# Variation in Compressive Strength of Handmade Adobe Brick

**Sasui[1], Watcharin Jinwuth[2],Sirimas Hengrasmee[3]**

Department of Architecture; Faculty of Architecture; Naresuan University [1,2,3]

***Abstract*—**The construction of houses with adobe brick is common practice among the developing communities of the world. The adobe is well known to have good compressive strength, according to the researches the compressive strength value varies and depends on the factors therefore soil proportion, curing age, form and dimensions. In order to examine the influence of these factors the experiment has been performed by conducting compressive strength test on five adobe masonry specimens of same soil texture, same curing age and of similar dimensions and shape. The experiment shows the greater variation in the compressive strength of each brick. The strength values shows 59.21% coefficient of variation 'CV'. By comparing the experimental results with the reviewed researches the study concluded that the adobe is a handmade brick; the variation in strength value may still occur, even though the bricks are prepared under similar factors.

***Key Terms*—**Adobe, compressive strength, variation factors.

## INTRODUCTION

Spanish word "adobe" referred to a sun dried brick, which are prepared by molding the mud manually. However machines are also used to mold adobe, but molding manually is an old practice. Construction with adobe is still highly practiced among the communities of developing countries as it is affordable and economical [1]. Local people use their experiences and rough estimation in producing bricks manually [2]. To produce adobe brick, soil is required which is comprised of three main contents, sand, silt and clay [3]. Soil is available locally in almost every part of the world and also its manual production makes it cheaper for the people who lack economic resources. Production of adobe bricks compared to the other bricks requires less energy. Apart from these benefits adobe stores heat in winter and transmits heat in summer to maintain the indoor temperature. These benefits fulfills the requirement of an adequate house, which is why it has been adapted by 50% population of world [4, 5]. Building with adobe without reinforcement is common in rural communities, where construction is limited to single stories, while in some areas adobe has been adopted to build up to three stories and also been adopted to build luxurious houses especially in middle east such as Iran [6].

However, adobe houses are not properly maintained which in result leads to the failure when environmental consequences and natural disaster triggers [3, 5, 7]. It has been observed that adobe houses cannot bear the excessive dead loads due to limited compressive strength property, as in monsoon it collapse on the increase of dead load of roof due to rains [8, 9].

Consequently, the compressive strength properties of earthen materials have not been specified, as per researches the strength values vary with different aspects. In order to analyze the former researches the study examines the adobe specimens which were prepared manually under similar aspects.

## VARIATION FACTORS OF COMPRESSIVE STRENGTH OF ADOBE:

Adobe brick generally lacks strength, as it is low in tensile strength but compressive strength is comparatively high [5]. The compressive strength of un-stabilized adobe brick is suggested minimum of 1.5 Mpa and maximum 2 Mpa [10]. However these strength values may vary and depends on several factors which are briefed below.

In the experimental researches, it is noted that the compressive strength of adobe brick depends on the content of soil therefore sand, silt & clay. The research conducted by Arvind Kumar [11] andNapat Sriwattanaprayoon[2] shows the variation in compressive strength with the addition of sand content in the soil.

Along with the soil proportions, the compressive strength of adobe also depends on the time of curing and temperature at which it is cured. Following researches [12-14] observed the increase of compressive strength with the increase of curing time at atmosphere temperature. On increasing the atmosphere temperature the reduction in compressive strength is possible with the increase of curing age [14]. Whereas the study conducted by C.T.S.Beckett & C.E.Augarde[15] shows the increase in compressive strength with the increase in temperature. The study also shows the

variation in compressive strength with curing time [16]. The increase in compressive strength with the increase of curing time has been observed by Ramadhan W. Salim[17], while the research by Vandna Sharma a[18], proves that the strength may vary up till 28 days of curing but the specimen of 28, 56 and 90 days age found to have same compressive strength and comparatively more than those of 7 and 14 days curing age.

It has also been noted that the moisture content also affects the compressive strength of adobe. Adobe may lose the compressive strength if the moisture content exceeds the balance moisture content of adobe. The moisture content may vary from 1-3% depends on the proportion of soil especially quantity of clay [13, 14, 19]. James R. Clifton[14] tested three different soil textured adobe specimens, the results shows a greater change in compressive strength, the strength tends to reduce with the increase of moisture content. The tests conducted were simulated with the adobe absorbs moisture from ground water/or rain water and the water absorption due to relative humidity.

Apart from these factors, the wetting and drying of adobe may also affects the compressive strength of adobe [14, 20]. The research mainly focuses on the soil proportion, curing time, form and size factor on the compressive strength of adobe.

