HIGH STRENGTH CONCRETE USING FLY ASH A CEMENT AND FINE AGGREGATE

Erniati Bachtiar[1], Arman Setiawan[2], Fajar Musahir[3]

[1]Department of Civil Engineering, Fajar University, INDONESIA
[2]Department of Civil Engineering, Universitas Bosowa, INDONESIA
[3]Department of Procurement of Goods and Services, Barru, South Sulawesi, INDONESIA
E-mail: erni@unifa.ac.id

ABSTRACT

At the moment, the cost of concrete is quickly increasing as the cost of cement and aggregates continues to rise. As a result, a replacement for fine aggregate as well as a substitute for cement is required to decrease the cost of concrete production. In general, concrete is composed of cement as a base material that is workable and satisfies specified performance, durability, and strength criteria, aggregate, and water. In the field of engineering constructions, reinforced high strength concrete has a significant impact on development. Apart from its exceptional strength, this kind of concrete must exhibit workability, minimal shrinkage, releasing characteristics, and self-compaction. The authors of this research performed a literature review to explore high-quality concrete made using fly ash as a replacement for cement and fine particles. Fly Ash is a waste product or byproduct of the coal-fired power plant's combustion process. Fresh concrete made using fly ash as cement and fine aggregate has an average slump value of 90-200 mm. The compressive strength of concrete made with fly ash ranges between 35 and 60 MPa after a 28-day curing period. The optimal percentage of fly ash in high strength concrete is between 10% and 30%.

Key word: fly ash; concrete; cement; fine aggregate; mechanic strength.

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INTRODUCTION

The development of infrastructure in Indonesia, especially in the field of civil engineering, has made Indonesia a country with very rapid progress. This can be proven by the implementation of development in each area that is evenly distributed from Sabang to Merauke. With the rapid development, the use of materials will also increase, both natural and man-made materials. The large amount of material needs makes the production process even more numerous, while the supply of natural resources is limited. Therefore, it is necessary to have solutions such as alternatives that can replace these materials to maintain the balance of nature. This alternative can then be applied in the future in order to reduce the use of materials from nature which are very detrimental and have a negative impact on the surrounding environment.

The use of concrete in the era of globalization has greatly increased, followed by the development of infrastructure which is increasing day by day. One of the building materials besides steel and wood is concrete. Concrete consists of 3 constituent materials, including: cement, aggregate (sand and gravel) and water as well as some additives or fillers if needed. These are some of the constituent materials of concrete whose strength is beyond doubt, although previously required design and strength adjustments in the form of trials.

In modern construction, high strength concrete is very widely used. Because in use it requires a lot of cement to make high quality concrete, so it releases a lot of heat during the hydration process. This causes the temperature at the core in high-strength concrete to reach 80 ° C. High temperature affects the hydration of the composite binder, and the effect can be microstructure and macro-properties of high-quality concrete (Han and Zhang, 2018).

Climate is one of the problems faced by the cement industry, thus making the cement industry movers to form two strategies in making early efforts to mitigate climate change by converting

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clinker to supplementary cementitious material (SCM) as an alternative to cement substitutes, most of which are reactive waste. chemicals from various industries such as blast furnace slag (BFS), fly ash, and others (Reis et al., 2020). Fly ash (FA) is industrial waste residue or a byproduct of coal-fired power plants. The use of FA in the concrete industry is very useful because there is a pozzolanic reaction from fly ash so that it functions as a substitute for Portland cement (for example; workability, heat evolution, durability, strength development, etc.), then the costs resulting from making concrete using FA are spelled out more. low, due to lower FA prices compared to cement prices.

Slump is defined as a mortar that is inserted into a cone which is then measured in height after the mold is taken. Slump is a guideline for knowing the concrete that is experiencing discomfort in the mortar, where the higher the elasticity of a concrete mix, the higher the workability value will be. Bleeding is a phenomenon where water is mixed in the basic cement material then dries up and goes to the surface and when the solid components of the mixture consolidate in a certain form. Segregation in concrete is the separation of aggregate and slurry caused by relative movement. If the mixture in the concrete experiences excess water, it will cause segregation which is indicated by the separation of the aggregate grains to the fresh concrete base and experiences deposition.

