STUDY ON STEEL DUST AS FILLER MATERIAL IN CEMENT BASED MASONRY

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ABSTRACT

Portland composite cement is a cement with a wide range of application in various concrete building projects, due to its good strength performance for both general purpose and structural concrete applications. With a composite material that combines concrete with steel reinforcements, it provides a strong, durable building material that could cater for both compressive and tensile stress. Disposal of waste materials has become a major concern, where its process should be done with an appropriate way without giving negative effect to the environment. One example of this industrial by-product is steel dust, the by-product of refining metals and making alloys. This study deals with the experimental investigation on strength gaining characteristics of masonry with the addition of steel dust. The purpose of the study was to identify the optimum proportion of steel dust and analyse its effect to the compressive strength of masonry bricks. Compressive strength of masonry bricks is considered as a suitable measure to determine the rate of strength gain of bricks with age and different addition of steel dust composition. The steel dust used in the research was obtained from steel industry Kuantan Wire Products Sdn.Bhd in Semambu, Kuantan. There were five different dosages of steel dust in the mortar mix that was based on the volume fraction of fine aggregate, which were 0, 2.5, 5, 7.5, 10% (0, 35, 70, 105, 140 kg/m^3). Based on the experimental results, particle size distributions of aggregates with the inclusion of steel dust presented insignificant effect to the compressive strength of cement brick. However in the workability test, inclusion of steel dust had a significant effect on the wet mixture and showed the fluctuated trend. Brick with 5% of steel dust inclusion has a higher compressive strength than others mixtures. For porosity test the brick with 5% of steel dust has lowest permeable space voids than others mixture. Conclusively, compressive strength and porosity performance of cement brick have shown the good potential of steel dust as filler in this construction material.

ABSTRAK

Simen Portland komposit adalah simen dengan pelbagai aplikasi dalam pelbagai projek bangunan konkrit, disebabkan oleh prestasi kekuatan yang baik untuk kedua-dua tujuan awam dan aplikasi konkrit struktur. Dengan bahan komposit yang menggabungkan konkrit dengan tetulang keluli, ia menyediakan, bahan bangunan tahan lama kuat yang boleh menampung kedua-dua tekanan mampatan dan tegangan. Pelupusan bahan sisa telah menjadi perhatian utama, di mana prosesnya perlu dilakukan dengan cara yang sesuai tanpa memberi kesan negatif kepada alam sekitar. Sebagai salah satu contoh, habuk keluli adalah sisa buangan industry dari penapisan logam dan membuat aloi. Kajian ini berkaitan dengan siasatan ujikaji kekuatan mendapat ciri-ciri batu dengan tambahan habuk besi. Tujuan kajian ini adalah untuk mengenal pasti bahagian yang optimum habuk keluli dan menganalisis kesan kepada kekuatan mampatan bata batu. Kekuatan mampatan bata batu dianggap sebagai langkah yang sesuai untuk menentukan kadar keuntungan kekuatan bata dengan usia dan tambahan berbeza komposisi habuk keluli. Habuk keluli yang digunakan dalam kajian ini telah diperolehi daripada industri keluli Kuantan Wire Products Sdn.Bhd di Semambu, Kuantan. Terdapat lima dos yang berbeza habuk besi dalam campuran mortar itu adalah berdasarkan kepada pecahan isipadu pasir 0, 2.5, 5, 7.5, 10% (0, 35, 70, 105, 140 kg / m3). Berdasarkan keputusan eksperimen, saiz zarah taburan pasir dengan kemasukan habuk keluli dibentangkan kesan yang tidak ketara kepada kekuatan mampatan bata simen. Namun dalam ujian kebolehkerjaan itu, kemasukan debu keluli mempunyai kesan yang besar ke atas campuran basah dan menunjukkan trend yang berubah-ubah. Bata dengan 5% daripada debu keluli kemasukan mempunyai kekuatan mampatan yang lebih tinggi daripada yang lain campuran. Untuk menguji keliangan bata dengan 5% daripada debu keluli mempunyai lompang ruang terendah telap, % daripada campuran lain. Muktamad, kekuatan mampatan dan keliangan prestasi bata simen telah menunjukkan potensi yang baik debu keluli sebagai pengisi dalam bahan binaan ini.

