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Research paper

Addition of superplasticizer and the effect of mixing iron powder in concrete mixtures

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Abstract

Concrete is in demand because it offers several advantages: a relatively low price, good strength, easy access to raw materials, long-lasting properties, fire resistance, and resistance to rot. This research aims to compare the compressive strength quality of K250 concrete under normal conditions and after adding superplasticizer and iron powder. Cube tests consisting of ages 7, 14, and 28 days were carried out using concrete with additional materials and iron powder with mixed variations; then, a concrete compressive strength test was carried out. The research results show that the maximum compressive strength of concrete without adding superplasticizer and iron powder (0% mixture) is 371.85 kg/cm2. Adding 0.5% superplasticizer and 10%, 20%, and 30% iron powder can increase the maximum compressive strength of concrete by 27.48%, 19.12%, and 8.36%, respectively. In conclusion, the addition of superplasticizers and iron powder can increase the compressive strength of concrete beyond the design compressive strength of normal K250 concrete. Of the four concrete tests carried out with different mixture proportions, all mixtures achieved the design strength of normal K250 concrete. However, it is recommended that the use of iron powder not exceed 10% of the aggregate weight because use above 10% will affect the slump value and increase the weight of the concrete.

Keywords: *Compressive Strength; Iron Powder; Superplasticizer.*

1. Introduction

Structural development is currently experiencing rapid progress in various fields, for example, buildings, bridges, towers, and so on [1 - 3]. Concrete is one of the choices as a structural material in building construction [4 - 6]. Concrete is in demand because it has many advantages compared to other materials, including relatively cheap prices, good strength, easily available raw materials, durability, fire resistance, and not easily weathered [7 - 11]. Concrete technological innovation is always required to answer demand challenges, and the resulting concrete is expected to have high quality, including strength and durability, without ignoring economic value [12 - 14]. Another thing that underlies the selection and use of concrete as a construction material is its effectiveness and efficiency. Concrete filler materials are made from materials that are easy to obtain, easy to process (workability), and have the durability and strength required for construction [15 - 17]. The properties of concrete make it an alternative material for developing physical forms and methods of implementation [18 - 20]. Improving the quality of concrete can be done by providing substitute materials or additional materials [21 - 23]. Some substitute and additional materials available include iron powder. Apart from improving the quality of concrete, it can also affect the stress and strain in concrete [24 - 26]. Therefore, efforts are being made to make iron powder a useful material, including using iron powder as a concrete mixture [27 - 29].

In every reinforced concrete construction project, these activities often leave behind construction waste in the form of leftover steel cuttings that cannot be reused. This steel material becomes unusable construction waste. This steel waste will then be reused through recycling and reshaped according to need. However, continuous recycling tends to decrease its quality [30]. This is due to unavoidable contamination during the recycling process. Recycled steel can contain mixtures of other metals, oxides, or other impurities. The more frequent the recycling process, the higher the possibility of this contamination increasing, which can affect the final quality of the steel [31]. The utilization of steel waste through recycling is reshaped according to needs. Another way to utilize steel waste is by processing steel scraps into iron powder. Currently, concrete material technology is developing, one of which is nanotechnology that allows concrete to be formed with specific profiles [32]. Iron powder can be used as an additive in concrete mixtures. The addition of iron powder to normal concrete mixtures is intended to increase the flexural strength of the concrete. The addition of iron powder to normal concrete mixtures is still rarely done, which forms part of the researchers' background for conducting research on the effect of adding iron powder as an additive in concrete.

In this research, superplasticizer additives were also used to make it easier to work on the concrete mixture for mixing, pouring, transporting, and compacting. The addition of this material to the concrete mixture will most likely make the concrete mixing job easier [33 - 35]. This is because superplasticizer is a concrete mixture that has a dual function, namely that when mixed in a certain dose it can reduce the amount of water used, speed up hardening time, increase workability, and reduce the water content in the concrete mixture [36 - 38]. Based on the description that has been presented, the problem to be studied can be formulated: What is the compressive strength of the concrete before adding superplasticizer and iron powder?

2. Method

This research uses an experimental method to determine the extent of the effect of adding additives and mixing iron powder in the K250 concrete mixture in terms of concrete compressive strength. Sample making and testing will be carried out at the UPTD Laboratory of the Palangka Raya Quality Testing Center. This data is strengthened by data from literature books that are appropriate to this research.

