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RESEARCH ARTICLE

Empirical Elasticity Models of Concrete made with local aggregates.

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Abstract

Deformation affects durability, serviceability, long-term reliability and structural integrity of concrete. Elasticity of concrete is an important factor in structural design because when a concrete member is put into service, it will experience temporary and/or permanent deformation which might result to structural failure over the years. This project was carried out to investigate the empirical consideration of the elastic modulus of concrete and also the effect of aggregate size to the elasticity of the concrete using local aggregate as a construction material. Three different aggregate size were employed in the investigation which are; 20mm, 30mm and 60mm size of gravels. The grading of the fine and coarse aggregate were studied. The mix ratio and water/cement ratio adopted for the study was 1:2:4 and 0.65 respectively. Twenty concrete (20) cubes (150mm × 150mm × 150mm) were casted for each coarse aggregate size of which four were crushed at each maturity age namely; 7, 14, 21, 28 and 56days. Three (3) different Elastic models: BS8110, EC:02 and IS-456 were analysis experimentally and analytically for the three each of the concrete sample made with 20mm, 30mm and 60mm coarse aggregate. The BS8110 elasticity model for 20 cubes was tested for each aggregate size, which shows an elastic modulus of 23.86kn/mm^2, 23.78kn/mm^2 and 22.67kn/mm^2 respectively at 28 days of maturity age. The Euro-code has an elastic modulus of 26.79kn/mm^2, 25.02kn/mm^2 and 23.99kn/mm^2 at 28 days of maturity age of the concrete. And also the Indian code of practice(IS – 456) elasticity model showed an elastic modulus of 21.95kn/mm^2, 19.59kn/mm^2 and 18.26kn/mm^2 respectively at 28 days of maturity age. Consequently, it was concluded that the elastic modulus of concrete depends greatly on the compressive strength, surface nature and sizes of aggregates. It can be empirically concluded also that there is a variation in the elasticity of the concrete with the three predicted models.

Introduction:-

The price of washed gravel, stone chipping which are steadily on the increase has made it imperative to search for alternative materials that will satisfy. Of recent, cases of collapsed building have been reported in Anambra state especially in Onitsha, Awka and Nnewi Area, Ezeagu et al. (2014). Poor elasticity of locally made concrete has been part of the contributory factor for such collapse. Hence there is need to evaluate the elasticity of locally made concrete in Awka metropolises and also to find out how empirical they are.

Aim and Objectives of the Study:-

To determine a comprehensive testing and evaluation of locally available concrete mix to determine these mechanical and physical properties of awka normal-weight as well as light weight concrete, especially for the concretes used in pre-stressed concrete structure, so that correct values for these properties can be used in structural design.

At present, the properties of concrete that are used in Awka such as its elasticity is based on the limited research of the locally available material.

This research has the following major objectives:

- To evaluate the effects of aggregate on elastic modulus behavior of concrete.
- To determine the elastic modulus behavior of the typical concrete used in Nigeria.

Limitation of the Study:-

- Due to the time constraint, no replicate batch of the concrete mix in the testing program was tested.
- Structural concretes using other coarse aggregates will not be evaluated, due to cost
- The effect of the type and amount of mineral admixture (fly ash, slag and silica fume) and other admixture will not be evaluated.

Literature review:-

According to ASTM (1997), the modulus of elasticity, denoted as E, is defined as the ratio between normal stress to strain below the proportional limit of a material, and it is used to measure instantaneous elastic deformation. There is no test exist to evaluate the direct elastic modulus of concrete.

Factors Affecting Modulus of Elasticity:-

One of the important factors affecting the modulus of elasticity of concrete is the strength. This can be represented in so many ways such as the relationship between ratio of mix or water/cement ratio. The modulus of elasticity also depend upon the state of wetness of concrete when other conditions being the same. Wet concrete will show higher modulus of elasticity than the dry concrete. This is in contrast to the strength property that dry concrete has higher strength than wet concrete. The possible reason is that wet concrete being saturated with water, experiences less strain for a given stress and therefore, gives a higher modulus of elasticity, whereas dry concrete shows higher strain for given stress on account of less gel water and inter-crystal absorbed water.

