Pol. J. Environ. Stud. Vol. 33, No. X (2024), 1-11
DOI: *10.15244/pjoes/185537* ONLINE PUBLICATION DATE:

Original Research

Research and Prediction Model for Water Loss Properties in Poly(Magnesium acrylate)/ Cement Hybrid Network Composites

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Received: 23 January 2024
Accepted: 29 February 2024

Abstract

To enhance the application of water-stopping and leakage-plugging materials in water-rich strata and wide crack sections with load demand, we developed a hybrid network composite material by combining poly(magnesium acrylate) acrylate and cement. This material exhibits superior performance in both organic and inorganic phases, offering broader potential applications than pure poly(magnesium acrylate) acrylate. However, it is susceptible to system instability and cracking attributed to water loss and shrinkage properties. In response, we conducted research to investigate the impact of maintenance conditions, poly-ash ratio, and various additive dosages on the water loss properties of poly(magnesium acrylate)/cement composites. The analysis of the water loss process involved curve fitting, and we established a multiple regression prediction model. Our findings reveal three stages of water loss for the material: isokinetic water loss, decelerated water loss, and smooth water loss. The implementation of water conservation measures significantly enhances material stability. Particularly noteworthy is the substantial influence of the poly-ash ratio on water loss performance. The optimal formula, derived from our study, is as follows: poly-ash ratio of 1, initiator dosage of 1.5%, and crosslinking agent dosage of 1.0%.

Keywords: Poly(magnesium acrylate)/Cement composite, acrylate, water loss performance, curve fitting, multiple linear regression

Introduction

Grouting and plugging are commonly utilized techniques to mitigate water ingress in cracks, especially for waterproofing and reinforcing large structures. However, Muhammad et al. observed that efforts to address crack leakage often fall short of simultaneously achieving waterproofing and strengthening, leading to persistent water leakage issues in extensive cracks [1]. Otegui et al. emphasized the extensive use of polyacrylate hydrogels, characterized by hydrophilic polymer networks, due to their controlled curing time, high swelling capacity, and notable resistance to seepage and corrosion [2-5]. Despite these advantages,

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the singular network structure results in low mechanical strength, restricting their development and application [6-8].

This combination yields materials with unique mechanical properties. It's essential to clarify that this article does not intend to provide a comprehensive review of all these materials; rather, it offers an overview of their known attributes and potential engineering applications. The initial network layer is intentionally designed to be brittle and stiff, promoting efficient energy dissipation and enhancing resistance to crack propagation [9-16]. As highlighted by Liao et al. [17-19], this design significantly improves the mechanical properties of polymer hydrogels while preserving their excellent characteristics. It's noteworthy that Karthiyaini et al. did not explore this subject further. The study examined three simultaneous reactions leading to the formation of reticulated polymer hydrogels, achieved through radical polymerization and crosslinking of the magnesium acrylate monomer in the presence of an initiator and crosslinking agent [20-22]. The text adheres to the desired characteristics, being free of grammatical, spelling, and punctuation errors. Hybridized composites exhibit superior performance in construction projects located in water-rich formations with substantial load demands and extensive crack sections, surpassing the capabilities of traditional networks. It is crucial to acknowledge that they may not be the optimal choice for applications in water-scarce regions or for smaller cracks. When selecting materials for construction projects, a comprehensive consideration of these factors is essential.

In the development of heterogeneous network composites, incorporating polyacrylic acid, magnesium, and cement, our group extensively assessed curing times ranging from 40 to 500 seconds. We observed that adjusting the formulation during construction easily modifies the required gel time. Our composites exhibit excellent perpendicular thickening and pumpability, maintaining low viscosity during pumping, with an initial viscosity ranging from 7 to 10 mPa. The slurry pumping time after rapid coagulation is optimal for high-speed grouting of leaks. Mechanical strength is substantial, reaching the C20-C30 strength level of concrete [23-24]. Heterogeneous network polyacrylic-magnesium-cement composites offer several advantages, including a streamlined production process, low energy consumption, lightweight, high strength, low thermal conductivity, good refractoriness, and low manufacturing process costs. Promoting the use of poly(magnesium polyacrylate)/cement hybrid network composites in environmental engineering can better address the national low-carbon initiative and promote global low-carbon processes. These composites demonstrate outstanding overall performance. This experiment aims to investigate the preservation conditions of the material, which possesses a rigid-flexible hybrid network structure with water loss and shrinkage properties influenced by various factors and complex mechanisms. Specifically, we aim to explore the effects of curing conditions, poly-ash ratio, initiator dosage, and crosslinker dosage on the water loss performance of poly(magnesium acrylate)/cement hybrid network composites. The water loss rate over time is analyzed through curve fitting, and a model predicting the total water loss rate is developed using multiple linear regression analysis [25]. The findings from this study will offer valuable insights into the factors influencing the water loss performance of these composites.

