Innovations in traditional masonry industry
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Abstract

This paper explores the innovations in building with Brick so it could be used effectively as an efficient building material, concentrating on types of additives, and their effect on compressive strength of the brick. Moreover; what is available in market...
Summary

Mud is considered as one of the oldest materials used for construction, it is popular for many reasons; such as it's low cost, low-maintenance, availability, and does not need highly skilled labors to use it. 30% of the world’s population is using mud for construction. Mud is used intensively in most of the underdeveloped countries, yet there have not been enough innovations on it to reach its full potential. Coming myself from a country that is famous with mud housing towers, Yemen, I recognize how important to improve this material to help underdeveloped countries start producing bigger scale projects and revolve the wheel of development.

This paper explores the innovations done to improve the compressive strength of the mud/clay brick and the potential emergence of a secondary and tertiary industries that rely on recycling wastes coming from Mining and agricultural industries to create building materials. What is available in market, concentrating on types of additives, and their influence on the brick. Current improvements are focusing on making Clay stronger and more thermal resistant; it was found that mechanized process that Clay goes through. Additives poured into the clay mixture can effectively improve the quality of the indoor environment, and reduce the energy dependence of the building. Moreover, it also improved the building resistance to earthquakes. There have been many uses of mud. Innovations such as Cob, Adobe, and Rammed earth are found in many countries around the world. Additives such as animal waste, straw, animal’s blood, were all found through hundreds of years and after many trials and errors.

Now technology advancement in construction had accelerated the process of innovation and with focus on creating more sustainable materials there has been an influence on making use of waste products of other industries in Construction materials. Mud’s ability to be mixed with other materials enables it to be a great medium for innovation in building. Since it is expected that by 2025 a 19 billion tons of waste will be generated annually from around the globe, there has been a direction to re-use waste materials in construction. These wastes are dumped in nature, endangering living creatures and creating pollution. This is a great potential to combine both of construction and waste recycling industries in developing countries and establish new ventures as well.
Introduction
Through centuries, human race had survived by using what nature had offered for protection and shelter. Many cultures had used mud and clay as an essential material for building settlements for them. For the need of people to dwell and colonize, their homes needed to stay longer and provide comfort and safety. That's when builders started thinking of strengthening the mud by either adding other materials to it or by compressing it under pressure.

Science of Brick
It is important to understand the physical and chemical composition of the brick to understand the influential components in either strengthening or weakening a piece of brick.

Porosity
Porosity of a brick is a characteristic of its fine capillaries. These miniscule gaps influence the moisture absorption of the brick (breathing process), thermal resistance and its compressive force. Studies had shown that brick’s compressive strength is inversely proportional to the thermal resistance, since they both are influenced by the porosity of the brick itself. Bricks with higher compressive strength showed lower thermal resistance since there are less air gaps in it which is transferred heat in shorter amount of time.
Plasticity & Shrinkage

It is a characteristic of earthy materials which means its ability to deform under pressure when wet, but then holds the shape when pressure is removed. Shrinking of brick is a characteristic related to plasticity of brick; about 30-50 volume % of empty space is left behind if non plastic additive was introduced to the mixture.

Compressive Strength

“It is the capacity of a material or structure to withstand axially directed pushing forces. When the limit of compressive strength is reached, materials are crushed.”
Traditional Mud Construction

Types

Rammed Earth

Rammed Earth is the man-made alternative of sedimentary rock. Rammed Earth is made with well proportioned ratios of clay, gravel and sand (15 to 18 % clay: 23 % course aggregate, with different sizes: 30 % sand of sand, 32% silt.) However, Clay could be added up to 30%, depending on the quality of the clay. Usually, soil is taken from the site, moistened, and compact. Builders had found many ways to adapt their materials to the environmental conditions by adding tree branches, lime, animal wastes, and blood to add extra durability.

Modern Rammed earth construction uses Cement, emulsified asphalt or hydrated lime as additive to increase the compressive strength and water resistance, also to reduce the soil expansion.

Adobe (Mud Bricks)

Mud brick ingredients are quite simple. Essentially it is made out of Mud, straw and water. It will then be made into rectangular cubes and baked under the sun until they are completely dry. Straw works as a binder to increase the strength of the brick and also to permit the mud brick to dry evenly by transferring the water from the center of the brick to the edges, preventing the brick from cracking from the mid part of the brick.

