AN ASSESSMENT OF THE QUALITY OF SANDCRETE HOLLOW BLOCKS WITH PARTICULAR REFERENCE TO BAUCHI AND GOMBE STATES

BY

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL

AHMADU BELLO UNIVERSITY IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE HIGHER DEGREE OF

MASTER OF SCIENCE (STRUCTURAL ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING
FACULTY OF ENGINEERING
AHMADU BELLO UNIVERSITY ZARIA.
October, 1998

DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been accepted in any previous publication for a higher degree.

All sources of information are specifically acknowledged by means of references.



DUNA Samson.

CERTIFICATION

This thesis entitled "An assessment of the quality of sandcrete hollow blocks with particular reference to Bauchi and Gombe states" by DUNA SAMSON meets the regulations governing the award of the degree of Masters of Science in Structural Engineering, and is approved for its contribution to knowledge and literacy presentation.

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DEDICATION

This thesis is dedicated to: Genuine quest for knowledge.

ACKNOWLEDGEMENT

I will like to first and foremost thank God for giving me the strength and knowledge in carrying out this research work, I will also like to express my appreciation to my supervisors Dr. S.P. Ejeh and J.O Afolayan for their constructive criticisms and suggestions in improving my manuscripts, engineer Douglas Osula, for his suggestions and advice and other staff of Civil Engineering Department of Ahmadu Bello University Zaria who have shown concern in one way or the other during my course work, I say thank you.

I will also like to thank Engineer A.U. Elinwa my internal supervisor for his tiredness effort in going through the write-up his constructive criticism and suggestions really helped in improving the manuscript, I say thank you.

I will also like to express my appreciation to the staff of Civil Engineering programme of Abuakar Tafawa Balewa University Bauchi, Mr. Sani Ali of physics department and Mallan Usman Abubakar.

I will also like to express my gratitude to my friends and relations, Dr. Yakubu, Dr. Ankama, Engr. Bello, Obeth Maipandi, Dr. Duna, Hassan Ladula, Hussaini Daure, Gideon Dan, Joab Saje and members of Frieynz Club, for their spiritual, financial and moral support.

I will also like to thank my wife Mrs. Agatha Samson, for her advice and moral support urging me to complete this work in time. I say thank you.

Finally I thank Mrs. Njoku for typing this project.

ABSTRACT

Quality and standardization of all construction materials are of paramount importance and serve as yard sticks for measurement reflecting the level of development attained by a nation. Sandcrete hollow blocks are construction materials which have gained wide acceptance and use in the construction industries because of the many characteristics properties attached to them.

In this research, the study has focused on the quality of blocks produced in Bauchi and Gombe states with a view to assessing their qualities in terms of strength, density, shrinkage, water absorption etc. The results reveal that the compressive strength of the sandcrete hollow blocks in use in this part of the country are very low with the highest as 1.04 N/mm^2 as compared with 2.8 N/mm^2 recommended by Bs 2028 (1968) and 2.76 N/mm^2 by NIS (1974) . The following factors have been attributed to the low performance of the blocks they are: Experience and skill of production crew, poor workmanship, mix ratio and method of curing. The study has also suggested the importance of moderating the activities of these manufacturers by way of involving the standard organization of Nigeria and other professional bodies in the day to day activities of these industries.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Quality and standardisation of sandcrete blocks are of paramount importance in the study of building components. These will serve as yard sticks for measurement reflecting the level of development attained by a nation. The quality of sandcrete blocks is influenced by so many factors such as the constitutents material, the process adopted in the manufacture, duration of curing, forms and sizes of blocks etc, and calls for constant study and evaluation to ascertain the quality of blocks used in the construction industrties. Recently new materials like bricks, modified clay blocks, etc have found their ways into the Nigerian construction industries with little effort geared towards uplifting the conventional products to meet the set standards and objectives. Despite the introduction of such new materials, the use of sandcrete blocks in the construction industries has gained wide usage, these are due to some of its characteristic properties vis-a-vis strength, density, water absorption, shrinkage, durability etc. In addition to ease of handling, lower cost and technical know how of the material. That not withstanding, it has been observed from the failures of masonry walls and cracks development, that sandcrete blocks produced for general construction purposes in Nigeria, are

very poor in quality. This can be attributed to the profit the manufacturers, contractors are quickly trying to make and possibly the ignorance on the part of the manufacturers, the contractors and specifiers in interpreting the code of practice.

1.2 Aims and Objectives

In recognition of the wide application of sandcrete blocks and the need to continuously evaluate the quality of the products is of paramount importance. the objective of this study is to assess the quality of sandcrete blocks produced in Bauchi and Gombe States of Nigeria and to compare such parameters with the existing codes of practices giving recommendations as the need arises.

1.3 Justification for the Study

At present many block manufacturing industries are operating in the country, and are not knowledgeable in sound engineering practices. The results of these are that sub-standard blocks are produced and these manifest themselves in the rate of deterioration and cracks development in our buildings. One of the steps necessary to guide against such practices, is the creation of awareness through proper documentation and dissemination of information on data collected from these manufacturers. This will serve as data banks for designers, specifiers and researchers involved in

the use of blocks for construction and also in code formulation.

CHAPTER TWO

LITERATURE REVIEW

Sandcrete blocks are construction materials in small forms and sizes but larger than bricks. They are made from a binding material using cement, water and sand. Sandcrete blocks used for making blocks are made with a wide range of compressive strength using appropriate mix proportions with some degree of compaction.

Cracking of wall is a complex problem governed primarily by the quality of blocks made from low quality materials and the mortar used. The West African Building Research Institute Annual Report (1961) emphasizes on the danger of cracks; that good quality blocks free from cracks improves hygiene and reduces maintenance, thereby increasing the lifespan of the building. BS 2028 (1968) has categorized the blocks into three, namely:

i) Type A: Dense aggregate concrete block which is suitable for general use in building including the use below the ground level.

ii) Type B: Light weight aggregate concrete blocks suitable for general use in building including the use below the ground level, damp proof course, internal walls and external walls.

iii) Type C: Light weight aggregate concrete block primarily for non load bearing walls.

It also defines the three forms of sandcrete blocks as:

a) Solid block as being solid if the solid material is not less than 75% of the total volume of the block.

b) Hollow block is deemed hollow if it has one or more large holes or cavities which pass through the block and the solid material is between 50% and 75% of the total volume of the block.

c) Cellular block is deemed to be cellular if it has one or more moulded holes or cavities which do not effectively pass through the block and the solid material is between 50% and 75% of the total volume of the block.

Everett et al (1970), classified the three classes of sandcrete blocks as shown in table 1.

Table 1. Allowable percentage of void with respect to total volume (Everett et al, 1970)

Table of Block	Allowable void percentage
Solid blocks	25%
Hollow blocks	Greater than 25%
Cellular blocks	not more than 50%

Tables 2 and 3 show the various work sizes of concrete blocks as given by Jackson (1984) and BS 2028 (1968) respectively.

Table 2. Work sizes of concrete blocks (Jackson, 1984)

Length (mm)	Height (mm)	Thickness (mm)
390	190	60, 75, 90
440	140	100, 190, 200
440	190	and
440	215	215
440	290	
590	140	
590	190	
590	215	

Table 3. Dimensions of blocks (BS 2028 1968)

Type	Dimensions	Work size (mm)	Coordinated size (mm)*
A	Length	448	317 or 499±3
	Height	143 or 219	92 or 194±3
	Thickness	51,64,76, 102	76,92,102±1.5
		152 or 219	143,178 or 194
B	Length	448	
	Height	219	
	Thickness	76, 89, 102,	76,92,102±1.5
		152, 203,or 219	143, 113 or 194

*The coordinated sizes are the allowable limits for the dimension of the blocks when measured as stipulated by BS 2028 (1968).

West African Building Research Institude (1961) do not support the use of sea sand for block production. They argue that sea sand are mostly single size or too fine and so do not conform to the grading requirement. Hence affect the strength of the blocks. Grading of aggregate is very important because it reduces the amount of voids present which would affect the strength. (BS) 882 part 2 (1973) stipulates that any fine aggregate whose grading falls within the limits of zones, 1,2,3 and 4 should be suitable for concrete production. Since at least three quarter of the volume of sandcrete blocks is occupied by the fine aggregate, the quality is therefore of considerable importance. The fine aggregate (sand) shall be clean and free from deleterious matter and shall pass through 4.76mm of BS test sieve. Building research digest (1958) observes that the sand should not contain very fine particles such as silt and clay. This will produce concrete that requires a higher water content, or containing chemical impurities which may affect the setting and hardening of the block. When clay or silt exist as coating to the sand particles it is likely to result in poor bond between the particles and cement. BS 882 (1973), specifies that the silt content in sand for any concrete should not exceed 6%. Oversea Building notes (1977), states that light weight aggregate blocks have better advantages over dense aggregate blocks. They have better fire resistance, thermal and sound absorption properties, easy handling during transportation, cutting and

fixing, however dense aggregate blocks have higher strength, thermal capacity and resistance to sound transmission than lighter blocks. Gage et al (1980) in their findings stipulated that the cost of aggregate can account for up to 40% of the manufacturing cost of blocks. Iloghalu (1985) emphasise the danger of dirts and impurities in the water used for the production of blocks which results in low strength, it is therefore recommended that water used for the production should be clean almost fit for drinking and should be free from salts and organic matter.

Gage et al (1980), are of the opinion that the method of curing significantly affects the properties of block particularly with regards to shrinkage. Nigerian standard organisation (1974), recommends that after removal from the machine, they should be left on pallets in rows with space between them for at least 24 hours and kept wet by spraying. When they are removed from the pallets, curing should continue for at least 3 days after which should be stored for at least 3 days before use. Jackson (1984) studied the various curing required and observed that the longer the period during which concrete is kept under water the greater its final strength.

Gage et al (1980) in their paper defined strength as the average compressive strength of the weakest individual block in the test sample and must not be less than 80% of the average value. NIS (1974), FMW 1979, BS 2028 (1968), have given the average compressive strength as 2.50 N/mm^2,

2.10N/mm², 3.50 N/mm², for (type A) and 2.8 N/mm², (type B) respectively. Cracks in concrete and other masonry materials is as a result of shrinkage, which is detrimental and affects the strength and durability of the structure. Cracks in concrete occur when the stress induced by creep is greater than the tensile strength of the concrete (Owolabi, 1995). Owolabi (1995) also observed that shrinkage increases with time and the most noticeable increases occuring at the early ages. He concluded that concrete cured in an environment with higher relative humidity experienced less shrinkage than those cured in an environment with lower relative humidity. It has also been observed that shrinkage decreases with an increase in the size of the specimen, but above some value the size effect is no longer appropriate (Neville 1977).

Surface of good quality blocks is not affected by soluble salts, except very slightly by gases in polluted environment.

Table 4 Shows the average value of shrinkage as recommended by BS 2028 (1968)

Type	Average Compressive strength N/mm²	Block density kg/m³	Maximum drying shrinkage
A	Less than 10.5	All	0.05
	10.5 and above	All	0.06
B	Less than 7.0	Over 625	0.07
		625 and less	0.09
	7.0 and above	All	0.08
C	All blocks	over 625	0.08
		625 and less	0.09

CHAPTER THREE

THEORY OF STUDY

The study is in two parts:

i) There was a survey of existing reputable blocks industries for data/sample collection and

ii) An experimental investigation into the quality of blocks using the various standards as guide.

3.1 Survey

The survey was carried out in Bauchi and Gombe States in the northern part of Nigeria. The states were zoned into five for proper coverage and industries chosen are in Azare, Bauchi, Tafawa Balewa, which are in Bauchi state and Gombe and Billiri, in Gombe State.

For easy identification the industries are named A, B, C, D and E respectively. From the survey results (Table 5) more block industries are located in Bauchi and Gombe. This is as a result of the level of construction work going on in these areas. The number can be attributed to the fact that both are state capitals respectively.

Table 5. Survey Data from the various sites.

S/N	Information	A Azare	B Bauchi	C T/Balewa	D Gombe	E Billiri
1	Number of years in production	11	10	3	8	2
2	Staff strength	18	20	7	22	8
3	Type of blocks produce (mm)	230x215x460 150x215x460	230x215x460 150x215x460 100x215x460	230x215x460 150x215x460	230x215x460 150x215x460	230x215x460 150x215x460
4	Number of blocks produce per day	100	1200	400	1300	400
5	Cement/sand ratio: for 50 kg of cement.	1:9	1:10	1:12	1 :8	1:12
6	Number of blocks produce per 50kg of cement. 230x215x460 150x215x450	25 37	26 38	28 42	23 36	27 42
7	Source of water	Borehole	Tap water	Stream	Bore hole	Bore hole
8	Curing period (days)	2-3	3-4	2	3-4	2
9	Type and source of sand	Course and soft sand (stream)	Course river sand	Course and soft stream	Course and soft stream	Course (stream)
10	Type of cement	Sokoto & Ashaka	Ashaka	Ashaka	Ashaka	Ashaka
11	Type of equipment.	Machine	Machine	Manual	Machine	Manual
12	Water/cement ratio.	Water is arbitary added to arrive at satisfactory consistency.				

MAP OF BAUCHI/GOMBE STATES OF NIGERIA SHOWING THE LOCATION OF EACH INDUSTRY.

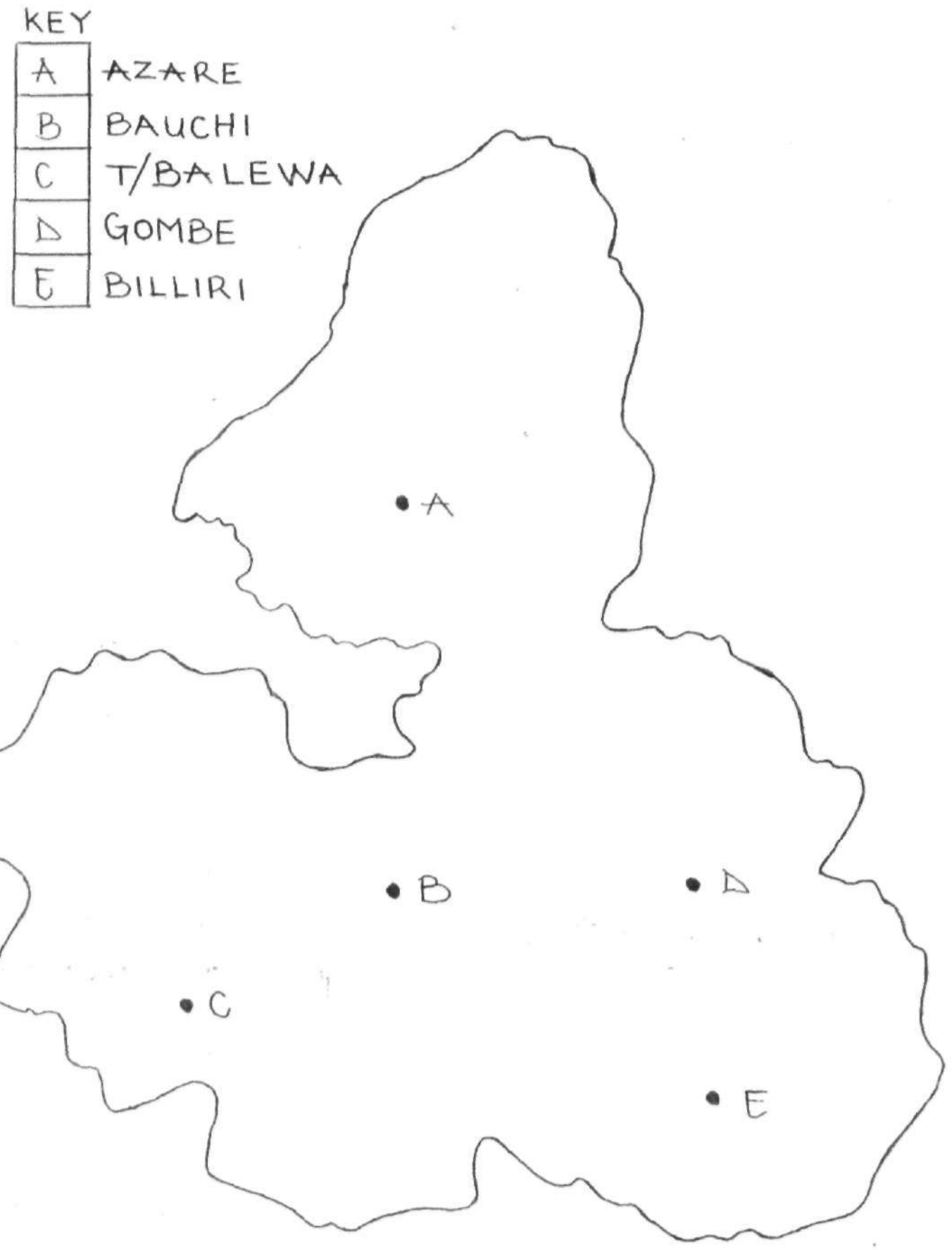




PLATE I



PLATE II

Plate I: Wet Moulded Blocks Spread on Wood Pallets

Plate II: Dry Blocks Undergoing Curing

3.2.1 Experimental Investigation

(A) Materials

(i) Cement

From Table 5, the industry visited are using Ashaka Cement except for industry A, where Sokoto brand was also used apart from using Ashaka brand.

Table 7 shows the various tests and results carried out on the samples of cement collected from the various industries. These tests are carried out in accordance with BS 12 (1973) and NIS (1974).

Table 6. Mix proportion of Sandcrete blocks (Rosecometta Machine Manual).

Information	Type A	Type B
Normal sand free from dust, lime or clay (0-2mm) litres.	900	200
Quary or river (gravel) dust free (3-5m) crushed stone (6-10mm) litres.	- -	800 200
Ordinary Portland Cement (litres)	140-175	119-123
Water free from impurities (litres)	8-100	60-70
Ratio of Cement and sand	1.5-1.6	1.5-1.7
Water cement ratio	0.4-0.7	0.4-0.6

Table 7. Physical properties of Ashaka Cement.

