FINAL TASK

STUDY OF ANALYSIS OF THE EFFECT OF USING IRON SLAG AS A PART REPLACEMENT OF FINE AGREGATE IN PAVING BLOCK ACCORDING TO SNI-03-0691-1996

Aimed to Islamic University of Indonesia Yogyakarta to Fulfill the Requirements to Obtain a Bachelor's Degree in Civil Engineering

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CIVIL ENGINEERING PROGRAM
FACULTY CIVIL ENGINEERING AND PLANNING
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I solemnly declare that the final project report that I compiled as a requirement for the completion of the Bachelor program at the Civil Engineering Study Program, Faculty of Civil Engineering and Planning, Islamic University of Indonesia is my own work. As for certain parts in the writing of the Final Project report that I quoted from the work of others, have been written in the source clearly in accordance with the norms, rules, and ethics of writing scientific papers. If in the future all or part of my own report is found or there is plagiarism in certain parts, I am willing to accept sanctions, including revocation of my academic degree in accordance with applicable laws and regulations.

Yogyakarta, 31 August 2022

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PREFACE

All praise from the author to almighty Allah.swt, whom has bestowed his grace, knowledge, and guidance, through his blessing the author could finish this final project report to the best of his abilities. This final project report is one of the academic requirements in completing undergraduate studies at Civil Engineering Study Program, Faculty of Civil Engineering and Planning, Universitas Islam Indonesia.

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The author is fully aware that this final project report is far from perfect, due to the author lack of experience and knowledge. The author hope that this final project report can benefit and help other academic writer and serve as reliable reference for the sake of knowledge.

Yogyakarta, August 2022

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P	= Compressive Load, N
L	= Area of Pressure, mm^2
A	= Wet state weight of paving block (kg)
B	= Dry state weight of paving block (kg)
FM	= Fineness Modulus
$\sum$sievedcumulative	= Cumulative of the sieved aggregate
ρ	= Bulk Density (gr/cm^3)
m	= Aggregate Weight (gr)
v	= Bucket Volume (cm^2)
Bk	= Weight of oven dried sample (gram)
B	= Weight of pycnometer with water (gram)
Bt	= Weight of pycnometer with water + sample (gram)
V1	= First reading of the *Le Chatelir* scale bottle
V2	= Second reading of the *Le Chatelir* scale bottle

ABSTRAK

Perkembangan zaman ini di era globalisasi yang semakin pesat, semakin banyaknya barang bekas/limbah yang keberadaannya dapat menjadi masalah bagi kehidupan, salah satunya dengan adanya limbah besi (slag). Beton terak merupakan alternatif dari permasalahan tersebut, terak dapat digunakan sebagai pengganti agregat halus, agregat kasar atau sebagai bahan tambahan pada campuran paving block.

Tujuan dari penelitian ini adalah untuk memanfaatkan limbah terak besi sebagai pengganti beberapa agregat halus dalam pembuatan paving block, untuk mengetahui apakah penggantian sebagian agregat halus dengan limbah terak besi termasuk dalam persyaratan dalam SNI 03-0691- 1996, dan untuk mencari campuran maksimum dan minimum antara variasi paving block.

Variasi dalam penelitian ini adalah 1Semen.:6Pasir(standar)(0%); 1Semen:5Pasir:1TerakBesi(16%);1Semen:4Pasir:2TerakBesi(33%);1Semen:3Pasir:3Terak Besi(50%); dan 1Semen:2Pasir:4Besi Terak (66%). Penelitian ini akan menggunakan metode eksperimen.

Hasil yang diperoleh, untuk penyerapan air minimum diperoleh pada variasi 66% sebesar 8,92% dan menunjukkan bahwa semakin besar penambahan limbah terak besi ke dalam campuran, semakin rendah air yang diserap, semua variasi paving block termasuk dalam kategori D menurut SNI , untuk kuat tekan, kuat tekan maksimum diperoleh pada variasi 0% dengan 15.409 MPa dan menunjukkan bahwa semakin besar penambahan terak besi ke dalam campuran, semakin rendah kualitas dan kuat tekan paving block, hanya campuran 0% dan 16% yang termasuk dalam kategori C menurut SNI, sedangkan tiga lainnya tidak, untuk ketahanan aus, ketahanan aus maksimum terdapat pada variasi 50% dengan loss 0,364/menit, namun kenaikan dan penurunan sering terjadi dengan penambahan terak besi, semua variasi dilakukan tidak termasuk dalam kualitas apapun menurut SNI. Hal ini disebabkan beberapa faktor, seperti korosi pada butiran, perbedaan alat yang digunakan dalam SNI.

ABSTRACT

The development of this era in the era of rapid globalization has resulted in an increasing number of used / waste goods whose existence can be a problem for life, one of which is the presence of iron waste (slag). Slag concrete is an alternative to this problem, slag can be used as a substitute for fine aggregate, coarse aggregate or as an additive to the paving block mixture.

The purpose of this study was to use iron slag waste as a substitute for some fine aggregate in the manufacture of paving blocks, to find out whether the partial replacement of fine aggregate with iron slag waste was included in the requirements in SNI 03-0691-1996, and to find the maximum and minimum mixture among the variations of paving block.

Variations in this research are 1Cement.:6Sand(standard)(0%); 1Cement:5Sand:1IronSlag(16%);1Cement:4Sand:2IronSlag(33%);1Cement:3Sand:3IronSlag(50%); and 1Cement:2Sand:4IronSlag(66%). This study will use an experimental method.

Results obtained are for water absorption the minimum obtained at variation of 66% by 8.92% and indicates that the greater the addition of iron slag waste to the mixture, the lower water absorbed, all variations of paving block were included in category D according to SNI, for compressive strength, the maximum compressive strength obtained at 0% variation with 15,409 MPa and indicates that the greater the addition of iron slag to the mixture, the lower quality and compressive strength of paving blocks, only mixture of 0% and 16% are included in category C according to SNI, while other three doesn't, for wear resistance, maximum wear resistance found at 50% variation with 0.364 loss/minute, but the increase and decrease often occur with the addition of iron slag, all variations doens't fall into any qualities according to SNI. This is due to several factors, such as corrosion of the granules, the different tools used in SNI.

CHAPTER I
PRELIMINARY

1.1 Preliminary

Paving block is a composition of building materials made from a mixture of Portland cement or other hydraulic adhesive, water and aggregate with or without other additives that do not reduce the quality of the concrete, paving block can be colored like their original color or colored in their composition and used for courtyards both inside and outside buildings (SNI 03-0691-1996). According to SNI 03-0691-1996, there are four classifications of paving block according to their uses, mainly type A can be used for streets, type B can be used for parking, type C can be used for pedestrian, and type D can be used for used for garden and other uses. The more widespread use of paving blocks and the increasing scale of construction shows that there is also a growing need for paving blocks in the future, thus influencing the development of paving block technology which will require new innovations regarding the paving block itself. The development of this era in the era of rapid globalization has resulted in an increasing number of used / waste goods whose existence can be a problem for life, one of which is the presence of iron waste (slag). For this reason, many things have been done in order to recycle in order to overcome the problem of the existence of this waste. One of them is slag concrete technology. In this slag concrete, slag can be used as a substitute for fine aggregate, coarse aggregate or as an additive to the paving block mixture.

According to Anggraeni (2018), the advantage of this iron slag contains 40% silica which can provide a strong bond between cement and aggregate. From this explanation, it is possible that the added building materials such as concrete, concrete blocks, and paving blocks. However, the specific gravity of the slag is so big that the slag mixture will be more appropriate if it is used as an added material in the building material for the lower structural components.

On the other hand, in line with the increasing development in Indonesia, the demand for paving blocks will indirectly increase as well. This affects the availability of material which is a natural resource which will eventually run out and cannot be renewed, this is the problem that an alternative replacement will be looked for.

This study aims to utilize iron slag waste as a substitute for some of the fine aggregate in the manufacture of paving blocks and to obtain the maximum compressive strength value, maximum average water absorption value (according to SNI 03-0691-1996 about paving block) and the most efficient among the planned mix ratios, so it is expected that paving blocks made with a mixture iron slag can have more value and can reduce the amount of waste.

According to Anggraeni (2018), at the age of 7, 14, 21 and 28 days the concrete containing with the ratio of 1cement:3sand:3iron slag has the highest compressive strength value of all the other mixture variation for example at the age of 21 days,the compressive strength value reached 309,61 kg/cm^2, the value of the compressive strength of the concrete has greatly increased compared to concrete without iron slag (1cement:6sand) which has the compressive strength of 187,55 kg/cm^2. But there is a decrease in the compressive strength of concrete with a greater than 50% partition of iron slag content (1cement:2sand:4iron slag) which has a compressive strength of 268,47 kg/cm^2. Seeing this, it can be concluded that iron slag can be used as a substitute material in the manufacture of concrete. The similarity with the research to be carried out is to use iron slag as a partial substitute for fine aggregate. While the difference of this analysis from the Borole's is the substitution of iron slag in concrete with a ratio of (1cement:6sand), ratio of (1cement:5sand:1ironslag), ratio of (1cement:4sand:2ironslag), (1ement:3sand:3ironslag), and (1C:2S:4IS).

The reason to choose ratio of (1cement:6sand), ratio of (1cement:5sand:1ironslag), ratio of (1cement:4sand:2ironslag), (1cement:3sand:3ironslag), and (1cement:2sand:4ironslag) is because from the thesis of Yetty (2018) that has been described before stated that the optimum compressive strength reached at the ratio of (1cement:3sand:3ironslag), and decreased at the ratio of (1cement:2sand:4ironslag). Each 3 specimens was made for 1 curing periods which is 28 days, reason behind the choosing of 28 curing day is according to Hawkar Ibrahim (2018), the compressive strength reached optimum rather than 7 and 14 days, also the decreasing compressive strength after the optimum strength were not so great when it was cured for 28 days, which has a difference of 5 MPa, meanwhile the 7 and 14 days has a difference of 10 MPa decreasing after reaching optimum compressive strength, Each variation of the mixture will be seen by the results of the maximum compressive test and the maximum average water absorption and the wear resistance of it is determined to include the quality of the paving block where each variation of the mixture is according to SNI 03-1691-1996 about paving block.

1.2 Problem Formulation

The subject matter that will be discussed is based on the background of the problems that have been described are:

1. What is the maximum and minimum percentage of variations of iron slag mixture in the concrete mixture?
2. How big is the comparison of the compressive strength of concrete using iron slag in various variations of the mixture?
3. How big is the comparison of the average water absorption of a concrete mixture using iron slag in various variations of the mixture?
4. How big is the comparison of the wear resistance results of a concrete mixture using iron slag in various variastions of the mixture?
5. What quality does the object with the various kinds of the mixture falls into according to SNI 03-1691-1996?

1.3 Research Objectives

Based on existing problems, the authors conducted research with the aim of:

1. Finding the maximum and minimum percentage of variations of iron slag mixture in the concrete mixture
2. Comparing the compressive strength of concrete using iron slag in various variations of the mixture
3. Comparing the average water absorption of a concrete mixture using iron slag in various variations of the mixture
4. Comparing the wear resistance results of a concrete mixture using iron slag in various variastions of the mixture
5. Matching the quality of the object with the various kinds of the mixture falls into according to SNI 03-1691-1996

1.4 Research Benefits

Based on the research objectives above, the benefits of this study are as follows:

1. Develop knowledge of concrete technology, especially in the field of structure and construction
2. Utilizing iron slag powder as a substitute for the fine aggregate mixture in the concrete mixture

1.5 Research Limitation

Research limitations are determined so that the discussion does not become broad, as the following:

1. The research was carried out at the Engineering Construction Materials Laboratory (BKT), Islamic University of Indonesia (UII).
2. The iron slag used is gotten from the waste of Coan Workshop a workshop located in Yogyakarta city center
3. The iron slag used is iron slag that has been mashed and has passed

the 4.75 mm sieve

4. Value of iron slag powder used in the concrete mixture are as much as these ratios ([1Cement:6Sand];[1Cement:5Sand:1IronSlag];[1Cement:4Sand:2IronSlag];[1Cement:3Sand:3IronSlag];[1Cement:2Sand:4IronSlag])
5. The tests performed are the compressive strength test, water absorption test and wear resistance test
6. The total number of specimens to be used is 25 whole paving block samples.
7. The specimen of paving block is in the form of blocks with a size of 6 cm x 10 cm x 20 cm.
8. The cement used is Portland composite cement with the Tiga Roda brand.
9. Fine aggregate in the form of sand with a maximum grain size of 4.75 mm in diameter originates from the Yogyakarta Merapi sand.
10. The water used is from the Engineering Construction Materials Laboratory (BKT), Faculty of Civil Engineering and Planning, Islamic University of Indonesia.
11. The water cement ratio that will be chosen for the mix design will be 0,3 in order to reach the minimum amount of compressive strength of paving block quality A which has a minimum compressive strength of 35 MPa according to SNI-03-0691-1

CHAPTER II
LITERATURE REVIEW

Literature review is one part of the theoretical framework that contains related research used to develop concepts and research steps. In this study, the literature review used refers to references and previous studies with the appropriate topic.

2.1 General Review

Paving block is a composition of building materials made from a mixture of Portland cement or other hydraulic adhesive, water and aggregate with or without other additives that do not reduce the quality of the concrete, paving block can be colored like their original color or colored in their composition and used for courtyards both inside and outside buildings (SNI 03-0691-1996).

According to Antoni (2007), slag is the residual material from casting iron (piq iron), where the process uses a kitchen (furnace) whose fuel is from blown air (blast). According to Syarif (2010) the average silica content in iron slag is as big as 41.54%. This is one of the advantages of iron slag, because with a high silica content it can provide a strong binding power between cement and aggregate. According to Achmadi (2009), solid waste (slag) is included in B3 waste.

Limbah Bahan Berbahaya dan Beracun (B3 waste) According to Permen LH (Peraturan Menteri Lingkungan Hidup) No. 2 of 2008, hazardous and toxic waste, hereinafter abbreviated as B3 waste, is the residue of a business and / or activity containing hazardous and / or toxic materials due to its nature and / or concentration and / or quantity, either directly or indirectly. pollutes and / or damages the environment, and / or can endanger the environment, health, the survival of humans and other living things. B3 waste whose components are consistent with the utilization criteria are wastes whose characteristics, characteristics and components are relatively the same for each sources such as fly ash from coal burning, bottom ash from coal combustion, EAF (electrical arc furnace ash) dust from iron and steel smelting, slag from iron and steel smelting and slag from copper smelting (Permen LH No. 2 of 2008).