The literature on experimental researches involving variation in compressive strength of adobe specimen/brick of different factors has been concluded. The table below shows the coefficient of variationof results obtained by other authors.

**Table I: Compressive strength results from reviewed researches.**

| # | Source | Soil texture/ Classification | Compressive strength test type | Variation factor | CV (%) |
|---|---|---|---|---|---|
| **Variation due to soil content** | | | | | |
| R1 | [11] | CH (as per "USC" system) | Unconfined compressive strength 'UCS' | Difference in Sand particles | 8.51 |
| Summary of R1: The research shows increase in compressive strength with the increase of sand in soil. The strength increased by adding sand up to 10%; however the sand above 10% decreases the strength of adobe specimen. | | | | | |
| R2 | [21] | Clayey soils Classification Soil A= CL Soil B= CL Soil C= CH | Unconfined compressive strength 'UCS' | Difference in sand clay and silt particle | 23.20 |
| Summary of R2: The experiment conducted on three soils of same texture but the ranges of soil content is different. The result shows variation in compressive strength due to the difference in the quantity of sand, clay and silt. | | | | | |
| R3 | [14] | N/G | N/G | Two collected soil A & B; soil C is a modified soil A. | 26.84 |
| Summary of R3: The research conducted test on two different soils, while the third soil was simulated to check the effects of reduced silt and clay particle on compressive strength. The result shows high compressive strength of the soil contains more clay. | | | | | |
| **Variation due to curing age and temperature.** | | | | | |
| R4 | [14] | Sand=18% Clay=27% Silt=55% | N/G | Specimens tested at the curing age 7 days up to 35 days at 21 °C. | 0.89 |
| | | | | Specimens tested at the curing age of 1 to 4 days at 60 °C. | 8.66 |
| Summary of R4: The test conducted to observe the influence of drying temperature and curing time on the compressive strength of adobe. Results shows increase in strength with the increase of curing time when it was dried under normal environmental temperature therefore 21 °C. Whereas at high temperature of 60 °C the strength tends to reduce with the increase of curing age. | | | | | |
| **Variation due to curing age.** | | | | | |
| R5 | [17] | Sandy loam | Dry compressive strength test | Difference in curing time. | 4.27 |
| Summary of R5: The research shows the little change in the compressive strength, the strength increases with the time of curing. | | | | | |
| R6 | [18] | Sandy clay SC (as per Indian standard classification 'ISC') | Unconfined compressive strength | Difference in curing time. | 11.32 |
| Summary of R6: The research also shows the increase in strength with the increase in curing time up till 28 days. A result illustrates the strength remained same after 28 days of curing. | | | | | |
| **Variation due to form** | | | | | |

**Table I: Compressive strength results from reviewed researches.**

| | | | | | |
|---|---|---|---|---|---|
| R7 | [18] | Sandy clay/ SC (as per India standard classificatio 'ISC') | Unconfined compressive strength | Difference in specimens' form. | 28.51 |
| Summary of R7: The test conducted on two specimens of same soil but different form, the results shows a greater influence of forms on compressive strength. | | | | | |
| R8 | [22] | Adobe brick collected from 3 different sources | imple compressio test | Difference in forms of adobe brick 1 | 9.08 |
| | | | | Difference in forms of adobe brick 2 | 14.96 |
| | | | | Difference in forms of adobe brick 3 | 5.88 |
| Summary of R8: In this research three different adobe brick were tested with two different forms therefore cube & cylinder. Result illustrated the difference in strength in both cube and cylindrical formed specimens of all 3 adobe bricks | | | | | |
| **Variation due to size** | | | | | |
| R9 | [23] | N/G | N/G | Difference i specimen's slenderness ratio. | 18.26 |
| Summary of R9: Compressive strength test conducted on prism specimens of different slenderness ratio. The variation in strength value was observed from the results of this research. | | | | | |

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## EXPERIMENTAL PROGRAM ON ADOBE SPECIMEN

### A. *Soil consideration*

The content of soil to produce the quality adobe brick has been recommended by several authors, however the soil recommended in Australian earth building handbook has been followed [24]. The soil contents' limits are; Sand 30-75% "particle size 20mm", Silt 10-30% and clay 10-40%. The experiments were conducted in Naresuan University Thailand, so the soil from nearby site was taken and identified by conducting three site tests therefore sedimentation test (1), ribbon test (2) and dry strength test (3) as shown in figure 1. After conducting these tests, the soil was found to be clayey and the proportion of each content was; sand 24.65%, Silt 18.6% & clay 56.74%. To simulate the available soil with the recommended proportion, the sand was added and the soil was retested. The test shows the increase of sand particles while silt and clay was in single layer in 2nd sedimentation test. The illustrated percentages of soil content are as follows; sand 48% and silt plus clay 52%.