High-strength concrete has a difference with conventional concrete. High-strength concrete develops attention to higher compressive strength along with increasing ductility, durability, and high modulus of elasticity so that it is now widely applied to many structures. There are many problems that make scientists and other academics challenged to research and find alternatives as solutions in the description of future problems. From the description that has been described above, the researcher is interested in conducting a literature study entitled "Study of High-Quality Concrete Using Fly Ash as a Cement Substitution and Fine Aggregate".

RESEARCH METHODS

This research uses a type of literature study or library research method. Research with literature studies is research that has the same preparation as any other research. However, the sources and methods of data collection are obtained in the library, reading, taking notes and processing the research material, which can then be obtained and analyzed in depth by the author.

The steps in obtaining literature study data are (1) Collecting literature data from both national and international scientific journals, then will be reviewed on important terms which will be studied later. The important terms that can be defined in this study are high strength concrete using fly ash as a substitute for cement and fine aggregate. (2) Collecting research results that are relevant (relevant) which can later assist in the analysis process so that objective conclusions can be obtained. (3) Conduct an in-depth analysis to be able to compile a discussion of the literature obtained. The discussion in this case was carried out with the aim of obtaining conclusions about the mechanical properties and physical properties of concrete using fly ash as a substitute for cement and fine aggregates. (4) Determine conclusions from the results of the analysis carried out, where the conclusions contain statements that are in accordance with the research objectives. (4) Make suggestions from the literature obtained. The results of the literature study that have been obtained during the analysis process can be used as input and suggestions to researchers and readers.

RESULTS AND DISCUSSION

Fresh Concrete Physical Properties

The physical properties of fresh concrete can be seen from the slump test, the separation of water from the concrete (bleeding), and the separation of coarse aggregates (segregation). From the results of literature studies, there are several results of research on the physical properties of fresh concrete in concrete using fly ash as shown below Table 1.

Table 1. Literature review of the physical properties of fresh concrete in concrete using fly ash.

Fly Ash-Type and Variation	Physical Properties	Authors
F-Type Fly ash as a cement substitute: 0%, 10%, 20%, 30%, 40%, 50% and 60%.	The results of the slump test obtained values of 150 mm, 155 mm, 175 mm, 180 mm, 200 mm and 205 mm from each variation of FA. There is no segregation and bleeding.	Shaikuthali et al., 2019
F-Type Fly ash as a cement substitute: 10% and 20%.	The results of the slump test obtained a value of 23 cm and 24 cm for each variation of FA. There is no segregation and bleeding	Kabay et al., 2015
C-Type Fly ash as a cement substitute: 0%, 10%, 15%, 20%, 25% and 30%.	The slump values did not show a significant difference between the mix and the mean was about 15 cm. There is no segregation and bleeding	Zachar et al., 2011
F-Type Fly ash as a cement substitute: 0%, 15%, 20% and 25%	No testing for slump, segregation and bleeding is done.	Turuallo & Mallisa, 2018
F-Type Fly ash as a cement substitute: 15%, 20%, 25% and 30%.	No testing for slump, segregation and bleeding is done.	Yen et al., 2007
F-Type Fly ash as a cement substitute: 15%, 25%, 35% and 45%.	The results of the slump test obtained values of 20 cm, 19.5 cm, 20 cm and 20 cm for each FA variation. Segregation and bleeding were not identified.	Khongpermgoson et al., 2020
F-Type Fly ash as a cement substitute: 40%, 60% and 80%.	No testing for slump, segregation and bleeding is done.	Rivera et al., 2015
F-Type Fly ash as a cement substitute: 0%, 5%, 10% and 15%	No testing for slump, segregation and bleeding is done.	Zein et al., 2018
F-Type Fly ash as a cement substitute: 10%, 20% and 30%	The results of the slump test obtained a value of 5 cm at the 30% FA variation and did not include the readings at the 10% and 20% variations. Segregation and bleeding were not identified.	Madhavi, 2013

