Production of Re-dispersible Polymer Powder 2024

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A Thesis submitted by

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In partial fulfillment of the requirement for the degree of

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in

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Department of Materials

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DEDICATION

This work is dedicated to our parents and all teachers of department of Materials.

Their love and support encourage us always.

May Allah give them long and happy life. (Ameen)

CERTIFICATE

This case study, carried out and written by **Muhammad Ahmad Khan and Taha Jamal Mustafa** under the direction of their supervisor Dr. Asif Hafeez and approved by all the members of Project Committee of the department, has been presented to and accepted by the Chairman, Department of Materials and Dean, School of Engineering & Technology in fulfillment of the requirement of degree Bachelor of Science in Polymer Engineering.

Supervisor **Internal Examiner**

Chairman DOM **Dean SET**

DISCLAIMER

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Muhammad Ahmad Khan

Taha Jamal Mustafa

ACKNOWLEDGMENT

It is in the name of Allah, the Most Forgiving, the Most Merciful! All praise and gratitude be to Allah for the completion of this report. We praise God for granting us the time, resources, and perseverance we needed to produce this report. There was a lot of difficulty for us to overcome. We owe a debt of gratitude to the Holy Prophet Muhammad (Peace be upon him), whose example of piety and service to others has been an inexhaustible wellspring of motivation for us. As a first order of business, we'd like to thank our supervisor, Dr. Asif Hafeez, for all of his guidance, tolerance, and understanding. In particular, he has provided us with positive reinforcement and a pleasant disposition to help us finish our thesis. It's been a pleasure and a privilege to work with him. In addition to our supervisor, we are grateful to the other members of the Department of Materials for their encouragement and support throughout our work with epidemic situations, especially Dr. Khubab Shakir for his motivation and the prayers of the whole faculty. Our sincere appreciation goes out to everyone who helped us emotionally and spiritually during our study, including team members, friends, and family. For the times we've shared and the friendship you've given, I am grateful. Finally, we owe an incalculable amount of gratitude to our loving parents for their never-ending support, prayers, and encouragement. We appreciate your kindness toward those who contributed to our research in a roundabout way. May God bestow prosperity and respect to the individuals mentioned above! Thank you very much!

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Sustainable Development Goals

Sustainable Development Goals (SDG) 9: Industry, Innovation, and Infrastructure

This project aligns with SDG 9 by contributing to the advancement of industry, innovation, and infrastructure. Through the synthesis of redispersible polymer powder (RDP) using methyl methacrylate (MMA) as the base monomer, innovative solutions are being developed to enhance the performance and functionality of materials used in various industries.

Sustainable Development Goals (SDG) 11: Sustainable Cities and Communities

In alignment with SDG 11, this project contributes to creating sustainable cities and communities by addressing the challenges of environmental pollution and resource management. The synthesis of redispersible polymer powder (RDP) using methyl methacrylate (MMA) as the base monomer offers a sustainable alternative to traditional materials in construction, coatings, and adhesives. By enhancing the performance and durability of building materials, RDP can contribute to the development of resilient infrastructure and sustainable urbanization.

Abstract

Redispersible polymer powder (RDP) was synthesized using methyl methacrylate (MMA) as the base monomer, aiming to enhance its applicability in various industries. The production process involved emulsion formation with MMA and subsequent vacuum oven drying, followed by ball milling to convert the dried emulsion into powder form. The resulting RDP exhibited favorable properties for applications in construction, coatings, and adhesives. The study investigated the effects of synthesis parameters on RDP characteristics, including particle size distribution, redispersibility, and adhesion strength, utilizing techniques such as Fourier-transform infrared spectroscopy (FTIR) and dynamic light scattering (DLS). FTIR analysis provided insights into the chemical composition and structural properties of the RDP, while DLS measurements enabled the assessment of particle size distribution and colloidal stability. The fabricated RDP showed improved performance in terms of hydrophobicity validated through FTIR and DLS analysis. These findings underscore the potential of MMA-based RDP as a versatile material for various industrial applications, highlighting its enhanced properties over traditional polymer powders."

Chapter 1: Introduction

Redispersible polymer powders (RDPs) are a versatile class of dry-mix additives that have revolutionized the construction industry. Redispersible polymer powder (RDP) is a type of dry polymer that can be easily redispersed in water to form a stable latex. They are composed of fine particles of synthetic polymers that are coated with a surfactant to prevent agglomeration and allow for easy redispersion in water. When mixed with water, RDPs form a stable emulsion that can be used to improve the workability, adhesion, and strength of cement-based mortars and adhesives.[6]

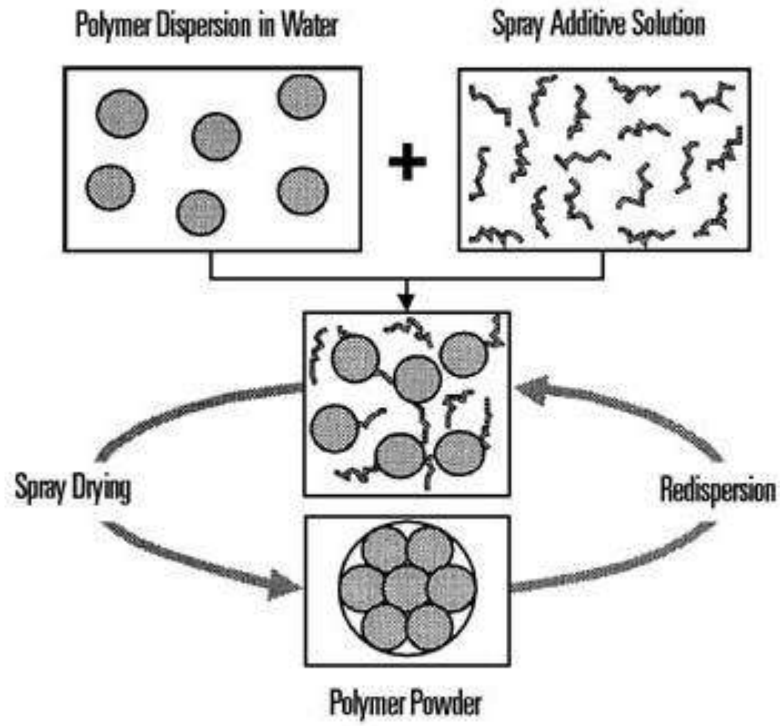


Figure 1 The action of spray additives in the spray drying of aqueous polymer dispersions.

