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Exploring the Effect of Triethylenetetramine (TETA) Hardener, Amide Hardener, and Cycloaliphatic Hardener on the Compressive Strength of Bisphenol-a Epoxy Resin.

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ABSTRACT

This study aimed to cover the preparation for hardening BPA epoxy resin with Teta, Amide and cycloaliphatic hardners; Testing the effect it has on compressive strength. Hardeners were added in their most effective ratio as used in previous patents, and compressive strength was tested to failure.

Introduction

Material technology and the advancements in material science have played a huge role in shaping humanity, with almost every industry changing and improving with the advent of innovation or advancement in material technology. From plastics to metamaterials, from nanotechnology to semiconductors, materials have greatly impacted the world [1]. One such class of material is resin.

Resins are solid or semi-solid, natural or synthetic materials that are typically viscous and can be converted to polymers [2]. There are many different types of synthetic resins and one of the most common is epoxy resin. Epoxy resins are materials that form polymers and typically react with hardeners or curing agents to form durable and tough materials. They are resins that contain epoxide groups [3].

Due to the properties of epoxy resins—such as outstanding mechanical properties, high durability, high adhesion strength, great heat resistance, electrical resistance, chemical resistance, and versatility—they have been extensively employed for coatings, electronic materials, adhesives, the aerospace industry, and the construction industry [3]. The most widely used epoxy resins are bisphenol-A epoxy resins [4].

Considering the importance and usefulness of epoxy resins, it is vital to study the properties of epoxy resins, such as compressive strength, and the factors that affect their properties.

This paper studies the effect of different hardeners and time on the compressive strength of bisphenol-A epoxy resins.

Methods

As the goal of this study was to find out the compressive strengths of epoxy resins based on the hardener used, the process mainly involved using molds to create different samples of epoxy resin with different hardeners and then testing the sample's compressive strength. The properties of the hardener and epoxy resin used are given below.

Product	Supplier	Amine value	Viscosity	Ratio of mixing

		Koh/gm		
TETA hardener	Huntsman Corporation	1443 [5]	21.4 [5]	9:1 [5]
Amide hardener	Chemieresin Industries Pvt.Ltd	390 [6]	1600 [6]	1:0.05 [6]
Cycloaliphatic hardener	Air Products and Chemicals, Inc.			

Product	Supplier of material	EEW	Viscosity	Epoxy equivalent eq/kg
Bisphenol-A epoxy resin	Chemieresin Industries Pvt.Ltd	190-200	2000	5.15

As three different hardeners were used, the study can be divided into three experiments.

Experiment-1

Materials

The materials used included bisphenol-A epoxy resin, which was used as the main base. Triethylenetetramine (TETA) hardener was used. Other apparatus were kept constant through the testing and included a Plastic bucket, Electronic mixer, Electronic scale, Metal molds, Grease, Compression testing machine, Distilled water, ruler and Safety equipment (glasses, gloves, and lab coats).

Steps

1. Bisphenol-A epoxy resin and TETA hardener were poured into a plastic bucket at a ratio of 9:1. The electronic scale was used to measure and add the correct mass of epoxy resin and TETA hardener to the bucket.
2. The electronic mixer was placed in the bucket and the mixture was mixed for approximately a minute to properly mix the chemicals.
3. Nine metal molds were prepared, each of which created a 5cm by 5cm by 5cm cube.
4. The epoxy resin and TETA hardener mixture were poured into the molds while ensuring that the molds did not overflow.
5. After twenty-four hours, three samples were taken, and the hardened epoxy resin was removed from the molds using grease to make the removal easy.
6. The three samples were thoroughly washed with distilled water to remove any dust or grease.
7. The mass of the three samples was measured using an electronic scale.
8. One sample was placed inside the compression testing machine while using a ruler to ensure that the sample was perfectly centered.
9. The compressive strength machine was turned on, and the compressive strength was measured.

10. The steps were repeated for the other two samples to measure their compressive strengths. The data was recorded, and the mean for the final compressive strength of bisphenol-A epoxy resin with TETA hardener one day after air curing was calculated.
11. Three days after the epoxy resin and hardener were mixed, three samples were taken and their compressive strength measured.
12. The data was recorded, and the mean for the final compressive strength of bisphenol-A epoxy resin with TETA hardener three days after air curing was calculated.
13. Seven days after the epoxy resin and hardener were mixed, three samples were taken, and their compressive strength was measured.
14. The data was recorded, and the mean for the final compressive strength of bisphenol-A epoxy resin with TETA hardener seven days after air curing was calculated.
15. During the experiments, proper safety equipment, such as glasses, gloves, and lab coats, was worn. The lab was kept clean to prevent impurities from entering the samples.
16. The environmental conditions in which the tests were conducted remained constant, as the difference between mixing samples was under 10 minutes.