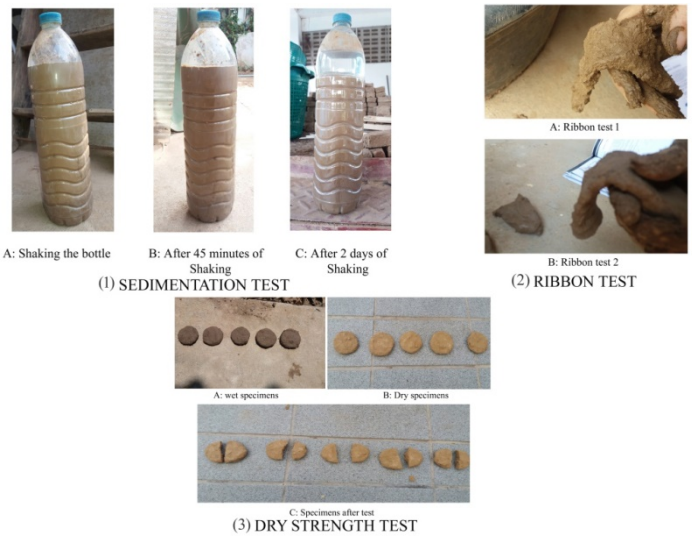


**Fig1: Site test to identify the soil.**

### B. *Preparing the specimens:*

After simulating the soil, the specimens were prepared, wooden mold of 300 x 200 x 100 mm was used for molding, two bricks were obtained from one mold by cutting it half. These half bricks were dried partially for one week to make masonry prism specimen according to Australian standards As 3700 for compressive strength test of masonry prism/earth wall. Total five specimens were prepared, each specimen consist of three courses of bricks and were cured for 28 days under shades. Fig 2 illustrates the specimens prepared and cured for test.

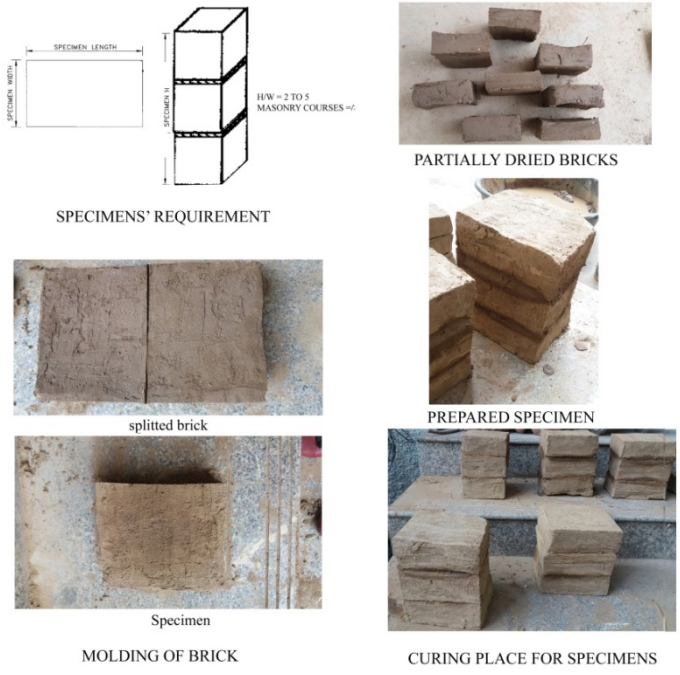


**Fig2: Specimens prepared and cured for test.**

*C. Compressive strength Test set up*

After curing the specimens for 28 days, each specimen was measured and weighed. According to the Australian standards, the height to width ratio was calculated for each specimen 'shown in Fig 3' in order to find the correction factor. The parameters of each specimen are shown in table II below.

**Fig3: Prepared specimens for compression test**

**Table II: Parameters of specimens**

| SPECIMEN TAG | LENGTH (mm) | WIDTH (mm) | HEIGHT (mm) | WEIGHT (KG) | H/W RATIO | CORRECTION FACTOR Ka |
|---|---|---|---|---|---|---|
| **CP1** | 178 | 127 | 249 | 13.89 | 1.96 | 0.70 |
| **CP2** | 167 | 131 | 258 | 12.74 | 1.969 | 0.70 |
| **CP3** | 174 | 123 | 251 | 13.04 | 2.04 | 0.70 |
| **CP4** | 175 | 122 | 248 | 13.16 | 2.03 | 0.70 |
| **CP5** | 176 | 132 | 268 | 14.20 | 2.03 | 0.70 |

These specimens were tested in compression testing machine "Technotest KL200". Following the standards the loads applied on the specimen was even with the travelling rate of 1-5 mm/min and force applied was 1N.