Experiments	Results	NIS 1974
Initial setting time (min)	40.3	Not more than 45 minutes.
Final setting time (min)	356	Not less than 10 hours.
Soundness test (mm)	3.0	Not more than 10 mm.
Average compresive strength cured for 3 days (MN/m^2)	13.15	Not less than 15 MN/m^2.

(ii) **Fine Aggregate (Sand)**

From Table 5, the type of fine aggregate used are obtained either from the river or stream. The tests carried out are the grading analysis and the silt content analysis and the results are shown in Tables 8 and 9 respectively. The silt content test and the particle size distribution was performed in accordance with BS 812 1973 Clause 14 and BS 882 (1973) respectively.

$$Silt\ Content\ (\%) = \frac{Difference\ in\ level\ of\ silt\ (cm^3)}{Height\ of\ sand + silt\ in\ volume\ (cm^3)}\ x100\ 1$$

Table 8. Aggregate Grading Analysis for the Various Industry.

Industry	Grading Zone				
	1	2	3	4	Remarks
A		*			Suitable for sandcrete bloks manufacture
B	*				
C		*			
D		*			
E	*				

Table 9. Silt Content Analysis.

Industry	Silt content (%)	BS 812 (1973)
A	9.89	% of silt content by volume must not exceed 6%.
B	8.38	
C	5.40	
D	5.70	
E	8.21	

3.2.2 Experimental Investigation (Blocks)

Sixty two (62) blocks were randomly selected from each of the industries (A, B, C, D and E), total of three hundred and ten (310) blocks tested in accordance with BS 2028 (1968). The following tests were carried out:

i. Dry compressive test

ii. Wet compressive test

iii. Wet compressive strength bedded with Cement mortar

iv. Dry density

v. Drying shrinkage test.

vi. Water absorption test

(a) Dry and Wet Compressive Strenghts

The dry and wet compressive strengths were conducted using the samples collected from the various industry and crushed for 1, 2, 3, 7, 14, 21 and 28 days in accordance with appendix C4 BS 2028 (1968). The average block dimensions were obtained using a vernier callipers. The blocks are then crushed in the machine at a specified rate of loading. The crushing load is then obtained. The compressive strength is obtained by dividing the crushing load by the gross area of the block.

$$Compressive\ Strength = \frac{Crushing\ load\ (KN)}{Gross\ Area\ (mm^2)} \quad \ldots\ldots\ldots \quad 2$$

A total of 3 blocks were crushed for each curing regime and the average taken. The results are as tabulated in Tables 10 to 19. Also carried out, is the wet compressive strength bedded with mortar. The mortar mix for the bedding is in the

ratio 1:1 and cured for 28 days before crushing.

Results are as tabulated in Tables 20 to 24.

(b) Density of the Blocks

This test is aimed at determing the unit weight of the blocks. The density of the blocks at curing ages of 1, 2, 3, 7, 14, 21 and 28 days were determined in accordance with Appendix B, BS 2028 (1968). Results are as tabulated in Tables 25-29.

$$Density = \frac{Mass\ of\ Block\ (Kg)}{Volume\ of\ Block\ (M^3)} \quad \ldots\ldots\ldots\ldots\ 3$$

(c) Drying shrinkage Test

The drying shrinkage of the Sandcrete hollow blocks was measured in accordance with BS 2028 (1968). The difference between the length of the block which has been immersed in water and the length when subsequently dried, all under specified conditions, expressed as a percentage of the length of the specimen, results are as tabulated in Table 30.

$$Shrinkage = \frac{Length\ when\ immersed - Length\ Dried}{Length\ of\ Specimen} x100 \quad \ldots\ 4$$

(d) Water Absorption Test

This test was carried out in accordance with Appendix B.1, NIS (1974), and are good indicators of the apparent porosity of the blocks. The block is weighed dry and then immersed in water for a period of 24 hours and then weighed again to find the weight. The difference between the dry and wet weights expressed as a percentage of the dry weight will give the percentage water absorption of the blocks. Results are as tabulated in Tables 31-35.

Table 10. Dry Compressive Strength of Sandcrete Blocks for Industry A

(Dimensions in mm)(Mould Size 457x152x217)

S/No	DIMENSION (mm)			Cross surface area(mm^2)	Age (Days)	Failure load (KN)	Crushing strength (N/mm^2)	BS 2028
	Length	Height	Height					
1	461	152	218	70,072	1	1.70	0.024	Average of 2.8 N/mm^2 Lowest individ-ual block 2.25 N/mm^2 At 28 days.
2	459	152	216	69,768	2	8.20	0.118	
3	459	151	215	68,309	3	11.40	0.167	
4	458	149	214	68,242	7	20.10	0.295	
5	458	150	216	68,700	14	31.0	0.451	
6	459	150	216	68,850	21	36.50	0.530	
7	458	149	214	68,242	28	39.0	0.571	

Table 11. Dry Compressive Strength of Sandcrete Blocks for Industry B

(Dimensions in mm)(Mould Size 457 x 152 x 217)

S/N	DIMENSION (mm)			Cross surface area (mm^2)	Age (Days)	Failure load (KN)	Crushing strength (N/mm^2)	BS 2028
	Length	Height	Height					
1	457	150	216	68,550	1	1.60	0.023	Average of 2.8 N/mm^2 Lowest individual block 2.25 N/mm^2 At 28 days.
2	454	152	216	69,008	2	7.0	0.101	
3	455	151	218	68,400	3	12.20	0.177	
4	456	150	214	68,250	7	22.0	0.32	
5	455	150	216	68,250	14	33.0	0.484	
6	454	151	217	68,554	21	36.0	0.525	
7	455	150	218	68,250	28	37.0	0.542	

Table 12. Dry Compressive Strength of Sandcrete Blocks for Industry C

(Dimensions in mm)(Mould Size 457 x 152 x 217)

S/N	DIMENSION (mm)			Cross surface area (mm^2)	Age (Days)	Failure load (KN)	Crushing strength (N/mm^2)	BS 2028
	Length	Height	Height					
1	457	150	217	68,550	1	1.0	0.015	Average of 2.8 N/mm^2 Lowest indivi-dual block 2.25 N/mm^2 At 28 days.
2	455	151	215	69,705	2	6.0	0.087	
3	455	151	216	68,705	3	8.0	0.116	
4	454	149	216	68,646	7	16.50	0.244	
5	454	151	214	68,554	14	23.0	0.335	
6	455	150	217	68,250	21	28.0	0.410	
7	456	150	215	68,400	28	27.0	0.395	

Table 13. Dry Compressive Str[illegible] of Sandcrete Blocks for Industry D

(Dimensions in mm)(Mould Size 460 x 152 x 217)

S/N	DIMENSION (mm)			Cross surface area (mm^2)	Age (Days)	Failure load (KN)	Crushing strength (N/mm^2)	BS 2028
	Length	Height	Height					
1	461	151	216	69,611	1	2.0	0.029	
2	459	151	214	69,309	2	11.50	0.167	Average of 2.8
3	460	150	216	69,000	3	16.40	0.237	N/mm^2
4	458	151	216	69,158	7	26.40	0.382	Lowest indivi-
5	459	150	218	68,850	14	36.0	0.522	dual block
6	458	151	216	69,158	21	40.80	0.589	2.25 N/mm^2
7	458	150	218	68,700	28	41.0	0.596	At 28 days.

Table 14. Dry Compressive Strength of Sandcrete Blocks for Industry E

(Dimension in mm)(Mould Size 460 x 152 x 217)

S/N	DIMENSION (mm)			Cross surface area (mm^2)	Age (Days)	Failure load (KN)	Crushing strength (N/mm^2)	BS 2028
	Length	Height	Height					
1	460	151	218	69,460	1	1.40	0.02	Average of 2.8 N/mm^2 Lowest individual block 2.25 N/mm^2 At 28 days.
2	460	151	216	69,460	2	5.80	0.08	
3	459	150	216	68,850	3	9.60	0.139	
4	458	152	215	69,616	7	16.0	0.229	
5	459	148	217	67,932	14	22.0	0.324	
6	458	151	218	69,158	21	24.20	0.349	
7	459	150	216	68,850	28	24.0	0.349	

Table 15 Wet Compressive Strength of Sandcrete Blocks for Industry A

(Dimension in mm)(Mould Size 460 x 152 x 217)

S/N	DIMENSION (mm)			Cross surface area (mm^2)	Age (Days)	Failure Load (KN)	Crushing Strength (N/mm^2)	BS 2028
	Length	Height	Height					
1	463	153	220	70,839	1	38.5	0.544	Average of 2.8 N/mm^2 Lowest indivi-dual block 2.25 N/mm^2 At 28 days.
2	462	154	219	71,148	2	36.9	0.519	
3	463	152	218	70,376	3	30.7	0.436	
4	463	154	218	71,302	7	32.8	0.460	
5	463	153	220	70,839	14	35.0	0.495	
6	462	153	218	70,686	21	33.8	0.479	
7	462	152	217	70,224	28	34.3	0.489	

Table 16 Wet Compressive Strength of Sandcrete Blocks for Industry B

(Dimension in mm)(mould size 457 x 152 x 217)

S/N	DIMENSION (mm)			Cross surface area (mm^2)	Failure Load (KN)	Crushing strength (N/mm^2)	Age (Days)	BS 2028
	Length	Height	Height					
1	458	153	219	70,074	36.40	0.52	1	Average of 2.8 N/mm^2 Lowest indivi-dual block 2.25 N/mm^2 At 28 days.
2	459	153	217	70,227	35.10	0.500	2	
3	459	153	218	70,227	33.40	0.476	3	
4	459	152	218	69,768	34.80	0.500	7	
5	459	153	217	70,227	36.0	0.515	14	
6	458	152	216	69,616	35.50	0.510	21	
7	459	153	218	70,227	36.50	0.513	28	

Table 17 Wet Compressive Strength of Sandcrete Blocks for Industry C

(Dimension in mm) (mould size 457 x 152 x 217)

S/N	DIMENSION (mm)			Cross surface area (mm^2)	Failure Load (KN)	Crushing strength (N/mm^2)	Age (Days)	BS 2028
	Length	Height	Height					
1	458	153	217	70,074	26.70	0.381	1	Average of 2.8 N/mm^2 Lowest indivi-dual block 2.25 N/mm^2 At 28 days.
2	457	153	216	69,921	25.40	0.363	2	
3	459	153	218	70,227	24.80	0.353	3	
4	458	152	217	69,616	26.30	0.378	7	
5	459	153	217	70,227	28.60	0.408	14	
6	458	152	217	69,616	28.60	0.411	21	
7	458	153	217	70,074	27.60	0.395	28	

Table 18 Wet Compressive Strength of Sandcrete Blocks for Industry D

(Dimension in mm) (mould size 460 x 152 x 217)

S/N	DIMENSION (mm)			Cross surface area (mm^2)	Failure Load (KN)	Crushing strength (N/mm^2)	Age (Days)	BS 2028
	Length	Height	Height					
1	463	153	218	70,839	43.60	0.616	1	Average of 2.8 N/mm^2 Lowest indivi-dual block 2.25 N/mm^2 At 28 days.
2	463	154	217	71,302	42.00	0.589	2	
3	463	153	220	70,839	39.70	0.561	3	
4	463	152	218	70,376	40.80	0.580	7	
5	462	153	218	70,376	41.70	0.590	14	
6	463	153	218	70,686	42.00	0.593	21	
7	462	152	217	70,224	42.80	0.609	28	

Table 19 Wet Compressive Strength of Sandcrete Blocks for Industry E

(Dimension in mm) (mould size 460 x 152 x 217)

S/N	DIMENSION (mm)			Cross surface area (mm^2)	Failure Load (KN)	Crushing strength (N/mm^2)	Age (Days)	BS 2028
	Length	Height	Height					
1	463	153	219	70,839	24.10	0.340	1	Average of 2.8 N/mm^2 Lowest individual block 2.25 N/mm^2 At 28 days.
2	464	153	218	70,992	23.80	0.335	2	
3	462	152	217	70,224	22.30	0.318	3	
4	464	154	218	71,456	23.80	0.333	7	
5	463	153	219	70,839	23.50	0.332	14	
6	462	153	218	70,686	22.60	0.320	21	
7	463	154	217	71,302	21.90	0.307	28	

Table 20: Wet Compressive Strength of Sandcrete Blocks Bedded with Mortar at 28 days (Industry A).

S/No	DIMENSION (mm)			Failure load (KN)	Compre-ssive Strengt N/mm²	BS 2028
	Length	Breadth	Height			
1	463	153	219	60	0.85	Average of
2	464	154	218	58	0.81	2.8 N/mm²
3	462	152	220	48	0.68	Lowest
4	463	153	219	62	0.86	indivi-dual
5	463	154	219	56	0.79	strength of
6	464	152	217	65	0.92	2.25 N/mm²
7	462	152	218	60	0.85	
8	463	154	220	68	0.95	
9	461	152	219	64	0.77	
10	464	153	218	64	0.90	

Average Compressive Strength = 0.84 N/mm²

Standard deviation = 0.075 N/mm²

Table 21: Wet Compressive Strength of Sandcrete Blocks Bedded with Mortar at 28 days (Industry B)

S/No	DIMENSION (mm)			Failure load (KN)	Compressive Strength N/mm²	BS 2028
	Length	Breadth	Height			
1	458	152	217	45	0.65	Average of 2.8 N/mm²
2	459	154	215	50	0.71	Lowest individual block 2.25 N/mm²
3	459	153	220	54	0.77	
4	458	152	217	60	0.86	
5	457	152	217	52	0.75	
6	458	151	218	44	0.64	
7	459	151	220	48	0.69	
8	457	153	219	62	0.89	
9	457	153	220	50	0.72	
10	458	153	219	55	0.78	

Average Compressive Strength = 0.75 N/mm²

Standard deviation = 0.07 N/mm²

Table 22: Wet Compressive Strength of Sandcrete Blocks Bedded with Mortar at 28 days (Industry C).

S/No	DIMENSION (mm)			Failure load (KN)	Compressive Strength N/mm²	BS 2028
	Length	Breadth	Height			
1	457	152	219	44	0.63	Average of 2.8
2	458	153	219	40	0.57	N/mm²
3	459	152	218	38	0.55	Lowest
4	457	154	217	44	0.63	individual
5	458	152	218	56	0.80	block
6	457	152	216	40	0.58	2.25 N/mm²
7	458	153	220	36	0.51	
8	459	152	218	42	0.60	
9	460	153	220	44	0.63	
10	457	152	217	45	0.65	

Average Compressive Strength = 0.62 N/mm²

Standard deviation = 0.074 N/mm²

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Table 23: Wet Compressive Strength of Sandcrete Blocks Bedded with Mortar at 28 days (Industry D).

S/No.	DIMENSION (mm)			Failure load (KN)	Compressive Strength N/mm²	BS 2028
	Length	Breadth	Height			
1	461	154	219	80	1.12	Average of
2	463	154	218	82	1.15	2.8 N/mm²
3	464	153	218	72	1.01	Lowest
4	462	152	219	70	1.00	individual
5	463	153	217	64	0.90	strength of
6	464	152	218	68	0.96	2.25 N/mm²
7	462	154	216	59	0.83	
8	463	153	219	81	1.14	
9	463	153	217	83	1.17	
10	463	154	220	78	1.09	

Average Compressive Strength = 1.04 N/mm²

Standard deviation = 0.11 N/mm²

Table 24: Wet Compressive Strength of Sandcrete Blocks Bedded with Mortar at 28 days (Industry E).

