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Epoxy Resin Development for Anticorrosion Coatings

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ABSTRACT
In this study, a high molecular weight epoxy resin (ELM-NG 900Z) based on diglycidyl ether of bisphenol A was cured with different types of hardeners to examine their impact on the physical and mechanical properties of the epoxy resin. The hardeners used were G-5022X70 (140-170 mg KOH/g), G-A0533 (310-350 mg KOH/g), and G-0930 (280-320 mg KOH/g). The results indicated that the hardener G-A0533 provided the best mechanical properties for the epoxy resin compared to other hardeners. Furthermore, various additives including silica fume, talc, barium sulfate, ferric oxide, and pigments were mixed with the epoxy resin in the presence of the hardener G-A0533 to enhance its mechanical properties. It was observed that the addition of 3% silica fume, 10% ferric oxide, and 3% inorganic pigments improved the mechanical properties, while the addition of 5% talc decreased most mechanical properties and only increased hardness. The incorporation of barium sulfate into the epoxy resin enhanced adhesion and flexural strength but decreased tensile strength and hardness. The inclusion of organic pigment had no significant effect on the mechanical properties of the epoxy resin. This enhancement in mechanical properties is attributed to the type of hardener used as well as the types and amounts of additives mixed with the epoxy resin.

Keywords: Epoxy, hardener, mechanical, corrosion, additives.

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Introduction

Epoxy resins are a type of polymer that contains two or more epoxy rings. Anticorrosive paints are often made from thermosetting polymers known as epoxy resins. The curing process of these resins can be done by one or two components using chemical cross-linkers such as hardeners. These epoxy resins can be cross-linked with hardeners (amines) for various industrial applications such as coatings, paints, anti-corrosion coatings, and adhesives due to their good thermal and mechanical properties [1]. They can react with various curing agents that contain active groups, including hydrogen, such as amines and anhydrides [2]. Hardener amines are categorized into primary (one hydrogen molecule), secondary (two hydrogen molecules), and tertiary (three hydrogen molecules). Additionally, hardeners are classified as aliphatic or aromatic amines and play a key role in curing epoxy resins at room temperature. The physical and mechanical properties of epoxy resins vary depending on the type of hardeners and the ratio between epoxy resins and hardeners [3]. The combination of aliphatic hardeners with epoxy resins enhances both the bonding properties and resistance to alkalis and certain inorganic acids [4]. However, the aromatic hardeners improve the heat resistance of the epoxy resins as well as chemical resistance [[5], [6]]. Selecting an appropriate hardener requires careful consideration of the processing conditions, including pot life, viscosity, mixing ratio, and temperature, as well as the desired properties of the final product, such as strength, chemical and thermal resistance, toughness, and flexibility.

The Silica fume is a kind of filler that has active and inorganic powder [7]. Silica fume differs significantly from epoxy resin. It enhances epoxy properties by reducing shrinkage, improving stability, preventing cracking, and lowering coating costs. Research has shown that silica fume increases the strength, thermal stability, and hardness of epoxy resins [[7], [8], [9], [10], [11], [12], [13]]. On the other hand, the mixing of barium sulfate and ferric oxide has different influences on the mechanical properties of the epoxy resin. The results showed that barium sulfate increased the mechanical properties, while ferric oxide improved the adhesion of epoxy on the metal [[14], [15]]. The effect of different pigments on the properties of epoxy resins was investigated by authors [[16], [17], [18]]. Pigments are classified as organic, inorganic, etc. Most pigments enhance the properties of epoxy and others disperse problems with the epoxy resins. To solve the problem of dispersing, mixing very well by using a dissolver and followed by milling. This study aims to develop an anticorrosion coating based on epoxy for industrial applications. Various additives, such as barium sulfate, talc, ferric oxide, silica fume, and inorganic and organic pigments, are mixed with epoxy and different hardeners to enhance the coating's mechanical properties.

