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Nickel Slag as A Partial Substitution of Fine Aggregate in Concrete

UNDERGRADUATE RESEARCH SESSION

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Theodore Karol Gabriel Nobel Judah Perwira

Supervisors:

Dr. -Ing. Josia Irwan Rastandi, S.T., M.T.

Dr. Jessica Sjah, S.T., M.T., M.Sc.

Dr. Dipl.-Ing. Nuraziz Handika, S.T., M.T., M.Sc.

Dr. Ir. Sotya Astutiningsih, M. Eng.

Content

Background

FERRONICKEL SLAG (FNS)

FNS is a by-product of Ferronickel production [1]. Ferronickel is used in the production of stainless steel and battery worldwide [2].

BY-PRODUCT MATERIALS

The use of by-product materials as a partial substitution of cement and fine aggregate to reduce emissions [3].

FNS PRODUCTION

Every 1 ton of Ferronickel produced, 12-14 ton of FNS are produced as a by-product [4]. In Indonesia, 13 million metric tons of FNS are produced every year but is not used well [5].

ANALYZING USING DIGITAL IMAGE CORRELATION (DIC)

DIC method are used to determine the local displacement under certain loads. The displacement could be converted into strains while loads into stresses.

FNS IN MORTAR AND CONCRETE

Some studies shows that FNS as a partial substitute for natural sand in mortar and concrete could increase workability and compressive strength by varying ammount [6].

Research Methodology

MIX DESIGN PROPORTIONS

In this research, a total of 3 variations subtitution were used. 0%, 50%, and 100%. For each variation, 4 samples were used

Batch	w/c	Water (kg/m^3)	OPC (kg/m^3)	FNS (kg/m3)	M-Sand (kg/m^3)	Split Stone (kg/m^3)
FNS-0	0.412	206	501	0	694	992
FNS-50	0.412	206	501	347	347	992
FNS-100	0.412	206	501	694	0	992

Research Methodology

SPECIMEN PREPARATIONS

Each batch of concrete was cast into two types of molds, D10-20 cm^3 cylinders and 15x15x15 cm^3 cubes, cured for 7, 14, and 28 days for cylinder specimens and 28 days for cubic specimens. One of the flat surfaces of the cubic specimens were painted white and gently sprayed with black paint to facilitate DIC analysis.

Research Methodology

TESTING METHOD

- Destructive Compressive Test to evaluate the compression strength
- Digitial Image Correlation (DIC) to evaluate the deformation behaviour

Test set up for DIC

Compressive load dial

Specimen

Lighting

Camera

Results

COMPRESSIVE STRENGTH

The specimen with FNS replacement shows an increased in compressive strength at all ages, with the 28-day compressive strength of FNS-50 was found to be the highest, followed by FNS-100 and FNS-0 with 41.4 MPa, 37.0 MPa, and 34.2 MPa respectively.

