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# Innovative Adobe Made of Recycled Rubble: Environmental Material for Rural Buildings

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***Abstract*** **–**Rubble of destroyed buildings in Turkey is a growing environmental problem, in Ankara only, there are 12 landfills to collect and store them. Adobe is a world common building material; many studies inferred its environmental qualities.
This study examines the production of adobe using recycled rubble sand and aggregate, in order to use the adobe ecological qualities and decrease the rubble wastes impact. Moreover, experimenting different mixtures and compositions of adobe helps to define the most suitable mixture for different uses, especially in rural areas in Turkey.
The empirical approach used in the study compares different sets of specimens prepared in lab conditions; each set is made of five cube samples. The specimens are examined to define their qualities related to strength of materials.
The initial results shows the possibility to use recycled bulk in making adobe for construction materials and elements, even the resistance under compression decreased 5% using recycled sand, comparing to adobe produced using new materials, it still achieve the objective structurally and environmentally. Future work will study the use of this material in structural elements, and examining their mechanical and structural properties.

***Keywords*** *– Adobe, rubble, recycle, environment, strength of materials*

## I. INTRODUCTION

Currently, large amounts of rubble exists at landfill areas in Turkey. There are 12 rubble landfill areas only in Ankara. In order to prevent environmental pollution and reduce the use of local recourses and the consumption of new materials, studies are being carried out to recycle and reuse these rubble masses. In this study, it is aimed to determine the impact of the recycled sand and fine aggregate on mechanical behavior of adobe, especially used in rural areas of Turkey and in many other countries as a significant structural material. In addition, the effect of the amount of hay on mechanical behavior of adobe produced by local materials is investigated.

While studies on using recycled materials in production of adobe were not applied, since it is already a cheap material. Our study objective is not to decrease the cost of construction, hence, it is to recycle rubble and decrease the construction solid wastes in an environmental manner. The research project on the adobe material containing recycled material, aims to use the characteristics of adobe to recycle demolition rubble, thus it will conduct a research on the structural elements made of adobe containing recycled materials.

RELATED WORK

Adobe is a construction material that provides suitable environmental conditions for human health, consumes little energy in its production and use, it is environmentally friendly and its material cost is low [1]. However, adobe is a weak material in terms of compressive strength and resistance to water [2].

Many studies have been carried out to improve the mechanical properties of adobe material. These studies were generally made on adobe containing different additive materials in different ratios. In some of these studies the materials such as phosphogypsum, fly ash [2], glass fiber, air-entraining admixture [3], silica füme [4], fiber plastic, textile fibers, pumice, lime and cement [5] were used as additive materials in adobe.

In addition to the investigation of the adobe material, there are also academic studies on adobe buildings or adobe structural members. In some of these studies, behavior of adobe members or adobe buildings were examined by diagonal loading [6-7], cycled loading [8] and shaking table test [9].

All the previously mentioned studies, did not consider the use of recycled rubble neither as mixture for adobe nor as additives, this study will examine their use in producing adobe blocks to be used for construction in rural areas.

## II. METHODOLOGY

A series of experiments were prepared to investigate the potentials of using recycled rubble in adobe production. Three different sets of mixtures were prepared; each set is made of five cubes 10 cm.

### *A. Mixtures used*

In the first and second set all the materials used were new non- recycled materials: Earth, sand, fine aggregate, hay and water. The difference was in the percentages of each component in order to test the change in strength in case of using different ratios, and to obtain reference results to compare with the mixtures made of recycled materials.

The Earth was obtained from the university campus. It is dried by natural ventilation, as shown in Fig.1.

Fig.1 Drying earth by natural ventilation

In Table 1 the chemical composition of the earth used is shown.

Table 1. Chemical composition of the used earth

| **Material** | **Composition in Per Cent (%)** |
|---|---|
| Aluminum oxide | 34 |
| Silicon dioxide | 50 |
| Magnesium and Lime | 6 |
| Iron oxide | 8 |
| Organics | 2 |

While in the third set, we have used recycled sand and fine aggregate, from a 40 years destroyed building in Ankara Turkey. The materials obtained by manually crushing big pieces from remains of concrete destoyed elements, as shown in Fig 1.

