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Use of Steel Slag with Variations of Fas Compressive Strength of Concrete

Hanif
Department of Civil Engineering, Politeknik Negeri Lhokseumawe, Aceh Indonesia

Email: hanifts@pnl.ac.id

Abstract. Concrete represents function of structured construction material by water, cement, pebble, sand or habit of supplied with materials growing other (admixture). most influencing parameter of strength of concrete the quality of cement, proportion cement to mixture, strength and hygiene of aggregate, adhesion or interaction between pasta cement with aggregate. Slag represent product of is nonmetal which represent material in form of refinement until big logs, from result of made cool combustion. Compression of slag as harsh aggregate at concrete with proportion of slag vary 0%, 50%, 100%, and variation of fas 0,4; 0,5; 0,6; by using object test cylinder (15x30 cm) counted five samples of each variation and slag of fas be strong depress concrete until 28 days old. To get concrete mixture composition value the method of ACI (American Concrete Institute) is used. The result of strength test heighten strength depress concrete because tendency add it increase of strength depress in FAS 0.4 slag steel 100% depressed mean 44.979 (N/mm2).

1. Introduction

Concrete is one of famous construction materials in Indonesia because it has high compressive strength, easy to form along with the model and it is available all the time. In principal, concrete is a mixed material of aggregate and sand. The paste contains from water and sand which bind the aggregate (sand and pebble) becomes a solid mass such rocks.

Coarse aggregate as the mixture of concrete can be such pebble as the natural disintegration from rocks or rubble stone smashed manually or using special machine with certain sizes. Generally, the number of the coarse aggregate has a dominant percentage. For this reason, the substitution of the coarse aggregate with other material like steel slag might be applied.

Nowadays, a research has been done to steel slag produced from the fire of blast furnace which is actually the waste from modern steel manufacture. modern (*modern steel plant*). From the research, it is expected that steel slag can be re used to various field in Civil Engineering. At the present time, the usage of steel slag has been improved as the compound material to the structural concrete to reduce the construction and maintenance cost to the existing infrastructures. It is expected that steel slag will have economically high value. Besides, the negative impact of the steel slag to the environment damage can be minimalized. Steel slag is also expected to be the alternative material to reduce the usage of the aggregate (*material recycled for concrete aggregates*), so the environment will be cleaner and free from solid waste.

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2. Materials and Methods

2.1. Materials

Reference [1] stated that cement water factor is the ratio of water weight to cement weight in mixture and the water absorbed in the aggregate is not included. "In concrete material and certain experiments, the amount of mixture determines the concrete quality, as long as the mixture is plastic enough and workable".

The most important characteristic to the quality of a concrete is in how big a compression strength can be achieved. Compression strength is really depending on the cement active and the cement ration. Cement with high active will produce stronger concrete but using the same cement will give different quality of a concrete, it is affected by the variation of water amount added to the concrete compound.

Compression strength is the maximum size of a concrete in receiving the axial load. It is a main physical characteristic of concrete and used in designing many constructions. The Compression Strength is represented with maximum compressive strain $f'c$ [N/mm²] or Mpa. A compression strength of a 28 old days concrete is about ± 10 – 65 Mpa [2].

Compression strength becomes very important because most of concrete construction plans are based on its compression strength. Besides, other concrete strengths are approached from its compression strength.

The value of compression strength can be gained from an examination of ASTM D39-86 standard. The compression strength of each specimen is determined with the highest compression strength achieved by a 28-old day specimen during the experiment.

To examine the specimen of cylinder concrete (ø =15cm and height = 30 cm) for the compression strength, a *Compression Testing Machine* is used.

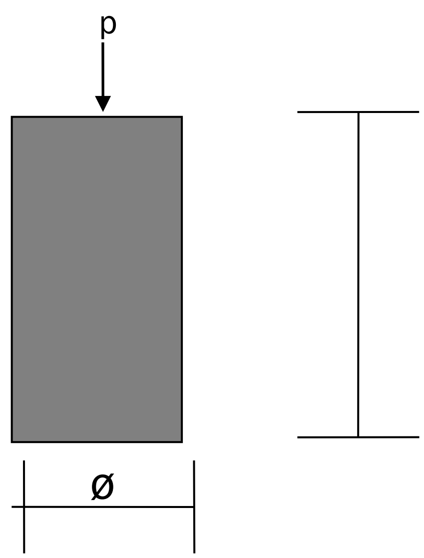

Figure 1. The sketch of compression strength of crushed concrete examination

The construction compound when the steel is extracted from its seed. It is a side product from steel manufacturing during the separation of molten steel from the dirt in blast furnace.