Experimental

Materials

The sample consisted of a 30% solution of magnesium acrylate, homemade; ordinary, batch number: XK08-001-05074, ordinary Portland cement produced by Jinan Caitong Building Materials Co., Ltd. in China; analytically pure ammonium persulfate (APS) produced by Sinopharm Chemical Reagent Co., Ltd. CAS number: 7727-54-0; and analytically pure polyethyleneglycol diacrylate (PEGDA) produced by Shanghai McLean Biochemistry and Technology Co. CB number: CB6172662.

Sample Preparation

The composite was prepared using 30% magnesium acrylate solution as the main agent, cement as the filler, ammonium persulphate as the initiator and polyethylene glycol diacrylate as the cross-linking agent [26]. The specimen was obtained by waiting for the slurry to gradually gelatinize and form a solid. Table 1. shows the factors influencing the setting and the proportions used. Where: poly-ash ratio (P / C) for the magnesium acrylate aqueous solution and the mass ratio of the

Table 1. Influencing factors and composition.

Factor	Proportion				
Poly-ash ratio	1.00	1.25	1.50	1.75	2.00
APS/wt%	0.5	1.0	1.5	2.0	2.5
PEGDA/wt%	0	0.5	1.0	1.5	2.0
Curing time/day	0	3	7		

cement; initiator, cross-linking agent dosage for the proportion of the magnesium acrylate solution by mass; maintenance age for the time of water conservation.

Performance Test

Water Loss Rate Test

Reference to JC/T 2037-2010 "Acrylate Grouting Materials" Chinese standard for testing, while introducing a stable water loss rate, when the difference between the resulting two water loss rates is less than 1% to stop the test, and the last measured value is the total water loss rate ΔM_n. The water loss rate of the cured material $\Delta M_{n,t}$ is calculated as:

$$\Delta M_{n,t} = (M_0 - M_{n,t})/M_0 \times 100\% \qquad (1)$$

Where: $\Delta M_{n,t}$ is the water loss rate of the solid at moment t, (%); M_0 is the initial mass of the specimen, (g); $M_{n,t}$ is the mass of the specimen at moment t during the water loss process, (g).

Micro-morphological Characterization

The specimens underwent section morphology observation using a scanning electron microscope (Japan Electron Field Emission Scanning Electron Microscope JSM-7800F) positioned on a gold film-coated platform. Poly(magnesium polyacrylate) specimens were subjected to freeze-drying, while the cement and poly(magnesium polyacrylate)/cement hybrid network composite specimens underwent heat drying.

Results and Discussion

Influence of Poly-Ash Ratio on the Water Loss Properties of Solids

Experiments were conducted with a constant initiator dosage of 1.5% and a curing agent dosage of 1.0% to explore the impact of polyash ratio on the water loss characteristics of polymagnesium acrylate/cement hybrid network composites. Polyash ratios ranged from 1.00 to 2.00, and the corresponding water loss rate-time curves are illustrated in Fig. 1.

Fig. 1. illustrates a rising trend in both the water loss rate of the solid body and the water loss rate at each time point with an increasing poly-ash ratio. During the initial two phases, the time to reach the smooth phase of the water loss rate gradually extends. Specifically, the P/C = 2.00 specimen exhibits significantly higher rates and total water loss compared to the P/C = 1.00 specimen, surpassing them by 1.49 and 1.55 times, respectively. The P/C = 2.00 specimen takes 15 days to achieve stability in terms of water loss properties, with moisture loss stabilization occurring thereafter.

Throughout the drying process, water loss predominantly occurs through capillary pores on the surface and within the solid body, along with the cross-linking of the poly(magnesium acrylate) gel network containing a substantial amount of free water [27]. Consequently, both water loss rate and shrinkage increase. As drying time progresses, the structure of the solid body system stabilizes, hindering water migration and maintaining a constant water loss rate. In systems with a higher polyash ratio, acrylate's polar groups can form numerous hydrogen bonds with ions such as Ca^{2+} and Si^{4+} in the cement. The polymer also includes numerous hydrophilic groups, enhancing the specimen's water retention capacity. This leads to a prolonged duration for the water loss characteristics to reach a steady state.

Influence of Initiators on the Water Loss Properties of Consolidates

In exploring the impact of the initiator on the water loss properties of poly(magnesium polyacrylate)/cement hybrid network composites, we held a constant polyash ratio of 1 and a curing agent dosage of 1.0%, varying the initiator dosage (0.5%, 1.0%, 1.5%, 2.0% and 2.5%).