Fig. 2 Crushing demolition rubble manually to obtain sand and fine aggregate

Using the sieves 7, 8 to obtain fine aggregate and 10, 11 for sand, separating gradient sizes of bulk recycled material to be mixed with earth, as shown in Fig 3.

Fig. 3 Obtained sand and fine aggregate after using sieves

By using the aforementioned materials, we prepared the sets of specimens, the mixtures components and ratios are shown in table 2.

Table 2. Materials used in the mixtures

| **Set No.** | **1** | **2** | **3** |
|---|---|---|---|
| **Content of Soil %** | 65 | 75 | 75 |
| **Content of Sand %** | 15 | 15 | xx |
| **Content of Fine aggregate %** | 5 | 5 | xx |
| **Content of Recycled Sand %** | xx | xx | 15 |
| **Content of Recycled Fine aggregate %** | xx | xx | 5 |
| **Content of Hay %** | 15 | 5 | 5 |
| **Number of Specimen** | 5 | 5 | 5 |

The materials were mixed manually, as in Fig. 4 using 20% of water for mixing all the components together.

Fig. 4 Preparing the mixtures manually.

Using these three different mixtures, each set is made of five specimens with cubic shape of 10 cm dimension, as shown in Fig. 5

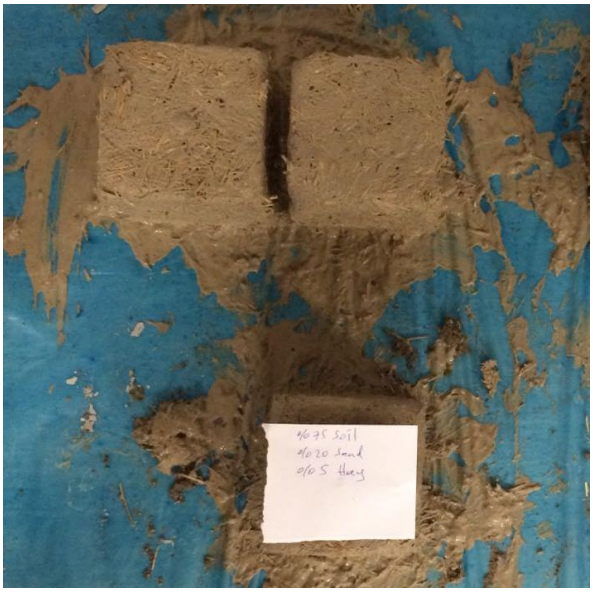

Fig. 5 Cubic specimens of set N.1.

*B. Treatment of specimens*

The specimens were left for 21 days to dry in the lab using natural ventilation, no additional treatment was applied to the specimens.

## III. EXPERIMENTS

After passing 21 days the first experiment applied to the specimens was the shrinkage measurement, all the cubes of each set were measured as in Fig.6. The results shows that all the cubes suffered a shrinkage with different percentages due to the different mixtures used previously, all the dimensions are shown in table 3.

Table 3. Cubes dimensions ( in Cm) after shrinkage

| Cube No. | Set 1 | Set 2 | Set 3 |
|---|---|---|---|
| 1 | 9.5*9.5*9.5 | 9.0*9.0*9.0 | 9.7*9.7*9.7 |
| 2 | 9.7*9.7*9.7 | 9.2*9.2*9.2 | 9.8*9.8*9.8 |
| 3 | 9.9*9.9*9.9 | 9.2*9.2*9.2 | 9.2*9.2*9.2 |
| 4 | 9.7*9.7*9.7 | 9.3*9.3*9.3 | 9.6*9.6*9.6 |
| 5 | 9.9*9.9*9.9 | 9.5*9.5*9.5 | 9.8*9.8*9.8 |

Fig. 6 Shrinkage measurement

Even all the specimens show a shrinkage ratio, they did not show any kind of cracks or fracture.