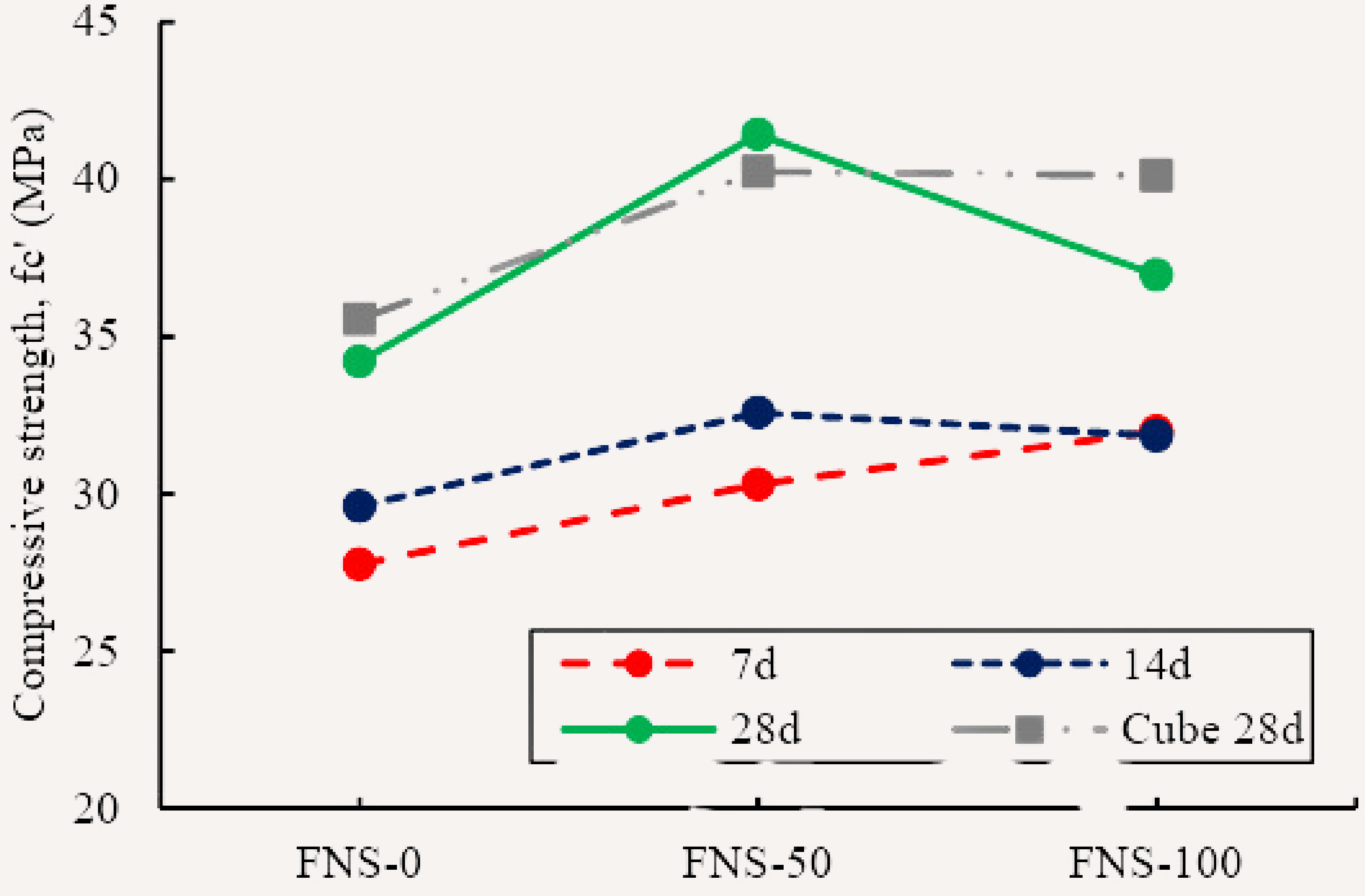


Figure 6. Effects of FNS substitution on compressive strength.

Results

DENSITY

The density of all specimens ranged from 2.28-2.42 g/cm^3, with the highest density of 2.42 g/cm^3 was found in 28-days FNS-50. Nevertheless, the overall density of FNS-100 batch across all specimen and ages was higher than the other two. These increasement happened due to the higher specific gravity of FNS than sand.