2.2 Previous Research

In this study, the literature used is research that has been or has been done before, among others:

1. Study of The Analysis of Iron Slag Waste as a Substitute for Some of The Fine Aggregate in Making Paving Blocks

   This research was conducted by Anggraeni (2018), The purpose of this study is the utilization of iron slag waste as a substitute of some fine aggregates in the manufacture of paving blocks, to find out the maximum compressive strength and the most efficient production cost among the mixture 1PortlandCement: 6Sand (standard); 1Cement: 5Sand: 1IronSlag; 1Cement: 4Sand: 2IronSlag; 1Cement: 3Sand: 3IronSlag; 1Cement: 2Sand: 4IronSlag; 1Cement: 1Sand: 5IronSlag. Paving blocks made with size (21 x 10.5 x 6) cm. Based on the average 28-day estimate, standard paving blocks have a compressive strength of 204.09 kg/cm2, the maximum compressive strength is in the mixture of 1Cement: 3Sand: 3IronSlag of 335.28 kg/cm2, an increase of 64.28% of the standard paving block. While the minimum compressive strength is in the mixture of 1Cement: 1Sand: 5IronSlag of 195.89 kg/cm2, decreased 4.02% compared to standard paving blocks. When reviewed based on production costs, the standard paving block has a production cost of Rp 1.004,29. A mixture of 1Cement: 3Sand: 3IronSlag has a production cost of Rp 974,29 decreased 2.99% when compared to standard paving blocks. The most cost efficient production mix is 1Cement: 1Sand: 5IronSlag of Rp 894,69. Reduced by 10.91% of standard paving blocks.

2. Mechanical Properties of Concrete Using Iron Waste as A Partial Replacement of Sand

   This study is conducted by Ibrahim (2018) from Koya Technical Institute. The aim of this study is to assess the possibility of applying iron waste in different percentages (6%, 12%, 18%, 24%, and 30%) as fine aggregate replacement of sand to increase the strength of concrete. For this purpose, the mix proportion was designed as (1:2.12:2.37) and made into cubes with dimension of (100 x 100 x 100 mm) for giving 33 MPa of compressive strength of concrete at 28 days of curing. In order to achieve the goal of the study, laboratory experiments, compressive strength, and flexural tensile strength were conducted to determine the influence of iron waste on the strength of concrete. Thus, based on this study, the progress of strength with the

   percentages of iron waste in different time was plotted. According to the results, it can be found that 12% of iron waste is more efficient than the other percentages in both compressive and flexural strength because it obtains the maximum strength in the shortest time, and it seems that increasing iron waste more than 12% leading to decrease the strength of the concrete.

3. Compressive Strength of Concrete With The Addition of Powdered Iron and Steel

   In a research conducted by Paryati (2001), iron and steel powder was used as an added material in making concrete as an effort to solve the waste problem, by examining how far the utilization of waste in the form of iron and steel powder can be used as an added material in the concrete mixture with a percentage 0%, 25%, 50%, 75% in terms of compressive strength. This study used an experimental method with a test object in the form of a 15cmx15cmx15cm cube that was pressed at the age of 28 days. Each variation of the addition of 6 specimens with the weight ratio between cement: fine aggregate: coarse aggregate is 1: 3: 5, so that the total number of test objects is 24 pieces. The results showed that the compressive strength characteristics of concrete at variations in the addition of 0%, iron and steel powder σk = 125.4894 kg / cm2, 25% iron and steel powder σk = 121.9823 kg / cm2.50% iron and steel powder σk = 118.063 kg / cm2, 75% iron and steel powder σk = 80.3928 kg / cm2. These results indicate that the greater the addition, the lower the compressive strength of the concrete achieved. This is due to several factors, including the existence of an error in selecting the pressed surface, corrosion between grains, segregation and the appearance of water bubbles and the mixing process of imperfect concrete constituents.

2.3 Autencity of Carried Out Research

Comparison of current research with previous research can be seen in Table 2.1 as follows.

Table 2.1 Comparison with Previous Research

	Previous Research	
Researcher	Anggraeni (2018)	Ibrahim (2018)
Title	Study of The Analysis of Iron Slag Waste as a substitute for some of the Fine Aggregate in Making Paving Blocks.	Mechanical Properties of Concrete using iron waste as a partial replacement of sand.
Parameter Tested	Compressive Strength and Production Costs.	Compressive Strength and Flexural Strength.
Research Methods	The material used in this study include Portland cement type I, the brand of Semen Gresik. For fine aggregate, iron slag waste which passes through the filter no. 4 (4,75 mm) and Muntilan sand which passed the filter No. 4 (4,75 mm), and artesian well water. The test object made in this study is a paving block with a size of 21 cm x 10,5 cm x 6 cm. The composition of the ingredient used is by using an aggregate ratio (1Pc: 6Ps (standard); 1Pc: 5Ps: 1Tb; 1Pc: 4Ps: 2Tb; 1Pc: 3Ps: 3Tb; 1Pc: 2Ps: 4Tb; 1Ps: 1Pc: 5Tb). The number of test objects made of 3 pieces for each comparison of the mixture at each age of the paving block test (7, 14, 21, and 28 days), so the total is 72 pieces.	To find out what experimental method were used, both flexural tensile and compressive strength were considered to be tested. Regarding this, the research is planned as firstly ordinary concrete with only cement, aggregate, and water as control was prepared. Then fine aggregate sand is partially replaced with iron waste in different percentage. The percentage are as follows: (6%, 12%, 14%, 18%, 24% and 30%) for compressive strength and for flexural strength. For each percentage, nine cubes and nine beams were made. Overall, total samples made were 54 cubes and 54 beams. Cubes with dimension of (100 x 100 x 100 mm) were used for compressive strength test, and utilizing beam specimens with dimension of (100 x 100 x 500 mm) for the flexural tensile strength test. The sample were tested after three different time of curing (7, 14 , and 28 days).

Research Results	Based on the average 28-day estimate, standard paving blocks have a compressive strength of 204,09 kg/cm2, the maxium compressive strength is in the mixture of 1Pc: 3Ps: 3Tb of 335,28 kg/cm2, an increase of 64,28% from the standard paving block. While the minimum compressive strength is in the mixture of 1 Pc: 1 Ps: 5Tb with 195,89 kg/cm2, decreased 4,02% compared to standards. When reviewed based on production costs, the standard paving block has a production cost of Rp 1004,29. A mixture of 1Pc: 3PS: 3Tb has a production cost of Rp 974,29. decreased 2,99% when compared to standards. The most cost efficient production mis is 1Pc: 1Ps: 5Tb of Rp 894,69, reduced by 10,91% from standard paving block.	The workability of the concrete is slightly and gradually decreased by increasing iron waste. The strength of concrete increased while curing was prolonged. The compressive and flexural strength are slightly increased by increasing iron waste ratio until 12%. It can be noted that using 12% iron wasre in concrete gave it 15% more compressive strength in 28 days than normal concrete. It should be significantly concentrated on that the mix ratio was basically designed to gives 33 MPa at 28 days but more than this can be obtained at 7 days by adding 12% of iron waste which was about 35 Mpa. So in case, the concrete needs to reach the maximum compressive strength in the shortest time, 12% iron waste can be recommended to be use in the concrete.

Continuation of Table 2.1 Comparison with Previous Research

	Previous Research	**Reseach That is Being Conducted**
Researcher	Paryanti (2001)	Furqon (2021)
Title	Compressive Strength of Concrete With the Addition of Powdered Iron and Steel	Study of The Analysis of Iron Slag Waste as A Substitute for Some of the Fine Aggregate in Making Paving Blocks and Classifying them Into Each Category According to SNI-03-0691-1996
Parameter Tested	Compressive Strength	Compressive Strength, Water Absorption and Wear Resistance and Quality

Research Methods	The concrete made in this study consisted of cement, water, gravel, sand and iron and steel powder with a weight ratio for each of the 6 specimens. The weight ratio for 6 specimens between cement: water: fine aggregate: coarse aggregate is 5: 3,4: 15: 28. 50% and 75%. In this study the data were obtained by laboratory test. The test objects were in the form of cubes with dimension of (15 x 15 x 15 cm) with variations in the addition of iron powder to 25% fine aggregate as many as 6 pieces, 50% amounted to 6 pieces, 75% as many as 6 pieces and normal concrete (0%) amounted to 6 pieces. So the total sample is 24 specimens. And all test objects will be tested for their compressive strength.	The material used in this study include Portland cement type I, the brand of Holcim. For fine aggregate, iron slag waste which passed through the filter no. 4 (4,75 mm) and Muntilan sand which passed the filter no. 4 (4,75 mm), and water from UII lab. Test object that will be made in this study is a paving block with a size of 21 x 10,5 x 6 cm. The composition of the ingredients used by using an aggregate ratio (1Pc: 6Ps (standard); 1Pc: 5Ps:1Tb; 1Pc: 4Ps: 2Tb; 1Pc:3S:3PS; 1Pc:2Ps:4Tb) The number of test objects for compressive strength test made of 5 pieces for each comparison of the curing time (28 days), so that the total objects for compressive strengh testing is 5 pieces, 5 pieces for water absorption test for each variations, and 5 pieces for wear resistance test for each variations. Then they will be classified into their qualities according to SNI 03-0691-1996.

Research Results	The results showed that the compressive strength characteristics of concrete at variations in the addition of 0%, iron and steel powder has the strength of 125,49 kg/cm2, 25% iron and steel powder has the strength of 121,98 kg/cm2, 50% iron and steel powder has the strength of 118,06 kg/cm2, and 75% iron and steel powder has the strength of 80,39 kg/cm2. These results indicate that the greater the addition, the lower the compressive strength of the concrete gotten. This is due to several factors, including the existence of an error in selecting the pressed surface, corrosion between grains, segregation and the emergence of water bubbles and the mixing process of imperfect concrete constituents.	

2.4 Research Authenticity

The research that will be carried out is different from previous studies, the difference can be found in the variation of the substitution of fine aggregate in paving blocks in the form of iron slag waste which previously was 0%, 15%, 30%, 45% and 50%, while this study also used 0%, 15% , 30%, 50%, and 60%, and previous studies only carried out compressive strength testing, while this research will be testing compressive strength, water absorption, and wear resistance which from the results of these tests can be used to categorize paving blocks according to their variations, based on their quality according to SNI 03-0691-1996.

CHAPTER III
THEORETICAL BASIS

3.1 General

Paving block is a composition of building materials made from a mixture of Portland cement or other hydraulic adhesives, water and aggregates with or without other additives that do not reduce the quality of the concrete (SNI 03-0691-1996).

3.2 Paving Block Constituent Materials

Basically, the main components of paving blocks consist of cement, fine aggregate, and water with or without added ingredients.

1. Cement

   Cement is a material that has both adhesion and cohesion properties, that is, it can be used as an adhesive after contact with water. If cement is mixed with water it will become cement paste, if cement paste is mixed with fine aggregate it will become mortar, if added with coarse aggregate the mortar will become a fresh concrete mixture which after hardening will become hard concrete (Mulyono, 2003).

   Based on SNI 15-2049-2004, portland cement is hydraulic cement produced by grinding portland cement slag mainly consisting of hydraulic calcium silicate and milled together with additional materials in the form of one or more crystalline forms of calcium sulfate compounds and may be added with other additives. According to Mulyono (2003), the main ingredients of cement can be seen in Table 3.1 below.

Table 3.1 Main Ingredients for Portland Cement (Mulyono, 2003)

Ingredients	Composition (%)
Calcium (CaO)	60-65
Silica (SiO_2)	20-25
Iron Oxide (Fe_2O_3)	7-12
Aluminium Oxide (Al_2O_3)	7-12

2. Water

Water is one of the important factors in the concrete mix because water can react with cement which then forms chemical compounds. Water is also useful as a lubricant between the aggregates so that the concrete mixture is easy to work with, compacted, and concrete maintenance so that the concrete can harden perfectly.

Water can affect the compressive strength of concrete, because the addition of excessive water to the concrete mix for ease of work can cause a decrease in the strength of the concrete. In addition, excess water will cause bleeding, namely the water and cement will move up the surface of the fresh concrete that has just been poured into the mold. The requirements according to SK SNI S-04-1989-F that must be met for the use of water as a concrete mixture are as follows.

a. Water has to be clean
b. Does not contain mud (other floating objects) more than 2 grams/liter.
c. Does not contain salts that can damage concrete (acids, organic substances, etc.).
d. Does not contain chloride (Cl) more than 0.5 gram/liter.
e. Does not contain sulfate compounds (SO3) more than 1 gram/liter.

3. Fine Aggregate

Fine aggregate is natural sand resulting from the disintegration of rocks that can be obtained from rivers or from excavated soil, or sand produced from the process of breaking rocks. Fine aggregate is aggregate with a grain size smaller than 4.76 mm. According to SK SNI S-04-1989-F, fine aggregate used in concrete mixtures must meet the following requirements.

a. Sand consists of sharp and hard grains in order to produce hard concrete.
b. Sharp shapes are needed so that the aggregates can interlock well in the concrete mix. However, the sharp shape of the aggregate can cause large friction that will reduce mobility or ease of movement from the concrete mix.
c. Must not contain mud more than 5% of dry weight.
d. If the silt content is more than 5%, then the fine aggregate needs to be washed. Because of the mud on fine aggregates can prevent bonding with cement paste.
e. Must not contain organic ingredients, because these materials can react with portland cement compounds.
f. According to Tjokrodimulyo (1992), the fine aggregate gradation must meet the requirements as shown in Table 3.2 below.

Table 3.2 Sand Gradation

Sieve	Percentage passing the sieve			
	Area I	Area II	Area III	Area IV
10	100	100	100	100
4,8	90-100	90-100	90-100	95-100
2,4	60-95	75-100	85-100	95-100
1,2	30-70	55-90	75-100	90-100
0,6	15-34	35-59	60-79	80-100
0,3	5-20	8-30	12-40	15-50
0,15	0-10	0-10	0-10	0-15

X`

3.3 Iron Slag

According to Antoni (2007), slag is the residual material from casting iron (piq iron), where the process uses a kitchen (furnace) whose fuel is from blown air (blast). According to Syarif (2010) the average silica content in iron slag is as big as 41.54%. This is one of the advantages of iron slag, because with a high silica content it can provide a strong binding power between cement and aggregate. According to Achmadi (2009), solid waste (slag) is included in B3 waste.

