"YOYO" SAND CONCRETE FOR STRUCTURAL USE- A PRELIMINARY INVESTIGATION

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ABSTRACT

The paper reports on the results of an investigation into the physical and strength characteristics of concrete (nominal mixes) which contains "Yoyo" sand (newly discovered fine aggregate) instead of nornal river sand. 45 No. beams of 150mm x 150mm x 750mm sizes and 180 No. 150mm cubes as well were tested with varying mix ratio, Yoyo/normal sand ratio and curing periods. The percentage content of Yoyo sand in the aggregate varied from 0 to 100% in steps of 25%. The results of the investigation showed the strength characteristics of Yoyo sand concrete to be better than that of normal river sand concrete and therefore Yoyo sand may thus be considered wholly or as partial replacement of river sand in concrete for load-bearing structural elements.

KEY WORDS

"Yoyo" sand normal river sand, slump, moisture content, particle size distribution, compressive strength, flexural strength.

INTRODUCTION

Due to escalating cost of construction especially in developing countries, different attempts have been made to substitute wholly or partly some of the constituents of concrete. Examples are the researches on laterized concrete, (1-3). The economic consideration for the possible use lateritic material involved its mining from the ground as against the hectic collection of normal sharp from the rivers and riverbeds.

Thomas and Lisk (4) investigated the suitability of crushed laterite rock obtained in Sierra Leone for use as coarse aggregate in concrete and concluded that lateritic aggregates are suitable materials for concrete. Tebedge (5) reported on scoria in Ethiopia as being suitable as coarse aggregate for making concrete.

Recent researches may show the possibility of a new type of fine aggregate, apart from that of latertic material, generally referred to as "Yoyo" sand. Yoyo sand occurs in commercial quantity in South-Western States of Nigeria. It may also occur abundantly in other parts of tropical regions of the world, with the same geological formations as south-western states. Yoyo sand different from the conventional river sand by its colour which is pink or yellowish and most likely of lateritic origin, though containing less than 10% clay. It is mined from the ground and normally very close to formation where laterite is mined.

Nearly all block-makers in Lagos metropolis have been using Yoyo sand either partially with conventional river sand or wholly to produce load-bearing blocks without considering the engineering properties of the sand and even the resulting products. The sand is sometimes used as filling material by some construction companies. Efforts are going on by Nigerian Buildings and Roads Research Institute to look into the use of Yoyo sand in brick-making. Little or nothing is known yet about Yoyo sand in concrete production including its strength characteristics.

Wroth and Houlsby (6) observed that real soils rarely consist exclusively of either sand or clay fraction and it only requires a relatively small fraction (say 10-15%) of clay to make behaviour of a sandy soil like that of a clay. It is therefore, necessary to determine the clay content of any fine aggregate for its suitability in concrete production.

If Yoyo sand is found suitable, the cost of production may be about 60% cheaper than conventional sand, which present cost continues to rise daily due to the Nigerian economic situation. At present, the cost of 5 - ton -lorry load of Yoyo sand is ₦2,200 while that of river sand is between ₦3,500 and ₦5000, depending on from which river, for Ikeja location.

This paper thus reports on experimental investigation on physical and strength properties of concrete with varying percentage of Yoyo sand as substitute in fine aggregate as well as different mix proportions.

PHYSICAL EXAMINATION OF YOYO SAND

Various colours of Yoyo sand are observed such as pink, brownish yellow, deep red and so on but during mining these colours blend together to form a predominantly pink colour which appears to occur in largest proportion. No reasons have been attributed to the colouration, however, it is suspected that it is not

unconnected with the presence of iron in the soil and variation in moisture content. It is yet to be confirmed if the colouration has any adverse effect on the engineering properties of the concrete produced. The sand is referred to as "Yoyo" because of this pinkish colouration and finenish appearance.

Visual examination of Yoyo sand shows that it is finer than the conventional river sand and as such the concrete from the Yoyo sand may be denser than that from normal sand. More cement may also be required for the same volume of concrete.

EXPERIMENTAL PROCEDURE

For preliminary tests to determine physical properties of concrete made from Yoyo sand, grading of the sand, moisture content, absorption capacity, specific gravity, pH and slump tests were carried out. The Yoyo sand used in this investigation was obtained from Olubosun pit site at Ojota along Lagos-Ibadan Express Way, Lagos State in Nigeria while the cement is ordinary Portland Cement per BS12 (7), collected from the Sagamu Factory in Ogun State of Nigeria.

For the compressive strength and flexural properties of concrete elements with Yoyo sand as part of the constituents, the coarse aggregate used was crushed granite with density of 2650kgm^{-3} and maximum diameter of 19mm. The fine aggregate was made of Yoyo and normal river sands. Figure 1 shows the grading curves of the aggregates.

