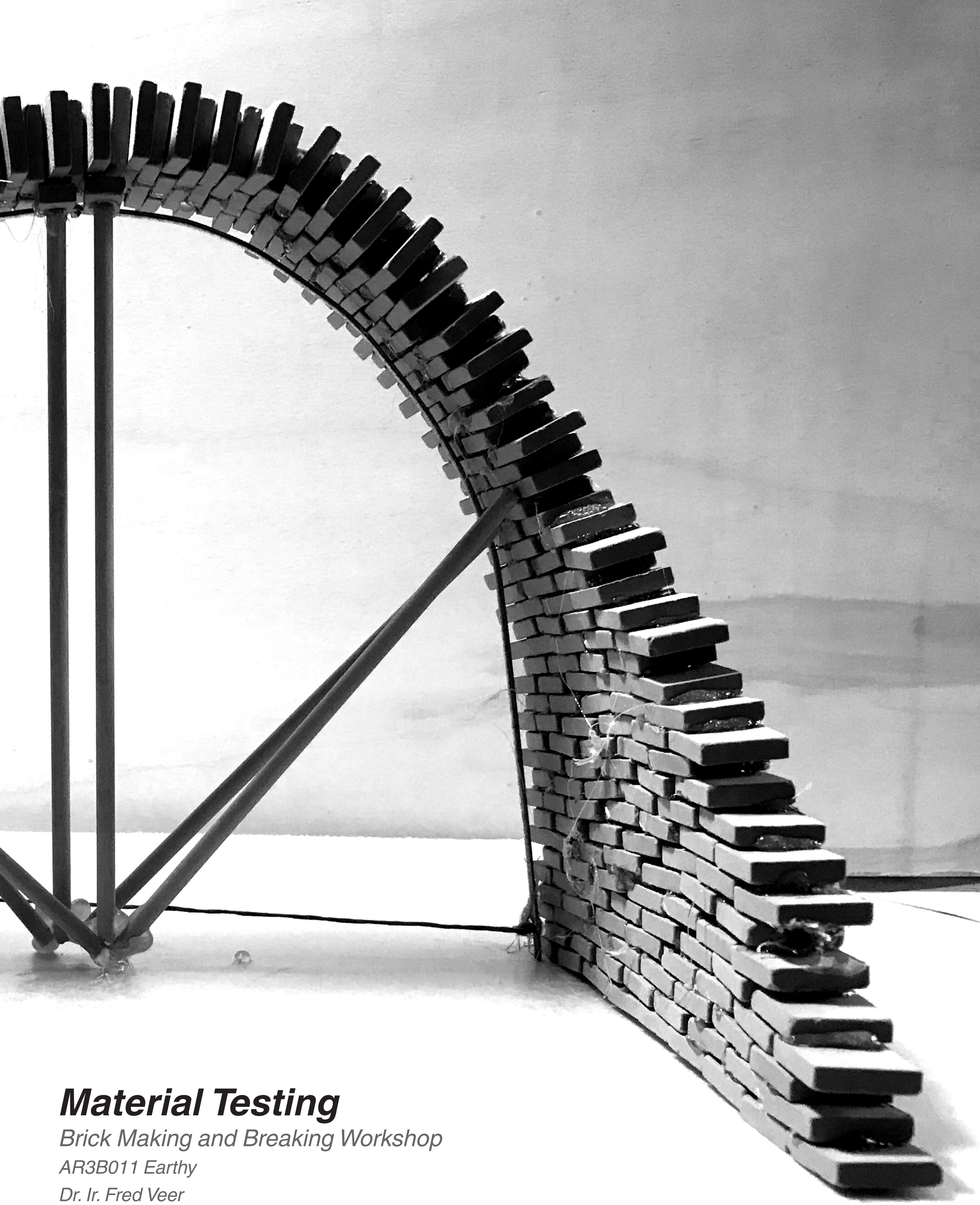

Material Testing

Brick Making and Breaking Workshop

AR3B011 Earthy

Dr. Ir. Fred Veer

Material Testing Experiment

An exploratory exercise to determine design values of Adobe Bricks.

AR3B011 Earthy

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Content

01 | Introduction

The Syrian conflict in 2011 caused a large population to migrate from Syria to Jordon. To facilitate these massive populations, the Jordanian government has set up refugee camps which are a temporary solution (REACH, 2016). However, since 2011 the camp of Al Zaatari, Jordan, with the help of non-government agencies is developing to provide better habitat. Although because of the temporal nature of the camp, the current environment of these habitats is container boxes and makeshift tent structure which does solve the practical needs but lack humanitarian needs.

Adobe buildings made from earth has a potential of solving the functional and comfort requirements of the habitants. Since the refugee camp is in an arid region with an abundance of materials for adobe, this construction technology can be a better alternative for making temporary buildings which can also be developed by the people using it.

However, due to lack of resources in the camp, it is imperative to understand that the adobe structures would be compression-only and its strength will largely depend upon the adobe bricks used for construction. Therefore, this paper will investigate various brick making strategies, mixes and design values for further development of the adobe buildings.

02 | Methodology

The objective of this experiment is to discover the mechanical properties of various combinations of raw materials used to create adobe bricks. The mechanical properties to be considered are Young's Modulus and compressive strength. Although, mechanical properties like tensile strength, density values will rely on literature study. Insight into these mechanical properties of various mixtures of the adobe bricks will be used as inputs for the material properties in further structural analysis of the Skill Development Center of Zaatari camp designed by group 1. Since Adobe is a material that lacks certifications due to deviations in soil composition and the uncontrolled, natural drying process, we are not interested in the ultimate strengths of the material, but rather design values which can be used to create safe structures. The main research question is, What are the design values for compressive strength and Young's Modulus of the adobe bricks made during the brick-making workshop? To answer this primary research question, several sub-questions have been formulated:

1. *How can mechanical properties be determined of these bricks?*

2. *How can the data found to be interpreted to find design values?*

3. *Which safety factors should be considered for these adobe brick structures?*

Prerequisite of this experiment is the creation of the Adobe bricks with various raw materials. The goal is to find successful combinations and ratios of raw materials to create blocks that are as strong as possible. However, it is imperative to understand which raw materials can be used to develop stronger adobe bricks and why?

2.1 Limitations on Material Availability

Since we are working in the context of Zaatari refugee camp in Jordan, there are several limitations on the availability of materials which can be used to create Adobe mixtures. Since many refugees flee to Zaatari without many personal belongings or money, many of the available objects and materials cannot be used for construction. UNHCR and other aid organisations bring in mainly the necessary artefacts and elements which need to be used for the specific reasons they are brought into the camp. This means the available materials should be found mainly from waste streams since these are the only materials that are not being used and are not wanted by anyone in the camp, its dependency on the physical factors and the vote of the people dwelling in the space.

2.2 Research Design

The research consists of two main parts, the first part is the making of the adobe bricks and the second part is the breaking of the adobe bricks. The making part of the research starts with literature research, followed by methodically making moulds and mixtures for the blocks. The breaking part consists of bricks undergoing a uniaxial compression test, which records the applied force and displacement on a computer. By interpreting the results of this experiment correctly, it is possible to find design values for various mixtures of the adobe bricks which will help in structural optimisation.

2.2.1 Making: literature research

Firstly, literature research is conducted to learn more about adobe brick creation. According to Christian Bock (2016), generally for stabilised earth blocks, cement is used as a binder, clay acts as fine aggregate and sand is used as the large aggregate. However, we do not have access to any cement in this case, so we will be considering the clay as the binder, fine sand as small aggregate and coarse sand as the large aggregate.

