Carment: Magnesium Cement from Glass Waste as a Solution to The Cement Industry's Carbon Emission Problems

Muhamad Bahrul Ulum[1*], Gracella Audrey Toar[1], Jihad Akbar Hadrani[1], Erika Desi Cahyani[1], Zel Andesra[1], M Aldi Nugroho[1]

***Abstract*—In dealing with carbon emissions generated from the cement industry in general, the author has the idea to use Carment. Carment is a concept of carbon absorbing cement based on magnesium silicate which is derived from silica and is able to reduce carbon emissions from the manufacturing process compared to the manufacture of cement in general. There are several solutions that have existed in overcoming the problem of carbon emissions from the cement industry, such as the Waste Heat Recovery Power Generator (WHRPG), reducing the clinker ratio through blended cement products, and using alternative fuels to replace coal. However, its existence is still quite expensive and has not been able to overcome the problem of carbon emissions resulting from the cement industry. Carment is an innovation in the industrial sector where Carment as a magnesium cement from glass waste can solve the problem of carbon emissions from the calcination process. The availability of glass waste, which has a high availability, contains more than 70% silica and is inexpensive, increases the potential to produce magnesium cement from glass waste in Indonesia.**

***Keywords*—Carment, Carbon emissions, Silica, WHRPG**

I. INTRODUCTION

Indonesia, as a developing country, is the 4th most populous country in the world. Indonesia's population until 2020 is recorded at around 271 million people, of which 68.39% are productive age [1]. However, this situation does not necessarily have a positive impact on Indonesia. The large amount of population causes a high number of necessities for life for meeting daily needs, such as housing, food, and transportation. All of them cannot run well if they are not equipped with good infrastructure too. For this reason, more massive and sustainable infrastructure development is needed to meet and facilitate the sustainability of the needs of the Indonesian population.

In the last few years, infrastructure development has occurred massively and has spread throughout Indonesia to ensure guaranteed availability of infrastructure. This plays a vital role in improving human welfare and meeting the needs of life. However, the existence of these developments often still ignores the concept of environmental sustainability, which Magnesium phosphate cement (MPC), an unused sort of cementitious cover, is delivered by the acid-base response between dead burnt magnesia and phosphates [2]. It is additionally alluded to as "chemically bonded phosphate ceramic" since of its likeness to ceramic materials [3]. Given its quick rate of setting, tall early quality, great fire resistance, and adhesive properties, MPC has been broadly utilized for the restoration of gracious designing structures [4].

Therefore, it is necessary to have an idea with a constructive and comprehensive concept in overcoming the problem of climate change as a result of the cement industry's carbon emissions as written in the Sustainable Development Goals number 9 Industry Innovation and Infrastructure, number 12 is Responsible Consumption and Production and number 13, climate action. The development of increasingly advanced technology produces some of the latest innovations in overcoming the[1] problems that occur in this life. The author proposes an idea to solve the problem of carbon emissions as a solution to the problems of the cement industry through Carment, namely the concept of carbon absorbent cement based on magnesium cement. Carment is able to become an environmentally friendly cement concept that can help the government and related agencies in realizing the target of reducing carbon emissions in Indonesia by 2045 [5].

II. METHOD

The process for making magnesium silicate widely used in industry can be seen in the process flow diagram according to Figure 1. Carbon emission reduction is also carried out in its manufacture specifically to reduce SO_X, NO_X, and carbon dioxide (CO_2) gases produced from the manufacture of magnesium silicate to minimize the effects of global warming.

