PAMUKKALE ÜNİVERSİTESİ MÜHENDİSLİK FAKÜLTESİ
PAMUKKALE UNIVERSITY ENGINEERING COLLEGE
MÜHENDİSLİK BİLİMLERİ DERGİSİ
JOURNAL OF ENGINEERING SCIENCES
YIL : 2005
CİLT : 11
SAYI : 2
SAYFA : 309-316

UTILISATION OF ALTERNATIVE MATERIALS IN MANUFACTURING OF MUD BRICK

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Geliş Tarihi : 07.02.2004

ABSTRACT

The population in the rural area of Turkey has increased due to KKP (in Turkish Köy-Kent Proje). Most of the buildings in the area are made out of limestone and adobe. But this material does not have sufficient resistance to earthquakes. The research in the field of construction at The University of Cukurova elaborates on the mechanical properties and workability of raw materials such as fibre, wheat stem, strafor, basaltic pumice and clay. The production of bricks using a significant fraction of mixed waste from wheat and different ratios of clay mixed with fibre, strafor, cement, gypsum, lime and basaltic pumice was investigated. This paper presents the use of waste in the construction of soft bricks at the KKP. The results of this study suggests that using these materials have many advantages such as energy savings, low cost and improvements in the final properties of products.

Key Words : Fibre, mud brick, Wheat stem, Strafor, Basaltic pumice, Clay

KERPİÇ ÜRETİMİNDE ALTERNATİF MALZEMELERİN KULLANIMI

ÖZET

Türkiye'de Köy-Kent projesi yüzünden kırsal bölgelerde yaşayan nüfusta son zamanlarda artış görülmektedir. Bu bölgelerde yapılarda çok ağır olan kireç taşı kullanılmaktadır. Ancak bu malzeme depreme karşı yeterli dayanıma sahip değildir. Kerpiç üretiminde kullanılacak malzemelerin mekanik özelliklerini araştırmak için Çukurova Üniversitesinde bir çalışma yapılmıştır. Bu malzemeler; fibre, buğday sapı, strafor, pomza ve kildir. Kerpiç üretiminde atık malzemeler kullanılmıştır. Çalışma sonunda fibre kerpicinin yapı üretiminde kullanımının ekonomi, enerji tasarrufu ve gelişmiş mekanik özellikleri gibi bir çok avantajı olduğu görülmüştür.

Anahtar Kelimeler : Fiber, Kerpiç, Buğday sapı, Strafor, Bazaltik pomza, Kil

1. INTRODUCTION

Earth has been used in the construction of shelters for thousands of years, and approximately 30 % of the world's present population still lives in earth structures (Cofirman, 1990). A large quantity of energy is consumed to manufacture fired bricks and cement for construction industry. This generates a large quantity of green house gases to the environment. Earth is a cheap, envirimentally friendly and abundantly available building material. It has been used extensively for wall construction around the world, particularly in developing countries. Mud structures are able to perform satisfactorily under some environmental conditions. However, mud walls have a tendency to erode under rain impact and can collapse when exposed to continuous rain for several hours. Water is a significant factor for mud brick deterioration. Therefore, mud buildings, which are not protected, suffer greatly from durability problems due to water penetration and evaporation (Ren, 1995). Home brick-makers may need to experiment to find the right balance of ingredients. The consistency of the brick mixture should be optimal. With the utilisation of waste materials high ecological construction products can be manufactured due to the consequent saving in raw material (not opening of new mineral deposits) with an economic saving in production costs which also impart some excellent properties to the brick, as measured according to European standards (Acosta, 2002).

There is general exodus of rural population to the cities with the rapid industrialisation in developing countries. The infrastructure to support these cities, such as building for housing and industry, mass transit for moving people and goods, and facilities for handling water and sewage will require large amounts of construction materials. Enhanced construction activities, shortage of conventional building materials and abundantly available industrial wastes have promoted the development of new building materials (Kumar, 2002).