Compressed Earth Blocks

This type of brick is relatively the newest of all traditional mud brick. This type of brick was developed in the 18th century. A machine was developed in France to produce brick by using the compression force. Soon after that, many improvements on the machine had appeared to compress bigger sizes of brick. This improvement gave mud further push to compete with other building materials in the industrial era.
Traditional Mud construction

Types

- Rammed Earth
  - Water Mud + Compression (Pressure) in frame work
  - Water Mud Frame

- Adobe (Mud Brick)
  - Water Mud Frame Fiber + Sun Dry or Fire Burning

- Compressed Earth Block
  - Water Mud Frame + Compression (Pressure)
Seismic Strengthening

Enhancing the compressive strength of a brick reflects directly on the shape and size of the building. Buildings made with less compressive strength adobe are limited to the boxy shaped, one storey building, and to less openings in the walls. Stronger bricks give the designer more freedom in the design layout. Furthermore, most countries suffering from earthquakes rely on brick as an essential material for construction.
Adobe is the main building material for many developing countries due to its low cost. Adobe construction will continue to be used in high-risk seismic areas, therefore, development of cost-effective building technologies leading to improved seismic performance of adobe construction is of utmost importance for people living in these areas.

Figure 5 – Typical Patterns of Earthquake Damage as Illustrated in Reports in EERI/LAEE World
Traditionally, to improve the seismic resistance in a building, walls are provided with reinforcement mostly because on earthquakes brick tends to shake and cause cracks in the corners breaking up the walls in big pieces. Also, there is the ring beam which is an enforcement that goes all around the walls in a ring shape, holding the walls together and preventing the brick from cracking into big parts and endangering people living in the building. The ring must be strong, continuous and well tied to the walls. Ring beam could be made of concrete or timber. Vertical reinforcement is essential to tie the wall to the foundation and to the ring beam, while horizontal reinforcement helps to transfer shear forces from plane to the walls, as well as restraining the shear stress between adjoining walls and to reduce vertical crack producing. Metal mesh is also a technique used to reinforce the adobe walls. Modern brick that has a higher compressive strength is higher resistant to earthquakes since it has less porosity and reduces the shaking of walls while bringing more freedom to the architect to make bigger span buildings with freer layout.

Typical modes of Failure in adobe

- Severe cracking and disintegration of walls.
- Separation of walls at the corners.
- Separation of roofs from the walls.
Seismic Reinforcement for the walls By using ring beam.
The reinforcement can be made by any strong ductile material such as bamboo, cane, reeds, vines, rope, timber or steel bars.
The safest building Form is a squat single story House with small window and a regular, compact Plan with frequent Cross-walls.

Wire mesh reinforcement for existing buildings.
Additive Innovations

Approximately there are a twenty known techniques of earth buildings on the planet. The rich tradition in earth architecture had influenced architects and scientists to develop researches and respond to the new needs of a changing world. Natural disasters, need for low cost housing, and sustainability are all important reasons to direct the focus of research to reinterpret the ancient techniques and develop updated versions of them. Cob is one of the simplest techniques of all types of earth buildings techniques, which is simply a mixture of mud, straw and water. Many other additives had crawled in the industry since then. Currently there is a trend of using byproduct materials coming from agricultural industry and from mining industry and solid municipal wastes, mainly because there is a rising awareness of the dangers it affects on the environment and the importance to preserve on natural resources of the world. It is estimated that the quantity of solid wastes generation was twelve billion tons in 2002. Among this amount eleven billion tons were industrial wastes and one point six billion tons were municipal solid wastes. By 2025 this number is expected to increase to Nineteen billion tons annually. It has been proven through research that these additives could increase the compressive strength and thermal mass of the brick up to 36 % or more. These results are favored since it will reduce the reliance on natural resources and increase role of recycling industry in building industry.

Types of Fiber

Natural
Wood Based Materials: Sawdust, wood chips
Renewable agricultural waste materials
sawdust
rice-peel
seed-shell
Sun flower seed shell
Cellulose
ByProduct from
Paper industry

Synthetic
Synthetic wastes
Plastic Fibers
Polysterine
Basaltic Pumice
Solid Wastes
Hazardous & Non Hazardous
Marble processing wastes
CCRs (Fly Ash)
Jarosite
Metallurigical residues.
Agricultural Byproducts Wastes
These are considered as natural additives. Compressive strength tests for bricks made with additives of wood Based Materials: sawdust and renewable agricultural waste materials such as rice peel and seed flower shells had been elaborated. Thermal resistance increased around 16%, 26%, and 36% respectively. On the other hand, due to the increase in porosity in the brick, these materials could also reduce the compressive strength of the materials. Compressive strength in those materials are however stronger than straw by 6, 8, and 14 times respectively.