Experimental part

Materials

Epoxy resins ELM-NG 900Z were supplied by Elcos Marketing LLP, Almaty Kazakhstan. ELM-NG 900Z has an epoxy value of 5.25-5.5 eq/Kg, weight per epoxide of 450-525 g/eq, viscosity of 13000 mPa-s at 25 ^{o}C and density of 1.1 gm/cm^3. G-5022X70 has amine value 140-170 mgKOH/g and viscosity 585 mPa-s at 25 ^{o}C, G-A0533 has amine value 310-350 mg KOH/g and viscosity 935 mPa-s at 25 ^{o}C and G-0930 has amine value 280-320 mg KOH/g and viscosity 8,000 mPa-s at 25 ^{o}C were purchased from Kukdo chemical company, South Korea. Silica fume, talc, barium sulfate, Fe_2O_3 and inorganic pigment (cobalt blue) & organic pigment (carbon black) were supplied by ETC – company, Almaty, Kazakhstan.

Mixing epoxy resin with hardeners

Epoxy resin ELM-NG 900Z was mixed with different hardeners (G-5022X70, G-A0533 and G-0930) at a ratio of 1.0: 0.5 respectively. All ingredients were thoroughly mixed, both slowly and deliberately, to minimize the introduction of air bubbles. Scrape the sides and bottom of the container to ensure all components are fully mixed. Mixed was cast to specimens of dimensions of 7 mm x 7 mm x 7 mm in steel molds and allowed to dry at room temperature for 6 days and keep it for tests [19].

Mixing epoxy resin with additives

In all experiments, the epoxy resin ELM-NG 900Z was transferred to a vial and mixed for 10 minutes at a speed of 500 rpm. After adding the silica fume (3% based on the epoxy resin), talc (5% based on epoxy weight), barium sulfate (15% based on epoxy resin), ferric oxide (10% based on epoxy weight), and pigments (3% based on epoxy weight) to the epoxy separately, the mixture was stirred for 30 minutes at a speed of 1200 rpm. Hardener was then added, and the mixture was stirred at a speed of 500 rpm for 5 minutes. The mixture was cast into specimens with dimensions of 7 mm x 7 mm x 7 mm in steel molds and allowed to dry at room temperature for 6 days before being tested for mechanical properties [[19], [20]].

Tests (Physical and Mechanical properties)

Viscosity was measured at room temperature using a Brookfield viscometer, according to ISO 12058-1 (ISO 12058-1, 2018) [21] at 25 ^{o}C. The MTS 10/M tensile testing equipment was used to quantify the tensile properties of the cast films with a crosshead speed of 50 mm/min. A minimum of four values were averaged, and a 1-kN load cell was utilized A cylindrical Mandrel Tester (ASTM D522, 2001) [22] was used to assess the resistance of a coating of product to cracking and/or detachment from a metal substrate when subjected to bending around a cylindrical mandrel under standard conditions. The tubular impact tester (ASTM D2794, 2019) [23] determined film resistance to impact, and the economic cross hatch tester (ASTM D3359, 2001) [24] was used to evaluate the adhesion of applied coatings. For adhesion strength measurements of the epoxy and diluted epoxy mixture, pull-out tests were conducted according to the EN 1542 standard (En,1542, 1999) [25].

Results and discussion

Physical properties

Table 1 shows the viscosity of epoxy resin ELM-NG 900Z mixed with different hardeners in a 1:0.5 ratio, measured at 25°C and speeds of 5 and 50 rpm. The viscosity decreased as speed increased from 5 to 50 rpm. Hardener G-0930 had the highest viscosity at both speeds, while hardener G-A0533 had the lowest. The variation is due to the influence of the hardeners on the epoxy's viscosity. Additionally, hardener G-A0533 exhibited the highest thixotropic index (6.4), and hardener G-5022X70 had the lowest (2.35).

Table 1 - Viscosity and thixotropic index of epoxy resin mixed with hardeners in ratio (1: 0.5)

Sample code	ELM-NG 900Z	ELM-NG 900Z / G-5022X70	ELM-NG 900Z / G-0930	ELM-NG 900Z / G-A0533
Viscosity at 5 rpm (mPa-s)	13000	8000	11000	4500
Viscosity at 50 rpm (mPa-s)	2500	3400	2200	700
Thixotropic index (TI)	5.2	2.35	5.0	6.4

Mechanical properties

Table 2 shows the mechanical properties of epoxy resin mixed with different hardeners at a 1:0.5 ratio. The hardener G-A0533 provided the highest values in adhesion strength (64 Kgf/cm²), tensile strength (315 Kgf/cm²), hardness (69), and flexural strength (834 Kgf/cm²). In contrast, the hardener G-5022X70 showed the lowest values in adhesion strength (100 Kgf/cm²), tensile strength (627 Kgf/cm²), hardness (84), and the same flexural strength (834 Kgf/cm²). Generally, the performance of epoxy resin depends on the type of hardeners and the crosslinking network formed during the reaction. However, all epoxy resin mixtures passed impact tests, cylindrical mandrel, and cross-hatch tests [[25], [26], [27]].