Laterite and lateritic soils are commonly found in Cameroon on nearly 67 % of the national territory. They are used as building materials for the construction of roads and houses. For the construction of walls, mud and bricks are widely used according to economic factors. The climatic conditions cause damage to mud, which is air-dried and unstabilized. Bricks are however, resistant materials. Their production needs considerable consumption of firewood, which the manufacturers use to raise the temperature in traditional furnaces during firing higher than 900 ^{0}C according to the standard of developed countries. About 30 % of the cost of production of these bricks is ascribed to energy, therefore, final products are costly (Mbumbia, 1997).

Most studies reported in the literature are focused on the stabilisation and utilisation of laterite and lateric soils with the addition of lime, cement, or betonite (Attoh-Okine, 1990). The method of mixing these additives with soil is not well appreciated either by the manufacturers or the user of bricks in Cameroon. People used to mix lime or cement with sand and gravel to produce bricks, although the problem of the control of temperature during firing remains the major problem (Laurent, 2000).

Romans used natural pozzalans whenever they were available (Naples, Rome, Santorin, Germany). It is now well known that the acquisition of hydraulic properties by these materials is due to the puzzolanic action of brick powder on hydrated lime. The two fundamental characteristics of puzzolans are usually defined as the ability to react with lime and ability to form insoluble products with binding properties. Since an exact classification of pozzalans is difficult due to the many materials that show an identical behaviour when mixed with lime and water, it is commonly accepted to divide the pozzalans into natural and artificial categories. While natural pozzalans do not require any treatment when utilised, artificial ones result from chemical and/or structural modifications of materials originally having no or weak puzzolanic characteristics (Massaza, 1976).

Turkey is rich in natural pozzalans, which are also called 'trass' in the cement industry. Almost 155 000 km^2 of the country is covered by tertiary and Quaternary-age volcanic rocks, among which tuffs occupy important volumes. Although there are many geological investigations on these volcanic rocks, their potential as natural pozzalans is not well established (Kaplan ve Binici, 1996). In Turkey, like the in most Mediterranean countries, tuffs have been used in mixture with lime since historical times. Today, the cement industry in Turkey is one of the most well-established and developed industries and it has a continuous interest in new supply sources of tuffs since almost about one-third of the total production in recent years was ''trass cement'' which is a Portland-puzzolan cement (Turkmenoglu, 2002).

Housing is a great problem in today's world. In Turkey, many houses in KKP are built on one floor. The most common building material for construction of houses is the usual burnt clay brick. Continuous removal of topsoil, in producing conventional bricks, creates enverimental problems. In Osmaniye-Adana region of Turkey, a huge quantity of wheat stem waste is produced every summer. This is often a cause of major concern because farmers burn this material and give rise to ecological problems. Instead of burning, this material can be used in brick production. Background soil is a common building material and people have been making use of it for a long time. Most bricks are made of clay. Concrete contains sand and pebbles and cement is mostly mixed with sand. Recently mud-brick has become a popular and very attractive way of building houses.

There are a number of important issues related to the production of mud-bricks which must be resolved, for example it is essential to establish the best method to produce the strongest mud –bricks and the correct procedures for crushing and measuring the strength of these bricks. The other questions that also require explanation are; why did the early pioneers often build houses made of mud mixed with straw and why do mud-brick houses build today still have wide verandas? The positive and negative characteristics of these types of mud bricks in relation to the climate inside and outside the house must be known and should be related to the physical characteristics of different kinds of mud bricks. Work is needed to establish an empirical relationship between the reduction of heat (from outside towards the inside) and the thickness of the wall built using different kind of mud-bricks. Furthermore, it is vital to ascertain the advantages and disadvantages of using mud-brick and the right balance of ingredients for making the most suitable mud-bricks for a given construction application.