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F-Type Fly ash as a cement substitute: 0%, 3%, 6%, 9%, 12% and 15%.	The results of the slump values obtained are 260 mm, 270 mm, 275 mm, 280 mm, 285 mm and 290 mm in each variation of FA. Fresh concrete does not undergo segregation. There was bleeding due to the use of water which was categorized as large, namely 205.08 kg / m3. Disappointment occurs with the increase in the percentage of fly ash content used.	Sebayang, 2010
Fly ash as a cement substitute: 0%, 25%, 30%, 35% and 40%.	The results of the slump test obtained values of 7.3 cm, 7.1 cm, 6.7 cm, 6.4 cm and 6 cm for each variation of FA. Segregation and bleeding tests were not carried out.	Mohamad et al., 2020
F-Type Fly ash as a cement substitute: 0%, 10%, 12.5%, 15%, 20% and 25%.	The results of the slump values obtained were 6.3 cm, 6.75 cm, 7.00 cm, 5.50 cm, 5.33 cm, 6.00 cm for each variation of FA. Segregation and bleeding were not identified.	Adibroto et al., 2018
F-Type Fly ash as a cement substitute: 0%, 25%, 50%, 75% and 100%.	No testing for slump, segregation and bleeding is done.	Shehab et al., 2016
F-Type Fly ash as a substitute for fine aggregate: 0%, 10%, 20%, 30% and 40%.	No testing for slump, segregation and bleeding is done.	Zawawi et al., 2020
F-Type Fly ash as a substitute for fine aggregate: 0%, 10%, 20%, 30% and 40%.	No testing for slump, segregation and bleeding is done.	Siddique, 2003
FA as a substitute for fine aggregate: 0%, 15% and 30%.	No testing for slump, segregation and bleeding is done.	Nguyen & Duong, 2019
F-Type Fly ash as a substitute for fine aggregate: 0% and 25%.	No testing for slump, segregation and bleeding is done.	Zhang et al., 2020
F-Type Fly ash as a substitute for fine aggregate: 0%, 10%, 20% and 30%.	No testing for slump, segregation and bleeding is done.	Mahzuz & Hasan, 2020
F-Type Fly ash as a cement substitute: 0%, 25% and 45%	No testing for slump, segregation and bleeding is done.	Poon et al., 2000
FA as a cement substitute: 50%	No testing for slump, segregation and bleeding is done.	Papayianni & Anastasiou, 2010

FA as a cement substitute: 0%, 20% and 30%.	No testing for slump, segregation and bleeding is done.	Golewski, 2017
F-Type Fly ash as a cement substitute: 10%, 30%, 50% and 70%.	The results of slump identification obtained values of 620 mm, 685 mm, 705 mm and 670 mm for each variation of FA. Bleeding and segregation occurred at the 50% FA variation.	Dinakar et al., 2013
F-Type Fly ash as a cement substitute: 0%, 25% and 35%.	No testing for slump, segregation and bleeding is done.	Kou et al., 2007

First, namely research conducted by (Shaikuthali et al., 2019). The percentage of fly ash used is 0%, 10%, 20%, 30%, 40%, 50% and 60%. The results of the slump test obtained values of 150 mm, 155 mm, 175 mm, 180 mm, 200 mm and 205 mm from each variation of FA. There is no segregation and bleeding. Next by Kabay et al. (2015), the proportions of the variation of pumice and fly ash powder used as a substitute for cement were 10% and 20%, respectively. The results of the slump test obtained values of 23 cm and 24 cm for each variation of FA. There is no segregation and bleeding.

Then by (Zachar, Ph and Asce, 2011). The proportions of the variation of fly ash used are 0%, 10%, 15%, 20%, 25% and 30%. The slump values did not show a significant difference between the mix and the mean was about 15 cm. There is no segregation and bleeding. Research by(Turuallo and Mallisa, 2018). The proportions of the variation of fly ash used were 0%, 15%, 20% and 25% with a concrete treatment period of 3, 7, 21 and 28 days. No testing for slump, segregation and bleeding is done. (Yen et al., 2007) using the replacement ratio of fly ash as a substitute for sand is 15%, 20%, 25% and 30%. No testing for slump, segregation and bleeding is done.