Adobe bricks have fair compressive mechanical properties, with inferior tensile mechanical properties. The compressive tests will be conducted to determine the compressive strength; however, the tensile strength can be considered as 10% of the compressive strength (Minke, 2006). Several types of research have been conducted to add fibrous materials to the adobe mixture to improve the compressive strength of the bricks further. Adding sugarcane bagasse, for example, has shown improving compressive strength of adobe bricks by 58.61% (Bock-hyeng et al., 2016). Sugarcane bagasse is the dry pulpy fibrous residue left over after crushing sugarcane to extract the juice. Mostly these are long dry fibres which are mixed into the adobe to make the brick stronger. Since sugarcane does not grow in the harsh climate of Zaatari, we can use dried straw, which is also a dry pulpy fibrous material.

After analysing a report presented by Oxfam discussion forum (2017), we have concluded that 40% of the waste produced in the Zaatari refugee camp is cardboard. Woodchips can also be found as a by-product of construction waste in the camp, while corn-starch can be seen as a cooking product in the camp. Corn-starch (maizena) is used as binder in cooking and baking, so we will use this in our mix as binder as well for the bricks.

To keep the building completely biodegradable and healthy, plastics or other non-organic materials will not be considered even though these are also available in the form of waste. This means straw, cardboard/paper, woodchips and corn-starch will be regarded as available materials to add to our adobe mixtures.

2.2.2 Making: process

After choosing several materials to add to the combinations of the adobe bricks comes the step of making the mixtures. At least three specimens were made out of each mix for data reliability. The overall sample count was 28. The main adobe recipe consisted of 30% clay, 30% fine sand and 40% course sand for the first ten specimens out of which 5 were small, and 5 were large bricks. About 10% water of the total weight of the dry mixture was added to this recipe. Next, the combination was mixed with a professional electric mixer (fig 1) for several minutes.

Next, several moulds were created for shaping the bricks. Plastic Tupperware boxes with 95 x 70 x 30 mm3 dimensions were used to create the ‘small’ specimen, while a custom mould was created for the ‘large’ brick sample. This mould with aspects of 170 x 90 x 40 mm3 was created with Polystyrene foam pieces and wooden skewers (fig 2).

The first five specimens were smaller and were created by using the Tupperware box.

Figure 1: Mixing with industrial mixer. Source: Author.

Figure 2: Polystyrene foam and skewer mould. Source: Authors

The mixture was put into the Tupperware mould and pressed/rammed by hand from the top to fill any gaps in the bottom of the box. Next, the head was cleared of any excess adobe, and the mixture was left into the mould for somewhere between 5 to 10 minutes before removing the Tupperware box.

The large specimens made with the foam mould were created similarly. The mould was filled with the mixture and pressed/rammed from the top to fill any gaps. After reaching the top of the mould and leaving the dough in the mould for about 5 to 10 minutes, the skewers were removed, which are holding the sidewalls of the mould and thus the specimen was demounted. Then the mould is rebuilt by putting the skewers back into the foam walls, and another sample brick can be created with the same mould. To increase the efficiency of this process, two foam moulds were made, so as one brick sample is being demounted from the mould while another sample can already be made with the other mould.

After the first ten specimens made, other different mixtures were created. The different materials used, along with their composition, is tabulated in table 1.

After creating the 28 specimens, they were left to dry inside the modelling hall (fig 3) of the faculty of architecture in Delft. After two days, the samples were turned upside down for even drying. After exactly one week of drying, the samples were transported to faculty of 3mE for the compression testing.

Brick Type	Code	Clay (%)	Fine Sand (%)	Coarse Sand (%)	Additive		Water (%)	Weight of mixture (Kg)
					Type	%		
Adobe	A1 – A-11	30%	30%	40%	-	-	10%	10.8
Adobe+Straw	S1-S4	30%	30%	40%	Straw	1% by volume	10%	11.3
Adobe + Woodchips	WD1-WD3	30%	30%	40%	Wood Chips	1% by volume	10%	4.17
Adobe + PaperPulp	PP_1-PP_5	25%	25%	-	Paper Pulp	50%	-	6
Adobe + Straw+Strach	SM_01-SM05	30%	30%	30%	Straw	1% by volume	10%	9

Table 1: Different mixtures used for making specimens. Source: Authors

2.2.3 Adobe Brick Breaking

After a week of drying, most specimens were dried up and hard enough to carry in a bucket without breaking or deforming, except for the few samples made with paper pulp. These last specimens were still very wet and deformed while transporting. Therefore, it was decided to exclude the five bricks made out of paper-pulp from the testing procedure, resulting in the final 23 out of 28 samples made.

At the materials lab of 3mE, a setup was made to test the bricks. Zwick z100 machine was set up to perform the compression operation with a maximum loading capacity of 100KN. The tagged specimens were placed on a wooden plate underneath the compression machine one by one. The device outputs the amount of force it is pressing down with (in Mega Pascal) versus the vertical displacement (in millimetres) to a computer where these values were recorded in a table and graph. The machine kept pressing down with increasing force from 0 to maximum 10 tons of force. Usually this maximum limit would not be reached since the device would be stopped after it was evident the specimen had failed. The definition of failing, in this case, is when a sample stops linearly deforming and suddenly breaks and thus shows a further displacement with the same amount of force being exerted on the specimen. This process would be repeated for all 23 samples.

Figure 3: Specimens drying.
Source: Authors

Figure 4: Setup before test.
Source: Authors

Figure 5: Setup after test.
Source: Authors

The adobe bricks will be used for making compression-only structures for the displaced refugees in the camp of Al Zaatari, Jordon. For the same, laboratory test was performed for determining the mechanical properties of the adobe bricks. As mentioned in section 2.2.3, 23 out of 28 samples of different composition were subjected to a uniaxial compression test, as shown in fig 4 and 5.

The bricks were placed on a base with a flat plate over it for uniform distribution of load during the compression test. The load was exerted continuously over the brick blocks till the bricks failed in compression resulting in maximum force at failure and deflection in brick height at failure. The values observed from the tests were used for analytical calculation of compressive strength using Equation 1. The modulus of elasticity of the bricks was calculated using Equation 2.

$$\textit{Compressive Strength}\ \left[\frac{N}{mm^2}\right] = \frac{F_{max}}{Area}$$

Equation 1: Formula to Calculate compressive Strength. Source: Authors

$$\textit{Modulus of Elasticity}\ [MPa] = \frac{Stress}{Strain}$$

Equation 2: Formula to Modulus of Elasticity. Source: Authors

3.1 Maximum force at Break

The failure of the bricks was observed as the development of diagonal cracks on the sides of the bricks (fig 6). However, it was noted that the adobe bricks were subjected to disintegration when subjected to load, as shown in fig 7. The bricks with straw or wood were not entirely disintegrated as adobe bricks (fig 8). It can be explained in a way that the straw fibres and wood chips hold the soil mixture together better then adobe which may also result in delayed failure of the brick blocks in compression. (Illampas, Ioannou, & Charmpis, 2011)

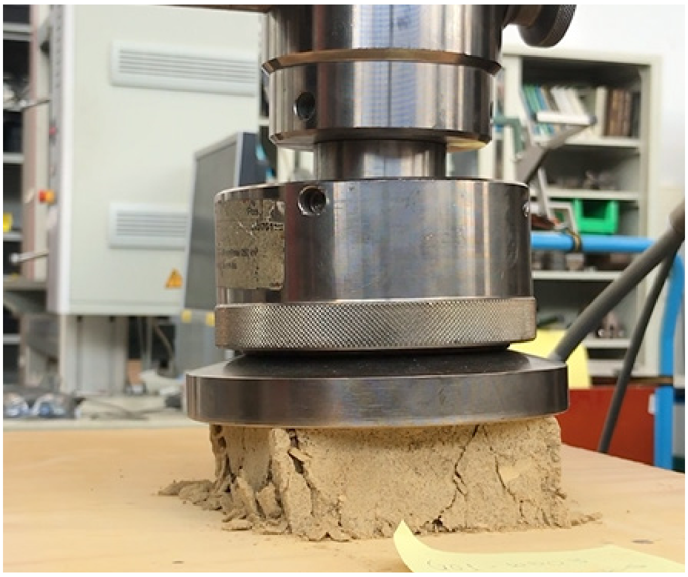


Figure 6: Diagonal Cracks at sides of Adobe Bricks. Source:Authors.

