AGEING INVESTIGATION ON THE FIRST CASE-STUDY BUILDING CONSTRUCTED WITH GYPSUM-STABILISED EARTHEN MATERIAL ALKER IN 1983

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Abstract. Mechanical and physical properties of earthen material for construction can be modified by stabilisation in order to meet current requirements. Although cement stabilisation is generally used, gypsum is the subject of stabilisation in studies conducted by Istanbul Technical University. New composite is called Alker. In case of new material and technologies, ageing of the material and structure is important due to safety and maintenance concerns. Though gypsum has been used in historical architecture, gypsum stabilisation of earth as construction material is not much known. The aim of this study is to gain experience on Alker as construction material. A case-study building out of Alker was constructed in 1983 after the basic laboratory studies having started in 1978. Production process and properties of the material, construction techniques, design criteria and life-cycle performance of the building will be proved for answering the question on ageing.

Keywords: gypsum stabilised earth, Alker, ageing of earthen construction.

AIMS AND BACKGROUND

Turkey experienced earthen construction throughout the history and today abundantly. Since the industrialised materials are in the market the technology of the earthen construction remained underdeveloped. The global advances in building-ecology and building-biology paved the way to understand the contribution of earthen construction material to the human life. Istanbul Technical University conducted researches on stabilising earth with gypsum and called the material Alker. The gypsum has been used in Mesopotamia region, from Iran down to Yemen. Earth stabilisation with gypsum was a new way as amended mixture and has been the subject of systematic research. After determining the basic properties of Alker in the laboratory, a case-study building was constructed in 1983 (Fig. 1a, b). The building furnished as nursery school of the University and inhabited. Within this study the construction technology of Alker and the life-cycle performance of the building will be summarised.
EXPERIMENTAL

The soil of traditional earthen material contains 30–60% clay and maximum grain size has to be 20 mm, which makes the production labour intensive. Soil for Alker containing about 8–10% of clay can be rich of silt and the diameter of gravel can rise up to 5–7 cm. This kind of soil is easily available.

The soil for block production should consist of small particles and, therefore, should be sieved. If the production technique is ramming, sieving is not needed. Topsoil with the rest of the plants should be removed and saved for the garden uses. If the foundation soil amount of the building is not enough for the building, excavation soil from nearby can be used.

The material proportions for stabilising are shown in Table 1. Lime, gypsum and clay in the mixture act as binder, all together. Therefore, binding amount is about 20%. The minerals in the clay will react with gypsum resulting in unsoluble new salts. If the gypsum is not modified, it is water absorbent, swells with water and shrinks while drying. Gypsum erosion due to water is high if it is not modified.

Table 1. Proportions of the mixed components in (%) of soil by weight

<table>
<thead>
<tr>
<th>Component</th>
<th>Content (%)</th>
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<tbody>
<tr>
<td>Gypsum</td>
<td>10</td>
</tr>
<tr>
<td>Lime</td>
<td>2</td>
</tr>
<tr>
<td>Water</td>
<td>20*</td>
</tr>
</tbody>
</table>

* According to the dryness of the soil.

Compared to contemporary earthen material, the new composite Alker has more water-resistance ability and its mechanical properties are improved (Table 2). Due to hydration of gypsum, the composite hardens in short time, resulting in accelerated construction period. Production of material and building is less labour
intensive. Heat transfer value is lower. Emission savings due to lower embodied energy and energy savings through the Alker wall are remarkable\(^2\).

**Table. 2. Mechanical properties of Alker**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength</td>
<td>2.0–4.0 N/mm(^2)</td>
</tr>
<tr>
<td>Shear strength</td>
<td>0.9–1.3 N/mm(^2)</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>min. 2.0 N/mm(^2)</td>
</tr>
</tbody>
</table>

By SIA (Schweizerischer Ingenieur-und Architekten Verein) standards\(^3\).

**CONSTRUCTION TECHNIQUES**

Construction of the first Alker case-study building was performed in two ways. Sieved soil was mixed with stabiliser and blocks were produced manually (Fig. 2a). Mortar for the masonry was based on soil but gypsum was not mixed. The second production way was with the coarse part of the soil. It was stabilised and rammed into the wall form of the building (Fig. 2b).

**Fig. 2. Alker block production (a), case-study building with rammed earth walls (b)**

**DESIGN FEATURES**

Design of the case-study building considers the seismic code of Turkey\(^4\). Therefore, design principles will be summarised in this respect.

**Definition of the project.** Adaptation of gypsum-stabilised earth Alker to the new construction technology has been the subject of a postgraduate thesis. The thesis with the title ‘Researching the Manufacturing Opportunities of Gypsum-stabilised Earthen Production’ prepared by C. Tanriverdi\(^5\) has been conducted by Prof. R. Kafescioglu. The case-study building was designed to serve as a Nursery School for Istanbul Technical University (Figs 3 and 4). While Alker case-study building has been used as Nursery School for nine years, its thermal conditions such as interior + exterior temperature and moisture differences have been measured for
a year and a half. The single-story building is composed of three rooms, a kitchen and a bathroom.