Effect of Concrete Aggregate on Elastic Modulus of Concrete:-

- **Effect of Coarse Aggregate Type on Elastic Modulus:-**

Coarse aggregate type is another very important factor affecting the elastic modulus of hardened concrete. Different types of aggregate can have quite distinct effects on elastic modulus. Even different coarse aggregates of the same type but from different properties, the reported findings by Zhou et al[1995] shows that the coarse aggregate type has a considerable influence on the elastic modulus of concrete.

- **Effects of Mix Design on Elastic Modulus of Concrete:-**

Normally, the compressive strength of concrete is the only mechanical property to be considered in the mix design of a concrete. According to BS-Code prediction equation, a high compressive strength will give a high predicted elastic modulus than a concrete with a lower compressive strength, not only the design strength but also the mix ingredients will have a great influence on the elastic modulus of the concrete.

Relationship between Modulus of Concrete and Compressive strength:-

Stress-strength ratio stronger concrete has higher strain. This also can be explained that, the stronger the concrete the stronger the gel and hence higher is the modulus of elasticity. Modulus of elasticity of concrete increases approximately with the square root of the strength

Models for Predicting Elastic Modulus of Concrete:-

There is no universal specification that is possibly applied to relatively compressive strength to elastic modulus of concrete.

It is safe to assume that if concrete is very strong, its elastic modulus would be very high because it would resist deformations at high stress applications. The models used in this research to predict the elastic modulus of concrete are the following.

• **The Euro-Code (EC-02) (Beeby and Narayanan, 1995a)** Recommends for 28 days:

$E_{cm} = 22[f_{cm}/10]^{0.3}$……………………………[2.1]

The variation of modulus of elasticity with time is estimated using the expression:

$E_{cm}(t) = [f_{cm}(t) / f_{cm}]^{0.3}$ Ecm………………………….. [2.2]

Where $E_{cm}(t)$ and $f_{cm}(t)$ are the values at an age of t days and E_{cm} and f_{cm} are the values at 28 days.

• **Model Recommended by BS8110 for Normal-Weight.** Recommends for 28 days:

$E_c = 20 + f_{cu} / 5$……………………………………………[2.3]

But the value at any age t can be accessed from the expression

$E = E_c(2 + 3\, f_{cut} / f_{cu28}) / 5$……………………………….[2.4]

• **The Indian Code of Practice (IS: 456)** recommends that:

$E_c = 5000 \sqrt{f_{ck}}$ ……………………………………..[2.5]

Materials and methodology:-

The fine aggregate used for this research work was river bed collected from Amansea River, Awka North Local Government Area of Anambra state. Three different sizes of coarse aggregate 20mm, 30mm and 60mm was used. The coarse aggregate used were bought in Awka, which were actually sourced from ugwu-eme in ogwu local government Enugu State. The Dangote brand of ordinary Portland cement was used in the work. It is marketed in most cement shops within Awka. Water used for mixing and curing the concrete was clean, drinkable water and free of visible impurities. The particle size distribution of the coarse and fine aggregates was carried out after they were air dried.

The batching of the concrete was by weight and a mix ratio of 1:2:4 was adopted. Water/cement ratio of 0.65 was employed. Four cubes were cast for each aggregate size for for a particular age at curing, namely; 7 days, 14 days, 21 days, 28 days and 56 days. In other words , 20 concrete cubes (150mm × 150mm × 150mm) were casted for each aggregate size, total of 60 cubes. The fresh concrete was thoroughly tampered in the mould with steel rod and reference numbers were given to the moulds for easy identification of the concrete made with the same size of coarse aggregate. The moulds were removed after 24hours and were immersed in water throughout the curing period.

The slump test was determined in accordance with ASTM C143. The slump test is a measure of relative fluidity and was performed to determine the consistency of the fresh concrete. The test was run during the 3 minute-resting period of the mixing process

Four cubes were removed from each set of cubes at each maturity age. The cubes were weighed and crushed using the crushing machine. The ratio of the crushing loads to the surface area of the cubes gave the compressive strengths of the cubes which were average for each aggregate size at each curing age.

The average compressive strength for each of the aggregate sizes was used in evaluating the modulus of elasticity, which was obtained from the empirical expressions given by the various design codes; The Euro-Code, British code (BS8110) and Indian Code of Practice (IS: 456).

