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# Tile Adhesive Manufacturing with a Green Engineering Approach: Sustainable Practices in Raw Material Selection and Production

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***Abstract*: Tile adhesive is essential in the construction and renovation industry, ensuring strong bonding, durability, and aesthetic appeal of tiled surfaces. This article explores the various types, properties, and manufacturing processes of tile adhesives, with a particular focus on recent advancements in adhesive technology. It covers the careful selection and proportioning of raw materials such as cement, dolomite powder, MHEC polymer, RD polymer, PVA polymer, and fly ash to achieve the desired properties in the final product. The manufacturing process includes key steps like raw material selection, mixing, and preservation, all aimed at producing a homogeneous, high-performance adhesive. Furthermore, the article discusses the classification of tile adhesives, from Type 1 to Type 5, each tailored for specific substrates, tile types, and environmental conditions. Overall, this comprehensive overview highlights the significance of tile adhesive manufacturing in modern construction practices, offering insights into selecting the most suitable adhesive for a variety of applications.**

***Keywords*: manufacturing process, raw material selection, mixing procedure, preservation, homogeneous adhesive, high-performance adhesive.**

## 1. Introduction

Tile adhesive plays a crucial role in the successful installation and durability of tiles on various surfaces. As an essential component in the construction and renovation industry, tile adhesives are designed to ensure strong bonding, minimize the risk of tile displacement, and enhance the aesthetic appeal of tiled spaces. The evolution of tile adhesives has led to the development of advanced formulations that cater to diverse environmental conditions, types of tiles, and substrate materials. We are exploring the types, properties, and applications of tile adhesives, highlighting the latest advancements in adhesive technology and their impact on the overall performance of tiling systems. Additionally, it examines the factors that influence the choice of adhesive, such as ease of use, setting time, flexibility, and resistance to moisture, ensuring a comprehensive understanding of the material's role in modern construction practices.

## 2. Tile Adhesive Manufacturing

The manufacturing of the tile adhesive typically involves a combination of several key components. The primary ingredients include cement, which serves as a binder providing strength and durability. Fine aggregates such as sand are added to enhance the adhesive's texture and workability. Polymers, like latex or acrylic, are incorporated to improve flexibility, bonding strength, and water resistance. Additives such as thickeners, retarders, and accelerators are used to adjust the setting time and consistency [1]. Additionally, fillers and additives like cellulose or starch may be included to modify the adhesive's performance, making it easier to apply and ensuring it adheres effectively to both tiles and substrates. These components work together to create a strong, durable, and flexible adhesive suitable for various types of tiles and installation conditions.

### *A. Raw Material Selection*

The manufacturing procedure for tile adhesive typically involves several key steps:

#### *1) Cement*

Cement is manufactured from materials heated together at high temperature to form a rock like substance that is grind into a fine powder. Main ingredients used in cement are Calcium, Silica, Alumina, Iron, Magnesium. Limestone, marl and clay are commonly used source of these primary elements [2].

1. Limestone is mined and transported to the cement plant where it is stored with other raw materials and next After grinding and binding, the raw materials are heated to around 1450'C in the suspension pre - heater tower and next the heated raw materials pass through to the rotary kiln and next the hot clinker that emerges from the rotary kiln is passed through the cooling system.
2. Low temperature unit of the residual heat electricity generating unit is attached to the cooling system, next the cooled clinker is stored and finally clinker, and small number of raw materials are ground into cement ball milling after the cement product packaged and stored in the godown for dispatch.

Efforts in green engineering involve utilizing alternative low-carbon materials to reduce carbon percentage and eventually bringing them to zero on mother earth [3], [7]. The

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forms of carbon like such as fly ash and slag, are one of the best to reduce the environmental impact of cement production.

*2) Dolomite Powder*

Dolomite powder is generally form by using sedimentary rocks. It has long been used as a vital ingredient in construction and building materials. Its exceptional hardness and durability make it an ideal choice for creating strong and resilient structures. It is commonly used as a crushed stone or aggregate in concrete mixes, providing increased strength and reducing the risk of cracking. The high melting point of this mineral also makes it an excellent component in refractory bricks, which are used in furnace linings to withstand extreme temperatures. Moreover, its chemical composition enables it to act as a fluxing agent in the production of cement, aiding in the formation of clinker and enhancing the strength of the final product.

Generally, Dolomite Powder is used as a component of filler in manufacturing of Tile Adhesive. In tile adhesive, it serves as a filler material to enhance the adhesive's strength. Sustainable sourcing practices and recycling of dolomite residues can reduce the environmental impact.