Experiment-2

Materials

The materials used included bisphenol-A epoxy resin, which was used as the main base. Amide hardener was used. Other apparatus were kept constant through the testing and included a Plastic bucket, Electronic mixer, Electronic scale, Metal molds, Grease, Compression testing machine, Distilled water, ruler and Safety equipment (glasses, gloves, and lab coats).

Steps

1. Bisphenol-A epoxy resin and amide hardener were poured into a plastic bucket at a ratio of 1:0.05. The electronic scale was used to measure and add the correct mass of epoxy resin and amide hardener to the bucket.
2. The electronic mixer was placed in the bucket and the mixture was mixed for approximately a minute to properly mix the chemicals.
3. Nine metal molds were prepared, each of which created a 5cm by 5cm by 5cm cube.
4. The epoxy resin and amide hardener mixture were poured into the molds while ensuring that the molds did not overflow.
5. After twenty-four hours, three samples were taken, and the hardened epoxy resin was removed from the molds using grease to make the removal easy.
6. The three samples were thoroughly washed with distilled water to remove any dust or grease.
7. The mass of the three samples was measured using the electronic scale.
8. One sample was placed inside the compression testing machine while using a ruler to ensure that the sample was perfectly centered.
9. The compressive strength machine was turned on, and the compressive strength was measured.
10. The steps were repeated for the other two samples to measure their compressive strengths. The data was recorded, and the mean for the final compressive strength of bisphenol-A epoxy resin with amide hardener one day after air curing was calculated.

11. Three days after the epoxy resin and hardener were mixed, three samples were taken, and their compressive strength was measured.
12. The data was recorded, and the mean for the final compressive strength of bisphenol-A epoxy resin with amide hardener three days after air curing was calculated.
13. Seven days after the epoxy resin and hardener were mixed, three samples were taken, and their compressive strength was measured.
14. The data was recorded, and the mean for the final compressive strength of bisphenol-A epoxy resin with amide hardener seven days after air curing was calculated.
15. During the experiments, proper safety equipment, such as glasses, gloves, and lab coats, was worn. The lab was kept clean to prevent impurities from entering the samples.
16. The environmental conditions in which the tests were conducted remained constant, as the difference between mixing samples was under 10 minutes.

Experiment-3

Materials

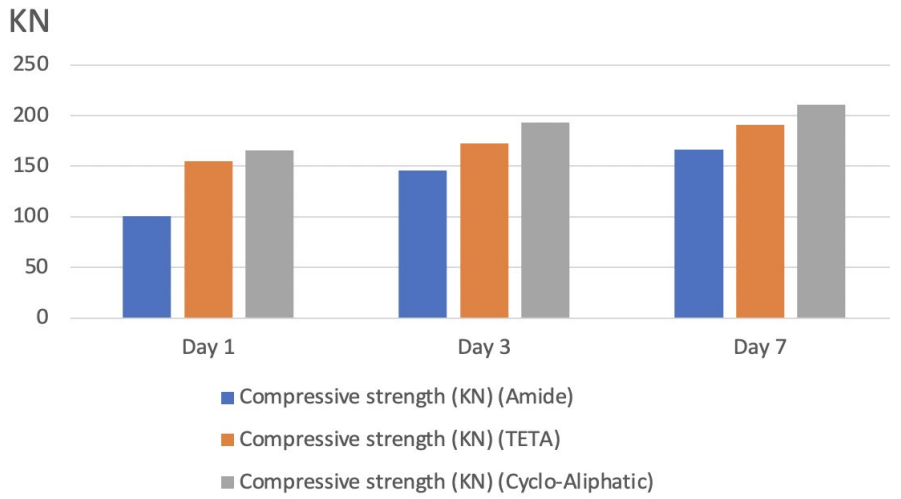
The materials used included bisphenol-A epoxy resin, which was used as the main base. Cycloaliphatic hardener was used. Other apparatus were kept constant through the testing and included a Plastic bucket, Electronic mixer, Electronic scale, Metal molds, Grease, Compression testing machine, Distilled water, ruler and Safety equipment (glasses, gloves, and lab coats).