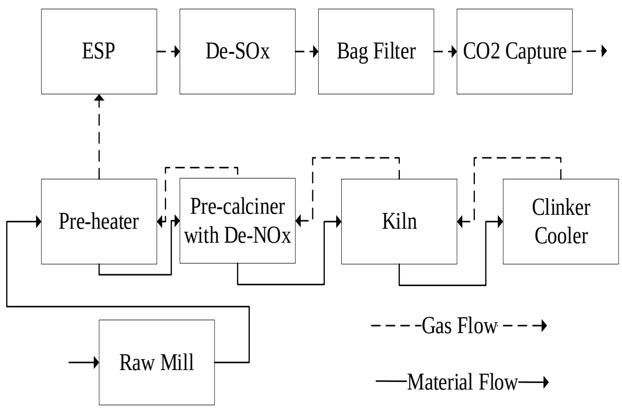

Figure 1. Stages of Making Magnesium Silicate

[1] Department of Industrial Chemical Engineering, Institut Teknologi Sepuluh Nopember, Kampus ITS Sukolilo, Surabaya, 60111, Indonesia. E-mail: ulummuhamadbahrul680@gmail.com

The Process how to make a magnesium cement is divided into three parts. First, sodium silicate solution synthesis process. Second, Magnesium Silicate synthesis process. Third, Magnesium Cement synthesis process. Overall stages of making magnesium cement are shown below:

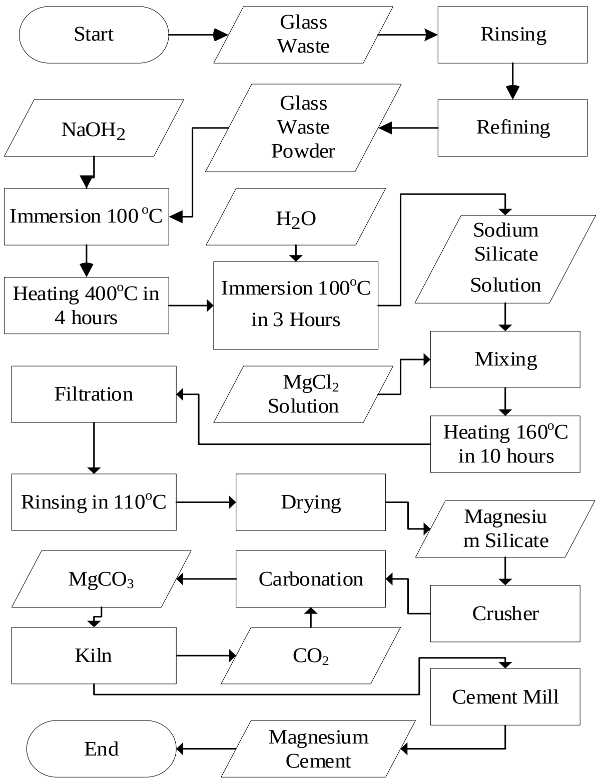

Figure 2. Overall Process to Make Magnesium Cement

The tools used in this research are glass waste, sodium hydroxide (NaOH), water, magnesium chloride ($MgCl_2$), sodium silicate, and magnesium silicate. The experiment began by making a solution of sodium silicate, magnesium silicate and magnesium cement.

