry, the cost, longevity, and durability of construction systems are continuously challenged by evolving environmental and economic conditions, necessitating robust and effective solutions. Using locally available soil can minimize natural resource exploitation and improve cost-effectiveness. However, cohesive soils with high plasticity may be unsuitable without treatment, such as chemical stabilization. Lime and cement are commonly used to enhance clayey materials by reducing plasticity, improving workability, and achieving long-term strengthening through soil drying and mineralogy modification. These techniques can create highly alkaline environments, initially with a pH above 12, decreasing over time.

## 2 BEHAVIOR OF PET BASED REINFORCEMENT IN HIGHLY ALKALINE ENVIRONMENTS AND AVAILABLE STANDARDS

Numerous publications discuss the degradation of PET fibers, with a key document being "Durability of Geosynthetics" by Greenwood, Schroeder, and Voskamp, reviewed by an international committee. This publication provides a thorough overview of testing and assessment methodologies for evaluating polymer life-limiting mechanisms. It identifies two independent hydrolysis mechanisms for polyester fibers. In acidic or neutral environments, "internal" hydrolysis occurs, related to the carboxyl end groups at polymer chain ends. In

alkaline soils (pH > 9), a second degradation form, "external" hydrolysis, occurs alongside internal hydrolysis, eroding the fiber surface and reducing strength proportional to the cross-sectional area change. Alkaline hydrolysis depends on the transport of hydroxyl ions through convection and diffusion, requiring moisture in the surrounding soil. Unprotected yarns are highly susceptible to alkaline solutions, rapidly losing tensile strength. However, the impact on products with specific coatings or manufacturing processes can vary significantly.
The reinforcement object of this research is made of strips comprising a core of high-tenacity polyester tendons encased in a tough polyethylene sheath, eventually bonded in the shape of geogrid or just left as geostrips (Fig.1).

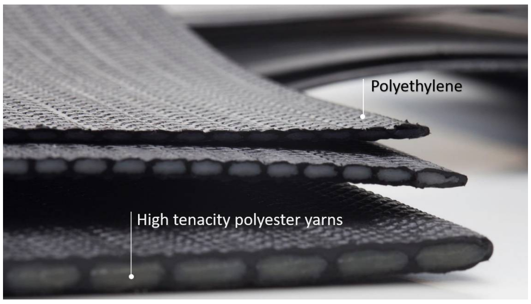


Figure 1. Bonded geogrids and geostrips cross sectional structure

Since 1999, Paraproducts were subjected to multiple tests to determine the effect of a range of alkaline solutions on samples of material. One of the research projects was carried out on the material exposed to installation damage test. Some of the tests were conducted at pH levels of 10, 12 and 14. The experimental hydrolysis conditions considered solutions at 60°C for 6 months (considered equivalent to 120 years at 20°C). Unlikely PVC, EVA or SBR coatings that offer no significant resistance to the diffusion of water vapor, a thick PE sheath was found chemically inert and not affected by any of the alkaline conditions and aqueous treatment. The research highlighted the importance of reinforcement section configuration on the propagation of alkaline solutions, with tendons fully encased in PE sheaths. It was observed that once the alkaline solution wicked into the lane, it saturated the void area and reacted with the polyester yarn, dissolving the surface of the filaments until the sodium hydroxide concentration dropped below the level required for the attack. Further tests on geostrips submerged in a solution with a pH of 13, aligning with the maximum pH expected in cement-stabilized backfill, demonstrated a retained strength of 98%, according to EN 14030 (currently EN ISO 12960).

The current standard for determining the long-term strength of geosynthetics is detailed in ISO TS 20432, which outlines methodologies for deriving reduction factors for geosynthetic soil reinforcement materials. Hydrolysis is identified as the main degradation cause for PET, with temperature significantly accelerating this process. Although fully coated polyester shows potential for slower degradation, PET is mentioned not to be used in environments with a pH greater than 9 unless durability is demonstrated. ISO TS 20432 also allows determining the degradation rate by analyzing exhumed products exposed to similar environments, installing, and retrieving samples to assess durability. The observation period must be long enough to extrapolate to the full design life, with sufficient specimens examined to account for statistical variability.

