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The Design Parameters Analysis and Testing of a Compression Testing Machine

Ekong, Godwin I[1]., Adawo, Akaninyene M[2]., John, Samuel E[3]. and Edet, Uwak-Mfon O[4].
[1,2,3,4] Department of Mechanical Engineering Akwa Ibom State University (AKSU)
Email: goddy3e@yahoo.com

Abstract:

This design parameters analysis of a compression testing machine is performed to establish the effectiveness of the machine. The designed parameters of the fabricated in-house compression testing machine are analysed and tested to ascertain the capability of the machine to withstand the work requirements under the operational conditions and service areas since it is operated manually, hence, can be used effectively by operators of the industries in local and rural areas where there is no electricity and in urban areas where the tariff for electricity consumption is very high. The key principal units of the machine include the top middle and bottom plate, hydraulic jack, dial gauge, support bracket, fluid pipe, and wheels. A review of similar works by others was performed with the Nigerian industrial standards of NIS 87:2000 and NIS 74:1976 for blocks and clay bricks respectively as the benchmark. The compression principles were applied in this study for the determination of force required by the hydraulic Jack, pressure, and the force acting on the frame supports. The performance of the in-house compression machine was validated against the performance of a standard machine and the results were in good agreement; evidenced in matching trends and profiles of the testing samples of both analyses.

KEYWORDS: Compression, Hydraulic, Strength, Machine, Blocks.

1. INTRODUCTION

A compression testing machine is a machine used to measure the compressive strength of materials. In this study, the design parameters analysis and testing of a compression testing machine is performed to ascertain the effectiveness of using locally sourced but very efficient materials, since the imported compression machines are expensive. The test will determine the behavior of materials under a compressive load and in service. The accessibility of compression testing apparatus by operators will enhance the effective control of quality and practice in our building and construction service areas and promote healthy quality control and competition in the industries. It is desirable for operators to have testing facilities in their domain to enhance continuous assessment of product quality in markets in compliance with relevant standards to meet the needs of customers and users and for the safety of personnel at building and construction service locations. Since materials perform differently under different conditions, it is essential to perform mechanical tests to ascertain the condition of materials before use. Compression testing is normally carried out on materials such as plastics, rock, concrete, blocks, bricks, Asphalt, and steel. The compressive strength is measured by making the test specimen undergo compression loading between two platens and applying a force to the test specimen with the help of a hydraulic jack as in this study. The aim of this study is to analysed the designed parameters of the fabricated in-house compression testing machine for material testing to ascertain the capability of the machine to withstand the work requirements under the operational conditions and service areas since it is operated manually, hence, can be used effectively by operators of the industries in local and rural areas where there is no electricity and in urban areas where the tariff for electricity consumption is very high.