*3) MHEC Polymer*

Methyl hydroxyethyl cellulose (MHEC) is also known as Hydroxyethyl methyl cellulose (HEMC). It is a non-ionic cellulose ether. HEMC powder is made from natural polymer cellulose. It provides many of the same benefits as other methylcellulose derivatives.

MHEC delivers superior thickening properties, ensuring optimal mortar consistency while boosting its cohesion for outstanding performance. Due to its performance improvement characteristics, it can be used with skim coats/wall putty, plasters/render, tile adhesives, and external thermal insulation systems. Green manufacturing focuses on sourcing renewable materials and minimizing waste during production, ensuring that MHEC contributes to the overall sustainability of tile adhesives.

*4) RD Polymer*

Redispersible (Emulsion undergone spray drying) Polymer Powder is a spray-dried powder of polymer emulsion. Redispersible Polymer Powder is re-emulsified with water and has the same properties as the original emulsion, that is a film can be formed after water evaporation. This film has high toughness, weather resistance and adhesion to a substrate.

RD polymer powders are used in tile adhesives, external wall putty, construction adhesives, building binders, joint mortars, plasters, filling compositions such as floor filling compositions, concrete repair joints, water proofing membrane applications and crack isolation membrane.

The use of sustainable production methods, including minimizing solvent use and waste, aligns with green manufacturing principles [3].

*Significance of RD Polymers*:

- Improve the adhesion of dry mortar to various substrates and ensure the weather resistance of mortar bond strength under various conditions of use. For example, to improve the bond strength between mortar and EPS board, EPS particles, concrete walls and brick walls in the thermal mortar.
- Reduce the elastic modulus of the materials, improve the elasticity and flexibility of the materials. The material can withstand certain substrate deformation, external force impact, temperature difference deformation, and freeze-thaw deformation. If Redispersible Polymer Powder can significantly improve the dynamic anti-cracking of the putty and the heat aging resistance of the tile adhesive, the impact resistance of the EPS board insulation system.
- Redispersible Polymer Powder can reduce the water absorption of the material; the special hydrophobic latex powder effect is more obvious. Reduce water and damage caused by water to the molded mortar.
- Some types of Redispersible Polymer Powder can improve the sag resistance and fluidity of the mortar, in order to improve the construction performance of the mortar.

*5) PVA Polymer (Polyvinyl Polymer)*

The ingredient that makes PVAs effective as adhesives is polyvinyl acetate, a rubbery polymer that forms a hard bond as it dries. Among its strengths when it comes to wood (and some other porous materials) is that the glue seeps into the fibres, creating a stronger bond as it hardens.

Polyvinyl alcohol is a water-soluble synthetic polymer. It has the idealized formula [CH2CH(OH)n. It is used in papermaking, textile warp sizing, as a thickener and emulsion stabilizer in polyvinyl acetate (PVAc) adhesive formulations, in a variety of coatings, and 3D printing. It is colourless (white) and odourless. It is commonly supplied as beads or as solutions in water. Without an externally added crosslinking agent, PVA solution can be gelled through repeated freezing-thawing, yielding highly strong, ultrapure, biocompatible hydrogels which have been used for a variety of applications such as vascular stents, cartilages, contact lenses, etc.

*6) Fly Ash*

Fly ash is the fine powder formed from the mineral matter in coal, consisting of the noncombustible matter in coal and a small amount of carbon that remains from incomplete combustion. Fly ash is generally light tan in color and consists mostly of silt-sized and clay-sized glassy spheres. It is composed of fine particles that are carried up by the flue gases and captured by electrostatic precipitators or baghouses. Fly ash primarily consists of silica (SiO2), alumina (Al2O3), and iron oxide (Fe2O3), along with trace amounts of other elements.

*Manufacturing of Fly Ash*:

- *Coal Combustion*: In power plants, coal is burned at high temperatures in a boiler. The combustion process creates ash.
- *Capture*: The fine particles, including fly ash, are carried up with the exhaust gases. These are then captured using various air pollution control devices, such as electrostatic precipitators, bag filters, or scrubbers.
- *Storage*: Once collected, fly ash is stored in silos or ponds until it is ready to be processed or used in various applications.

## 3. Material Proportion

The materials are carefully weighed and proportioned according to the formula for the desired type of adhesive. This step is crucial to ensure the correct properties in the final product, such as bonding strength and flexibility.

Table 1

| Component | Percentage |
|---|---|
| Cement | 30% – 35% |
| Filler | 54% - 80% |
| MHEC | 0.3% - 0.5% |
| RD Polymer | 1.0% - 2.0% |
| Calcium Formate | 3% - 8% |
| PVA | 10% - 15% |
| Fly ash | 5% - 30% |
| Other | 0.1% - 0.3% |

## 4. Mixing Procedure

The raw materials are mixed in a large industrial mixer. This ensures that all ingredients are evenly distributed, forming a homogeneous dry blend. The mixing time and intensity are controlled to prevent clumping and ensure smooth consistency.