The development of this era in the era of rapid globalization has resulted in an increasing number of used / waste goods whose existence can be a problem for life, one of which is the presence of iron waste (slag). For this reason, many things have been done in order to recycle in order to overcome the problem of the existence of this waste. One of them is slag concrete technology. In this slag concrete, slag can be used as a substitute for fine aggregate, coarse aggregate or as an additive to the concrete mixture.

The advantage of this steel slag contains 40% silica which can provide a strong bond between cement and aggregate. From this explanation, it is possible that the added building materials such as concrete, concrete blocks, and paving blocks. However, the specific gravity of the slag is so big that the slag mixture will be more appropriate if it is used as an added material in the building material for the lower structural components, which is why this study aims to utilize iron slag waste as a substitute for some of the fine aggregate in the manufacture of paving blocks and to obtain the maximum compressive strength value, maximum average water absorption value (according to SNI 03-0691-1996 about paving block) and the most efficient production cost among the planned mix ratios, so it is expected that paving blocks made with a mixture iron slag can have more value and can reduce the amount of waste.

The iron waste that will be used in this study is iron waste which is ground into powder first, then sieved and the iron waste that passes the sieve no. 4 (4.75 mm) will be used to replace some of the percentage of sand as fine aggregate for the paving block mixture.

The iron piq that is obtained will be crushed by first into powder then it can be continue to the next step.

3.4 Paving Block Mix Planning

As for the mix planning of the paving block, the paving block mixing plan is divided into five, the first is a mixture of portland cement with sand and water without mixing iron slag waste, with a mixture ratio of 1 Portland Cement: 6 PS (sand).

Then the second one is a mixture of paving block with portland cement, water, and a subtitution of sand with iron slag waste as much as ratio of 1Cement : 5Sand : 1IronSlag.

Then the third one is a mixture of paving block with portland cement, water, and a subtitution of sand with iron slag waste as much as the ratio of 1 PC : 4 PS : 2 TB (iron slag).

Then the forth one is a mixture with the ratio of 1Cement : 3Sand : 3IronSlag. And the final one is a mixture with the ratio of 1Cement : 2Sand : 4IronSlag.

Meanwhile the water cement ratio that is choosen will be 0,3 in order to reach the minimum value of compressive strength for paving block quality A that has a minimum value of 35 MPa.

The results of the mix comparison planning and the number of test objects can be seen in table 3.3 below.

Table 3.3 Comparison of Mixing Ratio and Test Objects

Mixing Ratios	**Number of Test Object per Testing Day**
	28 Days
1Cement : 6Sand	6
1Cement : 5Sand : 1IronSlag	6
1Cement : 4 Sand : 2IronSlag	6
1Cement : 3Sand : 3IronSlag	6
1Cement : 2Sand : 4IronSlag	6

3.5 Compressive Strength of Paving Block

Compressive strength is the maximum load per unit area with a certain shaped test object. The compressive strength of paving blocks is produced from a press machine with a rectangular paving block with dimensions of 6 cm x 10 cm x 20 cm. The compressive strength of concrete paving blocks is determined by the proportion or ratio of cement, fine aggregate, and water.

The test object used is a rectangle with dimensions of 6 cm x 10 cm x 20 cm. According to SNI 03-0691-1996 concerning paving blocks, the test objects will be cut into a cube with the ribs adjusted to the size of the test sample, then it is pressed with a press machine until it is crushed, set within 1 to 2 minutes, the direction of emphasis on the test sample is adjusted to the direction of the load pressure in its use, the compressive strength is calculated by the following formula.

Compressive Strength = P / L (Equation 3.1)

Description :

P = Compressive Load, N

L = Area of Pressure, mm^2

The average compressive strength of the concrete brick sample is calculated from the total compressive strength divided by the number of test samples.

3.6 Water Absorption Test

According to SNI 03-0691-1996, the water absorption test can be carried out by immersing the test object in water until it is saturated (for 24 hours), then weighed in a wet state, then dried in a dryer for approximately 24 hours, at a temperature of approximately 105 °C until the weight on the two weighings differs by not more than 0.2% of the previous weighing. Equation to determine the water absorption is.

$$\text{Water Absoption} = \frac{\text{A}-\text{B}}{\text{B}} \times 100\% \qquad \text{(Equation 3.2)}$$

Description:

A = Wet state weight of paving block

B = Dry state weight of paving block

3.7 Wear Resistance Test

Wear resistance here is the ability of paving blocks to withstand surface damage if there is friction between solid surfaces According to SNI 03-0691-1996 concerning paving blocks, the test object will be cut into a cube with the ribs adjusted to the size of the test sample, wear resistance test of paving block can be carried out by looking at SNI 03-0028-1987 as the step, by using a proper wear resistance testing machine. Meanwhile the machine in UII is different that what is used in SNI, different formula from ASTM abrasion test will be used to calculate the wear resistance as , the equation used is.

$$\text{Wear Resistance} = 1{,}2 \times \frac{Loss}{min} + 0{,}0268 \text{ mm/minute} \qquad \text{(Equation 3.3)}$$

Description:

1,2 = Standard Equation

Loss/min = Loss of samples head after testing

0,0268 = Standard Equation

CHAPTER IV
RESEARCH METHODS

4.1 General

The method used in this study is an experimental method and research conducted at the Engineering Construction Materials Laboratory, Department of Civil Engineering, Faculty of Civil Engineering and Planning, Islamic University of Indonesia. The experimental method is a research method carried out to obtain results or data from the variables studied. The test object in this study is a paving block that uses a substitute for iron slag powder which will replace part of the percentage of fine aggregate in the form of sand, there are 5 variations of the substitute mixture, namely 1cement:6sand, 1cement:5sand:1ironslag, 1cement:4sand:2ironslag, 1cement:3sand:3ironslag, 1cement:2sand:4ironslag

After the data obtained from the test results of the compressive strength of concrete and water absorption, then the data can be calculated using the formula equation. After that, the data from the results of these calculations can be concluded.

The manufacture of test objects and quality testing procedures are in accordance with those specified in the Indonesian National Standard (SNI 03-0691-1996).

4.2 Sample

Testing samples are divided by two kinds, one will be rectangular machine printed paving blocks with dimension 6x10x20 cm, and will be use for visual testing, water absorption testing, and dimension checking, meanwhile second one will be a cube cut from the original rectangular paving block with the ribs adjusted to the size of the test sample which in this case is 6 cm, so the cube dimension will be 6x6x6 cm, and will be use for compressive strength and wear resistance testing. Details of the sample that will be made for each testing can be seen in the table below

Table 4.1 Table of the Sample Details for Testing

Samples	Testing					Variation
	Compressive Strength	Wear Resistance	Water Absoprtion	Visual	Dimension	
Rectangular (6x10x20cm)	0	0	3	6	4	1cement:6sand
	0	0	3	6	4	1cement:5sand:1ironslag
	0	0	3	6	4	1cement:4sand:2ironslag
	0	0	3	6	4	1cement:3sand:3ironslag
	0	0	3	6	4	1cement:2sand:4ironslag
Cube (6x6x6cm)	3	3	0	0	0	1cement:6sand
	3	3	0	0	0	1cement:5sand:1ironslag
	3	3	0	0	0	1cement:4sand:2ironslag
	3	3	0	0	0	1cement:3sand:3ironslag
	3	3	0	0	0	1cement:2sand:4ironslag

4.3 Materials Used

Materials used to make paving blocks consist of portland cement, fine aggregate and water. Often additional mixed materials are added which vary greatly to obtain the desired properties of the brick. Usually the ratio of the mixture used is the ratio of the amount of paving block ingredients which is more economical and effective. The building blocks of paving blocks used in this study are:

1. Portland Cement from Tiga Roda brand.
2. Fine Aggregate in the form of sand taken from Merapi mountain, Yogyakarta.
3. Water taken from the Construction Materials Laboratory, Department of Civil Engineering, Faculty of Civil Engineering and Planning, Islamic University of Indonesia.
4. Iron slag waste that has been crushed into fine form taken from a factory.

For aggregate and cement, there are few inspections to be carried out which include:

a. Sieve analysis.
b. Density check.
c. Inspection of specific gravity.
d. Inspection of silt content and fine aggregate clay content.

4.4 Materials Inspections

Material inspection needs to be carried out to determine whether the material used meets the requirements used or not. If there is material that does not meet the requirements, then material replacement is carried out.

4.4.1 Fine Aggregate Inspections

Fine aggregate testing includes sieve analysis, bulk density, specific gravity, silt content, and clay content. The explanation of each fine aggregate test is as follows.

1. Sieve Analysis Test

   Aims to determine the gradation and distribution of sand grains and also iron slag waste powder, as well as to determine the fineness modulus of sand and iron slag waste powder. The steps to determine is as follows.

   a. Take the oven-dried sand (110±5)ºC;
   b. Provide 2 samples of sand each weighing 1000 g
   c. Arrange the sieves in a row from top to bottom: 9.52 mm; 4.76 mm; 2.38 mm; 1.19 mm; 0.60 mm; 0.30 mm; 0.15 mm and pan;
   d. Place the sieve arrangement on the sieve shaker machine;
   e. Put sample 1 on the top sieve and close it tightly;
   f. The engine is turned on for 5 (five) minutes;
   g. Weigh the sample retained on each sieve;
   h. Perform the above experiment for sample 2 and 3.
   i. From the testing we got the results that has been noted to detemine the fineness modulus of the aggregate using the table 3.2 above.

   The degree of fineness (roughness) of an aggregate is determined by the modulus of fineness with the limits that can be seen in table 3.2.

j. Testing Results

Fineness modulus of sand from the gradation table fall under slightly coarse sand (Area II), meanwhile fineness modulus of slag from the gradation table fell under coarse sand (Area I).

From this result, it can be concluded that a coarser iron slag can affect fine aggregate positively in the way that the gaps between coarser iron slag can be filled by a slightly less coarse fine aggregate.

2. Bulk Density

Aims to determine the density of fine aggregate, the steps can be seen below.

a. The bucket is weighed and then filled with aggregate to the 1/3 height of the bucket and then mashed 25 times evenly on the surface;
b. Aggregate is added again until it reaches the height of 2/3 the bucket and is beaten 25 times evenly on the surface, then the bucket is fully filled with aggregate and shoved 25 times evenly and the surface is leveled. In shaking for each layer must not penetrate the layer below it;
c. Weigh the bucket + aggregate;
d. The aggregate is removed and the bucket is cleaned and then filled with water until it is full, weigh the weight of the bucket + water and the temperature of the water in the bucket is measured;
e. After the data has been noted, calculate the bulk density with the equation

$$\rho = \frac{m}{v} \qquad (4)$$

Description:

ρ = Bulk Density (gr/cm^3)

m = Aggregate Weight (gr)

v = Bucket Volume (cm^2)

f. Testing Results

a. Sand (2 samples)

$\rho1$= 2495/1701,01

$\rho1$ = 1,467 gr/cm^3

$\rho2$ = 2413/1704,39

$\rho2$ = 1,416 gr/cm^3

ρaverage = 1,4415 gr/cm^3

b. Iron Slag (1 samples)

$\rho1$= 2928/1656,54

$\rho1$ = 1,768 gr/cm3

3. Clay Content

Aims to determine the percentage of clay content in the aggregate. The steps can be seen below.

a. Sand from the experimental mud content of 2 (two) samples with dry weight after washing the mud as the initial weight soaked in distilled water for 24 hours;
b. After soaking for ± 24 hours the distilled water is removed carefully so that no sand is thrown away;
c. Pour the sand in sieve no. 200 and washed under the faucet while kneading for ± 5 minutes;
d. The washed sand is poured into a pan and dried in an oven at 110 ± 5 C for 24 hours;
e. The dry sand from the oven is then weighed and recorded.
f. After the results noted, calculate the clay content with equation

$$\%\text{Clay Content} = \frac{A-B}{A} \times 100 \quad (5)$$

Description :

A = Starting weight of sample (residual from silt content test)

B = Sample weight after oven dried

Sand that meets the requirements and is suitable for use, if the clay content of the sand is < 1%.

g. Testing Results

2 Samples of sand are tested

$$\%\text{Clay Content1} = \frac{500 - 494}{500} \times 100$$

$$\%\text{Clay Content1} = 1{,}2\%$$

$$\%\text{Clay Content2} = \frac{500 - 497}{500} \times 100$$

$$\%\text{Clay Content2} = 0{,}6\%$$

$$\%\text{Clay Contentaverage} = 0{,}9\%$$

Which passed the maximum requirement of 1% of clay content as a usable sand.