1.1 Background overview:

A significant advancement in the world of building materials was the creation of RDPs in the 1960s. Just before the development of RDPs, it was challenging to achieve uniform dispersion and avoid agglomeration, which limited the use of polymer additives in cement-based materials. These difficulties were overcome by RDPs, which offered a stable and simple-to-use polymer form that was easily added to cement mixtures.

One kind of water-soluble polymer that can be redispersed is referred to as redispersible polymer powder (RDP) in water and mixed with mortar to improve its properties. Aqueous polymer dispersions, which are typically based on vinyl acetate, ethylene, vinyl versatate, and other monomers, are sprayed-dried to form RDP. RDP is used by the construction industry as an organic binder and ingredient in dry mix mortar formulas.

Cohesion, cohesiveness, flexibility, resistance to cracks, water impermeability, hydrophobicity, water repellency, decreased efflorescence, improved workability, and optimal leveling qualities of mortar can all be improved by RDP. RDP can also assist in lowering mortar's volatile organic compound (VOC) emissions, improving its environmental friendliness.

RDP was created in 1953 by Wacker Hemie, a German business. Since then, it has been widely utilized in a variety of applications, including tile grouts, floor leveling compounds and screeds, gypsum joint fillers and plasters, polymer binder applications, repairs, and renders based on cement and lime.[7]

1.2 Problem Statement:

RDPs are not without difficulties, even with their extensive use. Agglomeration is one of the primary problems, which can happen if the polymer particles' surfactant covering is broken or if the storage environment isn't ideal. Agglomeration can make it challenging to attain a uniform dispersion and cause performance discrepancies.

Particle morphology and size have a major impact on polymer powder processing and performance. Inconsistent particle size can lead to uneven flow characteristics, which can affect the homogeneity of coatings and molded parts. Irregular particle shapes can also affect packing density and mechanical qualities.

The possibility of residual monomers and solvents in the polymer powder following incomplete polymerization or inefficient solvent extraction is another challenge. The mechanical characteristics and color of the polymer could be affected by these impurities. They might also be detrimental to human health and the environment.

Stability and moisture absorption play important roles as well. Numerous polymers are hygroscopic, meaning they readily absorb moisture from the surrounding air. This could affect the flowability, stability, and processing behavior of the powder during long-term storage.

The cost of RDPs is another difficulty. The cost of RDPs is generally higher than that of conventional cement additives, which may be a barrier in some circumstances.Redispersible polymer powder (RDP) is an aqueous polymer dispersion that can be spray-dried to produce a white, free-flowing powder. RDP has several uses in the culinary, pharmaceutical, building, and cosmetic sectors and can be re-emulsified with water. Cement-based products' adhesion, flexibility, water resistance, and durability can all be enhanced by RDP. RDP can also be applied to other products as a coating agent, thickener, stabilizer, or binder.

However, there are a number of obstacles and restrictions associated with the manufacture of RDP, including high energy consumption, low efficiency, poor quality, and environmental impact. High pressure and temperature are necessary for the spray drying process, which is energy-intensive and may lead to the polymer's breakdown. The RDP's performance and re-dispersibility may be impacted by the water and volatile component losses that occur during the spray drying process. The selection and proportion of the polymer, protective colloid, surfactant, and anti-caking agent determine the quality and stability of the RDP. Agglomeration, caking, or sedimentation of the RDP may occur from using these components in the incorrect ratio or quantity. The environmental impact of the RDP production is also a concern, as it may generate waste water, air pollution, and greenhouse gas emissions.

As a result, it's necessary to create fresh approaches to the manufacturing of RDP that can get beyond these obstacles and constraints. This thesis' primary goal is to examine the viability and efficiency of substitute techniques for producing RDP, including freeze drying, supercritical fluid extraction, and spray drying with microwave assistance.

The expected outcomes of this thesis are:

• To present, using experimental data and theoretical models, a thorough and comparative review of the various approaches for producing RDP.

• To evaluate the benefits and drawbacks of each potential approach and suggest the most effective one for producing RDP in light of the demands and particular application.

• To give workable and sustainable solutions for the business and the community, while also advancing the science and technology of RDP production.

1.3 Aims of the study

The aim of this project is to produce Redispersible polymer powder for enhancing the properties of materials like tile adhesives, mortars, and other cementitious systems like:

- Film forming
- Adhesion
- Flexibility
- Crack resistance etc.

1.4 Objectives of the study

- Optimize polymer composition and molecular weight.
- To enhance the redispersion properties of the polymer powder.
- To improve the flow characteristics and storage stability of redispersible polymer powder.

1.5 Scope and Significance:

The creation and use of RDPs in cement-based materials will be the main subjects of this investigation. In order to increase the dispersion of RDPs in cement mixes and prevent agglomeration, the study will look into the elements that influence RDP agglomeration. The study will also determine whether employing RDPs in building applications is cost-effective and examine how well they work in various cement-based applications.