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LIST OF SYMBOLS

%	Percentage
mm	Millimeter
N/mm^2	Newton per millimeter square
kg	Kilogram
kg/m^3	Kilogram per meter cube
kN	Kilo Newton
℃	Degree Celsius
∑	Sum
w/c	Water to cement ratio
mm^2	Millimeter square
min	Minute
µm	Micrometer
MPa	Mega Pascal
m^2/kg	Meter square per kilogram
m^3	Meter cube
g	Gram
Mg/m^3	Milligram per meter cube
ρ	Density of water

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BS	British Standard
BOF	Basic Oxygen Furnace
EAF	Eclectics Arc Furnace
LF	Ladle Refining
WEPA	World Environmental Protection Agency
CPC	Composite Portland Cement
YTL	YTL Corporation Berhad
JKR	Jabatan Kerja Raya

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The concrete as the main construction materials in the constructions, as the demands of the concrete increases, the demand of Portland cement and others filler also increases. Concrete is a good common to high compressive strength and low maintenance with long service life compared to other construction material like timber. Steel also one type of construction material used in construction project or infrastructure. Unfortunately, the production of Portland cement and steel also give the serious impact to earth surface environment, it generated by-product such as dust, fly ash, slag, sludge and other similar waste. This waste without proper way to deal with it, directly giving hazards to the environment and human health. To reduce the impacts to the environment, the engineers try to figure out deal with it or reused the by-product as filler to replaced construction materials.

Today, in Malaysia and other countries who still in developing required the great demand of construction materials such as cement, aggregate, timber, steel and similar materials for civil engineering industry, especially for concrete construction and infrastructural. With higher demand of construction materials directly burst the mining, steel, cement and other industries to fulfil with the demand of it. Hence, by-product of the industries either increases, required more space or land to store it or deal with it. Those by-products giving the direct impact to earth environment and human health, without a proper way of disposing it. Used the waste material to produce a useful product has become a great main solution to disposal problems (Hassan Y. Ahmed et al., 2006). With utilize by-product such as steel slag as filler to replace aggregate for road construction and hydraulic engineering constructions has given the good replacement. (H. Motz et al., 2001). The suitability of the by-product has to be proven by the technical properties with environmental compatibility, depending on the repetitive field that apply (H. Motz, 2001). The application of steel slag use as rail ballast and bridge construction was encouraging. Fully utilized of the by-product able provide a guarantee a caution and efficient use of the natural resources, improves the environment quality and minimized human health (H. Motz, 2001). Figure 1.1 Show production and utilization of natural aggregates and industrial by-product/ co-product in Germany 2001. From the figures show, the utilization of by-product and waste materials was lower, compare to natural aggregates and gravel. Thus, the Germanic countries of the respective industry are concentrated on increasing the utilization rate of industrial by-products and recycling materials. With increasing of the utilization rate of industrial by-product and recycling materials can reduce the production of the natural aggregate and gravel to save more natural resources.

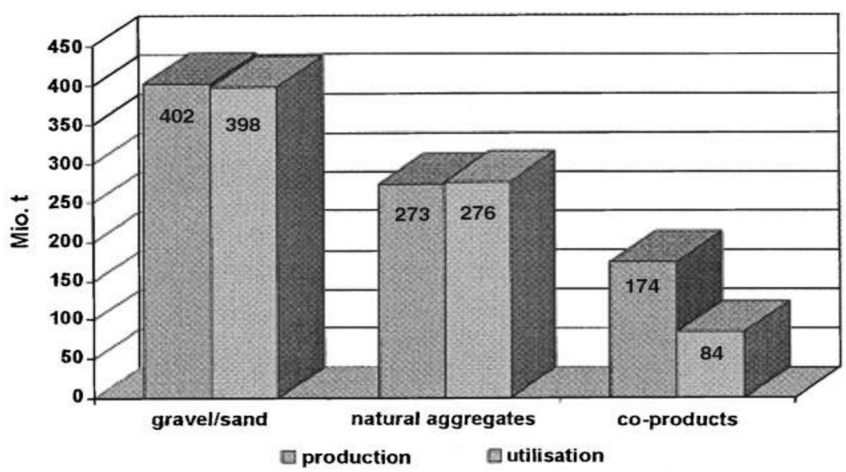

Figure 1.1: Production and utilization of natural aggregates and industrial by-product/ co-product in Germany 2001.