**Fig4: Test setup**

*D. Results*

The maximum force at which each specimen survived was recorded. The chart below showing the survival forces for each specimen.

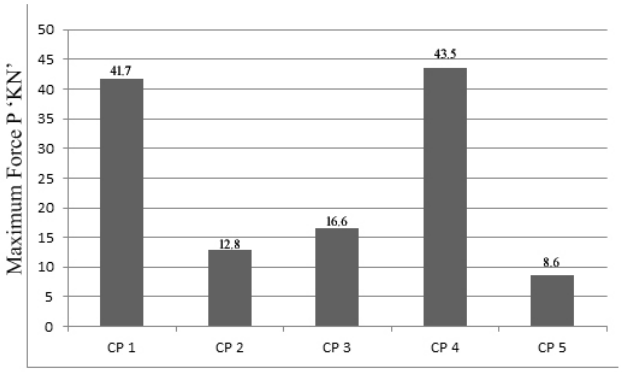


**Fig5: Force at which each specimen survived.**

Following the standard; the forces and the parameters of each specimen was putted in the equation 1, to calculate the compressive strength C. Fig 6 shows the compressive strength of each specimen.

**Equation 1:** $C = Ka(P \div A)$

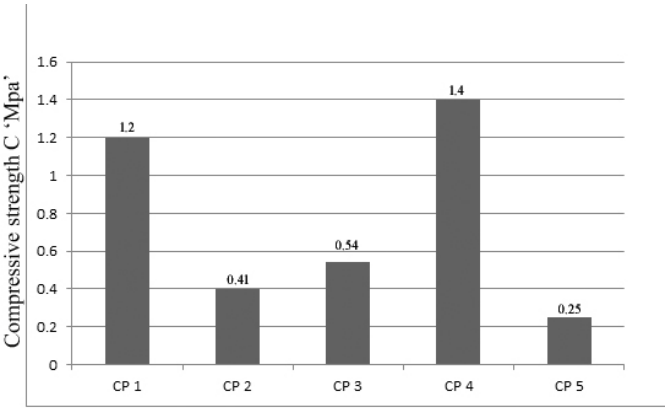


**Fig6: Compressive strength of specimens**

The experiment shows the difference in compressive strength. The standard deviation calculated for all five specimens is 0.45; it shows the maximum strength value of 1.21 MPA and minimum 0.25 MPA. While the coefficient of variation, therefore as CV, of all the specimens is 59.21 %.

## COMPARISON OF EXPERIMENTAL RESULTS WITH REVIEWED RESULTS:

The reviewed results in Table Ishow the variation in compressive strength of specimens due to the factors therefore, soil proportion, curing time, form and dimensions of specimens. However the 'CV' of all these reviewed researches are up to 28.51%. Comparing the reviewed results with the results obtained by experimenting the specimens that were prepared from same soil, cured for 28 days, carries similar form and specimens are of proportionally equal in dimensions. The result shows a greater variation in compressive strength with 59.21%.

These specimens were prepared manually with rough calculations. The possible factor of strength variation assumed to be the compaction of mud while molding. In the manual molding, the forces applied for compaction were rough so the level of reduction of porosity differs in each specimen.

## CONCLUSION& RECOMMENDATION

Comparing the experimental results with the results of reviewed researches it is concluded that, the compressive strength of adobe can't be specific even though they are prepared under the similar aspects. These are hand-made bricks so the strength may vary as the bricks are molded manually by using rough estimations. Further research is needed to analyze the influence of rough molding on the compressive strength of adobe, it is also recommended to analyze the solid reasons behind the variation in compressive strength of roughly prepared adobe specimens.

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## Authors:

**First Author** -Sasui, Student "M.Arch", Department of Architecture; Faculty of Architecture Naresuanuniversity, sassuikhuwaja126@gmail.com.

**Second Author** -Dr.WatcharinJinwuth, Assistant professor, Department of Architecture; Faculty of Architecture Naresuan university, watcharinj@nu.ac.th

**Third Author** -SirimasHengrasmee, Assistant professor, Department of Architecture; Faculty of Architecture Naresuanuniversity, sirimash@nu.ac.th.

**Correspondence Author** - Sasui,sassuikhuwaja126@gmail.com., +66 638608986.