2.1. Materials

The materials used in this research are as follows:

1) Coarse aggregate (crushed stone) from Tangkiling-Palangka Raya.
2) Fine aggregate (sand) from Tangkiling-Palangka Raya.
3) The cement in the Palangka Raya Market is of the Gresik cement brand.
4) Clean water used from the UPTD Palangka Raya Quality Testing Center.
5) The iron powder waste used for the mixture comes from the Katu manufacturing factory in Palangka Raya.
6) Superplasticizer (superplasticizer® concrete additive plasticizer).

2.2. Data collection

Data collection was carried out by making 36 test objects, with details of nine for conventional concrete for each age variation, three cube-shaped test objects consisting of ages 7, 14 and 28 days, then 27 for concrete with additional materials and iron powder consisting of three variations with a mixture of 10%, 20% and 30% for each mixing percentage, three cube-shaped test objects were made. Calculation of compressive strength based on the 1971 Indonesian Reinforced Concrete Regulations [39] can be seen in Table 1, while the quality of concrete with a comparison of the compressive strength of concrete at various ages can be seen in Table 2.

Table 1: Comparison of Concrete Compressive Strength in Various Test Objects

NO.	Test Object	Compressive Strength Comparison
1.	Cube 15 x 15 x 15 cm	1.00
2.	Cube 20 x 20 x 20 cm	0.95
3.	Cylinder 15 x 30 cm	0.83

Source: Indonesian Reinforced Concrete Regulations 1971 NI-2.

Table 2: Correlation Factor Value

Concrete age (days)	3	7	14	21	28	90	365
Ordinary Portland cement	0.40	0.65	0.88	0.95	1.00	1.20	1.35
Portland cement with high early strength	0.55	0.75	0.90	0.95	1.00	1.15	1.20

Source: Indonesian Reinforced Concrete Regulations 1971 NI-2.

SNI 2847:2019 [40] explains the calculation of concrete compressive strength, specifically the Determination of Characteristic Compressive Strength (fc′), which details the concept of concrete's characteristic compressive strength (fc′). This is the compressive strength value that is expected to be achieved or exceeded by 95% of concrete test results. In other words, there is a 5% chance that test results will fall below the fc′ value. This fc′ value serves as the primary basis for calculating the strength of concrete structural elements. Concrete Quality Specifications: SNI 03-2847-2019 regulates the concrete quality requirements that must be used in design. This concrete quality is expressed in terms of the characteristic compressive strength (fc′) at 28 days (or another age specified in the project specifications). For example, concrete quality K-300 is roughly equivalent to an fc′ of around 25 MPa. And Compressive Strength Testing: This standard refers to the concrete compressive strength testing methods specified in other SNI standards (for example, SNI 1974:2011 for cylinder testing). Standardized testing procedures ensure that test results are reliable and comparable. The standard test specimen used in the latest SNI is a cylinder with a diameter of 15 cm and a height of 30 cm.

2.3. Research stages

The research stages carried out are as presented in the flowchart in Figure 1.

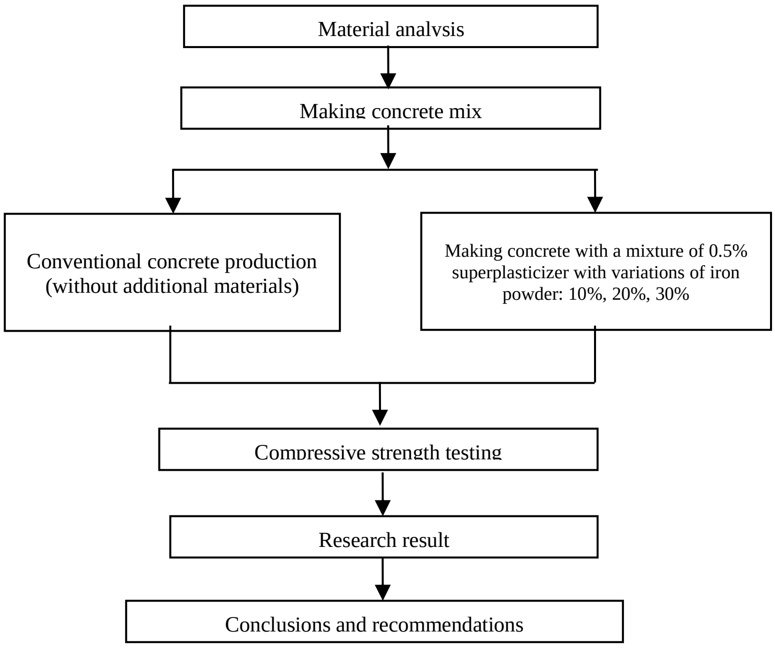

Fig. 1: Research Flow Diagram.

3. Results and discussion

K250 concrete before adding superplasticizer and iron powder; The characteristics of K250 concrete can be seen in Tables 3 to 6.