Source: H. Motz (2001)

1.2 PROBLEM STATEMENT

Concrete or cement based masonry basically as the building materials for most domestic or complex construction projects. With advanced technology for today, some of the building was constructed with combined concrete and steel to enhance the strength and durability of the building. Therefore, the demand of steel in the construction fields also almost same with the concrete. At the same time, the problem of the disposing of waste materials such as steel dust, slag, fly ash and other similar things produced by different industries, becoming a major concern since it required more land to keep it and create environmental hazards. With an estimated, more than 100 million tons of mineral waste were being produced and deposited on the earth's surface by the mining industries. Besides that, wastes the generated by steel industries such as dust, sludge and slag about 20 million tonnes for every year. To overcome the above mentioned problems, steel dust from steel industry used as filler to the construction material. In this study, carried out the experimental work to analyse the effect of steel as filler on cement based masonry by replacing the weight of fine aggregate to determine steel dust can enhance the performance of bricks.

1.3 OBJECTIVES

The research objectives of this study are:

i. To determine workability, compressive strength and porosity of masonry bricks containing steel dust.
ii. To identify the optimum replacement for steel dust to fine aggregate in masonry bricks.

1.4 SCOPE OF STUDY

The waste materials as steel dust the main character in this research as filler in the masonry bricks mix to produce cement based bricks. This study will focus in 5 mix proportion of mortar mix, the amount steel dust of the mix was 0, 2.5, 5.0, 7.5 and 10 % replaced by the weight of the fine aggregate. The cement used in this research from YTL Castle general purpose cement (CEM II / B-L 32.5 N). Fine aggregate used river sand with sieve according ASTM C33-08. The test included workability, compressive strength and porosity. The sample size used in this research was 200mm x 100mm x 60 mm formwork mould. All the mix was tested with workability and proceed with the casting. The masonry bricks cured in the water tank after removing from the formwork mould until the tested age. Entire sample tested at the age of 7 days, 14 days and 28 days for compressive strength and 28 days for porosity.

1.5 RESEARCH SIGNIFICANCE

The steel dust as a waste product from factory industry, without proper way to deal with, it caused environment pollution and harmful to human health also. The purpose of this research to investigate the effect of the steel dust as filler in cement based masonry with optimal addition, replacement content can enhance the performance of the bricks properties.

The steel dust is added into the masonry mix with the different percentage content, expected the masonry bricks of behaviour such as strength and durability will become better than control bricks. The potential use of steel dust as filler in cement based masonry be accepted. This research applied to become a reference for the future researcher to compare the data and help them for further research into related materials as filler for cement based masonry.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter was explained about the literature of the waste materials as filler to replace the aggregate for concrete, masonry bricks or similar product. The chapter consists of two sub-section included the waste materials as filler to replace aggregate in concrete or masonry bricks and the performance of the waste materials added to concrete or masonry bricks.

2.2 TYPE OF FILLER AND ITS FUNCTION

Fillers are particles or small materials added to the main material to lower the consumption of binder materials or enhance the properties of the mixture materials. The researchers (H. Moosberg-Bustnes et al., 2004) defined the fillers are the materials that gave function to the concrete with based on the size and shape. The function of it to enhance the particle packing and provided fresh concrete with other properties, provided same or higher strength of the concrete by reducing the amount of the cement content in the concrete. Or another explanation, filler such as a finely-ground material which similar with the Portland cement fineness, giving direct effect to concrete in term of workability, density, permeability and capillarity (Neville, A.M et al., 1995). With other researchers (Afifa Rahaman et al., 2012) stated normally fillers that used for concrete such as cement , lime, stone dust and other similar materials. Fillers divided into 2 group which is non-conventional and conventional.

2.2.1 Steel Slag

Steel slag defined as by-product of the metal or steel making, it was produced during the separation of the molten steel from impurities in steel making furnaces. About the (10-15% of the steel slag will produce during the steel making furnaces (J. Gokul et al., 2012). The steel slag divides into three major types during the steel production, which are basic oxygen furnace (BOF), electric arc furnace (EAF) and Ladle Refining slags (LF) (Meng, H.D et al., 2009). The BOF slag consists of a silica range between from 8-22%, the iron oxide (FeO/Fe_2O_3) of a BOF will have high value about 35% (Ebenezer, A.O et.al, 2014). With the type of steel, steel slag also can be either stainless steel or carbon steel slag. The steel slag can be processed into fine or coarse aggregate which, according to the field that apply in. This type of waste materials has higher performance in many applications compared to natural materials (Guptha, K.G. et al).