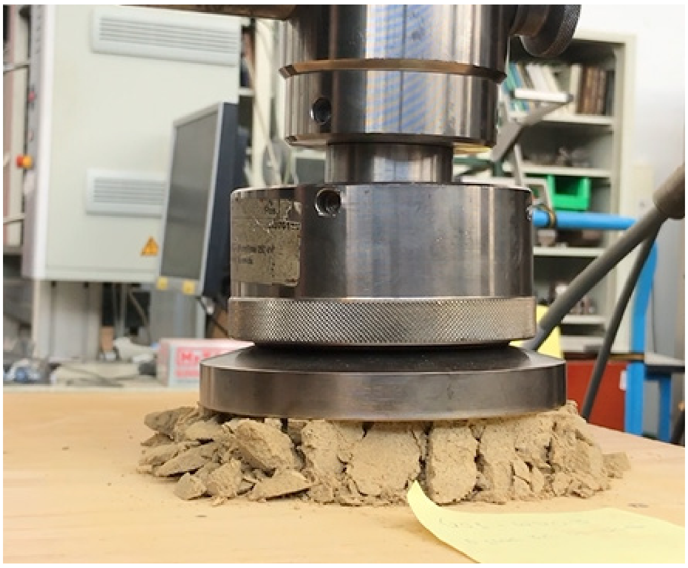


Figure 7: Disintegration of Adobe Bricks. Source: Authors

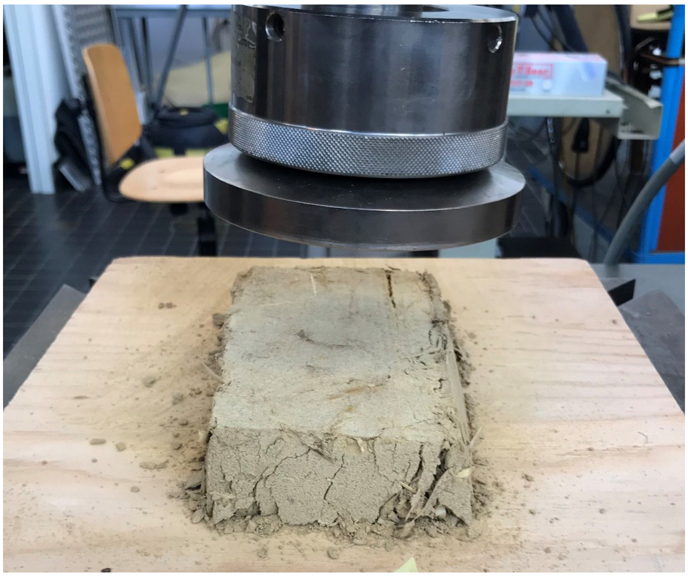
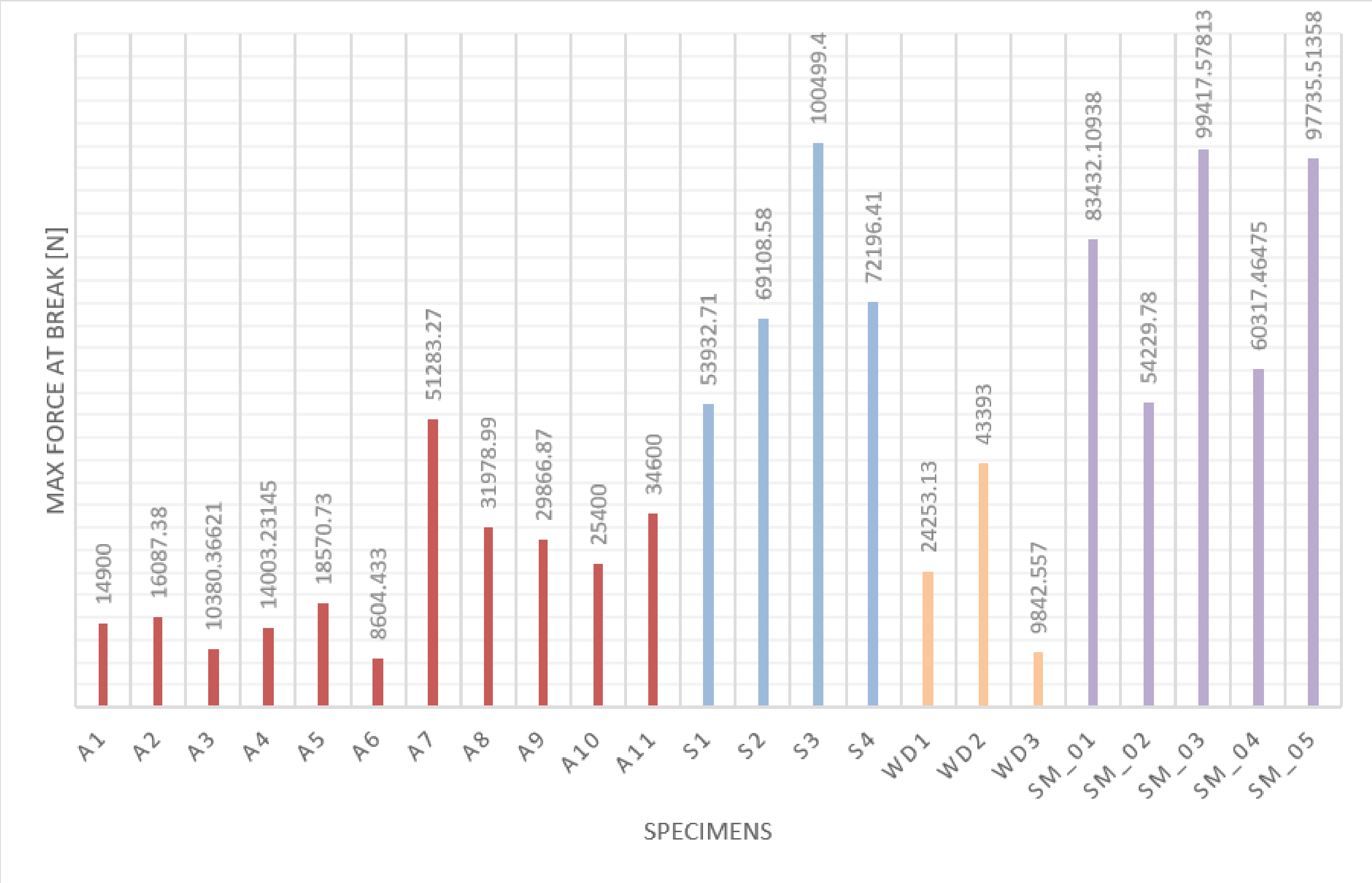
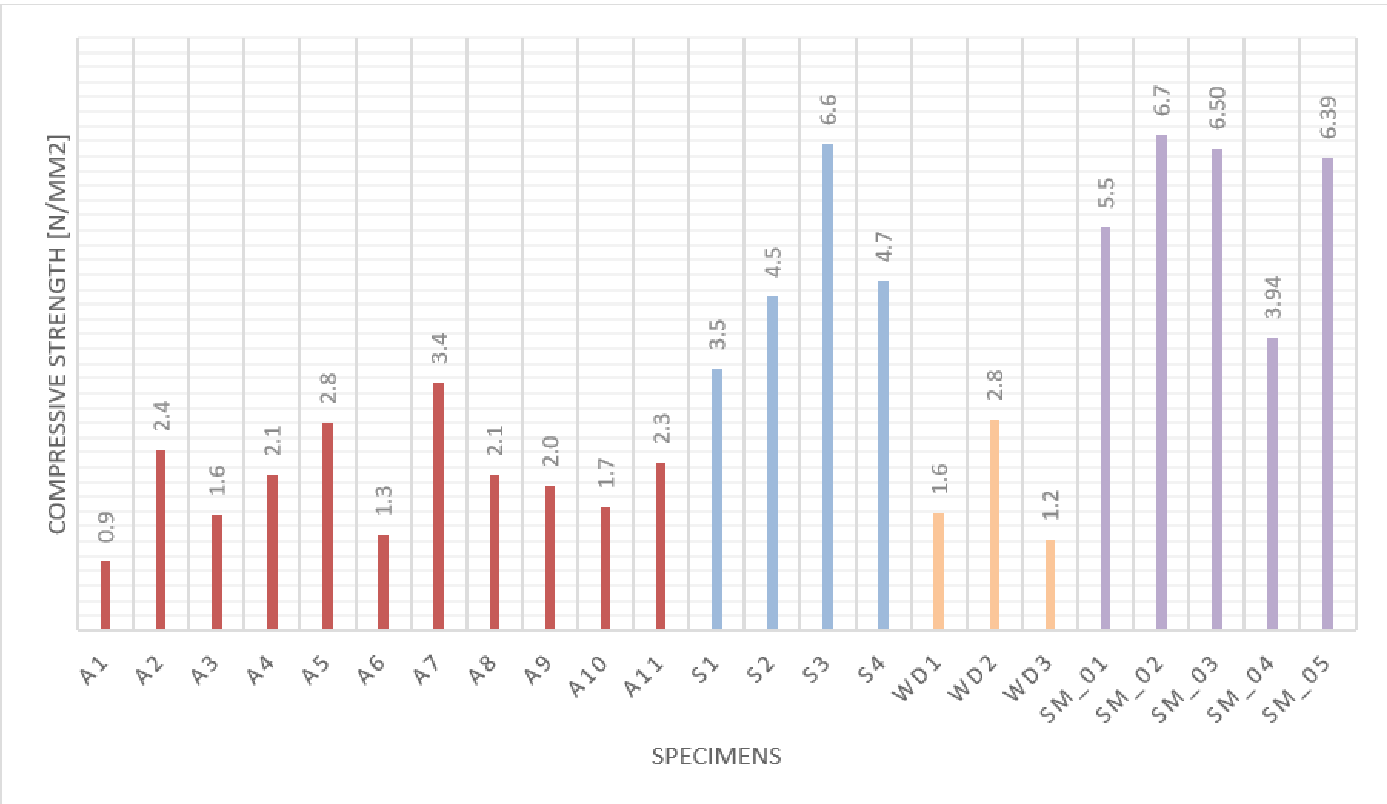