4. Specific Gravity and Water Absorption Test

Specific gravity and water absorption testing of fine aggregate aims to obtain bulk density, surface dry saturated density (SSD), apparent density, and water absorption rate in fine aggregate. The test was carried out by the author 2 (two) times with the sample in SSD condition. The steps of testing the specific gravity and water absorption of fine aggregate are as follows.

a. The fine aggregate to be tested must be immersed in water for ± 24 hours.
b. After 24 hours, the aggregates were removed from the water bath.
c. Then spread the aggregate evenly on the tray and dry it in hot air by inverting the test object until the saturated surface dry state.
d. Check the surface dry saturation (SSD) state by filling in the aggregate into the Abrams cone, per 1/3 of the Abrams cone and each part stabbed 8 times with an iron rod evenly, then flattened the surface.
e. The surface dry saturation state (SSD) is reached when the Abrams cone is lifted, the aggregate collapses ± half partially (still in the imprinted state). If the Abrams cone is lifted and the aggregate is still standing (no collapse), then the aggregate has not reached the SSD condition. Aggregate can be spread again evenly on the tray and can then be carried out with the same steps as the steps described previously, until the aggregate reaches the SSD condition.

f. If the fine aggregate has reached the SSD condition, then the aggregate is weighed as much as 500 grams.
g. After the fine aggregate is weighed, then it is put into the empty pycnometer.
h. The pycnometer which already contains fine aggregate is then filled with clean water until it reaches 90% of the contents of the pycnometer.
i. The pycnometer which has been filled with fine aggregate and water is rotated left and right until there are no visible air bubbles in the aggregate.
j. After the bubbles came out of the aggregate, then water was added to the pycnometer until the pycnometer volume limit was then weighed and the results were recorded.
k. The fine aggregate is removed from the pycnometer then the aggregate is placed into a pan and then put in the oven for ± 24 hours.
l. The empty pycnometer is filled with water to the limit of its volume capacity, then weighed and the weight recorded.
m. After 24 hours, the aggregate was removed from the oven and then weighed and the weight was recorded.
n. From the weighing results that have been recorded, then it is used to calculate the apparent density, surface dry saturated density, bulk density, and water absorption with the following equation.

$$\text{Bulk Specific Gravity} = \frac{\text{Bk}}{\text{B+500−Bt}} \quad (6)$$

$$\text{SSD} = \frac{500}{\text{B+500−Bt}} \quad (7)$$

$$\text{Apparent Specific Gravity} = \frac{\text{Bk}}{\text{B+Bk−Bt}} \quad (8)$$

$$\text{Water Absorption} = \frac{\text{500−Bk}}{\text{Bk}} \times 100\% \quad (9)$$

Description:

Bk = Weight of oven dried sample (gram)

B = Weight of pycnometer with water (gram)

Bt = Weight of pycnometer with water + sample (gram)

500 = Weight of the test object in a saturated surface dry state (gram).

o. Testing Results

a. Bulk Specific Gravity

$$\text{Bulk Specific Gravity} = \frac{492{,}85}{860 + 500 - 1169{,}5}$$

$$\text{Bulk Specific Gravity} = 2{,}590\ gr/cm2$$

b. SSD

$$\text{SSD} = \frac{500}{860 + 500 - 1169{,}5}$$

$$\text{SSD} = 2{,}625\ gr/cm2$$

c. Apparent Specific Gravity

$$\text{Apparent Specific Gravity} = \frac{492{,}85}{860 + 492{,}85 - 1169{,}5}$$

$$\text{Apparent Specific Gravity} = 2{,}688\ gr/cm2$$

d. Water Absorption

$$\text{Water Absorption} = \frac{500 - 492{,}85}{492{,}85} \times 100\%$$

$$\text{Water Absorption} = 1{,}4203\ \%$$

4.4.2 Cement Inspections

Inspections of cement consist only of one testing which is the inspections of specific gravity of cement. The explenation of it can be seen below.

1. Specific Gravity Test

This test is aimed to determine the specific gravity of cement. The steps for specific gravity test can be seen below.

a. Fill a *Le Chatelir* vial with kerosene or naphtha to between 0 and 1 scale, the inside of the pycnometer above the liquid level.

b. Put the *Le Chatelir* bottle into a water bath with the temperature set on the *Le Chatelir* bottle at ± 20 C to use the liquid temperature in the pycnometer l with the temperature set in the *Le Chatelir* bottle.

c. After the temperature in the *Le Chatelir* bottle is the same as the temperature set on the *Le Chatelir* bottle, read the scale on the *Le Chatelir* bottle (V1).

d. Put 64 grams of portland cement, little by little into the *Le Chatelir* bottle, avoiding the cement sticking to the walls in the *Le Chatelir* bottle above the liquid.

e. After the specimen is inserted, slowly turn the *Le Chatelir* bottle in an inclined position until air bubbles no longer appear on the surface of the liquid.

f. Repeat work no. 2 after the temperature in the *Le Chatelir* bottle is the same as the temperature set on the *Le Chatelir bottle*, read the scale on the *Le Chatelir* bottle (V2).

g. After the results has been noted, calculate the specific gravity with equation.

$$\text{Specific Gravity} = \frac{\text{Cement Weight}}{(\text{V2} - \text{V1})}$$

Description:

V1 = First reading of the *Le Chatelir* scale bottle

V2 = Second reading of the *Le Chatelir* scale bottle

Notes:

- Specific gravity of portland cement range between 3 - 3.2
- Allowed room temperature range between 20 C – 24 C

h. Testing Results

Specific gravity of Portland cement is 3,152 gr/ml

4.5 Equipments Used

This research uses equipments that are available in the laboratory of Construction Materials Technology, Department of Civil Engineering, Faculty of Civil Engineering and Planning, Islamic University of Indonesia. equipments used in this study are as follows.

1. set of sieve

A sieve or sieve is used to obtain the grain size of the retained aggregate. In this study, a sieve was used to find the fine modulus of the sand grains. In addition, a sieve is used to obtain iron slag waste powder that passes the 4.75 sieve. The sieve is equipped with a vibrating machine which functions to vibrate the sieve. The sieve used can be seen in Figure 4.1.

Figure 4.1 Sieve

1. Scales

   Scales are used to weigh or measure the weight of an object. In this study the scales were used to weigh the weight of the paving block constituent materials to be used to suit the needs. The scales used can be seen in Figure 4.2.

Figure 4.2 Scales

2. Oven

Oven is a tool that serves to dry an object with a certain temperature. In this study, the oven was used for testing the specific gravity and water absorption of fine aggregate and for testing the content of fine aggregate slurry. The oven used can be seen in Figure 4.3.

Figure 4.3 Oven

3. Small Shovel

Small shovel is a tool in the form of a mixing spoon made of metal plates and wood as a handle. In this study, the small shovel is used to take sand and cement which will be weighed with a bucket. The mold used can be seen in Figure 4.4.

Figure 4.4 Small Shovel

4. Bucket

The bucket in this study was used as a place to put the materials to make paving blocks. The bucket used can be seen in Figure 4.5.

Figure 4.5 Bucket

5. Mashing Rod

The mashing rod in stement is an iron rod with a diameter of 16 mm and a length of 600 mm which has a rounded end. In this study it was used to mash sand when checking the weight of the contents. The mashing rod used can be seen in Figure 4.6.

Figure 4.6 Mashing rod

6. *Le Chatelir* Bottle

A *Le Chatelir* bottle is required to store the fine aggregate sample with the cerosine petrol at the time of testing for specific gravity. The glass bottle can be seen in Figure 4.7.

Figure 4.7 Glass bottle

7. Measuring Cup

   A measuring cup with a capacity of 1000 ml is needed to mix the NaOH solution with water when testing the specific gravity of cement. The measuring cup can be seen in Figure 4.8.

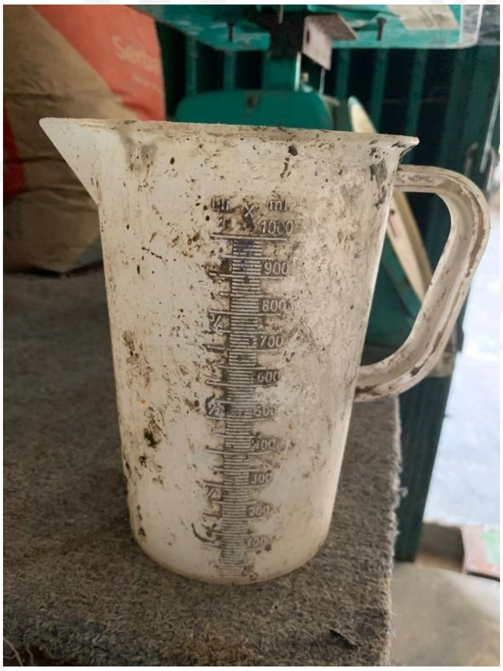

Figure 4.8 Measuring Cup

8. Pycnometer

Pycnometer is used when we test the specific gravity of cement. Can be seen in Figure 4.9.

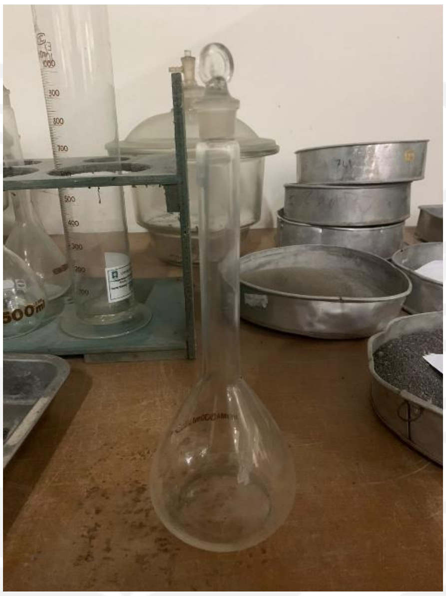

Figure 4.9 Pycnometer

9. Pan

Pan is used to put sand when it is dried in a testing of clay content of fine agregate. Can be seen in Figure 4.10.

Figure 4.10 Pan

10. Porcelain Cup

Used when pouring substance in a specific gravity of cement testing. Can be seen in Figure 4.11.

Figure 4.11 Porcelain Cup (Example)

11. Paving Block Mold

A mold of paving block with dimension of 6cm x 10 cm x 20 cm is used to pour the materials into the shape of a rectangular, this mold is then attached to compressing machine and pressed down. Can be seen in Figure 4.12.

Figure 4.12 Paving Block Mold With The Machine

12. Compressing Machine

    The press machine in this study was used to obtain the maximum load that the concrete can withstand. This machine gives a load with a constant compressive force until the concrete sample is crushed. The press machine used can be seen in Figure 4.13.

Figure 4.13 Compressing Machine

13. Wear Resistance Machine

    The wear machine in this study was used to calculate the wear resistance of the paving block by rotating the test object and rubbing the test object against another solid surface. machine wear can be seen in Figure 4.14.

Figure 4.14 Wear Machine

4.6 Manufacturing Test Object (Paving Block)

To manufacture a paving block, equipments that will be needed are as follows.

1. Sieve, to sieve sand with a size of 4.8 mm.
2. Scales, to weigh the needs of the materials used in the manufacture of test objects.
3. Bucket, for a place to accommodate the need for water which is used as a mixture of materials for making bricks.
4. Spoon specs, to mix and put the mixture into the mixing tub.
5. Shovel and hoe, to stir the brick mixture.
6. Paving block printing machine with size (20 x 10 x 6) cm.

And steps to manufacture a paving block are as follows.

1. Prepare all the necessary materials and tools.
2. Weigh the cement, sand and iron slag waste powder with the planned ratio.
3. Mix the ingredients in a mixing tube with each own ratio. Stir all ingredients until smooth and pasty.
4. Brick dough that has been mixed until smooth, plus enough water to

achieve an even half-wet (soil) mixture. In simple terms, this condition can be known by: The mixture that has been evenly clenched with the palm of the hand. Then dropped from a height of approximately 1.2 meters to the hard ground. When the mixture is good, 2/3 parts still collect and the other 1/3 is scattered (Utomo, 2010).

5. After that the dough that has been mixed evenly is put into the paving block machine fully, then compacted by the machine.
6. Then the printed paving block is lifted slowly and placed in a shady place, not exposed to direct sunlight and protected from rain.

4.7 Maintenance of Test Object (Paving Block)

Good Paving Block maintenance, which is in accordance with the following steps:

1. Avoid Paving Block from direct sunlight and rain water so that the dough binding is as expected.
2. Paving Block treatment for 3 different days which is 28 days namely by soaking and by maintaining room temperature.

4.8 Testing of Test Object (Paving Block)

There are 4 kinds of testing that will be done to the paving block, explanation of each testing can be seen below.

4.8.1 Visual Testing

Aims to determine the visual aspect of the paving block, which is according to SNI-03-0691-1996, Concrete bricks must have a flat surface, there are no cracks and defects, the corners and ribs are not easily crushed with the strength of your fingers. Equipments needed to do the visual testing are as follows.

1. The angle ruler is used to check the angle of each corner and the flatness of the surface of the paving block. The rest of the external inspection is

done using the senses, such as checking the sharpness and strength of the brick ribs, which are not easy to straighten with the strength of the fingers.

2. Capillary equipment or the like with an accuracy of 0.1 mm is required for checking the size of paving blocks. Measurements were carried out in three different places and the average value was taken.

After a treatment period of 28 days, the tested paving blocks must be dry. The steps that must be taken are as follows.

1. Clean the surface of the paving block test object from various adhering dirt.
2. Measure the length, width and thickness of the test object.
3. Observation of the surface of the test object includes: the state of the surface, the density and the state of the angles.

4.8.2 Water Absorption Testing

Aims to determine the wet and dry state weight of paving block, the equipments needed to do the testing are as follows.

1. A container filled with water to soak the test object until the paving block is saturated with water.
2. A rag is used to wipe the surface of the paving block from excess water after soaking.
3. Scales are used to weigh paving blocks in a saturated state of water and oven dry. Scales used with a capacity of 60 kg with an accuracy of 0.1 g.
4. Oven is used to dry paving blocks for water content after soaking. The oven used is equipped with a temperature control, with temperatures between 105 C to 110 C.

Paving blocks to be tested for water absorption must be dry. The steps that must be carried out in this test are:

1. Paving Block is cleaned of other adhering materials.
2. Paving Blocks are put into the oven for 24 hours/day, so that Paving Blocks are found in oven dry.
3. Weigh the Paving Block, so that the Paving Block weight is obtained in an oven dry state.
4. Soak the Paving Block for 24 hours / day or until the Paving Block is saturated.
5. Weigh the Paving Block, so that the Paving Block weight is found in a saturated state. After obtaining the necessary data, the water absorption can be calculated.

4.8.3 Compressive Strength Testing

Aims to determine the compressive strength of the paving block by using a compression machine, equipments that are needed are as follows.

1. The slide rule is used to measure the area of the compression area. A caliper is used to an accuracy of 0.01 mm.
2. The test equipment used is a compression machine.

Procedure of the testing are as follows.

1. Cut the paving block into a cube with the ribs adjusted to the size of the test sample.
2. The test object is removed from the soaking tub, then dried in the sun for ± 24 hours.
3. Weigh the test object and place it on the compressor machine so that it is right in the middle of the pressure tool.
4. Gradually a compressive load is applied to the test object by operating the machine until the test object collapses.
5. When the scale pointer does not go up or increases, then record the scale indicated by the needle which is the maximum load that can be carried by the test object.