Steel slag provided excellent bond in asphalt concrete and enhance the skid resistance in road materials. Thus, the aggregate used in construction industry come from natural resources, with used the steel slag replaced the aggregate reduce consumption of resources an better option to protect the environment resources (Guptha,K.G. et al ;H. Motz et al., 2001). Unfortunately, the problem that arises from the used of steel slag in the road or highway construction, that is no standard or specification with respect to the usage of steel slag in the globe. Thus, the steel slag should be used with caution and alert with standard and specification should be developed for its use in road or highway construction. From the previous research, steel slag was confirmed that harmful waste materials by industries, without an appropriate way to deal with it, we'll bring negative impact to human health and the environment. For safety purpose, the slag should be stored in an open space about 3 months at least before use. In 2006, use of steel slag has applied in several fields, about 51% the steel slag use in road passes and surfaces, 12 % in asphaltic concrete, 12 % miscellaneous, 18 % use as fill and the last 7 % use as clinker raw materials. Figure 2.1 Show the use of steel in different field in 2006.

Table 2.1: Physical properties of steel slag

Testing	Steel Slag (%)	JKR Specification (%)
Aggregate Crushing Value	26.05	<30
Los Angeles abrasion	9.80	<30
Aggregate Impact Value	17.20	-
Flakiness	4.00	<30
Soundness	ND	<18
Polished stone value	56.60	>40
Water absorption	1.20	<2
Stripping	>95	>95

Source: Ebenezer Akin Oluwasola (2014)

Table 2.2: Chemical properties of BOF and EAF particle in percentage.

Component	Basic Oxygen Slag (%)	Electric Arc Slag (%)
CaO	45-60	30-50
Al_2O_3	1-5	10-18
SiO_2	10-15	11-20
MgO	3-13	8-13
Fe_2O_3	3-9	5-6
FeO	7-20	8-22
MnO	2-6	5-10
P_2O_5	1-4	2-5
TiO_2	-	-

Source: Huang (2012)

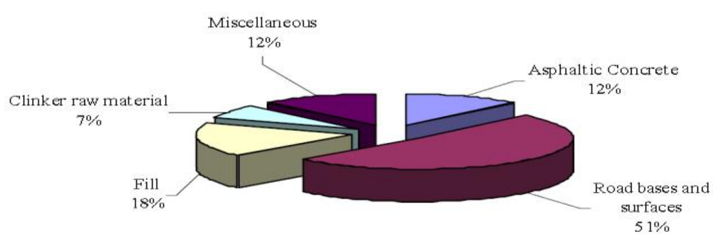

Figure 2.1: Use of steel slag in 2006

Source: Ebenezer Akin Oluwasola (2014)

2.2.2 Steel Dust

Steel dust is a by-product of cutting, drilling or other similar method in the steel making industries. It consists mainly of fine powder form with crystallizes due to cutting and drilling size of steel demand by industries or by-product of steel making after furnace. The steel dust will deposit on the machines, plates and collected by specially designed bag filters. An approximately 1% of the steel dust will produced during the steel manufacturing processes. With the research survey about more than 70 % of steel dust will be sent to landfill, for the remaining will reuse and process for other purposes. World Environmental Protection Agency (WEPA) has considered the steel dust as a hazardous materials due to reachability of heavy metals to the environment require to dispose immediately to stabilize it. To solidify and stabilize the steel dust it can be added the cement or cementations materials (M. Maslehuddin et al., 2009). Thus, during the experimental work in this research while handle with the steel dust required to wear personal protective equipment with mask as mentioned before steel dust is a hazardous materials that can be harmful to human health.

2.2.3 Quartz Filler

The researcher H. Moosberg, 2004 used the quart filler in the research with three different type which is M300, M500, M600 from SIBELCO S.A and by-product from processing industry. The M6000 filler will give the pozzlanic effect to the concrete after a long period time, the short-term strength of the concrete will not affect by the reaction.