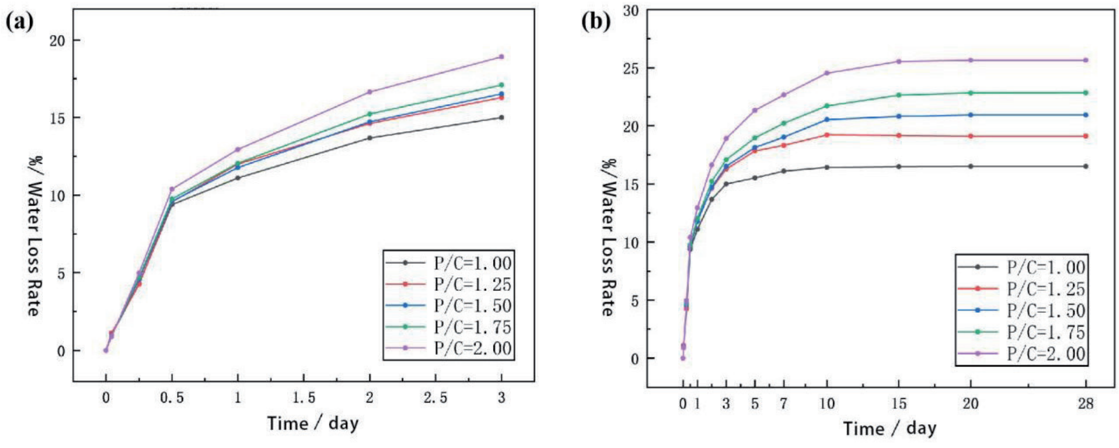

Fig. 1. a) Effect of 0-3 days P/C ratio on the water loss rate of the solid; b) Effect of 0-28 days P/C ratio on the water loss rate of the solid.

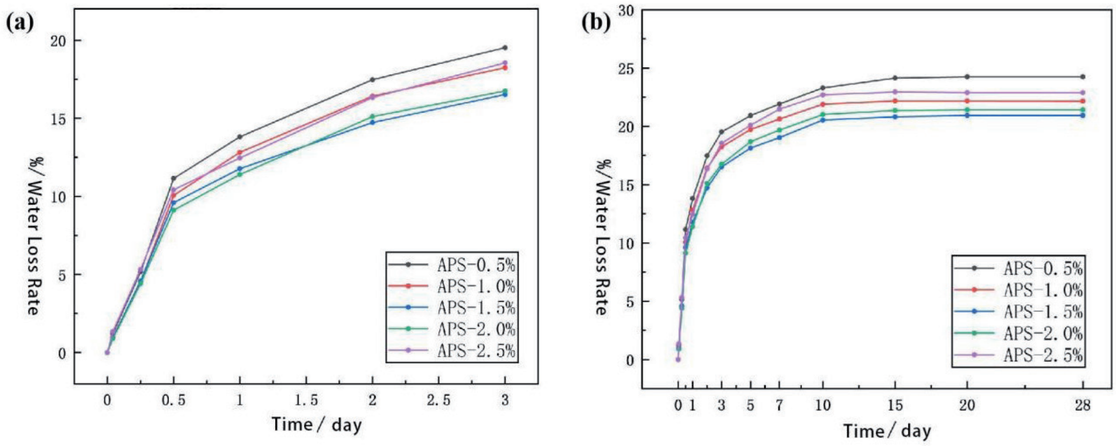

Fig. 2. a) Effect of 0-3 days initiator on water loss from solid; b) Effect of 0-28 days initiator on water loss from solid.

The corresponding water loss rate-time curves are depicted in Fig. 2.

Fig. 2. demonstrates that, with an increase in initiator concentration, the water loss rate and total water loss rate of the cementitious body initially decrease before rising again. The APS 1.5% sample exhibits the lowest water loss rates, showing reductions of 11.27% and 15.81%, respectively, compared to the maximum value of APS 0.5%. Ammonium persulfate doping enhances the hydrolysis process, generating more free radicals and promoting the complete polymerization of the magnesium acrylate monomer. This results in the formation of numerous polymers containing hydrophilic groups uniformly attached to the cement nodule bodies, significantly enhancing water retention properties.

When the concentration of APS doping exceeds 2%, a violent polymerisation reaction occurs in magnesium acrylate. Leading to excessively fast coagulation times and an increase in network defects [28]. This not only hampers cement hydration, prolonging the time for specimens to reach a stable state, but also diminishes water retention due to uneven distribution. The water loss process stabilizes after the 10th day. However, the APS-0.5% specimen requires up to 15 days to reach a steady state, as the small amount of ammonium persulfate is insufficient to promote the full reaction of magnesium acrylate, resulting in a low reaction rate and exothermic heat. Therefore, specimens should be prepared with an initiator mixing amount of 1-1.5%.

Influence of Cross-Linking Agents on the Water Loss Properties of Cements

This study aimed to explore the impact of crosslinker dosage on the water loss rate of poly(magnesium polyacrylate)/cement hybrid network composites. Maintaining a constant polyash ratio of 1 and an initiator dosage of 1.5%, we conducted comparative tests with crosslinker dosages of 0.5%, 1.0%, 1.5%, and 2%, alongside a 0% blank. Fig. 3. illustrates the water loss rate-time curves.

In Fig. 3., a noticeable increase in crosslinking agent doping reveals a pattern in the total water loss rate – initially decreasing and then increasing – accompanied by a significant extension in the time required for the water loss process to stabilize. Optimal water retention occurs with a crosslinking agent dosage between 0-1%, peaking at 1%. Compared to PEGDA-0% blank samples, there is a 7.10% improvement in the total water loss rate. Dosages exceeding 1% impede water retention, with a 2% dosage leading to a 5.66% increase in the total water loss rate compared to PEGDA-0% blank samples. The time for the water loss process to stabilize gradually extends from 7 to 15 days.