Fig. 3. General view of Nursery School, 1985

Fig. 4. View of kitchen (a) and bathroom (b), 1985

**Structural decision.** Wall configuration and openings: Exterior walls of Nursery School are 45 cm to provide thermal comfort, while interior walls are 30 cm since they are load-bearing (Fig. 5). Upper wall reinforced concrete bond beam, which also connects inclined roof slab, is covered by Alker on exterior surface. Thus, exterior plaster has been applied above material of the same type. On the other hand, thermal bridge effect of reinforced bond beam has been reduced.

Since Alker case-study building is designed to be used as Nursery School, parapets are 50 cm high. Window opening escalates up to the bottom of bond beam. Windows are oak and their glasses are low-E. Top of parapet has been protected by casted concrete from exterior and marble plate from interior.
Foundation: Since all walls of Alker Nursery School are load-bearing, a foundation lies beneath all of them. Alker wall is protected against rain water by elevating flooring 30 cm from natural ground.

Bond beam and roof slab: Flooring of Nursery School building, which is situated on ground, is lean concrete and above layers are designed as water proofing, thermal insulation, floor heating pipes and ceramic tiling. Reinforced bond beam connecting upper wall also carries reinforced inclined floor (Fig. 6). Reinforced prefabricated beam and hollow blocks have been used to construct roof, which is covered with insulation and roof board.

Sanitary and installation equipments. After walls of Alker building have been completed, cavity has been dug into the wall for the required installation and later it is plastered. The Nursery School is heated through the floor (Fig. 7a, b). Heating
installation pipes required for this purpose have been placed under ceramic tiles. Boiler has been installed to the wall (Fig. 8). Plastic installation system has been used to prevent corrosion.

*Exterior and interior wall siding.* Interior of walls is covered by ready-made gypsum plaster in living rooms and by ceramic tiling applied with cement mortar in wet areas. Exterior walls are covered by different plasters including lime-sand or cement mortar based on soil (Fig. 9a, b).

![Fig. 7. Pipes installed for flooring heating (a) and boiler (b), 1985](image)

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![Fig. 8. Placing the installation into the Alker wall; heating system, waste water, clean water, electrical cables, 1985](image)

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![Fig. 9. Deterioration of cement-based plaster (a) and resisting performance of lime+soil plaster (b)](image)

Fig. 9. Deterioration of cement-based plaster (a) and resisting performance of lime+soil plaster (b)
Both exterior and interior temperature and moisture measurements on the 1st case-study building were carried out during 18 months between 1986 and 1987. As a result of these experiments, heat transition value of Alker wall material is calculated as $\lambda = 0.4 \text{ W/m K}$ (Ref. 2) and inner space comfort of the building has been proved. Plaster test having been started on exterior surface of the building has continued for 5 years. Five companies have participated to test program on ‘Contemporary Plasters on Earthen Wall’ with 15 different materials. First case-study building constructed in 1983 still functions as office building of security forces of university campus.

**CONCLUSIONS**

The case-study building has been constructed in order to determine the results of workability and ageing of gypsum-stabilised earth. The results achieved with the construction of 1st case-study building can be summarised as follows:

**FINDINGS ON CONSTRUCTION TECHNIQUES**

1. Setting time, which is about 20 min due to gypsum hydration, should be considered.
2. Mortar prepared for construction should be consumed before setting time.
3. Lime is added to the mixture to delay setting time.

**THERMAL FINDING**

As a result of these monitoring, values for experimental thermal transition has been calculated by $\lambda = 0.4 \text{ W/m K}$. Humidity balance in the indoors is good, therefore, the air quality and health performance of the house is remarkable.

**DURABILITY FINDINGS**

Plaster based on cement binder needs a mash layer fixed to the wall before plastering. The main factors for tearing off the plaster from earthen external wall are:

- humidity transfer value through the plaster should be equal to the wall;
- the heat and humidity movements of the plaster should be equal to the wall.

The lime + soil mixed plaster succeeded throughout the time as seen in Fig. 8b.

The observation on the indoor walls revealed the following:
even there was damage in water installation system of the Nursery School, erosion does not occur at those particular walls, the walls do not swell and plaster does not fall off.

Acknowledgements. The building served as Nursery School of ITU between 1985–1994. Basic structure of the building has been supported by the Energy Saving Fund of Shell Company. At completion stage, roof covering has been provided by Eternit Company; thermal insulation of roof by Heraklit Company; wall and floor ceramic tiles by Toprak Seramik; sanitary equipments by Eczacibasi Company; windows and glasses by Isik A.S. both in terms of material and workmanship.

REFERENCES


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