6. The experiment is repeated for each test object.
7. After obtaining the necessary data, the compressive strength can be calculated

4.8.4 Wear Resistance Testing

Aims to determine the ability of paving blocks to withstand surface damage if there is friction between solid surfaces. According to SNI 03-0691-1996, wear resistance test of paving block can be carried out by looking at SNI 03-0028-1987 as the step, by using a proper wear resistance testing machine. The procedure for the testing are as follows.

1. Samples that have been cutted out into 50 mm x 50 mm with 20 mm thickness, and have been blowed by wind for a day, surface cleaned.
2. Weigh the samples using a 0,5 grams accuracy weigh.
3. Check the dimension of the samples with a calliper with a 0,1 mm accuracy.
4. Put the samples into the center of the machine.
5. Turn the machine on for 5 minutes.
6. Clean the samples and weigh again.
7. Then calculate the wear resistance durability with this formula:
   Durability: 1,2 x Loss/minutes + 0,0286

4.9 Paving Block Mix Design Calculation

The estimation calculation of this Paving Block mix design is based on the ratio of the composition of Cement: Sand, which is 1 : 6. And in this mixing, water is used based on an estimation during the process of mixing the ingredients.

Sand cement ratio 1 : 6, with the volume of paving block 20x10x6 cm is 1200 cm^3, gotten solid volume weight of sand 1,442 gr/cm^3, hydraulic compaction factor of the pressed machine in Pusat Inovasi according to earlier research is 1,3, then amount of sand needed for a single paving block can be calculated as follow.

$$\text{Sand Needs} = \frac{Ratio\ of\ Sand}{\text{Sand Ratio} + 1} \times Solid\ volume\ weight$$
$$\times\ Paving\ Volume \times compaction\ factor$$

$$\text{Sand Needs} = \frac{6}{6+1} \times 1{,}442 \times 1200 \times 1{,}3$$

$$\text{Sand Needs} = 1927.491\ \text{gr}$$

Because we needed minimum 6 of each ratio to be compacted into the machine, then amount of sand needed for 6 paving blocks is.

$$\text{Sand Needs for } 6 = 1927{,}491 \times 6 = 11564.949\ \text{gr}$$

Meanwhile for the amount of cement needed for a single paving block can be calculated with the following formula.

$$\text{Cement Needs} = \frac{\text{Amount of Sand}}{Ratio\ of\ Cement\ per\ Sand}$$

$$\text{Cement Needs} = \frac{1927{,}491}{6}$$

$$\text{Cement Needs} = 321.249\ \text{gr}$$

Then it can be calculated for 6 paving blocks the amount of cement needed is 1927.491 gr.

For the calculation of slags amount needed for each variation, the variation 1PC:5PS:1IS will be used for the example.

By precenting the ratio of sand with slags, we get 16% of sand will be replaced by the slags for this variation, then the amount of slag can be calculated by this following formula.

$$Slag\ Needs = Sand\ Needs \times Percentage$$

$$Slag\ Needs\ for\ 6\ samples = 11564{,}95 \times 16\%$$

$$Slag\ Needs = 1850.392\ gr$$

$$Sand\ Needs = 11564{,}95 - 1850{,}3920 = 9714.557\ gr$$

While the other mix variations are calculated using the same way as the mixture earlier

Description of mix design of each mixing ratios can be seen in Table 4.1 below.

Table 4.2 Paving Block Mix Design Planning

Water	Iron Slag Substitution	Cement	Sand	Slag	Samples	Ratios
Liter	(%)	(gr)	(gr)	(gr)	(pieces)	
0,8	0	1927.491	11564.949	0.000	6	1Cement:6Sand
0,8	16	1927.491	9714.557	1850.392	6	1Cement:5Sand:1IronSlag
0,8	33	1927.491	7748.516	3816.433	6	1Cement:4Sand:2IronSlag
0,8	50	1927.491	5782.474	5782.474	6	1Cement:3Sand:3IronSlag
0,8	66	1927.491	3932.083	7632.866	6	1Cement:2Sand:4IronSlag
Total		**9637.457**	**38742.578**	**19082.165**	**30**	

4.10 Data Processing

After testing the test object, then the results obtained testing which is still in the form of rough data. The rough data obtained are then further processed to determine the relationship between one test and another, so that it will produce the effect of variations in substitution of iron slag glass waste powder as fine aggregate on the compressive strength of concrete, wear resistance, and water content of paving blocks. Data processing is carried out using the help of a computer program, namely Microsoft Excel Software.

4.11 Research Flow Chart

Scientific research must be carried out systematically or in a clear and orderly sequence of work, so that good, maximum, and accountable results are obtained. The flowchart of the stages of this research can be seen in Figure 4.15 below.

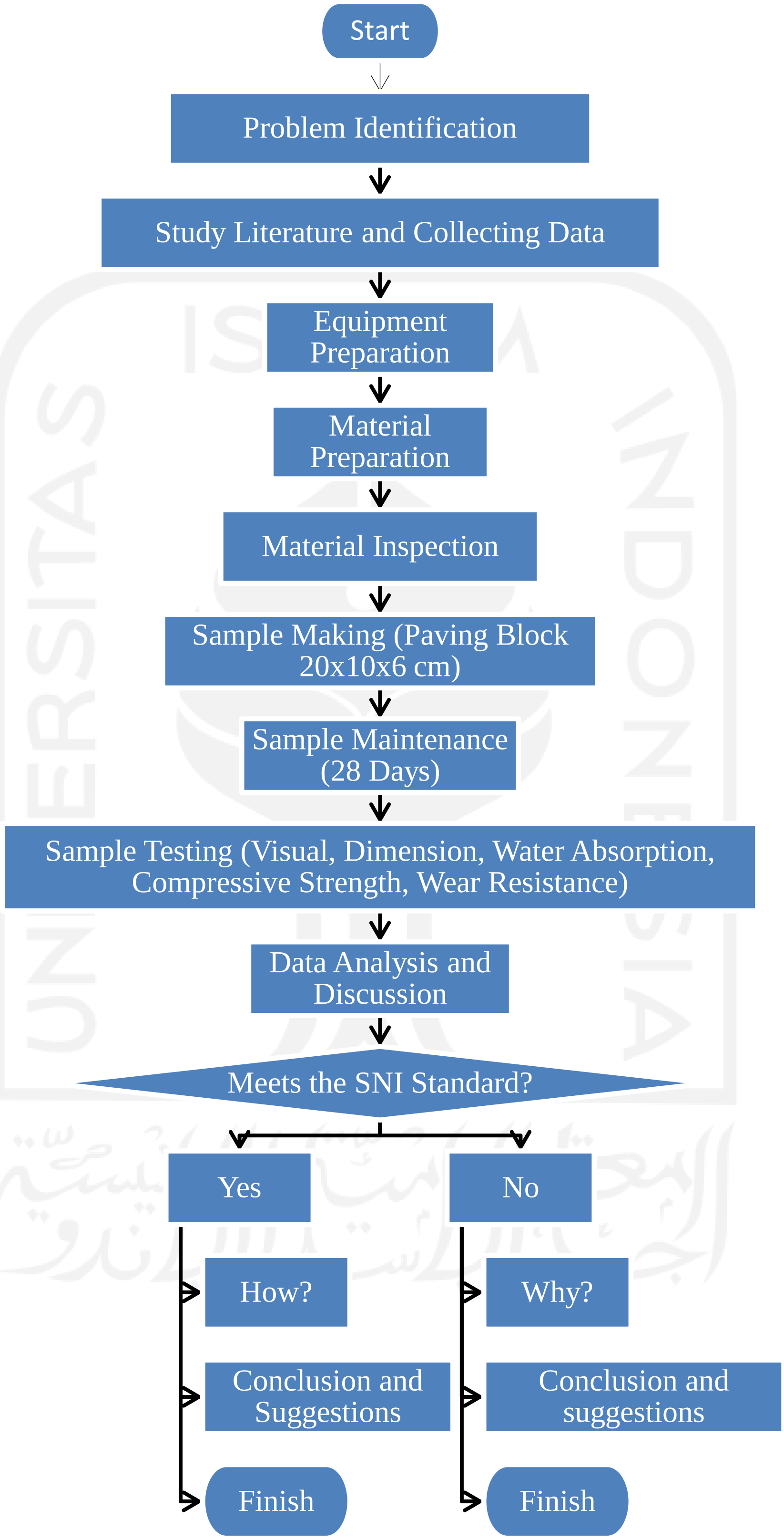

Figure 4.15 Flowchart of research steps

CHAPTER V
ANALYSIS AND DISCUSSION

5.1 Paving Block Testing

5.1.1 Visual Testing

From paving blocks that has been made, we could see the visual as follow:

Table 5.1 Visual Testing Results

Description	Paving Block Variation				
	1Cement : 6Sand	1Cement : 5Sand: 1IronSlag	1Cement : 4Sand : 2IronSlag	1Cement : 3Sand : 3Ironslag	1Cement : 2Sand : 4IRonSlag
1.Areas					
a.Flatness	YES	YES	YES	YES	YES
b.Crack	NO	NO	NO	NO	NO
c.Smoothness	YES	YES	YES	YES	YES
2.Lateral					
a.Right Angle	RIGHT	RIGHT	RIGHT	RIGHT	RIGHT
b.Acuteness	YES	YES	NO	YES	YES
c.Strength	YES	YES	YES	YES	YES

From the visual testing results it can be seen that almost all of the variation which is (1Cement:6Sand, 1Cement:5Sand:1IronSlag, 1Cement:3Sand:3IronSlag, and 1Cement:2Sand:4IronSlag) paving blocks have a flat, uncracked, and smooth surface, as well as angled, sharp and strong sides and has met the external appearance requirements according to SNI 03-0691-1996. But for variation 1Cement:4Sand:2IronSlag has a slightly not acute sides, the cause of this irerrugalirty was mainly, the cause of this irerrugalirty was mainly because when mixing was happening, a little bit more of this variations ingredients has been accidentally falls making the amount of final mixture less than it should be and made it when pressing ingredients into the machine, not enough mixture was there so some of the finished product for this variations are left with sides that are not too acute, thus it doesn’t met the requirements according to SNI 03-0691-1996.

5.1.2 Dimension Checking

After examining the visible properties, the dimensions and cross sectional dimensions can be checked in accordance with the provisions of SNI 03-0691-1996, using paving blocks on average 4 intact test objects are used. As a measuring tool, a ruler with an accuracy of 0.1 mm is used and thickness measurements are made at least 3 (three) times in different places and the average value is taken.

Table 5.2 Dimension Checking Result

No	Variation	Type	Thickness (cm)			
			Left Side	Middle	Right Side	Average
1	1Cement : 6Sand	V1S1	5.8	5.7	5.7	5.73
2		V1S2	5.9	5.9	5.7	5.83
3		V1S3	5.5	5.8	5.8	5.70
4		V1S4	5.7	5.9	5.8	5.80
5	1Cement : 5Sand : 1IronSlag`	V2S1	5.9	5.9	5.9	5.90
6		V2S2	5.6	5.6	5.7	5.63
7		V2S3	5.8	5.6	5.9	5.77
8		V2S4	5.5	5.7	5.6	5.60
9	1Cement : 4Sand : 2IronSlag	V3S1	5.6	5.7	5.8	5.70
10		V3S2	5.5	5.6	5.7	5.60
11		V3S3	5.6	5.7	5.7	5.67
12		V3S4	5.7	5.7	5.7	5.70
13	1Cement : 3Sand : 3IronSlag	V4S1	5.4	5.6	5.6	5.53
14		V4S2	5.6	5.6	5.6	5.60
15		V4S3	5.6	5.6	5.6	5.60
16		V4S4	5.5	5.6	5.6	5.57
17	1Cement : 2Sand : 4IronSlag	V4S1	5.6	5.6	5.6	5.60
18		V4S2	5.6	5.5	5.6	5.57
19		V4S3	5.6	5.7	5.7	5.67
20		V4S4	5.5	5.8	5.7	5.67

It can be seen from the test results data, the condition of the paving blocks shows a difference in thickness caused by the even distribution of the mixture on the printing machine at the time of making paving blocks, so the paving blocks are not too flat when printed. In examining the thickness of the paving block in all variations of paving blocks, the thickness is less than 6 cm (60 mm), but it can still meet the requirements of a tolerance of 8% (5.52 mm). So all the paving blocks meet the requirement of SNI 03-0691-1996.

5.1.3 Compressive Strength Testing

The results of the compressive strength testing of paving blocks in this study are as follows:

Table 5.3 Compressive Strength Testing Results

Sample Code	Length (mm)	Wide (mm)	Weight (kg)	Load (kN)	Comp. Strength (Mpa)	Average	Quality
V1S1	60	60	0.485	73.060	20.294	15.409	C
V1S2	60	60	0.449	40.452	11.237		
V1S3	60	60	0.433	52.907	14.696		
V2S1	60	60	0.459	41.433	11.509	12.867	C
V2S2	60	60	0.471	47.758	13.266		
V2S3	60	60	0.499	49.769	13.825		
V3S1	60	60	0.532	24.615	6.837	7.400	-
V3S2	60	60	0.495	28.341	7.873		
V3S3	60	60	0.485	26.968	7.491		
V4S1	60	60	0.546	16.867	4.685	5.439	-
V4S2	60	60	0.520	22.555	6.265		
V4S3	60	60	0.504	19.319	5.366		
V5S1	60	60	0.572	21.182	5.884	5.013	-
V5S2	60	60	0.552	16.181	4.495		
V5S3	60	60	0.540	16.779	4.661		

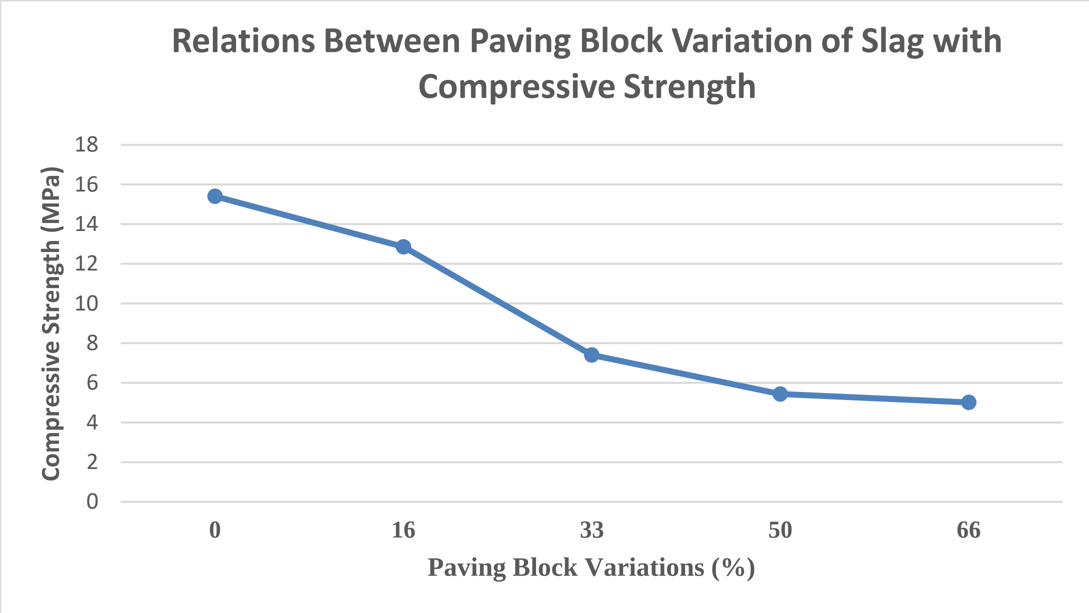

Figure 5.1 Graph of Relations Between Paving Block Slag Variations with Compressive Strength.