2.2.4 Limestone Powder

Limestone is sedimentary rocks primarily of calcium carbonate, generally obtained from the calcareous of the dead body of marine either fresh water organisms embedded in calcareous mud (Tarun, R.N. Et al., 2003; Lea, F.M., 1971). The researchers stated by A. Jayaraman, 2014; Tarun R.N. et al., 2003) used on limestone as concrete aggregate has been suspected unstable due to the poor grade rocks, it has less resistant to fire compared to other concrete with others aggregate. With the suggestion of the previous researcher line stone are not suggested as aggregate to the concrete structure building.

Table 2.4: Chemical properties of limestone powder particle in percentage.

Component	Limestone powder (%)
SiO_2	1.81
Fe_2O_3	0.23
Al_2O_3	52.38
CaO	1.68
MgO	0.26
SiO_2	0.26
Blaine specific surface [m^2/kg]	390

Source: A.Jayaraman (2014)

2.2.5 Alumina Filler

Alumina filler waste usually generated during the valorisation aluminium salt slags. The Aluminium Foundries plant was generating the by-product of salt slag, where the salt required to undergo for smelting process, during the process the alumina filler generated as well also. The researchers L. Miqueleiz, 2013 targeted this type of filler can replacement of clay to the unfired bricks production.

Table 2.5: Chemical properties of alumina filler waste in percentage.

Component	Alumina filler waste (%)
CaO	1
$Ca(OH_2)$	-
MgO	6
Al_2O_3	70
SiO_2	8
Fe_2O_3	-

Source: Miqueleiz (2013)

2.2.6 Coal Ash

Coal ash generated at the fired coal power plant after the combustion of materials. The coal ash was recommended by the researchers L. Miqueleiz, 2013 as a main material for brick production due to its availability. With the full utilization of coal ash to construction material can reduce the environmental impact.

Table 2.6: Chemical properties of coal ash waste in percentage.

Component	Coal ash waste (%)
CaO	1
$Ca(OH_2)$	-
MgO	1
Al_2O_3	28
SiO_2	52
Fe_2O_3	11

Source: L. Miqueleiz (2013)

2.2.7 Saw Dust

Saw dust or called as wood dust is a by-product of cutting, drilling or other similar method to the timber materials. The main used of the saw dust as main materials of the particleboard. The saw dust significant give effect to the concrete or cement based bricks based on strength, durability and suitability with the cement to saw dust ratio, size and shape of it (A. Ziziwa et al., 2006; Sorfa 1984; Wolfe and Gjinolli, 1999)

2.3 PREVIUOS RESEARCH OF FILLER ON HOT MIX ASPHALT CONCRETE

With the investigative research by Hassan Y. A. et al., 2006 cement dust replaced the limestone filler by the weight proportion in the hot mix asphalt concrete. With the laboratory testing, cement dust has enhance in Marshall and mechanical properties of asphalt concrete mixes. The tensile strength and compressive strength of the sample increases as the cement dust ratio increase. The flow values, void ratio and gap between aggregates also with a significant decrease as the cement dust ratio increase. Thus, the author mentioned waste materials with full utilize has environmental advantages and reduce waste pollution.

Steel slag replacement as aggregate in hot mix asphalt also getting attention from the civil engineering fields. Due to steel slag of its characteristic almost similar to the conventional aggregates. The result obtains from the research, the steel slag mixture has a higher value than a conventional mixture in term of optimum bitumen content (Hainin et al., 2012). For the resilient modulus results show the steel slag mixture has higher value compared to normal aggregate mixtures. In terms of creep test, steel slag also shows lower permanent deformation and strain compared to normal aggregates. The researcher found that the interlocking properties of steel slag give greater impart adhesion to the mixture, and researcher suggests the steel slag used as an aggregate replacement for friendly environment development in highway construction.

2.4 PREVIOUS RESEARCH OF FILLER ON CONCRETE

With another research carry out by A. Jayaraman et al., 2014 use the combination of lateritic sand and limestone filler replaced the fine aggregate in the concrete mixes. The compressive strength and tensile of concrete found increase with age as normal concrete. The combination of lateritic sand and limestone filler with 3 proportion - 25 % lateritic sand to 75% limestone filler, 50 % for both lateritic sand and limestone filler and 75% of lateritic sand to 25% limestone filler. Hence, the author finds out the strength of properties of compressive or tensile for the proportion of 25% literate sand to 75% limestone filler has higher value compared to others in proportion. The researcher, by Tarun R. Naik et al., 2003 investigate the limestone powder as filler to concrete. With the study, the addition of limestone to Portland cement causes the increase of hydration of concrete or mortar at early ages, including the earth strength, but the later strength will drop due to dilution effect. The porosity of the concrete decrease in the early age due limestone increases the heat of hydration in the concrete.