Because they contain important information about the creation and use of RDPs, the study's conclusions should have a big influence on the building sector. By using this data, RDPs can be used more effectively in construction applications and new and enhanced RDP solutions can be created.

1.6 Properties:

The benefits of using RDPs in cement-based materials include:

- Improved workability: RDPs make cement mixes more fluid and workable, reducing the amount of effort required to mix and apply the material.[4]
- Enhanced adhesion: RDPs improve the adhesion of cement mixes to a variety of substrates, including concrete, masonry, and tiles.[4]
- Increased strength: RDPs can increase the strength of cement mixes, making them more resistant to cracking and abrasion.[4]

- Improved durability: RDPs can enhance the durability of cement mixes by improving their resistance to water, chemicals, and weather conditions.[4]

1.7 Applications

Ever since they were introduced, RDPs have found widespread application in a variety of construction applications, RDPs are used in a wide variety of applications, including paints, coatings, adhesives, and construction materials. They are particularly useful in applications where it is necessary to form a film or coating from a dry powder. This is because RDPs can be easily redispersed in water and applied to a variety of surfaces including:

- Tile adhesives
- Dry mix mortar
- Grouting
- Self-leveling compounds
- External renders

RDPs have also been used in specialized applications, such as repair mortars and fire-resistant coatings.[3]

2. Chapter 2: Literature Review

2.1 Introduction:

Because of its inherent drawbacks—poor bonding strength, low tensile strength, and low chemical resistance—the market for building materials is currently seeing a daily decline in the demand for cement, concrete, and mortar. These drawbacks are addressed by the use of contemporary admixtures and additives. Because of its distinct physical and chemical characteristics, RD powder is attracting the interest of numerous researchers as a potential solution to these issues. German Wacker Hemie created the RD polymer powder in 1953, which enables the creation of a dry mix-mortar that has been altered by the polymer. The first batch of RD polymer powder used in practical applications was created in Germany in 1953. The first kind of RD polymer powder in the world is called VA homo polymer powder. Better flexibility was demonstrated in 1960 when an additional powder type based on EVA copolymer was successfully manufactured. This type of powder works well in an alkaline system. In the construction sector, a wide variety of polymers are employed as additives that primarily function as complementing binders. In addition to the most commonly used additives—EVA, SA, VAE, SB, and so on—terpolymers and homopolymers are also occasionally employed. These polymers are typically utilized as RD powder, which are spray-dried polymer dispersions.

This is a reversible process, and when the RD powder comes into contact with water, it exhibits characteristics identical to the initial dispersion. A type of polymeric materials known as redispersible polymer powders (RDPs) have undergone a transformation from aqueous polymer emulsions to free-flowing powders. Redispersing in water, these particles have a remarkable ability to generate stable emulsions that share features with the original emulsions. Because RDPs can improve mortar and concrete mixture performance, they have become increasingly popular in the building sector [6].

2.2 Production Methods of Redispersible Polymer Powder:

Redispersible Polymer Powder is produced through a multistep process that involves the dispersion of polymer particles in water, followed by drying to create a powder form. The production methods play a crucial role in determining the properties and performance of the final powder.[4]

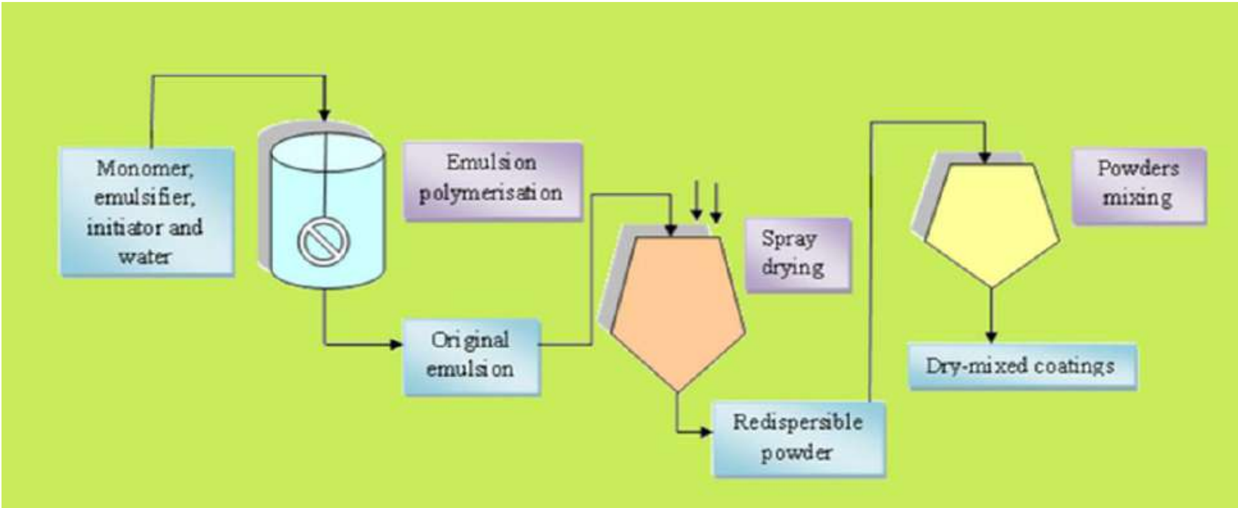


Figure 2 Representation of stages of RDP preparation from original emulsion to redispersed emulsion.

2.2.1 Polymer Dispersion:

Making a stable dispersion of polymer particles in water is the first stage in the production of re-dispersible polymer powders.

Emulsifiers and water are mixed with polymer resins, which are often based on vinyl acetate or ethylene-vinyl acetate copolymers. To break the polymer into smaller particles, this mixture is subjected to intense shear pressures or mechanical agitation. Emulsifiers are essential for maintaining the stability of the dispersion and avoiding particle coalescence.[4]

2.2.2 Chemical Modification:

The polymer dispersion may change chemically, depending on the final powder's intended characteristics.