2. LITERATURE REVIEW

This section presents a review of the previous work relating to the compression testing machine which has been extensively discussed by several scholars. The application of compression testing machines in research, laboratories, and industries for strength measurement and control analysis and real-life measurement of the strength of materials such as concrete, blocks, bricks polymers, and steel and to help reduce cost and waste in industries and construction sites has been performed by different authors. This has given rise to effective strength testing machines in block moulding industries. The review presents some of the previous work on compression testing to determine how a product or material reacts when it is compressed, squashed, crushed, or flattened by measuring fundamental parameters that determine the specimen behaviour under a compressive load such as in Melchior [1] which developed a configuration for effective testing of polymers up to large strains as well as yield stress and small strain measurement of metals, the results confirmed in the literature. The modifications made to the IST are successful and the new load-frame and load-cell results in a significant improvement in the quality of the measured signals. The wedge bar displacement sensor performed as expected, repeatedly performing within the design resolution of 2 mm. In addition, the strain rate histories obtained are reasonably constant with yield stress captured at above 80% of the average strain rate for the majority of the materials tested. Hassan and Bukar [2] design and fabricate a cost-effective and efficient compression strength tester to carter for the needs of stakeholders in the blocks and bricks industries the results from the manufactured machine were evaluated against a standard foreign machine in the Standards Organisation of Nigeria using statistical methods and the result showed that the locally fabricated machine is 97% effective. A stress analysis with a Universal testing machine was carried out Mathew and Francis [3] and the results indicate that from the stress-strain graph obtained it was concluded that 3D printed test samples are not highly reliable to access the accurate values through tensile testing, hence, for proper comparison values material with isotropic nature are preferable, while Brunbauer [4] develop, validate and calibrated a compression creep test machine and the results indicate that a variable number of specimens can be applied with stress in parallel. Thus various reproductive creep measurements can be performed simultaneously at the same test conditions. The developed testing machine is able to characterise the compressive creep behavior of polymers at load levels up to 2000 N and temperatures ranging from room temperature to 200◦C. According to Walls [5], a compression testing of an advanced, three-dimensional weave, carbon-carbon composite was performed from room temperature to 2192°F (1200°C) in an oxidizing environment and the results demonstrate that the structural integrity of the material was maintained from room temperature to 1472°F (800°C), while moderate oxidation was observed from room temperature to 1472°F (800°C) and severe oxidation occurred above 1472°F (800°C). In the work by Chauhan and Patel [6] the frame design analysis was carried out and the result show a reduced thickness of the frame within the limit and the frame should be light in weight for reducing the cost of manufacturing. According to Roselli [7] a spring-loaded detainment device was designed which allows the battery to be confined in the axis perpendicular to compression without completely rigid walls. This provides a testing environment far more similar to the conditions of a real-world crash situation. Curatalo [8] evaluates compression damage to corrugated shipping containers used in the small parcel delivery system. The results of the tests show that compression strength increases less as corrugation becomes more perpendicular to the applied force. By altering the corrugation direction, the end-to-end compression strength can be increased at a higher percentage rate than the top-to-bottom compression strength is reduced and Xiaobin [9] conducted an extensive experimental research program on the true uniaxial and triaxial compression behavior for both high-strength concrete (HSC) and steel fiber reinforced high strength concrete (SFHSC). According to this research, under triaxial compression, there is no apparent advantage of steel fiber-reinforced high-strength concrete (SFHSC) over high-strength concrete (HSC) in terms of triaxial strength, ductility, and stress~ strain behavior

3. MATERIALS AND METHODS

This section presents the materials and methods use in the analysis of the in-house compression testing machine and the samples blocks used is in accordance with (NIS 87:2000) standard recommendation in Nigeria according to NIS [10]. The design of the machine, from the upper plates, the frames, the upper and lower platens, the hydraulic jacking system, up to the lower plate, and the threaded axel were critically analysed to ascertain functionality of the in-house fabricated compression testing machine. The compression principles were applied in this study for the determination of force required by the hydraulic Jack, pressure and force acting on the support of the machine, and testing was carried out.

From literature, concepts are used in this study where symbols retain their usual nomenclature and meaning according to Gere and Timoshenko [11], Faupel and Fisher [12], Eugene and Theodore [13], and Khurmi and Gupta [14].

The force required is given in Equation 1 as,

$$P = \frac{\text{Force}}{\text{Area}} \quad (1)$$

where, P = the maximum operating compressing pressure

A = surface area of block/brick sample to be compressed

To determine the size of the frame supports, the force acting on each support (Fs) is,