S/No.	DIMENSION (mm)			Failure load (KN)	Compressive Strength N/mm²	BS 2028
	Length	Breadth	Height			
1	463	149	220	40	0.58	Average of 2.8 N/mm²
2	463	152	219	44	0.63	
3	464	152	220	48	0.68	
4	463	153	218	36	0.51	Lowest inividual block 2.25 N/mm²
5	462	152	217	42	0.60	
6	463	152	219	34	0.48	
7	464	153	218	48	0.68	
8	461	154	219	46	0.65	
9	464	152	220	38	0.54	
10	463	154	219	44	0.62	

Average Compressive Strength = 0.60 N/mm²

Standard deviation = 0.066N/mm²

Table 25: Dry Density of sandcrete Blocks At Various Ages(Industry A)

S/No	AREA (mm^2)	VOLUME (m^3)	WEIGHT (KG)	AGE (DAYS)	DENSITY KG/m^3	BS 2028
1	70,072	0.015	17.20	1	1147	Less than 1500 kg/m^3
2	69,768	0.015	16.82	2	1121	
3	68,850	0.015	16.62	3	1108	
4	68,700	0.015	16.20	7	1080	
5	68,242	0.015	16.10	14	1073	
6	68,242	0.015	16.06	21	1071	
7	68,2	0.015	16.00	28	1067	

Table 26: Dry Density of Sandcrete Blocks At Various Ages(Industry B)

S/NO	AREA (mm^2)	VOLUME (m^3)	WEIGHT (KG)	AGE (DAYS)	DENSITY KG/m^3	BS 2028
1	69,160	0.015	16.10	1	1073	Less than 1500 kg/m^3
2	69,007	0.015	15.80	2	1053	
3	68,400	0.015	15.64	3	1043	
4	68,252	0.015	15.42	7	1028	
5	67,950	0.015	15.40	14	1026	
6	67,795	0.015	15.39	21	1026	
7	67,500	0.015	15.38	28	1025	

Table 27: Dry Density of Sandcrete Blocks At Various Ages (Industry C)

S/NO	AREA (mm^2)	VOLUME (m^3)	WEIGHT (KG)	AGE (DAYS)	DENSITY KG/m^3	BS 2028
1	68,705	0.015	16.35	1	1090	Less than 1500 kg/m^3
2	68,560	0.015	15.94	2	1063	
3	65,500	0.015	15.72	3	1048	
4	68,250	0.015	15.60	7	1040	
5	67,100	0.015	15.51	14	1034	
6	67,800	0.015	15.45	21	1030	
7	67,540	0.015	15.44	28	1029	

Table 28: Dry Density of Sandcrete Blocks At Various Ages (Industry D)

S/NO	AREA (mm^2)	VOLUME (m^3)	WEIGHT (KG)	AGE (DAYS)	DENSITY KG/m^3	BS 2028
1	70,072	0.015	16.90	1	1126	Less than 1500 kg/m^3
2	69,768	0.015	16.50	2	1100	
3	69,611	0.015	16.36	3	1090	
4	69,000	0.015	16.10	7	1073	
5	68,850	0.015	16.00	14	1067	
6	68,700	0.015	15.92	21	1061	
7	68,242	0.015	15.90	28	1060	

Table 29: Dry Density of Sandcrete Blocks At Various Ages (Industry E)

S/NO	AREA (mm^2)	VOLUME (m^3)	WEIGHT (KG)	AGE (DAYS)	DENSITY KG/m^3	BS 2028
1	69,768	0.015	16.82	1	1121	Less than 1500 kg/m^3
2	69,611	0.015	16.50	2	1100	
3	69,640	0.015	16.42	3	1095	
4	68,850	0.015	16.30	7	1087	
5	68,700	0.015	16.25	14	1083	
6	68,309	0.015	15.20	21	1080	
7	68,242	0.015	16.10	28	1073	

Table 30: Drying Shrinkage Test Result

SAMPLE NO.	DRYING SHRINKAGE (%)	AVERAGE DRYING SHRINKAGE (%)	BS 2028
BA/A/46 BA/A/47 BA/A/48	0.03 O.01 0.01	0.02	For Type B
BA/B/46 BA/B/47 BA/B/48	0.01 O.02 0.05	0.03	Not more than 0.07% if the average compressive strength are less than $7.0N/mm^2$ and density over $625kg/m^3$
BA/T/46 BA/T/47 BA/T/48	0.03 O.02 0.01	0.02	
GM/G/46 GM/G/47 GM/G/48	0.04 O.03 0.01	0.03	
GM/B/46 GM/B/47 GM/B/48	0.01 O.03 0.01	0.03	

Table 31: WATER ABSORPTION TEST RESULT FOR SITE A

Sample No.	BH/A/43	BH/A/44	BH/A/45	NIS (1974)
Dry weight (kg)	15.18	15.20	15.65	Up to 25% by Weight
Wet Weight (kg)	16.86	16.92	17.35	
Water absorption %	11.06	11.31	10.86	
Average water absorption (%)	11.08			

Table 32: WATER ABSORPTION TEST RESULT FOR SITE B

Sample No.	BH/B/43	BH/B/44	BH/B/45	NIS (1974)
Dry weight (kg)	15.40	15.63	15.15	Up to 25% by Weight
Wet Weight (kg)	16.82	16.73	16.87	
Water absorption %	9.22	7.03	11.35	
Average water absorption (%)	9.20			

Table 33: WATER ABSORPTION TEST RESULT FOR SITE C

Sample No.	BH/T/43	BH/T/44	BH/T/45	NIS (1974)
Dry weight (kg)	15.40	15.61	15.25	Up to 25% by Weight
Wet Weight (kg)	17.32	17.52	17.48	
Water absorption %	12.46	12.23	14.62	
Average water absorption (%)	13.10			

Table 34: WATER ABSORPTION TEST RESULT FOR SITE D

Sample No.	BH/G/43	BH/G/44	BH/G/45	NIS (1974)
Dry weight (kg)	15.85	15.63	15.80	Up to 25% by Weight
Wet Weight (kg)	17.49	17.84	17.95	
Water absorption %	10.34	14.14	13.61	
Average water absorption (%)	12.70			

Table 35: WATER ABSORPTION TEST RESULT FOR SITE E

Sample No.	BH/BR/43	BH/BR/44	BH/BR/45	NIS (1974)
Dry weight (kg)	15.15	15.43	15.25	
Wet Weight (kg)	17.33	17.56	16.81	Up to 25% by Weight
Water absorption %	14.39	13.80	10.23	
Average water absorption (%)	12.81			

TABLE 36: COMPRESSIVE STRENGTH OF CEMENT MORTAR CUBES

FOR ALL BLOCKS

S/N	Length (mm)	Breadth (mm)	Height (mm)	Volume (m^3)	Weight (kg)	Density mg/m^3	Age (days)	Failure Load (kN)	Crushing Strength N/mm
1	150	151	151	0.0034	7.20	2118	7	558	24.63
2	151	150	151	0.0034	7.77	2285	14	610	26.57
3	150	151	151	0.0034	8.04	2365	21	630	27.63
4	151	150	151	0.0034	7.78	2288	28	602	26.58

Average crushing strength = 26.35N/mm^2

CHAPTER FOUR

ANALYSIS AND DISCUSSION OF RESULT

From the survey carried out (table 5), quantity of water added for a good consistency is not measured. Water is added by all the industries visited until comfortable workable mix is achieved. The codes (BS 2028 1968 and NIS 1974) are silent on the quantity of water to be added for a quality production but the Rosacometta machine manual (table 6) specifies a water cement ratio 0.4 - 0.6. Table 7, shows the results of test on samples of cement collected from the industries (Physical properties). The results conforms with the specifications of the standards (BS 12 1968 and NIS 1974). As shown in figures 1-6 samples of the fine aggregate collected from all the industries conform with the stipulated grading requirements (BS 882 part 2, 1973) and thus suitable for block production. The silt content for industries A,B,C,D and E are 9.89, 8.38, 5.40, 5.70 and 8.21 respectively as shown in Table 9. BS 12 1973 recommends that the percentage of silt content by volume must not exceed 6%, and this condition is satisfied by industries C and D. It has been shown that excess silt interfers with the process of hydration of cement and the development of good bond between the aggregate and cement paste (Jackson, 1984).

Figure 7, shows the dry compressive strength plotted against age of curing.

The curves are parabolic in nature with industries A, B and D showing better strength development over industries C and E. At 28th day, the compressive strength recorded for industries A, B, C, D and E are 0.571 N/mm², 0.542 N/mm², 0.395N/mm², 0.596 N/mm², and 0.348 N/mm² respectively. The 7/28 day strength ratio for the various industries are given as 0.52, 0.59, 0.6, 0.63 and 0.66 respectively. Rasheed (1992) and Ayinmode (1993), gave the dry compressive strength of sandcrete blocks as 1.06 N/mm² and 0.68 N/mm² respectively. These are lower than the values specified by the codes BS 2028 (1968) and NIS (1974). BS 2028 (1968) has given the minimum compressive strength to be 2.8 N/mm² while NIS (1974) gave for load bearing block as 3.45 N/mm² and non load bearing blocks as 2.76 N/mm² respectively. NIS further recommends that the weakest individual blocks should have a compressive strength not lower than 2.76 N/mm² and 2.21 N/mm² respectively for the load bearing and non load bearing blocks. Also, FMW (1979) recommends an average compressive strength of 2.1 N/mm² while the lowest strength of individual block should not be less than 1.7 N/mm². Generally, it is observed that none of the block industries surveyed satisfies the minimum strength recommended by any of the standards. The reasons for the poor performance of the blocks can be attributed to the following reasons:

i) Experience and skill of production crew;

ii) Poor workmanship due to inexperience on the part of the production crew which leads to poor quality blocks;

iii) Mix ratio used during production and

iv) Method of curing the blocks.

Table 5, shows the various cement sand ratio used by the industries, industries C and E produced about 42 blocks from 50kg bag of cement where as industries A and D produced 37 and 36 blocks respectively, these again can be linked to the various strengths developed by the blocks. Iloghalu et al (1982) recommends that for 6" blocks 30 - 32 blocks from 50kg bag of cement should be produced. FMW (1979) recommends a mix ratio of 1:5 to 1:6 as against the various mixes used by the industries ie 1:9, 1:10, 1:12, 1:8 and 1:12 respectively for A, B, C, D and E.

The curing method adopted by the various industries as shown in Table 5, is also a contributory factor to the low strength. curing is done for 2 to 4 days as shown in the records of the survey (Table 5). NIS (1974) recommends that curing should be at least for 7 days before usage. Gage et al (1980), recommends 4-7 days curing under shade for normal air curing. It is also the findings of this study that the type of equipments used during production affect the strength of the blocks. Industries A, B and D produced their blocks using mechanical means while industries C and E are manual and this leads to inadequate compaction which affects strength.

Figure 9, shows the results of the wet compressive strength from the various industries. The dry strength obtained in the dry compressive strength at 28 days is taken to be the strength for the wet compressive strength at zero immersion. Strength recorded falls initially for the first three days before rising until the 26th day, then again it starts falling. The need for the wet compresswive test arises from the fact that masonry units show marked reduction in strength when tested in the wet condition. Rasheed (1992) and Ayinmade (1993) in their studies gave the wet compressive stength as 0.79 N/mm² and 0.75 N/mm² as 0.61 N/mm² achieved by the present study. Figure 11, shows a histogram plotted for the average wet compressive strength of the blocks bedded with cement mortar. The strengths recorded for the bedded are higher than the dry or wet compressive strength (Figure 12). This test is in accordance with the code of practice (BS 2020 1968) and is to reflect the actual behaviour of the blocks in service. From the cube strength test on the mortar (Table 36), an average strength of 25.24 N/mm² is recorded. This is far above the value obtained for the bedded block, this shows that the mortar contributes minimally to the strength of the blocks while in use and is only effective in bonding the blocks to avoid slip or displacement.

The test results for the dry densities at varying ages are presented in Figure 13. Density is a function of the weight of the material, and weight depends on the level of

compaction achieved. It is observed that industries A has the highest value followed by industries E, D, C and B and at early ages higher densities are attained with a gradual fall with age. This behaviour can be attributed to the fact that the blocks give up the retained water due to evaporation. The values obtained conform with the specification of the code BS 2028 (1968) which states that the value should not be greater than 1500 kg/m^3 for type B blocks.

Figure 15 is the histogram for the drying shrinkage test for the various industries. Shrinkage is a measure of quality of blocks and assures us the possibility of crack developing in a particular situation. Industries B, D and E recorded the highest shrinkage value of 0.03 while A and C are having 0.02. This is in conformity with the values obtained by Rasheed (1992) and Ayinmode (1993) which are 0.03 and 0.02 respectively, also the values obtained are within the values specified by BS 2028 (1968); that it should not be more than 0.07%.

The water absorption for the various industries are 10.08%, 9.20%, 13.10%, 12.70% and 12.81% with an average of 11.60 (Figure 16). Water absorption tests are good indicators of the quality of the blocks. they give us an idea on the compaction of the blocks.

Rasheed (1992) and Ayinmode (1993) again gave their average water absorption as 13% and 9.7% respectively. NIS (1974), specifies a water absorption of up to 25% by weight

for burnt clay bricks.

Figure 17, shows the dimensional deviation in terms of length, breadth and height of the blocks surveyed from the various industries. As shown in Table 37, industries A, B, C, D and E have an average value recorded for the length, breadth and height as 1.37mm, 1.54mm and 1.00mm respectively. Also BS 2028 (1968), gives the tolerance limit required for the length, breadth and height of any block ± 3mm is given for the length and height while ± 1.5mm for the breadth. NIS (1974), does not specify any tolerance limit. It can be concluded that all the industries produced blocks that are within the tolerance limit as given by BS 2028 (1968).

Table 37: Average tolerance value for length, breath and height for all the industries

Industry	Length (mm)	Breadth (mm)	Height (mm)
A	1.14	1.57	1.42
B	1.43	1.43	0.57
C	1.71	1.71	1.29
D	1.43	1.43	0.86
E	1.57	1.57	0.86
Average	1.37	1.54	1.00

PARTICLE SIZE DISTRIBUTION

LOCATION No..... BORE HOLE No..... SAMPLE No..... PRETREATMENT DETAILS.....

DATE OF TEST..... DESCRIPTION..... LOSS ON PRETREATMENT.....%

ZONE 2

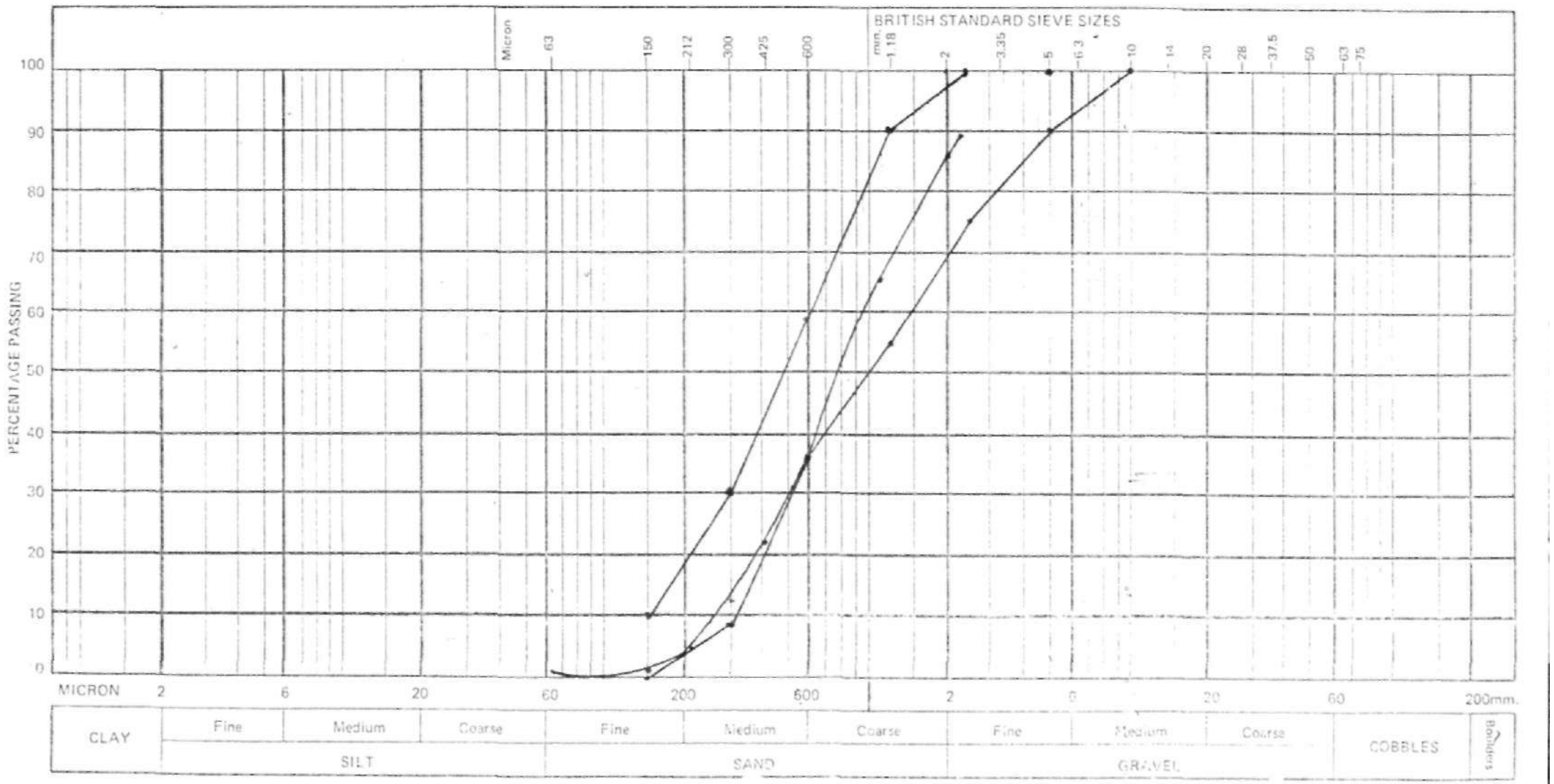


Figure 1: Grading Curve for Industry A

Signed.....

PARTICLE SIZE DISTRIBUTION

LOCATION No..... BORE HOLE No..... SAMPLE No..... PRETREATMENT DETAILS.....

DATE OF TEST..... DESCRIPTION..... LOSS ON PRETREATMENT.....%

ZONE 1

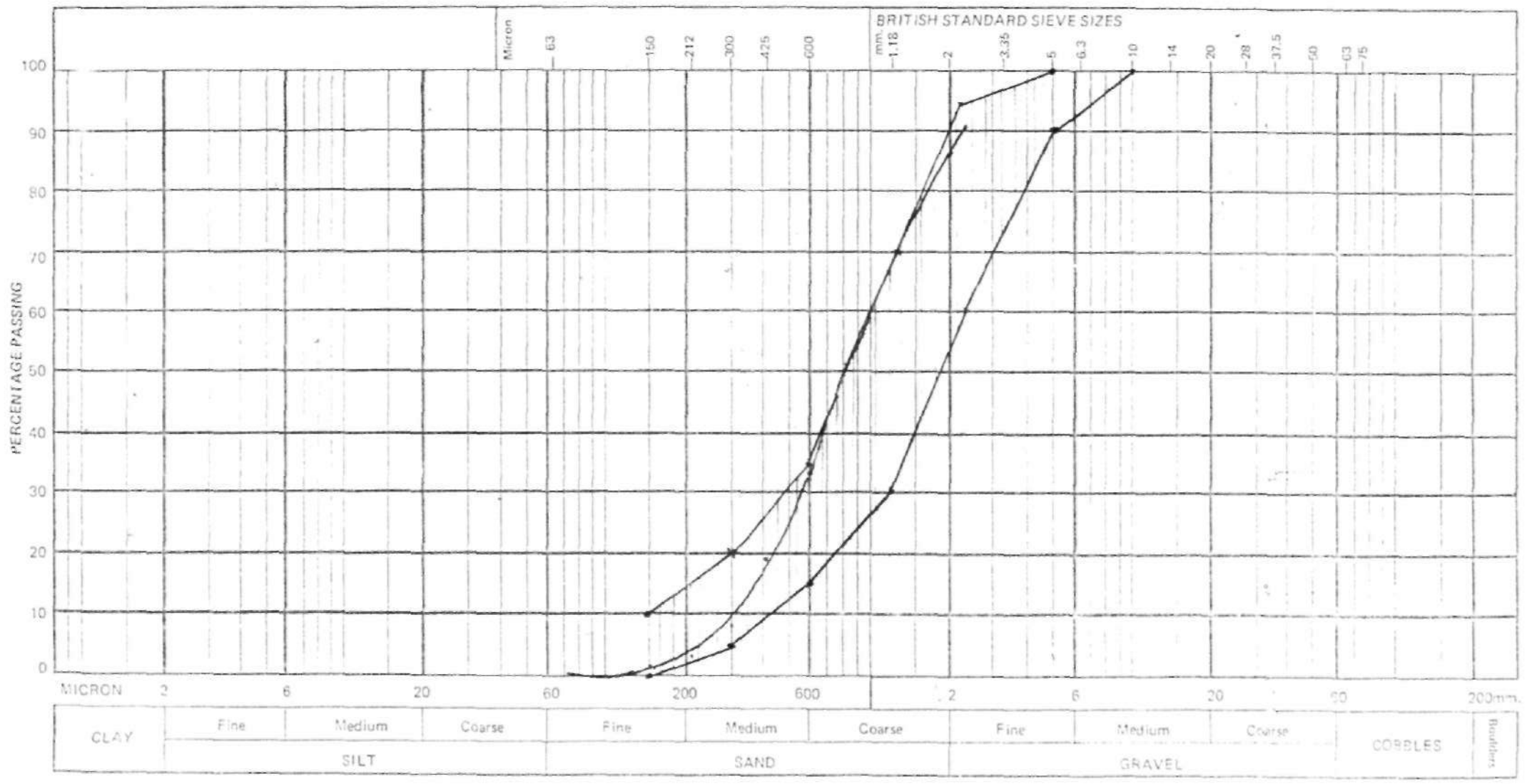


Figure 2: Grading Curve for Industry B

PARTICLE SIZE DISTRIBUTION

LOCATION No..... BORE HOLE No..... SAMPLE No..... PRETREATMENT DETAILS.....