If the components have any moisture content, they may be dried in a rotary drum dryer to achieve the desired moisture level [4]. This step is particularly important for cement-based adhesives to avoid premature setting.

The mixture is sieved to remove any large particles or impurities. This ensures that the adhesive is fine and smooth, with a uniform texture [5].

## 5. Classification

### *A. Type 1 Adhesive*

This adhesive is suitable mainly for tiles with apparent porosity greater than 3 percent. It is suitable for most of the clay and ceramic tiles of small dimension (size not more than 300 mm x 300 mm) and the majority of cement-based backgrounds (substrates) like cement plaster, cement concrete, cement screed, etc., and for interior dry area applications only [6].

Type 1 adhesive is generally C1T grade (Cementitious Standard Slip Resistant) and it contains varying small amounts of chemical polymers; hence the name general purpose adhesive is suitable for general, internal, ceramic floor and wall tiling. The vital minor amounts of chemical polymers enable powder adhesives, which are based on bulk cement and filler, to be modified to have appropriate properties.

### *B. Type 2 Adhesive*

This adhesive is suitable mainly for tiles with an apparent porosity less than or equal to 3 percent. It is suitable for vitrified tiles, glass mosaic tiles, all stones, dense and large dimension (More than 300 mm × 300 mm size) tiles and stones. This type of adhesive is generally C2T Grade (Cementitious improved performance slip-resistant) recommended for both interior floor and wall applications, and for exterior floor applications [8], [9].

### *C. Type 3 Adhesive*

This adhesive is suitable mainly for tiles and stone tiles on exterior wall substrates like plaster or concrete. It is suitable for tiles like ceramic, clay tiles, basalt tiles, vitrified, glass mosaic tiles and porcelain tiles and all natural stone tiles. Generally, it contain grade of C2TE (Cementitious improved performance slip-resistant with extended open time).

### *D. Type 4 Adhesive*

This adhesive is suitable mainly for tiles and stone tiles. It is suitable for all types of tiles and stones except metal tiles or engineered stones to be installed on dry wall board substrates like gypsum boards, plywood, wood, medium density fibre boards, fibre cement boards, cement boards, etc.

For all tiles/stones of size more than 600 mm × 600 mm, the adhesive shall also comply with 'S1' category of transverse deformation. Similar results to polymer modified adhesive can be achieved by the addition of a liquid admixture to the standard general-purpose adhesive which is called as polymer fortified adhesive.

Generally, the grade of type 4 Adhesive is C2TES1 that means cementitious improved performance slip-resistant, deformable adhesive with extended open time.

### *E. Type 5 Adhesive*

This adhesive is suitable for all types of tiles including engineered stones (manufactured stones) which are intended for installation on glass or metallic substrates like, grid iron, mild steel, stainless steel, aluminum or copper, etc. It is suitable for metal tiles, glass tiles, engineered stones or for all types of tiles and stones to be installed on different cement-based substrates like cement screeds, plaster, concrete, drywall boards like gypsum boards, plywood, wood, metals composite boards, modified backer boards and the metallic substrates.

Type 5 adhesive is generally a mixture of synthetic resin, mineral fillers and organic additives in which hardening occurs by chemical reaction. They are available in one or more component forms and in essence, these cover polyurethanes, epoxy adhesives.

Through green manufacturing, tile adhesive production has made strides in reducing its environmental impact, ensuring that the industry progresses toward more sustainable construction practices [9], [10].

## 6. Conclusion

Tile adhesive is a critical component in modern construction, ensuring the strength, durability, and visual appeal of tiled surfaces across various environments. Its manufacturing process involves the careful selection of raw materials and precise blending techniques to meet diverse performance needs. By adopting a green manufacturing engineering approach, the industry can substantially minimize its environmental impact through practices such as utilizing eco-friendly raw materials, optimizing energy usage, and repurposing industrial byproducts like fly ash.

The integration of advanced formulations and cutting-edge production technologies not only enhances the performance of tile adhesives but also addresses global challenges related to sustainability and resource conservation. The classification of

adhesives into distinct types ensures their compatibility with a broad range of substrates and applications, from interior installations to demanding outdoor environments.

As the construction sector advances, the adoption of sustainable practices in tile adhesive manufacturing marks a significant step toward environmentally responsible building solutions. These initiatives contribute to sustainable development while enabling the production of more durable, efficient, and eco-friendly materials. Ultimately, the transition to sustainable tile adhesive production reflects a seamless synergy between technological innovation and environmental responsibility.

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