Table 2 - Mechanical properties of epoxy resin mixed with hardeners in ratio (1: 0.5)

Sample code	ELM-NG 900Z / G-5022X70	ELM-NG 900Z / G-0930	ELM-NG 900Z / G-A0533
Adhesion Strength (Kgf/cm²)	64	80	100
Tensile Strength (Kgf/cm²)	315	425	627
Flexural Strength (Kgf/cm²)	834	710	460
Hardness (Shore D)	69	75	84
Impact test	Pass	Pass	Pass
Cylindrical Mandrel	Pass	Pass	Pass
Crosshatch	Pass	Pass	Pass

The effect of silica fume and talc on the mechanical properties of epoxy resin

Table 3 shows that adding 3% silica fume to epoxy resin enhances its mechanical properties when mixed with different hardeners at a 1:0.5 ratio. Silica fume increased adhesion by 21% for G-A0533, 11.25% for G-0930, and 10.9% for G-5022X70 due to hardener activity and crosslinking bonds. Tensile strength also improved by 10.04% for G-A0533, 12.2% for G-0930, and 11.11% for G-A0533. Conversely, adding 5% talc decreased adhesion by 2% for G-A0533, 16.25% for G-0930, and 14.06% for G-5022X70 as shown in Table 4, while hardness strength increased by 5.9%, 10.66%, and 7.0% respectively.

Table 3 - Mechanical properties of epoxy resin mixed with hardeners in the ratio (1: 0.5) in the presence of 3% silica fume

Sample code	ELM-NG 900Z / G-5022X70	ELM-NG 900Z / G-0930	ELM-NG 900Z / G-A0533
Adhesion Strength (Kgf/cm²)	71	89	121
Tensile Strength (Kgf/cm²)	350	477	690
Flexural Strength (Kgf/cm²)	634	410	380
Hardness (Shore D)	71	78	86
Impact test	Pass	Pass	Pass
Cylindrical Mandrel	Pass	Pass	Pass
Crosshatch	Pass	Pass	Pass

Table 4 - Mechanical properties of epoxy resin mixed with hardeners in the ratio (1: 0.5) in the presence of 5% talc

Sample code	ELM-NG 900Z / G-5022X70	ELM-NG 900Z / G-0930	ELM-NG 900Z / G-A0533
Adhesion Strength (Kgf/cm^2)	55	67	98
Tensile Strength (Kgf/cm^2)	285	305	576
Flexural Strength (Kgf/cm^2)	573	369	295
Hardness (Shore D)	76	83	89
Impact test	Pass	Pass	Pass
Cylindrical Mandrel	Pass	Pass	Pass
Crosshatch	Pass	Pass	Pass

The effect of barium sulfate and ferric oxide on the mechanical properties of epoxy resin

Table 5 shows increasing in the adhesion strength and flexural strength but decreasing in the tensile strength and hardness of the epoxy resin mixed with 15% barium sulfate in the presence of different hardeners. Flexural strength increased from 834 to 1005 Kgf/cm^2 for epoxy mixed with hardener G-5022X70 and 15% barium sulfate, from 710 to 934 Kgf/cm^2 for hardener G-0930 and from 460 to 860 Kgf/cm^2 for hardener G-A0533. While adhesion of epoxy increased from 64 to 70 Kgf/cm^2, from 80 to 86 Kgf/cm^2, and from 100 to 110 Kgf/cm^2, for harnerers G-5022X70, G-0930 and G-A0533, respectively. Table 6 shows the increase in mechanical properties including tensile strength, adhesion, hardness and decreasing in the flexural strength of epoxy resin mixed with 10% ferric oxide and different hardeners. For example, 10% ferric oxide gave the highest adhesion 170 Kgf/cm^2 for hardener G-A0533, while 10% ferric oxide gave the lowest adhesion 77 Kgf/cm^2 for hardener G-5022X70. However, 10% ferric oxide increased tensile strength by 12.12 % for hardener G-A0533, 16.4% for hardener G-0930 and 28,5% for hardener G-5022X70. The increase in the mechanical properties of epoxy resin is attributed to the hydroxy group resulting from the reaction of epoxy group and hardeners. Epoxy resin's improved mechanical properties come from the reaction between the epoxy group and hardeners, forming hydroxy groups that enhance adhesion, tensile strength, and elongation at break [[15], [19], [20]].

