Study on the Influence of Cellulose Ether Structure on the Performance of Tile Adhesive

Abstract

This study systematically investigates the influence of different cellulose ether structures on the properties of tile adhesive, including water demand, viscosity, density, air content, rheology, and wettability. By combining analyses of setting time, strength development, and hydration kinetics, the impact and mechanism of cellulose ether on the hydration process are explored. The effects of various cellulose ethers on the mechanical properties of tile adhesive—such as tensile bond strength under standard curing conditions, bond strength after water and heat resistance, and strength after open time—are examined. Additionally, the microstructure and hydration products of tile adhesive are studied. The main conclusions are as follows:

(1) The water demand of tile adhesive increases with higher methylcellulose (MC) content. The structure of cellulose ether has a relatively minor influence on water demand: as the degree of methyl substitution increases, water demand gradually rises. At low substitution levels, tile adhesive containing hydroxyethyl methylcellulose (HEMC) requires more water than that with hydroxypropyl methylcellulose (HPMC). At high substitution levels, the water demand of both becomes similar. The methyl content in cellulose ether has a greater impact on water demand, while the hydroxyalkyl content has less influence. Higher substitution degrees lead to greater thickening effects.

(2) The density of tile adhesive decreases with increasing cellulose ether content. HEMC and HPMC affect density differently: density increases with higher methyl substitution in HEMC-based tile adhesive but decreases in HPMC-based tile adhesive, with hydroxypropyl substitution playing a more significant role. Factors determining density are not only related to the surface tension of cellulose ether solutions but also to other variables.

(3) The air content of tile adhesive increases with higher cellulose ether content and shows a strong linear correlation with density (correlation coefficient r = 0.93).

(4) The rheology of tile adhesive exhibits reduced viscosity with increased cellulose ether content. Methyl substitution has minimal impact on rheology, while higher hydroxyethyl content results in lower viscosity and improved lubricity. In contrast, higher hydroxypropyl content increases viscosity. Overall, HEMC-based tile adhesive demonstrates lower viscosity than HPMC-based tile adhesive.

(5) The wettability of tile adhesive decreases with higher methyl substitution. Even with nearly identical water retention rates, wettability is influenced by surface moisture evaporation and the reduction of internal free water. Thermal gelation of cellulose ether solutions leads to reduced wettability and shorter open time.

(6) Cellulose ethers with different substitution degrees affect the setting time of tile adhesive differently. Across varying cellulose ether contents, a consistent trend is observed: higher methyl substitution shortens both initial and final setting times. Cellulose ether significantly retards hydration.

(7) Under different cellulose ether contents, the early strength development of tile adhesive follows the order: HEMC3 > HEMC5 > HEMC2 > HPMC4 > HEMC1, with HEMC3 and HEMC5 exhibiting nearly identical strength development. Strength progression is closely related to the cellulose ether used, with higher methyl substitution leading to faster strength development.

(8) All cellulose ethers delay early hydration reactions to varying degrees, reduce the peak heat release, and exhibit enhanced retardation and reduced total heat release as methyl substitution decreases. Methyl content is the dominant factor affecting retardation, while hydroxyethyl and hydroxypropyl contents have minor influences.

(9) Regardless of whether HEMC or HPMC is used and across different cellulose ether contents, the bond strength under standard curing conditions gradually decreases with higher substitution degrees. Post-water resistance strength is significantly lower than the original strength and also declines with increased substitution. Post-heat resistance strength shows no loss, while strength after 20 minutes of open time decreases by up to 50%. Different cellulose ethers also lead to varying failure modes. For example, under standard

curing, decreasing strength is accompanied by a transition in failure mode from within the tile adhesive to the tile interface.

(10) The delaying effect of cellulose ether on tile adhesive hydration does not negatively impact long-term bond strength. Early strength (e.g., at 16 hours or 1 day) increases with higher substitution degrees, giving tile adhesives with highly substituted cellulose ether an early strength advantage. After one day of curing, strength can exceed 0.5 MPa, meeting standard requirements.

(11) SEM images of tile adhesive after 1 day of hydration show that cellulose ether alters the microstructure, slowing the formation of primary hydration products such as AFt and C-S-H gel networks. Higher cellulose ether content significantly delays hydration progress. XRD patterns indicate that cellulose ether does not change the types of hydration products. Low-substitution cellulose ether delays the precipitation of $Ca(OH)_2$ *crystals, while high-substitution cellulose ether has less retarding effect. DSC-TGA thermal analysis reveals that cellulose ether influences the quantity of hydration products, with higher substitution degrees resulting in greater amounts of hydration products.*

Source of Conclusions
The conclusions summarized above are derived from the engineering master's thesis titled "Study on the Influence of Cellulose Ether Structure on the Performance of Tile Adhesive" (纤维素醚结构对瓷砖胶性能影响研究), authored by Zhang Xiaohong and completed at East China University of Science and Technology.