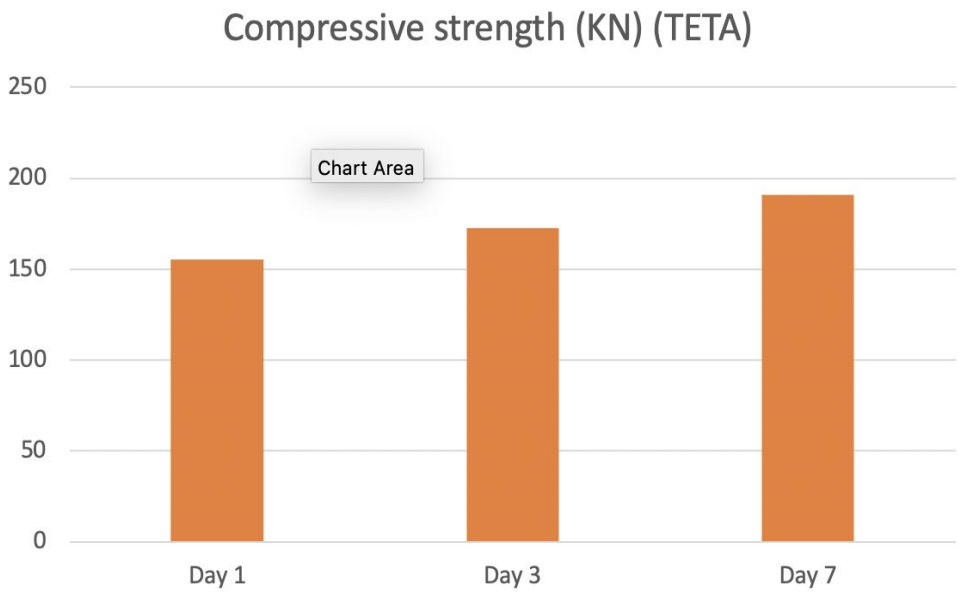
Steps

1. Bisphenol-A epoxy resin and cycloaliphatic hardener were mixed at a ratio of 1:0.4. The electronic scale was used to measure and add the correct mass of epoxy resin and amide hardener.
2. The electronic mixer was used to thoroughly mix the mixture for approximately a minute.
3. Nine metal molds were prepared, each of which created a 5cm by 5cm by 5cm cube.
4. The epoxy resin and cycloaliphatic hardener mixture were poured into the molds while ensuring that the molds did not overflow.
5. After twenty-four hours, three samples were taken, and the hardened epoxy resin was removed from the molds using grease to make the removal easy.
6. The three samples were thoroughly washed with distilled water to remove any dust or grease.
7. The mass of the three samples was measured using an electronic scale.
8. One sample was placed inside the compression testing machine while using a ruler to ensure that the sample was perfectly centered.
9. The compressive strength machine was turned on, and the compressive strength was measured.
10. The steps were repeated for the other two samples to measure their compressive strengths. The data was recorded, and the mean for the final compressive strength of bisphenol-A epoxy resin with cycloaliphatic hardener one day after air curing was calculated.
11. Three days after the epoxy resin and hardener were mixed, three samples were taken, and their compressive strength was measured.
12. The data was recorded, and the mean for the final compressive strength of bisphenol-A epoxy resin with cycloaliphatic hardener three days after air curing was calculated.
13. Seven days after the epoxy resin and hardener were mixed, three samples were taken, and their compressive strength was measured.

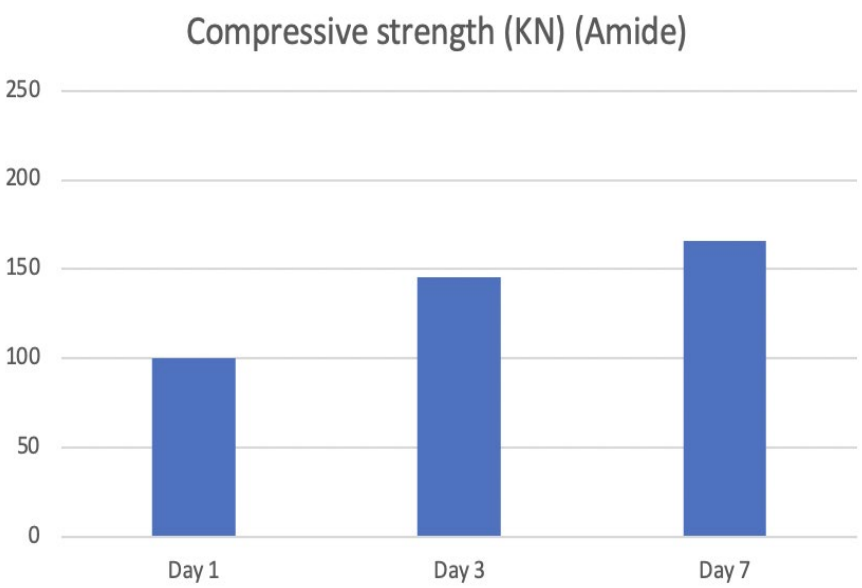
14. The data was recorded, and the mean for the final compressive strength of bisphenol-A epoxy resin with cycloaliphatic hardener was recorded seven days after air curing.
15. During the experiments, proper safety equipment, such as glasses, gloves, and lab coats, was worn. The lab was kept clean to prevent impurities from entering the samples.
16. The environmental conditions in which the tests were conducted remained constant, as the difference between mixing samples was under 10 minutes.