The percentage of Yoyo sand by weight of the total fine aggregate was varied in steps of 25% up to a maximum of 100%, corresponding to yoyo concrete while the 0% corresponds to normal concrete. Varying concrete mixes (cement : Yoyo/normal sand: granite) of 2:3:6, 1:2:4 and 1:3:6 with corresponding water/cement ratio of 0.55, 0.65 and 0.75 to obtain normal consistency according to Reynolds and Steedman (8) were also considered. In all, 180 cubes with varying curing periods, mix ratio and Yoyo/normal sand ratio were tested for physical and strength properties.

Forty-five beams of 150mm x 150mm x 750mm with nominal longitudinal reinfeorcement of 2 y16 at the bottom were tested, three samples corresponding to the same Yoyo sand content, mix proportion and water/cement ratio. The cubes were immersed in water of about 27° C temperature for different curing periods of 7, 14, 21 and 28 days, at the end of which they were removed and allowed to drain for 2 hours before testing. The beams were cured under damp sand for 3 days and kept in the laboratory environment until tested at 28 days.

The cube crushing tests were performed on ELG Budenberg compression machine with maximum capacity of 600kN while the beams were tested on simply supported span of about 700mm on third point loading in increment of about 5kN using the Universal Avery testing machine with the maximum capacity of 1000kN. To determine the deflection under loading, dial gauges were placed at the bottom face at the midspan of the beam and readings were taken before and after each load increment. During the testing, development of crack, mode of failure, ultimate failure load and its corresponding central deflecton were noted and recorded for each mix.

RESULTS AND DISCUSSION

Physical Properties

The results of sieve analysis of the aggregates, presented in figure 1 show that Yoyo sand has particles size ranging between 63 micron and 3.35mm just as normal sand. With a uniformity coefficient of about 4, the Yoyo sand is well graded, containing negligible amount of silt of about 4%. It also contains traces of gravel as about 2-3% passes through the 3.35mm sieve.

The natural moisture content obtained varies between 4.0% to 4.4% while the average specific gravity of the sand is 2.43 and absorption capacity is 15.60% Clays show specific gravities of 2.68 - 2.72 typically for many British Soils. (Head 9); and as such Yoyo sand cannot be classified as clay (laterite). With a pH value of 8.8, Yoyo sand is not acidic but has a very weak basic property and this may not adversely affect the durability and other properties of concrete.

Table 1 shows the values of the slump with different mix proportions and percentage content of Yoyo sand; higher values are obtained for mix of 2:3:6 with water/cement ratio of 0.55 compared to others. No particular trend is observed for the same mix, with inrease in percentage of Yoyo sand. For percentage content of Yoyo sand between 0 to 25 the slumps for all mixes showed the same value as for 100%. All the slumps obtained are normal, no shear or collapse slumps are observed with their values between 50 to 100mm. The results of the slump tests for the mixes showed that 2:3:6 had generally higher slump followed by the mix 1:2:4 and lastly 1:3:6. This may not be unconneted with the higher specific surface of mix 2:3:6 compared to mixes 1:2:4 and 1:3:6 and due to the water/cement ratio of 0.55, 0.65 and 0.75 respectively for the mixes 2:3:6; 1:2:4 and 1:3:6 as more free mixing water produce more workable mix. Generally, workability is medium and based on this, the Yoyo concrete can be suitable, just as normal sand concrete, for normal reinforced concrete construction without vibration, canal linings, arches and piles as outlined Mudrock (10)

There is no particular trend in the densities of Yoyo sand concrete with increasing age for all the percentage content of Yoyo sand. Generally, the density of concrete with 100% content of Yoyo sand shows highest value for the mix proportion of 2:3:6 with 0.55 water/cement ratio. It was also observed that there was no significant difference in the densities of different mix proportions and water/cement ratios considered. None of the densities, even at 7 days was lower than 2400 kg/m^3 even with varying Yoyo sand content in concrete. This shows that the Yoyo sand is very dense compare with normal river sand and the compaction can be related to the molecules of the Yoyo binding the fine particles of sand. With very low content of silt and clay, the Yoyo sand shows low affinity for water. The Yoyo concrete would be heavy weight and should be suitable for use in load-bearing structural elements.

Table 1: Values of Concrete Slumps with varied % Yoyo Sand Content

% Yoyo Sand Content	Slump (mm) with mix proportion		
	2 : 3 : 6	1 : 2 : 4	1 : 3 : 6
0	97	55	44
25	97	55	45
50	65	54	44
75	60	53	45
100	97	55	44

Compressive Strength

The values of the average cube strength for all the mix proportions corresponding water/cement ratios and varying percentage contents of Yoyo sand are summarized in Table 2. The compressive strength/age characteristics of different mix proportions for normal and Yoyo sands content are shown in figures 2 and 3 respectively.

For a given mix proportion the compressive strength does not increase appreciably with increase in Yoyo sand content. However, there is an increase in the strength with increase in age. With a mix proportion of 2:3:6 and water/cement ratio(w/c) of 0.55, the average cube strength of normal sand concrete at 28 days was observed to be 27.5 N/mm^2 while for the same mix proportion and water cement ratio, the Yoyo sand concrete cube strength at 28 days was 29.1 N/mm^2, showing only an increase of 5.5%. This dictates that the Yoyo sand behaves just like the river sand in concrete and even shows higher strength. This may be attributed to difference in particle size distribution and layer surface area of Yoyo sand that would require more cement to coat.