The chosen PEGDA cross-linking agent, with unsaturated double bonds, facilitates bridge bond formation through electrophilic addition. This process crosslinks the linear molecular chain of poly(magnesium polyacrylate), resulting in a three-dimensional mesh structure with enhanced gel strength and water retention properties. Adding an appropriate amount of cross-linking agent proves beneficial in reducing the material's water loss rate, thereby improving stability. The increased crosslinking agent augments the formation of an internally gradually dense mesh structure, inhibiting internal water migration and volatilization, thus extending the time to stability. However, an excessive crosslinking agent quantity (exceeding 1%) leads to hydrogel formation with an overly large crosslinking density, causing increased hydrophobicity. Moreover, heightened network rigidity hinders full stretching, causing uneven dispersion of cement particles. Consequently, complete hydration of cement is impeded, resulting in increased total water loss and an extension of the time required to reach stability to 15 days.

The Impact of Maintenance Age on Consolidate Water Loss Properties

Examining the impact of curing age on the water loss properties of poly(magnesium acrylate)/cement hybrid network composites under various formulation

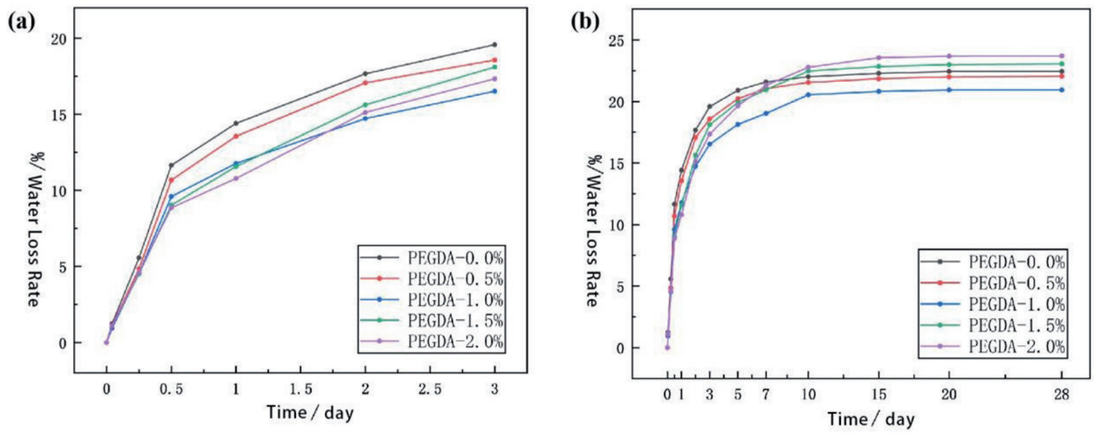

Fig. 3. a) Effect of 0-3 days cross-linking agent on water loss from the solid; (b Effect of 0-28 days cross-linking agent on water loss from the solid.

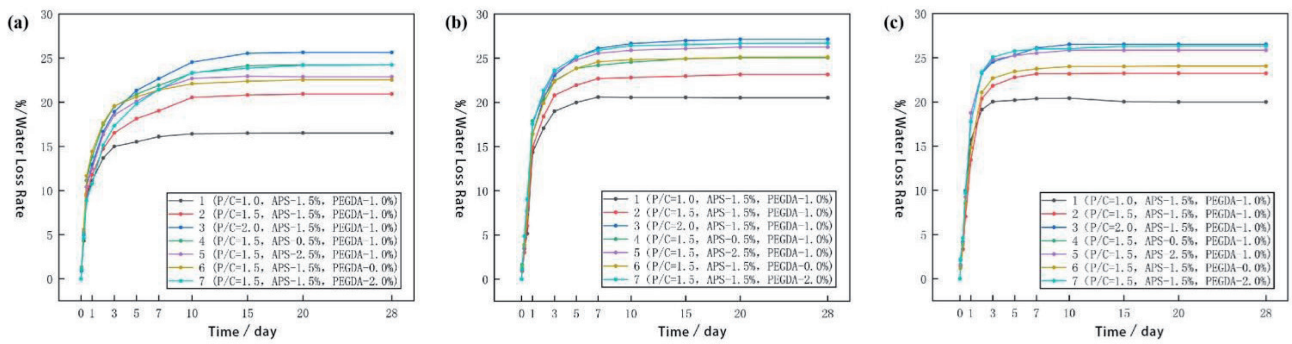

Fig. 4. a) Effect of curing age 0 days on the water loss rate of the solid; b) Effect of curing age 3 days on the water loss rate of the solid; c) Effect of curing age 7 days on the water loss rate of the solid.

conditions, we chose seven specimen groups. These groups encompassed a poly-ash ratio ranging from 1 to 2, initiator dosages from 0.5% to 2.5%, and cross-linking agent dosages from 0% to 2%, all subjected to aqueous curing. Curing ages were categorized as 0 days, 3 days, and 7 days, and the corresponding water loss rate-time curves are depicted in Fig. 4.