Results and discussion:-

Particle Size Distribution:-

Figure 1 is the sieve analysis carried out on both the fine aggregate and the coarse aggregate. The figure shows that the fine aggregate used for the experiment was well graded with a maximum size of 4.75mm. It can also been seen that the coarse aggregate sizes were uniformly grading (that is they posses particles of almost the same diameter).

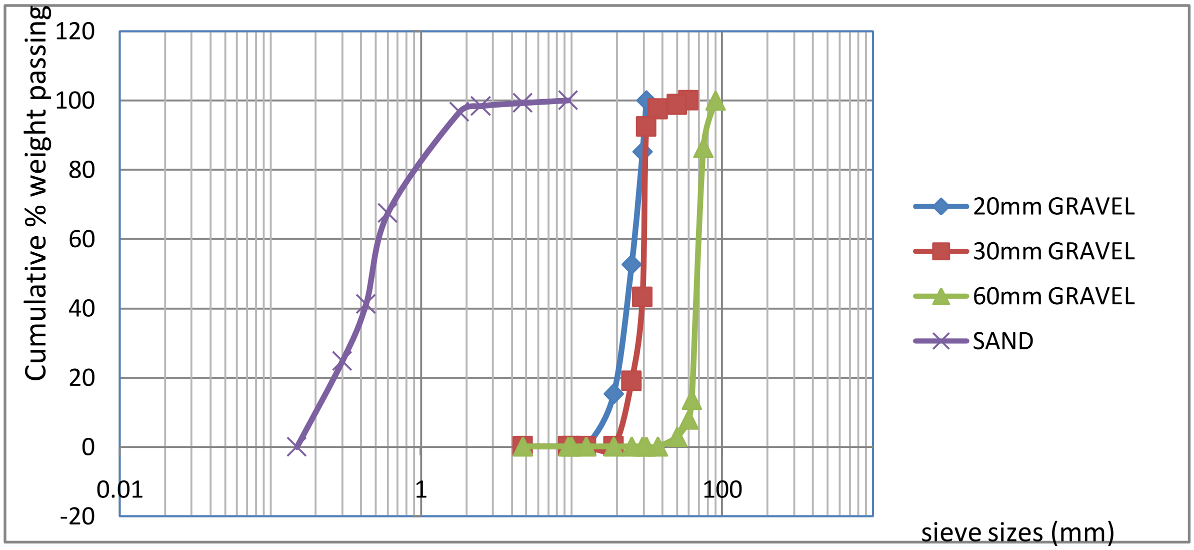

Figure 1:- particle size distribution of fine and coarse aggregates

Table 1:- Slump Test Result

Slump Test

20mm	16	10 – 30	0.85 – 0.90
30mm	13	10 – 30	0.85 – 0.90
60mm	0	0 - 10	0.65 -0.85
Aggregate size	Slump value (mm)	Slump range (mm)	Compacting factor

.From the table above it shows the results of slump cone test, with the water/cement ratio of 0.65. The results of the fresh concrete properties obtained from the slump test carried out on the fresh concretes are in the range of 10–30mm, for fresh concrete with 20mm and 30mm aggregate size, while for 60mm aggregate its slump range is 0-10mm.

Elastic Modulus:-

Table 2, 3, 4 shows the results of the elastic modulus according to the model recommended by BS code, EC-02 and indian code of practice respectively at 7,14,21,28 and 56 days as well as the various comparison considered in the course of the study.it is observed that in all models that the elastic modulus of the concrete tends to increase as the curring age increases and also the smaller the coarse aggregate size the higher elastic modulus of the concrete.