Figure 8: Adobe Straw Bricks less disintegrated as compared to Adobe Bricks. Source: Authors



Graph 1. Comparison of Maximum Force at Break for Different Brick types. Source: Authors.



Graph 2. . Comparison of compressive strength for Different Brick types. Source: Authors

From Graph 1, we can observe that Bricks with Straw (S1-S4) and Straw+Strach (SM_01-SM_05) mixture resisted more force during the breaking test. The adobe bricks (A1-A11) and the adobe+wood chips bricks (WD_1-WD_3) resisted much less force comparatively. In the adobe bricks specimen A1-A6 were small bricks while A7-A11 were large bricks. Therefore, from the graphs it can be interpreted that the blocks with naturals fibres were able to hold the soil and clay matrix better than only adobe bricks.

3.2 Compressive Strength

The compressive strength of the adobe bricks is related to maximum force exerted divided by the area upon which the force was applied. Graph 2 shows the compressive strength of the specimen tested. From the graph, we can observe that the Adobe Bricks are low on compressive strength while Adobe with natural fibres that is straw and Adobe with Straw and Starch are high on Compressive Strength.

However, to determine the design values, the data for adobe bricks, adobe+straw and adobe+wood chips from the entire class was considered. The data received from group 1 to group 7 (Appendix 2-7) was normalised using mean and standard deviation values. The outliers were removed then mean values were calculated again to identify the strength values for various compositions of bricks.

Table 2 summarises the mean values from the normalised data. We will consider the range of the compressive strength between one standard deviation from the mean. The graphs can be refereed in appendix 2-7. However, the adobe bricks with straw and starch the data were synthesised from the five samples made.

The data mentioned in table 2 represents the maximum compressive strength of the block at failure. However, according to literature it was noted that the a compressive element made up of Adobe may achieve its maximum compressive stress at 10% of reduction in its height (Illampas et al., 2011). This means that the brick would deform when the compressive stress induced due to self-weight, wind, etc reaches at 10% of deformation in height. This stress could be much lower than the maximum compressive strength of the brick at failure.

Therefore, the stress values were calculated for bricks made by group 1 – group 7 at 1.5%, 5% and 10% deformation at height. These stresses were calculated and compared for adobe bricks (group 1-7), Adobe+straw bricks (group 1-7), Adobe+Woodchips (group 1-7) and Adobe+Straw+Starch (group 1) respectively.

From table 3 we can observe that all the samples holds similar compressive stress at 1.5 % deformation. However, at 5% and 10% deformation The bricks with additives like woodchips or straw fibre and straw fiber with starch exhibit better compressive strength. This could be explained as that the natural fibres binds the soil matrix better thus delaying the failure (Illampas et al., 2011).

Brick Type	Mean [N/mm2]	Standard Deviation [N/mm2]	Range (Σ-σ to Σ+σ) [N/mm2]
Adobe Bricks	1.33	.61	.72-1.94
Adobe + Straw	2.7	.82	1.88-3.52
Adobe + Wood Chips	2.1	.7	1.4-2.8
Adobe+Straw+Starch	5.8	1.02	4.8-5.8

Table 2: Mean compressive strength of different type pf bricks. Source: Authors.

Brick Type	σ at 1.5% deform. In height [MPa]	σ at 5% deform. In height [MPa]	σ at 10% deform. In height [MPa]
Adobe Bricks	.13	.13	.7
Adobe + Straw	.12	.3	.8
Adobe + Wood Chips	.13	.4	.9
Adobe+Straw+Starch	.1	.5	1.02

Table 3: Compressive strength at deformations. Source: Authors.

3.3 Young's Modulus

The Young's modulus or modulus of elasticity is determined by equation 2. The maximum stress and deflection attained at break were considered for the calculation. The data was again taken from group 1-7, normalised and mean values were taken. Table 4 summarises the E calculated from the brick testing. However, the adobe bricks with straw and starch the data were synthesised from the five samples made.