Moreover, all the specimens were weight to calculate the loss in weight due to humidity loss, the results are shown in table 4.

Table 4. Weight of specimens (Gram) before and after drying

| Cube | Set 1 | | Set 2 | | Set 3 | |
|---|---|---|---|---|---|---|
| 1 | 800 | 643.5 | 1200 | 999 | 1200 | 916 |
| 2 | 800 | 651 | 1200 | 945.5 | 1200 | 921 |
| 3 | 800 | 644.5 | 1200 | 944.5 | 1200 | 956.5 |
| 4 | 800 | 653.5 | 1200 | 1010 | 1200 | 951 |
| 5 | 800 | 640 | 1200 | 1016.5 | 1200 | 915 |

Finally, three specimens of each set are chosen with the closest shrinkage ratio, weight of specimen and were tested under compression as shown in Fig.7, and all the results are shown in table 5.

Fig. 7 Compression test of specimens.

Table 5, specimens results under compression (Mpa)

| Set 1 | | Set 2 | | Set 3 | |
|---|---|---|---|---|---|
| Cube | Result | Cube | Result | Cube | Result |
| 2 | 1.19 | 1 | 1.35 | 1 | 1.3 |
| 3 | 1.14 | 3 | 1.42 | 2 | 1.22 |
| 4 | 1.11 | 4 | 1.42 | 5 | 1.35 |

## IV. RESULTS

The experiments results shows the average dimension and shrinkage ratio as following: set 1(65% earth, Sand15 %, fine aggregate5%, hay15%) =9.74, 2.6% respectively. Set 2 (75% earth, Sand15 %, fine aggregate5%, hay5%): 9.24, 7.6%. Set 3(75% earth, recycled Sand15 %, recycled fine aggregate5%, hay5%) 9.62, 3.8%.

The average weight and average weight loss ratios are as following: set 1: 646.5 g, 19%, set 2 : 983.1 g, 18%, and set 3: 931.9 g, 22.3%.

Finally the average strength under compression test were: Set1: 1.146 mpa, Set 2: 1.396 mpa, and set 3: 1.29 mpa.

## V. DISCUSSION

The experiments shows that having higher ratio of hay in the mixture resulted in lighter adobe, but with less resistance under compression, but with almost the same ratio of losing weight, and lowest ratio of shrinkage. This mainly caused by the fermented organic material of hay, which works as adhesives of the other component materials.

Using less percentage of hay in second set of specimens, and increasing the earth ratio enhanced the compression strength

of the adobe but this increased the ratio of shrinkage to 7.6%. Using recycled materials decreased the strength of compression by 8% compared to using new materials, but it enhanced by 12% compared to the set using higher percentage of hay.

Even the weight loss were close to each other between 18 to 22%, but clearly using recycled materials caused bigger loss, that because it has some cement remains from the old concrete recycled sand and fine aggregate. Moreover, the shrinkage ratio in recycled material specimens was less than the new materials, mainly because they already shrank in their first use in the buildings.

To sum up, using recycled materials in preparing adobe, has enhanced some mechanical qualities of adobe, and decreased others, thus in the future work we will examine other experiments as tension and shear stress…etc.

## VI. CONCLUSION

The mechanical behaviour of different mixtures of adobe are investigated in this study, and it shows that using recycled materials is possible in adobe, for building in rural areas.

This will help in solving the problem of construction solid wastes, rubble and bulk instead of dumbing them in landfills. Moreover, even the compression strength is 8% less than using new materials, but this still enough for using in constructing masonry adobe walls in rural areas, thus the future work will focus on using this mixture in making structural elements, such as walls, arches and walls.

Another future work is being examined now is to replace the sand with shredded recycled plastic, which is another big problem in Turkey since only up to 22% of plastic wastes are recycled in Turkey.

Environmentally, using rubble in adobe will help the Turkish cities to get rid of their wastes, and use minimum energy with the least emissions ratio, since the process does not need high technology or complex production techniques.

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