2024 ENGINEERING INSTITUTION OF ZAMBIA SYMPOSIUM

EFFECT OF COARSE AGGREGATE SIZE ON CONCRETE STRENGTH

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DATE : Friday 19th April 2024

Avani Victoria Falls Resort, Livingstone, Zambia

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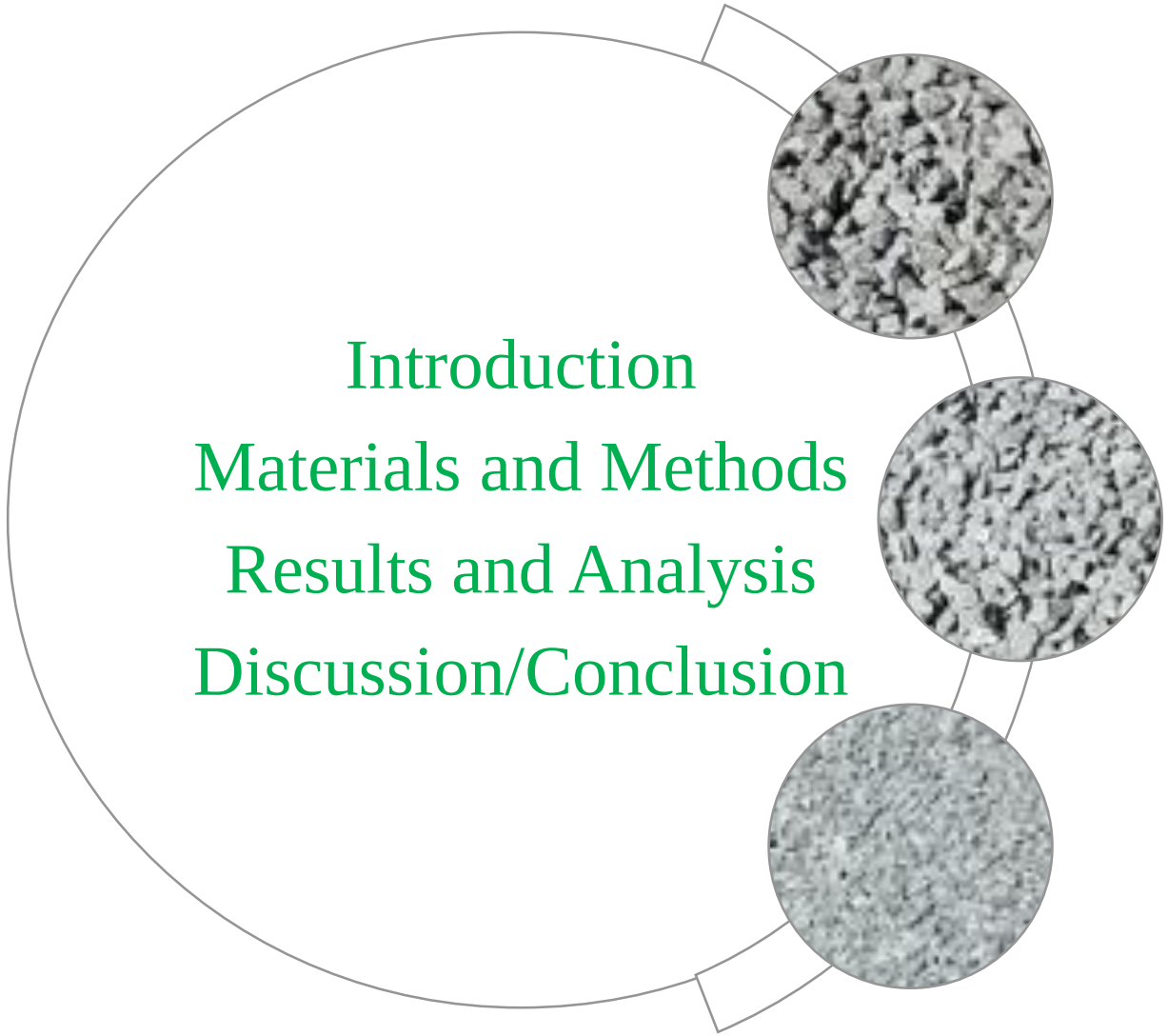


Introduction:

- Concrete is a blend of aggregates, sand and gravel or crushed stone bounded together by a hydraulic binder like Portland cement and activated by water to form a dense semi homogeneous mass (The concrete society, n.d.).
- Coarse aggregates are aggregates that are greater than 5mm (retained on the 5mm sieve) while fine aggregates are aggregates that are smaller than 5mm (passing through the 5mm sieve size) (BS:882, 1992)
- The huge percentage/volume of aggregate in concrete warrants concerted studies to fully understand their influence on the strength characteristics of concrete.