Figures 2 and 3 show that the rate of strength development with age is similar for all the mixes considered. About 60% of the 28 days strength was developed in 7 days in all the cubes tested. The early strength development is not unconnected with the fine grains of the Yoyo sand compared with river sand as well as the high uniformity coefficient of Yoyo sand.

General increase in compressive strength with 0 to 100% content of Yoyo sand replacement is consistently around 5% for the various mixes while variation in strength up to 50% was observed among the mix proportions investigated for all different Yoyo sand content. The highest strength was exhibited by the mix proportion of 2 : 3 : 6 by weight with water/cement ratio of 0.55, followed by that of 1: 2: 4 with w/c of 0.65. This is expected as in Normal River sand concrete possibly due to higher cement content in the mix.

The minimum compressive strength at 28 days for mixes 2:3:6 with w/c of 0.55 and 1: 2: 4 with w/c of 0.65 for all the Yoyo sand content was not less than 20 N/mm^2. This compares favourably with normal concrete and can be useful in load-bearing structural elements.

Table 2: Variation in Density and Compressive Strenght with % Yoyo Sand Content

% Yoyo sand Content	Age of concrete cubes (Days)	Average Density (kg/m^3) with mix proportion*			Average cube strength (N/mm^2) with mix proportion*		
		2 : 3 : 6	1 : 2 : 4	1 : 3 : 6	2 : 3 : 6	1 : 2 : 4	1 : 3 : 6
0	7	2440	2617	2627	16.8	13.4	8.0
	14	2489	2509	2489	20.9	13.7	9.6
	21	2548	2578	2598	23.3	18.3	13.2
	28	2459	2449	2400	27.5	22.7	14.5
25	7	2489	2598	2617	16.7	12.8	8.0
	14	2430	2558	2439	20.7	13.8	9.5
	21	2568	2519	2607	23.1	18.5	12.9
	28	2489	2578	2430	27 5	22.5	14.6
50	7	2528	2558	2508	16.6	13.1	8.1
	14	2430	2568	2459	20.6	13.7	9.9
	21	2449	2499	2690	23.1	18.7	12.6
	28	2588	2459	2459	27.3	21.7	14.4
75	7	2518	2558	2499	17.5	12.9	7.9
	14	2578	2469	2440	20.5	13.9	9.9
	21	2489	2440	2368	23.3	18.5	12.3
	28	2499	2500	2448	28.4	22.9	14.4
100	7	2558	2548	2361	18.6	13.4	8.2
	14	2550	2410	2489	21.4	14.5	10.4
	21	2499	2439	2459	23.6	18.7	13.6
	28	2643	2489	2400	29.1	23.2	15.3

* The water - cement ratios for the mix proportion of 2: 3: 6, 1: 2: 4 and 1: 3: 6 are respectively 0.55; 0.65 and 0.75.

Flexural Strength

Table 3 gives the variation of flexural strength in concrete with % Yoyo sand content while figures 4 and 5 show the effect of mix proportion on flexural strength of plain and reinforced concrete beams with different % of yoyo sand content.

Analysis of the tables shows that there is no significant difference in the flexural strength of beams produced from Yoyo or normal sand. This applied for both normal and reinforced concrete. The investigation gave values of 5.6N/mm^2 and 5.2N/mm^2 respectively for reinforced concrete beam from normal and Yoyo sand for mix of 2 : 3 : 6 with w/c of 0.55. In the case of mix of 1 : 2 : 4 with w/c of 0.65, the values are 4.65N/mm^2 and 4.70N/mm^2 for normal and Yoyo sand reinforced concrete beams respectively while for mix of 1:3:6 with w/c of 0.75 the flexural strength values are 4.25 N/mm^2 for the two types of sand. The effect of the type of fine aggregate was not felt due to the fact that the beam could have been under reinforced and the failure was due to the yielding of the reinforcement.

It could also be observed that the addition of reinforcement improved the flexural strength, ductility and post-cracking behaviour of the beams tested for the two types of sand. The flexural strength of normal sand reinforced concrete increased to 5.20 N/mm^2 from 0.90 N/mm^2 for mix proportion of 2 : 3 : 6 while for the same mix the Yoyo sand reinforced concrete beams flexural strength increased to 5.60 N/mm^2 from 0.70 N/mm^2.

Figures 4 and 5 showed that the flexural of both plain and reinforced concrete beams do not depend much on the % content of Yoyo sand but depends mainly on the mix proportion. The mix proportion of 2 : 3 : 6 exhibited the highest flexural strength of 5.60N/mm^2 (0.90 N/mm^2 - unreinforced), followed by 1 : 2 : 4 mix of 4.5 N/mm^2.