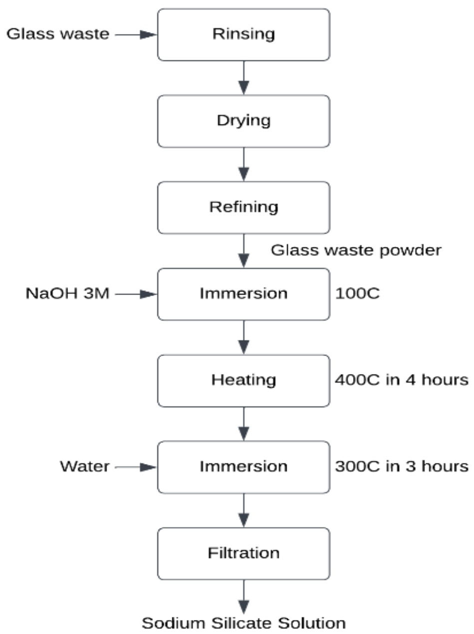

Figure 3. Stages of Making a Sodium Silicate Solution

The synthesis stage of magnesium silicate functions to obtain magnesium silicate from glass waste in two stages, the preparation of Sodium Silicate Solution and the manufacture of Magnesium Silicate. First of all, the glass waste was washed using water and then dried and crushed. The waste glass powder was then immersed in 3 M NaOH with a mass ratio of 1:6 while it being heated at 100ºC until the water evaporated. Then, the mixture was heated at 400ºC for 4 hours to obtain solid sodium silicate. The solid obtained was added to water (H_2O) with a mass ratio of 1:10 while it was being heated again for 3 hours at 100ºC. Furthermore, it was filtered to obtain filtrate which is a solution of sodium silicate.

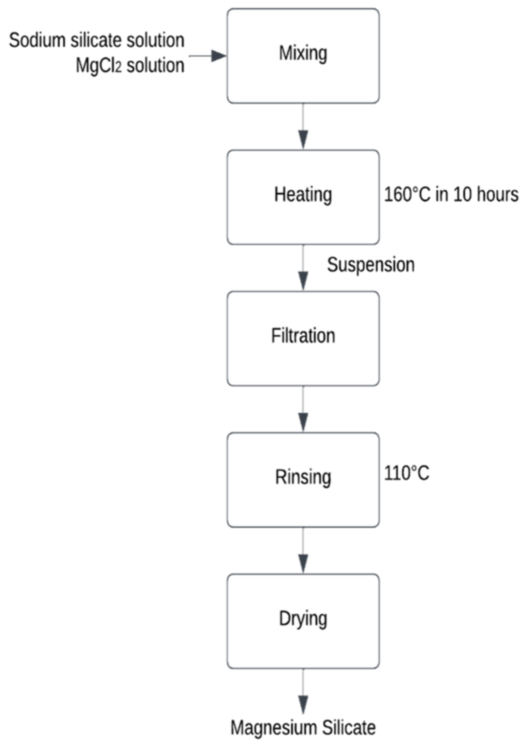

Figure 4. Stages of Making Magnesium Silicate

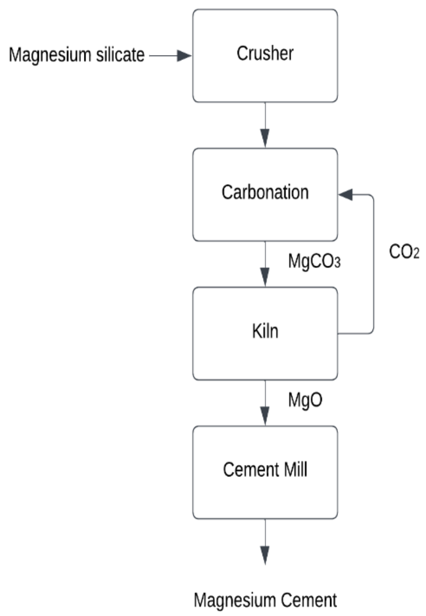

Figure 5. Stages of Making Magnesium Cement

At the stage of making Magnesium Silicate, the sodium silicate solution that has been obtained previously was added to the $MgCl_2$ solution. Then it was heated at 160°C for 10 hours until a white suspension was formed. The suspension that has been formed was then left to stand for 1 night then filtered and washed with water to a pH of 7 then dried at 110°C to obtain Magnesium Silicate ($MgSiO_3$) [10].

At the stage of making magnesium cement, it is divided into four major stages, Crusher, Carbonation, Kiln, and Cement Mill. Processing of cementitious materials based on MgO from magnesium silicate begins with the crushing and grinding of the raw material. The magnesium silicate powder was then transferred in an autoclave and carbonated with CO_2 at 180°C and a maximum pressure of 150 bar. From the carbonation process, the resulting product was $MgCO_3$ along with silica. Then, $MgCO_3$ was calcined at around a temperature of about 700°C. The CO_2 produced in the calcination process was then circulated in the autoclave to be reused in the carbonation process. Furthermore, Magnesium Hydroxycarbonate was processed from MgO and formulated to become the final product of magnesium cement [11].