Steel slag in a nonmetallic material resulted from the metallurgy operational of steel manufacture where its main ingredients are calcium, magnesium, and silicate aluminum with several combinations [3].

The form of *Steel slag* is solid, containing several free irons so it creates high density and hardness. The usage of steel slag as concrete aggregate with Portland cement will produce a very good quality of concrete. The same case happens if steel slag aggregate is used together with *silica fume* (50 Mpa up to 125 Mpa) [1].

From the experiment in the field, to the *ready-mix concrete plat* in Montreal Canada, it gives good quality concrete in one day old with the compression strength 130 Mpa, where the mixture of the concrete consists of 60% *steel slag*, 30% Portland cement and 10% *silica fume* [4].

The *steel slag* aggregate has uneven surface with *very prismatic shape*. Its volume weight and specific gravity are high, its friction coefficient is also high with medium water absorption (up to 3%).

Table 1 The typical of Steel Slag Physical Characteristic.

Physical Characteristic	Value
Specific Gravity	3.2 – 3.6
Volume Weight, kg/m3 (lb/ft3	1600 – 1920 (100 – 120)
Water Absorption	Up to 3%

(Source: National Slag Association 808 North Fairfax Street, Arlington, Virginia 22314) [5]

Table 2 The typical of Steel Slag Chemical Composition

Ingredient	Composition (%)
CaO	40 – 52
SiO2	10 – 19
FeO	10 – 40 (70-80%FeO,20-30% Fe2O3)
MnO	5 – 8
MgO	5 – 10
Al2O3	1 – 3
P2O5	0.5 – 1
S	<0.1
Fe	o.5 – 10

(Source: National Slag Association 808 North Faifax Street, Arlington, Virginia 22314) [5]

The main compound of steel slag is the crystalline compound such as dicalcium silicate, *tricalcium silicate*, dicalcium ferrite, calcium-magnesium iron oxide, some of hydrated lime and Pericles.

Steel slag has good characteristic to aggregate usage, it is also good of abrasion resistance, characteristic strength and carrying capacity.

Table 3 The typical of Steel Slag Mechanical Characteristic

Los Angles Abrasion (ASTM C131), %	20 – 25
Sodium Sulphate Soundness Loss (ASTM C88), %	< 12
Angle of Internal Friction	40º - 50º
Hardness (measured by Moh's scale of mineral hardness) *	6 to 7
California Bearing Ratio (CBR), % top size 19 mm (3/40) **	Up to 300
* Hardness of dolomite measured on same scale is 3 to 4. ** Typical CBR value for crushed limestone is 100 %	

(Source: National Slag Association 808 North Fairfax Street, Arlington, Virginia 22314) [5]

2.2. Method

The materials used in making the specimens to original concrete examination are sand, pebble, steel slang and Portland Cement (PC). While the materials used in making the specimens for high performance concrete are the mixed compound of coarse aggregate beside the material usually used in making the original concrete.

The coarse aggregate used is the natural one with maximum diameter 25 mm. Fine aggregates used is taken from Krueng Tingkeum, Bireun district.

2.2.1. Mixture Designing

The original concrete mixture design uses the water and cement ration (w/c) 0,4; 0,5; 0,6 with the specific gravity of coarse aggregate in concrete mixture in the following composition: 100% steel slag and 0% natural pebble, 50% steel slag and 50% natural pebbleand 0% steel slag ,100% natural pebble, this is the control of the research which is in line with SK.SNI.T-28-1991-03 or ASTMC-684 standard [6].

2.2.2. Specimen Designing

The specimen of concrete is designed to be divided to three specimen groups; the cylinder with 15 diameter and 30 cm, each group consists of five specimens with the variation of Cement Water Factor (CWF) 0, 4; 0,5; and 0,6. To determine the proportional material mixture to each group, mix design with ACI (American Concrete Institute) method is done. The design of concrete specimen is shown in the following table.