Research by Khongpermgoson et al. (2020), the percentage of variations of fly ash as a cement substitution is 15%, 25%, 35% and 45%. The results of the slump test obtained values of 20 cm, 19.5 cm, 20 cm and 20 cm for each FA variation. Segregation and bleeding were not identified. On research by(Rivera et al., 2015), the ratio of fly ash replacement as cement substitution in this study was 40%, 60% and 80%. No testing for slump, segregation and bleeding is done. Then by (Zein, Meillyta and Wahyuni, 2018). This study uses the proportion of variations of fly ash, namely 0%, 5%, 10% and 15% as a cement substitution. No testing for slump, segregation and bleeding is done.

Research by Sebayang (2010), namely the compressive strength test at the age of 7, 14, 28 and 56 days. The proportions of the variations of fly ash used in this study were 0%, 3%, 6%, 9%, 12% and 15%. The results of the slump values obtained are 260 mm, 270 mm, 275 mm, 280 mm, 285 mm and 290 mm in each variation of FA. Fresh concrete does not undergo segregation. There was bleeding due to the use of water which was categorized as large, namely 205.08 kg / m3. Disappointment occurs with the increase in the percentage of fly ash content used. Mohamad, Rachman and Mointi (2020) using the proportion of variations of fly ash, namely 0%, 25%, 30%, 35% and 40%. The results of the slump test obtained values of 7.3 cm, 7.1 cm, 6.7 cm, 6.4 cm and 6 cm for each variation of FA. Segregation and bleeding tests were not carried out.

In research conducted by Siddique (2003), using the proportion of variations of fly ash as a substitute for fine aggregate, namely 0%, 10%, 20%, 30% and 40 No testing for slump, segregation and bleeding is done. Nguyen and Duong (2019) using variations of FA, namely 0%, 15% and 30%. No testing for slump, segregation and bleeding is done. Research by Zhang et al. (2020) using variations of FA as a sand substitution, namely 0% and 25%. No testing for slump, segregation and bleeding is done.

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Poon, Lam and Wong (2000) using variation proportions, namely 0%, 25% and 45% FA as a cement substitution. No testing for slump, segregation and bleeding is done. Papayianni and Anastasiou (2010), using only one variation, namely 50%. No testing for slump, segregation and bleeding is done. Golewski (2017) using the proportion of variation in FA, namely 0%, 20% and 30%. No testing for slump, segregation and bleeding is done. Dinakar, Kartik Reddy and Sharma, (2013) using the proportion of FA variation as a cement substitution, namely 10%, 30%, 50% and 70%. The results of the identification of the slump obtained values, namely 620 mm, 685 mm, 705 mm and 670 mm for each variation of FA. Bleeding and segregation occurred at the 50% FA variation.

Mechanical Properties of Concrete

Research on the mechanical properties of concrete has become a major objective in recent decades in infrastructure development. The properties of concrete depend on the characteristics possessed by the aggregate microstructure. Several experimental studies have been carried out to examine the various effects that concrete constituents have, such as size, shape, aggregate mineralogy, surface texture and characteristics, which basically refer to the mechanical properties of concrete. The compressive strength of concrete is a test of the mechanical properties of concrete by looking at the conditions of the maximum strength that the concrete can withstand and bear. The compressive strength of concrete is marked in units of N / mm2 or MPa (mega pascal) with the maximum stress σ. Apart from being influenced by the nature and type of aggregate, the compressive strength of concrete is also influenced by water cement, workability, type of mixture, age of concrete, and curing.

Research on the mechanical properties of concrete has become a major objective in recent decades in infrastructure development. The properties of concrete depend on the characteristics possessed by the aggregate microstructure. Several experimental studies have been carried out to examine the various effects that concrete constituents have, such as size, shape, aggregate mineralogy, surface texture and characteristics, which basically refer to the mechanical properties of concrete. The compressive strength of concrete is a test of the mechanical properties of concrete by looking at the conditions of the maximum strength that the concrete can withstand and bear. Apart from being influenced by the nature and type of aggregate, binder and curing. Literature study results can be seen of Table 2.