Reactive monomers are an example of a chemical modifier that can be used to improve a material's adhesion, flexibility, or water resistance. This stage enables the polymer to be tailored, making it appropriate for a range of applications with distinct performance needs.[5]

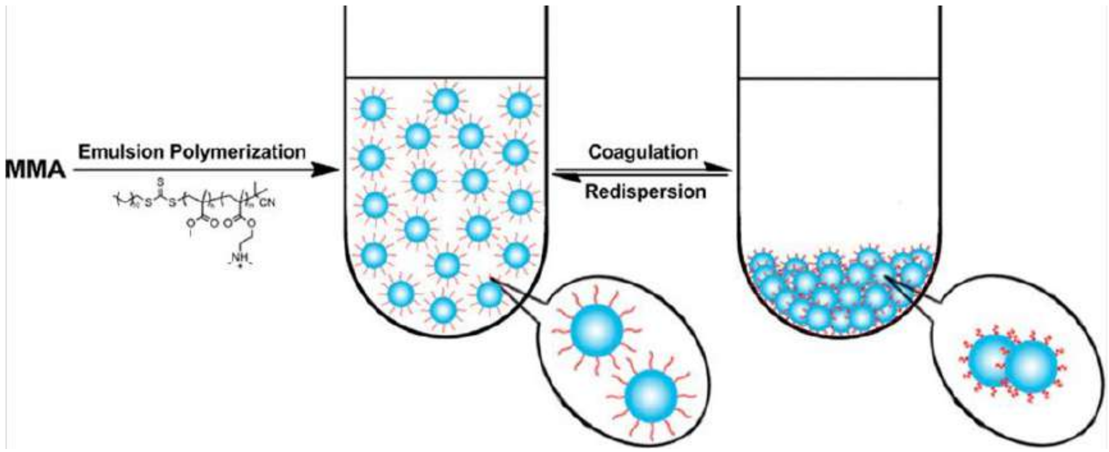


Figure 3 Sketch of Reversibly Coagulatable/Redispersible PMMA Latexes Prepared through Emulsion Polymerization of MMA Using PDM Surfactant

2.2.3 Spray Drying:

To convert the polymer dispersion into a powder while preserving its dispersibility, it is dried. After being atomized into tiny droplets, the polymer dispersion is added to a drying chamber. The water content is removed using hot air, resulting in the powdered individual polymer particles being left behind. To achieve the necessary powder qualities while maintaining dispersibility, careful consideration must be given to the selection of drying parameters, including temperature, airflow, and residence time.[6]

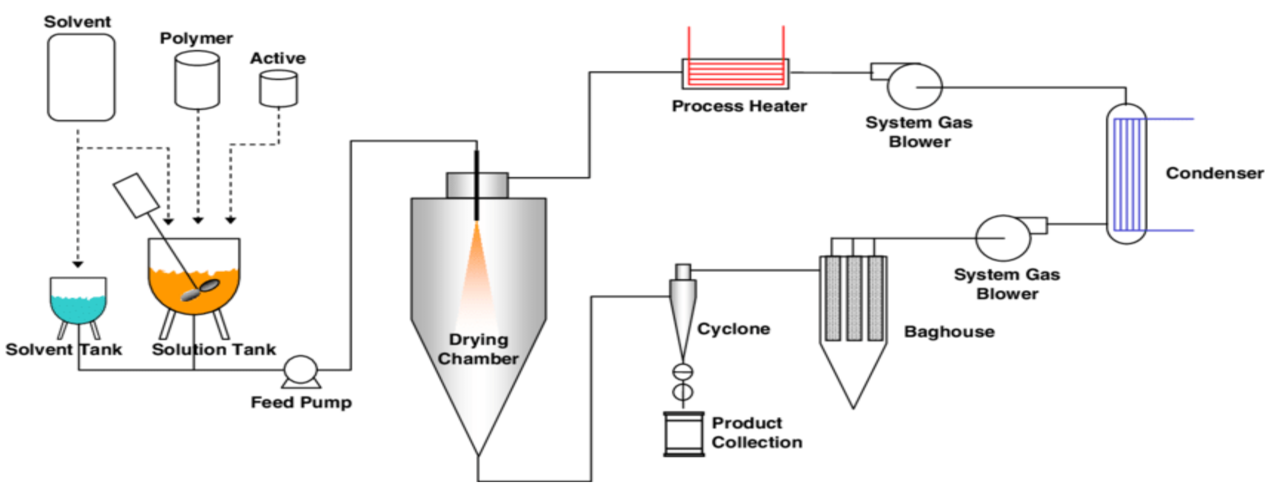


Figure 4 General spray-drying equipment configuration

2.3 Factors Affecting Redispersibility:

Re-dispersible polymer powders have a property called redispersibility that affects how well they work in different applications. To optimize the formulation and use of these powders, it is crucial to comprehend the various elements that influence dispersibility. Let's take a closer look at the main variables.

2.3.1 Particle Size:

Better dispersibility is typically associated with smaller particle sizes. When rehydrated, fine particles allow for a faster and more thorough dispersion. During the production process, it is essential to regulate the distribution of particle sizes. In order to obtain the appropriate particle size, grinding and sieving techniques are frequently used.

