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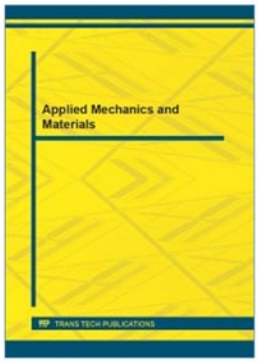

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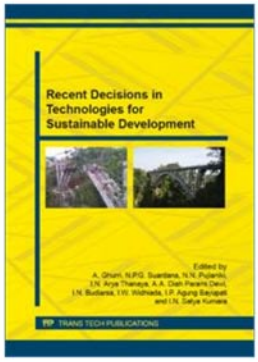

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Preface

This volume was selected from papers presented at the 3rd International Conference on Sustainable Technology Development (ICSTD Bali 2014), which have been held in Udayana University Bali during October 30-31, 2014. The conference was organized by Faculty of Engineering, University of Udayana Bali Indonesia. This conference covered wide range of engineering issues toward the achievement of sustainablility.

In order to meet high standard of Applied Mechanics and Materials, the organization committee has made their efforts to do the following things. Firstly, all submitted papers have been reviewed by 2 anonymous expert reviewers, poor quality papers have been rejected after reviewing. Secondly, periodically review meetings have been held around the reviewers about three times for exchanging reviewing suggestions. Finally, the conference organization had several preliminary sessions before the conference. Through efforts of the scientific committee and Editors team, the volume will be the best collected papers.

We would like to thank the Faculty of Engineering, University of Udayana, the member of organizing and scientific committees, and also to TTP publisher.

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Determination of Optimal Clinker Factor in Cement Production by Chemical Grinding Aids Addition

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Keywords: cement, clinker factor, grinding aids, Agglomerate

Abstract. The cement industry has remarked as an intensive consumer of energy. The amount of energy consumed in the cement manufacturing has a correlation to the increasing of CO2 emission. It is reported that the cement Industry has contributed to 5–7% of the total CO2 emission in the world. Thus, there is a need to make an innovation in order to overcome the environmental problem. One of effort can be made is by using chemical grinding aids (CGA) as an additive material in the cement production process. This study aimed to determine the optimal clinker factor of the cement production by the addition of chemical grinding aids (CGA). The experiments are conducted in PT Semen Padang consisting of four variable of the clinker factor without CGA and with CGA addition 300 ppm. The clinker factor varies from 78.3% to 72.9%. The results show that the optimal clinker factor is at 74.5% with the CGA addition 300 ppm. It can improve the cement fineness to 3848cm2/gr and decrease the sieving R45μ to 10%. In addition, the strength of the cement produced is higher than the standard. The findings show the chemical grinding aids (CGA) addition in the cement production process can reduce the clinker factor as well as reducing the CO_2 emissions. It can aid the cement industry to achieve the higher performance in green manufacturing and so as to increase the competitiveness.

Introduction

Sustainability has become an important issue amongst industries worldwide. Many industries are directing their resources to minimize the environmental impact of their products and operations. Achieving sustainable manufacturing has been regarded as a critical need due to diminishing non-renewable resources, stricter regulations related to environment and occupational health and safety, and increasing consumer preference for environmental-friendly products [1]. It has been reported that those industries adopting sustainable practices are able to achieve better product quality, higher market share, and increased profits [2]. Sustainable manufacturing implementations have also been seen to be positively associated with competitive outcomes [3]. Therefore, developing sustainable approaches to manufacturing industries have been regarded as a critical global concern [4].