III. RESULTS AND DISCUSSION

In dealing with carbon emissions generated from the cement industry in general, the author has the idea to use Carment. Carment is a concept of carbon absorbing cement based on magnesium silicate which is derived from silica and is able to reduce carbon emissions from the manufacturing process compared to the manufacture of cement in general. Magnesium cement is a new type of cement that is different from cement in general, such as Portland cement which is made from limestone with $CaCO_3$ content.

Unlike portland cement, magnesium cement has a lower production cost. In the calcination process, magnesium cement only requires low temperatures of 600-900°C compared to portland cement which requires high temperatures of up to 1600°C[6]. The process of burning raw materials that do not require a lot of energy can reduce carbon emissions produced in the combustion process and reduce cement production costs. In addition, the MgO content in magnesium cement can absorb CO_2 from the atmosphere to form various carbonates and hydroxycarbonates [6]. This has the potential to absorb a large amount of CO_2 in the hardening process. With these two interrelated aspects, magnesium cement can be an environmentally friendly cement in handling carbon emissions.

Carment can replace the cement manufacturing process in general which always produces large amounts of CO_2 through the calcination process. In the Carment manufacturing process, the CO_2 produced is then circulated in the autoclave to be reused in the carbonation process[7]. This process can reduce CO_2 emissions in the production process up to 100%[8]. This makes the cement manufacturing process free of carbon emissions.

There are two reasons for choosing glass waste as the basic material for making Carment. First, the percentage of silica in glass waste has a relatively high silica (SiO_2) content, which is more than 70%[9]. Based on data from the Ministry of Environment and Forestry (2017), glass waste produced in Indonesia reaches 1.1 million tons per year and has increased every year. Second, the price of waste glass is very low when compared to the price of new glass. This can reduce the price of making cement to be cheaper and more environmentally friendly. In addition, the use of waste glass can be an alternative solution in replacing silica precursors, which are very expensive and can be harmful to the environment.

1) SWOT Analysis

Carment is an idea that has advantages, disadvantages, and opportunities, as well as challenges that still need to be developed further. The following is an analysis conducted by the author regarding Carment through the SWOT method:

TABLE 1.
SWOT ANALYSIS

STRENGTHS	WEAKNESSES
• Ability to reduce carbon emissions in the production process up to 100% • Does not require a large amount of energy in the production process • Has the ability to absorb CO_2 from the atmosphere • Potential for waste glass as a base for cement with a silica content of more than 70% • The potential for glass waste is quite large, 1.1 million tons per year • The strength of magnesium cement can reach 28 MPa in 24 days • Cheaper price compared to cement in general • Environmentally friendly	• Implementation time is quite long • The need for large stakeholder involvement to operate
OPPORTUNITIES	**THREATS**
• Cement commodity which is the main material in the world of construction • Support the realization of SDGs points 9, 12 and 13	• Government regulations regarding the use of magnesium cement

2) Implementation of Ideas

In realizing this idea and realizing it, various related parties are needed, including

1. Researcher

The role of experts is needed to test the efficiency of reducing carbon emission of magnesium cement from glass waste. The aspect of cement that is reviewed concerns the aspect of its impact on building infrastructure and the environment as well as the efficiency of reducing carbon emissions produced during the cement production process.

2. Government

The government's role in this case is quite important, namely providing funds and making policies so that each region within a certain range can produce cement. The government is also expected to provide outreach to the glass industry to be able to collect glass waste and sell it to cement production sectors.

3. Environmental Service

The role of the Environmental Service is expected to change direction in handling carbon emissions in the cement industry, especially in cement production areas that have the potential for the glass industry. In addition, it is also hoped that it can educate the use of magnesium cement from glass waste so that the process of handling the cement industry's carbon emission problems can be more effective.