With 7% concentration sun flower seed-shell showed 36% Increase in thermal resistance
With 7% concentration Rice peel showed 26% Increase in thermal resistance
With 7% concentration sawdust showed 16% Increase in thermal resistance

Thermal Resistance

Compressive & Flexural Strength

<table>
<thead>
<tr>
<th>Pore forming additives</th>
<th>Sawdust</th>
<th>Rice-peel</th>
<th>Seed-shell</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay component</td>
<td></td>
<td>Mixture of yellow and gray clay minerals in ratio of 4:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additive concentration</td>
<td>4%</td>
<td>7%</td>
<td>4%</td>
<td>7%</td>
</tr>
<tr>
<td>Sample No.</td>
<td>F4</td>
<td>F7</td>
<td>R4</td>
<td>R7</td>
</tr>
</tbody>
</table>
Synthetic Wastes

Synthetic additives are usually recycled products coming from Plastics such as water bottles, etc. This material had proven through studies that it improved the compressive strength of the clay brick up to 6.7 N/mm², (The compressive strength of bricks produced in the United States ranges from about 1000 lbf/in² to 15,000 lbf/in² (7 to 105 MPA, or N/mm²), exceeding the Polystyrene fibers with 22% and traditional straw with 32%. Basaltic Pumice works better as a stabilizer in the clay mixture, but cannot stand as an additive alone.

It is important to notice that synthetic additive needed to be added with stabilizers since they provide more strength and consistency to the mixture. Gypsum, Basaltic Pumice, Cement were added in the experiments, providing different results, However; they were all a strong results.

<table>
<thead>
<tr>
<th>Plastic Fibers</th>
<th>Water</th>
<th>Clay</th>
<th>Cement</th>
<th>Gypsum</th>
<th>Basaltic Pumice</th>
</tr>
</thead>
</table>

Plastic Fiber
- 0.2
- Straw
- 2
- Polystyrene Fiber
- 0.6

Plastic Fiber’s compressive strength is 22% higher than Polystyrene fiber and 32% higher than Straw.

Basaltic Pumice and Cement had the highest compressive strength followed by Gypsum and Straw was the least.
Recycled solid wastes & Brick

Advances in solid waste management resulted in alternative construction materials as a substitute to traditional materials like bricks, blocks, tiles, aggregates, ceramics, cement, lime, soil, timber and paint. To protect the environment, efforts are being made for recycling different wastes and utilize them in value added applications.

The major industrial non hazardous inorganic solid wastes are coal combustion residues, bauxite red mud, tailings from aluminium, iron, copper and Zinc primary extraction process. There is a great practical significance for developing building material components as substitutes for the traditional materials to the housing industry in a cost effect manner.
In Organic Solid Waste generation, recycling and Utilization

Inorganic solid wastes are of both non-hazardous and hazardous in nature. In organic non-hazardous solid wastes are primarily from mining sector and these wastes are the primary process rejects which constitute overburden wastes. However, the inorganic hazardous wastes are mainly from the secondary process of non-ferrous metal extraction like lead, zinc; and copper. The details of non-hazardous and hazardous inorganic wastes generation, recycling potentials and their environmental concerns are reported and discussed in the following section.

Solid Waste generation from mining operations and their utilization

After the ore is extracted from the mine, the first step in benefaction is generally crushing and grinding. The crushed ores are then concentrated to separate the valuable mineral and metal particles from the less valuable rock. Beneficiation process include physical/chemical separation techniques such as gravity concentration, magnetic separation, electrostatic separation, flotation, solvent extraction, electro-winning, leaching, precipitation, and amalgamation. The beneficiation process generate tailings, which generally leave the mill as slurry consisting of 40-70% liquid and 30-60% solids. Most mine tailings are disposed of in on-site impoundments/ponds.