Table 2. Literature Study Results of High Strength Concrete Using Fly Ash as a Cement and Fine Aggregate

Fly Ash		The Compressive Strength (MPa)					Author
%	Type	3	7	14	21	28	
0	F	27.5	27.3	34.1		47.3	Shaikuthali et al., 2019
10		24.2	26.7	33.6		44.5	
20		23.9	25.3	32.7		38.9	
30		18.5	25.1	24.2		36.5	
40		18.3	23.2	26.5		33.4	
50		14.6	18.7	24.1		26.2	
60		11.3	13.5	17.1		24	
10	F		58.4			72.3	Kabay et al., 2015
20			54.1			67.5	
0	C	22.1	26.2	29		33.1	Zachar et al., 2011
10		26.2	29	32.4		37.2	
15		28.3	37.9	45.5		46.9	
20		33.8	38.6	42.7		55.8	

25		35.2	43.4	49		57.9	
30		30.3	42.7	50.3		57.2	
10	F	36.26	57.24		58.17	60.26	Turuallo & Mallisa, 2018
15		42.04	56.8		59.95	66.75	
20		43.73	52.4		57.64	61.55	
25		39.29	45.11		54.84	56.62	
0	F					64.02	Yen et al., 2007
15						62.47	
20						54.95	
25						54.72	
30						51.47	
15	C	53.3	64.7	68.2		74.5	Khongpermgos on et al., 2020
25		49.5	62.3	68.1		72.5	
35		49.5	58.6	62.6		70.7	
45		29.9	40.6	43.3		48.4	
40	C, F	12.5	25.7			51.55	Rivera et al., 2015
60		9.12	19.8			44.29	
80		2.54	6.1			32.33	
0	-		43.56			44.8	Zein et al., 2018
5			42.4			40.67	
10			42.58			39.91	
0	F	34.89	31.04			42.61	Madhavi, 2013
10		26.51	28.11			43.4	
20		25.64	29.14			39.86	
30		20.65	24.29			31.03	
0	F		32.71	41.12		43.26	Sebayang, 2010
3			28.13	30.57		38.06	
6			31.34	37.3		41.12	
9			32.1	38.67		41.88	
12			31.34	31.32		41.12	
15			25.22	32.1		38.52	
0	-					52.9	Mohamad et al., 2020
25						53.31	
30						45.81	
35						43.66	
40						41.08	
0	F		24.42			28.13	Adibroto et al., 2018
10			20			30.77	
12.5			18.23			28.04	
15			17.35			25.84	
20			15.6			24.6	
25			15.04			20.05	

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0			17.35		24.51	
25			25.69		29.61	Shehab et al., 2016
50	F		31.08		35.2	
75			30.3		33.83	
100			28.43		31.38	
0			27.1		28.3	
10			29.5		30.02	Zawawi et al., 2020
20	F		26.02		26.9	
30			24.08		25.8	
40			22.67		25.76	
0			17.2		26.1	
10			20.4		27.4	
20	F		22.2		29.9	Siddique, 2003
30			24.5		34.2	
40			27.1		38.1	
0					34.48	
15	-				43.13	Nguyen & Duong, 2019
30					30.89	
0	F	21.4	27.3	32.1	35.9	Zhang et al., 2020
25		34.1	40.7	42.5	53.8	
0					21.48	
10	-				29.36	Mahzuz & Hasan, 2020
20					25.53	
30					21.09	
0		70	79.5		97.4	
25	F	62.3	74.6		105.8	Poon et al., 2000
45		42.5	56.3		89.4	
50	-		52.5		64.2	Papayianni & Anastasiou, 2010
0		26.86	35.42		49.28	
20	-	19.62	26.84		50.25	Golewski, 2017
30		16.95	32.28		47.01	
10		44.42	58.37		78.97	
30	F	48.33	51.2		88.06	Dinakar et al., 2013
50		27.1	35.91		60.83	
70		18.14	21.77		44.21	
0			53.8		66.8	
25	F		39.9		54.4	Kou et al., 2007
35			30.6		45.9	