$$Fs = \frac{F}{4} \quad (2)$$

3.3 The Material Selection

The design of a functional, durable, and aesthetic machine is based on accurate material selection. Material selection is the major factor in the design of any machine, as such in this study, materials for the construction of this machine were based on high carbon steels due to its mechanical properties such as hardness and wear resistance among others, to withstand the stress under the working condition. And consideration for the reliability of the material, portability, and reducing cost of production was given utmost priority. In order to ensure that this product meets up to the standard requirement of the product in Nigeria, each component of the machine was thoroughly analysed and compared with the standard set by the Standard Organisation of Nigeria (SON). The computer-aided design (CAD) of the compression testing machine used in this study is shown in Figure 1. The creativity techniques such as the theory of inventive problem solving (TRIZ), which incorporate lateral thinking during the brainstorming session, and forty inventive principles for problem-solving offered by Ekong *et al* [15] the application of Creativity Tools to Gas Turbine Engine Compressor Clearance Control, Ekong [16] the application of Creative techniques in Effective Management of a Power Generation Plant, Ekong [17] the application of Ideal Final Result in the design of a Pneumatic Foot Pump for rural areas, Ekong [18] the application of 40 inventive principles in tip clearance control concepts in Gas Turbine H.P compressor, Ekong [19] the Improvement of Government Parastatals using Creativity tools, Ekong [20] the application of Ideal Final Results in the Establishment and Management of a Cold storage facility for rural areas and Ekong *et al* [22] the development of concepts for the control of tip clearance in Gas turbine HP compressors using TRIZ and Ekong *et al* [23] in Tip Clearance Control Concept in Gas Turbine H.P. Compressors were used in the conceptual stage of study for the selection of materials for the fabrication of the in-house compression machine shown in Figure 2.

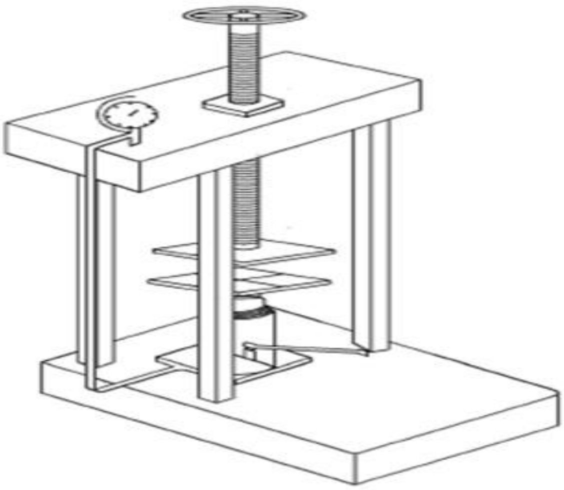

Figure 1: A CAD version of the Compression Testing Machine

Figure 2: In-house Fabricated Compression Testing Machine

4. THE ANALYSIS OF THE COMPRESSION TESTING MACHINE

The compression testing machine parameter includes the maximum force by the hydraulic jack is 20 tons, on an area of the compression plate of 25cm x 25cm.

4.1.1 Determination of Force required to be supplied by Hydraulic Jack

The hydraulic jack is expected to provide the force required for the compression of the specimen from Equation 1 given as,

$P = \frac{\text{Force}}{\text{Area}}$

Where, $F = P \times A$

Given a maximum force = 20 tons

1 ton = 9964.02N

$\therefore F = 20\, x\, 9964.02 = 199280.33N$

Given the area of the compression plate attached to the jack 25cm x 25cm in this study,

Area = $0.25 \times 0.25 = 0.0625\text{m}^2$

$$P = \frac{Force}{Area}$$

$$P = \frac{199280.33}{0.0625} = 3188485.28\, N/m^2$$

4.1.2 Determination of force acting on the frame supports

Let the force acting on each support be (Fs) and using Equations 2,

$$Fs = \frac{F}{4}$$

The total force acting on the support from equation 2 is given as,

$$\text{Fs} = \frac{199280.33}{4} = 49820.08N$$

4. 2 TESTING PROCEDURE

The samples blocks tested are 1:8, that is 1 bag of Poland cement to 8 head pan of the sand mixture in accordance with (NIS 87:2000) standard recommendation in Nigeria, was carefully placed between the centres of the compression plates of the fabricated compression testing machine, and the test was carried out. A 9” sizes block with 450mm x 225mm x 225mm (9”) dimension and a 6” 450mm x 225mm x 150mm after 15-28 days of manufacture. Four samples were selected for test and the loads were then applied uniformly till failure occurred by means of a hydraulic jack for the fabricated machine while for the standard machine, the loading was electronically controlled. All the samples were tested dry on the fabricated compression testing machine, the maximum or failure loads of the blocks from each specimen were recorded and the compressive strength of both size samples was determined with the two types of the machine and the result was tabulated as shown in Tables 1 and 2 for the fabricated machine, and Tables 3 and 4 for the standard machine respectively.