Fig. 4. illustrates an increase in the total water loss rate among different specimens with curing age, peaking before a minor decline. Compared to uncured specimens, there was an average increase of 11.92% after 3 days and 9.91% after 7 days of curing. The total water loss rate notably surged, and the time for water loss characteristics to stabilize decreased from 15 days to 3 days. Sample 3 displayed the highest total water loss rates during 0d, 3d, and 7d curing, requiring an extended stabilization time but achieving stability earlier than anticipated, between 15 days and 7 days. Conversely, sample 1 exhibited the lowest total water loss rate and the shortest stabilization time. The total water loss rate increased by an average of 22.71% during the 0-7 days curing period compared with the sample of 0 d.. The polyash ratio primarily influences water loss performance, with specimens being most sensitive to curing age when the polyash ratio is 1.

Differential internal stresses in the organic and inorganic phases, coupled with non-uniform water loss during the solid body's pre-drying process, lead to pronounced structural effects, resulting in internal stress disparities and an increased likelihood of early cracking. Prolonging the curing age enables the poly(magnesium polyacrylate) gel network to absorb substantial free water, facilitating the complete hydration reaction of cement particles. This accelerates the formation of an organic-inorganic hybrid three-dimensional network, resulting in a denser structure with enhanced stability. Extending the curing age and employing water curing can improve the stability performance of the cementitious body, reducing the risk of early cracking despite the increased water loss rate. It is crucial to note that this assessment relies on objective data rather than subjective opinions.

Micro-Morphological Analysis

SEM (Scanning electron microscope) was employed to assess the microscopic morphology of poly(magnesium acrylate), cement, and poly(magnesium acrylate/cement) hybrid network composites. The study aimed to elucidate the impact of the cross-linking agent

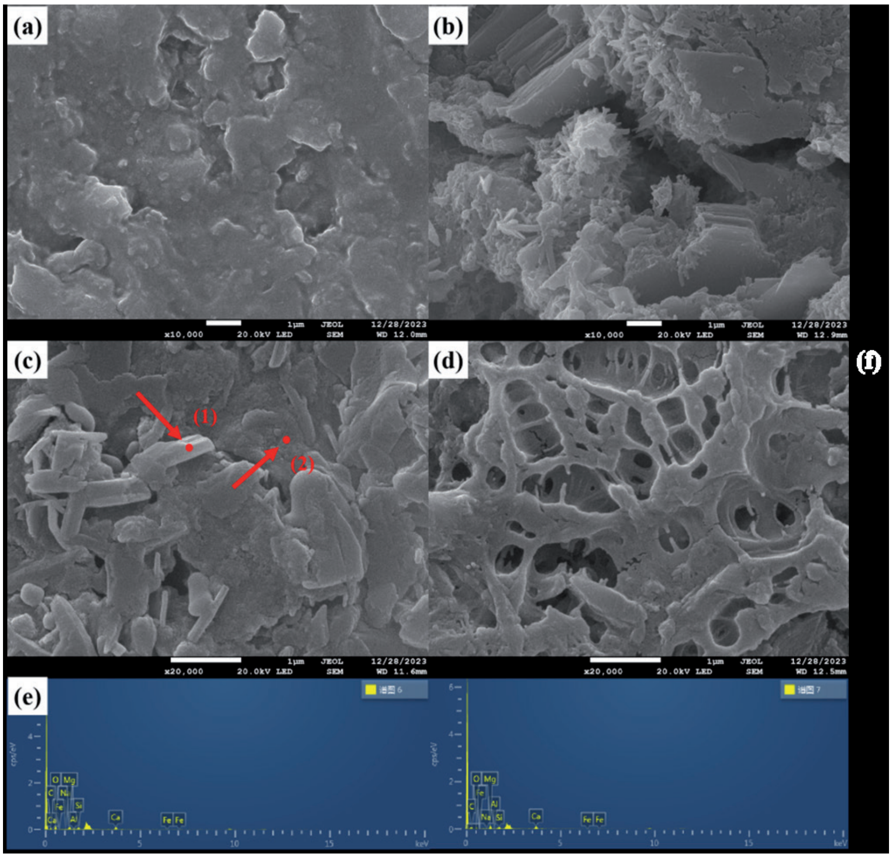

Fig. 5. SEM image. [a) pure magnesium acrylate hydrogel; b) 3 days pure cement hydration products; c) 3 days poly magnesium acrylate/cement hybrid network composite (P/C = 1.00, PEGDA-0.0%); d) 3 days poly magnesium acrylate/cement hybrid network composite (P/C = 1.00,PEGDA-2.0%); e) EDS point scan element composition diagram].

on the microscopic morphology of the poly(magnesium acrylate/cement) hybrid network composites. Fig. 5. presents the acquired SEM images.