DATE OF TEST..... DESCRIPTION..... LOSS ON PRETREATMENT.....%

ZONE 2

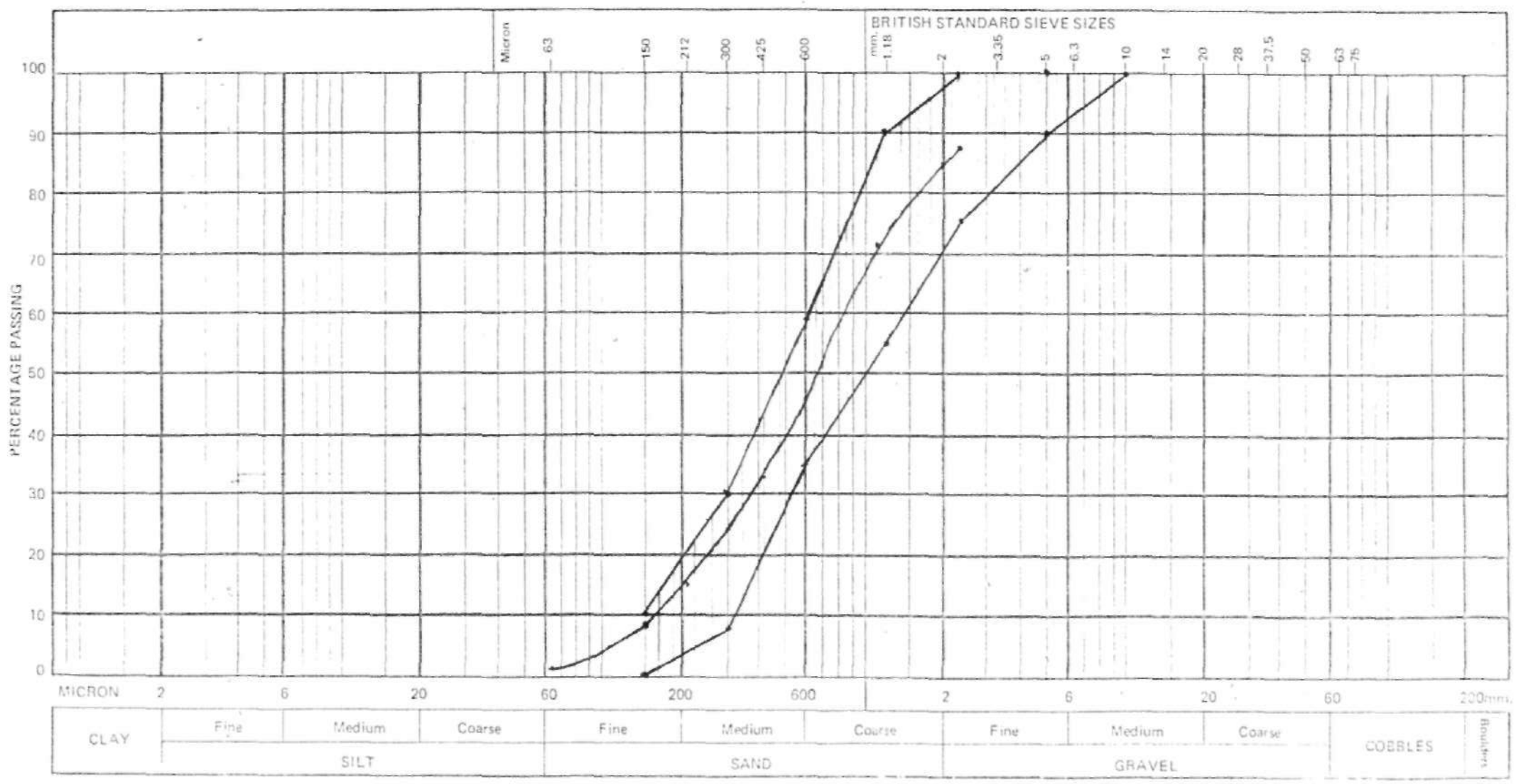


Figure 3: Grading Curve for Industry C

Signed.....

PARTICLE SIZE DISTRIBUTION

LOCATION No..... BORE HOLE No..... SAMPLE No..... PRETREATMENT DETAILS.....

DATE OF TEST..... DESCRIPTION..... LOSS ON PRETREATMENT.....%

ZONE

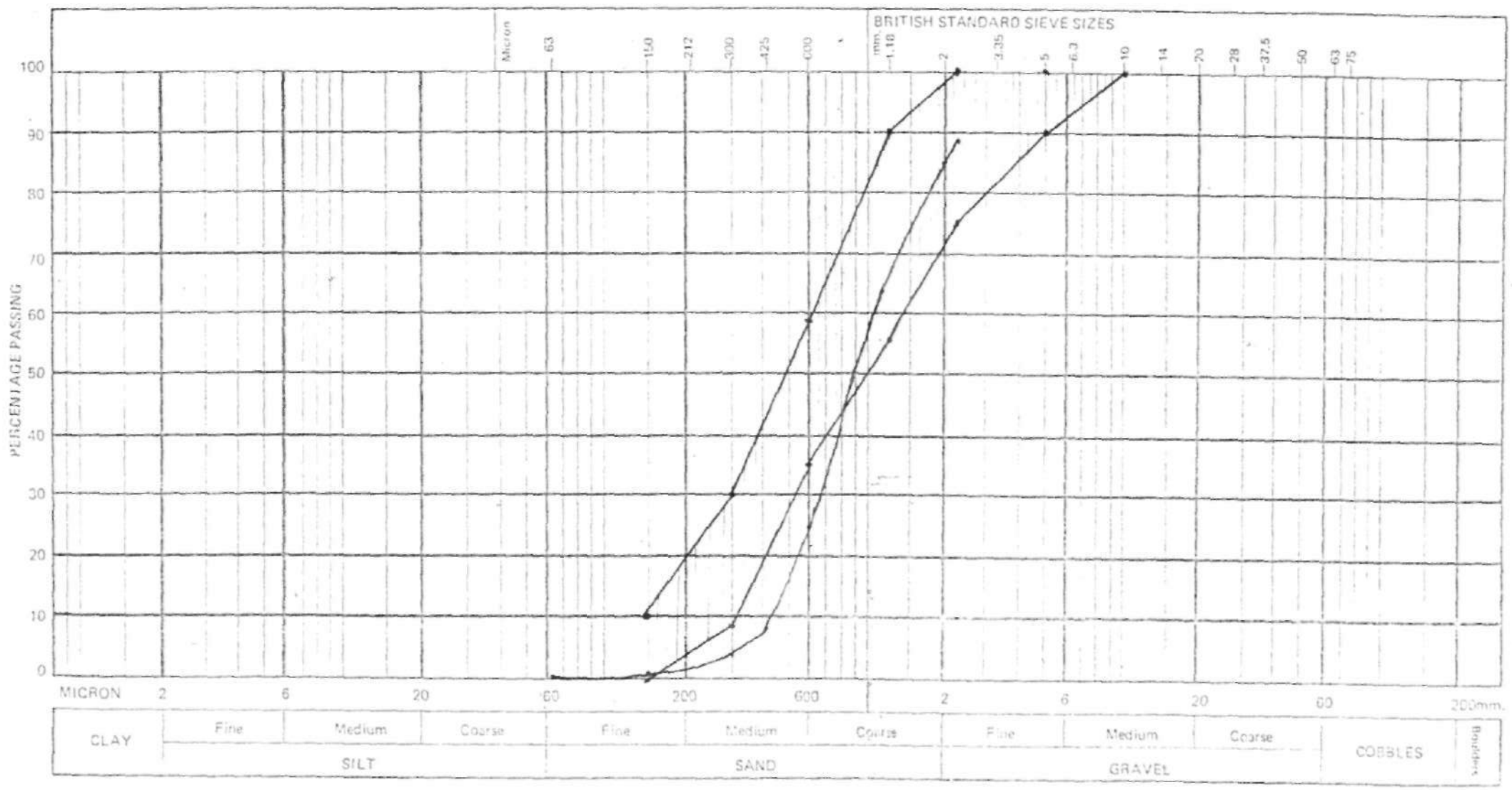


Figure 4: Grading Curve for Industry D

Signed.....

PARTICLE SIZE DISTRIBUTION

LOCATION No..... BORE HOLE No..... SAMPLE No..... PRETREATMENT DETAILS.....

DATE OF TEST..... DESCRIPTION..... LOSS ON PRETREATMENT.....%

ZONE I

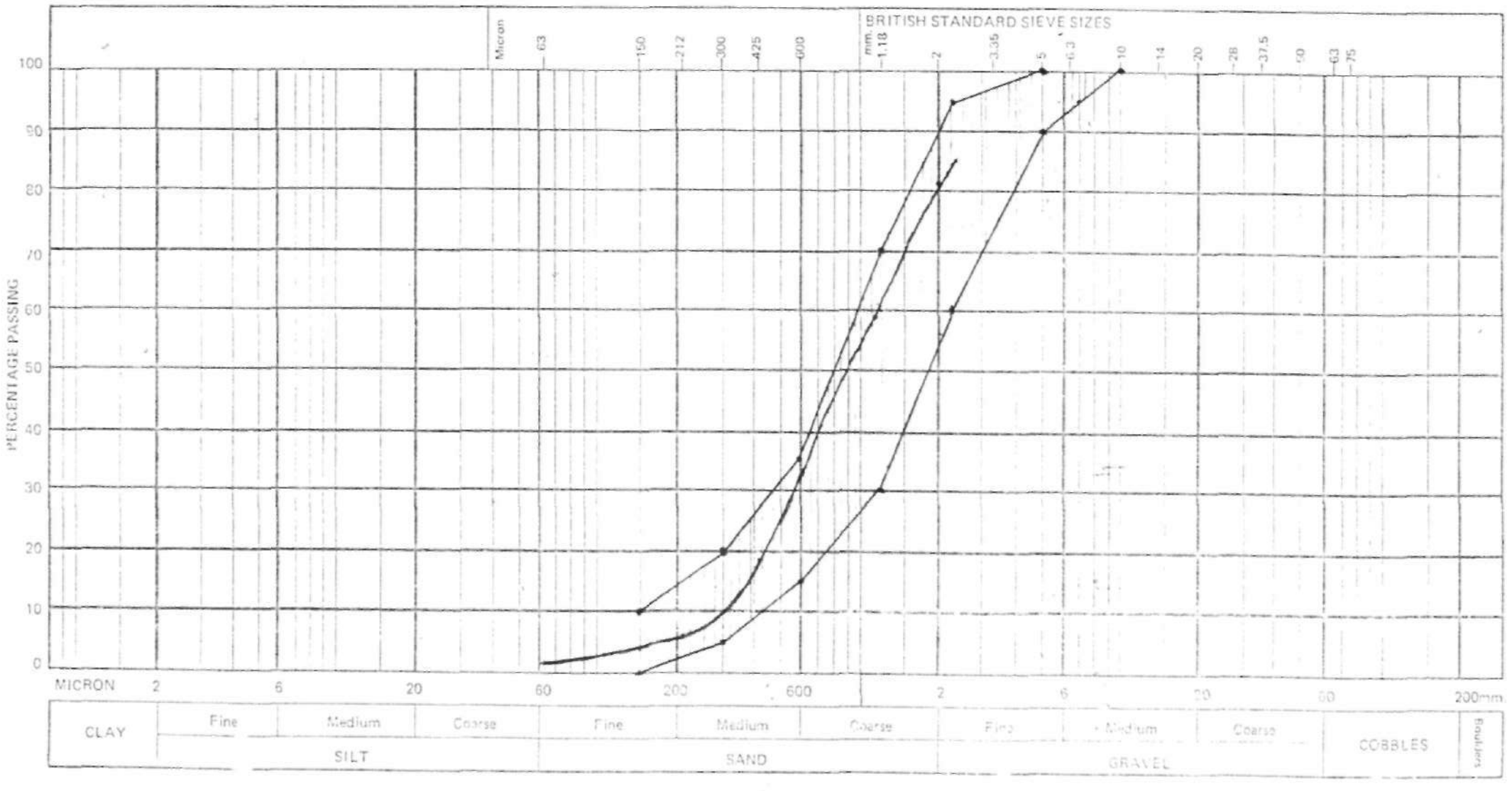


Figure 5: Grading Curve for Industry E

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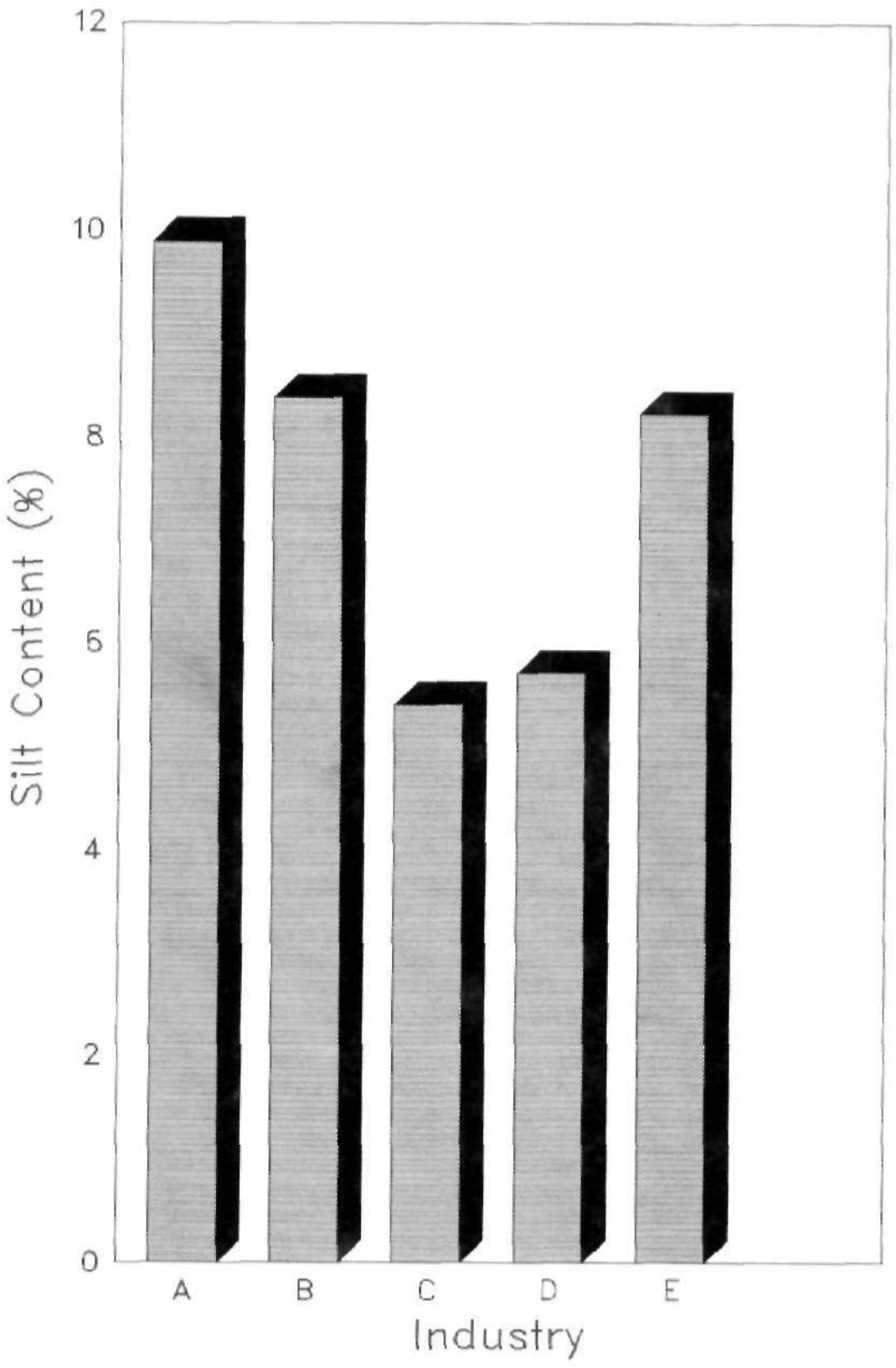
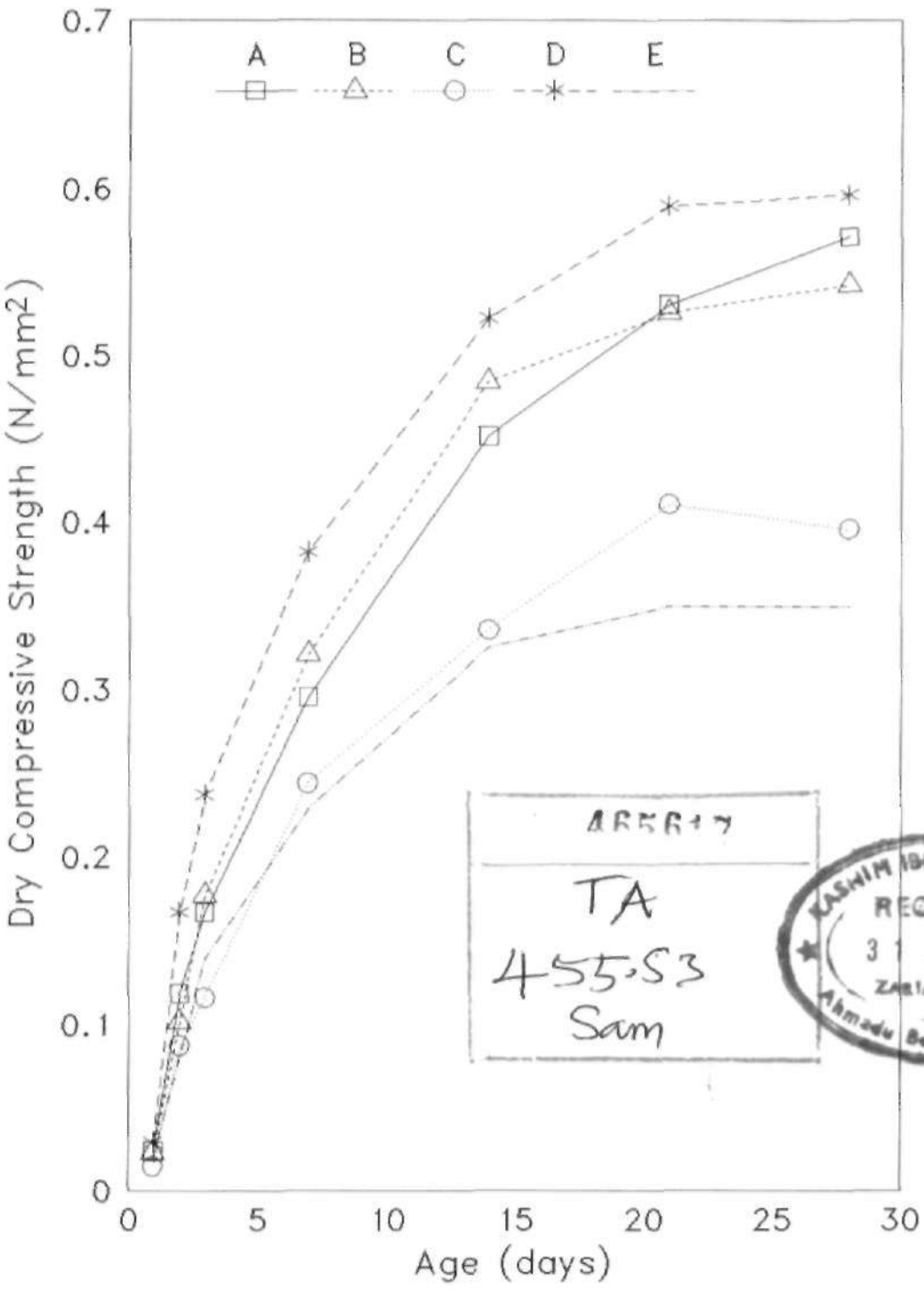