The cement industry is one of the most strategic industries since cement, as the most important ingredient of concrete, is a fundamental building material for society's infrastructure construction around the world [5]. However, its products and processes are a significant source of environmental impact. Cement plants are characterized as an intensive consumer of natural raw materials and fossil fuels, and has remarked as emitters of pollutants [6, 7]. Furthermore, the cement industry has been regarded as one of the most energy intensive consumers amongst industries in the world [8].The milling process of cement production needs the electrical supply about 2% of the total electrical consumption in the global scale. Of those, the clinker grinding process need 1/3 of the total electrical used to produce pertonne of cement. It can be concluded that the average electrical consumption of the cement production is 57 kWh/ton [9] and the CO_2emission released from the power generator is 9.1 CO_2/ton [10]. Thus, the amount of energy consumption has a proportional correlation with the CO_2 emission produced in the cement production. The cement Industry has contributed to 5–7% of the total CO_2 emission in the world [11].

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Nowadays, the cement industry is become one of target industries in reducing the CO_2 emission globally. Many efforts have been conducted to reduce the CO_2 emission of the cement production, such as using alternative renewable fuel, and developing eco-efficiency technology [12]. However, it still limited to reduce CO_2 emission only. Hence, it is needed an innovation to optimize the CO_2 emission reduction. In this study, the chemical grinding aids are used to reduce the clinker factor. Clinker factor is one of the parameter of the cement quality. In the cement production, if the clinker factor is decreased, then the energy consumed is also reduced. The reduction of energy consumption indicates the reduction of CO_2 emission produced. This paper analyzed the effect of the chemical grinding aids addition of the cement production in PT Semen Padang in order to determine the optimum clinker factor and so as to reduce CO_2 emission.

Chemical Grinding Aid

The grinding aid used in the cement production aimed to degrade the particles (*ball coating*) of clinker which attach in the grinding media (steel balls) during the clinker mill process. The particles attached at the grinding balls are proved that there are electrostatic force between the cement particles and the steel balls. As the results, the cement particles will bonds together, which effected to decrease the efficiency of mill process. The phenomena are shown by the increasing of energy consumption in order to maintain the fineness constant [13].

There are several kind of grinding aids are commonly used in the mill process such as amine alifatic like triethylenetetramine (TETA), tetraethylenepentamine (TEPA), and aminealcohols called dietanolamine (DEA), trietanolamine (TEA) and triisopropanolamine (TIPA); glycol compounds like ethyleneglycol (EG), diethyleneglycol (DEG) [14]. Besides, there are more complex compounds such as aminoethylethanolamine (AEEA) and hydroxyethyl diethylenetriamine (HEDETA). Fenol and its generations are also can be used as the grinding aids. Generally, the concentration of grinding aids added is 50–500 ppm [15]. In the cement Industry, tertier amine (TIPA) is commonly used as the grinding aids. The addition of several amount of TIPA in the cement production will significantly increase the cement strength level [13].

The addition of grinding aids in order to remove the ball coating in the cement mill can increase the effectivity of mill process, so that the cement fineness can be achieved and the cement quality will increase. Subsequently, the higher cement quality produced then the clinker factor can be reduced , so that the production cost can be lower, the CO_2 emissions can be decrease, and the company can achieve the concept of green industry according to company's vision.

Green Industry

Green industry is a term introduced at International Conference on Green Industry in Asia held in Manila, Philipine in 2009, conducted by United Nations Industrial Development Organization (UNIDO), United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), United Nations Environment Program (UNEP), International Labour Organization (ILO), and participated by 22 countries including Indonesia. One of the outcomes of the conference is a document of Manila Declaration on Green Industry in Asia. The document is nonlegally binding, and is the commitment of all Asian countries in order to overcome the environmental problem through the efficiency of natural resources utilization and the reduction of carbon emissions especially in the industrial sector. The efficiency of natural resources can be conducted by applying the 3R (reduce, reuse, and recycle) which are the concept of the cleaner production. The low carbon can be achieved by applying the CO2 emissions reduction which is similar to Clean Development Mechanism (CDM), energy efficiency, and diversification to develop the renewable energy. Green industry is a commitment of all industry to reduce the effects into environmental resulted from the production processes and the products produced through the efficiency of natural resources utilization continuously, and applying the low carbon into the raw material selection, the production processes, andthe products and services of the all industry activities.