Table 2:- elastic modulus base on BS-Code

Size of coarse aggregate	Age (days)	Average compressive strength (N/mm^2)	Elastic Modulus of concrete (KN/mm^2)
20mm	7 days	2.92	19.14
	14 days	17.35	22.43
	21 days	18.32	23.15
	28 days	19.28	23.86
	56 days	20.58	24.83
30mm	7 days	10.20	18.45
	14 days	12.31	20.33
	21 days	14.09	21.93
	28 days	15.35	23.07
	56 days	17.25	24.78
60mm	7 days	8.86	18.10
	14 days	10.24	19.51
	21 days	11.25	20.54
	28 days	13.34	22.67
	56 days	15.32	24.69

Table 3:- Elastic Modulus base on Euro code – 02

Table 2, 3 and 4 Based on model recommended by BS 8110, Euro code 2 and IS 456 respectively, shows an increase in the elastic modulus of the three samples with respect to increase in the curing age. It can be seen that from 7 days to 21 days, the concrete of 20mm aggregate size is higher in elastic modulus followed by the 30mm and 60mm.

Size of course aggregate	Age (days)	Average compressive strength (N/mm^2)	Elastic Modulus of concrete (KN/mm^2)
20mm	7 days	12.92	17.97
	14 days	17.35	20.83
	21 days	18.32	21.40
	28 days	19.28	21.95
	56 days	20.58	22.68
30mm	7 days	10.20	15.97
	14 days	12.31	17.54
	21 days	14.09	18.77
	28 days	15.35	19.59
	56 days	17.25	20.77
60mm	7 days	8.86	14.88
	14 days	10.24	16.00
	21 days	11.25	16.77
	28 days	13.34	18.26
	56 days	15.32	19.57

Table 4:- Elastic Modulus based on IS-456

Size of course aggregate	Age (days)	Average compressive strength (N/mm^2)	Elastic Modulus of concrete (KN/mm^2)
20mm	7 days	12.92	23.76
	14 days	17.35	25.96
	21 days	18.32	26.38
	28 days	19.28	26.79
	56 days	20.58	27.32
30mm	7 days	10.20	22.13
	14 days	12.31	23.42
	21 days	14.09	24.39
	28 days	15.35	25.02
	56 days	17.25	25.91
60mm	7 days	8.86	21.22
	14 days	10.24	22.16
	21 days	11.25	22.79
	28 days	13.34	23.99
	56 days	15.32	25.01

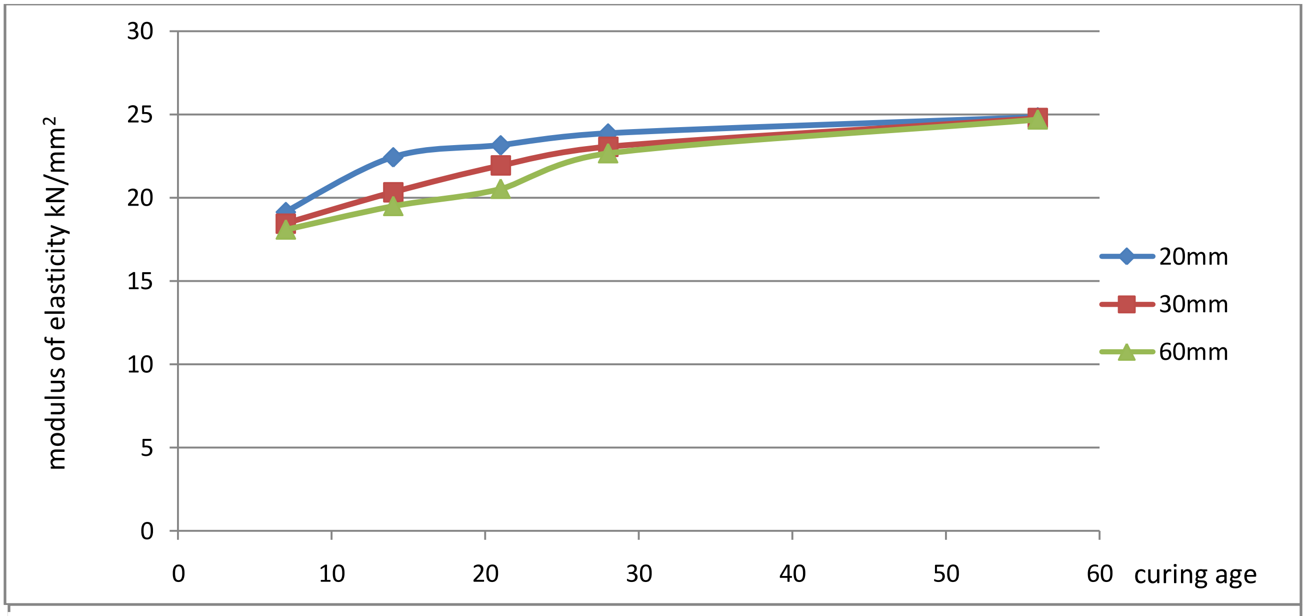

Fig 2:- Graph of elastic modulus with aggregate sizes against age at curing based on BS-Code