Figure 6 Silt Content of Samples



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Figure 7 Dry compressive Strength for all Samples, Industries A – E

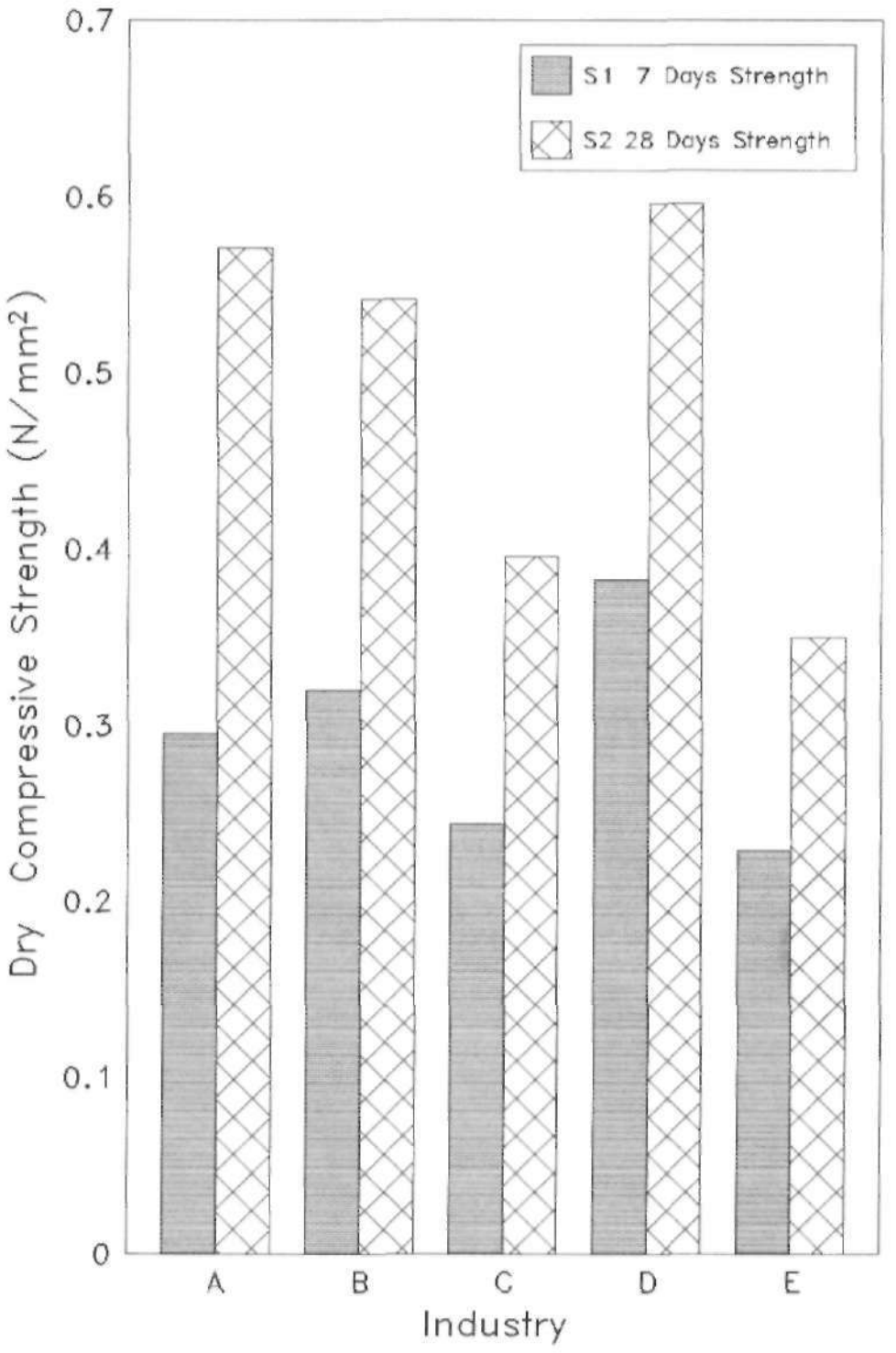


Figure 8 Dry Compressive Strength
for 7 and 28 Days of Samples

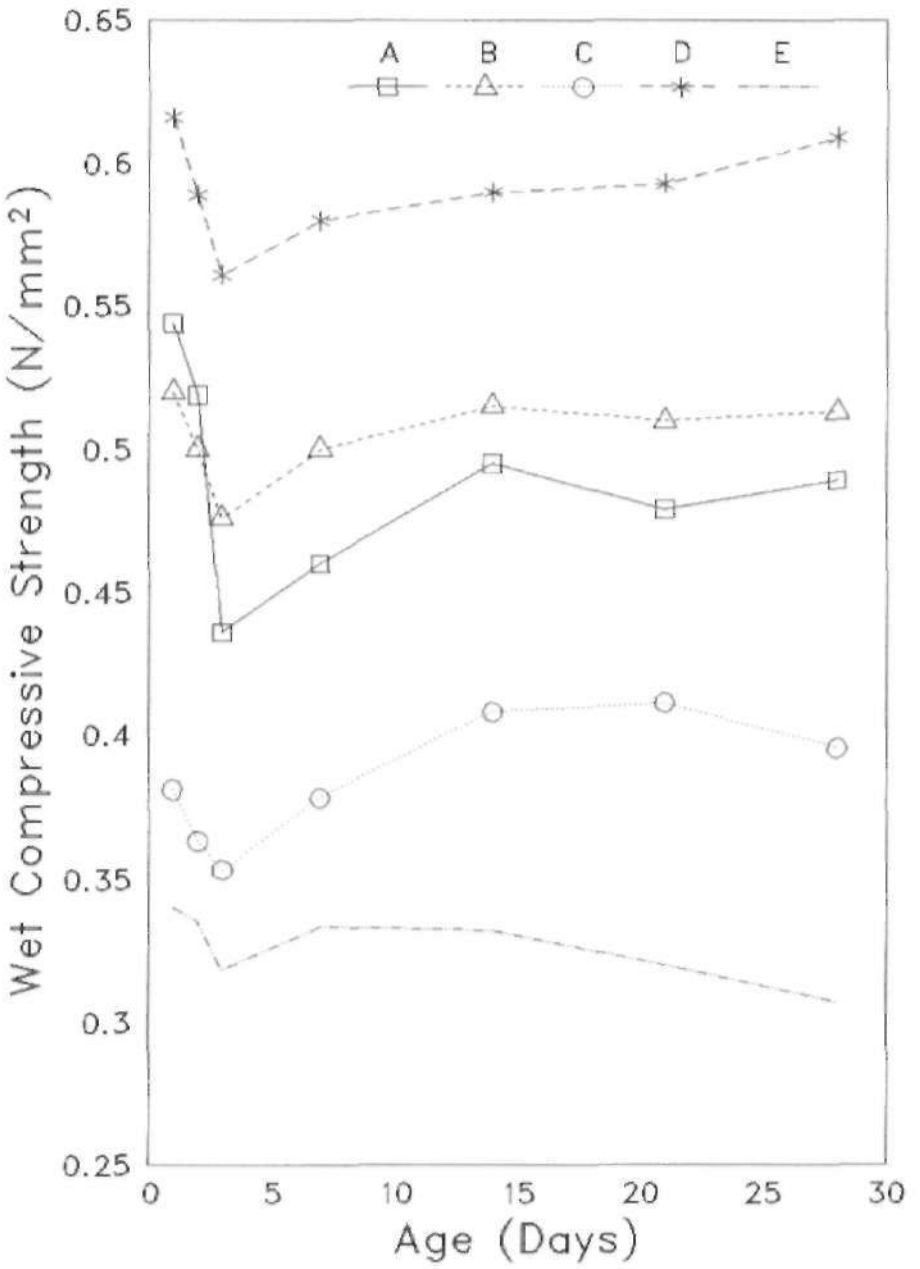


Figure 9 Wet Compressive Strength for all Samples

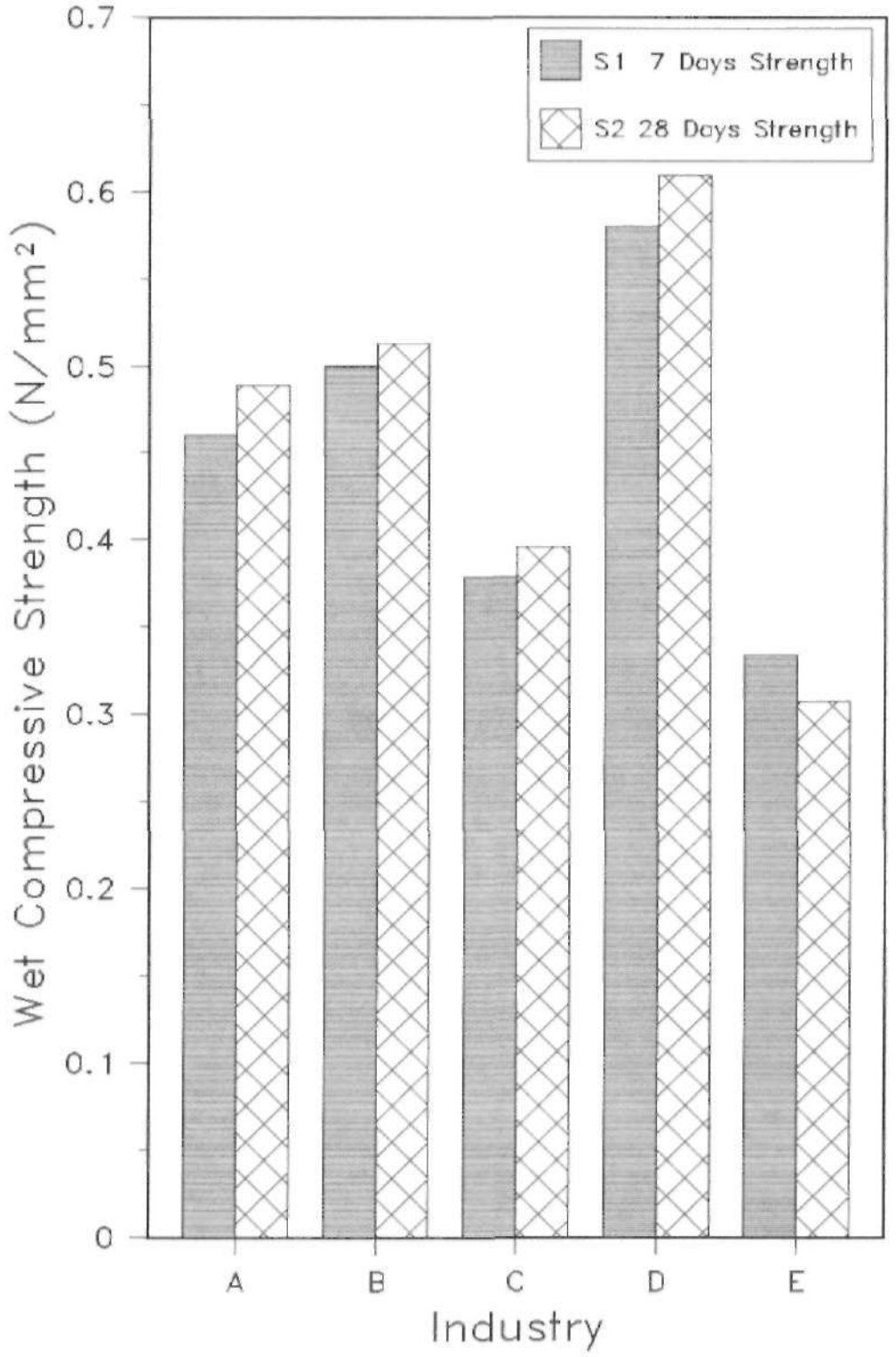


Figure 10 Wet Compressive Strength
for 7 and 28 Days of Samples

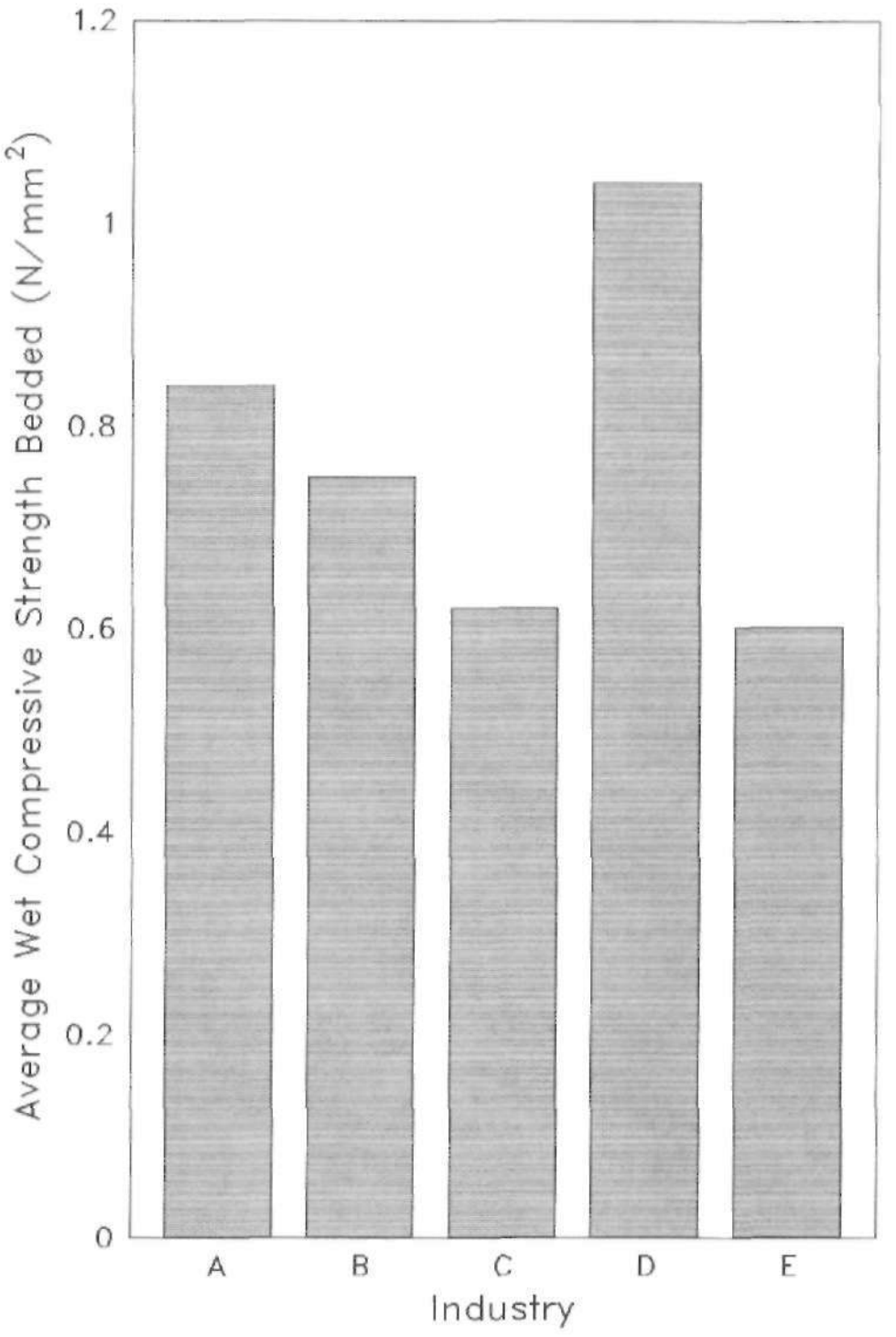


Figure 11 Average Wet Compressive strength Bedded With Mortar at 28 Days

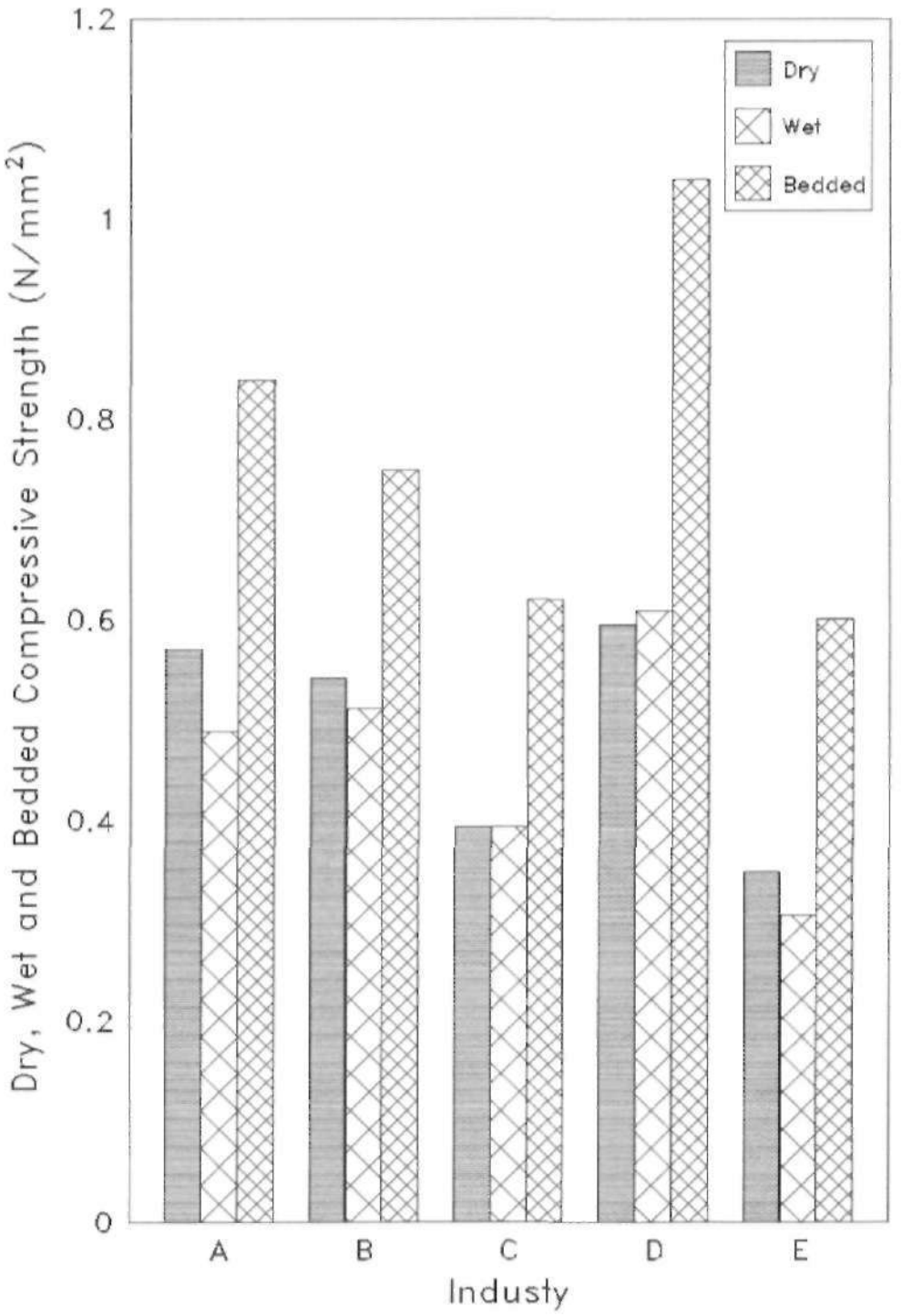


FIGURE 12 Dry, Wet and Bedded Compr-
essive Strength at 28 Days for all Samples

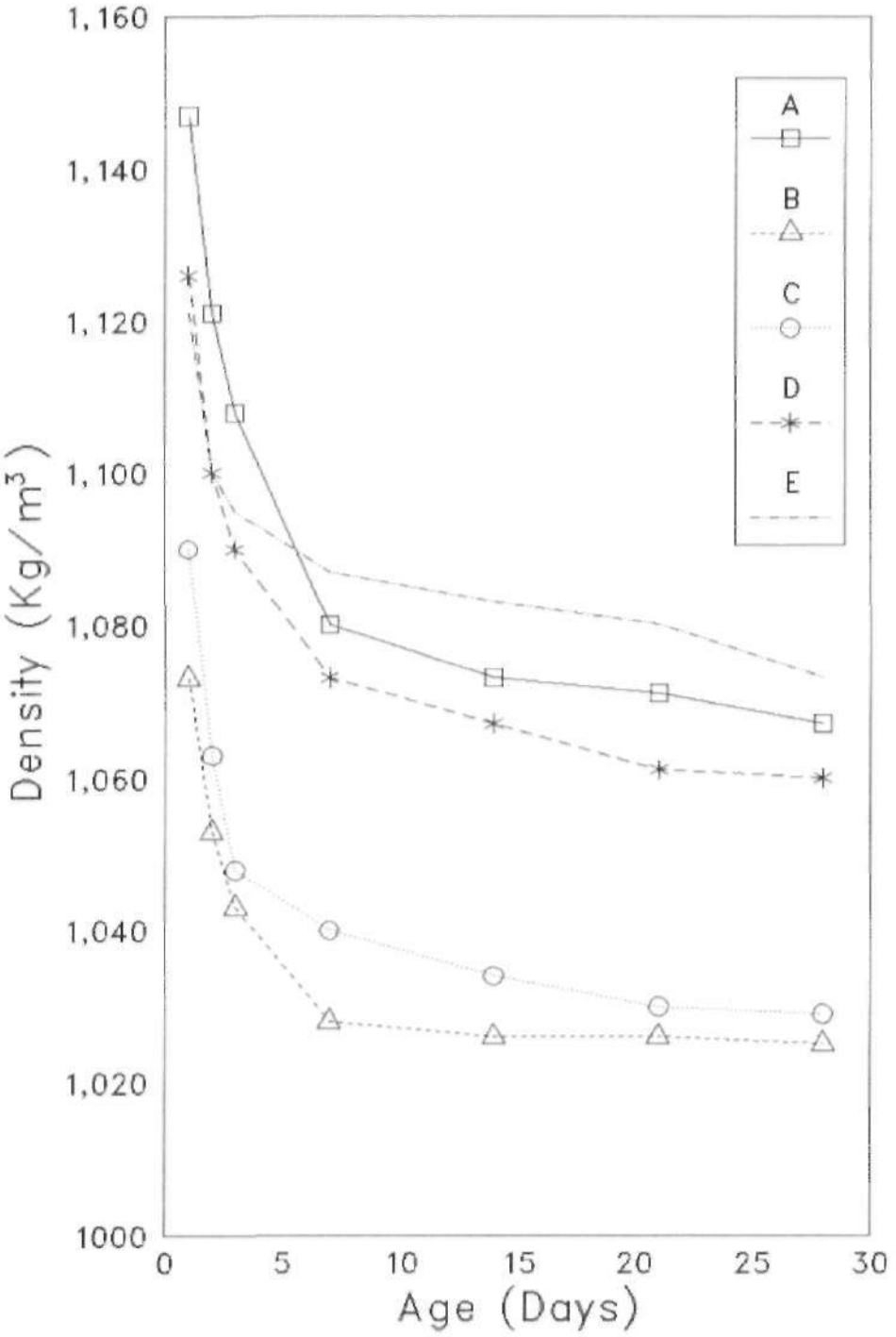


Figure 13 Desities of Samples

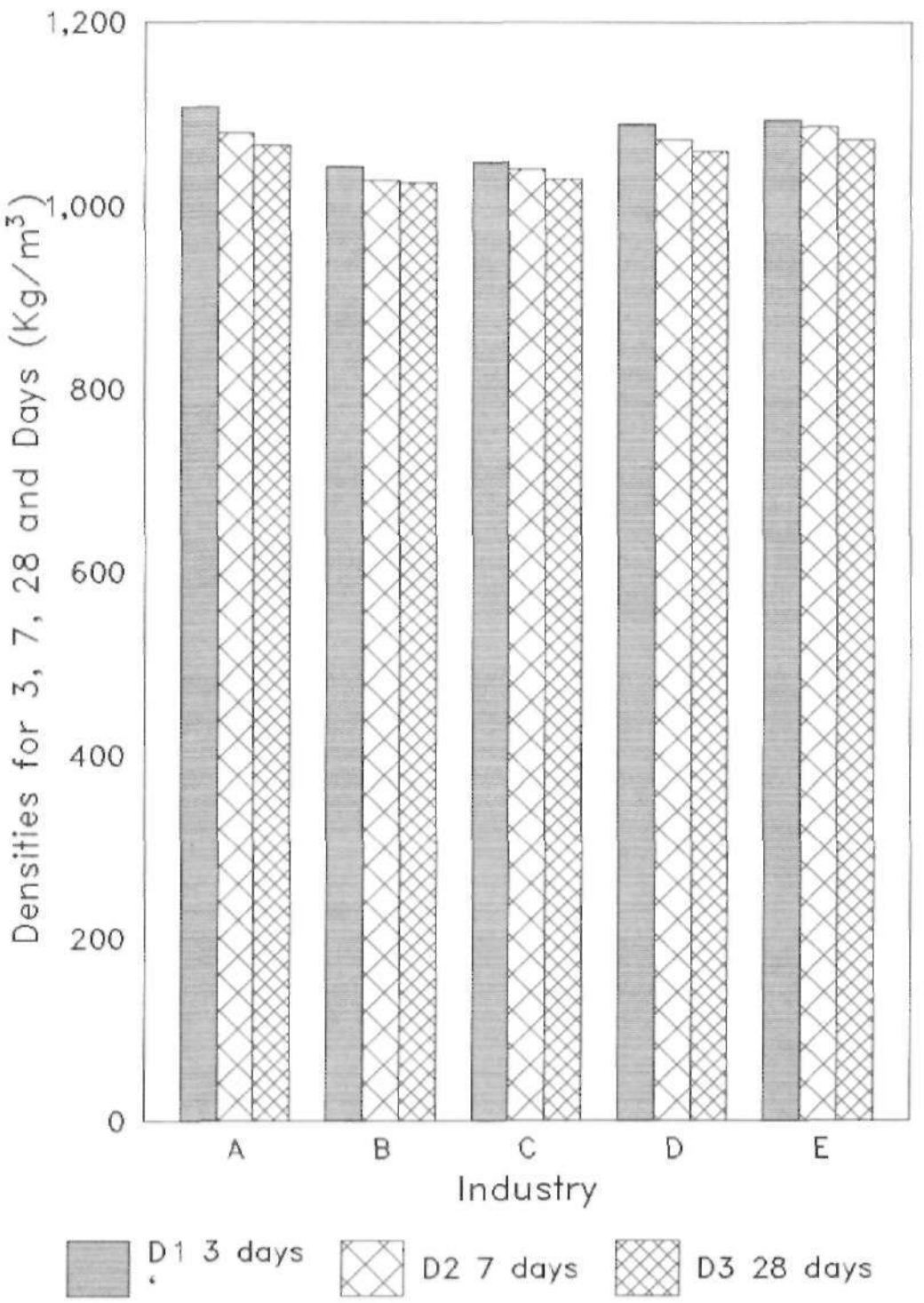


Figure 14 Densities for 3, 7 and 28 Days for all Samples

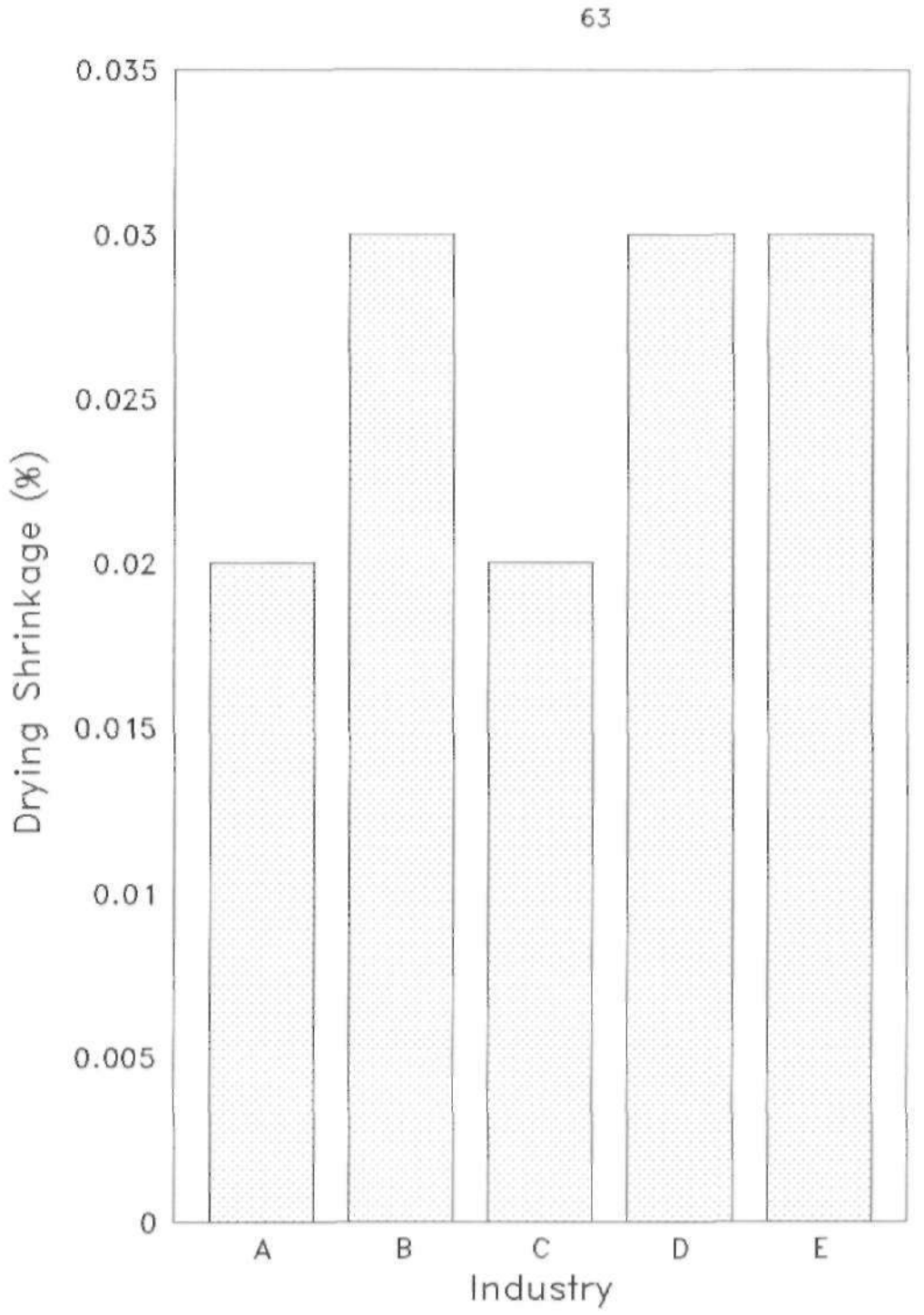


Figure 15 Drying Shrinkage of Samples

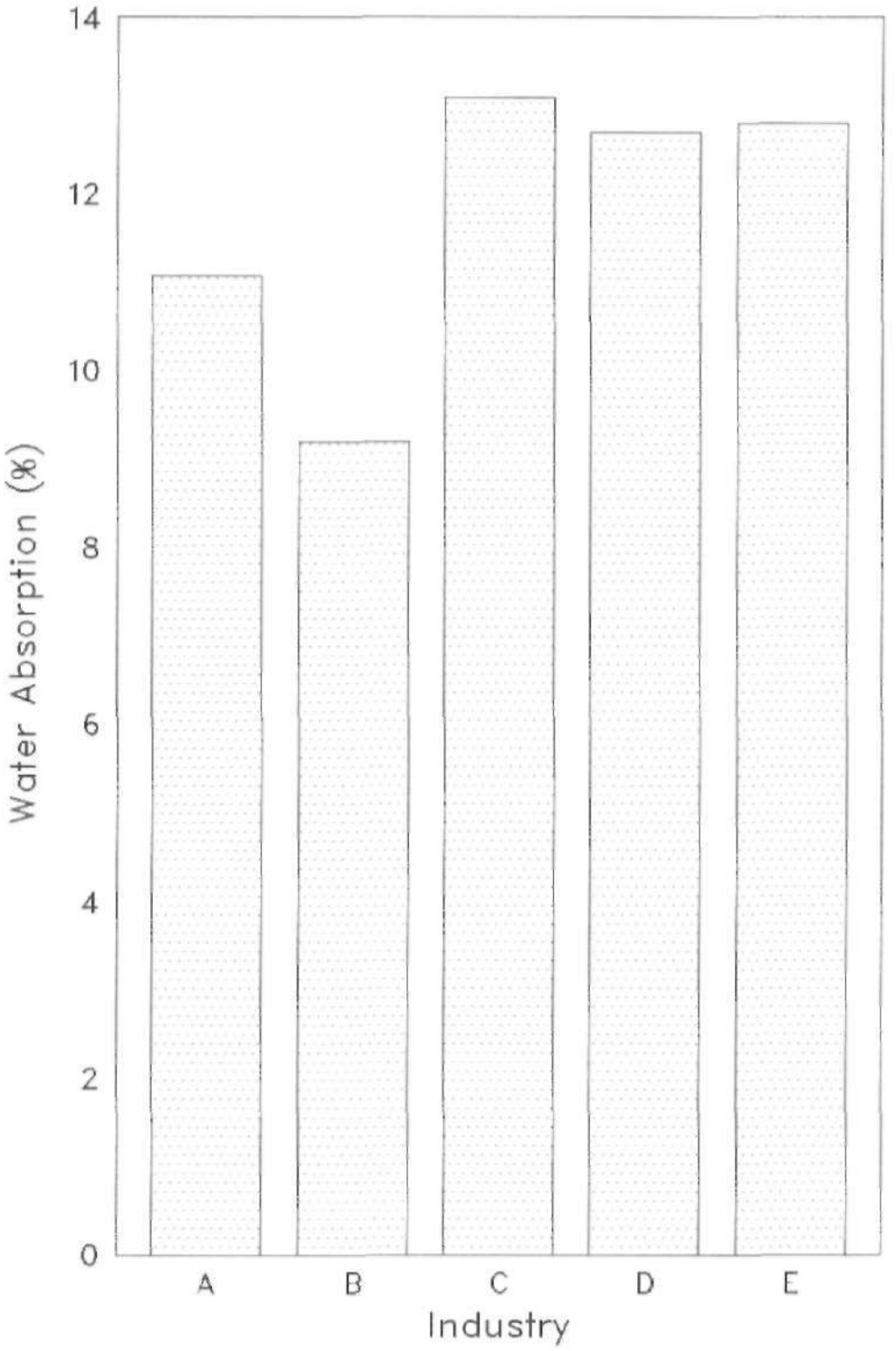


Figure 16 Water Absorption of Samples

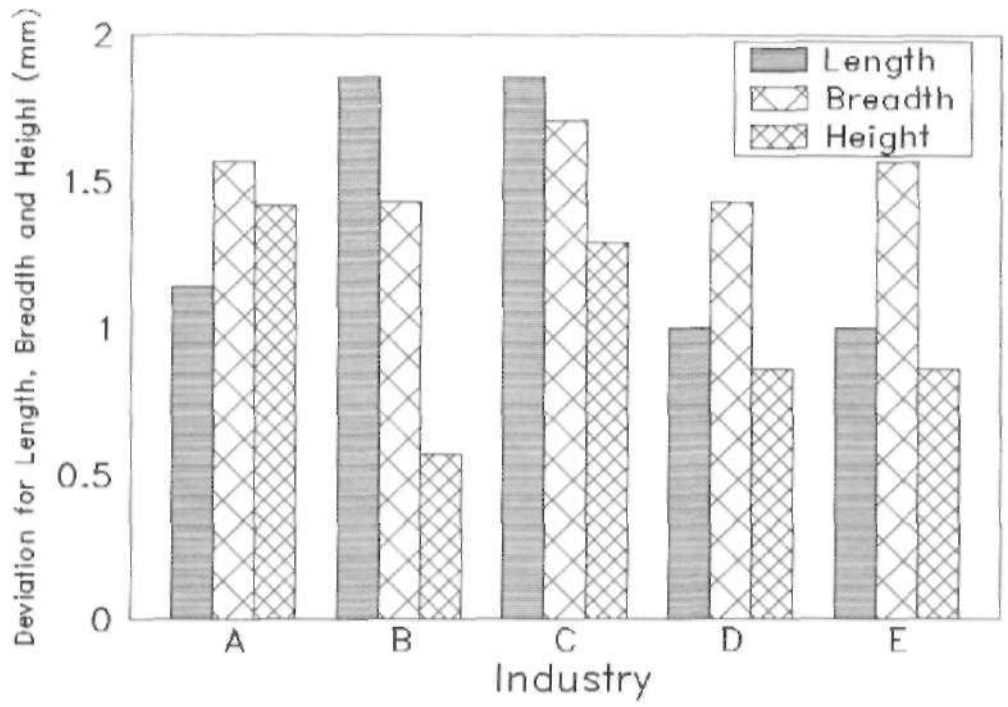


Figure 17 Deviation for Length, Breadth and Height of all Samples

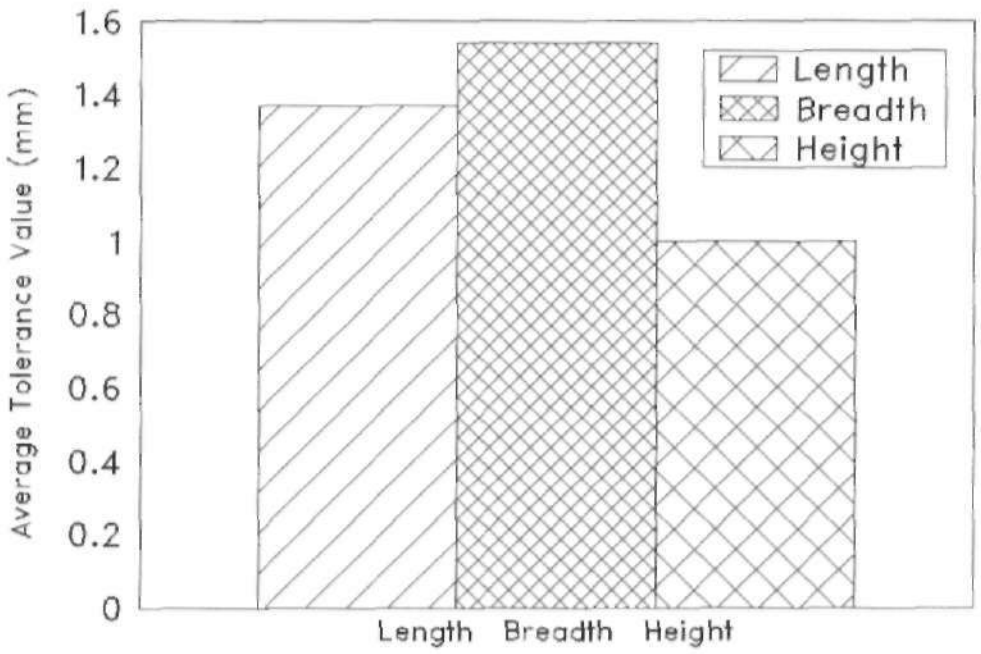


Figure 18 Average Tolerance Values for Length, Breadth and Height for all Samples

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The study is on the quality of hollow sandcrete blocks produced in Bauchi and Gombe States. It undertook to study the quality of production through various tests and analysis in order to ascertain the adequacy of the products.

The study reveals that the quality of blocks produced in these parts of the country do not measure up with the standards specified by BS 2028 (1968). The highest dry compressive strength achieved from this study is 0.594 N/mm² which is approximately 18.6% of the desired strength specified by BS 2028 (1968). The low values of strength can be attributed to poor mix ratios, inadequate curing, improper compaction, the skill and experience of the workers. Also, contributory to this are the inherent variation in the constituent materials (cement/sand) used in the production of the sandcrete blocks.

It is also noticed that the mortar used for the bedding does not contribute to the strength of the blocks but to hold them in place. This is shown from the strength recorded by the bedded blocks as against strength of the mortar cube.

In conclusion, the quality of any material can only be promoted through a set of nationally or internationally accepted standards and becomes very important that both the

manufacturer and the specifier/user are fully knowledgeable in the contents of the standard.

5.2 Recommendation

It is advocated that the Nigerian Standard Organization and other affiliated bodies like the Builders Society of Nigeria, Nigerian Society of Engineers etc, should periodically monitor the production of these industries. A way of doing this, is to make it mandatory for them to be registered with the necessary organizations which will monitor and issue test certificates on these products.

Also, a form of seminar/conferences should be arranged from time to time by these organizations for update of knowledge for the manufacturers.

REFERENCES

1. British Standard Institution BS 2028 (1968) "Precast concrete Blocks" Gaylard and Sons, London.