Introduction Cont'd:

- In a study to investigate the effect of coarse aggregate size on the compressive strength and the flexural strength of concrete beams by Ajamu and Ige (2015).
- 13.2 mm – 21.26 N/mm^2, 19 mm – 23.41 N/mm^2, 25 mm – 23.66 N/mm^2, and 37.5 mm – 24.31 N/mm^2.
- The study also revealed that flexural strength of concrete beam is inversely affected by the increase in coarse aggregate size.
- Studies by Ogundipe et al. (2018) and Arum and Olotuah (2006) showed that increasing aggregate size leads to corresponding increase in compressive strength.

Introduction Cont'd:

Oyewole et al. (2011) investigated the effects of aggregate sizes on structural concrete's qualities in order to determine the aggregate size that will enhance those properties. This study concluded that;

- The average compressive strength of concrete increases as the sizes of coarse aggregates are reduced.
- The smallest coarse aggregate size gave the lowest slump at constant water/cement ratio

Introduction Cont'd:

- In another study on effect of size of coarse aggregate on compressive strength of high strength concrete by Yaqub and Bukhari (2006), coarse aggregate sizes of 5 mm - 10 mm showed higher compressive strength than that of 10 mm - 20 mm, 20 mm - 25mm, and 25 mm - 37.5 mm.
- Anthony et al. (2015) also studied the effect of maximum coarse aggregate size on the compressive strength of concrete produced in Ghana. This study showed that the compressive strength of concrete made with 10 mm maximum aggregate size was higher than that of 14 mm - 20 mm sizes.

Introduction Cont'd:

- Despite several studies on the influence of various factors on the strength of concrete, there is non-consensual conclusions on the effect of coarse aggregate size on concrete strength.

- In this study, the effect of three different coarse aggregate sizes on concrete strength was investigated. The materials used were locally (Zambian) produced concrete ingredients - to provide local guidance and enhance the performance and sustainability of concrete strength.

Materials and Methods

The materials that were used for the laboratory works are;

- Ordinary Portland cement – grade 42.5 N/mm2

- Fine aggregates (natural river sand)

Materials and Methods Cont'd

- Coarse aggregate (crushed stones), the coarse aggregates of size 20 mm – 25 mm, 10 mm – 20 mm and 5 mm-10 mm were used.

Materials and Methods Cont'd

Concrete mix design

Concrete design strength of 25 N/mm2 was targeted. The concrete mix design was done according to the Design of Experiments (DOE).

Sr.	Coarse Aggregate size	Volume	Water	Cement	Fine Aggregate	Coarse Aggregate	Mix Design Ratio
1	5mm – 10mm	$1m^3$	230kg	460kg	713.4kg	1026.6kg	1:1.55:2.23
2	10mm – 20mm	$1m^3$	210kg	420kg	584.1kg	1185.9kg	1:1.39:2.82
3	20mm – 25mm	$1m^3$	190kg	380kg	520.8kg	1339.2kg	1:1.37:3.52

Materials and Methods Cont'd

Concrete laboratory tests

- Slump test on fresh concrete (BS 1881-102:1983)

- Water absorption test on concrete cubes (BS 1881-122:1983)

Materials and Methods Cont'd

Concrete laboratory tests

- Concrete compressive test (BS 1881-116:1983)

- Tensile split test (BS 1881-117:1983)

Results and Analysis:

Slump test

The slump test was done on fresh concrete in order to determine the workability of concrete according to BS 1881: Part 102

Sr.	Aggregate size (mm)	Form of slump	Slump	
		True, shear or collapse	Measured (cm)	Design (cm)
1	5 – 10	True	3.3	3 - 6
2	10 – 20	True	4.7	3 - 6
3	20 – 25	True	5.2	3 - 6

According to the mix design, the investigation was based on a slump of 30 - 60 mm.