Green industry is an environmental management program in the industry which considers the environmental aspect at every company's activities, products and services, and causing the continual important environmental effect. It related to the efforts to overcome the environmental contaminations and to conduct the environmental protections for the purpose of environmental balancing in the present and the future.

PT Semen Padang

This study conducted in a cement manufacturing company located in Padang, Indonesia. Established in 1910, PT Semen Padang is the first cement manufacturing plant in Indonesia. Currently, the company has four plants with a total of production capacity of 7,300,000 tons per year. The raw materials used in the cement production processes consisting of lime stones, silica stones, clays, and iron sands in a determined composition are mixed into raw mill to produce raw mix which homogenized in a cement silo. The raw mix is fed into the kiln system for the purpose of calcinations, and clinkering process at ± 1450^{o}C and subsequently be cooled (quenching) in a cooler until the clinker temperature decrease to ± 100^{o}C. The clinker is then milled in the cement mill with the another additive materials (gypsum, lime stone, and pozzoland) to produce cement.

The cement demand is increase as the population increment. It is estimated that the cement consumption of the world especially in the developing countries will be highly increased in year 2050 [12]. If the cement productions increase, then the requirement of natural and energy resources will be increased. It will become a challenge for the cement industry, in order to increase the cement production with the more limited availablity of the natural and energy resources.

PT Semen Padang has a highly commitment to develop the concept of green industry, which reflected in the company's vision and mission. The vision of PT Semen Padang is to become a great, preminent, and environmentally benign cement company in West Region of Indonesia and South East Asia Region. The mission of PT Semen Padang is powering, developing, and sinergizing the company resources environmentally benign. In order to achieve the company's vission and mission, PT Semen Padang develop an integrated management system as the guidance for all company's activities, and transformed into nine aspects consisting of effectivity and efficiency, sustainability and innovation, quality, occupational health and safety; environmental, security, legally, data accuration, and corporate social responsibility. These nine aspects become the requirements for all business process applied in the company.

Methodology

Materials. The experiments are conducted in the cement mill of PT. Semen Padang. The materials used consisting of clinker, gypsum, and the additional materials consist of lime stone, and pozzoland.

Experimental Variables. The independent variable used in the experiment is the clinker factor. The experiments are conducted in four variable of the clinker factor consisting of one experiment without CGA and three experiments with CGA. The first experiment is conducted without the CGA addition with the clinker factor of 77.8%. The subsequent three experiments are conducted with the clinker factor varies from 78.3% to 72.9%. The details can be seen in Table 1.

Table 1. Independent variables of experiment

Type	Clinker factor	CGA
1	77.8 %	(-)
2	78.3 %	(+)
3	74.5 %	(+)
4	72.9 %	(+)

Note: (-) : Without CGA
(+) : With CGA

The controlled variables used in the experiment consisting of CGA, lime stone, pozzoland, gypsum The descriptions of the controlled variables can be seen in Table 2.

Table 2. Controlled variables of experiment

Variables	Descriptions
CGA	300 ppm (1L/minute)
Limestone : Pozzoland	1 : 1
Gypsum	3 %
Feeding	200 tph

Experiment Procedures.