2. British Standard Institution BS 812 (1975) "Sampling and testing of Mineral Aggregate, Sands and Fillers Gaylard and Sons, London.
3. British Standard Institution BS 882 (1973) "Concrete Aggregates from Natural sources" Gaylard and Sons, London.
4. Building research station digest No. 22 (March 1958), "Sand for concrete"
5. Everett, Alan. (1970) "Mitchell's Building Construction Materials". B. T. Batfords Limited. pp 134 and 135.
6. Federal Ministry of works Annual Conference report (1979) Kano.
7. Gage, M. and Kirkbride, T. (1980) "Design in Block Work" 3rd Edition the Architectural Press, London. pp 7 - 35.
8. Iloghalu, Frank T.(1985). The Properties of Fired Building bricks viewed against that of sandcretes. October (1995). Proceedings of the seminar on the use of clay Bricks and blocks zaria pp 288 - 296.
9. Jackson, N. (1984) "Civil Engineering Materials 3rd edition Macmillan Publishers Ltd.; London pp 167 - 175; pp 235 - 246.
10. Nigerian Standard Organization NIS (1974). "Specification for burnt clay building units" UDC 624 . 012 . 8.

11. Nigerian Standard Organization NIS (1974). "Specification for Sandcrete Blocks" Draft Federal Ministry of Industry Lagos.

12. Neville, A. M (1981) "Properties of Concrete" 3rd Edition, Longman Group Limited.

13. Owolabi A. O. (1995), Nigerian Society of Engineers Technical Transactions Design and tests of Low Shrinkage Concrete from Local Materials.

14. Adeshola F. A. (1993) "Quality of sandcrete Hollow Blocks Manufactured in Ilorin and Its Environs" A Thesis submitted to the Postgraduate School, Ahmadu Bello University in partial fulfillment of the requirements for the degree of masters of Engineering in Civil Engineering. (unpublished)

15. Rasheed, O. B. (1992). "Quality of sandcrete Hollow Blocks in Kaduna State. A Thesis submitted to the Postgraduate School, Ahmadu Bello University in partial fulfillment of the requirements for the degree of masters of Engineering in Civil Engineering. (unpublished)

16. ROSA COMETTA (1975) Instrutions and Specifications for Operations And Maintenance of the Vibrobloc Model V.5 p.

17. West African Building Research Institute Annual Report (1961) West Atrican Building Research Institute Accra Ghana.

APPENDIX A1

Sieve Analysis for Industry A

Sieve size (mm)	Total Percentage Passing %		
	Sample 1	Sample 2	Average
2.36	90.1	89.2	89.7
2.00	86.3	85.3	85.8
1.18	67.3	65.9	66.6
600 μm	37.6	35.9	36.8
425 μm	23.0	21.8	22.4
300 μm	13.1	12.1	12.6
212 μm	6.20	3.7	5.0
150 μm	2.40	1.4	1.9
63 μm	0.7	1.0	0.9

APPENDIX A2

Sieve Analysis for Industry B

Sieve size (mm)	Total Percentage Passing		
	Sample 1	Sample 2	Average
2.36	90.5	88.5	90.5
2.00	88.5	85.3	86.9
1.18	68.4	65.6	67.0
600 μm	35.7	31.9	33.8
425 μm	21.0	17.9	19.50
300 μm	6.6	7.8	7.2
212 μm	2.9	3.1	3.0
150 μm	1.3	1.0	1.2
63 μm	0.5	0.8	0.7

APPENDIX A3

Sieve Analysis for Industry C

Sieve size (mm)	Total Percentage Passing %		
	Sample 1	Sample 2	Average
2.36	87.3	88.5	88.1
2.00	85.4	86.4	85.9
1.18	71.3	72.4	71.9
600 μm	46.0	45.9	46.0
425 μm	33.2	33.1	33.2
300 μm	24.2	24.8	24.5
212 μm	16.2	16.5	16.4
150 μm	8.6	8.8	8.7
63 μm	1.6	1.9	1.8

APPENDIX A4

Sieve Analysis for Industry D

Sieve size (mm)	Total Percentage Passing %		
	Sample 1	Sample 2	Average
2.36	88.3	89.3	88.0
2.00	84.30	85.9	85.10
1.18	58.90	67.70	63.30
600 μm	17.50	32.2	24.90
425 μm	5.95	12.10	9.03
300 μm	2.15	4.90	3.50
212 μm	0.90	1.50	1.20
150 μm	0.20	0.70	0.50
63 μm	0.10	0.30	0.20

APPENDIX A5