Fig. 5a). depicts the pure poly(magnesium acrylate) hydrogel, showcasing a smooth single network structure that facilitates free water penetration into the polymer network. However, this structure impedes the mechanical strength development of the gel. In Fig. 5b)., cement 3d displays a loose and coarse structure with numerous fibrous C-S-H and lamellar $Ca(OH)_2$ interspersed with intergrowth. Fig. 5c). presents a composite specimen with a polyash ratio of 1. Differing from (a) and (b), the surface of the cement hydration product is covered with a smooth and indeterminate morphology of hydrogel-like material. This coverage results in the interweaving and interspersion of the brittle and rigid hydration product and the soft and ductile Poly(magnesium acrylate), forming a heterogeneous network. This network enhances microstructure compactness, improves interfacial adhesion of the matrix, reduces internal crack generation, and enhances overall water retention capacity.

Fig. 5d). illustrates samples with the addition of a 2.0% crosslinking agent, revealing a more pronounced three-dimensional network structure compared to Fig. 5c). The linear polymer crosslinks under the influence of the crosslinking agent, forming bridging bonds. This network can absorb a significant amount of free water stored in the hydrophilic groups, resulting in enhanced water absorption and water retention performance.

Table 2., as analyzed by EDS, demonstrates that the composite heterogeneous network includes essential elements of hydration products – Si, Ca, Al, and Fe – alongside Mg derived from poly (magnesium acrylate). This implies a strong bond between the polymer hydrogel and neighboring hydration products, resulting in a densely crosslinked network.

Analysis of the Water Loss Process in Poly(magnesium acrylate)/Cement Hybrid Network Composites.

The water loss process curve displays three stages: isokinetic water loss, decelerated water loss, and smooth stages. These stages are defined based on the changing water loss rate and micromorphological characterization of solidification at varying maintenance ages for different ratios. To illustrate the water loss process of the poly(magnesium acrylate/cement) hybrid network, we employed a functional model for fitting. This choice was guided by the geometric characteristics of the water

Table 2. EDS point scanning element composition.

EDS-(1)			EDS-(2)		
Elemental	Mass fraction (percentage)/wt%	Atomic fraction/ wt%	Elemental	Mass fraction (percentage)/wt%	Atomic fraction/ wt%
C	26.42	37.16	C	27.55	39.38
O	44.65	47.15	O	38.51	41.32
Mg	9.13	6.35	Mg	13.76	9.72
Al	1.89	1.18	Al	0.25	0.20
Si	4.07	2.45	Si	4.39	2.68
Ca	12.88	5.43	Ca	15.25	6.53
Fe	0.96	0.29	Fe	0.24	0.01

Table 3. Fitting results of water loss rate-time curve.

Model	α	β	R^2	Revision R^2
1	17.3394	0.5434	0.99307	0.9923

loss rate-time for the optimal formulation (2) identified in the study (polyash ratio: 1, initiator dosage: 1.5%, crosslinking agent dosage: 1.0%). The fitting results are presented in Table 3. and Fig. 6a).

$$\Delta M_{n,t} = \alpha t/(\beta + t) \quad (2)$$

Where $\Delta M_{n,t}$ represents the water loss rate at time point t (%), t represents time (in days), and α and β represent the water loss coefficients. The goodness of fit is greater than 0.99, indicating that the model can accurately describe the relationship between the water loss rate and time during the water loss process of Poly(magnesium acrylate)/cement hybrid network composites.

Water plays a crucial role in the curing process of magnesium acrylate and cement, operating through three pathways depicted in Fig. 6b): (i) direct hydration with cement particles, (ii) vaporization during a segment of the exothermic process, and (iii) storage in the heterogeneous network. This stored water supports cement hydration and gradually migrates to the surface, evaporating during drying.

The isokinetic water loss stage occurs when the surfaces of the cementitious body and larger pores reach dynamic equilibrium in water diffusion and surface vaporization, concluding within 0.5 days. The decelerated water loss stage involves internal water diffusion to the surface, succeeded by predominant vaporization. Factors such as polymerization ratio, additive quantity, and maintenance conditions significantly impact this stage, exerting the most influence on the water loss process. Generally, this stage concludes between 3 and 15 days. The smooth stage denotes a stable state with no further water migration.

Predictive Model For the Total Water Loss in Hybrid Composite Networks Made of Poly(magnesium acrylate)/ Cement

The multivariate linear regression equation was used to predict the total water loss of the poly(magnesium