Using equation 3.1, we get compressive strength of each variations and from the results it can be seen that the highest compressive strength obtained is in the normal variation of 1Cemend:6Sand with 15.409 Mpa, and then the compressive strength decreased for the next variations, for variation 1Cement:5Sand:1IronSlag the compressive strength obtained is 12.867 MPa, these 2 variations met the requirements for quality C paving block according to SNI 03-0691-1996, which is better to used for pedestrians.

3 others variation such as 1Cement:4Sand:2IronSlag the compressive strength obtained is 7.400 MPa, for variation 1PC:3PS:3TB compressive strength obtained is 5.439 MPa, and for variation 1PC:2PS:4TB compressive strength obtained is 5.013 MPa, these 3 variations did not met the requirement for any qualities according to SNI 03-0691-1996, so they can not be used for anything.

As for why the results decrease greatly across all the variations may be caused by caused by the increasing substitution of iron slag causing the paving block to rust or corrosion is happened between the granules after being cured in water, reducing the strength of the paving block itself proved by the decreasing trend from the original mixture to the most iron slag substitution, as stated by Ninik Paryati (2001) as well that in her journal stated that she got an optimum compressive strength reached at the replacement of slags into fine agregate is at 25%, her lowest variations. And for the variation of paving block with iron slag as a replacement for fine aggregate to reach maximum compressive strength would be the variation 1Cement:5sand:1IronSlag (or 16% of sand volume) as it has the highest compressive strength among other added iron slag variation.

Figure 5.2 Reddish Looking Paving Blocks due to Corrosion

5.1.4 Water Absorption Testing

The results of the water absorption test on paving blocks are as follows:

Table 5.4 Water Absorption Testing Results.

Code	Wet Weight (kg)	Dry Weight (kg)	Absorption (%)	Average (%)	Quality
V1S1	2.469	2.246	9.929	9.63	D
V1S2	2.474	2.261	9.421		
V1S3	2.465	2.250	9.556		
V2S1	2.592	2.361	9.784	9.56	D

V2S2	2.601	2.374	9.562		
V2S3	2.598	2.376	9.343		
V3S1	2.969	2.707	9.679	9.45	D
V3S2	2.974	2.714	9.580		
V3S3	2.966	2.719	9.084		
V4S1	2.992	2.732	9.517	9.25	D
V4S2	2.989	2.735	9.287		
V4S3	2.986	2.741	8.938		
V5S1	3.059	2.800	9.250	8.92	D
V5S2	3.052	2.811	8.573		
V5S3	3.049	2.799	8.932		

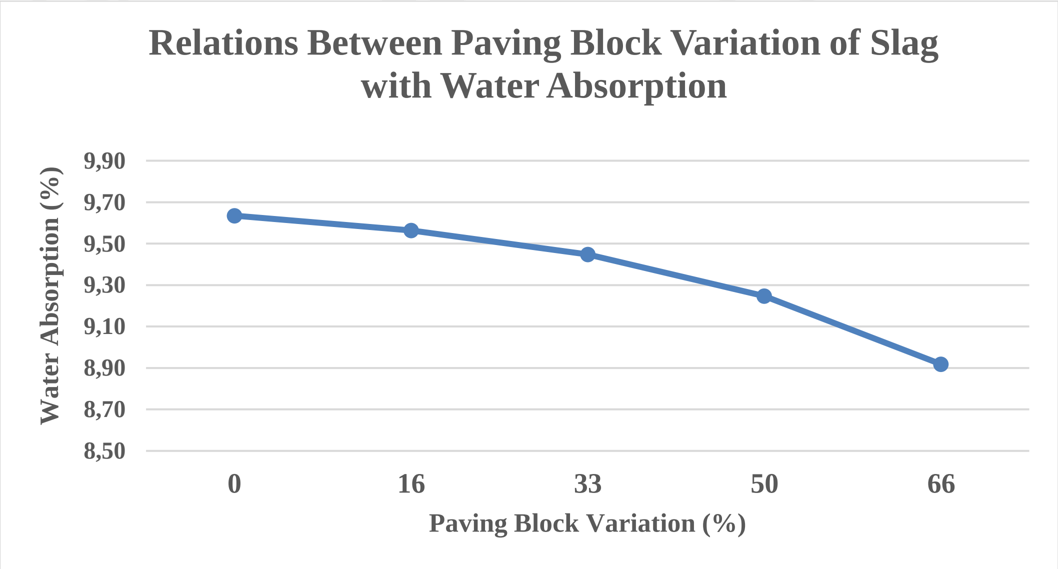

Figure 5.3 Graph of Relations Between Paving Block Variation of Slag with Water Absorption

Using equation 3.2, we get water absorption from each variations, and from the graph above it can be seen that the biggest water absorption found is in normal variation of 1Cement:6Sand with 9.63% of water absorption and the smallest water absorption found is in 1Cement:2Sand:4IronSlag variation with 8.92%, the graph shows a decreasing trend meaning with more substitution of iron slag to the concrete mixture, the smaller the water absorption value is, it could happen mainly because of the characteristics of iron that does not absorp water as good or as much as normal aggregate like sand, thereby reducing the value of water absorption which make the graph decreasing from left to right. All of the paving blocks met the requirements and is included in quality D that can be used for parks and other uses according to SNI 03-0691-1996. And for the variation of paving block with iron slag as a replacement for fine aggregate to reach minimum water absorption would be the variation 1Cement:2sand:4IronSlag (or 66% of sand volume) as it has the lowest water absorption, mainly because the density of iron is denser than sand making the granules between the aggregate tighter.

Mutu	Kuat Tekan (Mpa)		Ketahanan Aus (mm/menit)		Penyerapan Air Rata-Rata
	Rerata	Min	Rerata	Min	(%)
A	40	35	0,090	0,103	3
B	20	17,0	0,130	0,149	6
C	15	12,5	0,160	0,184	8
D	10	8,5	0,219	0,251	10

Sumber: SNI 03-0691-1996

Figure 5.4 Table of Qualities of Paving Blocks

5.1.5 Wear Resistance Testing

The results of the wear resistance testing of paving blocks in this study are as follows:

Table 5.5 Wear Resistance Testing Results

Code	Initial Weight	Final Weight	Loss	Loss/Min	Durability	Average	Quality
V1S1	434.96	433.41	1.55	0.310	0.40	0.3556	-
V1S2	439.63	437.89	1.74	0.348	0.44		
V1S3	434.13	433.31	0.82	0.164	0.22		
V2S1	463.09	461.32	1.77	0.354	0.4516	0.5196	-
V2S2	486.39	484.92	1.47	0.294	0.3796		
V2S3	464.68	461.76	2.92	0.584	0.7276		
V3S1	496.32	495.12	1.2	0.24	0.3148	0.3244	-
V3S2	510.23	509.13	1.1	0.22	0.2908		
V3S3	516.91	515.49	1.42	0.284	0.3676		
V4S1	460.85	459.16	1.69	0.338	0.4324	0.4892	-

V4S2	494.28	491.84	2.44	0.488	0.6124		
V4S3	483.27	481.62	1.65	0.33	0.4228		
V5S1	480.18	477.87	2.31	0.462	0.5812	0.3628	-
V5S2	498.95	497.78	1.17	0.234	0.3076		
V5S3	527.09	526.37	0.72	0.144	0.1996		

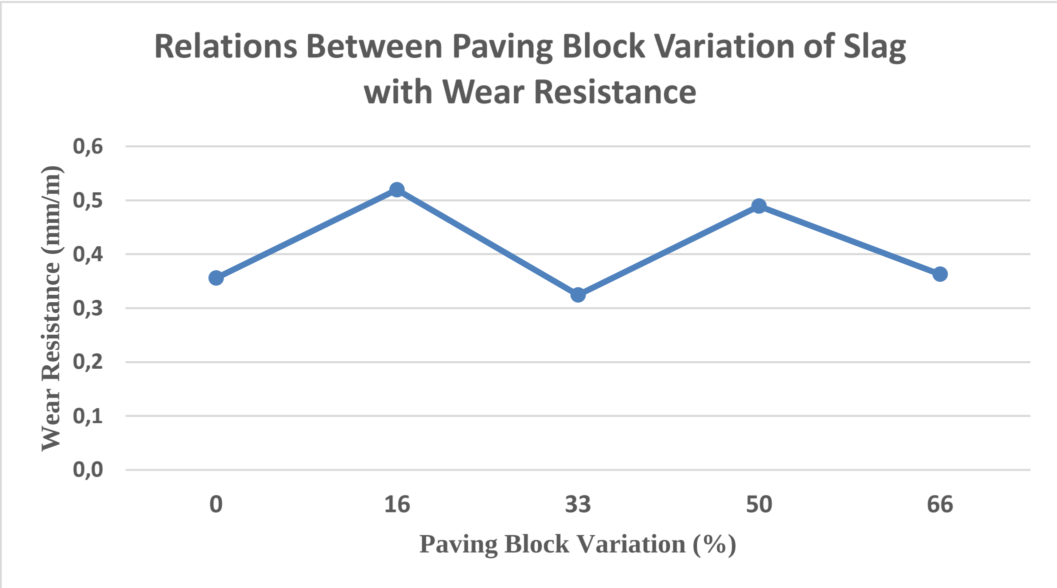

Figure 5.5 Graph of Relations Between Paving Block Variation of Slag with Wear Resistance.

From the graph above it can be seen that normal paving block without the substitution of slag (variation 1Cement:6Sand) reach a wear resistance about 0.356 mm/minutes and the results did not met the requirement (too great) for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality).

For the variation 1Cement:5Sand:1IronSlag the wear resistance increase to 0.520 mm/minutes and the results also did not met the requirement for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality).

For the variation 1Cement:4Sand:2IronSlag the wear resistance decrease to 0.324 mm/minutes and the results also did not met the requirement for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality).

For the variation 1Cement:3Sand:3IronSlag the wear resistance increase again to 0.489 mm/minutes and the results also did not met the requirement for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality).

For the final variation of 1Cement:2Sand:4Ironslag the wear resistance decrease again to 0.363 mm/minutes and the results also did not met the requirement for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality).

As to why the results can be varied greatly across all variation may be caused by the unsureness of the formula that has to be used to calculate the wear resistance, because the machine that is used for the wear resistance testing that is located in UII laboratory is different than the one that is used in SNI standard machine, making it is not possible to use the same calculation like the one in SNI, other reasons may be caused by corrosion that happened between the granule after it was cured in the water, making it weaker. Just like stated by Muhammad Yahya Rangkuti (2016) in his final task that all of his his paving blocks variations testing of wear resistance also passed the minimum limit of all the requirement in SNI 03-0691-1996 because of the limit knowledge of the wear resistance testing machine. And for the variation of paving block with iron slag as a replacement for fine aggregate to reach optimum water absorption would be the variation 1Cement:4sand:2IronSlag (or 33% of sand volume) as it has the lowest loss of wear resistance.