Presently most of these wastes are being recycled and used for manufacture of various building materials. Studies on potential use of different mining tailings in bricks have revealed that this waste along with clay can be effectively utilized for making better quality fired bricks and use of copper tailing (60%) has resulted in achieving strength of 190 kg/cm² under firing temperature of 1742 F (950 C).
Physico-chemical characteristics of solid wastes generated from Hazardous and non-hazardous sources over clay and cement

Physical Characteristics

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Characteristics</th>
<th>CCRs</th>
<th>Jarosite</th>
<th>Copper slag</th>
<th>Red mud</th>
<th>Marble dust</th>
<th>Sand</th>
<th>Clay (Kaolinite)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Particle size (μm)</td>
<td>130-260</td>
<td>14-23</td>
<td>&lt; 150</td>
<td>&lt; 2.0</td>
<td>43.9-103.1</td>
<td>300-600</td>
<td>&lt; 15</td>
</tr>
<tr>
<td>2</td>
<td>Bulk density (g/cc)</td>
<td>0.96-1.25</td>
<td>0.97-1.0</td>
<td>1.44-1.62</td>
<td>1.36-1.6</td>
<td>1.87</td>
<td>1.59</td>
<td>1.48</td>
</tr>
<tr>
<td>3</td>
<td>Specific gravity</td>
<td>2.08-2.3</td>
<td>2.92-3.0</td>
<td>2.8-3.8</td>
<td>2.6-3.4</td>
<td>2.51-2.76</td>
<td>2.64</td>
<td>2.27-2.35</td>
</tr>
<tr>
<td>4</td>
<td>Porosity (%)</td>
<td>37.45-37.5</td>
<td>66.5-67.7</td>
<td>49.26-54.66</td>
<td>39.65-49.0</td>
<td>68.4</td>
<td>36.31</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>pH</td>
<td>6.98-7.03</td>
<td>6.7-6.85</td>
<td>5.70</td>
<td>11.12.5</td>
<td>8.36-9.5</td>
<td>8.18</td>
<td>7.64</td>
</tr>
<tr>
<td>6</td>
<td>EC (μmols/cm)</td>
<td>491.65-504.24</td>
<td>13260-14090</td>
<td>500.56</td>
<td>495-766.48</td>
<td>276.94-500.0</td>
<td>246.11</td>
<td>6506.67</td>
</tr>
</tbody>
</table>

Chemical Characteristics

<table>
<thead>
<tr>
<th>S No.</th>
<th>Constituents in %</th>
<th>CCRs</th>
<th>Jarosite</th>
<th>Red Mud</th>
<th>Marble waste</th>
<th>Copper slag</th>
<th>Phosphogypsum</th>
<th>Cement OPC</th>
<th>Clay (Kaolinite)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SiO₂</td>
<td>55.9-57.6</td>
<td>2.91-4.0</td>
<td>5-13.5</td>
<td>1.69-8.5</td>
<td>28.0-32.0</td>
<td>2.41</td>
<td>19.7-22.6</td>
<td>42.09-61.54</td>
</tr>
<tr>
<td>2</td>
<td>Al₂O₃</td>
<td>16.0-24.0</td>
<td>0.70-4.4</td>
<td>10-23</td>
<td>1.3-6.1</td>
<td>2.4-6.8</td>
<td>&lt;0.5</td>
<td>4.93-66</td>
<td>28.65-32.9</td>
</tr>
<tr>
<td>3</td>
<td>Fe₂O₃</td>
<td>5.38-6.34</td>
<td>51.28</td>
<td>28.56</td>
<td>0.25-3.66</td>
<td>44.47-70</td>
<td>&lt;0.5</td>
<td>3.19-3.5</td>
<td>11.77-12.88</td>
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<td>4</td>
<td>CaO</td>
<td>0.25-6.5</td>
<td>0.98-12.0</td>
<td>8-17</td>
<td>29.5-55.4</td>
<td>1.65-6.66</td>
<td>32.41</td>
<td>63.0-64.0</td>
<td>0.13-2.2</td>
</tr>
<tr>
<td>5</td>
<td>MgO</td>
<td>1.01-1.34</td>
<td>1.81-1.94</td>
<td>0.35</td>
<td>4.04-20.6</td>
<td>0.75-2.54</td>
<td>0.30</td>
<td>0.7-2.38</td>
<td>2.04-2.63</td>
</tr>
<tr>
<td>6</td>
<td>K₂O</td>
<td>1.62-2.13</td>
<td>0.71-0.75</td>
<td>0.39-0.90</td>
<td>0.01-1.9</td>
<td>0.61</td>
<td>&lt;0.22</td>
<td>0.55-0.6</td>
<td>0.74-3.51</td>
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<tr>
<td>7</td>
<td>ZnO</td>
<td>1-2.6</td>
<td>13.29</td>
<td>&lt;0.5</td>
<td>NA</td>
<td>0.005-1.30</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>8</td>
<td>PbO</td>
<td>&lt; 0.1</td>
<td>1.8-2.04</td>
<td>&lt;0.2</td>
<td>NA</td>
<td>0.002-0.28</td>
<td>4.511</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>9</td>
<td>CuO</td>
<td>&lt; 0.1%</td>
<td>0.45-1.65</td>
<td>&lt;0.2</td>
<td>NA</td>
<td>0.46-3.76</td>
<td>3.42-17.6</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>10</td>
<td>LOI</td>
<td>1.53-</td>
<td>&gt;12.6</td>
<td>6-14</td>
<td>40.0-43.46</td>
<td>&lt;1</td>
<td>19.20</td>
<td>0.3-1.75</td>
<td>&lt;12.55</td>
</tr>
</tbody>
</table>
Copper tailings