Table 5 - Mechanical properties of epoxy resin mixed with hardeners in the ratio (1: 0.5) in the presence of barium sulphate (15%)

Sample code	ELM-NG 900Z / G-5022X70	ELM-NG 900Z / G-0930	ELM-NG 900Z / G-A0533
Adhesion Strength (Kgf/cm^2)	70	86	110
Tensile Strength (Kgf/cm^2)	300	405	610
Flexural Strength (Kgf/cm^2)	1005	934	860
Hardness (Shore D)	60	71	82
Impact test	Pass	Pass	Pass
Cylindrical Mandrel	Pass	Pass	Pass
Crosshatch	Pass	Pass	Pass

The effect of different pigments on the mechanical properties of epoxy resin

The effect of inorganic pigment (cobalt blue) & organic pigment (carbon black) on the mechanical properties of epoxy resin mixed with different hardeners are presented in Tables 7 and 8. Table 7 shows an increase in adhesion, tensile strength and hardness while a decrease in flexural strength of epoxy resin mixed with different hardneres. For example, increased adhesion strength 10%, 7.5% and 7.8 % for epoxy mixed with hardeners G-A0533, G-0930 and G-5022X70, respectively. While tensile strength of the epoxy increased by 7,3%, 2,3% and 11.11% when mixed with hardeners G-A0533, G-0930 and G-5022X70, respectively. Flexural strength of epoxy resin 15.2%, 2.1% and 15.4% mixed with hardeners G-A0533, G-0930 and G-5022X70, respectively. However, there is no significant influence of organic pigment on the mechanical properties of the epoxy mixed with different hardners as shown in Table 8.

Table 6 - Mechanical properties of epoxy resin mixed with hardeners in the ratio (1: 0.5) in the presence of ferric oxide (10%)

Sample code	ELM-NG 900Z / G-5022X70	ELM-NG 900Z / G-0930	ELM-NG 900Z / G-A0533
Adhesion Strength (Kgf/cm^2)	77	90	170
Tensile Strength (Kgf/cm^2)	405	495	703
Flexural Strength (Kgf/cm^2)	645	515	390
Hardness (Shore D)	74	80	92
Impact test	Pass	Pass	Pass
Cylindrical Mandrel	Pass	Pass	Pass
Crosshatch	Pass	Pass	Pass

Table 7 - Mechanical properties of epoxy resin mixed with hardeners in the ratio (1: 0.5) in the presence of inorganic pigment (3 %)

Sample code	ELM-NG 900Z /. G-5022X70	ELM-NG 900Z / G-0930	ELM-NG 900Z / G-A0533
Adhesion Strength (Kgf/cm^2)	69	86	110
Tensile Strength (Kgf/cm^2)	350	435	673
Flexural Strength (Kgf/cm^2)	705	695	390
Hardness (Shore D)	71	79	91
Impact test	Pass	Pass	Pass
Cylindrical Mandrel	Pass	Pass	Pass
Crosshatch	Pass	Pass	Pass

Table 8 - Mechanical properties of epoxy resin mixed with hardeners in the ratio (1: 0.5) in the presence of organic pigment (3 %)

Sample code	ELM-NG 900Z /. G-5022X70	ELM-NG 900Z / G-0930	ELM-NG 900Z / G-A0533
Adhesion Strength (Kgf/cm^2)	62	81	105
Tensile Strength (Kgf/cm^2)	320	419	630
Flexural Strength (Kgf/cm^2)	832	703	469
Hardness (Shore D)	70	74	86
Impact test	Pass	Pass	Pass
Cylindrical Mandrel	Pass	Pass	Pass
Crosshatch	Pass	Pass	Pass

Conclusion

The following results were obtained during the development of epoxy resin for anticorrosion coating.