Table 1: Show the Testing Results of 9" blocks obtained from the fabricated compression testing machine.

Number of sample	samples	Block net compression area (Mm²)	Crushing load		Compressive strength (N/mm²)
			PSI	Newton	
1.	9" (1)	55925	10.46	21990	0.39
2.	9" (2)	55925	10.73	22550	0.40
3.	9" (3)	55925	10.99	23110	0.41
4.	9" (4)	55925	13.39	28140	0.50
Average					0.425

Table 2: Show the Testing Results of 6" blocks obtained from the fabricated compression testing machine.

Number of sample	samples	Block net compression area (Mm²)	Crushing load		Compressive strength (N/mm²)
			PSI	Newton	
1.	6" (1)	34250	7.64	16060	0.46
2.	6" (2)	34250	7.92	16750	0.48
3.	6" (3)	34250	8.29	17430	0.50
4.	6" (4)	34250	8.94	18800	0.54
Average					0.495

4.3 Validation of Results

4.3.1 Validation of the performance analysis of the Tested Sample

The testing results from Standard compression testing are presented in Tables 3 and 4.

Table 3: Show the Testing Results of 9" blocks obtained from the Standard compression testing machine [21].

Number of sample	Samples	Block net compression area (Mm²)	Crushing load (KN)	Compressive strength (N/mm²)
1.	9" (1)	55925	23.27	0.41
2.	9" (2)	55925	23.83	0.42

3.	9” (3)	55925	24.39	0.43
4.	9” (4)	55925	29.42	0.52
Average				0.445

Table 4: Show the Testing Results of 6” blocks obtained from the Standard compression testing machine [21].

Number of sample	**Samples**	**Block net compression area (Mm²)**	**Crushing load (KN)**	**Compressive strength (N/mm²)**
1.	6” (1)	34250	17.34	0.50
2.	6” (2)	34250	18.03	0.52
3.	6” (3)	34250	18.71	0.54
4.	6” (4)	34250	20.08	0.58
Average				0.535

Let EAJE data represent the results of this in-house fabricated compression machine while STANDARD represents the results of the Standard compression testing machine The results of this study are validated against the result of a Standard compression testing machine and they were in good agreement since the matching trends and profiles were similar as shown in Tables 5 and 6. The validation is presented graphically as shown in Figures 3 and 4 for 9” and 6” blocks respectively.

Table 5: Show the Testing Results of 9” blocks obtained from the Standard compression testing machine.

SN	**Number of sample of EAJE**	**Compressive strength (N/mm²)**	**Number of sample of STANDARD**	**Compressive strength (N/mm²)**
1	1	0.39	1	0.41
2	2	0.40	2	0.42
3	3	0.41	3	0.43
4	4	0.50	4	0.52

Table 6: Show the Testing Results of a 6" blocks obtained from the Standard compression testing machine.

SN	Number of sample of EAJE	Compressive strength (N/mm²)	Number of sample of STANDARD	Compressive strength (N/mm²)
1	1	0.46	1	0.50
2	2	0.48	2	0.52
3	3	0.50	3	0.54
4	4	0.54	4	0.58