Brick Type	Mean E [MPa]
Adobe Bricks	10.63
Adobe + Straw	12.37
Adobe + Wood Chips	11.3
Adobe+Straw+Starch	17.5

Table 4. Young's Modulus for different brick types. Source: Authors

04 | Discussion of Results

4.1 Compressive Strength

Upon comparing the mean compressive values from various literature studies and the data analysed from the brick making tests. It can be concluded that the compressive strength achieved by the blocks are valid enough to be used for further calculations. Graph 3 also summarise this comparison. The graph also shows that brick with straw and starch can significantly improve the compressive strength of the blocks. However, if the compressive strength at 10% deformation is considered we can observe that the above-mentioned values in graph 3 cannot be used since they are much higher than the stress developed at maximum allowable deformation of the bricks.

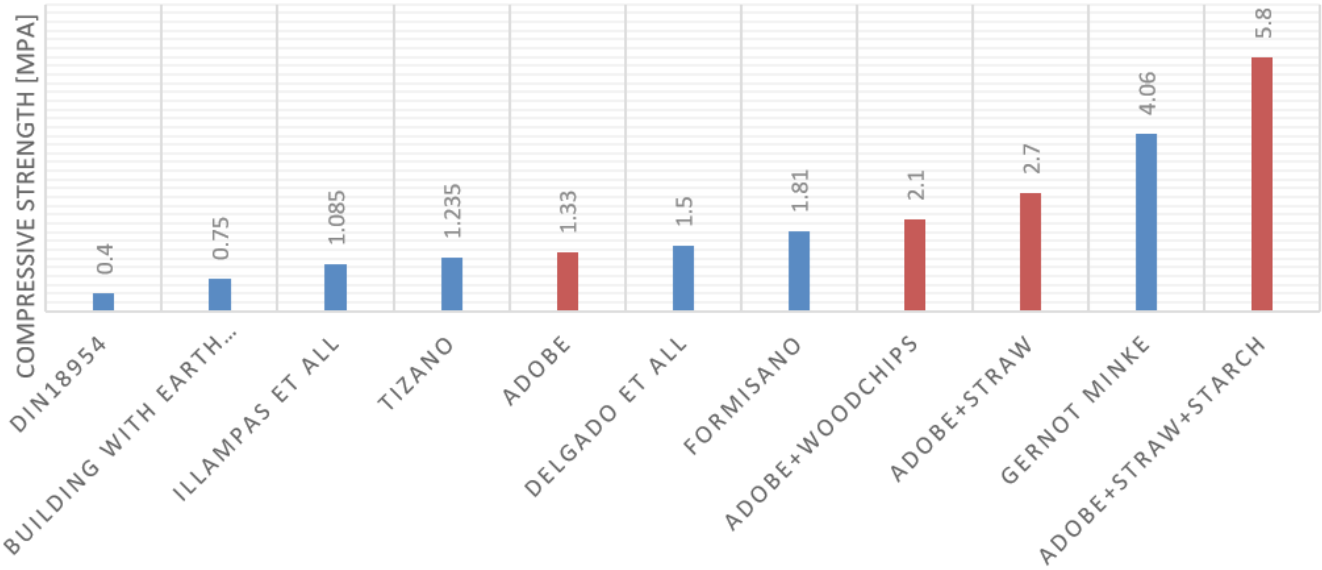
Graph 4 compares these values and we can observe that the adobe with straw and starch are comparatively better. Hence, these values could be utilised into the construction depending upon the type of use. For instance, the adobe bricks could be used for flooring; the blocks with straw could be used for partition walls while the bricks with straw and starch can be used for the main structure.

4.2 Young's Modulus

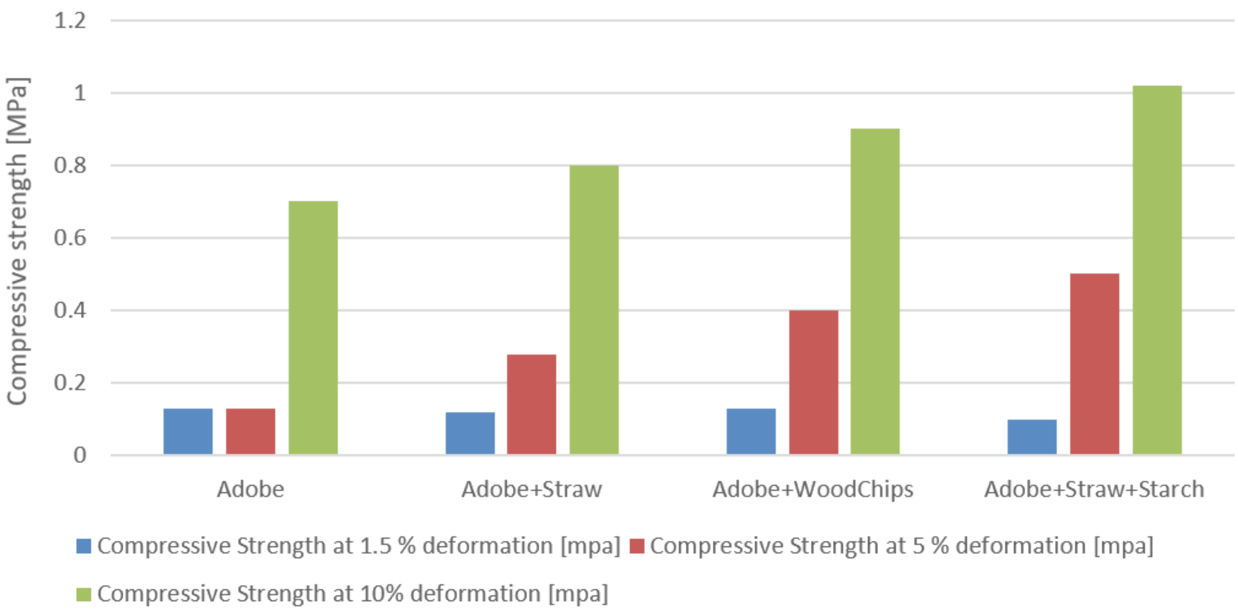
To determine the young's modulus, a comparison was made from the literature data and the data obtained from the group 1-7. However, it can be observed from graph 5 that the young's modulus of the tested specimen is very low as compared to different literature studies. This could be because of the short curing time. As well as the outdoor conditions within which the bricks were cured. Considering the bricks would be better cured in the high temperatures of Jordon. The bricks can receive higher Young's Modulus.