Table 3: Variation of Flexural Strength in Concrete with % Yoyo Sand Content

% Yoyo Sand Content	Mix Proportion*	Flexural Strength of Plain Yoyo sand Concrete (N/mm^2)	Position of Fracture to nearer support (mm)	Flexural Strength of Reinforced Yoyo sand Concrete (N/mm^2)	Position of Fracture nearer to support
0	2:3:6 1:2:4 1:3:6	0.90 0.60 0.35	265 305 305	5.20 4.65 4.25	220 227 230
25	2:3:6 1:2:4 1:3:6	0.80 0.65 0.40	255 310 290	5.15 4.65 4.15	217 232 232
50	2:3:6 1:2:4 1:3:6	0.85 0.60 0.30	292 302 332	5.45 4.40 3.95	212 220 207
75	2:3:6 1:2:4 1:3:6	0.75 0.55 0.30	302 290 260	5.20 4.30 3.75	212 217 222
100	2:3:6 1:2:4 1:3:6	0.70 0.60 0.30	317 302 222	5.60 4.70 4.25	212 217 212

The w/c ratios for the mix proportions of 2:3:6, 1:2:4 and 1:3:6 are respectively 0.55; 0.65 and 0.75.

The position of fracture in the case of unreinforced concrete for different mix proportions and Yoyo sand contents is at the middle third, of the beam where it is pure flexure, however, for the reinforced beams the position mainly at the end of the first third, where the effect of shearing stress is pronounced apart from the bending failure.

CONCLUSIONS AND RECOMMENDATIONS

The results of the experimental investigation carried out showed the following:

1. With density of more than 2400 kg/m3, moisture content of about 4%, and silt content of less than 10% Yoyo sand can be comparable with conventional river sand and can be used in production of heavy weight concrete. Yoyo sand is naturally well graded fine aggregate.

2. There exists a consistent pattern of strength-age curves for concrete with normal and Yoyo sand content, though Yoyo sand concrete exhibited higher strength at 28 days compared to the corresponding river sand concrete. There was early strength development - About 60% of 28 days strength was observed at 7 days in all the mixes.

3. For a given mix proportion the compressive strength does not increase appreciably with increase in Yoyo sand content. However, the highest strength was exhibited by mix proportion of 2 : 3 : 6 by weight with water/cement ratio of 0.55 for 100% Yoyo sand fine aggregate.

4. The flexural strength of both plain and reinforced concrete beams with varying Yoyo sand content does not depend on the percentage content of the Yoyo sand but depends mainly on the mix proportion. The mix proportion of 2 : 3 : 6 with water/cement ratio of 0.55 showed the highest value.

5. The introduction of reinforcements improved the flexural strength, ductility and post-cracking behaviour of the beams with different percentage % of Yoyo sand content. However, the increase in strength effect is more pronounced in Yoyo sand than in normal sand beams.

The presence of Yoyo sand in concrete increases the strength characteristics compared to normal river sand. Yoyo sand can therefore be considered as a total or partial substitute for river sand in concrete for load bearing structural members.

Investigation was carried out on partial replacement of fine aggregate with Yoyo sand on short-term strength characteristic and normal exposure condition, it is recommended that future work should concentrate on long-term resistance and durability of concrete with Yoyo sand. The impact tests should also be considered for concrete with Yoyo sand content.

A concentration on the very common mixes of 1:3:6 and 1:2:4, used more predominantly, with different water/cement ratios is necessary for further investigation in order to give guidance on designed on designed mixes.

REFERENCES

1. **Balogun L. A. and Adepegba, D.** "Effect of varying sand content in Laterized Concrete". International Journal of Cement Composites and Light-weight Concrete 4, pp. 235 - 240 (1982).

2. **Salau M. A. and Balogun, L. A.** "Shear Resistance of Reinforced Laterized Concrete Beams without Shear Reinforcement". Building and Environment 25 (1) pp. 71-76 (1990)

3. **Osunade, J. A. and Ogundeko, O. F.** "Fibre Reinforcements as they affect Shear and Tensile Strength of Laterized Concrete". International Journal for Housing Science and its Application, U. S. A. pp. 265-77, (1992).

4. **Thomas, K and Lisk, W. A. A.** "Investigation into Suitability of Crushed Laterite Rocks for use as Coarse Aggregate for Concrete" Proc. Conference of Reinforced Concrete in hot Countries, Vol. 1 pp. 18 3-198 (1971).

5. Neguisse "Scoria Concrete for Structural Use-A Preliminary Investigation" Proc. of SAREC-ESTC. Conference on Research, Development and Consent Research Activities in Ethiopia, (1988).

6. **Wroth, C. P and Houlsby, G. T.** "Soil Mechanics-property Characterization and Analysis Procedures". Proceedings of the 11th International Conference on Soil Mechanics, and Foundation Engineering (1987).

7. B. S. 12, "Specifications for Ordinary and Rapid-hardening Portland Cement". British Standards Institutions (1978).

8. **Reynolds, C. E and Steedman, J.C** "Reinforced Concrete Designers Handbook 8th Edition: A Viewpoint Publication, Wexham Springs Brighton (1990).

9. **Head, K. H** "Manual of Soil Laboratory Testing" Vol. 1 Pentech Press, London (1980).