Sieve Analysis for Industry E

Sieve size (mm)	Total Percentage Passing %		
	Sample 1	Sample 2	Average
2.36	86.2	84.6	85.40
2.00	82.5	80.7	81.60
1.18	64.80	53.50	59.20
600 µm	32.4	32.0	32.20
425 µm	15.6	23.4	19.50
300 µm	6.7	8.5	7.6
212 µm	6.7	6.50	6.60
150 µm	1.6	4.7	3.20
63 µm	0.8	1.2	1.0

APPENDIX A6

Silt Content Analysis

Industry	Material	Height of sand (cm^3)	Height of sand + silt (cm^3)	Difference in level (cm^3)	Silt content %	Average silt content %
A	Sand	65.0 68.0 67.0	72.0 76.0 74	7.0 8.0 7.0	9.72 10.52 9.45	9.89
B	Sand	62.0 64.0 70.0	68.0 69.0 77.0	6.0 5.0 7.0	8.82 7.25 9.09	8.38
C	Sand	72.0 70.0 68.0	76.0 74.0 72.0	4.0 4.0 4.0	5.26 5.40 5.55	5.40
D	Sand	73.0 81.0 77.0	77.0 86.0 82.0	4.0 5.0 5.0	5.19 5.81 6.09	5.70
E	Sand	61.0 63.0 66.0	67.0 68.0 72.0	6.0 5.0 6.0	8.95 7.35 8.33	8.21

APPENDIX B1

Dry Compressive Strength Development Test Result for Industry A Blocks.

Identidi-cation number	Dimensions			Weight (Kg)	Age (days)	Density (kg/m^3)	Failure load (KN)	Crushing strength (N/mm^2)	Average strength (N/mm^2)
	Length (mm)	Breadth (mm)	Height (mm)						
BH/A/1	401	150	217	17.20	1	1146	2.00	0.028	0.024
BH/A/2	460	152	214	16.85		1123	1.60	0.023	
BH/A/3	461	152	215	17.35		1157	1.54	0.020	
BH/A/4	460	151	216	16.60	2	1107	4.50	0.065	0.118
BH/A/5	458	152	214	16.80		1120	9.00	0.129	
BH/A/6		151	214	16.50		1100	11.00	0.159	
BH/A/7	459	150	216	16.70	3	1113	15.00	0.218	0.166
BH/A/8	458	151	216	16.50		1100	9.20	0.133	
BH/A/9	459	151	215	16.40		1093	10.00	0.146	
BH/A/10	457	150	214	16.20	7	1080	26.00	0.379	0.295
BH/A/11	458	149	215	16.10		1073	15.20	0.220	
BH/A/12	458	149	213	15.90		1060	19.30	0.283	
BH/A/13	458	149	215	15.90	14	1060	39.00	0.571	0.451
BH/A/14	457	150	213	16.00		1067	30.50	0.445	
BH/A/15	458	149	213	16.80		1120	23.00	0.337	
BH/A/16	458	150	216	15.90	21	1060	38.00	0.553	0.530
BH/A/17	459	150	215	16.50		1100	40.50	0.588	
BH/A/18	458	149	214	16.10		1073	30.80	0.451	
BH/A/19	457	148	213	18.80	28	1120	33.00	0.488	0.571
BH/A/20	458	149	216	15.90		1067	43.00	0.630	
BH/A/21	458	150	215	16.40		1093	41.00	0.596	

APPENDIX B2

Dry Compressive Strength Development Test Result for Industry B Blocks.

Identification number	Dimensions			Weight (Kg)	Age (days)	Density (kg/m^3)	Failure load (KN)	Crushing strength (N/mm^2)	Average strength (N/mm^2)
	Length (mm)	Breadth (mm)	Height (mm)						
BH/B/1	457	151	217	16.40	1	1093	1.40	0.020	0.023
BH/B/2	457	149	215	16.10		1073	1.60	0.024	
BH/B/3	456	150	216	16.30		1087	1.80	0.026	
BH/B/4	455	152	216	16.10	2	1073	5.00	0.072	0.101
BH/B/5	455	151	214	15.80		1053	10.00	0.146	
BH/B/6	454	152	217	16.00		1067	6.00	0.186	
BH/B/7	456	150	219	15.80	3	1053	11.60	0.170	0.178
BH/B/8	455	151	218	15.60		1040	15.00	0.218	
BH/B/9	454	151	216	16.00		1067	10.00	0.146	
BH/B/10	457	150	213	15.70	7	1047	15.00	0.219	0.322
BH/B/11	456	150	214	15.30		1020	28.00	0.409	
BH/B/12	455	150	215	15.50		1033	23.00	0.337	
BH/B/13	455	151	217	15.80	14	1040	32.00	0.466	0.484
BH/B/14	456	149	218	15.30		1020	28.00	0.412	
BH/B/15	455	150	215	15.40		1027	39.00	0.571	
BH/B/16	454	151	217	15.30	21	1020	42.00	0.613	0.525
BH/B/17	456	151	216	15.50		1033	30.00	0.436	
BH/B/18	454	151	217	15.50		1033	36.00	0.525	
BH/B/19	454	149	218	15.40	28	1027	40.00	0.590	0.544
BH/B/20	454	149	217	15.20		1013	38.00	0.562	
BH/B/21	455	151	216	15.40		1027	33.00	0.480	

Appendix B3

Dry Compressive Strength Development Test Result for Industry C Blocks.