4.3 Design Values

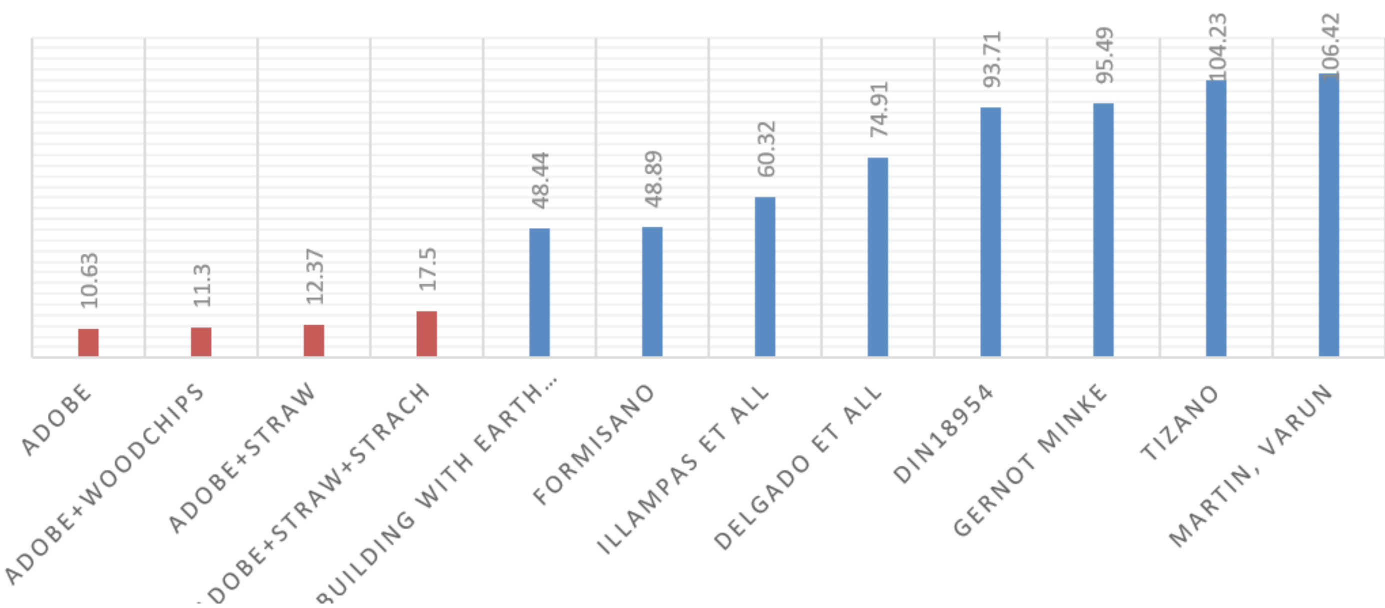
Based on the various literature studies and analysis of the results from the experiment the design values can be determined for the structure analysis of the structure proposed. Table 5 illustrated the design values to be used further to propose a safe structure.



Graph 3 : Comparison of compressive strength from literature and test results. Source: Authors.



Graph 4 : Comparison of compressive strength at various deformation in height. Source: Authors.



Graph 5 : Comparison of Young's Modulus from literature and test results. Source: Authors.

Design Values		
Brick Type	Adobe+Straw+ Starch	
Compressive Strength	1 MPa	Experiment
Young's Modulus	80 MPa	Literature
Tensile strength (1/10 Compressive Strength)	0.1 MPa	Literature

Table 5. Design Values determined for structural analysis. Source: Authors

05 | Reliability of Data

For this experiment, there were several factors which could influence the authenticity of the gathered data. First, the mixes of raw materials of all the groups were made individually, which means the bricks from all groups could have slightly different ratios of the raw materials, which could affect the brick strength. Also, the brick making process was not generalised for the entire class. One group could be ramming the earth into the mould with more force, while other groups could be gently putting the earth into the moulds. The first of these two methods would most likely make stronger bricks since the earth would be more tightly packed into the mould.

After consulting literature on the strength of adobe bricks, it was evident that our bricks had a much lower Young Modulus than those mentioned in literature. This could be the effect of the short seven-day curing time of our bricks, while bricks from the research were cured somewhere between one month and half a year and in some cases in higher temperatures. Due to the scope of this project, we were unable to allow our bricks to cure for such long periods.

Lastly, some of the bricks put under the compression machine during compression testing could be slightly off centre, which would mean the load coming down on it would be non-uniformly distributed across the area of the brick.

06 | Conclusion

The primary objective of the research experiment was to determine the design values of the adobe bricks and the mixture which exhibits best properties in comparison to the literature studies. From the data collected from the experiment the mechanical properties like Compressive Strength, Young's Modulus can be calculated. These were calculated by the formula mention in section 3.5 of this report. The data collected from all the groups was analysed to determine the compressive strength and young's modulus.

From this synthesis it can be concluded that the bricks with additive materials like natural fibres(straw) and starch as binding agent increase the mechanical properties of the blocks. Therefore, the sample SM_01-SM_05 which exhibited a higher compressive value and Youngs Modulus will be considered for structural calculations.

For the compressive strength the design values were taken of the adobe, straw, starch mix which exhibited the greatest compressive strength at 10% deformation in the brick which is ! MPa. It could be understood that considering this value also incorporate a safty factor since this value is quite low as compared to the compressive strength achieved at break which is 5.8 MPa. The young's Modulus of this mix was calculated at 17 MPa . However, this value is quite low as compared to literature. The reason is depended upon the curing time and the temperature at which the bricks was cured. Therefore, a higher value of 80MPa will be taken considering that a higher Young's Modulus is possible to achieve in the high temperatures of Jordon.

07 | Recommendations

To have better reliability of data in the future, it would be recommended that the entire batch of bricks are made from the same mixture of raw materials. This means that all the specimens would have the same ratios of the raw materials. Also, the curing time should be longer for all samples. It is shown in the literature that curing at higher temperatures and for periods more extended than seven days have given better results for mechanical properties.

Furthermore, when performing compression testing, the specimens should be placed under the compression machine with more care, so the load is always evenly distributed over the entire brick.

08 | References

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Appendix 1 : Maximum Force at Break (Group 1)

Specimen	Max Force at Break [N]	Specimen	Max Force at Break [N]	Specimen	Max Force at Break [N]	Specimen	Max Force at Break [N]
A1	14900	S1	53932.71	WD_1	24253.13	SM_01	83432.10938
A2	16087.38	S2	69108.58	WD_2	43393	SM_02	54229.78
A3	10380.36621	S3	100499.4	WD_3	9842.557	SM_03	99417.57813
A4	14003.23145	S4	72196.41			SM_04	60317.46475
A5	18570.73					SM_05	97735.51358
A6	8604.433						
A7	51283.27						
A8	31978.99						
A9	29866.87						
A10	25400						
A11	34600						

Appendix 2 : Test data from Group 1-Group 7 for Adobe Only

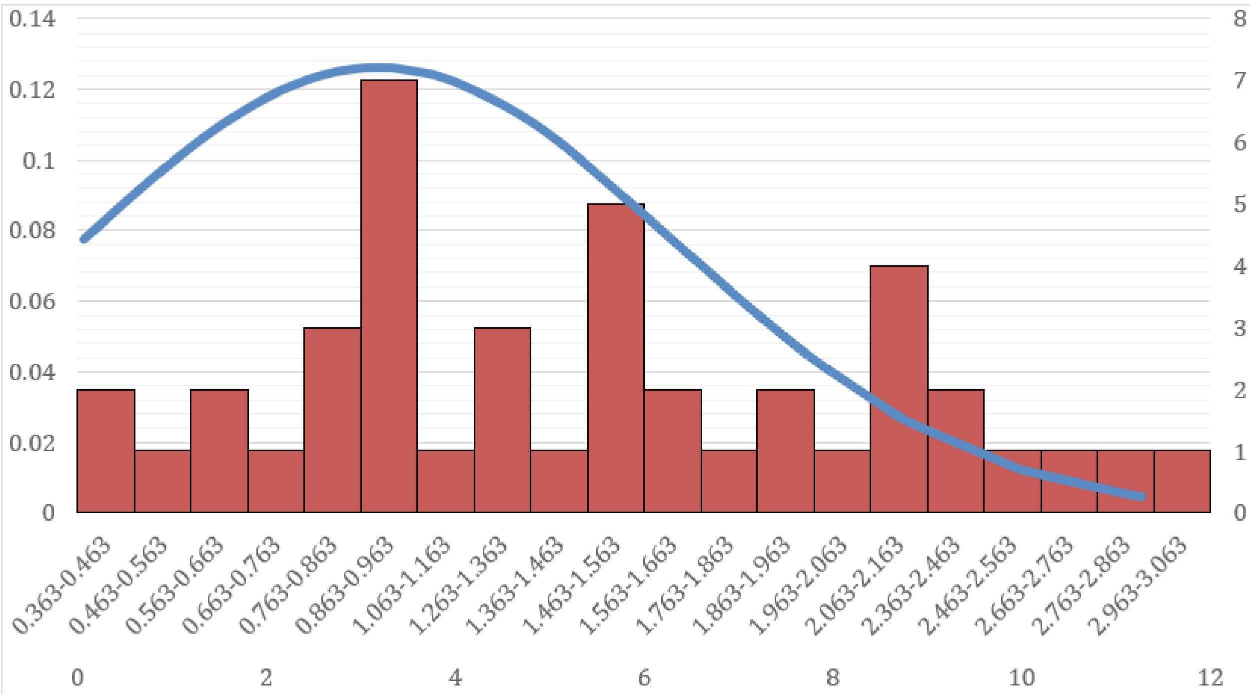
Code	Dimensional Properties (mm)			Fmax (N)	dL at Fmax
	L	W	H		
Group 1					
A1	160	100	60	14900	-
A2	95	70	30	16087.38	6.81
A3	95	70	30	10380.37	4.911062
A4	95	70	30	14003.23	5.904611
A5	95	70	30	18570.73	7.75
A6	95	70	30	8604.433	8.11
A7	170	90	40	51283.27	19.53
A8	170	90	40	31978.99	7.55
A9	170	90	40	29866.87	9.68
Group 2					
1A	164	121	71	8,319.96	11.76
1B	159	124	63	15,680.92	11.81
1C	155	124	67	10,478.11	11.19
1D	159	114	64	12,005.94	13.09
1E	159	128	68	8,844.50	12.41
2A	113	113	43	19,500.00	-
2B	109	111	40	93,036.24	24.98
2C	109	108	36	1,01,160.80	24.30
2D	116	109	42	20,700.00	-
2E	111	102	40	99,968.26	24.05
Group 3					
S1s	95	70	30	9216	-7,91
S2s	95	70	30	21900	-
S3s	95	70	30	17900	-
S4s	95	70	30	20200	-
S5s	95	70	30	16900	-

