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Polyvinyl alcohol (PVA): A viable polymer for Geosynthetics

by

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Polyvinyl alcohol (PVA): A viable polymer for geosynthetics

Polyvinyl alcohol (PVA) is a high-performance polymer used in geosynthetics for specialized, heavy-duty soil reinforcement. Key properties and benefits of PVA include high strength with a massive tensile modulus required for critical structural reinforcement, low creep for resisting deformation under long-term continuous heavy loads and superb alkali resistance to withstands high-pH environments (such as cement-stabilized soils where pH exceeds 12). Due to these properties; high-tenacity PVA reinforcement is routinely used in the stabilization of steep slopes, retaining walls, and roadways.

Polyvinyl alcohol (PVA) for geosynthetics is manufactured by polymerizing vinyl acetate into polyvinyl acetate (PVAc), converting it via hydrolysis into PVA polymer, and then extruding or spinning the PVA into high-strength fibers or grids. Key types used for geosynthetics include high-tenacity structural fibers, water-soluble manufacturing grades, and chemically modified variants.

High-Tenacity and High-Modulus PVA Fibers

- **Structural Geotextile Grades:** Engineered with high molecular weight and complete acetalization or heat-drawing, providing tensile strengths of 1,200–1,800 MPa and high elasticity modulus for soil and pavement reinforcement.
- **Alkali-Resistant Monofilaments:** Used extensively in composite soil layers and concrete interlayers because they form a strong chemical-mechanical bond with cementitious and earthen matrices.

Hydrolysis and Polymerization Grades

- **Fully Hydrolyzed (98%–99% Hydrolysis):** Offers maximum chemical resistance, high tensile strength, and minimal moisture sensitivity which is ideal for permanent load-bearing geotextiles.
- **Partially Hydrolyzed (86%–89% Hydrolysis):** Provides higher flexibility and distinct dissolution or softening characteristics and is utilized when partial degradation or specialized matrix bonding is required.

American Association of State Highway and Transportation Officials (AASHTO) guidelines do not broadly recognize polyvinyl alcohol (PVA) geogrids primarily due to a lack of standardized testing protocols and long-term durability criteria for that specific polymer type within transportation

frameworks. While specifications exist for common polymers, alternative materials require separate validation.

Key Factors in Material Recognition

- **Standardized Protocols:** AASHTO specifications like R 69/PP 66 cover installation damage and creep testing mainly for polypropylene (PP), polyethylene (PE), and polyester (PET) but not PVA. ASTM D5296 “standard test method for GPC” can be used. However, the general practice for characterization of PVA molecular weight distribution typically relies on customized aqueous GPC/SEC setups. It is often coupled with Multi-Angle Laser Light Scattering (MALLS) or differential viscometry rather than a rigid ASTM designation due to challenges involving polymer-column interactions and varying degrees of hydrolysis.
- **Durability Criteria:** Standardized chemical and biological resistance tests (such as hydrolysis guidelines) are not yet fully established or universally agreed upon for PVA within AASHTO documents.
- **Empirical Data:** Acceptance requires extensive, controlled field or trafficking data to generate universal design input parameters, which remain limited for PVA in standard pavement specifications.

PVA is a versatile polymer widely used in various industries. One of the critical factors that determine its properties and applications is the degree of hydrolysis. Understanding the differences between fully hydrolyzed and partially hydrolyzed PVA can help in selecting the right grade of PVA to use determined by specific needs

Fully hydrolyzed PVA refers to a type of polyvinyl alcohol where all the acetate groups are converted into hydroxyl groups. This results in a polymer chain with complete hydrolysis, making it water-soluble and highly crystalline. Fully hydrolyzed PVA typically has a high degree of polymerization, which means longer polymer chains, resulting in excellent mechanical properties such as high tensile strength and elasticity. Due to its fully hydrolyzed nature, this type of PVA is commonly used in applications requiring strong bonding and film-forming properties.

One of the key advantages of fully hydrolyzed PVA is its superior water resistance. Since all the acetate groups are hydrolyzed, the polymer is less prone to water absorption, making it ideal for applications where moisture resistance is essential. In terms of viscosity, fully hydrolyzed PVA grades tend to have a higher viscosity compared to partially hydrolyzed grades.

When comparing the properties of fully hydrolyzed and partially hydrolyzed PVA grades, several key differences become apparent. Fully hydrolyzed PVA typically exhibit higher tensile strength and water resistance due to its complete hydrolysis, making it suitable for applications requiring

robust bonding and moisture protection. In contrast, partially hydrolyzed PVA offers improved flexibility and lower viscosity, making it ideal for applications where conformability and processability are essential. Hence, most geosynthetics are made from fully hydrolyzed PVA.

AASHTO M288 is the national material specification for geotextiles used in highway construction and transportation engineering applications. Section 4.1 states: “Fibers, yarns, straps, and sheets used in the manufacture of geotextiles and geogrids used in a reinforcement application, and the threads used in joining geotextiles by sewing, shall consist of long-chain synthetic polymers, composed of at least 95 percent, by weight, polyolefins or polyesters. They shall be formed into a stable network such that the filaments, yarns, or ribs retain their dimensional stability relative to each other, including selvages”.

Based on this wording, geotextiles and geogrids must be manufactured using polyester or polyolefin polymers (PP or PE). Several years ago, we attempted to use a geotextile manufactured from **PVA (Polyvinyl Alcohol)** on a project; however, it was not accepted due to this requirement. Hopefully this white paper assists with shifting the paradigm on this technical matter involving AASHTO.