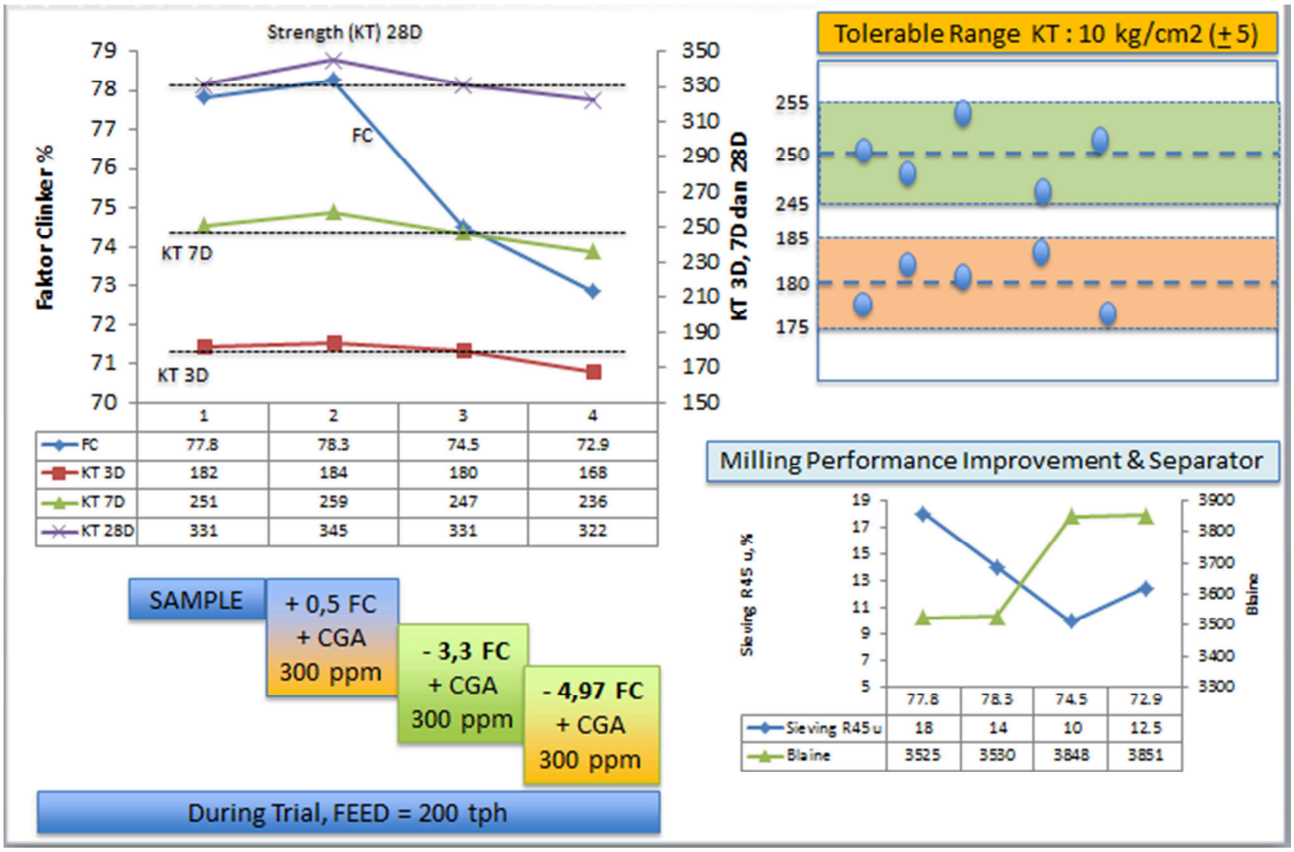
The main material required in the experiment is the clinker at the determined composition (as shown in Table 1). The clinker is grinded with gypsum and the additional materials of lime stone and pozzoland at the determined composition (as shown in Table 2). During the grinding process, the CGA is added with 300 ppm (1 L/minute). The results of the experiment is analized for every one hour and then accumulated for one day in order to check the product quality.

Results and Discussions

The Fig.1 shows the results of experiment. The first experiment with the clinker factor of 77.8% and the sample without CGA, resulting the cement fineness at 3525cm2/gr and the sieving R45µ at 18%. The results show that the sample with the factor clinker of 74.5% (lower than sample without CGA) and with the CGA addition 300 ppm has optimized to improve the cement fineness at 3848cm2/gr and decrease the sieving R45µ at10%. In addition, the strength of the cement is still higher than the standard.