Table 3: Mixture Compressive Strength 0%

Concrete Class	Age	Slump (cm)	Heavy (Kg)	Load Max (KN)	Compressive strength (kg/cm^2)	Compressive strength (kg/cm^2)
	7	7	8,10	550	244.44	
	7	7	8.22	560	248.89	242.97
	7	7	8.12	530	235.56	
	14	7	8.09	740	328.80	
Concrete K-250	14	7	8.12	750	333.33	325.71
	14	7	8.12	710	315.00	
	28	7	8.08	840	373.33	
	28	7	8,10	860	382.22	371.85
	28	7	8,11	810	360.00	

Table 4: Compressive Strength of Concrete After Adding 0.5% Superplasticizer and Mixing 10% Iron Powder

Concrete Class	Age	Slump (cm)	Heavy (Kg)	Load Max (KN)	Compressive strength (kg/cm^2)	Compressive strength (kg/cm^2)
	7	7	8.48	710	315.56	
	7	7	8.44	730	324.44	320
	7	7	8.55	720	320.00	
	14	6.5	8.42	960	426.67	
Concrete K-250	14	6.5	8.40	980	435.56	431.11
	14	6.5	8.42	970	431.11	
	28	7	8.41	1000	444.44	
	28	7	8.40	1100	488.89	474.07
	28	7	8.40	1100	488.89	

Table 5: Compressive Strength of Concrete After Adding 0.5% Superplasticizer and Mixing 20% Iron Powder

Concrete Class	Age	Slump (cm)	Heavy (Kg)	Load Max (KN)	Compressive strength (kg/cm^2)	Compressive strength (kg/cm^2)
	7	8	8.62	690	306.7	
	7	8	8.60	700	311.1	305.19
	7	8	8.66	670	297.7	
	14	7	8.60	930	413.3	
Concrete K-250	14	7	8.58	940	417.7	410.37
	14	7	8.61	900	400.0	
	28	8.5	8.60	1000	444.4	
	28	8.5	8.61	1000	444.4	442.96
	28	8.5	8.59	990	440.0	

Table 6: Compressive Strength of Concrete After Adding 0.5% Superplasticizer and Mixing 30% Iron Powder

Concrete Class	Age	Slump (cm)	Heavy (Kg)	Load Max (KN)	Compressive strength (kg/cm^2)	Compressive strength (kg/cm^2)
	7	9	8.80	600	266.67	
Concrete K-250	7	9	8.74	550	244.44	263.70
	7	9	8.60	630	280.00	

	14	8.5	8.60	810	360.00	
	14	8.5	8.58	750	333.33	357.03
	14	8.5	8.61	850	377.78	
	28	9	8.60	920	408.89	
	28	9	8.61	840	373.33	402.96
	28	9	8.59	960	426.67	

In Figure 2, normal K250 concrete is shown before adding superplasticizer and iron powder. It can be seen that the compressive strength value of concrete increases as the age of the concrete increases [41] [42]. The graph shows that the standard compressive strength of concrete at the age of seven days is 242.96 kg/cm^2 and increases again in the second concrete test at the age of 14 days the compressive strength reaches 325.93 kg/cm^2, and in the third test at the age of 28 days the compressive strength increases slowly until it reaches a compressive strength of 371.85 kg/cm^2.

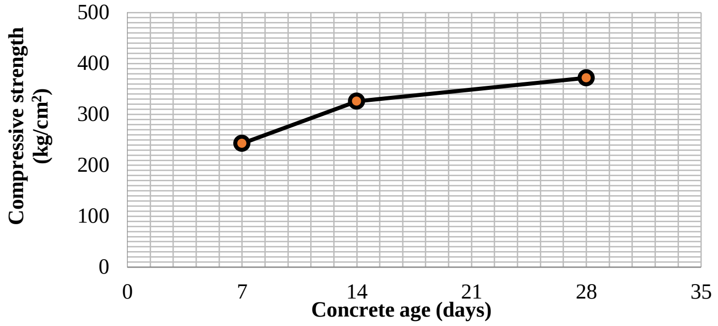

Fig. 2: Mixture Compressive Strength 0%.

In Figure 3, the addition of 0.5% superplasticizer and 10% iron powder can be seen that the compressive strength value of the concrete increases as the age of the concrete increases. The graph shows that the compressive strength of the concrete at seven days was 320 kg/cm^2, and increased again in the second concrete test at 14 days, namely, the compressive strength reached 431.11 kg/cm^2. and in testing at the age of 28 days, the compressive strength increased slowly until it reached a compressive strength of 474.07 kg/cm^2.
If you observe the comparison of the compressive strength of Figure 3 with Figure 2, you can see the differences in the compressive strength characteristics of concrete. In the graph of the compressive strength of concrete with a mixture of 0.5% superplasticizer concrete additives and 10% iron powder, the compressive strength value of the concrete increases as the age of the concrete increases [43][44]. The compressive strength of concrete experienced an increase in compressive strength in the seven-day age test compared to normal concrete. The strength of the concrete at 28 days is only comparable to 27.4% of the strength of the control concrete.