With this study, fibre mud brick, a matterial of construction at The University of Cukurova elaborates on the mechanical properties and workability of raw materials such as fibre, wheat stem, strafor, basaltic pumice and clay. The production of bricks using a significant fraction of mixed waste from wheat and different ratios of clay mixed with fibre, strafor, cement, gypsum, lime and basaltic pumice was investigated. This paper presents the use of waste in the construction of soft bricks at the KKP.

2. EXPERIMENTAL PROGRAM

2. 1. Materials

The materials used for mud brick production were basaltic pumice, cement, wheat stem, strafor, clay and water. The cement used was obtained from Adana Cement Plant.

Brick clays usually have high SiO_2 (45-75 %), and low Al_2O_3 (10-35 %) content. They also contain usually considerable amounts of iron oxide (4-9 %), calcium carbonate (up to 10 % as CaO), potassium oxide (up to 4 %), and low content in sodium oxide (up to 1 %), titanium oxide (up to 2 %) and sulphates (up to 2 % as SO_3). The main minerals in brick clays, depending on composition, are usually kaolinite and chlorite with illite, quartz and organic matter. Due to uncertain composition of the chlorite and others minerals the calculation of it is not normally used for other clays (Worral, 1982).

The basaltic pumice cone deposits are of Quaternary age and are located in the Osmaniye-Adana province (Southern Turkey), and the are reserves estimated to be approximately 1.000 million tonnes. The pumice comprises an average of 85 % volcanic glass and 15 % of phenocrystic feldspars along with minor spheroid hematite minerals, determined by microscopy. XRD shows the presence of dominant illite and kaolinite as clay minerals along with feldspar. The high porosity of the basaltic pumice is an advantage for easy and economical crushing (Kelling, 2000).

2. 2. Chemical Analysis

The mineralogical composition of cement used in this study is given in Table 1 and chemical analyses of all materials used are given in Tables 2-6.

Table 1. Mineralogical Composition of Cement

HM= Hydraulic Modula,

$$= \frac{CaO}{SiO_2 + Al_2O_3 + Fe_2O_3},$$

SM= Silicate Modula= $\dfrac{SiO_2}{Al_2O_3 + Fe_2O_3}$

AM: Alimunat Modula= $\dfrac{Al_2O_3}{Fe_2O_3}$,

LM = Lime Modula=

$$\frac{100.CaO}{2.8SiO_2 + 1.1Al_2O_3 + 0.7Fe_2O_3})$$

Table 1. Mineralogical Composition of Cement

HM	SM	AM	KS	C_3S	C_2S	C_3A	C_4AF	AK
2.19	2.05	1.42	99.73	66.56	5.67	8.15	11.90	2.62

Table 2. Chemical Composition of Basaltic Pumice

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	P_2O_5
48.89	14.11	12.10	9.27	8.94	-	3.34	1.21	1.35

Table 3. The Chemical Composition of Cement

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3
19.46	5.57	3.91	63.43	1.89	2.03

Table 4. Chemical Composition of Clay

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_4	K_2O	TiO_2
52.40	25.12	7.95	-	2.45	0.64	4.27	0.70

Table 5. Chemical and Physical Properties of Clay (Ozbek et al., 1994).

Mineral			Concentration (meq/l)								Density (g/cm^3)	Permeability
			Cation				Anion					
Clay	Sand	Silt	Ca+	Mg+	Na+	K+	HCO^-_3	CO^-_3	CL^-	SO^-_4		
32.04	43.44	25.52	3.5	3.7	0.31	0.31	4.28	0.44	1.3	4.49	1.278	Quickly

Table 6. Chemical Compositions of Lime

Component	Content (%)
MgO+CaO	87.00
MgO	3.62
CO_2	1.82
SiO_2(non solution)	0.5
Al_2O_3+Fe_2O_3	0.8
SO_3	0.8

2. 3. Process Operation

2. 3. 1. Mixing of Raw Materials

The basaltic pumice and clay were sieved through a 0.625 mm sieve. The materials were mixed thoroughly in dry state. The slaked lime slurry was sieved through a 1.18 mm sieve. Then other materials were added to the mixture and mixed thoroughly in dry state. Water was added and the ingredients were further mixed thoroughly by kneading until the mass attained a uniform consistency. Water was added to the mixture of dry materials and the water content was determined by drying approximately 100 kg raw material in a large-capacity electric drying oven at 105-110 ^{0}C for 24 h. After drying, the clay was crushed with grinding balls in a grinder to reduce the particle size. The results are presented in Figure 4 .