1. The effect of different hardeners on the physical and mechanical properties of epoxy was studied. The hardener G-A0533 resulted in the highest physical and mechanical properties compared to other hardeners due to its higher activity.

2. Adding 3% silica fume to the epoxy resin mixed with hardener G-A0533 increased adhesion by 21.0%, tensile strength by 10%, and hardness by 2%.

3. Adding 5% talc to the epoxy resin mixed with G-A0533 decreased adhesion, tensile strength, and flexural strength but increased hardness by 5%.

4. Premixed barium sulfate with epoxy resin increased adhesion by 10%, flexural strength by 86%, and decreased tensile strength and hardness in the presence of hardener G-A0533.

5. The mechanical properties of the epoxy resin mixed with 10% ferric oxide and different hardeners were investigated. The hardener G-A0533 provided the highest adhesion (170 Kgf/ cm^2), tensile strength (703 Kgf/cm^2), and hardness (92 shore D) compared to the epoxy resin without ferric oxide [adhesion 100 Kgf/ cm^2, tensile strength 627 Kgf/cm^2, and hardness 84 shore D].

6. The influence of inorganic pigment on the mechanical properties of epoxy resin mixed with different hardeners at a ratio of 1:0.5 was examined. Adding 3% inorganic pigment increased the mechanical properties of the epoxy resin mixed with hardener G-A0533 more than other hardeners, such as increasing adhesion by 10%, tensile strength by 7.3%, and hardness by 8.3%.

7. The addition of organic pigment to the epoxy resin mixed with different hardeners had no significant effect and slightly increased the mechanical properties of the epoxy resin in the presence of hardener G-A0533.

Conflicts of interest. The authors declare no conflict of interest.

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All authors agree to be accountable for the content and conclusions of the article.

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ТҮЙІНДЕМЕ
Бұл зерттеуде эпоксидті шайырдың физикалық және механикалық қасиеттеріне әсерін зерттеу үшін бисфенол А диглицидил эфирің негізіндегі жоғары молекулалы эпоксидті шайыр (ELM-NG 900Z) әр түрлі қатайтқыштармен қатайтылды. G-5022X70 (140-170 мг КОН/г), G- A0533 (310-350 мг КОН/г) және G-0930 (280-320 мг КОН/г) қатайтқыштар қолданылды. Нәтижелер қатайтқыш G-A0533 басқа қатайтқыштармен салыстырғанда эпоксидті шайырдың ең жақсы механикалық қасиеттерін қамтамасыз ететінін көрсетті. Сонымен қатар, механикалық қасиеттерін жақсарту үшін G-A0533 қатайтқыштың қатысуында кремний диоксиді, тальк, барий сульфаты, темір оксиді және пигменттер сияқты әртүрлі қоспалар эпоксидті шайырмен араластырылды. 3% кремний оксиді, 10% темір оксиді және 3% бейорганикалық пигменттерді қосқанда механикалық қасиеттер жақсарса, 5% тальк қосылғанда механикалық қасиеттердің көпшілігі төмендеп, тек қаттылық жоғарылағаны байқалды. Эпоксидті шайырға барий сульфаты қосылғанда адгезия мен иілу беріктігі артты, бірақ созылу беріктігі мен қаттылығы төмендеді. Органикалық пигментті қосу эпоксидті шайырдың механикалық қасиеттеріне айтарлықтай әсер еткен жоқ. Бұл механикалық қасиеттердің жақсаруы қолданылатын қатайтқыштың түріне, сондай-ақ эпоксидті шайырмен араласқан қоспалардың түрлері мен мөлшеріне байланысты.

Түйін сөздер: Эпоксидті шайыр, қатайтқыш, механикалық, коррозия, қоспалар.