Results

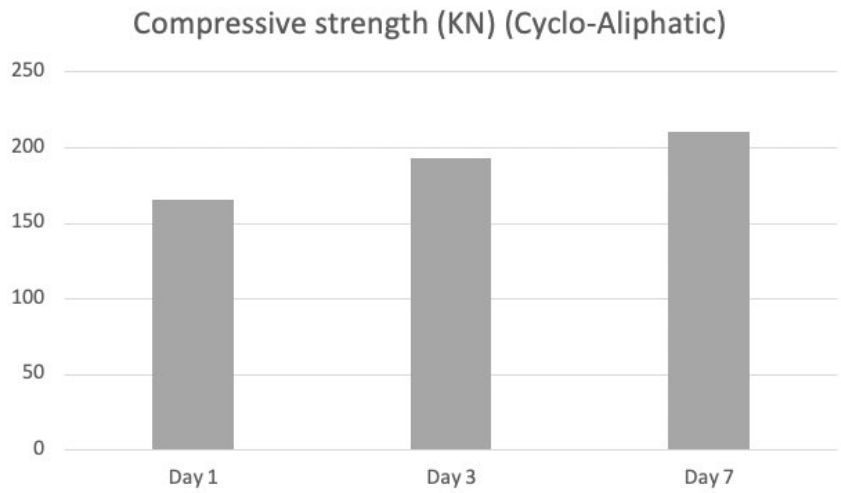




The compressive strength of BPA epoxy resin cured with TETA hardener showed an increase of 11.1% in compressive strength on day 3 and an increase of 23% on day 7. Teta hardener showed the second greatest initial and final compressive strength and exhibits the least rate of change among all tested hardeners.

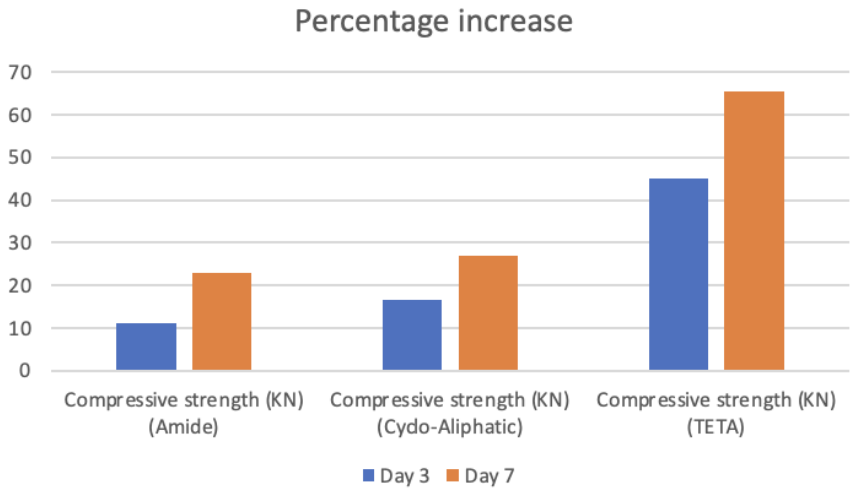


The compressive strength of BPA epoxy resin cured with Amide hardener showed an increase of 45.1% on day 3 and an increase of 65.4% on day 7. Amide hardener shows the greatest rate of change among all tested hardeners.



The compressive strength of BPA epoxy resin cured with Cyclo-Aliphatic hardener showed an increase of 16.6% on day 3 and an increase of 27% on day 7.

Summary



The experiments demonstrated that each hardener had a similar impact on the material's performance, increasing it drastically with similar slopes over a period of time. The TETA hardener exhibited notable compressive strength on day 1. Amide hardener exhibited the least compressive strength on day 1, but showed the greatest difference from day 1 to day 7 in compressive strength. The cyclo-aliphatic epoxy resin showed the greatest initial and final compressive strength.

Variance of data:
Teta:
Day 1 data- ± 0.16, Day 3 data - ± 0.035, Day 7 data - ± 0.125

Amide:
Day 1 data- ± 0.035, Day 3 data - ± 0.02, Day 7 data - ± 0.025

Cyclo-Aliphatic-
Day 1 data- ± 0.095, Day 3 data - ± 0.03, Day 7 data - ± 0.05

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