We formally proposed that AASHTO include **Polyvinyl Alcohol (PVA)** as an acceptable polymer for geotextiles and geogrids after it twenty plus years of successful use in geotechnical applications. The proposal remains under discussion, largely because one state expressed concerns that PVA is water-soluble. We believe there may have been some confusion between **Polyvinyl Acetate**, which is indeed water-soluble, and **Polyvinyl Alcohol fibers used in geosynthetics**, which exhibit excellent durability and chemical resistance when properly manufactured. In our professional judgment, PVA is a suitable raw material for geotextiles and geogrids used in reinforcement applications.

To support PVA’s acceptance, we cite several references and case histories, including:

- EBGeo – Recommendations for Design and Analysis of Earth Structures Using Geosynthetic Reinforcements (2011)
- ISO/TR 20432 – Guidelines for the Determination of the Long-Term Strength of Geosynthetics for Soil Reinforcement (2007)
- DIN EN 13251 – Geotextiles and Geotextile-Related Products (2016)
- “Geosynthetic Reinforcement Using Innovative Polymers” – IGS Award to HUESKER, International Geosynthetics Society (2010)
- BBA Certificate 05/4266 (British Board of Agrément) – Fortrac MDT Geogrids (2022) British Standards Institution (BSI), (1995) BS 8006.

- R. M. Koerner's *Designing with Geosynthetics* (2016)
- Huang C J. (2025)
- Mirababaei et. al. (2018)
- Alexiew, D. (1997),
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- Paes Jr., G. et. al. (2006),

Currently PVA is commonly used in geosynthetics across the different product classes. While PVA is predominantly applied in reinforcement applications, various commercially available PVA grades can also be found in geogrids, geocells and drainage products.

There are many points to consider when choosing the correct PVA grade. Typically, PVAs are classified according to their viscosity and degree of hydrolysis. Both parameters have a substantial effect on the polymer's performance. For example, as hydrolysis increases, so do crystallinity, melting temperature, and mechanical strength, due to the high level of hydrogen bonding between chains. A lower hydrolysis grade has higher solubility in water and may show better chemical resistance. Viscosity, determined by the polymer chain length, also has a great influence on the performance of a formulation. As the chain length rises and with it the molecular weight (MW), the viscosity in solution also increases. However, while all PVAs are water-soluble, the dissolution time and the maximum amount in solution are strongly dependent on the PVA's MW. With increasing MW, the time required for dissolution increases while the maximum soluble amount decreases. Viscosity is not only influenced by internal intrinsic factors but also by external factors.

Summary and Conclusions

The Federal Highway Administration (FHWA) is a federal government agency that regulates and funds U.S. roads. The American Association of State Highway and Transportation Officials (AASHTO) is a nonprofit group representing state transportation departments. They work together as regulatory partner and practitioner advocate to set national highway design, safety, and operational standards. In so doing AASHTO, (through M 288) set the standard specification that defines physical, mechanical, and durability requirements for geosynthetics used in highway construction. The lack of change within this standard specification is mainly due to the complexity-variability of PVA formulations, lack of education and perceived risk. While some states are very pro-active in updating and revising their geosynthetic specifications, others rely completely on AASHTO for guidance.

Polyvinyl alcohol (PVA) geogrids are high-strength geosynthetics used in civil engineering for soil reinforcement, steep slope stabilization, and base or ground improvement. They are specifically

chosen over standard polyester or polyolefin options when projects involve chemically aggressive, high-pH (alkaline), or acidic environments where other polymers degrade. Major Project Types and Applications for PVA include but are not limited to the following.

- **Residue and Waste Deposit Facilities:** Used in reinforced fills and steep external faces atop dikes where high-pH industrial sludge or chemical waste demands alkali-resistant reinforcement.
- **Landfill Recultivation and Slope Stabilization:** Deployed in slope remediation projects and landfill renovations with aggressive acidic or basic leachate environments that rule out standard polyester grids.
- **Levee and Embankment Repairs:** Utilized in large-scale flood protection overhauls (such as post-hurricane levee restorations) to distribute heavy loads across deep soil-mixed foundation piles.
- **Retaining Walls and Steep Slopes:** Applied where low creep behavior, high tensile modulus, and high durability are critical to maintaining the structural integrity of earth retention systems.

There are currently seven major geosynthetic manufacturers worldwide that specialize in PVA geosynthetic reinforcement. They have done so with success over the past twenty years. They are as follows:

- **Huesker:** Producing PVA-based Fortrac and HaTelit XP grids designed for high alkali resistance and asphalt reinforcement.
- **ACE Geosynthetics:** Produces the *ACEGrid® GV-Series*, woven from high-tenacity PVA multifilament yarns for earth structures.
- **Techfab India (TechGrid PVA Series):** Manufactures the *TechGrid PVA Series* using specialized high-tenacity multifilament PVA yarn for critical soil reinforcement.
- **PRS Geo Technologies:** (formerly PRS Mediterranean): supplies PVA geocells which are 3D cellular confinement systems made from high-strength synthetic polymer fibers designed for heavy-duty soil stabilization, load support, and seismic earth retention
- **Enka Solutions:** Utilizes PVA materials within their civil engineering geogrid and composite ranges.
- **Maccaferri:** uses PVA fibers or yarns in high-performance geosynthetics, soil reinforcement, or specialized technical textiles.

- **TenCate Mirafi (Solmax):** utilizes various polymer types (such as PP, PET, and PVA) within their engineered geotextile and reinforcement product lines.

With all of the above information, we believe it is long overdue for AASHTO M288 to be updated to include PVA as a viable geosynthetic polymer.

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