2.3.2 Chemical Composition:

During redispersion, the polymer's interaction with water and other components is determined by its chemical makeup and structure. Dispersibility can be improved by choosing polymers with the right chemical characteristics and performing chemical changes.[5]

2.3.3 Surface Chemistry:

The way polymer particles interact with water is determined by their surface properties, such as the existence of hydrophobic or hydrophilic groups. Enhancing the affinity of particles for water through additions or alterations can modify the surface chemistry and improve dispersibility.[5]

2.3.4 Protective Colloids and Additives:

Particle agglomeration can be avoided, and the stability of the dispersion can be affected by the presence of protective colloids and additives. It is critical to select appropriate protective colloids and additives that improve stability and dispersibility without compromising other qualities.

2.3.5 Drying Conditions:

The physical properties and dispersibility of the powder can be impacted by the drying procedure used during manufacture. Maintaining dispersibility while achieving the required powder qualities is made possible by regulating drying factors like temperature, airflow, and residence time.[6]

2.3.6 Chemical Modifications:

Reactive monomers or copolymerization are two examples of chemical changes that can affect how the powder behaves after redispersion. Chemically modifying the polymer to meet specific application needs can improve its dispersibility.[5]

2.3.7 Storage Conditions:

Improper storage conditions, such as exposure to high humidity, can lead to caking or agglomeration of the powder. Packaging the powder in moisture-resistant containers and storing it in a controlled environment helps maintain dispersibility over time.

2.3.8 Application-Specific Considerations:

Different applications may have specific requirements for re-dispersible polymer powders. Understanding the application needs and tailoring the powder's formulation to meet those requirements is crucial for optimal performance.[3]

2.4 Impact of Re-dispersible Polymer Powders on Construction Materials:

The incorporation of RDPs into construction materials has been shown to improve various performance characteristics.

- **Enhancing Strength and Durability:**

By strengthening the cohesive and adhesive qualities of building materials, RDPs greatly increase their strength and longevity. They function as a binder, essentially filling in the spaces created by the cement particles and aggregates to create a matrix that is denser and more cohesive. Because of its improved cohesiveness, the material is more resilient to abrasion and cracking, which prolongs its life and lowers maintenance expenses.[3]

- **Improving Flexibility and Water Resistance:**

The addition of RDPs to building materials increases their elasticity and increases their resistance to deformation and stress. This elasticity is very useful in flooring, pavements, and other applications where the material is subjected to movement or vibration. Furthermore, RDPs give building materials water resistance, which lowers water absorption and guards against moisture-related deterioration including efflorescence and spalling.[3]

- **Promoting Workability and Adhesion:**

Construction materials become easier to mix, apply, and shape with the use of RDPs. They make the material more malleable, which makes smoother finishes possible and less likely to have voids or air bubbles. Moreover, RDPs improve the adherence of building materials to a range of substrates, such as wood, brick, and concrete, guaranteeing a solid and long-lasting link between various layers or components.[2]

2.5 Specific Applications and Benefits:

RDPs have found widespread application in various construction materials, each offering unique benefits:

- **Mortars:** RDPs enhance the workability, bond strength, and water resistance of mortars, making them ideal for tile adhesives, plastering, and masonry repairs.
- **Concrete:** RDPs improve the strength, flexibility, and durability of concrete, reducing the risk of cracking and enhancing its resistance to water penetration.
- **Self-leveling compounds:** RDPs provide self-leveling compounds with improved flow and leveling properties, ensuring smooth and even surfaces for flooring applications.
- **External insulation systems:** RDPs enhance the adhesion and water resistance of external insulation systems, protecting buildings from weather damage and improving thermal insulation.
- **Dry-mix products:** RDPs are widely used in dry-mix products, such as grouts, adhesives, and repair compounds, providing enhanced workability, adhesion, and water resistance.

By offering a flexible and efficient way to improve the qualities of building materials, RDPs have completely transformed the construction sector. They have been widely used in many applications due to their capacity to increase strength, durability, flexibility, water resistance, and workability. This has produced more long-lasting, visually beautiful, and durable buildings.[2]

2.6 Future Directions in Redispersible Polymer Powder Research:

Re-dispersible polymer powder (RDP) research is characterized by a dynamic landscape that encompasses the following areas: the development of bio-based and sustainable alternatives to address environmental concerns; the investigation of advanced cross-linking techniques to enhance stability; the design of responsive and smart RDPs for targeted applications; and the exploration of nano structuring and nanocomposites for improved properties. Developing multifunctional RDPs, comprehending intricate redispersion mechanisms, customizing RDPs for 3D printing, and investigating uses in the pharmaceutical and medicinal domains are further directions. Future RDP research is expected to be shaped by advances in quality control, life cycle evaluations for environmental impact evaluation, and interdisciplinary collaborations. These developments are expected to meet the changing demands of many businesses.[1]

3. Chapter 3: Experimentation

3.1 Introduction

This chapter provides a comprehensive description of the experimental procedure followed to produce redispersible polymer powder. The experiment was designed with three primary objectives in mind:

1. Optimize the polymer composition and molecular weight.
2. Enhance the redispersion properties of the polymer powder.
3. Improve the flow characteristics and storage stability of the redispersible polymer powder.

3.2 Materials

The experiment required the following materials:

- Methyl methacrylate (MMA): 30 grams
- Potassium persulfate (KPS): 0.5 grams
- Sodium disulfate ($Na_2S_2O_7$): 0.2 grams
- Polyvinyl alcohol (PVA): 0.5 grams
- Tween 80: 0.5 grams

MMA is a colorless liquid that is widely used in the production of polymers and resins due to its ability to polymerize easily. It is the primary monomer used for the polymerization process in this experiment. The choice of MMA as the monomer was based on its excellent polymerization characteristics and the properties of the resulting polymer.

KPS is a white crystalline powder that is soluble in water and is commonly used as an initiator in the polymerization of vinyl monomers. It acts as the initiator in this experiment, triggering the polymerization reaction. The role of the initiator is to start the polymerization reaction by generating free radicals.