5.2 Overall Test Results

Of all the testing that has been done, data that are obtained are as follows:

a. From the visual testing results it can be seen that almost all of the variation which is (1Cement:6Sand, 1Cement:5Sand:1IronSlag, 1Cement:3Sand:3IronSlag, and 1Cement:2Sand:4IronSlag) paving blocks produce a flat, uncracked, and smooth surface, as well as angled, sharp and strong sides and has met the external appearance requirements according to SNI 03-0691-1996. But for variation 1Cement:4Sand:2IronSlag has a slightly not acute sides, the cause of this irerrugalirty was mainly because when mixing was happening, a little bit more of this variations ingredients has been accidentally falls making the amount of final mixture less than it should be and made it when pressing ingredients into the machine, not enough mixture was there so some of the finished product for this variations are left with sides that are not too acute, thus it doesn't met the requirements according to SNI 03-0691-1996.

b. From the dimension checking, it can be seen from the test results data, the condition of the paving blocks shows a difference in thickness caused by the even distribution of the mixture on the printing machine at the time of making paving blocks, so the paving blocks are not too flat when printed. In examining the thickness of the paving block in all variations of paving blocks, the thickness is less than 6 cm (60 mm), but it can still meet the requirements of a tolerance of 8% (5.52 mm).

c. From the compressive strength results it can be seen that the highest compressive strength obtained is in the normal variation of 1Cement:6Sand with 15.409 Mpa, and then the compressive strength decreased for the next variations, for variation 1Cement:5Sand:1IronSlag the compressive strength obtained is 12.867 MPa, these 2 variations met the requirements for quality C paving block according to SNI 03-0691-1996, which is better to used for pedestrians. 3 others variation such as 1Cement:4Sand:2Ironslag the compressive strength obtained is 7.400 MPa, for variation 1Cement:3Sand:3IronSlag compressive strength obtained is 5.439 MPa, and for variation 1Cement:2Sand:4Ironslag compressive strength obtained is 5.013 MPa, these 3 variations did not met the requirement for any qualities according to SNI 03-0691-1996, so they can not be used for anything. As for why the results decrease greatly across all the variations may be caused by caused by the increasing substitution of iron slag causing the paving block to rust or corrosion happened between the granules after being cured in water, reducing the strength of the paving block itself proved by the decreasing trend from the original mixture to the most iron slag substitution. And for the variation of paving block with iron slag as a replacement for fine aggregate to reach maximum compressive strength would be the variation 1Cement:5sand:1IronSlag (or 16% of sand volume) as it has the highest compressive strength among other added iron slag variation.

d. From the water absorption testing graph it can be seen that the maximum water absorption found is in normal variation of 1PC:6PS with 9.63% of water absorption and the minimum water absorption found is in 1PC:2PS:4TB variation with 8.92%, the graph shows a decreasing trend meaning with more substitution of iron slag to the concrete mixture, the smaller the water absorption value is, it could happen mainly because of the characteristics of iron that does not absorp water as good or as much as normal aggregate like sand, thereby reducing the value of water absorption which make the graph decreasing from left to right. All of the paving blocks met the requirements and is included in quality D that can be used for parks and other uses according to SNI 03-0691-1996. And for the variation of paving block with iron slag as a replacement for fine aggregate to reach minimum water absorption would be the variation 1Cement:2sand:4IronSlag (or 66% of sand volume) as it has the lowest water absorption

e. From the wear resistance testing results it can be seen that normal paving block without the substitution of slag (variation 1PC:6PS) reach a wear resistance about 0.356 mm/minutes and the results did not met the requirement (too great) for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality). For the variation 1PC:5PS:1TB the wear resistance increase to 0.520 mm/minutes and the results also did not met the requirement for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality). For the variation 1PC:4PS:2TB the wear resistance decrease to 0.324 mm/minutes and the results also did not met the requirement for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality). For the variation 1PC:3PS:3TB the wear resistance increase again to 0.489 mm/minutes and the results also did not met the requirement for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality). For the final variation of 1PC:2PS:4TB the wear resistance decrease again to 0.363 mm/minutes and the results also did not met the requirement for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality). As to why the results can be varied greatly across all variation may be caused by the unsureness of the formula that has to be used to calculate the wear resistance, because the machine that is used for the wear resistance testing that is located in UII laboratory is different than the one that is used in SNI standard machine, making it is not possible to use the same calculation like the one in SNI. Other reasons may be caused by corrosion that happened between the granule after it was cured in the water, making it weaker. And for the variation of paving block with iron slag as a replacement for fine aggregate to reach maximum water absorption would be the variation 1Cement:4sand:2IronSlag (or 33% of sand volume) as it has the lowest loss of wear resistance.

f. From all the testing that has been done, it can be seen that from water absorption testing, all variation of paving block are included in quality D according to SNI 03-0691-1996 which can be used for parks and any other uses, but from the compressive strength testing, only variation 1PC:6PS and 1PC:5PS:1TB that has the value that met the requirement to be in C quality of paving block according to SNI 03-0691-1996 which can be used for pedestrians, other variations compressive strength results did not met the requirement so that they can not be used for anything, and for wear resistance testing, all of the paving block variation did not met the requirements so that they all also can not be used for anything.

g. For relationships between the three parameters such as compressive strength, water absorption, and wear resistance, it can be seen that from the results that more slag is substituted into sand for paving block mixture, then the compressive strength will decrease gradually too, meanwhile the water absorption increase gradually as the substitution increase, as for the wear resistance results, no relationship can be found because the results are increasing and decreasing randomly making it is very difficult to find any relationship, the graph of relationships between substitution of slag and compressive strength and water absorption can be seen below.

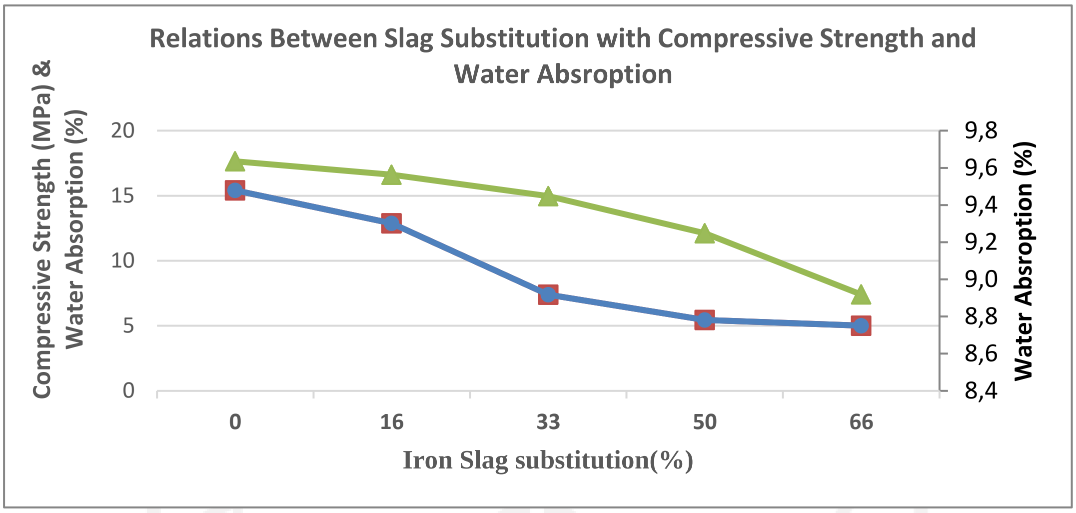

Figure 5.5 Graph of Relations Between Slag Substitution with Compressive Strength and Water Absroption

CHAPTER VI

CONCLUSION AND ADVICE

6.1 Conclusion

From the problem formulations and research results obtained from discussions that have been carried out, it can be concluded as follows:

1. For the maximum percentage of iron slag as a replacement for fine aggregate, the answer differed by the testing that has been done, for water absorption testing, the minimum percentage is 66% of sand volume or is in variation 1Cement:2Sand:4IronSlag, for compressive strength testing, the maximum percentage is 16% sand volume or is in variation 1Cement:5Sand:1Ironslag, and for the wear resistance testing, the maximum percentage is 33% sand volume or is in variation 1Cement:4Sand:2Ironslag.

2. Greatest compressive strength is also can be seen in the normal variation of 1Cement:6Sand with 15.409 Mpa, and then the compressive strength decreased for the next variations, for variation 1Cement:5Sand:1IronSlag the compressive strength obtained is 12.867 MPa, these 2 variations met the requirements for quality C paving block according to SNI 03-0691-1996, which is better to used for pedestrians. 3 others variation such as 1Cement:4Sand:2Ironslag the compressive strength obtained is 7.400 MPa, for variation 1Cement:3Sand:3IronSlag compressive strength obtained is 5.439 MPa, and for variation 1Cement:2Sand:4Ironslag compressive strength obtained is 5.013 MPa, these 3 varioations did not met the requirement for any qualities according to SNI 03-0691-1996, so they can not be used for anything. As for why the results decrease greatly across all the variations may be caused by caused by the increasing substitution of iron slag causing the paving block to rust or corrosion happened between the granules after being cured in water, reducing the

strength of the paving block itself proved by the decreasing trend from the original mixture to the most iron slag substitution.

3. From the water absorption testing graph it can be seen that the biggest water absorption found is in normal variation of 1PC:6PS with 9.63% of water absorption and the smallest water absorption found is in 1PC:2PS:4TB variation with 8.92%, the graph shows a decreasing trend meaning with more substitution of iron slag to the concrete mixture, the smaller the water absorption value is, it could happen mainly because of the characteristics of iron that does not absorp water as good or as much as normal aggregate like sand, andthe density of iron is denser than sand making the granules between the aggregate tighter. thereby reducing the value of water absorption which make the graph decreasing from left to right. All of the paving blocks met the requirements and is included in quality D that can be used for parks and other uses according to SNI 03-0691-1996.

4. From the wear resistance testing results it can be seen that normal paving block without the substitution of slag (variation 1PC:6PS) reach a wear resistance about 0.356 mm/minutes and the results did not met the requirement (too great) for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality). For the variation 1PC:5PS:1TB the wear resistance increase to 0.520 mm/minutes and the results also did not met the requirement for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality). For the variation 1PC:4PS:2TB the wear resistance decrease to 0.324 mm/minutes and the results also did not met the requirement for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality). For the variation 1PC:3PS:3TB the wear resistance increase

again to 0.489 mm/minutes and the results also did not met the requirement for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality). For the final variation of 1PC:2PS:4TB the wear resistance decrease again to 0.363 mm/minutes and the results also did not met the requirement for any qualities of paving blocks according to SNI 03-0691-1996 which has a minimum of 0.251 mm/minutes for the lowest quality (D quality).

5. For the visual testing and dimension checking almost all the paving blocks from all variations met the requirement from SNI 03-0691-1996, but for some sample from variation 1PC:4PS:2TB has a slightly not acute sides, the cause of this irerrugalirty was mainly because , the cause of this irerrugalirty was mainly because when mixing was happening, a little bit more of this variations ingredients has been accidentally falls making the amount of final mixture less than it should be and made it when pressing ingredients into the machine, not enough mixture was there so some of the finished product for this variations are left with sides that are not too acute, thus it doesn't met the requirements according to SNI 03-0691-1996.

6.2 Advice

Based on the conclusions and previous discussion, it is suggested as follows:

a. To get good quality, accuracy, planning, work methods, tools and materials to maintenance must be done properly and in accordance with the guidelines.

b. To minimize chances of corrosion, it is better to wash iron slag powder that is going to be use in oil.

c. There are so many limitations in this study, so it is hoped that further research will be carried out as follows:

1) Because of the results of test that haven't reach any optimum results in water absorption and compressive strength, for further research it is better to use variations that is higher or lower than this research variations in hope to find optimum variations for better water absorption and compressive strength results.

2) Different wear resistance testing machine was used, rather than the machine used in SNI 03-0691-1996 instruction which can be the reason why the wear resistance results greatly exceed the requirement from SNI 03-0691-1996.

REFERENCES

Anggraeni, T., Septrianto, W. and Fatmawati, L., (2018). *STUDI ANALISIS LIMBAH TERAK BESI SEBAGAI PENGGANTI SEBAGIAN AGREGAT HALUS PADA PEMBUATAN PAVING BLOCK*. Semarang, Politeknik Negeri Semarang.

Badan Standarisasi Nasional. (1996). Bata Beton (Paving Block) (SNI 03-0691-1996). Jakarta.

Badan Standarisasi Nasional. (1987). Cara Uji Coba Ubin Semen (SNI 03-0028-1987). Jakarta

Dubey, S., Singh, A. and Kushwah, S., (2019). Utilization of iron and steel slag in building construction. *PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON SUSTAINABLE MATERIALS AND STRUCTURES FOR CIVIL INFRASTRUCTURES (SMSCI2019)*,.

Id.wikipedia.org. (2021). *Terak - Wikipedia bahasa Indonesia, ensiklopedia bebas*. https://id.wikipedia.org/wiki/Terak

M-Gharrib Noori, K. and Hashim Ibrahim, H., 2018. Mechanical Properties of Concrete Using Iron Waste as a Partial Replacement of Sand. *IEC2018 Proceedings Book*,.

Mulyatun, M. (2017). Green Concrete Made From Iron Slag Waste. *Journal Of Natural Sciences And Mathematics Research*, *1*(2), 58-64. doi:http://dx.doi.org/10.21580/jnsmr.2015.1.2.1603

Paryati, N., n.d. *KUAT TEKAN BETON DENGAN PENAMBAHAN SERBUK BESI DAN BAJA*. Bekasi, Universitas Islam "45".

Paving Block Indonesia. 2021. *Cara Membuat Paving Block Manual dan Press Mesin*. https://pavingblock.co.id/cara-membuat-paving-block/

Yahya Rangkuti, M., (2016). *KAJIAN EKSPERIMENTAL BATA BETON (PAVING BLOCK) MENGGUNAKAN ABU VULKANIK ERUPSI GUNUNG SINABUNG SESUAI SNI 03-0691-1996*. Medan, Universitas Sumatera Utara.

Zulhan, Z., 2013. IRON AND STEELMAKING SLAGS: ARE THEY HAZARDOUS WASTE?. In: *2013 ASEAN Iron and Steel Sustainability Forum*. Jakarta, Bandung Institute of Technology.