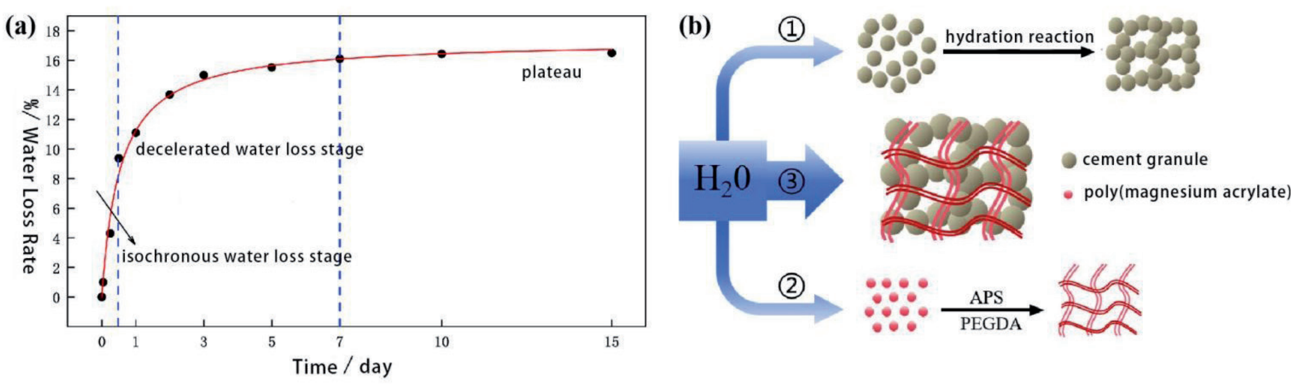

Fig. 6. a) Fitting results of water loss rate-time curve; b) Schematic diagram of the path of water.

acrylate)/cement hybrid composite network because the predicted values of the model were closest to the actual data, as verified by the measured data for the multivariate linear regression analysis model. Multivariate linear regression examines the linear relationship between a dependent variable (Y) and multiple independent variables (X_1, X_2, X_3, ...). This relationship is expressed mathematically as $Y = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + ... + \alpha_n X_n + \varepsilon$. Here, Y is the dependent variable, and X_i (i = 1,2,3, ...,n) represents the independent variable. The constant term is α_0, and the partial regression coefficients corresponding to X_1, X_2, X_3, ..., Xn are α_1, α_2, α_3,... , αn. The random error, ε, indicates the impact of independent variables on the dependent variable.

This study examines the impact of various factors on the total water loss of a solid body. To establish a multiple linear regression model and perform linear regression analyses, SPSS (Statistical Product and Service Solutions software) was used. The resulting model is summarized in Table 4., and the multiple linear regression equations are presented below:

$$Y = 9.845 + 7.767X_1 + 0.180X_2 + 0.711X_3 + 0.303X_4 \quad (3)$$

Where: Y is the total water loss of the solid, X_1 is the poly-ash ratio, X_2 is the initiator dosage, X_3 is the cross-linker dosage, and X_4 is the soaking time.

The correlation coefficient (|R|) ranges from 0 to 1, where a larger value indicates a more significant linear relationship between the dependent variable and explanatory variables. The coefficient of determination (R^2) quantifies explanatory variance as a percentage of the dependent variable's variance, and adjusted R^2 corrects for R^2 [29]. A linear fit exceeding 30% is generally considered favorable. In Table 4., R is 0.819, and both R^2 and adjusted R^2 are > 0.30, confirming a linear relationship. The Durbin-Watson value of 1.880 falls within the acceptable range (1.5-2.5), indicating no serious autocorrelation. Tolerance and VIF values for model variables are 1, suggesting no severe multicollinearity issues.

The significance test for mean differences in multiple samples, referred to as analysis of variance (ANOVA) or F-test, is employed. In Table 4., F = 20.311, P<0.001, indicating a highly significant linear relationship between independent variables and the dependent variable at a 95% confidence level, validating the obtained regression model equations. Magnitude differences impede direct comparability of X_1, X_2, X_3, and X_4. This challenge is addressed by simultaneously standardizing both independent and dependent variables. Examination of standardization coefficients reveals the significance order of formulation conditions on total water loss in Poly(magnesium acrylate)/cement hybrid network composites: poly-ash ratio, soaking time, cross-linking agent dosage, and initiator dosage.

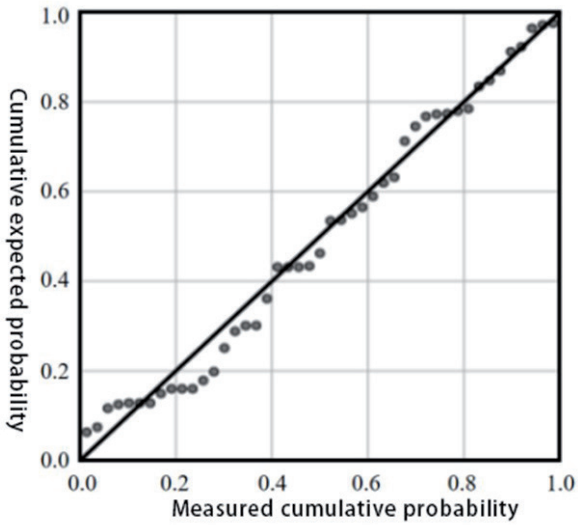

Fig. 7. The normal P-P plot of standardized residuals for the PCA regression model.

Multiple Linear Regression Model Tests

To demonstrate the validity of the model, Fig. 7. displays the results of the standardized residuals of the PCA regression model. The normal P-P plot of the standardized residuals of the PCA regression model shows an approximately linear trend, indicating that the residuals follow a normal distribution. This suggests that the regression equation is valid [30].