From the results, it can be concluded that the grinding aids addition has affected the clinker factor. The addition of chemical grinding aids (CGA) into the clinker mill is aimed to reduce the hydrostatic force and to minimize the agglomeration of cement particles which occur during the cement production process [8,16]. Grinding aids used in this experiment can increase the cement fineness and the cement strength. In this research, the CGA has added at the same concentration. The results show that the clinker factor is decrease as the CGA addition. The correlation between the clinker factor with the cement strength is vice versa. Furthermore, the higher clinker factor is reduced, the cement strength produced will be increased. Fig. 1 shows that the optimal value of cement strength is at 74.5% of the clinker factor, which is at the maximum range of the clinker factor referred to Indonesian National Standard (SNI).

In the clinker grinding process, most of the grinding media (cement mill) have a low efficiency. The cement particles can attached at the wall of the cement mill, covering the amour plating and can affect the agglomeration of cement particles. It needed the higher energy to destroy the agglomerated particles inside the cement mill. With the addition of grinding aids into the cement mill can reduce the agglomeration inside the cement mill and improve the effectivity of the mill process, so that the cement fineness can be increased and the cement quality produced can be improved. The higher cement quality produced, the clinker factor can be reduced and so as the CO_2 emission can be reduced.



	1	2	3	4
FC	77.8	78.3	74.5	72.9
KT 3D	182	184	180	168
KT 7D	251	259	247	236
KT 28D	331	345	331	322

	77.8	78.3	74.5	72.9
Sieving R45 u	18	14	10	12.5
Blaine	3525	3530	3848	3851

Fig 1. Results of chemical grinding aids addition

Conclusions

This study has determined the clinker factor of the cement production by chemical grinding aids addition. The results show that the optimal clinker factor is at 74.5% with the CGA addition. The findings suggest the CGA addition in the cement production process can improve the grinding quality which affect to the decreasing of clinker factor but the cement quality produced remain as the standard. The clinker factor is one of the parameter influencing the quality of cement product. The lower of the clinker factor is utilized then the cement quality produced will be higher. From the results, it can be concluded that the grinding chemical aids (CGA) addition can reduce the agglomeration occurs during the cement production process. The lower agglomeration can increase the cement fineness and have linear correlation with the cement quality. Subsequent, at the higher cement quality, the clinker factor can be reduced and the CO_2 emissions are also decreased.

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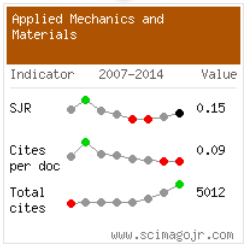

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SJR indicator vs. Cites per Doc (2y)

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The SJR indicator measures the scientific influence of the average article in a journal, it expresses how central to the global scientific discussion an average article of the journal is. Cites per Doc. (2y) measures the scientific impact of an average article published in the journal, it is computed using the same formula that journal impact factor ™ (Thomson Reuters).

Citation vs. Self-Citation

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Evolution of the total number of citations and journal's self-citations received by a journal's published documents during the three previous years.

Cites per Document vs. External Cites per Document

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Evolution of the number of total cites per document and external cites per document (i.e. journal self-citations removed) received by a journal's published documents during the three previous years.

Cites per Document in 2, 3 and 4 years windows

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Evolution of Citations per Document to a journal's published documents during the two, three and four previous years. The two years line is equivalent to journal impact factor ™ (Thomson Reuters) metric.

International Collaboration

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International Collaboration accounts for the articles that have been produced by researchers from several countries. The chart shows the ratio of a journal's documents signed by researchers from more than one country.

Journal's Citable vs. Non Citable Documents

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Not every article in a journal is considered primary research and therefore "citable", this chart shows the ratio of a journal's articles including substantial research (research articles, conference papers and reviews) in three year windows.

Journal's Cited vs. Uncited Documents

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Ratio of a journal's items, grouped in three years windows, that have been cited at least once vs. those not cited during the following year.

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