In India, J. Gokul, 2012) carries out and experimental work and prove the mild steel slag can be as a replacement for concrete aggregate. The compressive strength of mild steel slag has excellent the normal natural aggregate. An addition of mild steel slag as fine aggregate has improved the interlocking and mechanical properties of the concrete mixes. The stiffness of the concrete model were being is improved by the use of the fine crushed mild steel slag. With this application, the concrete blocks or concrete can be produced with lost cost with high strength and durability.

For other research that carry out (Mohammed Nadeem et al., 2012) which replaces the coarse and fine aggregate with steel slag (crystallized and granular). The research carried by the steel slag with crystallized replace the coarse aggregate in the mix with normal, natural river sand, while for steel slag with fine granular replace the fine aggregate in the mix without change others materials. The result shows the compressive strength of concrete increased by 4% to 6% for replacement of both coarse and fine aggregate of 30 % to 50%. But the compressive strength of 100% replacement of coarse aggregate with increasing 5% to 7%, for fine aggregate 100% replacement causes the strength decrease 7% to 10%. While for full replacement of the coarse aggregate improve the flexure and split strength of the mixes about 6% to 8%. The result shows the improvement due to the rough surface texture which create strong bonding and adhesion between aggregate and cement binder.

For steel slag to be modified and used as a clinker addition to the cement industry, with the research result come out defined the compressive strength of the concrete with addition steel slag up to 30% volume, mass where the value within in Grade 325 and 425 with Portland cement based (Hassan et al., 2008). While the author proves the use of slag can minimize the risk of cracking in the concrete for structural building. From the research, a suitable or optimal addition steel slag just can enhance the concrete properties such as size of fraction and addition steel slag volume fraction. The author tested with addition steel slag up 50% the result of the test for compressive strength was decreased due to the increases in the total porosity percentage and average pore diameter retard the hydration process resulting the prevention of filling of the pore by hydration products of cementitious materials (Hassan et al., 2008).

2.5 PREVIOUS RESEARCH OF FILLER ON BRICKS

The alumina filler waste replaces the clay to produce unfired brick production, carry out by the L. Miqueleiz et al., 2013. The alumina waste has potential to replace clay to produce bricks, but for unfired test has low performance compared to unfired clay bricks. While for another test like strength, resistance and water absorption value were within acceptable limits for masonry units. The composite bricks by using saw dust as one of the materials does not qualify for use as high strength external construction materials, since their strength is considerably low and it structurally highly affected by damp conditions (A. Ziziwa et al., 2006). The composite bricks with sawdust can be used for interior wall and decoration that with low damp conditions environment

2.6 PREVIOUS RESEARCH OF STEEL DUST ON CONCRETE

With some studies, conduct on the use of electric arc furnace dust in concrete have indicated that improves the mechanical properties of fresh and hardened concrete. A 15-30% Increase in the 7 and 28days compressive strength of concrete with an addition of steel dust (M. Maslehuddin et al., 2009). While with an addition of steel dust with an optimum percentage can enhance the performance of concrete, the author done the experimental work and given the prove addition of 7-15% steel dust enhance the concrete properties, however more than 20 % was not given the benefit to the concrete properties. With an addition of steel dust (electric arc furnace dust) has given a significant delay in the setting time of the concrete (M. Maslehuddin et al., 2009; Carlos Alberto Caldas de Souza et al., 2010). The addition of steel dust fresh concrete giving benefit in concreting operation with the hot condition weather due to the workability and slump can be retained. The drying shrinkage of concrete with the addition of steel dust were more than normal concrete without addition steel dust. The researcher M. Maslehuddin stated the use of steel dust (electric arc furnace dust) in the fly ash and silica fume cement concrete can technical benefits in result of cost saving in the range of 0.6 -4.4%. The useful service life of the structures in concrete was expected between the ranges in 24-55% with an addition steel dust in concrete.