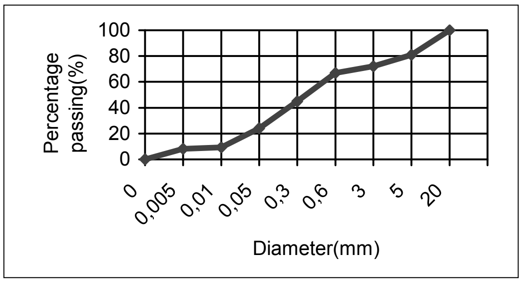


Figure 4. Grading curve from particle size analysis of clay-basaltic pumice-cement used for the preparation of specimens (ASTM and Turkish Standard requirement) (TS 2514, 2515).

2. 3. 2. Preparation of Bricks

Steel moulds of dimension 150 mm x 150 mm x 150 mm were used. The size of bricks was kept approximately the same as those of the normal bricks made of concrete samples in Turkey. The mix was placed in three layers and was properly compacted on a vibration table. The mix properties of mud bricks are given in Table 8, Names of mixture designations Table 7 and shape of samples of mud bricks are given in Figs.1-3.

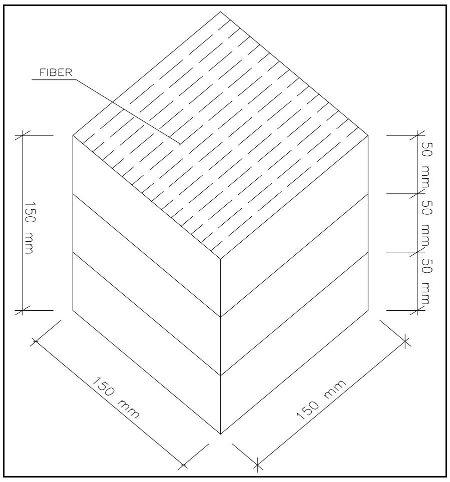


Figure 1. Shape of samples of mud bricks (A1-B1-C1-D1)

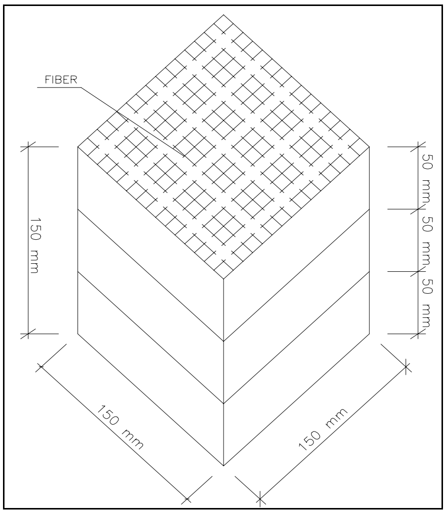


Figure 2. Shape of samples of mud bricks (A2-B2-C2-D2)