Results and Analysis Cont'd:

Compressive test

The test cubes for the compressive strength test were crushed on curing days of 7, 14 and 28 days.

Sr	Age	Compressive strength of concrete with three different coarse aggregate sizes (N/mm^2)		
	(Days)	Size 5 mm – 10 mm	Size 10 mm – 20 mm	Size 20 mm – 25 mm
1	7	18.4	19.6	25.06
2	14	19.6	24.26	27.75
3	28	21.15	25.26	29.39

The trend is relatively consistent with studies conducted by Ajamu and Ige (2015), Ogundipe et al. (2018) and Arum and Olotuah (2006)

Results and Analysis Cont'd:

Tensile split test

The test cylinders for the tensile split test were crushed on curing days of 7, 14 and 28 days.

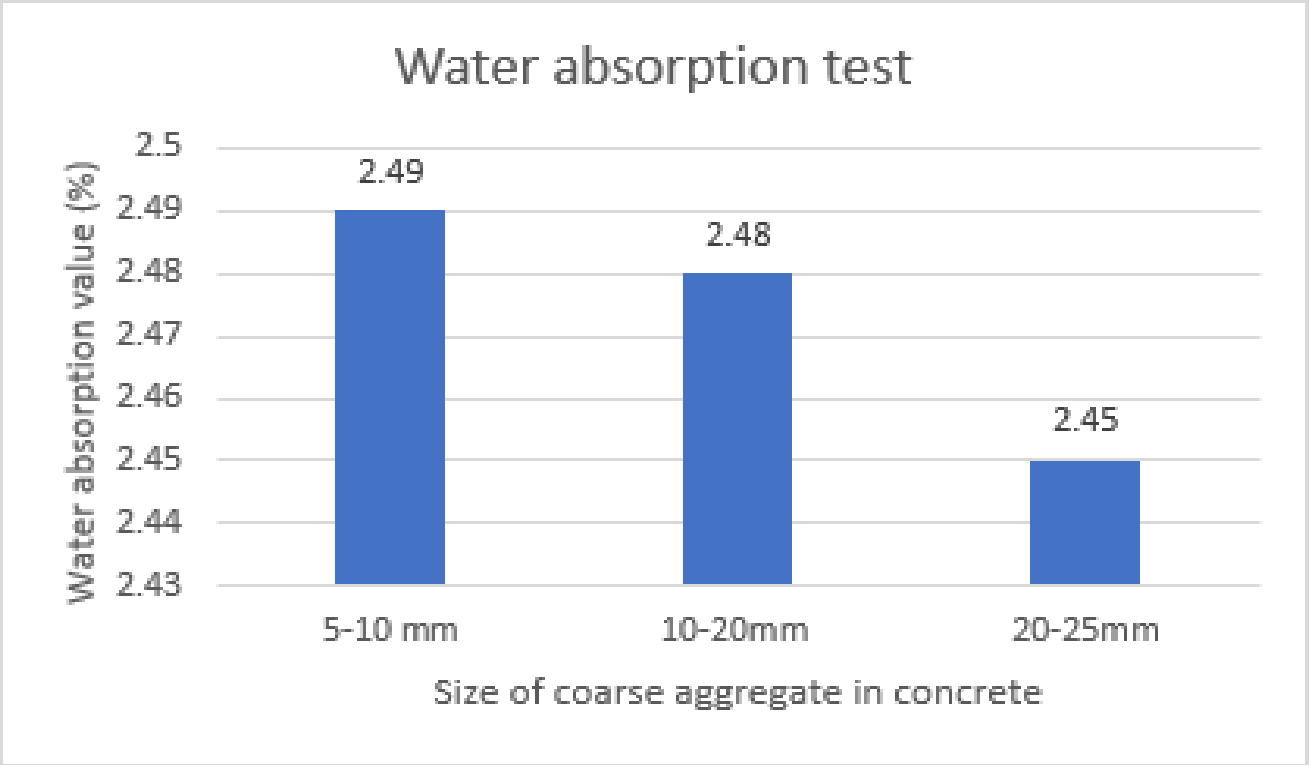
Sr.	Age	Tensile strength of concrete with three different coarse aggregate sizes (N/mm²)		
	(Days)	Size 5 mm – 10 mm	Size 10 mm – 20 mm	Size 20 mm – 25 mm
1	7	2.23	2.06	1.87
2	14	2.67	2.31	1.99
3	28	2.76	2.33	2.13

The trend is relatively consistent with a study conducted by Akcaoglu et al. (2003).