4. Glass Industry

The glass industry urgently needed to be able to collect glass waste which will be used as raw material for making cement. The glass waste that has been collected is then deposited in the cement production sectors.

5. Cement Industry

The cement industry is expected to be able to implement cement test results and implement cement products. The cement industry also receives glass waste raw materials from the glass industry.

6. Society

The role of the society is expected to be able to change direction in the use of cement in general and implement the use of Carment.

In planning and realizing magnesium cement from glass waste as a solution to the problem of carbon emission in the cement industry in Indonesia in 2045, it is necessary to formulate a structured concept. The Carment concept that was initiated will go through several stages before it can be used in handling carbon emissions in the cement industry. The stages take place over a span of 23 years starting in 2022 to 2045. These stages include the initiation stage, the construction and development stage, as well as the operational and maintenance stage.

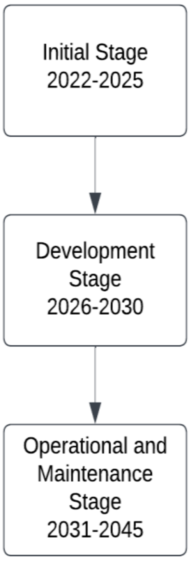

Figure 6. Planning and Realization of Magnesium Cement From Glass Waste

1. Initiation Stage (2022-2025)

The initiation stage is to initiate the preparation and maturation of Carment's concept ideas and takes place in the 2022-2025 range. The initiation phase includes various strategic steps, including:

a. Preparation of concepts
b. Preparation of basic designs and detailed designs
c. Manufacture of Carments
d. Testing of carbon emission reduction efficiency and environmental effects
e. Initiation of public-private partnerships
f. Submission of proposals and dissemination of test results.

The related parties who take roles in the initiation stage include Researchers, Government, Environmental Service, Cement Industry, and Glass Industry.

2. Development Stage (2026-2030)

The Development stage is to build and develop Carment's production sectors and take place in the 2026-2030 range. The Development phase includes various strategic steps, including:

a. Planning
b. Development of the Carment production sector, production supervision, and technology development.

The related parties who took part in the initiation stage include the Cement Industry and the Glass Industry.

3. Operational and Maintenance Stage (2031-2045)

The Operational and Maintenance phase is for monitoring, evaluating, and maintaining the Carment production sectors as well as outreach to the community and takes place in the 2031-2045 range. The Operational and Maintenance phase includes various strategic steps, including:

a. Socialization of Carment to the community
b. Monitoring and evaluation, as well as maintenance and care.

The related parties who took part in the initiation stage include the Community, the Cement Industry, and the Glass Industry.

IV. CONCLUSION

The existence of the Cement Industry today still ignores the concept of environmental sustainability which contributes quite a lot to greenhouse gas emissions. There are several solutions that have existed in overcoming the problem of carbon emissions from the cement industry, such as the Waste Heat Recovery Power Generator (WHRPG), reducing the clinker ratio through blended cement products, and using alternative fuels to replace coal. However, its existence is still quite expensive and has not been able to overcome the problem of carbon emissions resulting from the cement industry.

Carment is an innovation in the industrial sector where Carment as a magnesium cement from glass waste can solve the problem of carbon emissions from the calcination process. The availability of glass waste, which has a high availability, contains more than 70% silica and is inexpensive, increases the potential to produce magnesium cement from glass waste in Indonesia. Magnesium cement does not require a lot of energy in the combustion process, so it does not produce large carbon emissions.

This project can be a solution to address the problems of the Cement Industry where production costs from previous solutions are still quite expensive and still ignore the concept of environmental sustainability which contributes quite a lot to greenhouse gas emissions. With this concept, it is hoped that it will be able to replace the stigma of the cement industry as a large enough contributor to carbon emissions to become an environmentally friendly industry and support the target of reducing carbon emissions to generate development in the era of Society 5.0 Towards Golden Indonesia 2045.

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