The findings of Table 1 indicate that the average compressive strength of concrete containing fly ash is 35-60 MPa after a 28-day curing period. Additionally, the increase in strength is proportional to the age of the concrete when adding Type F or Type C fly ash. Additionally, by incorporating fly ash of both types C and F into concrete, high-performance concrete with a high compressive strength may be achieved. The fly ash composition in concrete has an effect on the value of high strength compressive strength. The optimal percentage of fly ash in high strength concrete is between 10% and 30%. The inclusion of fly ash material in the range of 10% to 20% will enhance the mechanical characteristics of concrete.

CONCLUSION

Based on the literature that has been done, the following conclusions can be drawn: (1) The physical properties of fresh concrete using fly ash as cement and fine aggregate have an average slump value between 90-200 mm. Bleeding occurs when a large volume of water is used, especially in concrete using fly ash. The average concrete that uses fly ash does not experience segregation. Disappointment in concrete will occur with the addition of the percentage of fly ash in each variation. (2) The results of the average compressive strength of concrete using fly ash are 35 - 60 MPa during the curing period of 28 days. (3) The optimum value of using fly ash on high strength concrete is between 10% - 30%. (4) The addition of fly ash material between 10% -20%, will be able to improve the mechanical properties of concrete.

REFERENCES

Adibroto, F., Suhelmidawati, E., & Zade, A. A. M. (2018). Eksperimen Beton Mutu Tinggi Berbahan Fly Ash Sebagai Pengganti Sebagian Semen. *Jurnal Ilmiah Rekayasa Sipil*, *15*(1), 11–16. https://doi.org/10.30630/jirs.15.1.85

Dinakar, P., Kartik Reddy, M., & Sharma, M. (2013). Behaviour of self compacting concrete using Portland pozzolana cement with different levels of fly ash. *Materials and Design*, *46*, 609–616. https://doi.org/10.1016/j.matdes.2012.11.015

Golewski, G. L. (2017). Green concrete composite incorporating fly ash with high strength and fracture toughness. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2017.10.065

Han, F., & Zhang, Z. (2018). Hydration, mechanical properties and durability of high-strength concrete under different curing conditions. *Journal of Thermal Analysis and Calorimetry*, 1–12.

Kabay, N., Tufekci, M. M., Kizilkanat, A. B., & Oktay, D. (2015). Properties of concrete with pumice powder and fly ash as cement replacement materials. *CONSTRUCTION & BUILDING MATERIALS*, *85*, 1–8. https://doi.org/10.1016/j.conbuildmat.2015.03.026

Khongpermgoson, P., Boonlao, K., Ananthanet, N., & Thitithananon, T. (2020). The mechanical properties and heat development behavior of high strength concrete containing high fineness coal bottom ash as a pozzolanic binder. *Construction and Building Materials*, *253*, 119239. https://doi.org/10.1016/j.conbuildmat.2020.119239

Kou, S. C., Poon, C. S., & Chan, D. (2007). Influence of Fly Ash as Cement Replacement on the Properties of Recycled Aggregate Concrete. *International Journal of Emerging Trends in Engineering Research*, *8*(5), 2097–2100. https://doi.org/10.30534/ijeter/2020/101852020

Madhavi, T. P. (2013). Partial Replacement of Cement and Fine Aggregate By Using Fly Ash and Glass Aggregate. *International Journal of Research in Engineering and Technology*, *02*(13), 351–355. https://doi.org/10.15623/ijret.2013.0213066

Mahzuz, H. M. A., & Hasan, J. (2020). *Compressive strength enhancement of concrete using fly ash as a partial replacement of fine aggregate and model development*. *14*(1), 44–53.

Mohamad, R. M., Rachman, A., & Mointi, R. (2020). Kuat tekan beton untuk mutu tinggi 45 MPa dengan fly ash sebagai bahan pengganti sebagian semen. *RADIAL*, *8*(1), 25–33.