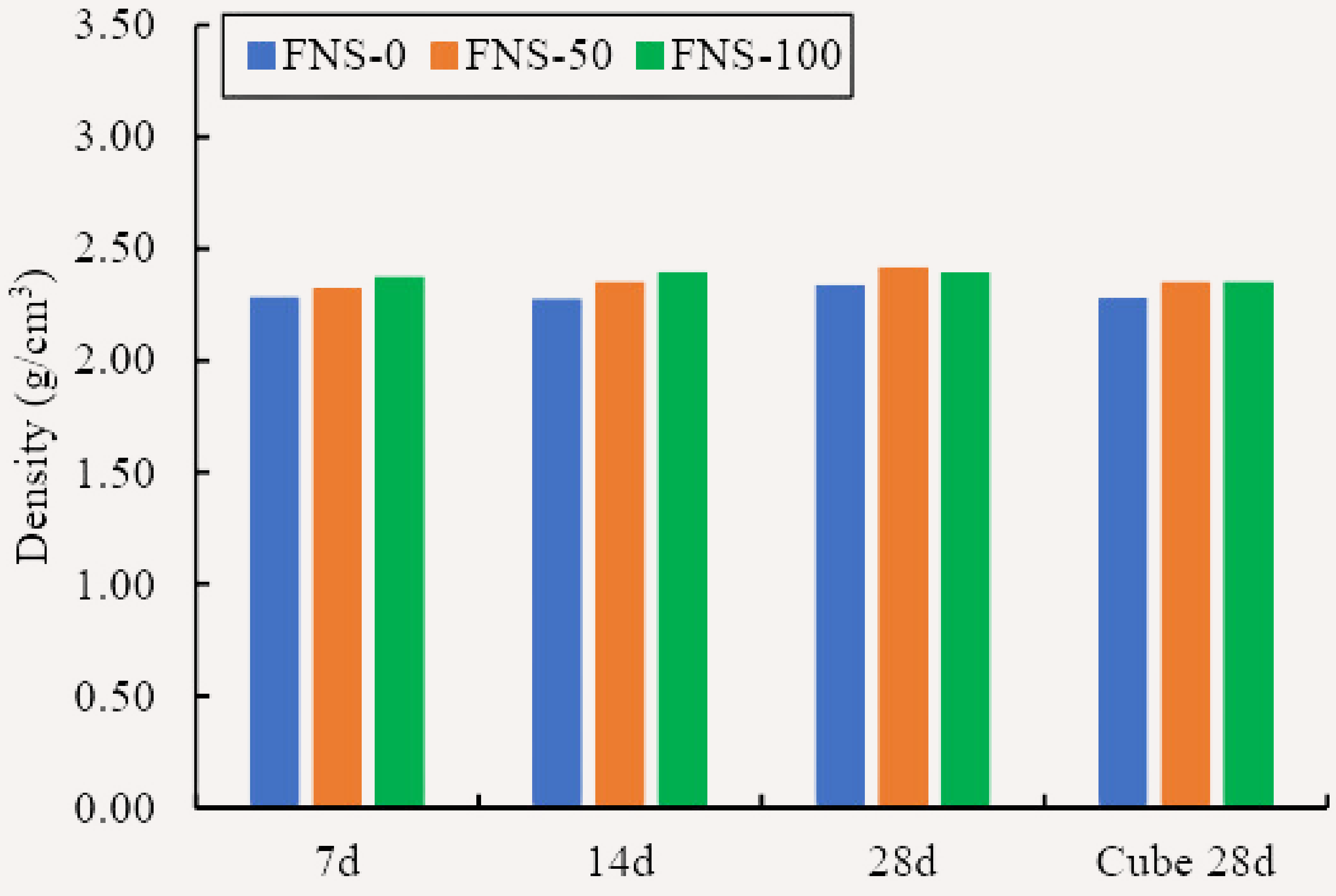


Figure 5. Effects of FNS substitution on density.

Results

POISSON'S RATIO

The Poisson's Ratio was calculated from DIC and strain gauge. It shows that FNS replacement decrease the Poisson's ratio. Generally, a higher-strength concrete has a relatively lower Poisson's ratio. This explains why FNS-50 and FNS-100 yielded a higher compressive strength than FNS-0.