10. **Mudrock, L. J.** "The Workability of Concrete" A Magazine of Concrete Research, No. 36 pp. 135 - 144 (1960).

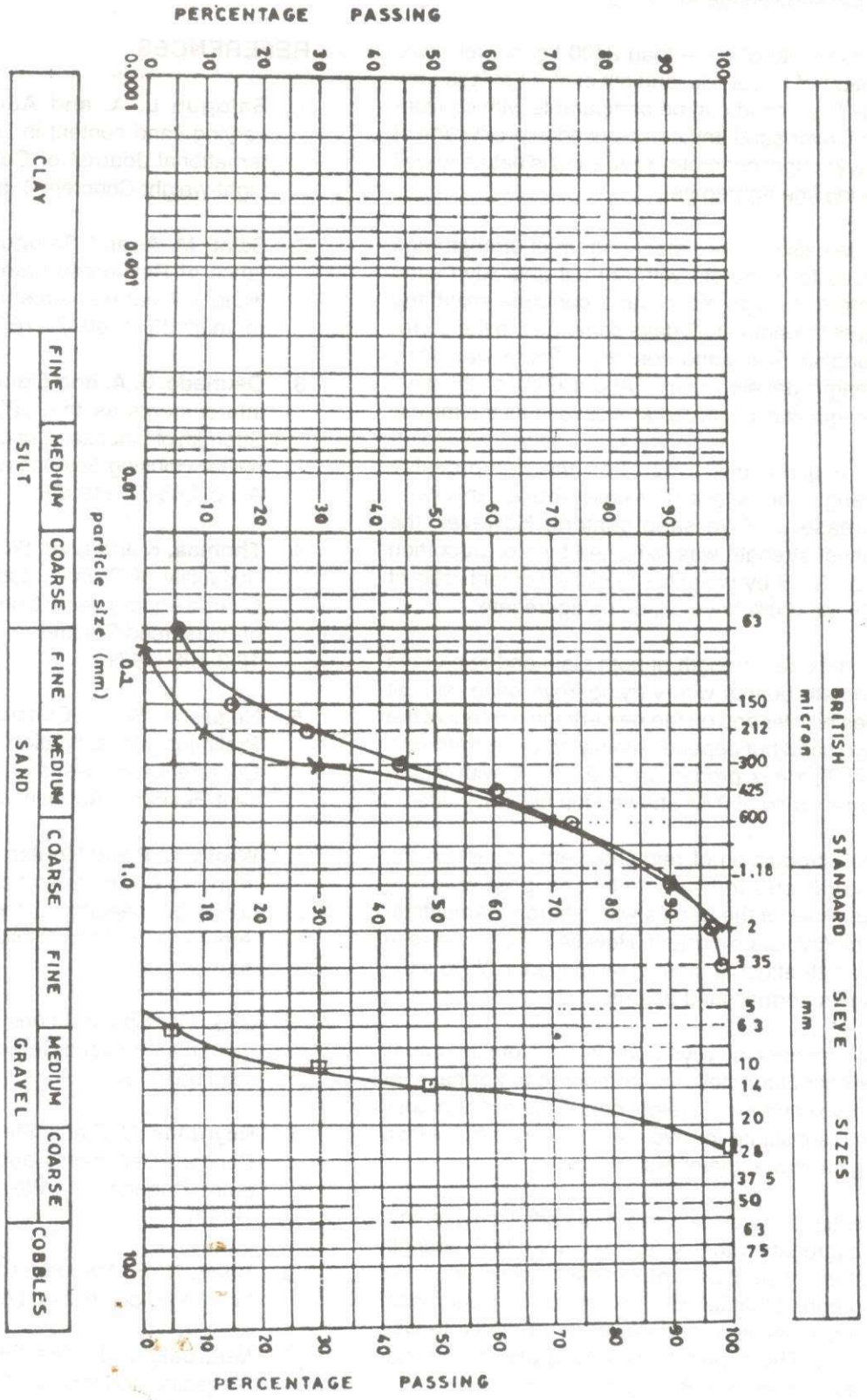


Figure 1 Particle size distribution