Results and Analysis Cont'd:

Water absorption test

To determine the durability of concrete, water absorption tests were carried out on concrete cubes.



Discussion/Conclusion:

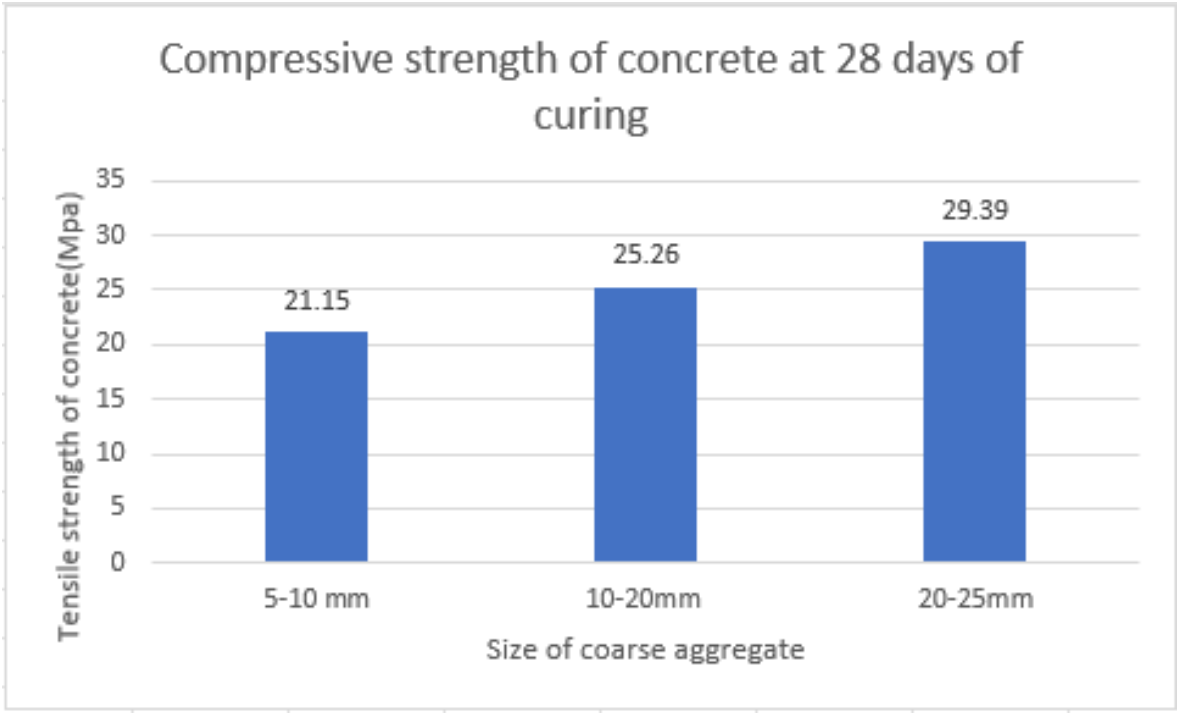
From the slump test

- The slump increased with an increase in the coarse aggregate size.
- This is attributed to the surface area of big aggregates being less.

- Thus, the concrete having large size aggregate is more workable.