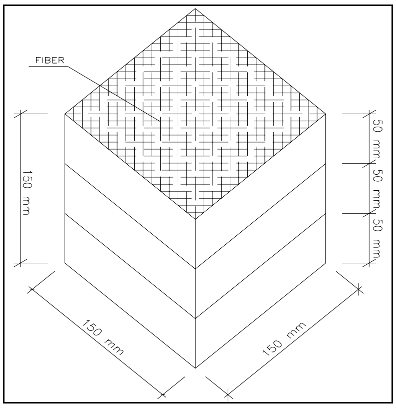
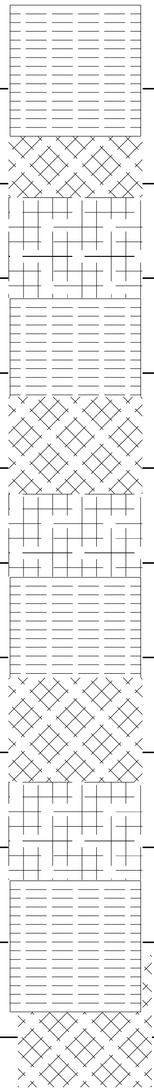


Figure 3. Shape of Samples of Mud Bricks (A3-B3-C3-D3)

Table 7. Names of Mixture Designations

Mix Designation	Composition of bodies of mud bricks	Conformation
A1	Clay+basaltic pumice+cement+lime+gypsum+nylon+water	
A2	Clay+basaltic pumice+cement+lime+gypsum+nylon+water	
A3	Clay+basaltic pumice+cement+lime+gypsum+nylon+water	
B1	Clay+basalticpumice+cement+lime+gypsum+wheat stem+water	
B2	Clay+basalticpumice+cement+lime+gypsum+wheat stem+water	
B3	Clay+basalticpumice+cement+lime+gypsum+wheat stem+water	
C1	Clay+basaltic pumice+cement+lime+gypsum+strafor+water	
C2	Clay+basaltic pumice+cement+lime+gypsum+strafor+water	
C3	Clay+basaltic pumice+cement+lime+gypsum+strafor+water	
D1	Clay++lime+gypsum+nylon+water	
D2	Clay+lime+gypsum+nylon+water	

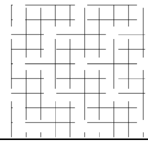
D3	Clay+lime+gypsum+nylon+water	

Table 8. Mud Bricks Mix Properties

Mix Designations	Components (kg)								
	Clay	Basaltic pumice	Cement	Lime	Gypsum	Fibre (nylon)	Wheat steam	Styrofoam	Water
A	50	15	10	2	3	0.01	-	-	20
B	50	15	10	2	3	-	2	-	20
C	50	15	10	2	3	-	-	0.5	20
D	50	-	-	2	3	0.01	-	-	20

3. RESULTS AND DISCUSSION

3. 1. Compressive Strength

The mechanical properties of mud bricks are given in Table 9. These results show that it is more than Turkish standard requirement.

2. 3. 3. Curing Method

The mud bricks were taken out from the moulds, covered with wet gunny bags and allowed to cure for a week.

2. 3. 4 Testing of Mud Bricks

The cured brick samples were determined for compressive strength after 28, 72 and 96 days of casting. The test results of the samples are expressed in terms of the average compressive strength of five specimens. If the individual variation was more than ± 5 % of the average, the value was not considered in calculating the average value.

The behaviour of brick-clay specimens during acoustic examination under loading could give useful information about their strength, structure and sintering techniques during manufacturing of bricks, tiles and similar products (Papargyris, 2001).

The compressive strength of tradioanal brick is 0,5-1 MPa., however, this value is raised to 1-7 MPa in the case of mud bricks made using the waste fibre. In practical terms it means that if the structure is durable the thickness of the outer carrier walls can be reduced to 30 cm.

3. 2. The resistance to Earthquakes

Most of the buildings in Turkey in the rural areas are made out of limestone and adobe. But this material does not have sufficient resistance to earthquakes. The compressive strength of the fibre-reinforced mud-bricks is greater than the traditional bricks, therefore, these bricks are more resistance to earthquakes. Moreover, the presence of fibres in mud-bricks provides flexibility to the structures thus enhancing their earthquake resistance. Another one of the earthquake studies is the application of two-dimensional loading on a mud brick specimen. From the tests carried out, it was observed that, mud brick was strong enough, ductile and resistant against earthquakes (Işık et al., 1999). Due to its naylon fibers, mud brick can store more elastic energy compared to other mud brick types, which renders it more resistant to earthquakes. For the same reason, this type of mud brick is more advantageous compared to the conventional mud brick.