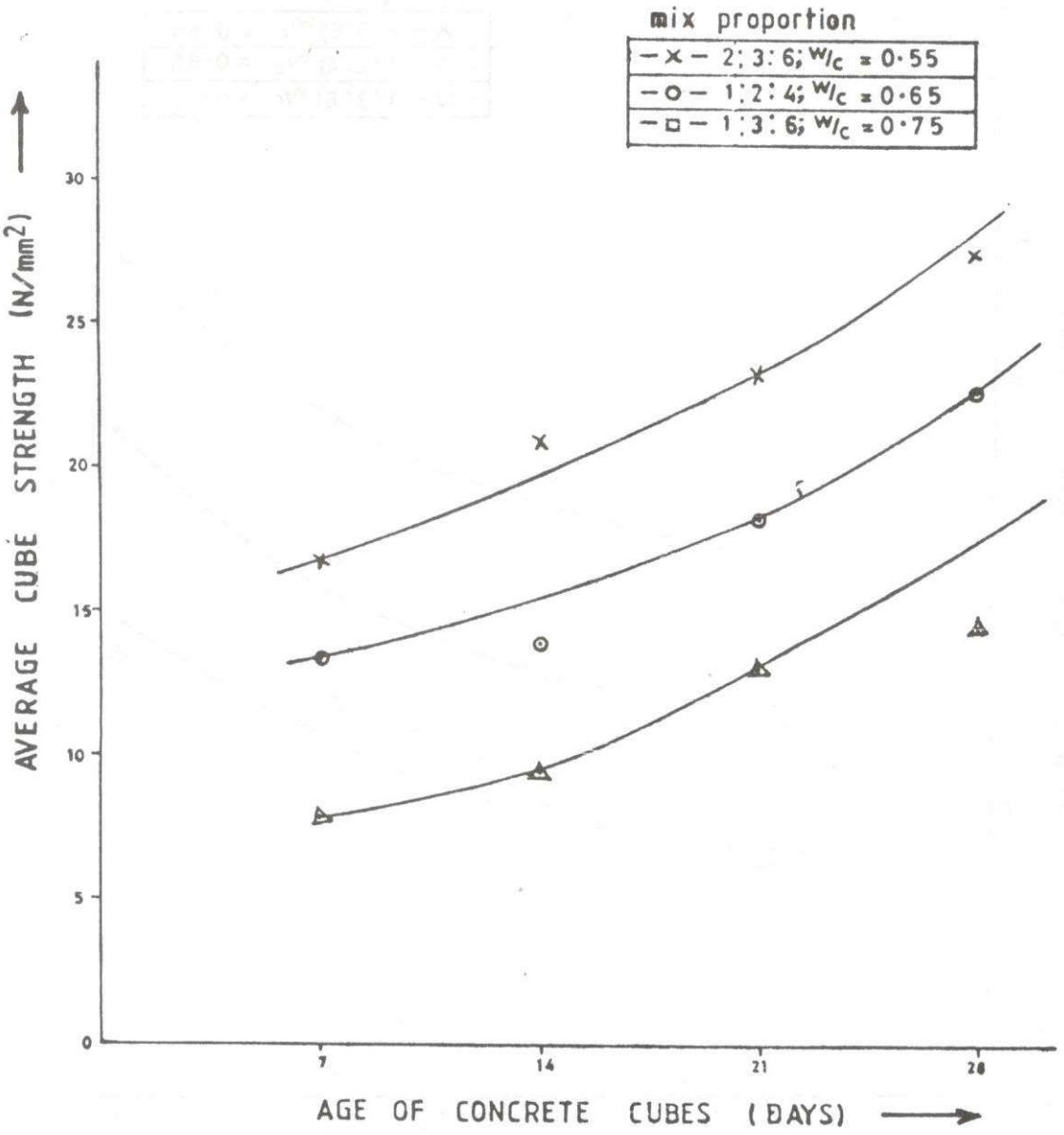


Figure 2 Compressive strength – age characteristics of diffrent mix proportions for normal sand concrete (0% yoyo sand fine aggregate)