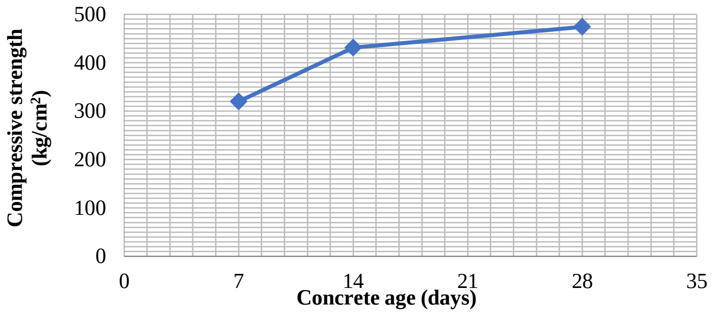

Fig. 3: Compressive Strength of 0.5% Superplasticizer Mixture and 10% Iron Powder Mixture.

In Figure 4, the addition of 0.5% superplasticizer and 20% iron powder shows that the compressive strength value of concrete increases as the age of the concrete increases. The graph shows that the compressive strength of concrete at seven days is 305.19 kg/cm^2, and increases again at The second concrete test was aged 14 days, namely the compressive strength reached 410.37 kg/cm^2, and in the test at 28 days the compressive strength increased slowly until it reached a compressive strength of 442.96 kg/cm^2.
If you observe the comparison of the compressive strength of Figure 4 with Figure 2, you can see the difference in the compressive strength characteristics of concrete. On the chart, the compressive strength of concrete with a mixture of 0.5% superplasticizer and 20% iron powder Figure 4, the compressive strength of concrete experienced an increase in compressive strength in the seven-day test compared to control concrete. The compressive strength of concrete increased by 25.6%, then the ratio increased in the 14-day age concrete test: 25.9%, and in the 28-day age test, it only compares to 19.1% of the concrete strength control.

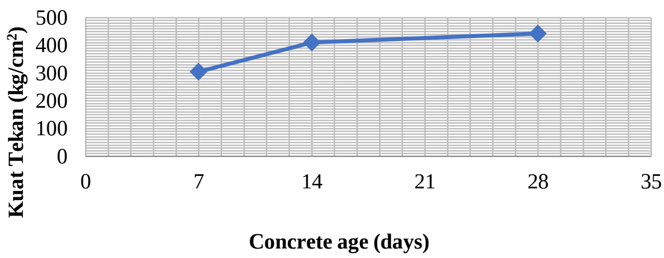

Fig. 4: Compressive Strength of 0.5% Superplasticizer Mixture and 20% Iron Powder Mixture.

In Figure 5, the addition of 0.5% superplasticizer and 30% iron powder shows that the compressive strength value of the concrete increases as the age of the concrete increases. The graph shows that the compressive strength of the concrete at the age of seven days is 263.70 kg/cm^2, and increases again in the concrete test. secondly, at 14 days of age, the compressive strength reached 357.03 kg/cm^2, and in testing at 28 days of age, the compressive strength slowly increased until it reached a compressive strength of 402.96% kg/cm^2.

If you observe the comparison of the compressive strength of Figure 5 with Figure 2, you can see the difference in the compressive strength characteristics of concrete. On the chart, the compressive strength of concrete with a mixture of 0.5% superplasticizer and 30% iron powder Figure 5, the compressive strength of concrete experienced an increase in compressive strength in the seven-day test compared to the control concrete. The compressive strength of concrete increased by 8.53%, then the ratio increased in the 14-day age concrete test: 9.62%, and in the 28-day age test, it only compares to 8.37% of the concrete strength normal. So the compressive strength of the concrete with this mixture of 0.5% superplasticizer and 30% iron powder still meets the planned concrete quality.

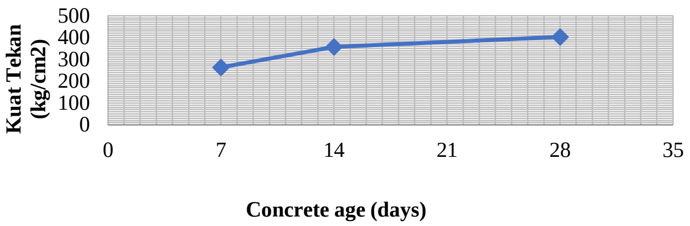

Fig. 5: Compressive Strength of 0.5% Superplasticizer Mixture and 30% Iron Powder Mixture.