Attachments 1

Time schedule of the research

No	Activity	Month		Dec-21		Jan-22				Feb-22				Mar-22	
		Weeks		3	4	1	2	3	4	1	2	3	4	1	2
		Time (Hour)	Weight (%)												
1	**Collecting materials and equipments**	24	4,35	4,35											
2	**Paving block making**														
	Preparation	50	4,35		4,35										
	Execution	50	21,74			21,74									
	Testing	50	21,74				5,44	5,44	5,44	5,44					
3	**Testing Processing**														
	Calculation	35	15,22								7,61	7,61			
	Calculation results checking	5	2,17									2,17			
4	**Calculation results verification**	20	8,70										4,35	4,35	
5	**Making reports**	50	21,74											10,87	10,87
Total		284	100	4,35	4,35	21,74	5,44	5,44	5,44	5,44	7,61	9,78	4,35	15,22	10,87
Cumulative				4,35	8,70	30,44	35,88	41,31	46,75	52,18	59,79	69,57	73,92	89,14	100

Attachments 2.1

Sieve Test of Sand Results

LABORATORIUM BAHAN KONSTRUKSI TEKNIK
PROGRAM STUDI TEKNIK SIPIL
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MODULUS HALUS BUTIR (MHB) / ANALISA SARINGAN AGREGAT HALUS

(SNI 03-1968-1990) PASIR

Pengirim	
Tanggal Terima	
Asal Agregat	
Keperluan	

Lubang Ayakan (mm)	Berat Tertinggal (gram)		Berat Tertinggal (%)		Berat Tertinggal Kumulatif (%)		Persen Lolos Kumulatif (%)		Rata-rata (%)
	Sampel		Sampel		Sampel		Sampel		
	1	2	1	2	1	2	1	2	
9,60							[illegible]	100	
4,8	1	1	0,05	0,05	0,05	0,05	99,95	99,95	
2,4	111	114	[illegible]	5,70	5,60	5,75	[illegible]	94,25	
1,2	360	357	18	18,35	23,60	24,10	[illegible]	75,90	
0,6	621	608	31,05	30,40	54,65	54,50	[illegible]	45,50	
0,3	436	443	21,80	22,15	76,45	76,65		23,35	
0,15	298	288	14,90	14,40	91,35	91,05		8,95	
Pan	170	174	8,50	8,70	100	100		0	
Jumlah	1997	1995	100	100					

Modulus Halus Butir = → 99,95; 94,4; 76,40; 45,35; 23,50; 8,05; 0

GRADASI PASIR

Lubang Ayakan	Persen Butir Agregat yang Lolos Ayakan			
(mm)	Daerah I	Daerah II	Daerah III	Daerah VI
10,00	100	100	100	100
4,80	90 – 100	90 – 100	90 – 100	95 – 100
2,40	60 – 95	75 – 100	85 – 100	95 – 100
1,20	30 – 70	55 – 90	75 – 100	90 – 100
0,60	15 – 34	35 - 59	60 – 79	80 – 100
0,30	5 – 20	8 – 30	12 – 40	15 – 50
0,15	0 - 10	0 - 10	0 - 10	0 – 15

Keterangan: **Daerah 1 : Pasir Kasar** — **Daerah II : Pasir Agak Kasar** — **Daerah III : Pasir Agak Halus** — **Daerah IV : Pasir Halus**

Attachments 2.2

Sieve Test of Iron Slag Results

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MODULUS HALUS BUTIR (MHB) / ANALISA SARINGAN AGREGAT HALUS

(SNI 03-1968-1990)

Pengirim	
Tanggal Terima	
Asal Agregat	
Keperluan	

2 kg limbah serbuk besi

Lubang Ayakan (mm)	Berat Tertinggal (gram)		Berat Tertinggal (%)		Berat Tertinggal Kumulatif (%)		Persen Lolos Kumulatif (%)		Rata-rata (%)
	Sampel		Sampel		Sampel		Sampel		
	1	2	1	2	1	2	1	2	
9,60									
4,8	6		0,301		0,301		99,699		
2,4	2		0,100		0,401		99,599		
1,2	4		0,200		0,601		~~[illegible]~~	99,399	
0,6	46		2,305		2,906		~~[illegible]~~	97,094	
0,3	1014		50,802		53,708		46,292		
0,15	822		41,182		94,89		5,11		
Pan	102		5,110		100		0		
Jumlah	1996		100						

Modulus Halus Butir =

GRADASI PASIR

Lubang Ayakan (mm)	Persen Butir Agregat yang Lolos Ayakan			
	Daerah I	Daerah II	Daerah III	Daerah VI
10,00	100	100	100	100
4,80	90 – 100	90 – 100	90 – 100	95 – 100
2,40	60 – 95	75 – 100	85 – 100	95 – 100
1,20	30 – 70	55 – 90	75 – 100	90 – 100
0,60	15 – 34	35 - 59	60 – 79	80 – 100
0,30	5 – 20	8 – 30	12 – 40	15 – 50
0,15	0 - 10	0 - 10	0 - 10	0 – 15

Keterangan: Daerah 1 : Pasir Kasar
Daerah II : Pasir Agak Kasar
Daerah III : Pasir Agak Halus
Daerah IV : Pasir Halus

Attachments 2.3

Bulk Density of Sand Test Results

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PEMERIKSAAN BERAT ISI PADAT AGREGAT HALUS Pasir
(SNI 03-4804-1998)

Pengirim	
Tanggal Terima	
Asal Agregat	
Keperluan	

Uraian	Hasil Penelitian	
	Sampel 1	Sampel 2
Berat silinder (W1), gram	5199	5263
Berat silinder + agregat kering permukaan (SSD) (W2), gram	7694	7676
Berat agregat (W3), gram	2495	2413
Volume Silinder (V), cm^3	1701,01	1704,39
Berat isi gembur = W3/V, $gram/cm^3$	1,467	1,416
Berat isi gembur rata – rata, $gram/cm^3$	1,4415	

Yogyakarta,

Diperiksa Oleh: Dikerjakan Oleh:

....

tinggi = 20,18 cm
D = 10,37 cm

$V = \frac{1}{4} \pi D^2 \times t$

$= \frac{1}{4} \pi \times 10,37^2 \times 20,18$

$= 1704,388$

Attachments 2.4

Bulk Density of Iron Slag Test Results

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PEMERIKSAAN BERAT ISI PADAT AGREGAT HALUS BES
(SNI 03-4804-1998)

Pengirim	
Tanggal Terima	
Asal Agregat	
Keperluan	

Uraian	Hasil Penelitian	
	Sampel 1	Sampel 2
Berat silinder (W1), gram	5264	
Berat silinder + agregat kering permukaan (SSD) (W2), gram	8147	
Berat agregat (W3), gram	2928	
Volume Silinder (V), cm^3	1656,521	
Berat isi gembur = W3/V, $gram/cm^3$	1,768	
Berat isi gembur rata – rata, $gram/cm^3$		

Yogyakarta,

Diperiksa Oleh: Dikerjakan Oleh:

……………………………………… ………………………………………….

Attachments 2.5

Specific Gravity Sand Test Results

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PEMERIKSAAN BERAT JENIS DAN PENYERAPAN AIR AGREGAT HALUS
(SNI 03-1970-1990)

Pengirim	
Tanggal Terima	
Asal Agregat	
Keperluan	

Uraian	Hasil Pengamatan		
	Sampel 1	Sampel 2	Rata-rata
Berat pasir kering mutlak, gram (Bk)	491,70	494	492,85
Berat pasir kondisi jenuh kering muka (SSD), gram	500	500	500
Berat piknometer berisi pasir dan air, gram (Bt)	1164	1175	1169,5
Berat piknometer berisi air, gram (B)	860	860	860
Berat jenis curah, ……………………………….(1) Bk / (B + 500 – Bt)	2.51	2,670	2,590
Berat jenis jenuh kering muka, …………………(2) 500 / (B + 500 – Bt)	2,55	2,703	2,625
Berat jenis semu, ………………………………..(3) Bk / (B+ Bk – Bt)	2,62	2,78	2,688
Penyerapan air, …………………………………..(4) (500 – Bk) / Bk x 100%, %	1,626	1,214	1,4203

Keterangan :

500 : berat benda uji dalam kondisi jenuh kering permukaan, gram

Kesimpulan	ok

Yogyakarta,

Diperiksa Oleh: ……………………………………

Dikerjakan Oleh: ………………………………………

Attachments 2.6

Clay Content of Sand Test Results

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PEMERIKSAAN BUTIRAN LOLOS AYAKAN NO.200
/ UJI KANDUNGAN LUMPUR DALAM PASIR
(SNI 03-4142-1996)

Pengirim	
Tanggal Terima	
Asal Agregat	
Keperluan	

Ukuran Butir Maksimum	Berat Minimum	Keterengan
4,80 mm	500 gram	Pasir
9,60 mm	1000 gram	Kerikil
19,20 mm	1500 gram	Kerikil
38,00 mm	2500 gram	Kerikil

Uraian	Hasil Penelitian	
	Sampel 1	Sampel 2
Berat agregat halus kering mutlak (W1), gram	500	500
Berat Agregat halus setelah dicuci dan dioven (W2), gram	494	497
Berat lumpur (W3) = (W1-W2), gram	6	3
Kadar lumpur = W3 x 100%, %	1,2	0,6
Kadar lumpur rata-rata, %	0,9	

Menurut Persyaratan Umum Bahan Bangunan di Indonesia 1982 (PUBI-1982), berat bagian yang lolos ayakan no. 200 (0,075 mm):

a. untuk pasir maksimum 5% (lima persen)
b. untuk kerikil maksimum 1% (satu persen)

Yogyakarta,

Diperiksa Oleh: ……………………………………

Dikerjakan Oleh: ……………………………………

Attachments 2.7

Paving Block Dimension Checking Results

Dimension Checking of Paving Block

No	Variation	Type	Thickness Left Side (cm)	Thickness Middle (cm)	Thickness Right Side (cm)	Thickness Average (cm)
1	1PC : 6PS	V1S1	5,8	5,7	5,7	5,73
2		V1S2	5,9	5,9	5,7	5,83
3		V1S3	5,5	5,8	5,8	5,70
4		V1S4	5,7	5,9	5,8	5,80
5	1PC : 5PS : 1TB	V2S1	5,9	5,9	5,9	5,90
6		V2S2	5,6	5,6	5,7	5,63
7		V2S3	5,8	5,6	5,9	5,77
8		V2S4	5,5	5,7	5,6	5,60
9	1PC : 4PS : 2TB	V3S1	5,6	5,7	5,8	5,70
10		V3S2	5,5	5,6	5,7	5,60
11		V3S3	5,6	5,7	5,7	5,67
12		V3S4	5,7	5,7	5,7	5,70
13	1PC : 3PS : 3TB	V4S1	5,4	5,6	5,6	5,53
14		V4S2	5,6	5,6	5,6	5,60
15		V4S3	5,6	5,6	5,6	5,60
16		V4S4	5,5	5,6	5,6	5,57
17	1PC : 2PS : 4TB	V4S1	5,6	5,6	5,6	5,60
18		V4S2	5,6	5,5	5,6	5,57
19		V4S3	5,6	5,7	5,7	5,67
20		V4S4	5,5	5,8	5,7	5,67

Pencatat

CS Scanned with CamScanner

Attachments 2.8

Paving Block Water Absorption Test Results

Water Absorption Testing of Paving Block

Code	Wet Weight (kg)	Dry Weight (kg)	Absorption (%)	Average (%)	Quality
V1S1	2,469	2,246	9,929	9,630	D
V1S2	2,474	2,261	9,421		
V1S3	2,465	2,250	9,556		
V1S4	\\\\	\\\\	\\\\		
V2S1	2,592	2,361	9,784	9,560	D
V2S2	2,601	2,374	9,562		
V2S3	2,598	2,376	9,343		
V2S4	\\\\	\\\\	\\\\		
V3S1	2,969	2,707	9,679	9,450	D
V3S2	2,974	2,714	9,580		
V3S3	2,966	2,719	9,084		
V3S4	\\\\	\\\\	\\\\		
V4S1	2,992	2,732	9,517	9,250	D
V4S2	2,989	2,735	9,287		
V4S3	2,986	2,741	8,938		
V4S4	\\\\	\\\\	\\\\		
V5S1	3,059	2,800	9,250	8,92	D
V5S2	3,052	2,811	8,573		
V5S3	3,049	2,799	8,932		
V5S4	\\\\	\\\\	\\\\		

Attachments 2.9

Paving Block Compressive Strength Test Results

Compressive Strength Testing of Paving Block

Sample Code	Length (cm)	Wide (cm)	Thickness (cm)	Weight (kg)	Load (kN)	Comp. Strength (MPa)	Average	Quality
V1S1				0,485	73,060	20,294	15,409	C
V1S2				0,449	40,452	11,237		
V1S3				0,433	52,907	14,696		
V1S4								
V2S1				0,459	41,433	11,509	12,867	C
V2S2				0,471	47,758	13,266		
V2S3				0,499	49,769	13,825		
V2S4								
V3S1				0,552	24,615	6,837	7,400	-
V3S2	6	6	6	0,495	28,341	7,873		
V3S3				0,485	26,969	7,491		
V3S4								
V4S1				0,546	16,867	4,685	5,439	-
V4S2				0,520	22,555	6,265		
V4S3				0,504	19,319	5,366		
V4S4								
V5S1				0,572	21,182	5,884	5,013	-
V5S2				0,552	16,181	4,495		
V5S3				0,540	16,779	4,661		
V5S4								

Attachments 2.10

Paving Block Wear Resistance Test Results

1,2 x 0,31 + 0,0286

Durability Testing of Paving Block

	Code	Initial Weight	Final Weight	Loss	Loss/Min	Durability	Average	Quality
1:6	V1S1	434,96	433,41	1,55	0,31	0,4006	0,3574	
1:6	V1S2	439,63	437,89	1,74	0,348	0,4462		
1:6	V1S3	434,13	433,31	0,82	0,164	0,2254		
	V1S4							
1:5:1	V2S1	463,09	461,32	1,77	0,354	0,4534	0,5214	
1:5:1	V2S2	486,39	484,92	1,47	0,294	0,3814		
1:5:1	V2S3	464,68	461,76	2,92	0,584	0,7294		
	V2S4							
1:4:2	V3S1	496,32	495,12	1,2	0,24	0,3166	0,3246	
1:4:2	V3S2	510,23	509,13	1,1	0,22	0,2926		
1:4:2	V3S3	516,91	515,49	1,42	0,28	0,3646		
	V3S4							
1:3:3	V4S1	460,85	459,16	1,69	0,338	0,4342	0,491	
1:3:3	V4S2	494,28	491,84	2,44	0,488	0,6142		
1:3:3	V4S3	483,27	481,62	1,65	0,33	0,4246		
	V4S4							
1:2:4	V5S1	480,8	486,77	2,31	0,462	0,583	0,395	
1:2:4	V5S2	498,95	497,78	1,17	0,234	0,4006		
1:2:4	[illegible]	[illegible]						
	V5S43	527,09	526,37	0,72	0,144	0,2014		

Attachments 2.11

Paving Block Visual Test Results

Visual Testing of Paving Block

Description	Paving Block Variation				
	1PC : 6PS	1PC : 5PS: 1TB	1PC : 4PS : 2TB	1PC : 3PS : 3TB	1PC : 2PS : 4TB
1.Areas					
a.Flatness	Y	Y	Y	Y	Y
b.Crack	N	N	N	N	N
c.Smoothness	Y	Y	Y	Y	Y
2.Lateral					
a.Right Angle	Right	Right	Right	Right	Right
b.Acuteness	Y	Y	N	Y	Y
c.Strength	Y	Y	Y	Y	Y

Note: Y= yes
N= No

Attachments 3.1

Weighing Materials

Attachments 3.2

Mixing Process

Attachments 3.3

Compressing Process

Attachments 3.4

Fresh Made Paving Blocks

Attachments 3.5

Paving Block Cured in Water for 28 Days

Attachments 3.6

Fresh Cured Paving Blocks

Attachments 3.7

Visual Testing and Dimension Checking of Paving Blocks

Attachments 3.8

Cutting Paving Block into Cubes

Attachments 3.9

Compressive Strength Testing of Paving Block

Attachments 3.10

Wear Resistance Testing of Paving Block