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Разработка эпоксидной смолы для антикоррозионных покрытий

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Аннотация
В этом исследовании высокомолекулярная эпоксидная смола (ELM-NG 900Z) на основе диглицидилового эфира бисфенола А была отверждена с различными типами отвердителей для изучения их влияния на физические и механические свойства эпоксидной смолы. Были использованы отвердители: G-5022X70 (140-170 мг КОН/г), G-A0533 (310-350 мг КОН/г) и G-0930 (280-320 мг КОН/г). Результаты показали, что отвердитель G-A0533 обеспечил наилучшие механические свойства эпоксидной смолы по сравнению с другими отвердителями. Кроме того, различные добавки, включая кремнеземную пыль, тальк, сульфат бария, оксид железа и пигменты, были смешаны с эпоксидной смолой в присутствии отвердителя G-A0533 для улучшения ее механических свойств. Было отмечено, что добавление 3% микрокремнезема, 10% оксида железа и 3% неорганических пигментов улучшило механические свойства, в то время как добавление 5% талька ухудшило большинство механических свойств и увеличило только твердость. Включение сульфата бария в эпоксидную смолу улучшило адгезию и прочность на изгиб, но снизило прочность на растяжение и твердость. Включение органического пигмента не оказало существенного влияния на механические свойства эпоксидной смолы. Это улучшение механических свойств объясняется типом используемого отвердителя, а также типами и количеством добавок, смешанных с эпоксидной смолой.

Ключевые слова: Эпоксидная смола, отвердитель, механический, коррозия, добавки.

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References

[1] Bhavith K, Prashanth Pai M, Sudheer M, Ramachandra CG, Maruthi Prashanth BH, Kiran Kumar B. The Effect of Metal Filler on the Mechanical Performance of Epoxy Resin Composites. Engineering Proceedings. 2023; 59(1):200. https://doi.org/10.18517/ijaseit.7.4.2480

[2] Najat J S, Adnan A A, Manal A T, Mariam E. A study on mechanical properties of epoxy resin cured at constant curing time and temperature with different hardeners. Engg. & Tech. Journal. 2011; 29:1804. https://doi.org/10.30684/etj.29.9.15

[3] Sudheer M, Subbaya KM, Jawali D, Bhat T. Mechanical Properties of Potasium Titanate Whisker Reinforced Epoxy Resin Composites. J. Miner. Mater. Charact. Eng. 2012; 11:193. https://doi.org/10.4236/jmmce.2012.112016

[4] Dheeraj KG, Gujjala R, Syam PP, Ojha S. Enhanced mechanical properties of glass fibre epoxy composites by 2D exfoliated graphene oxide filler. Ceramics International. 2021; 47(24):34860-34868. https://doi.org/10.1016/j.ceramint.2021.09.027 .

[5] Kowshik S, Shettar M, Rangaswamy N, Chate G, Somdee P. Effect of nanoclay on mechanical, flammability, and water absorption properties of glass fiber-epoxy composite. Cogent Eng. 2022; 9:2069070. https://10.1080/23311916.2022.2069070

[6] Ramkumar Y, Mayank S, Deepika S, Seul-Yi L, Soo-Jin P. The role of fillers to enhance the mechanical, thermal, and wear characteristics of polymer composite materials: A review. Composites Part A: Applied Science and Manufacturing. 2023; 175:107775. https://10.1016/j.compositesa.2023.107775

[7] Baroncini E, Kumar S, Palmese G, and Stanzione J. Recent Advances in Bio-based Epoxy Resins and Bio-based Epoxy Curing Agents. Journal of Applied Polymer Science. 2016; 44103:1. https://doi.org/10.1002/app.44103

[8] Allahverdi A, Ehsani M, Janpour H, Ahmadi S. The effect of nanosilica on mechanical, thermal and morphological properties of epoxy coating. Progress in Organic Coatings. 2012; 75(4):543-548. https://doi.org/10.1016/j.porgcoat.2012.05.013

[9] Avilés M, Perugachi R. Rigail-Cedeño A. Bio-Based Silica Reinforced Aliphatic Bio-Epoxy Composites. Global Partnerships for Development and Engineering Education. Proceedings of the 15th LACCEI International Multi-Conference for Engineering, Education and Technology. 2017; 1. http://dx.doi.org/10.18687/LACCEI2017.1.1.299

[10] Jin F-L, Park S-J. Thermal properties of epoxy resin/filler hybrid composites. Polymer Degradation and Stability. 2012; 97(11):2148-2153. https://doi.org/10.1016/j.polymdegradstab.2012.08.015