$Na_2S_2O_7$ is a white crystalline solid that is soluble in water and is often used as a reducing agent in various industrial applications. It is used as a stabilizer in this experiment to prevent premature polymerization. The stabilizer works by deactivating any excess free radicals that could lead to unwanted side reactions.

PVA is a water-soluble synthetic polymer with excellent film forming, emulsifying, and adhesive properties. It is used as a protective colloid in this experiment to stabilize the polymer particles during the polymerization and drying processes. The protective colloid works by forming a protective layer around the polymer particles, preventing them from aggregating and settling out of the solution.

Tween 80 is a nonionic surfactant and emulsifier often used in foods and cosmetics. It is also used as a protective colloid in this experiment, working in conjunction with PVA to stabilize the polymer particles. Tween 80 is particularly effective at reducing the surface tension of the solution, which helps to stabilize the polymer particles and enhance their redispersibility.

3.3 Experimental Setup

The experiment was conducted in a fume hood due to the potential harm of the chemicals used. Safety measures included wearing gloves, eye protection, and a lab coat. These precautions are necessary to protect the experimenter from potential chemical hazards. The fume hood provides ventilation and limits exposure to hazardous fumes. The gloves protect the hands from direct contact with potentially harmful substances. The eye protection prevents any splashes from getting into the eyes, and the lab coat protects the body and clothes from any spills or splashes.

3.4 Procedure

The experimental procedure was as follows:

MMA was dissolved in 200 mL of water in a beaker. This step is crucial as it ensures that the MMA is evenly distributed throughout the solution, allowing for a uniform polymerization reaction. The beaker was chosen for its resistance to heat and its wide opening, which allows for easy addition and mixing of ingredients.

The KPS initiator and $Na_2S_2O_7$ stabilizer were added to the solution and mixed well. The addition of these chemicals initiates the polymerization reaction and stabilizes the polymer particles, respectively. The mixture was stirred until the KPS and $Na_2S_2O_7$ were completely dissolved. This is important to ensure that these chemicals are evenly distributed throughout the solution.

The solution was heated to 80°C on a hot plate with stirring. This temperature was maintained throughout the polymerization reaction. The heat provides the energy necessary for the polymerization reaction to occur. The stirring ensures that the heat is evenly distributed throughout the solution, preventing hot spots and ensuring a uniform reaction.

Once the solution reached 80°C, PVA and Tween 80 were added and mixed well. These chemicals act as protective colloids, stabilizing the polymer particles during the polymerization and drying processes. The mixture was stirred until the PVA and Tween 80 were completely dissolved. This is important to ensure that these chemicals are evenly distributed throughout the solution.

The polymerization reaction was allowed to proceed for 6 hours, stirring occasionally. This duration was chosen to ensure complete polymerization. During this time, the monomer molecules react with each other to form polymer chains. The stirring was continued throughout this period to ensure that the reaction proceeds evenly.

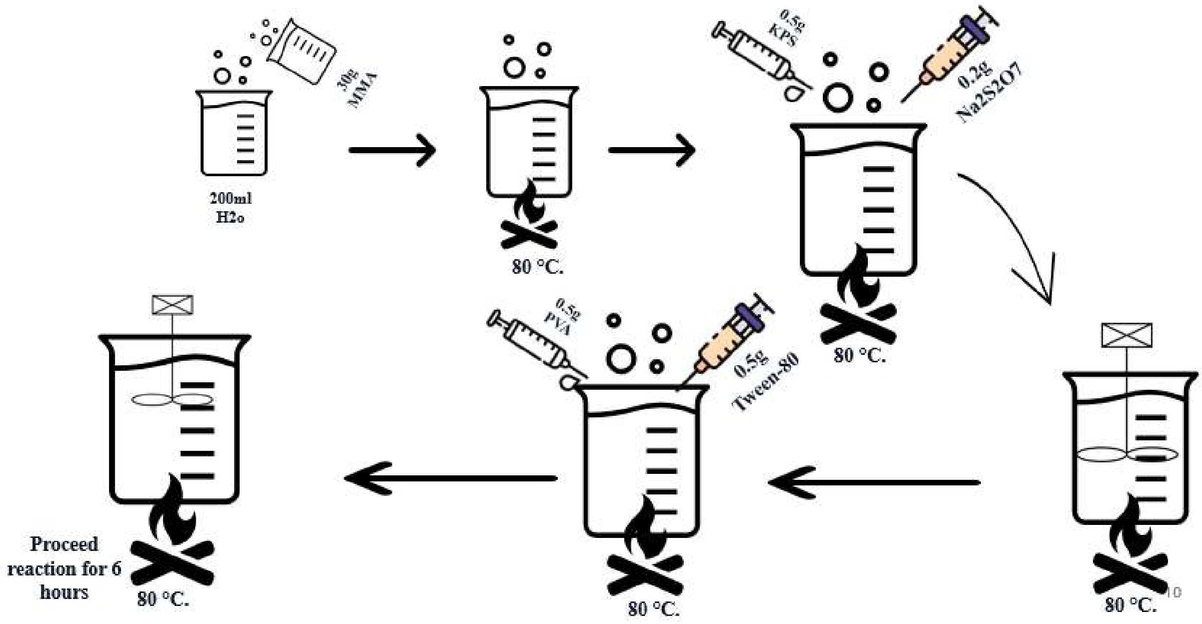


Figure 5 Preparation of Emulssion

3.5 Post-Processing

After the polymerization reaction was complete, the following post-processing steps were carried out:

1. The redispersible polymer (RDP) dispersion was poured into a shallow dish. This step is necessary to prepare the dispersion for the drying process. The shallow dish increases the surface area of the dispersion, allowing for faster evaporation of the water.
2. The emulsion was dried by evaporating water using a vacuum drying oven. This step removes the water from the dispersion, leaving behind the polymer particles. The vacuum drying oven was set at a temperature that is high enough to evaporate the water but low enough to prevent degradation of the polymer.
3. The dried product was crushed into a powder form. This step is necessary to break up any large clumps of polymer particles. The crushing was done using a mortar and pestle, which allows for control over the size of the particles.
4. The powder was further processed into a fine powder form using a ball milling machine. This step ensures that the powder has a uniform particle size, which is crucial for its redispersibility. The ball milling machine works by using small, hard balls to grind the material into a fine powder.