Discussion/Conclusion Cont'd :

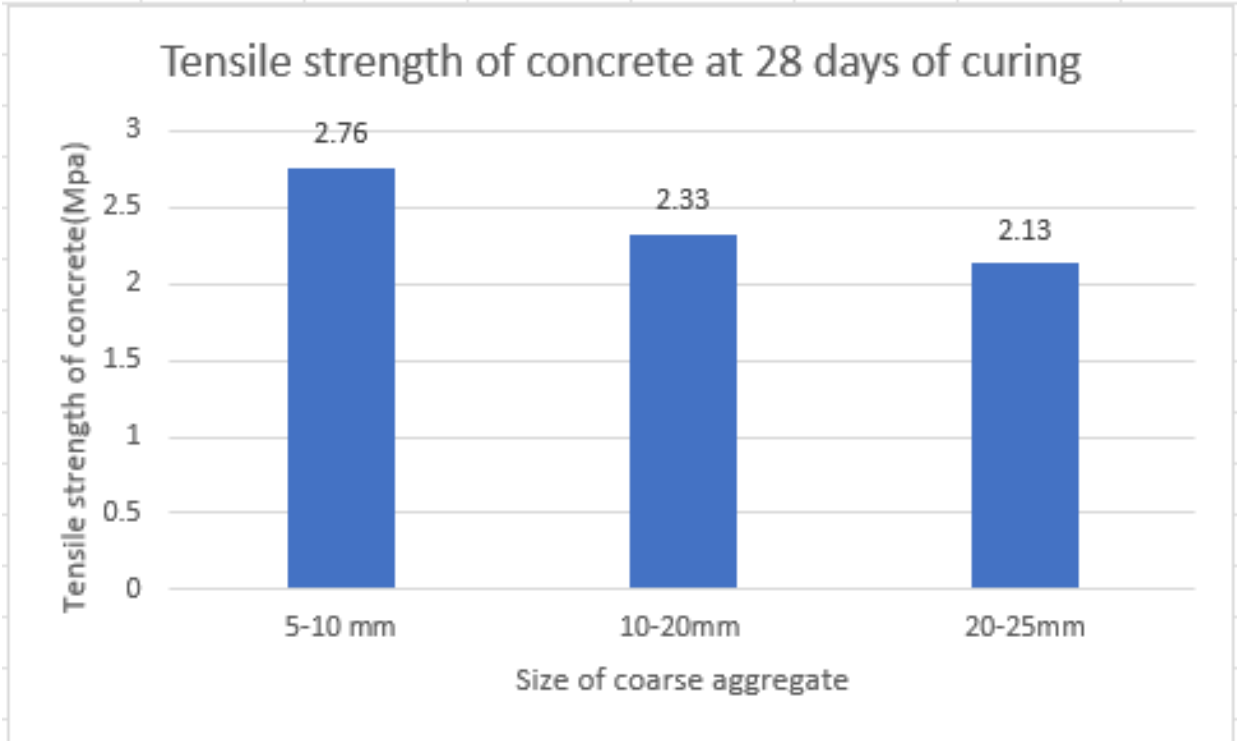
From the compressive test results



This shows that compressive strength increases with an increase in coarse aggregate size. This is attributed to the effect of the aggregate grain size on the restrained shrinkage of concrete and mortar, as postulated in a study by Karagüler and Yatağan, (2018). In this study, it is argued that larger grains restrain the inner strains and prevent the change of the micro-cracks to the macro-cracks.

Discussion/Conclusion Cont'd:

From the tensile split test results



This shows that tensile strength decreases with an increase in coarse aggregate size. This is attributed to the failure paths that follow the interface of the largest aggregate particles, cutting through the cement paste, and occasionally also through the aggregate particles themselves (Neville, 2011).

Discussion/Conclusion Cont'd:

From the water absorption tests

- Results for concrete with coarse aggregate sizes of 5 mm – 10 mm, 10 mm – 20 mm and 20 mm – 25 mm were 2.49%, 2.48% and 2.45% respectively.
- These results indicated that that the durability of concrete increases with an increase in coarse aggregate size.

Discussion/Conclusion Cont'd :

- This is attributed to larger aggregates having a lower surface area compared to smaller aggregates.
- Kong and Ge (2015) reported that the decrease in volume fraction of the interfacial transition zone by larger coarse aggregates can reduce the content of harmful pores in concrete.

Discussion/Conclusion Cont'd:

- Construction managers should ensure adherence to specifications for coarse aggregate sizes, ensuring that the aggregate size distribution falls within a specified size range.

The End

THANK YOU FOR YOUR ATTENTION.