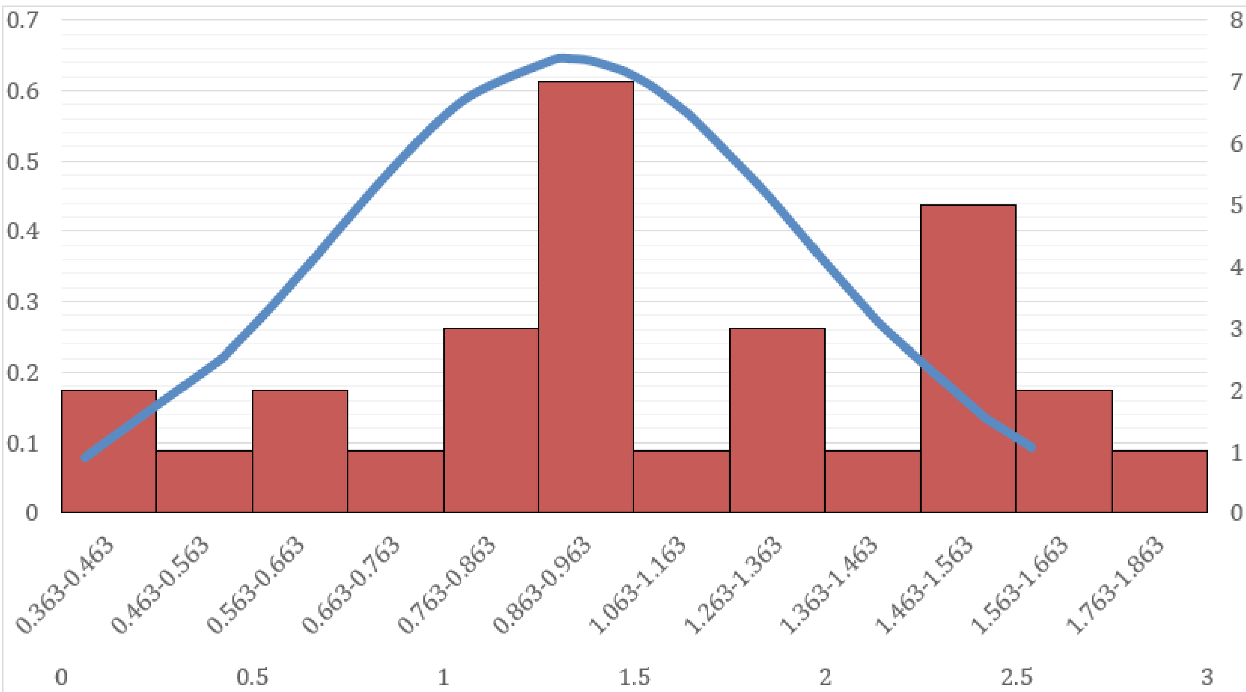
Group 4					
1	100	100	60	13310.3	9.126376
2	100	100	60	21595.4	9.896349
3	100	100	60	19246.79	12.69633
4	100	100	60	16456.54	14.32644
5	100	100	60	14791.9	8.94633
6	60	60	50	3360.184	2.726414
7	60	60	50	5351.55	12.53665
8	60	60	50	8721.683	3.744479
9	60	60	50	3059.625	3.816359
10	60	60	50	3241.821	6.386316
Group 5					
1	165	105	65	16122.84	8.98
2	165	105	65	1104.09	0.09
3	165	105	65	12435.69	9.60
4	165	105	65	15587.39	8.49
5	165	105	65	11456.90	9.67
6	110	80	30	98453.83	14.98
7	110	80	30	35100	9.97
8	110	80	30	59763.43	14.99
9	110	80	30	39892.43	9.97
10	110	80	30	35138.97	9.96

Group 6					
A1	175	85	40	12457.81	11.32
A2	175	85	40	13624.26	9.26
A3	175	85	40	13027.7	11.29
A4	175	85	40	15951.05	14.95
A5	175	85	40	19770.12	8.56
A6	175	85	40	21831.98	10.02
A7	105	75	30	78228.37	14.97
A8	105	75	30	88700	-------------
A9	105	75	30	29158.42	15
A10	105	75	30	87904.19	14.99
A11	105	75	30	30334.93	15
A12	105	75	30	79126.34	14.98

Group 7					
A1	100	75	30	38700	-
A2	100	75	30	83998.44	11.9737
A3	100	75	30	15700	-
A4	100	75	30	13672.56	9.4266
A5	100	75	30	52000	-
A6	100	75	30	14996.25	11.95588

Appendix 3 : Normalised Graph for Compressive Strength for Adobe Bricks only (Grp1-Grp7)