Table 9 Mechanical Properties of Mud Bricks

Mix Designations	Density (kg/m^3)	Absorption (%)	Loss of Weight after 7 days (%)	Compressive Strength(Mpa)		
				7 days	28 days	96 days
A1	1600	37.65	16.15	2.3	5.0	6.1
A2	1600	37.65	16.15	2.4	4.9	6.5
A3	1600	37.65	16.15	2.7	5.6	7.1
Average				2.4	5.1	6.5
B1	1525	36.84	14.26	1.6	3.8	5.0
B2	1525	36.84	14.26	1.7	4.1	5.3
B3	1525	36.84	14.26	2.0	4.8	5.8
Average				1.7	4.2	5.3
C1	1392	33.54	13.49	1.7	2.4	3.7
C2	1392	33.54	13.49	2.1	2.4	4.2

C3	1392	33.54	13.49	2.0	2.6	4.9
Average				1.9	2.4	4.2
D1	1446	28.02	10.67	0.9	1.3	1.9
D2	1446	28.02	10.67	1.1	1.4	2.3
D3	1446	28.02	10.67	1.5	1.8	2.6
Average				1.16	1.5	2.26

3. 3 Comparison of Brick Cost and Workability

Physical and mechanical properties of the fibre-reinforce mud bricks show a considerable improvement as compared to the properties of the traditional bricks. Toughness of the mud-brick can be enhanced by the addition of gypsum to the mixture. It brings benefits for drying workmanship waste of time and drying area in practice. And it provides quickness and cheapness. The cost of a mud bricks are given Table 10. These results show that fibre mud brick is cheaper than traditional brick.

Table 10. Cost of Bricks (Turkish liras TL)

Bricks	Transportation	Raw Material	Worker's fee for Drying	Machine Amortisation	Curing	Additive	Total
Fibre Mud brick	-	-	10.000	10.000	-	25.000	45.000
Traditional brick	20.000	10.000	5.000	15.000	12.000	20.000	82.000

3. 4. The Shrinking and Cracking of the Fibre Mud Bricks

Quick solidation of gypsum prevents normal shrinking, cracking and transformation during dry of gypsum.

3. 5. The Heating of the Fibre Mud Bricks

Inner surface heat of the fibre-mud brick wall has a higher temperature compared to the other walls. This provides saving from fuel for heating.

3. 6. The Sensitivity of the Fibre Mud Bricks Against to Water

Reduction of sensitivity of fibre mud brick against water, provides protection entirety even though it scattered in short periods and it prevents its wear out in the rain.

4. CONCLUSION

The following conclusions can be drawn from the present study.

- Fibre mud-bricks can be utilised in the construction of housing for dwellings. These materials are suitable for the production of KKP of high quality, good properties and attractive appearance.
- This study shows that fibre mud-brick will give a cost efficient construction of houses and the raw materials used improve the mechanical properties of the bricks and a reduction in construction time.
- According to the results, the group A_3 samples have higher compressive strength potential.
- Fibre mud-bricks will reduce the dead weight and materials handling cost for housing.
- An increase in basaltic pumice content increases water absorption and decreases density of the mud-bricks.
- These bricks require no skilled labour and can also be moulded into any shape and size depending upon the requirements.
- Mud-bricks fulfil the mechanical requirements in terms of compressive strength requirements of ASTM and Turkish Standards.
- Good quality mud bricks can be produced from these raw materials. Sufficient strength is obtained by muculding mud brick. These types of mud bricks can solve the problem of environmental degradation.

5. ACKNOWLEDGEMENTS

The authors wish to gratefully acknowledge the valuable assistance given by the Force Concrete Limited.

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