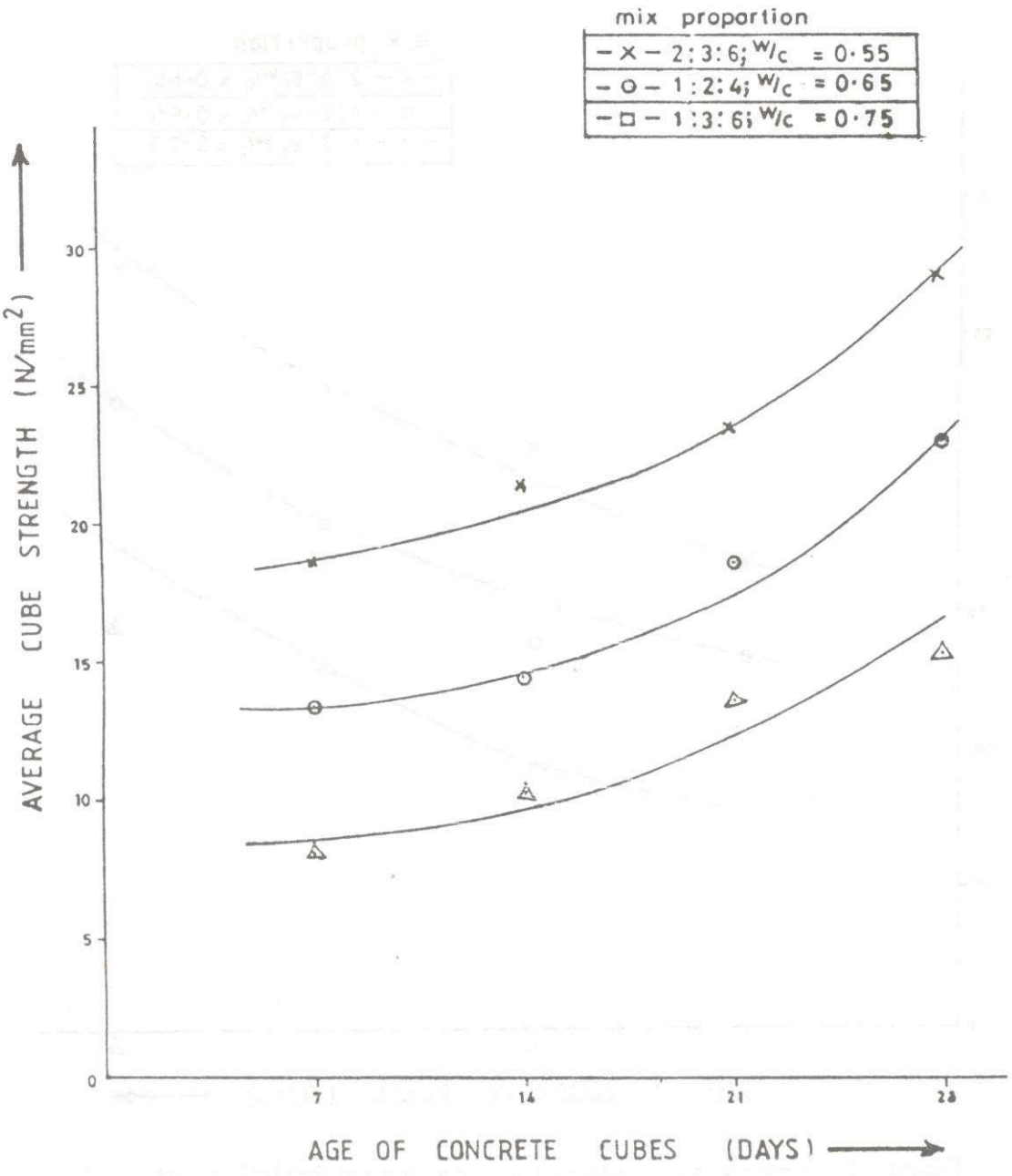


Figure 3: Compressive strength – age characteristics of diffrent mix proportions for yoyo sand concrete (100% yoyo sand fine aggregate)