Table 4 Concrete Specimen Design

Type of Coarse Aggregate Concrete Mixture	Age (Day)	CWF 0.4				CWF 0.5			
100% Slag and 0% Natural Pebble	28	X	1	1	1	X	1	2	1
		X	1	1	2	X	1	2	2
		X	1	1	3	X	1	2	3
		X	1	1	4	X	1	2	4
		X	1	1	5	X	1	2	5
50% Steel Slag and 50% Natural Pebble	28	X	1	2	1	X	2	2	1
		X	1	2	2	X	2	2	2
		X	1	2	3	X	2	2	3
		X	1	2	4	X	2	2	4
		X	1	2	5	X	2	2	5
0% Steel Slag and 100% Natural Pebble	28	X	3	2	1	X	3	2	1
		X	3	2	2	X	3	2	2
		X	3	2	3	X	3	2	3
		X	3	2	4	X	3	2	4
		X	3	2	5	X	3	2	5

2.3. The compression test of Specimen

The examination of specimens' compression test is conducted after it is 28 days old after molding. The specimens are tested by using the compression testing tool with 2000 KN capacity produced by MBT Indonesia. The result of the test is gained based on the value of maximum concrete read when the specimen is crushed, signed by the backward walk of black dial needle. The reading of the test is based on the number shown in the dial.

2.4. Data Analysis

Resulted raw data, the concrete strength, is analyzed first its accuracy. Whether or not the distribution of the data can be seen from deviation standard. The number of deviation standard depends on the accuracy level of the implementation and monitoring in the field. The less deviation standard achieved, the better data gained, for the coefficient various samples (CV) will be smaller too. The value of deviation standard is calculated with the following equations; (1) and (2).

$$S = \frac{\sqrt{\sum_{i=1}^{n}(xi-\overline{x})}}{n-1} \quad (1)$$

$$\overline{x} = \frac{\sqrt{\sum_{i=1}^{n} xi}}{n} \quad (2)$$

Where:
S = Deviation standard
xi = Concrete compression strength (MPa)
$\overline{x}$ = The average of concrete compression strength (MPa)
n = number of specimen

LabWork quality Classification, according to [7] is as follow:

1. CV $\leq$ 5%, Very Good
2. 5% < CV $\leq$ 7%, Accurate
3. 7% < CV $\leq$ 10%, Medium
4. CV > 10%, Less Accurate

The value of CV is calculated as follow:

$$CV = \frac{S}{X} \text{ x } 100\% \quad (3)$$

To observe the concrete compression strength, the following variable are; compression strength and independent variable in using steel slag with various CWF. To investigate the relation between these two variables, linear regression analysis is used.

3. Results and Discussions

The result of concrete mixture design with the effect of steel slag usage with different CWF variation and the result of the testing of concrete compression strength can be read completely in table 5. The test for the specimen compression is conducted with 2000 KN capacity compression machine test. The age of the specimen on the testing day is 28 days old. The strong relation between the compression strength specimen to the percentage of steel slag and the variation of CWF can be seen in the below graph.

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Table.5 Result of Concrete compression strength test

FAS	Steel slag	Benda Uji				Beban Maximum (N)	Luas Penampang (mm2)	Kuat Tekan (N/mm2)	Kuat Tekan Rata-rata (N/mm2)
		X	1	1	1	781000	17662.5	44,218	
		X	1	1	2	798000	17662.5	45,180	
0.4	100	X	1	1	3	792000	17662.5	44,841	44,980
		X	1	1	4	802300	17662.5	45,424	
		X	1	1	5	799000	17662.5	45,237	
		X	1	2	1	762000	17662.5	43,142	
		X	1	2	2	783200	17662.5	44,343	
0.5	100	X	1	2	3	801200	17662.5	45,362	44,494
		X	1	2	4	797000	17662.5	45,124	
		X	1	2	5	786000	17662.5	44,501	
		X	1	3	2	785000	17662.5	44,444	
0.6	100	X	1	3	3	772120	17662.5	43,715	43,885
		X	1	3	4	782300	17662.5	44,292	
		X	1	3	5	795000	17662.5	45,011	
		X	2	1	1	739000	17662.5	41,840	
		X	2	1	2	791000	17662.5	44,784	
0.4	50	X	2	1	3	781500	17662.5	44,246	43,603
		X	2	1	4	760000	17662.5	43,029	
		X	2	1	5	779200	17662.5	44,116	
		X	2	2	1	735000	17662.5	41,614	
		X	2	2	2	784000	17662.5	44,388	
0.5	50	X	2	2	3	782000	17662.5	44,275	43,354
		X	2	2	4	759000	17662.5	42,972	
		X	2	2	5	768720	17662.5	43,523	
		X	2	3	1	732250	17662.5	41,458	
		X	2	3	2	776000	17662.5	43,935	
0.6	50	X	2	3	3	782000	17662.5	44,275	43,122
		X	2	3	4	753000	17662.5	42,633	
		X	2	3	5	765000	17662.5	43,312	
		X	3	1	1	731250	17662.5	41,401	
		X	3	1	2	775000	17662.5	43,878	
0.4	0	X	3	1	3	800000	17662.5	45,294	43,100
		X	3	1	4	750000	17662.5	42,463	
		X	3	1	5	750000	17662.5	42,463	
		X	3	2	1	655000	17662.5	37,084	
		X	3	2	2	620000	17662.5	35,103	
0.5	0	X	3	2	3	625000	17662.5	35,386	36,971
		X	3	2	4	680000	17662.5	38,500	
		X	3	2	5	685000	17662.5	38,783	
		X	3	3	1	560000	17662.5	31,706	
		X	3	3	2	535000	17662.5	30,290	
0.6	0	X	3	3	3	572500	17662.5	32,413	31,621
		X	3	3	4	562500	17662.5	31,847	
		X	3	3	5	562500	17662.5	31,847	