3.5.1 Ball Milling Machine

Ball milling is a size reduction technique that uses media in a rotating cylindrical chamber to mill materials into fine powder. In the context of this experiment, ball milling was used to refine the crushed redispersible polymer powder into a finely milled product.

Figure 6 Ball Milling Machine

3.5.1.1 Preparation for Ball Milling

The first step in the ball milling process was the preparation of the material. After the polymer emulsion was dried and scraped from the dish, it was crushed into a coarse powder form. The total amount of this coarse powder obtained was approximately 5 grams. This quantity is significant because it represents the total yield of the polymerization reaction and subsequent drying process. It is also the starting material for the ball milling process.

3.5.1.2 Processing

The ball milling process began with the loading of the 5 grams of coarse polymer powder into the milling chamber. Along with the polymer powder, 10 milling balls were added to the chamber. The use of multiple balls increases the efficiency of the milling process by ensuring that all the powder comes into contact with the balls. The balls serve as the grinding media, which, due to their high kinetic energy, collide with the powder particles and reduce their size.

The speed of the ball milling machine was set at 450 revolutions per minute (rpm). This speed was chosen to provide a balance between the energy input from the balls and the rate of wear and tear on the machine. A higher speed would result in more energy input and faster milling, but it could also lead to increased wear and tear on the machine and the balls. Conversely, a lower speed would reduce wear and tear but would also result in slower milling.

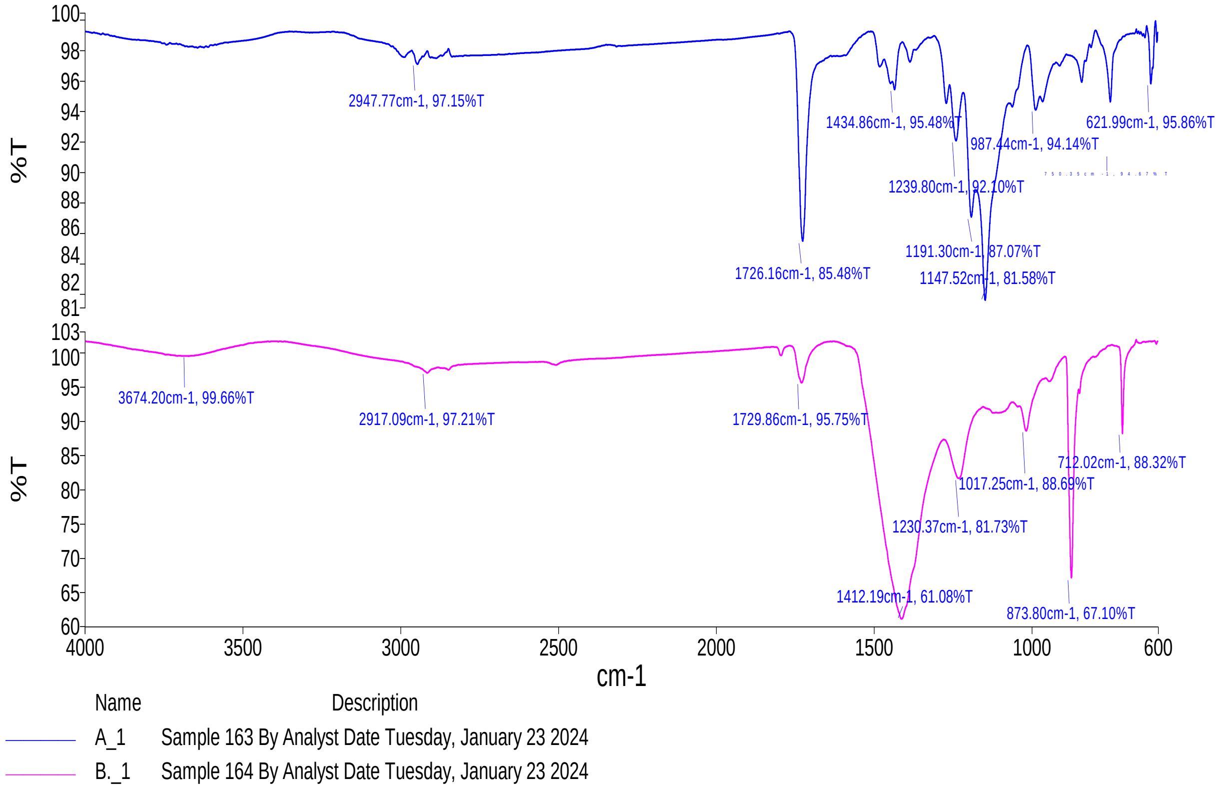
The milling time was set for 480 seconds, or 8 minutes. This duration was chosen based on preliminary tests that indicated it was sufficient to achieve the desired particle size. The milling process is a balance between size reduction and potential damage to the polymer structure. Milling for too long could lead to excessive heat generation, which could potentially damage the polymer structure and reduce its redispersibility.

The reverse function on the ball milling machine was turned on. This function changes the direction of rotation of the milling chamber at regular intervals. This helps to prevent the balls from moving in a set pattern and ensures that all the powder experiences the same amount of impact and shear forces. This leads to a more uniform particle size in the final product.