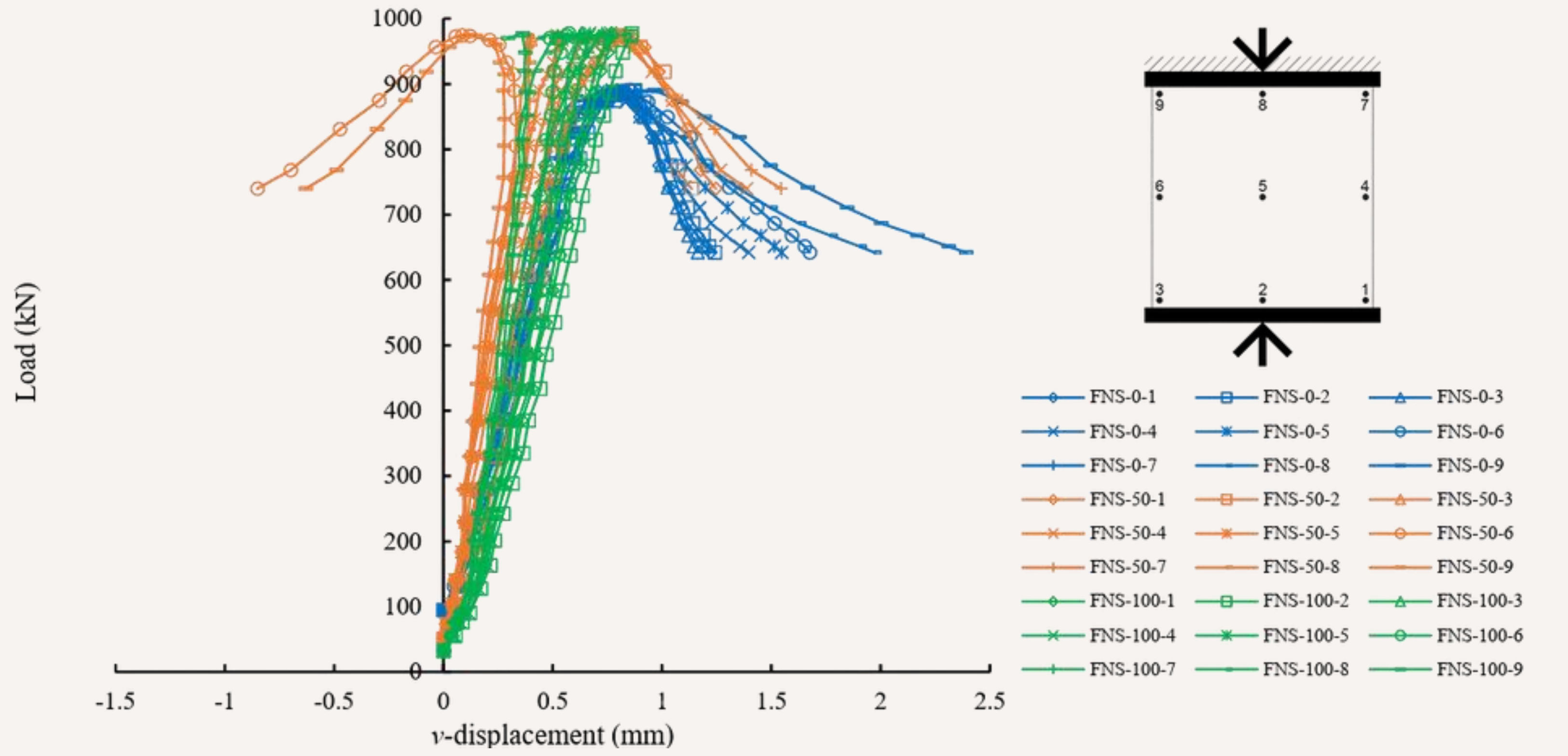
Batch	Poisson's Ratio	
	DIC	Strain Gauge
FNS-0	0.24	0.27
FNS-50	0.22	0.22
FNS-100	0.22	0.20

Results

LOAD-DISPLACEMENT RELATIONSHIP

The figure shows the displacement of the specimen against the applied load. Base on the load-displacement relationship, the FNS-100 showed a higher resistance than FNS-50, though FNS-50 has a higher average strength that FNS-100. Compared to control, FNS specimen showed a lower displacement response or a higher resistance.

All variations seemed to have a relatively constant response at early loading or elastic phase for every observation point.