## 3 EVIDENCE FROM SERVICE EXPERIENCE

These geogrids and geostrips have been extensively used in projects with highly alkaline environments due to lime or cement stabilization techniques. The first series of tests was conducted at three sites in the United Kingdom using bonded PET, which has a short-term tensile strength of 50 kN/m, combined with a green or stone facing system of Double Twist mesh with a polymer coating. The campaign, overseen by a BBA (British Board of Agreement) officer, involved proper sample labeling and third-party analysis to determine the pH at the time of exhumation and the retained strength of the geogrids. The residual strength of the geogrids after exhumation showed that almost no effects from installation damage, durability or creep had been suffered (Table 1).

| **Site** | **Reinforcement** | **Characteristic Tensile Strength ($T_{char}$)** | **Binder type** | **pH at time of installation** | **Average pH at time of exhumation** | **Expected Strength** | **Residual Strength / Tchar** | **Time of burial** |
|---|---|---|---|---|---|---|---|---|
| **Site 1 Glasgow** | **PG 50/05** | **50 kN/m** | **Lime** | **11.1-11.9** | **9.5 (9.2-9.8)** | **37 kN/m** | **100%** | **2 years** |
| **Site 2 Glasgow** | **PG 50/05** | **50 kN/m** | **Lime** | **11.0-12.0** | **9.1 (8.4-10)** | **34 kN/m** | **98%** | **5 years** |
| **Site 3 Luton** | **PG 50/05** | **50 kN/m** | **Cement** | **11.0-12.0** | **11.7 (10.9-12.0)** | **35 kN/m** | **96%** | **3.5 years** |

Table 1. Exhumation phase in two different sites in the UK

The second series of tests was conducted in Forlì, Italy. On-site, the employed solutions included the bonded PET geogrids with 550 kN/m tensile strength for basal reinforcement over piles, bonded PET geogrids with 150 kN/m tensile strength for primary reinforcement of a reinforced fill structure, geostrips for the vertical concrete facing panel walls. The project involved the construction of an embankment measuring 530 meters in length and a viaduct spanning 320 meters, both of which were constructed over cohesive alluvial soil. This soil is characterized by compressible sandy silt and clay, interspersed with sand and gravel layers. The soil stabilization was achieved with 2% lime. The installation of this embankment started in 2005 till 2008, therefore these structures are 18 years old. The procedure followed was as per previous sites (Fig. 2).

Figure 2. Exhumation of geogrids (550 kN/m and 150 kN/m) in Forlì and collection of the soil samples.

In the laboratory, pH tests were conducted according to ISO 10390 standard on both the natural soil and samples of lime-stabilized soil. For the natural soil, an Initial Consumption of

Lime (ICL) test was performed to verify the minimum amount of lime required for effective stabilization. The pH level of the natural soil was measured at 8. The residual pH levels of samples of lime-stabilized soil in direct contact with the geogrids ranged between 10.9 and 11.2, consistent with expectations. All geogrids showed almost no strength loss compared to the characteristic tensile strength (Table 2).

| Reinforcement | Characteristic Tensile Strength ($T_{char}$) | Expected Strength | Residual Strength / Tchar | Time of burial |
|---|---|---|---|---|
| **PG 150/05 Sample 1** | **150 kN/m** | **102 kN/m** | **99%** | **18 years** |
| **PG 50/05 Sample 2** | | | **100%** | |
| **PL 550/05 Sample 3** | **550 kN/m** | **373 kN/m** | **100%** | |
| **PL 550/05 Sample 4** | | | **100%** | |

Table 2. Results from exhumation in Italy

## 4 CONCLUSIONS

The study focused on evaluating the long-term performance of polyester based geogrids encased in tough polyethylene sheath, often utilized in lime or cement-stabilized backfills. After description of some of the extensive test analysis carried out from various laboratories, four distinct sites were selected where these geogrids had been installed and exhumations conducted to retrieve both soil and geogrid samples. These samples were subsequently tested at accredited laboratories to assess their current status and durability. The analysis revealed that two of the four jobsites, the pH of the soil had decreased to more moderate levels, conversely, the pH at the other two jobsites remained high, exceeding 11, which is supposed to be particularly critical for the durability of PET yarns, especially in an 18-year-old project. Despite these challenging conditions, the reinforcement performance of all exhumed geogrid showed almost no reduction in strength. These findings underscore the robustness and important impact of diverse types of coatings and production methodologies on the exposure of the PET yarns in highly alkaline environments, confirming their suitability for long-term infrastructure projects. The successful performance of these PET geogrids shall pose some questions on the way the standards for the determination of durability of geosynthetics approach the reinforcements analysis, considering only uncoated yarns, without a deeper assessment on ambient conditions such as exposure to fine soils that unlikely damage a tough coating nor investigate the propagation of alkaline solutions in damaged conditions. Further research is ongoing to better understand and define the propagation effect of alkaline solutions and how this contributes on the long-term performance of geosynthetic reinforcements.

## 5 REFERENCES

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