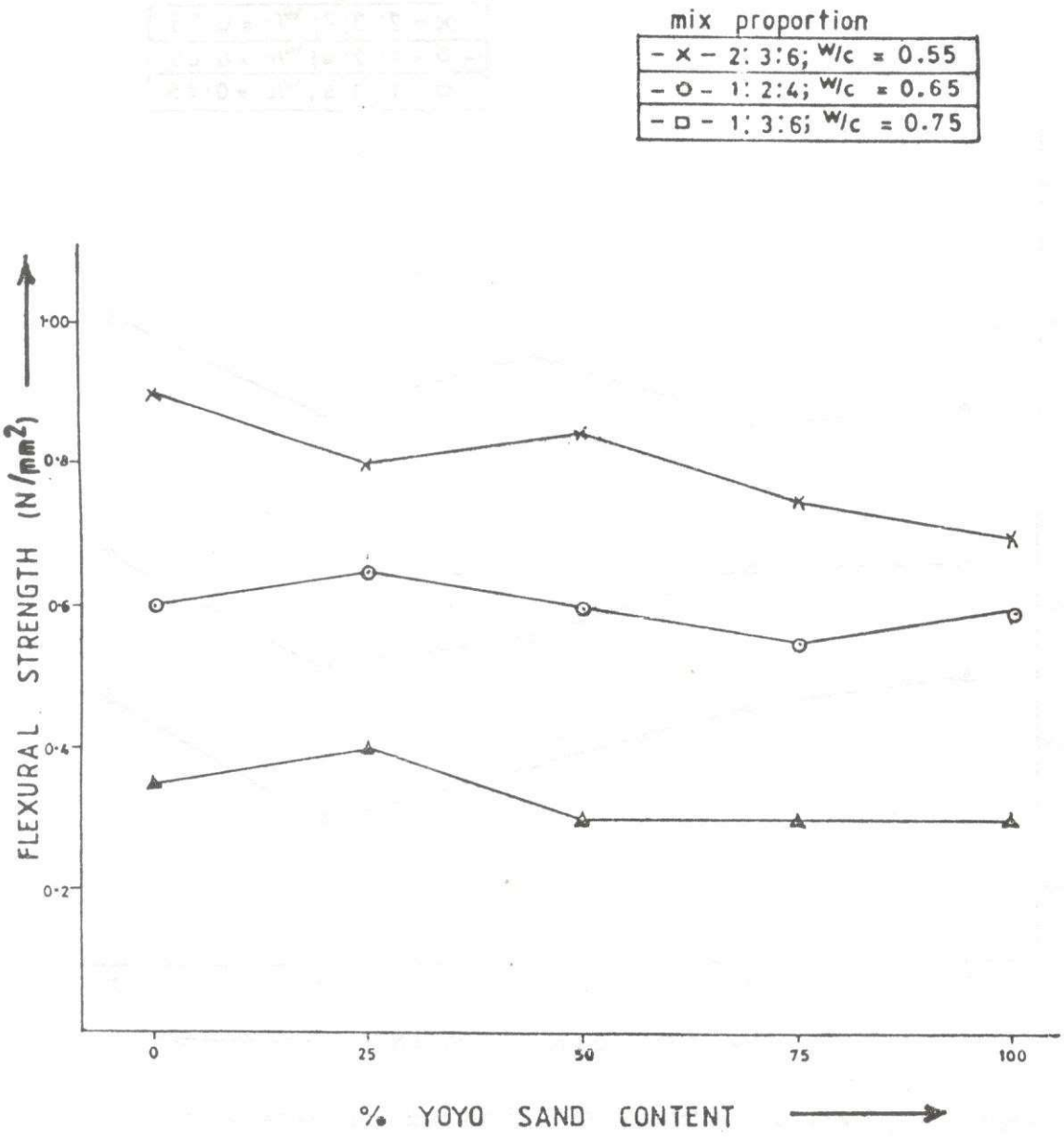


Figure 4: Flexural strength of plain concrete with varying % content of yoyo sand.

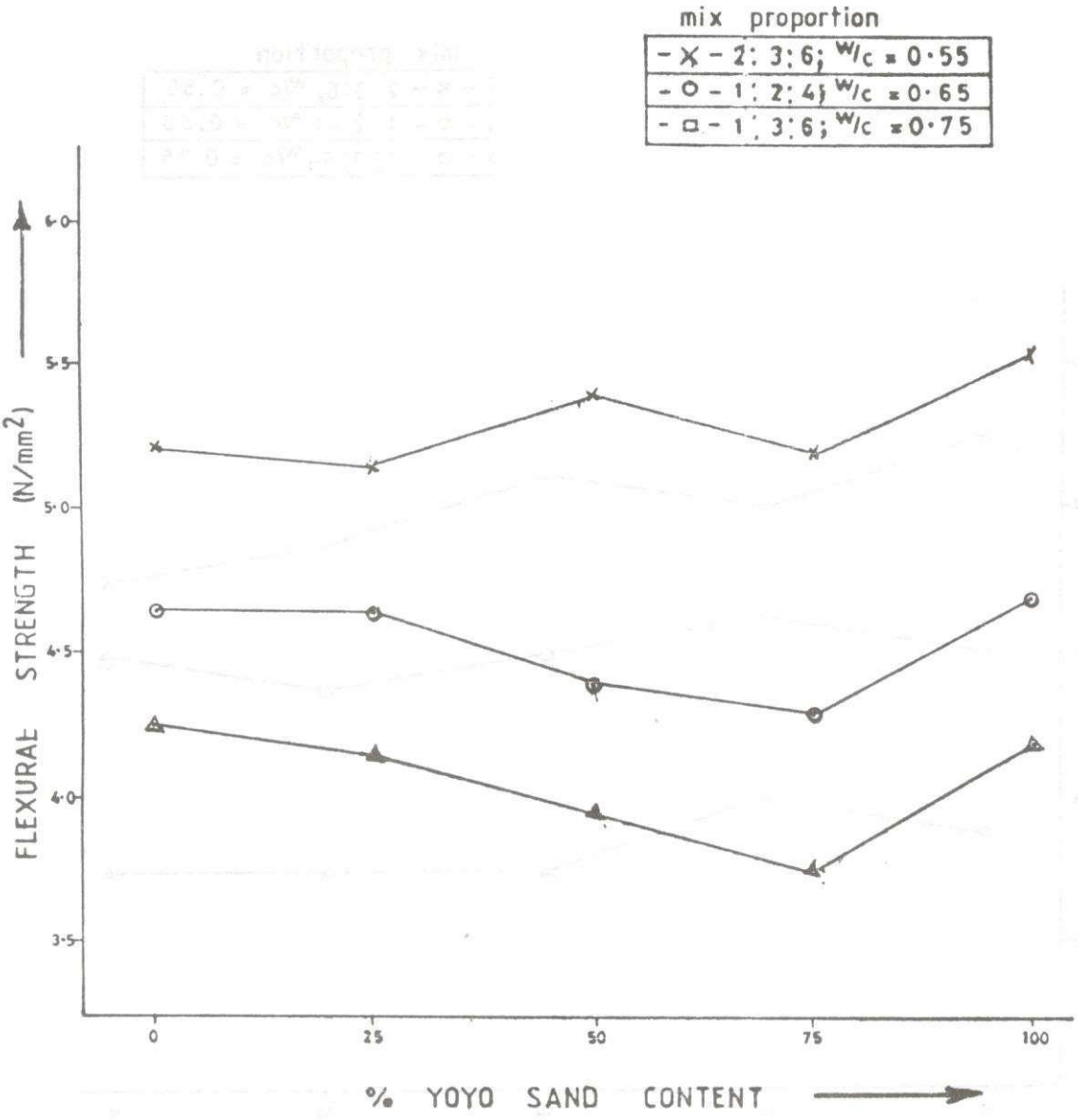


Figure 5: Flexural strength of reinforced concrete with varying % content of yoyo sand,