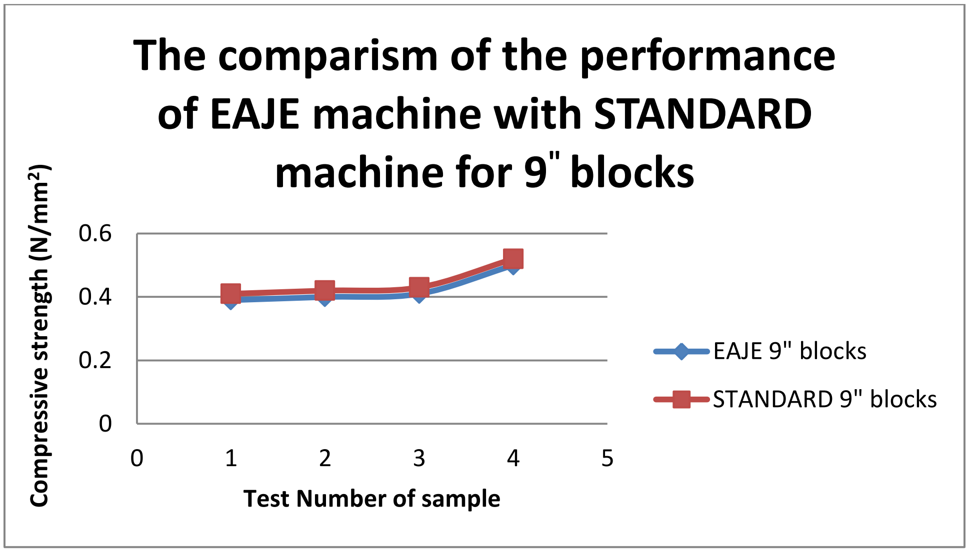

Figure 3: Validation of EAJE profile against the STANDARD profile for a 9" blocks

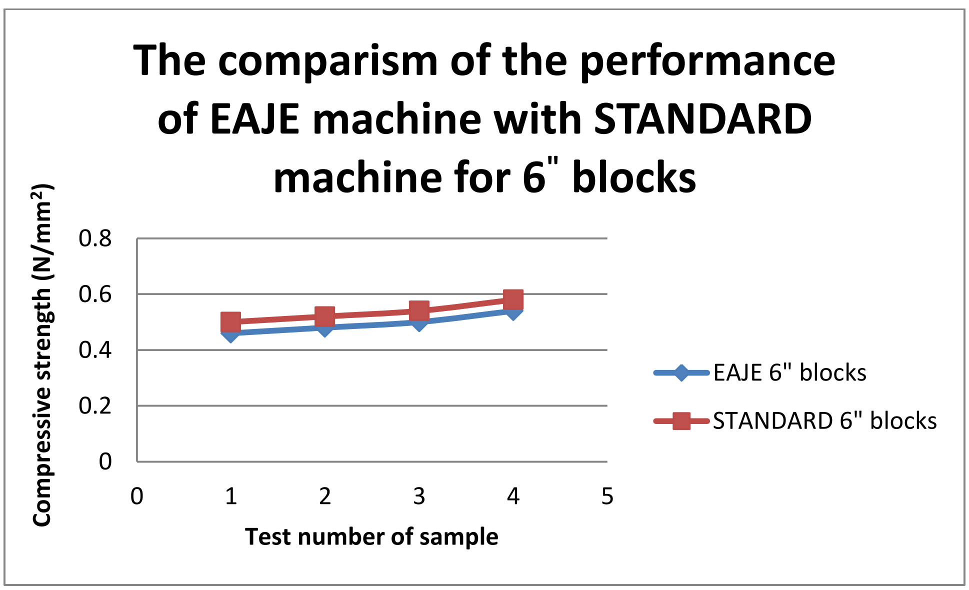

Figure 4: Validation of EAJE profile against the STANDARD profile for a 6" blocks

It is concluded that the result of the in-house fabricated compression testing machine is in good agreement with the standard compression testing machine, hence, the in-house compression testing machine is recommended for materials testing to help in quality control and reliability of materials in use in building and construction service sites.

5. CONCLUSION

The design parameters analysis for the manufacturing of the compression testing machine was investigated and the aimed achieved. The designed parameters of the fabricated in-house compression testing machine were analysed for material testing to ascertain the capability of the machine to withstand the work requirements under the operational conditions and service areas. The Nigerian industrial standards of NIS 87:2000 and NIS 74:1976 for blocks and clay bricks respectively were used as the benchmark. The compression principles were applied and force requirements by hydraulic Jack, pressure, the force acting on the frame supports, and the weight of the whole assembly was determined as the force of 199280.33N, the pressure of 3188485.28 N/m2, and 49820N respectively. Further analyses were carried and the results validated against the performance of a standard machine were in good agreement, evidenced in the matching trends and profiles. The in-house compression testing machine is recommended for materials testing to help in quality control and reliability of materials in use in building and construction service sites.

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