The regression model for the five experimental groups lacked additional measurements to validate the resulting empirical equation (3).The dosage of initiator and cross-linking agent is fixed at 1 %, and the curing age is 1d, and the poly-ash ratio (having the most significant impact on water loss rate) is set to 1.00, 1.25, 1.50, 1.75, 2.00 respectively. Test data for the regression model are presented in Table 5., while Fig. 8. illustrates the comparison between predicted and measured values.

The experimental model, developed using variance theory and multiple linear regression, highlights the

Table 4. Model Summary.

Model	R-test					F-test		Covariance statistics	
	R	R^2	Revision R^2	Errors in standardized estimates	Durbin-Watson Detection	F	Significant	Tolerances	VIF
1	0.819	0.670	1.637	1.3635206	1.880	20.311	0.000	are all 1.000	Are all 1.000

Table 5. Regression model detection data.

Model	A1	A2	A3	A4	A4
Predicted value/%	18.50	20.44	22.39	24.33	26.27
Measured value/%	19.82	21.46	22.87	24.51	26.79
Relative standard deviation/%	6.66	4.75	2.10	0.71	1.94

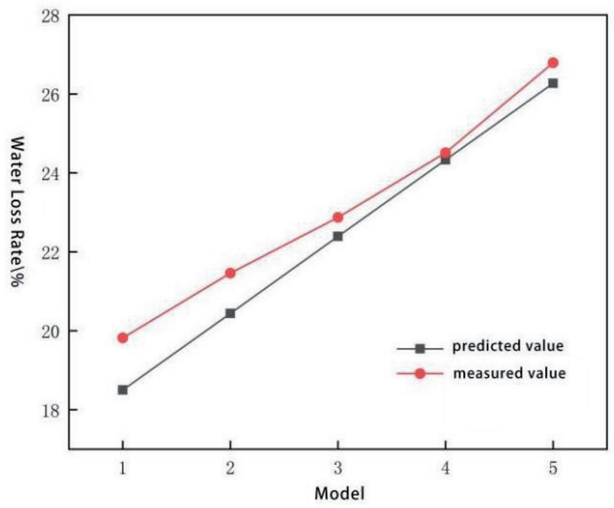

Fig. 8. Comparison of regression model predicted and measured values.

impact of linearly significant factors. Omitted factors may introduce errors [31-34]. Table 5. and Fig. 8. depict relative errors between predicted and measured values: 6.66%, 4.75%, 2.10%, 0.73%, and 1.94%, with corresponding residuals of 1.32, 1.02, 0.48, 0.18, and 0.52 .Both relative errors and residuals satisfy model testing accuracy requirements. The strong agreement between predicted and measured values underscores the applicability of the regression model for predicting water loss properties in poly(magnesium acrylate)/cement hybrid network composites [35-38].

Conclusions

(1) After a thorough assessment of water loss performance and shrinkage, we determined the optimal formula. The poly-ash ratio was fixed at 1, the initiator dosage (ammonium persulfate) at 1.5%, and the cross-linking agent dosage (polyethylene glycol diacrylate) at 1.0%. A recommended minimum water conservation age of 3 days was established. The material exhibited a water loss rate of 19.51%, which is 60% lower than traditional acrylate gel material. Additionally, water loss stabilization time was reduced to 3 days, significantly enhancing overall stability performance.

(2) Water loss in magnesium polyacrylate/cement hybrid network composites undergoes three phases: equal-velocity water loss, decelerated water loss, and a smooth phase. The durations of the first two phases are primarily influenced by the poly-ash ratio and age of maintenance. A smaller poly-ash ratio and a longer water conservation age lead to shorter durations in the first two phases, facilitating a faster progression to the stabilization phase.

(3) A multiple linear regression equation established the total water loss prediction model for Poly(magnesium acrylate)/cement hybrid network composites. The variable significance order is as follows: poly-ash ratio>curing time>cross-linking agent dosing >initiator dosing, consistent with experimental results. The validated model demonstrated its ability to predict total water loss characteristics under various ratios and curing conditions within a specified range. Further investigation is required to explore the diverse properties of poly(magnesium acrylate)/cement hybrid network composites and alternative initiator and cross-linking agent ratios. The existing literature on the water loss and shrinkage properties of dual network hybrid materials is limited and focuses on specific initiator and crosslinker ratios. This study aims to minimise the volumetric shrinkage phenomenon due to water evaporation of this material through multiple conditioning factors, thereby enhancing its durability performance. The impact of volumetric deformation on durability will be considered. Clear definitions of technical terms will be provided upon their initial use, maintaining an objective and value-neutral language. The text adheres to established academic structure and formatting, ensuring consistency in citation and footnote style. Biased language and unnecessary filler words are eliminated, and grammatical correctness is upheld.

Acknowledgments

This work was supported by the "Jiebangguashuai" Science and Technology Programme major Projects(2022JH1/10800016) of Liaoning Province in 2022, China; Liaoning Provincial Department of Education Basic Research Projects (JYTMS20231574) in 2023, China.

Conflict of Interest

The authors declare no conflict of interest.

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