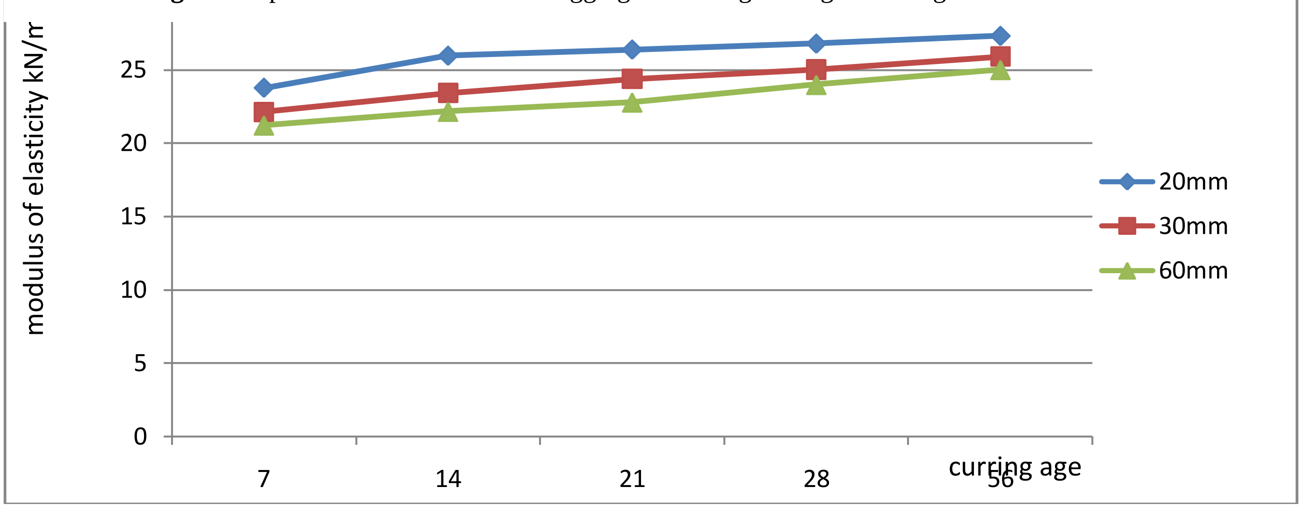

Fig 3. Graph of elastic modulus with aggregate sizes against age at curing based on Euro-Code

Age (days)	Elastic Modulus (kn/mm^2) based on EU-code	Elastic Modulus (kn/mm^2) based on BS-code	Elastic Modulus (kn/mm^2) based on IS-456
7	22.13	18.45	15.97
14	23.42	20.33	17.54
21	24.39	21.93	18.77
28	25.02	23.07	19.59
56	25.91	24.78	20.77