If you observe the comparison of compressive strength from Figure 6 with the previous Figure 2, you can see the comparison of four concrete tests with different mixture proportions. The highest compressive strength was achieved by concrete with a mixture of 0.5% superplasticizer and 10% iron powder, followed by concrete with a mixture of 0.5% superplasticizer and 20% iron powder, then followed by concrete with a mixture of 0.5% superplasticizer and 30% iron powder, and finally followed by 0% control concrete. Of the four concrete tests carried out with different mixture proportions, all mixtures achieved the design strength of normal K250 concrete.

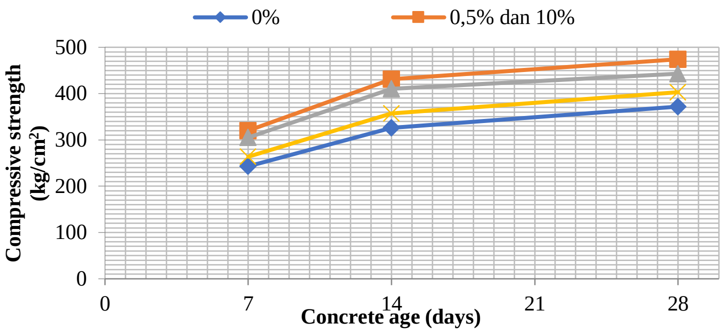

Fig. 6: Comparative Graph of the Compressive Strength of Normal Concrete and Concrete with the Addition of Superplasticizer and Iron Powder.

Based on the research results, it was found that out of the 3 concentration variations used, the variation of additives and iron powder at a 10% concentration yielded the best results for concrete compressive strength. The use of iron powder should not exceed 10% of the aggregate weight, as it can affect the slump value and increase the weight of the concrete. These research findings are consistent with the research conducted by Harahap et al. in 2024 [45], which varied the addition of Iron Powder as an Additive in Rigid Pavement Concrete. The variations in iron powder mixtures used in their study were 0%, 1%, 3%, and 5%. Their research found that the concrete mixture with a 3% addition of iron powder had the highest flexural strength value among the other concrete mixtures, with an average flexural strength of 5.447 MPa. Therefore, from their research, it can be concluded that the optimum addition of iron powder is 3%.

The addition of iron powder generally reduces the slump value of concrete, making it less workable. The extent of the slump reduction will depend on the amount of iron powder added, the particle size of the iron powder, the characteristics of the initial concrete mix (especially water content and aggregate type), and the potential presence of other admixtures in the mix. Therefore, when adding iron powder to a concrete mixture, it is necessary to include other admixtures such as superplasticizers, which will increase the specific gravity or magnetic properties of the concrete. The results of this study also show that the combination of superplasticizer and iron powder with concentrations of 10%, 20%, and 30% affects the slump value of the resulting concrete. As seen in Tables 4, 5, and 6, the concentration variations used influence the resulting slump value. Observing the tables, there is an increase in slump values, but there is no direct or automatic relationship, indicating that a higher concentration variation of the superplasticizer and iron powder mixture will necessarily produce a higher slump value. This is because the relationship between superplasticizer concentration and slump value is generally positive up to a certain limit. The higher the dosage of superplasticizer (within the optimal range), the higher the resulting slump value. However, there is a saturation point. Exceeding the optimal dosage can lead to segregation, excessive bleeding, or even significant setting delays, and does not always mean the slump value will continue to increase proportionally. Therefore, the results of this study also indicate that for the combination of superplasticizer and iron powder, the dosage of both materials needs to be optimized through mix design trials.

Based on the results of this research, it is shown that iron powder, which was initially waste, can be utilized in a technological innovation that can benefit the community or business actors in the construction sector. Iron powder waste, a byproduct of various industrial processes such as machining, grinding, and steel production, often becomes an environmental problem if not managed properly. The findings of this research indicate that iron powder waste has significant potential to be utilized in material technology innovation as a mixture in concrete. The utilization of iron powder waste as a concrete mixture offers significant potential in reducing industrial waste, improving concrete performance in specific applications, and potentially reducing production costs. However, the research results obtained require further development. With the right approach, iron powder waste can become a valuable resource in a more sustainable construction industry.

4. Conclusion

The addition of superplasticizer and mixing iron powder for all variations can be used because it can increase the compressive strength of the concrete beyond the normal compressive strength of normal K250 concrete.

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