Identification number	Dimensions			Weight (Kg)	Age (days)	Density (kg/m^3)	Failure load (KN)	Crushing strength (N/mm^2)	Average strength (N/mm^2)
	Length (mm)	Breadth (mm)	Height (mm)						
BH/C/1	458	151	212	16.50	1	1093	0.80	0.012	0.016
BH/C/2	457	150	213	16.40		1093	1.20	0.021	
BH/C/3	457	150	210	16.30		1087	1.00	0.015	
BH/C/4	456	151	213	16.10	2	1073	4.00	0.058	0.087
BH/C/5	455	151	215	16.00		1067	8.00	0.116	
BH/C/6	454	151	212	15.90		1060	6.00	0.087	
BH/C/7	455	151	210	16.00	3	1067	7.00	0.102	0.117
BH/C/8	455	151	214	15.70		1047	10.00	0.146	
BH/C/9	455	149	213	15.80		1053	7.00	0.102	
BH/C/10	456	149	210	15.40	7	1027	15.00	0.221	0.243
BH/C/11	454	150	212	15.60		1040	18.00	0.264	
BH/C/12	454	149	211	15.70		1047	16.50	0.244	
BH/C/13	454	150	214	15.50	14	1027	27.00	0.396	0.336
BH/C/14	455	151	216	16.40		1040	18.00	0.262	
BH/C/15	454	151	213	15.70		1047	24.00	0.350	
BH/C/16	455	151	210	15.50	21	1033	31.00	0.451	0.410
BH/C/17	454	149	212	15.30		1020	25.00	0.370	
BH/C/18	455	150	214	15.40		1027	28.00	0.410	
BH/C/19	457	150	215	15.30	28	1020	24.00	0.350	0.394
BH/C/20	456	150	215	15.40		1027	29.00	0.424	
BH/C/21	456	151	216	15.30		1020	28.00	0.407	

APPENDIX B4

Dry Compressive Strength Development Test Result for Industry D Blocks.

Identification number	Dimensions			Weight (Kg)	Age (days)	Density (kg/m³)	Failure load (KN)	Crushing strength (N/mm²)	Average strength (N/mm²)
	Length (mm)	Breadth (mm)	Height (mm)						
GM/G/1	461	151	214	16.9	1	1127	1.50	0.022	0.029
GM/G/2	461	151	215	17.20		1133	2.20	0.032	
GM/G/3	460	151	217	16.80		1120	2.30	0.033	
GM/G/4	460	150	216	16.90	2	1127	9.60	0.139	**0.166**
GM/G/5	459	152	215	16.70		1113	12.00	0.173	
GM/G/6	459	151	213	16.40		1093	12.80	0.185	
GM/G/7	460	150	216	16.60	3	1107	14.00	0.203	0.237
GM/G/8	459	150	216	16.50		1100	18.00	0.261	
GM/G/9	460	150	215	16.40		1093	17.20	0.249	
GM/G/10	458	150	216	16.20	7	1080	23.40	0.338	0.382
GM/G/11	459	151	213	16.30		1087	29.00	0.419	
GM/G/12	458	151	214	16.30		1087	26.80	0.388	
GM/G/13	459	150	212	15.80	14	1053	30.00	0.436	0.523
GM/G/14	459	150	210	16.00		1067	38.00	0.552	
GM/G/15	460	151	214	15.90		1060	40.00	0.581	
GM/G/16	458	151	214	16.00	21	1067	38.50	0.557	0.589
GM/G/17	460	149	213	15.90		1060	43.50	0.629	
GM/G/18	458	151	215	16.00		1067	40.30	0.583	
GM/G/19	458	150	215	15.90	28	1060	45.00	0.655	0.594
GM/G/20	458	149	216	15.90		1060	38.00	0.549	
GM/G/21	458	151	215	15.80		1053	40.00	0.578	

APPENDIX B5

Dry Compressive Strength Development Test Result for Industry E Blocks.

Identification number	Dimensions			Weight (Kg)	Age (days)	Density (kg/m³)	Failure load (KN)	Crushing strength (N/mm²)	Average strength (N/mm²)
	Length (mm)	Breadth (mm)	Height (mm)						
GM/B/1	460	151	216	16.90	1	1127	1.20	0.017	0.02
GM/B/2	459	150	214	16.80		1120	1.60	0.032	
GM/B/3	460	151	216	17.00		1133	1.40	0.020	
GM/B/4	460	151	215	16.60	2	1107	4.00	0.058	0.084
GM/B/5	460	150	213	16.30		1087	6.40	0.092	
GM/B/6	460	151	216	16.50		1100	7.00	0.101	
GM/B/7	460	151	215	16.50	3	1100	8.40	0.122	0.139
GM/B/8	459	150	215	16.40		1093	8.80	0.129	
GM/B/9	459	150	216	16.80		1120	11.60	0.168	
GM/B/10	459	151	216	16.20	7	1080	12.00	0.172	0.229
GM/B/11	458	151	215	16.60		1107	20.00	0.287	
GM/B/12	459	152	215	16.10		1073	16.00	0.230	
GM/B/13	459	149	214	16.20	14	1080	18.00	0.265	0.324
GM/B/14	458	149	215	16.50		1100	24.00	0.353	
GM/B/15	458	148	214	15.90		1060	42.00	0.353	
GM/B/16	458	150	213	16.30	21	1087	20.00	0.289	0.350
GM/B/17	459	149	215	15.30		1073	30.00	0.434	
GM/B/18	458	150	214	16.00		1067	22.60	0.327	
GM/B/19	458	150	216	16.10	28	1073	29.00	0.421	0.348
GM/B/20	458	150	214	15.90		1060	19.00	0.276	
GM/B/21	458	149	215	16.00		1067	24.00	0.349	

APPENDIX B6

Dry Compressive Strength Development Test Result for Industry A Blocks.

Identification number	Dimensions			Weight (Kg)	Age (days)	Density (kg/m^3)	Failure load (KN)	Crushing strength (N/mm^2)	Average strength (N/mm^2)
	Length (mm)	Breadth (mm)	Height (mm)						
BH/A/22	463	153	219	17.80	1	1148	40.20	0.567	0.543
BH/A/23	464	154	220	17.60		1135	33.40	0.471	
BH/A/24	462	152	220	18.40		1186	41.90	0.591	
BH/A/25	461	154	219	18.50	2	1193	31.60	0.444	0.518
BH/A/26	463	154	218	18.80		1212	39.20	0.551	
BH/A/27	463	153	220	18.70		1206	39.80	0.559	
BH/A/28	464	152	217	18.90	3	1219	28.00	0.398	0.436
BH/A/29	463	151	219	18.40		1186	26.00	0.369	
BH/A/30	462	153	220	18.10		1167	38.00	0.540	
BH/A/31	464	155	216	19.10	7	1231	33.60	0.471	0.460
BH/A/32	464	154	219	19.00		1225	30.00	0.421	
BH/A/33	462	154	218	17.80		1148	34.80	0.488	
BH/A/34	463	155	221	18.60	14	1199	40.00	0.565	0.494
BH/A/35	463	152	220	17.90		1154	33.00	0.466	
BH/A/36	462	153	219	18.50		1192	32.00	0.452	
BH/A/37	463	152	218	18.50	21	1193	30.00	0.424	0.479
BH/A/38	461	153	217	18.00		1160	35.60	0.504	
BH/A/39	462	154	219	17.80		1148	36.00	0.509	
BH/A/40	461	153	216	17.50	28	1128	37.00	0.527	0.488
BH/A/41	462	152	220	17.70		1141	32.00	0.456	
BH/A/42	463	152	216	17.40		1122	33.80	0.481	

APPENDIX B7:

Wet Compresive Strength Development Test Result for Industry B Blocks.

Identification	Dimensions			Weight (kg)	Age days)	Density (kg/m^3)	Failure load (KN)	Crushing strenght. N/mm^2	Average Strenght. (N/mm^2)
	Length (mm)	Breadth (mm)	Height (kg)						
BH/B/22	459	152	218	17.30	1	1116	38.00	0.542	0.519
BH/B/23	458	154	219	17.70		1142	35.00	0.510	
BH/B/24	458	153	220	17.80		1148	35.40	0.505	
BH/B/25	459	153	218	18.10	2	1168	33.00	0.470	0.500
BH/B/26	457	154	217	17.60		1135	32.00	0.456	
BH/B/27	460	152	217	18.80		1213	40.30	0.574	
BH/B/28	459	154	218	18.60	3	1200	28.00	0.399	0.476
BH/B/29	459	153	219	18.40		1187	38.00	0.541	
BH/B/30	458	152	217	18.30		1181	34.20	0.479	
BH/B/31	461	153	219	18.70	7	1206	32.00	0.459	0.499
BH/B/32	459	152	218	17.90		1155	39.00	0.559	
BH/B/33	459	152	216	17.60		1135	33.40	0.579	
BH/B/34	458	153	216	17.40	14	1122	37.00	0.527	0.514
BH/B/35	459	152	217	17.60		1135	39.20	0.558	
BH/B/36	460	153	218	17.60		1135	32.10	0.457	
BH/B/37	459	152	216	17.20	21	1110	40.20	0.577	0.510
BH/B/38	458	152	215	17.30		1116	35.50	0.510	
BH/B/39	458	153	218	17.40		1123	30.80	0.442	
BH/B/40	460	154	219	18.50	28	1194	38.00	0.541	0.513
BH/B/41	459	153	218	18.80		1213	29.00	0.413	
BH/B/42	459	152	217	18.40		1187	41.00	0.584	

APPENDIX B8

Wet Compresive Strength Development Test Result for Industry C Blocks.

Identification	Dimensions			Weight (kg)	Age (days)	Density (kg/m³)	Failure load (KN)	Crushing strength (N/mm²)	Average N/mm²
	Length (mm)	Breadth (mm)	Height (kg)						
BH/T/22	458	153	217	17.60	1	1135	25.80	0.368	0.381
BH/T/23	467	152	218	17.50		1129	32.20	0.474	
BH/T/24	458	153	217	17.80		1148	21.10	0.301	
BH/T/25	457	152	216	17.60	2	1135	20.00	0.286	0.363
BH/T/26	457	153	216	17.40		1123	28.20	0.403	
BH/T/27	458	153	217	17.30		1116	28.00	0.400	
BH/T/28	459	154	218	18.10	3	1168	19.00	0.270	0.353
BH/T/29	460	153	219	18.60		1200	30.20	0.430	
BH/T/30	458	153	218	18.20		1174	25.20	0.359	
BH/T/31	458	152	217	18.00	7	1161	35.00	0.503	0.378
BH/T/32	456	152	217	17.30		1116	24.00	0.345	
BH/T/33	459	153	218	17.90		1155	20.00	0.287	
BH/T/34	459	153	216	18.30	14	1181	31.00	0.441	0.407
BH/T/35	460	154	219	18.70		1206	30.00	0.427	
BH/T/36	458	153	217	18.60		1200	24.80	0.353	
BH/T/37	459	152	216	18.70	21	1206	32.00	0.460	0.411
BH/T/38	458	153	218	18.30		1181	26.00	0.373	
BH/T/39	457	152	217	17.90		1155	27.80	0.399	
BH/T/40	457	153	217	17.60	28	1135	29.40	0.420	0.394
BH/T/41	458	153	217	17.80		1148	26.80	0.382	
BH/T/42	458	152	218	18.00		1161	26.60	0.380	

APPENDIX B9:

Wet Compresive Strength Development Test Result for Industry D Blocks.

Identification	Dimensions			Weight (kg)	Age (days)	Density (kg/m³)	Failure load (KN)	Crushing strength (N/mm²)	Average N/mm²
	Length (mm)	Breadth (mm)	Height (kg)						
GM/G/22	463	153	217	19.10	1	1231	45.00	0.635	0.615
GM/G/23	464	152	218	19.00		1225	36.00	0.508	
GM/G/24	463	153	219	18.90		1219	49.80	0.703	
GM/G/25	464	154	216	18.60	2	1200	41.00	0.575	0.589
GM/G/26	463	154	217	18.40		1187	44.00	0.617	
GM/G/27	462	154	219	18.60		1200	41.00	0.575	
GM/G/28	464	153	220	19.00	3	1225	34.50	0.487	0.560
GM/G/29	463	152	220	18.80		1213	43.00	0.607	
GM/G/30	463	154	219	18.30		1181	41.60	0.587	
GM/G/31	464	153	216	19.20	7	1239	37.00	0.526	0.580
GM/G/32	463	152	218	18.60		1200	40.00	0.568	
GM/G/33	463	152	219	18.40		1187	45.40	0.645	
GM/G/34	463	153	219	18.50	14	1194	43.00	0.608	0.590
GM/G/35	462	153	218	17.90		1155	40.80	0.577	
GM/G/36	462	152	216	17.80		1148	41.30	0.584	
GM/G/37	464	153	217	18.60	21	1200	38.00	0.536	0.593
GM/G/38	463	154	218	18.40		1187	45.00	0.635	
GM/G/39	462	153	219	18.20		1174	43.00	0.607	
GM/G/40	462	152	218	18.00	28	1161	47.00	0.669	0.609
GM/G/41	462	152	216	17.90		1155	40.00	0.570	
GM/G/42	463	153	217	17.80		1148	41.40	0.590	

APPENDIX B10

Wet Compresive Strength Development Test Result for Industry E Blocks.

Identification	Dimensions			Weight (kg)	Age (days)	Density (kg/m^3)	Failure load (KN)	Crushing strength (N/mm^2)	Average N/mm^2
	Length (mm)	Breadth (mm)	Height (kg)						
GM/G/22	463	153	220	18.70	1	1206	20.00	0.282	0.340
GM/G/23	462	154	219	18.30		1181	31.00	0.438	
GM/G/24	464	153	219	18.60		1200	21.30	0.301	
GM/G/25	463	153	219	18.10	2	1168	27.00	0.380	0.335
GM/G/26	464	153	218	18.40		1187	25.00	0.352	
GM/G/27	464	152	216	18.60		1200	19.40	0.273	
GM/G/28	462	152	218	17.90	3	1155	18.50	0.263	0.317
GM/G/29	463	153	217	17.60		1135	28.00	0.399	
GM/G/30	462	152	217	17.70		1142	20.40	0.290	
GM/G/31	464	154	218	19.00	7	1225	26.80	0.375	0.333
GM/G/32	464	154	219	18.20		1174	24.00	0.336	
GM/G/33	464	153	217	18.80		1213	20.00	0.288	
GM/G/34	462	153	218	17.90	14	1155	21.70	0.306	0.331
GM/G/35	463	152	219	17.70		1142	28.20	0.398	
GM/G/36	463	153	219	17.60		1135	20.60	0.290	
GM/G/37	462	152	218	17.60	21	1135	22.40	0.317	0.320
GM/G/38	462	153	217	17.90		1153	23.60	0.334	
GM/G/39	463	153	218	18.30		1181	21.80	0.308	
GM/G/40	463	154	216	18.70	28	1206	27.00	0.379	0.307
GM/G/41	462	153	217	17.90		1155	20.00	0.280	
GM/G/42	463	154	219	17.50		1129	18.70	0.262	

APPENDIX C1

Deviation on the measured Dimension of the blocks for indusrty A.

Original Dimension (mm)			Measured Dimension (mm)			Difference (mm)		
L	B	H	L	B	H	L	B	H
460	152	217	461	152	218	-1	0	-1
			459	152	216	1	0	1
			459	151	215	1	1	2
			458	149	214	2	3	3
			458	150	216	2	2	1
			459	150	216	1	1	1
			458	149	214	2	2	3
					—	8	11	10
					X	1.14	1.57	1.42
					δ	0.99	1.18	1.29

$\bar{x}$ Total = 1.38
δ Total = 1.15

APPENDIX C2

Deviation on the measured Dimension of the blocks

for industry B.

Original Dimension (mm)			Measured Dimension (mm)			Difference (mm)		
L	B	H	L	B	H	L	B	H
457	152	217	457	150	216	0	2	1
			454	152	216	3	0	1
			455	151	218	2	1	-1
			456	150	214	1	2	3
			455	150	216	2	2	1
			454	151	217	3	1	0
			455	150	218	2	2	-1
					Σ	13	10	4
					$\bar{x}$	1.86	1.43	0.57
					δ	0.99	0.73	1.29

$\bar{x}$ Total = 1.29
δ Total = 1.00

APPENDIX C3

Deviation on the measured Dimension of the blocks

for industry C.

Original Dimension (mm)			Measured Dimension (mm)			Difference (mm)		
L	B	H	L	B	H	L	B	H
457	152	217	457	150	217	0	2	1
			455	151	215	2	1	1
			455	151	216	2	1	-1
			454	149	216	3	3	3
			454	151	214	3	1	1
			455	150	217	2	2	0
			456	150	215	1	2	-1
					$\bar{}$	13	12	9
					X	1.86	1.71	1.29
					δ	0.99	0.70	1.03

$\bar{x}$ Total = 1.62

δ Total = 0.91

APPENDIX C4

Deviation on the measured Dimension of the blocks

for industry D.

Original Dimension (mm)			Measured Dimension (mm)			Difference (mm)		
L	B	H	L	B	H	L	B	H
460	152	217	461	151	216	-1	1	1
			459	151	214	1	1	3
			460	150	216	0	2	1
			458	151	216	2	1	1
			459	150	218	1	2	-1
			458	151	216	2	1	2
			458	150	218	2	2	-1
					—	7	10	6
					X	1.0	1.43	0.86
					δ	1.07	0.49	1.36

$\overline{X}$ Total = 1.10
δ Total = 0.97

APPENDIX C5

Deviation on the measured Dimension of the blocks

for industry E.

Original Dimension (mm)			Measured Dimension (mm)			Difference (mm)		
L	B	H	L	B	H	L	B	H
460	152	217	460	151	218	0	1	-1
			460	151	216	0	1	1
			459	150	216	1	2	1
			458	152	215	2	0	2
			459	148	214	1	4	3
			458	151	218	2	1	-1
			459	150	216	1	2	1
					Σ	7	11	6
					$\bar{x}$	1.0	1.57	0.86
					δ	1.03	1.18	1.36

$\bar{x}$ Total = 1.05

δ Total = 1.19