After the milling process was complete, the finely milled polymer powder was collected. This powder is the final product of the experiment and is ready for further testing and characterization.

4. Chapter 4: Results

FTIR:

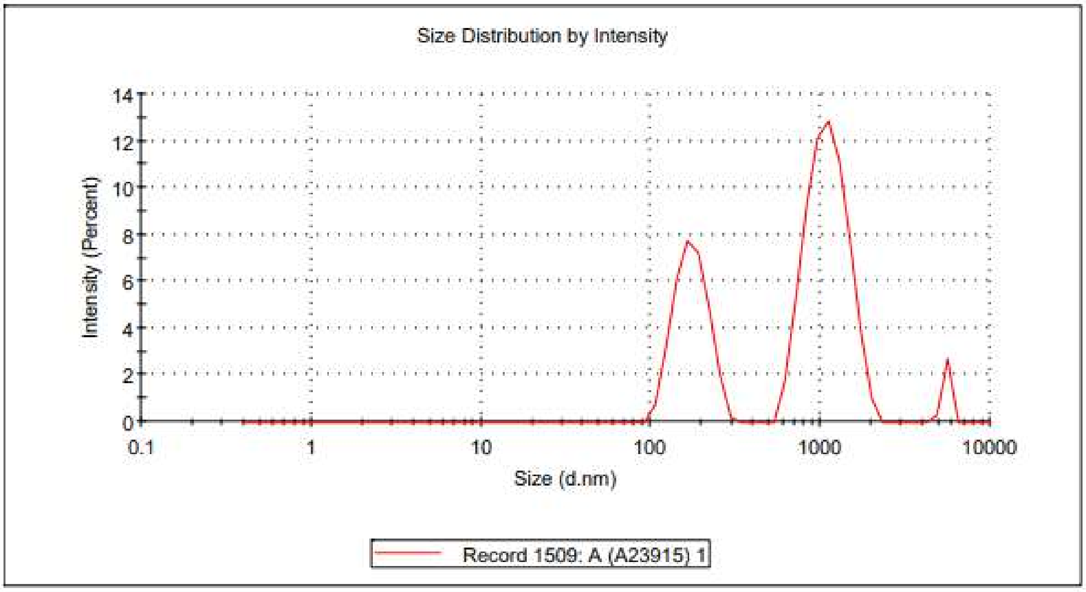


DLS for VAE

Results

			Size (d.nm):	% Intensity:	St Dev (d.n...
Z-Average (d.nm):	569.6	Peak 1:	1118	64.9	302.2
PdI:	0.876	Peak 2:	175.5	32.1	38.69
Intercept:	0.919	Peak 3:	5484	3.0	227.9

Result quality : Refer to quality report



DLS for MMA

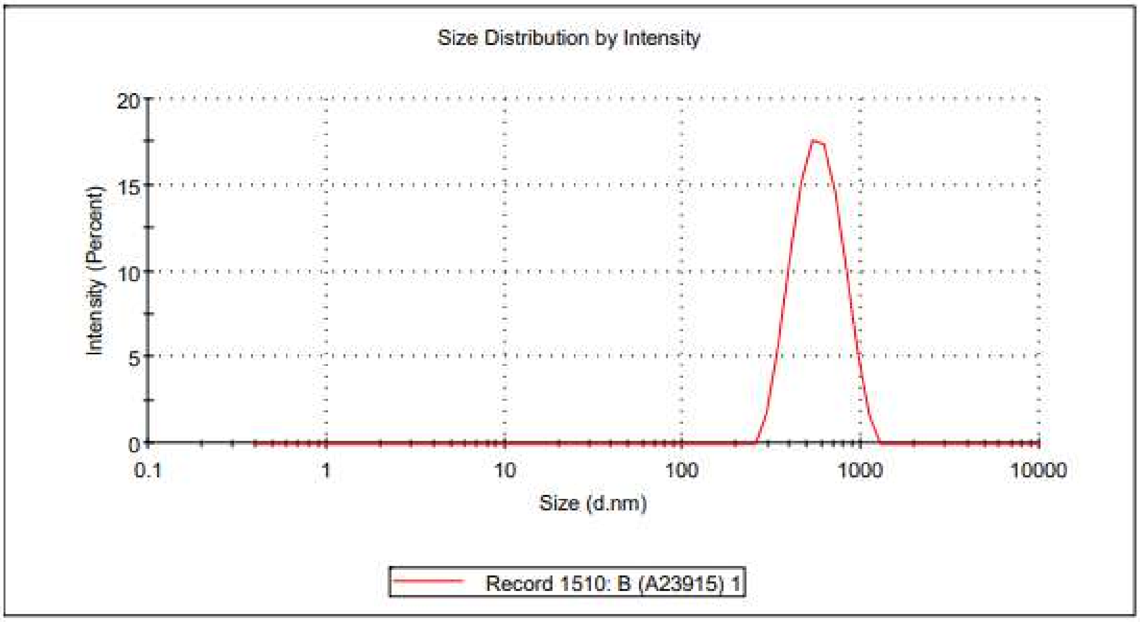
System

Temperature (°C):	25.0	**Duration Used (s):**	10
Count Rate (kcps):	165.2	**Measurement Position (mm):**	1.25
Cell Description:	Disposable sizing cuvette	**Attenuator:**	7

Results

			Size (d.nm):	% Intensity:	St Dev (d.n...
Z-Average (d.nm):	536.0	**Peak 1:**	592.1	100.0	177.7
PdI:	0.249	**Peak 2:**	0.000	0.0	0.000
Intercept:	0.883	**Peak 3:**	0.000	0.0	0.000

Result quality : Good



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