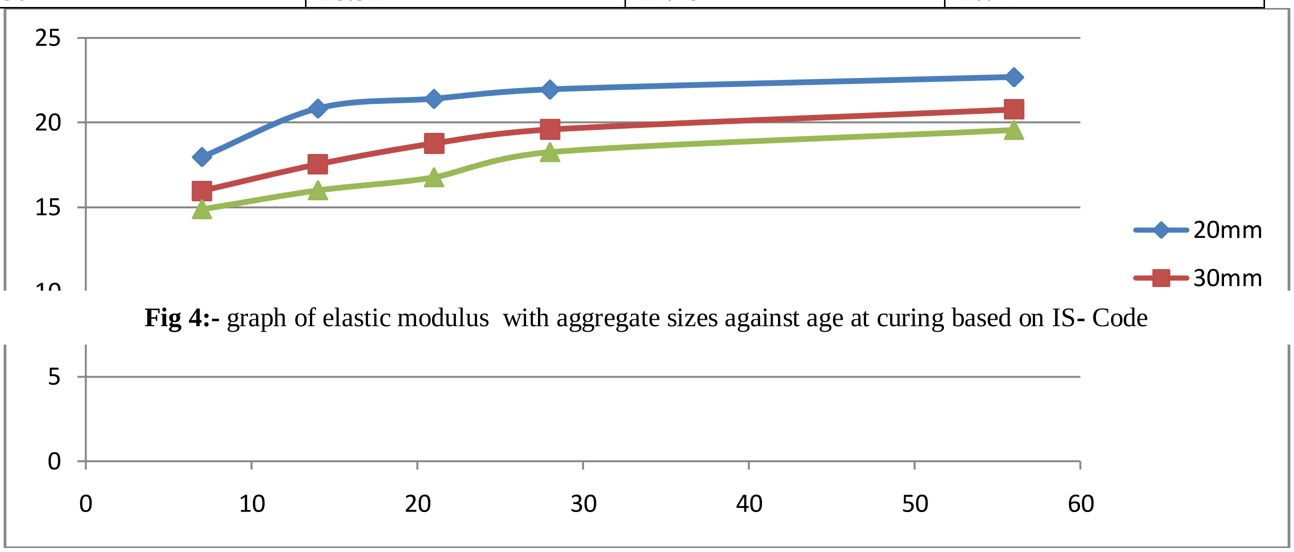

Fig 4:- graph of elastic modulus with aggregate sizes against age at curing based on IS- Code

Figure 2 based on model recommended by BS 8110, shows an increase in the elastic modulus of the three samples with respect to increase in the curing age. It can be seen in both the graph and the chart that from 7 days to 21 days, concrete with 20mm aggregate size is higher in elastic modulus followed by 30mm and 60mm, but at 56 days the diference in elastic modulus of the concrete samples reduces.Figure 3 and4 based on model recommended by EC:02 and indian code of practice respectively, shows that the elastic modulus concrete with 20mm aggregate size is higher in elastic modulus followed by 30mm and 60mm. It also shows that the elastic modulus increases with respect to increase in the curring age.

Comparison of Codal Provision for Modulus of Elasticity:-

Table 5:- Result show elastic modulus of concrete using 20mm aggregate size

Table 6:- Result show elastic modulus of concrete using 30mm aggregate size

Age (days)	Elastic Modulus (kn/mm^2) based on EU-code	Elastic Modulus (kn/mm^2) based on BS-code	Elastic Modulus (kn/mm^2) based on IS-456
7	23.76	19.14	17.97
14	25.96	22.43	20.83
21	26.38	23.15	21.4
28	26.79	23.86	21.95
56	27.32	24.83	22.68