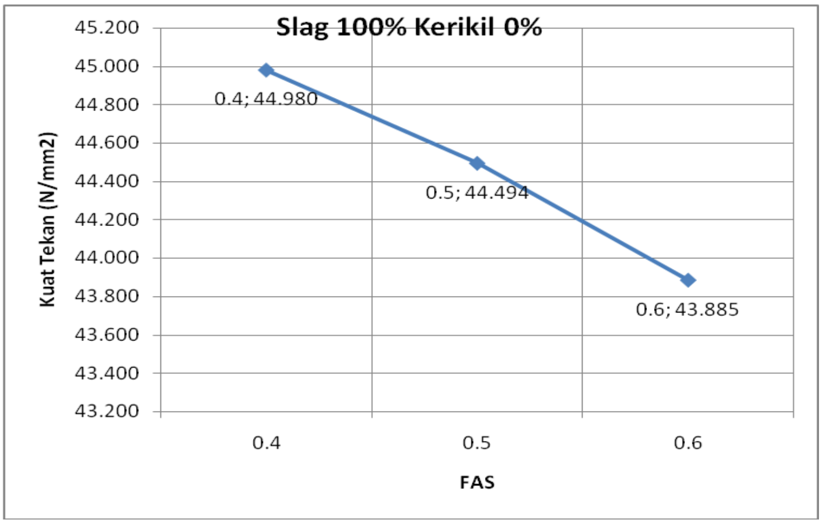

Figure 2. Graph for the ration of 100% Slag with 0% pebble

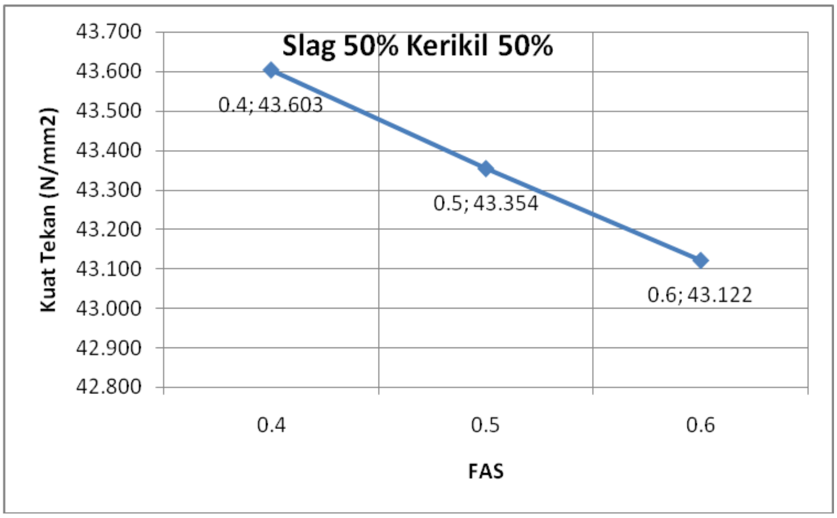

Figure 3. Graph for the ratio of 50% Slag with 50% pebble

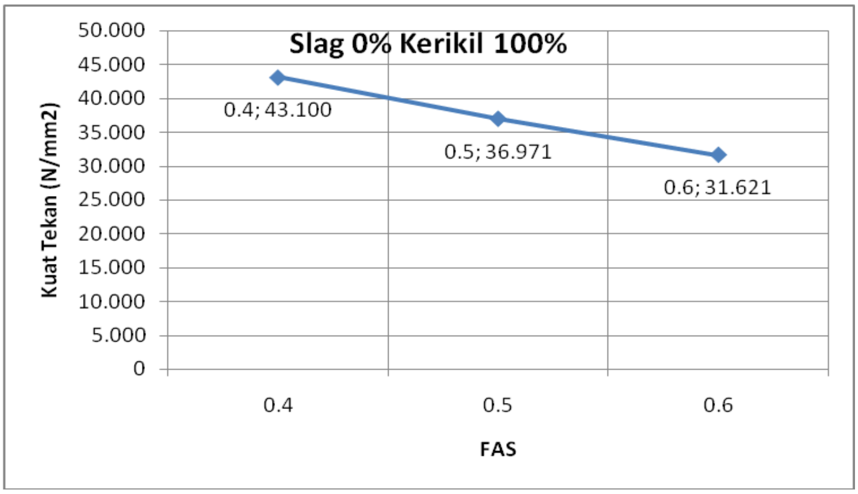

Figure 4. Graph for the ration of 0% Slag with 100% pebble

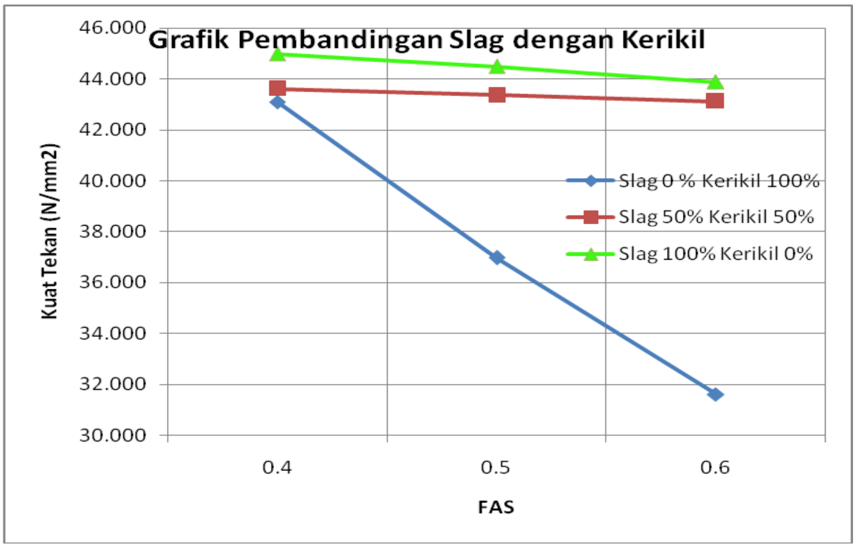

Figure 5. Graph for the relation result of Compression Strength to the percentage of Steel Slag and CWF Variation

4. Conclusion

To higher the compression strength of a concrete due to the trend of the increasing of the compression strength in CWF 0.4 steel slag 100% with the average compression is 44.979 (N/mm^2). To improve the final finishing and brighten up the color of the concrete. To reduce the hydrated axle in lowering the temperature. To reduce the rigid variation or concrete compression.

References

[1] Beedle, D., 2003, Portland Cement in The Making, Cement and Concrete Association.
[2] Istimawan D. 1994, Struktur Beton Bertulang, Jakarta. P.T. Gramedia Pustaka Utama.
[3] Burge, T.A., 2004, Hot Weather Concrete, Seminar Teknologi Beton FT Sipil UK Petra.
[4] Taylor.G.D., 2001, Construction Material, Longman Scientific & Technical.
[5] National Slag Association 808 North Fairfax Street, Arlington, Virginia 22314
[6] Dep. P.U. 1990, Tata Cara Rencana Campuran Beton Normal, SK-SNI T-15-1990. Bandung. Yayasan LPMB.
[7] Troxell, G.E. et all, Composition and Properties of Concrete, Second Edition, Mc Graw-Hill Book Company, New York, 1986
[8] Pierre Claude Aitcin. 1998, High Performance Concrete. E&FN SPON. An Imprint of Rountledge London and New York.
[9] Subakti, A.1994, Teknologi Beton dalam Praktik, Surabaya. Divisi Percetakan Sipil FTSP ITS.