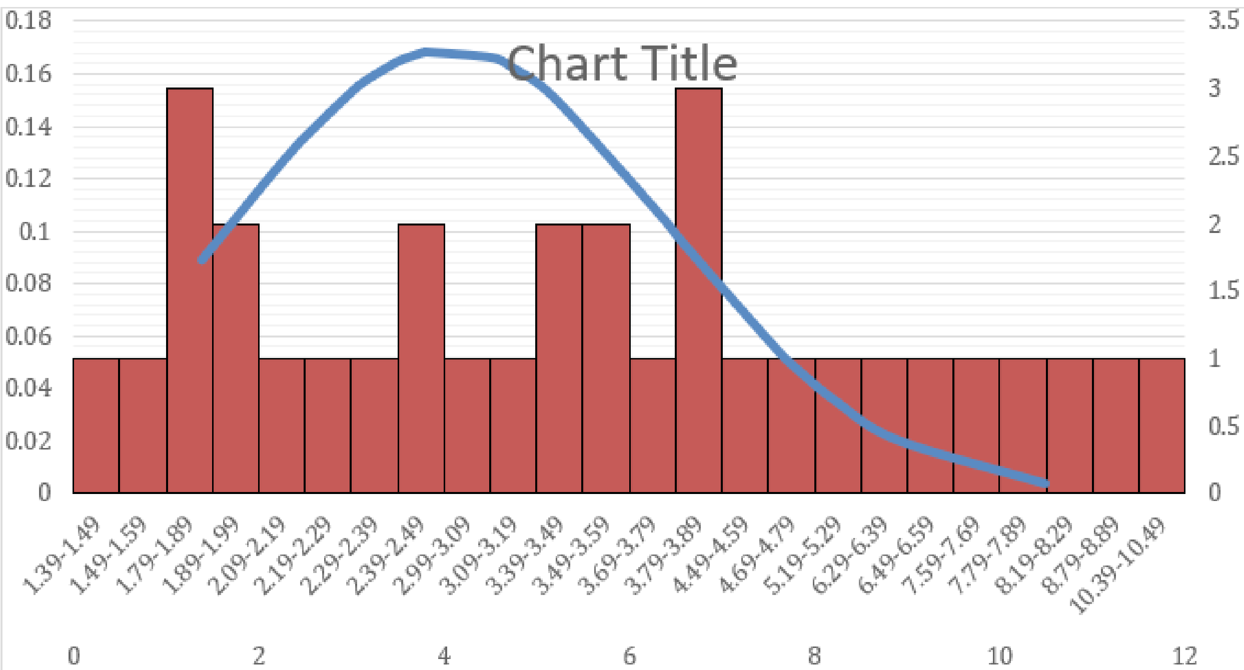


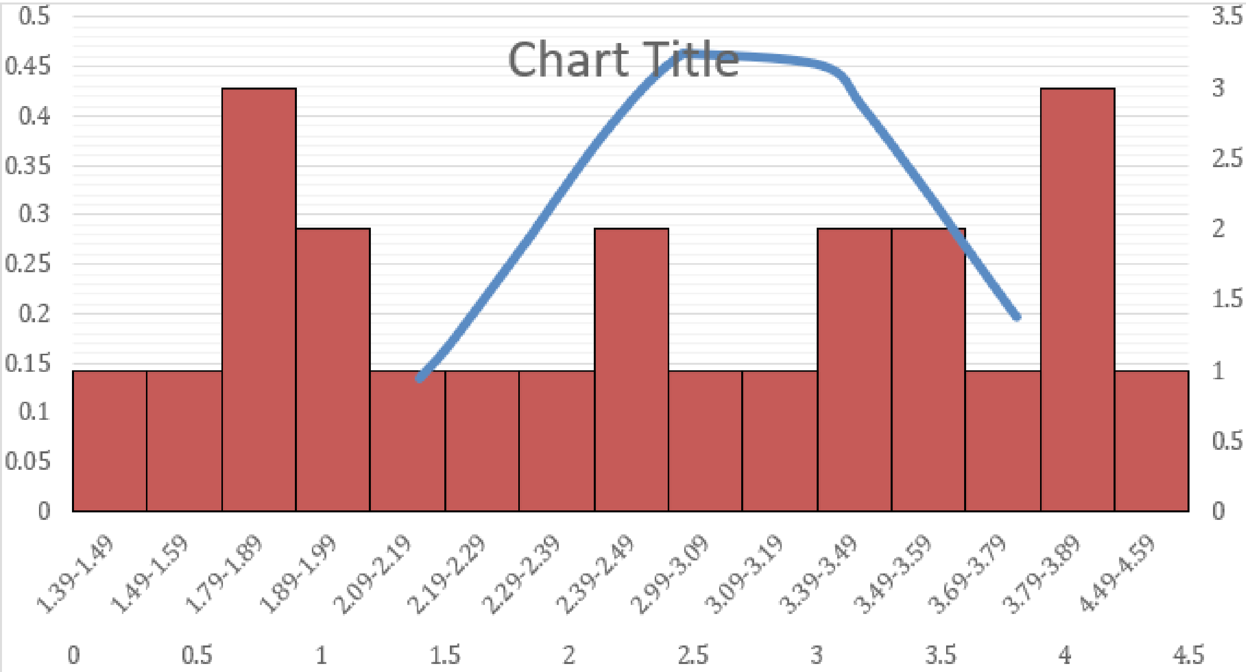


Appendix 4 : Test data from Group 1-Group 7 for Adobe + Straw

Code	Dimensional Properties (mm)			Fmax (N)	dL at Fmax
	L	W	H		
Group 1					
S1	170	90	40	53932.71	24.96
S2	170	90	40	69108.58	18.18
S3	170	90	40	100499.4	16.27
S4	170	90	40	72196.41	23.67
Group 2					
3A	115	111	40	100549.50	14.95
3B	116	114	41	100384.60	19.83
3C	111	110	41	100294.40	20.94
Group 3					
SS1b	175	85	40	35400	9,94
SS2b	175	85	40	28000	-
SS3b	175	85	40	29300	-
SS4b	175	85	40	31600	9,92
SS5b	175	85	40	44900	9,94
Group 4					
26	60	60	50	5483.833	4.786423
27	60	60	50	6759.476	11.73645
28	60	60	50	6607.645	5.546422
29	60	60	50	6904.746	11.15651
30	60	60	50	5017.566	6.716426
Group 5					
11	135	90	40	46286.38	14.94
12	135	90	40	29810.99	8.86
13	135	90	40	63061.82	14.95
14	135	90	40	46270.21	14.94
15	135	90	40	43370.08	13.16
16	135	90	40	38756.87	14.94
Group 6					
S1	175	85	40	36592.63	14.94
S2	175	85	40	33957.98	14.79
S3	175	85	40	56105.79	14.94
S4	175	85	40	51784.55	14.93
S5	175	85	40	56502.25	14.94
S6	105	75	30	27459.32	9.97
Group 7					
S1	100	75	30	78581.86	11.98106
S2	100	75	30	47607.38	11.965
S3	100	75	30	66655.61	11.96496

Appendix 5 : Normalised Graph for Compressive Strength for Adobe + Straw (Group 1-Group 7)





Appendix 6: Test data from Group 1-Group 7 for Adobe + WoodChips

Code	Dimensional Properties (mm)			Fmax (N)	dL at Fmax
	L	W	H		
Group 1					
WD1	170	90	40	24253.13	6.72
WD2	170	90	40	43393	16.73
WD3	90	90	40	9842.557	7.28
Group 2					
4A	125	118	50	38373.860	19.958
4B	122	115	52	65934.380	24.965
Group 3					
SW1s	95	70	30	15900	-
Sw2s	95	70	30	22700	-
Sw3s	95	70	30	16700	-
Group 4					
21	60	60	50	5277,722	4,866442
22	60	60	50	4646,697	6,486415
23	60	60	50	5063,669	4,01638
24	60	60	50	4873,333	5,03645
25	60	60	50	4665,315	4,4643
Group 5					
17	135	90	40	32480.30	9.24
18	135	90	40	35830.86	9.97
19	135	90	40	27850.94	14.94
20	135	90	40	26408.52	9.44
21	135	90	40	35840.77	14.69
Group 6					
W1	105	75	30	43293,21	11,96
Group 7					
WD1	100	75	30	56650.17	11.96532
WD2	100	75	30	38300	-
WD3	100	75	30	52495.67	11.98119

Appendix 7 : Normalised Graph for Compressive Strength for Adobe + WoodChips (Grp 1-Grp 7)