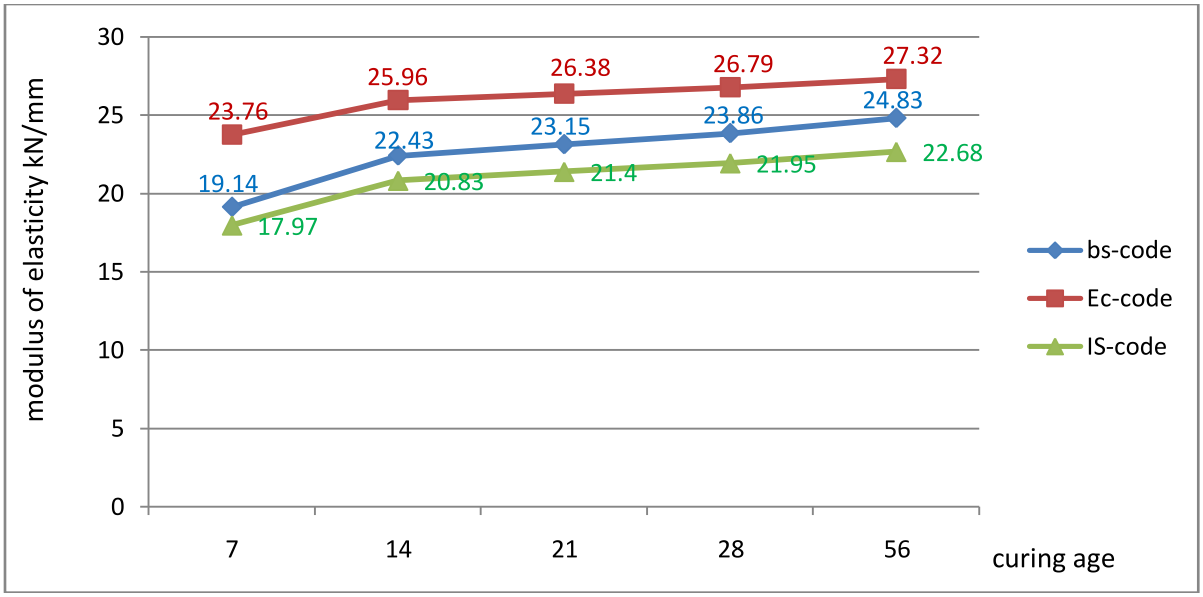

Fig 5:- Modulus of elasticity variation of models with aggregate size of 20mm against curing age

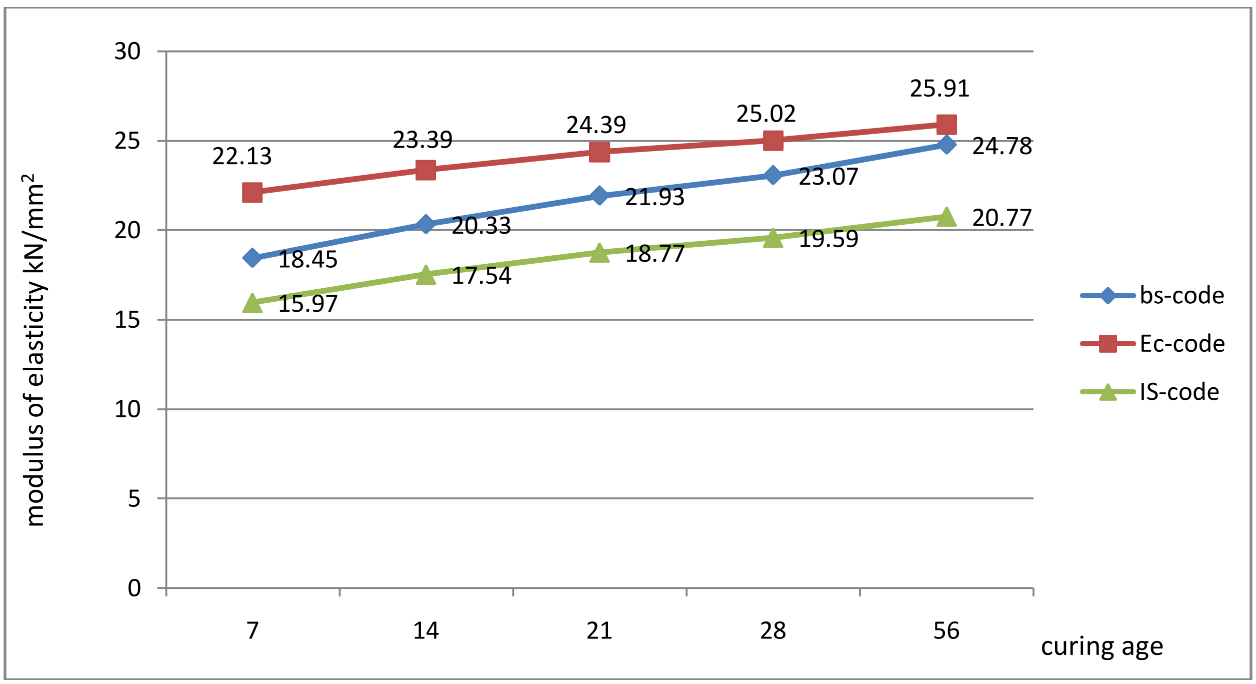

Fig 6:- Modulus of elasticity variation of models with aggregate size of 30mm against curing age

Table 7:- Result show elastic modulus of concrete using 60mm aggregate size

Age (days)	Elastic Modulus (kn/mm^2) based on EU-code	Elastic Modulus (kn/mm^2) based on BS-code	Elastic Modulus (kn/mm^2) based on IS-456
7	21.22	18.10	14.88
14	22.16	19.51	16.00
21	22.79	20.54	16.77
28	23.99	22.67	18.26
56	25.01	24.69	19.57