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DOI: http://dx.doi.org/10.32832/astonjadro.v11i2

Nguyen, D., & Duong, M. (2019). Compressive Resistance of Environmental Concrete Using Fly Ash and Fine Aggregate for Replacing Traditional Sand. *Mechanics and Materials*, *889*, 283–288. https://doi.org/10.4028/www.scientific.net/AMM.889.283

Papayianni, I., & Anastasiou, E. (2010). Production of high-strength concrete using high volume of industrial by-products. *Construction and Building Materials*, *24*(8), 1412–1417. https://doi.org/10.1016/j.conbuildmat.2010.01.016

Poon, C. S., Lam, L., & Wong, Y. L. (2000). A study on high strength concrete prepared with large volumes of low calcium fly ash. *Cement and Concrete Research*, *30*, 447–455.

Reis, D. C., Abrao, P. C. R. A., Sui, T., & John, V. M. (2020). Influence of cement strength class on environmental impact of concrete. *Resources, Conservation & Recycling*, 1–11.

Rivera, F., Martínez, P., Castro, J., & López, M. (2015). "Massive Volume Fly-Ash Concrete: A More Sustainable Material with Fly Ash Replacing Cement and Aggregates." *Cement and Concrete Composites*. https://doi.org/10.1016/j.cemconcomp.2015.08.001

Sebayang, S. (2010). Pengaruh kadar abu terbang sebagai pengganti sejumlah semen pada beton alir mutu tinggi. *Rekayasa*, *14*(1), 39–46.

Shaikuthali, S. A., Mannan, M. A., Thanon, E., Teo, D. D. C. L., Ahmadi, R., & Ismail, I. (2019). Workability and compressive strength properties of normal weight concrete using high dosage of fly ash as cement replacement. *Journal of Building Pathology and Rehabilitation*, *5*. https://doi.org/10.1007/s41024-019-0065-5

Shehab, H. K., Eisa, A. S., & Wahba, A. M. (2016). Mechanical properties of fly ash based geopolymer concrete with full and partial cement replacement. *Construction and Building Materials*, *126*, 560–565. https://doi.org/10.1016/j.conbuildmat.2016.09.059

Siddique, R. (2003). *Effect of fine aggregate replacement with Class F fly ash on the abrasion resistance of concrete*. *33*, 1877–1881. https://doi.org/10.1016/S0008-8846(03)00212-6

Turuallo, G., & Mallisa, H. (2018). Using Cementitious Materials Such as Fly Ash to Replace a Part of Cement in Producing High Strength Concrete in Hot Weather. *IOP Conference Series: Materials Science and Engineering*, *316*(1), 7–12. https://doi.org/10.1088/1757-899X/316/1/012039

Yen, T., Hsu, T. H., Liu, Y. W., & Chen, S. H. (2007). Influence of class F fly ash on the abrasion-erosion resistance of high-strength concrete. *Construction and Building Materials*, *21*(2), 458–463. https://doi.org/10.1016/j.conbuildmat.2005.06.051

Zachar, J., Ph, D., & Asce, M. (2011). *Sustainable and Economical Precast and Prestressed Concrete Using Fly Ash as a Cement Replacement*. *June*, 789–792. https://doi.org/10.1061/(ASCE)MT.1943-5533.0000243.

Zawawi, M. N. A. A., Muthusamy, K., P.P. Abdul Majeed, A., Muazu Musa, R., & Mokhtar Albshir Budiea, A. (2020). Mechanical properties of oil palm waste lightweight aggregate concrete with fly ash as fine aggregate replacement. *Journal of Building Engineering*, *27*(June 2019), 100924. https://doi.org/10.1016/j.jobe.2019.100924

Zein, K. C. S., Meillyta, & Wahyuni. (2018). Substitusi fly ash pada semen terhadap kuat tekan beton mutu tinggi. *Rekayasa Sains Dan Teknologi Berkelanjutan Dalam Manajemen Resiko Bencana*, 205–212.

Zhang, D., Yang, Q., Mao, M., & Li, J. (2020). Carbonation performance of concrete with fly ash as fine aggregate after stress damage and high temperature exposure. *Construction and Building Materials*, *242*, 118125. https://doi.org/10.1016/j.conbuildmat.2020.118125.