[11] Negim E, Shalash M, Al Azzam KM, Sagatbekovna MZ, Kairatovna BA, Konstantinovich AT, Adlikhanovna NA, Ermekovna KA, Ravindran B. Synthesis, Characterization, and Application of Polyurethane-Acrylic Hybrids as Anticorrosion Coatings. International Journal of Technology. 2024;15(6):009-2023. https://doi.org/10.14716/ijtech.v15i6.7044

[12] Rigail-Cedeño A, Schmidt DF. Bio-based epoxy clay nanocomposites. AIP Conference Proceedings. 2017; 1914:030023. https://doi.org/10.1063/1.5016710

[13] Sienkiewicz A, Czub P. Modification of Epoxy Compositions by the Application of Various Fillers of Natural Origin. Materials. 2023; 16(8):3149. https://doi.org/10.3390/ma16083149

[14] Abd El-Ghaffar MA, Abdelwahab NA, Amany M Fekry, Sanad MA, Sabaa MW, Soliman SMA. Polyester-epoxy resin/conducting polymer/barium sulfate hybrid composite as a smart eco-friendly anti-corrosive powder coating. Progress in Organic Coatings. 2020; 144:105664. https://doi.org/10.1016/j.porgcoat.2020.105664

[15] Neha KR, Sharif A. Synergistic effect of nanosize and irradiation on epoxy/conducting poly(o-phenyldiamine) nanospheres composite coatings: Synthesis, characterization and corrosion protective performance. Materials Chemistry and Physics. 2018; 204: 282-293. https://doi.org/10.1016/j.matchemphys.2017.10.044

[16] Bekbayeva L, Negim E-S, Zhanibekov R, Sharipov R, Maldybayev G, Puzikova D, Kenzin N, Maridan A. Epoxy coatings for anticorrosion applications: a review. Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources. 2026; 337(2): 35. https://doi.org/10.31643/2026/6445.15

[17] Sally C. The Munsell Color System: A scientific compromise from the world of art. Studies in History and Philosophy of Science Part A. 2014; 47:26-41. https://doi.org/10.1016/j.shpsa.2014.03.004

[18] Gatis V, Irina A, Yukako H, Ilvars I. Colour Extraction and Analysis Solution for Design of Cross-cultural Websites. Procedia Computer Science. 2015; 77:215-220. https://doi.org/10.1016/j.procs.2015.12.374

[19] Dong WK, Ki B N, Sung CH. Influence of tungsten on the activity of a Mn/Ce/W/Ti catalyst for the selective catalytic reduction of NO with NH_3 at low temperatures. Applied Catalysis A: General. 2015; 497:160-166. https://doi.org/10.1016/j.apcata.2015.01.013

[20] Negim SM, Bahruddin S, Mahyuddin R, & Idiris MS. Effects of TDI and FA-703 on physico-mechanical properties of polyurethane dispersion. Journal of Applied Polymer Science. 2011; 121(1):8-13. https://doi.org/10.1002/app.33569

[21] ISO 12058-1. International standard: Determination of viscosity using a falling-ball viscometer. 2018. ISO 12058-1:2018(E)

[22] American Society for Testing and Materials (ASTM). ASTM D3359. Standard Test Methods for Rating Adhesion by Tap Test – 2001.

[23] American Society for Testing and Materials (ASTM). ASTM D2794. Standard Test Methods for Resistance of Organic Coatings to The Effects of Rapid Deformation (Impact) – 2019.

[24] American Society for Testing and Materials (ASTM). ASTM D1652. Standard Test Method for Epoxy Content of Epoxy Resins – 2019.

[25] En, B., 1542. Products and systems for the protection and repair of concrete structures. Test methods Measurement of bond strength by pull-off – 1999.

[26] Syrmanova K, Negim E, Kaldybekoekova J, Tuleuov AM. Epoxylitane compositions modification with using thermoplastic polyurethane. Oriental Journal of Chemistry. 2016; 32(1). http://dx.doi.org/10.13005/ojc/320101

[27] Sabergaliyev M, Yeligbayeva G, Khassanov D, Muradova S, Orazalin Z, Ainakulova D, Sharipov R, & Negim E-S. Modified bitumen-polymer mastic to protect metal coatings from corrosion. Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources. 2024; 331(4); 12. https://doi.org/10.31643/2024/6445.35