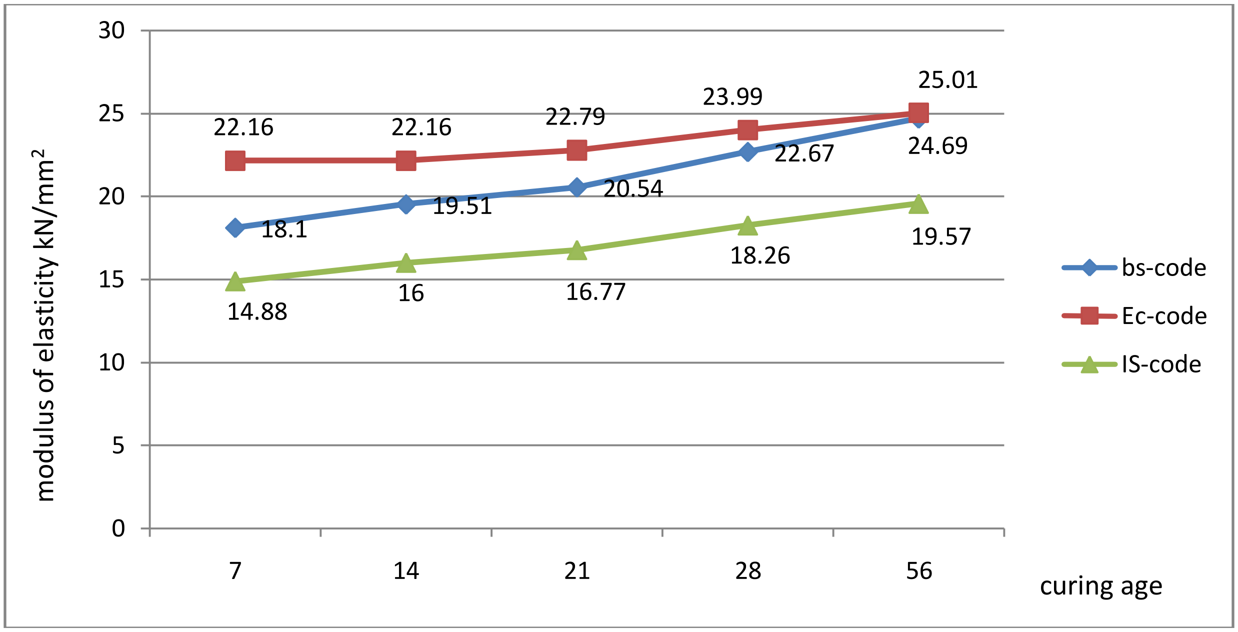

Fig 5:- Modulus of elasticity Variation of the models with aggregate size of 60mm against curing age

A comparison of modulus of elasticity obtained from the empirical expressions given by the various design codes for both 20mm, 30mm, 60mm coarse aggregate sizes are presented in fig 5, fig 6 and fig 7. From the figures it is seen that EC- 02 predict higher modulus of elasticity than BS:8110 followed by the IS:456. These observations can be seen in all three samples

Conclusion and recommendation:-

Based on the result of this investigation which have been discussed above, the following conclusions can be drawn:

- Aggregate size of 20mm produces concretes with higher elastic modulus as compared to aggregate size of 30mm and 60mm
- Models for the evaluation of elastic modulus of the concrete, all gave a different values of the elastic moduli of concrete in all concrete with different sizes. EC- 02 predict higher modulus of elasticity than BS:8110 followed by the IS:456.
- For economical reasons, 20mm aggregate size is the most desirable because it produced a characteristic strength of 19.28N/mm^2 which is about 96.4% of the designed characteric strength of 20N/mm^2.

It is, therefore recommended that:

- 20mm aggregate size should be used for the production of concrete. Although 30mm can also be used.
- Further investigation should be conducted on many more kinds of coarse aggregate available in Anambra to verify their suitability for the production of effective concrete.
- Only one w/c ratio was used during this investigation. Therefore further research should be conducted on the used local aggregate and other locally available materials using a wide range of w/c ratio

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