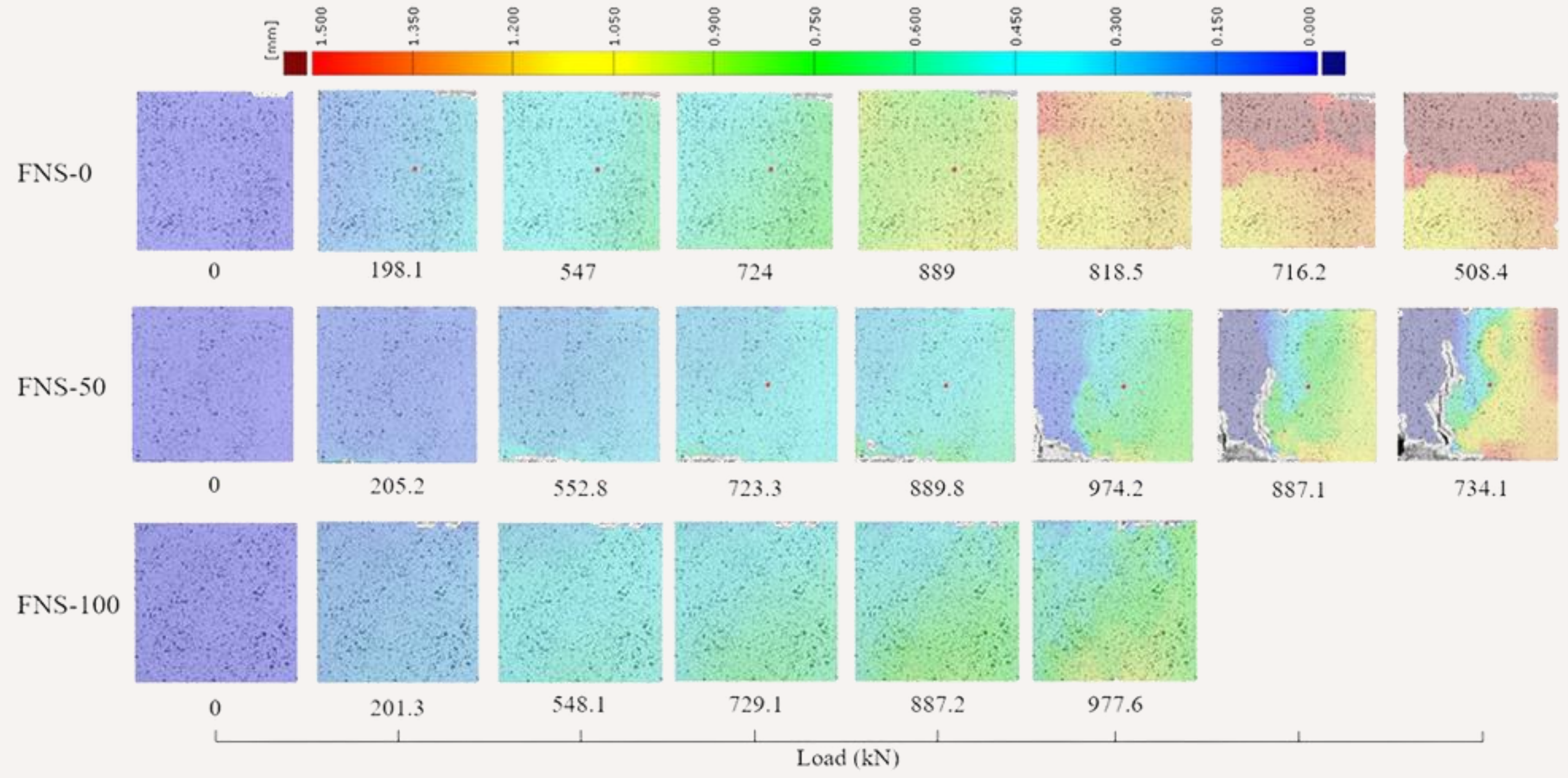


Figure 10. *v*-displacement field of cubic specimens.

Conclusion

Based on the results obtained, the following conclusions can be summarized:

- The specimens with FNS replacement has a higher compressive strength than the control, with 50% FNS replacement as the most optimal one.
- Density of the concrete increases scales with the increase of FNS replacement.
- Specimen with FNS replacement has a lower Poisson's Ratio than the control.
- The specimen with FNS substitution shows less displacement under the same load compared to the control.

References

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