- Copper tailings utilized in bricks have revealed that it improved the quality by 60% achieving strength of 190 kg/cm sq.

Bauxite

- Bauxite red mud is a by product from Aluminium extraction processes
- Below 900 C red mud can be a vital component in mixtures with carbonate rich clays
  Aluminium extraction+ (Bayer process)+ Caustic soda heat+pressure = Red mud Bauxite

major mud components of the red mud includes iron metal goethite, hematite and magnetite. 60% of them are released as wastes
Waste Gypsum

-Waste gypsum improved engineering properties without a harmful effect. Phosphogypsum and lime sludge were recycled for manufacture of portland cement, masonry cement, sandlime bricks, partition walls, flooring tiles, blocks, gypsum plaster, fibrous gypsum boards, and super-sulphate cement. They were also used as an aggregate in high strength concrete and light weight concrete.

Recycling Hazardous materials into - Non-Hazardous construction materials

Jarosite
Jarosite is a mud residue released as a byproduct of the zinc metal production through hydro metallurgical process which includes acid leaching. They are often very soluble in water, releasing acid and precipitating ferric hydroxides. Jarosite, Marble, Metallurgical residues incorporation with fine grained materials like clay can improve the Shrinkage and improve the quality of several building materials. It can be used effectively as an enrich medium for conditioning the clay matrix and recycling for developing good quality building materials.

This material could make a serious environmental problem since it releases toxic elements which pollutes the soil, earth, and water. The concentration of toxic elements in Jarosite is higher than the allowed limits of USEPA and all other countries. Currently the European union produces 60 million tones of zinc residues every year. Other countries who generate major quantities of Jarosite are Australia, the united states, Mexico, Argentina, Korea, and Japan. Research for recycling this residue is established from these countries too.

Experiments of mixing clay, Jarosite, Fly Ash, and water had proven that this mix when allowed to air dry, then to go under 960 degrees celcius heat for 90 minutes it could result into making brick with compressive strength of 27.27 kg/cm2/min. Compressive strength of the brick made out of 3:1 ratio of Jarosite clay is found as high as 140.8 KG/CM sq. Bricks made from jarosite and Clay ratio 1-4 showed higher strength as compared to the other products developed with incorporation of fly ash with the same ratio of jarosite and clay. However, minimum compressive strength can be established with 45% fly ash addition.
A comprehensive and hazardous sludge containing a high amount of hydrocarbons and trace of several metals such as Cr, As, and Hg are generated in petroleum oil section effluent treatment plants. The common known ways to dispose the sludge is by dewatering or drying it, solvent extraction or solidification by cementous materials. However, many of these ways are not economical. Here utilizing sludge in making masonary comes beneficial, since it was proven that it can enhance the compressive strength and surpace the commercial brick.

The sludge contains 4.8% hydrocarbon/oil, 88.2% water, and 7.0% inorganic materials. By replacing 30% of the raw material of the brick (water, sand, and water) with the sludge. The oil serves as 5% of the fuel requirement for brick making. The hydrocarbons are mainly comprised of resin, wax, asphaltene and some other paraffinic oil. The large amount of water and the presence of sulfate causes efflorescence to brick. Sludge blending with appropriate amount of clay and sand becomes important to obtain the favored brick composition.
### Compressive Strength Matrix

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Compressive strength N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw</td>
<td>1.8</td>
</tr>
<tr>
<td>Sun Flower Seed Shell</td>
<td>14</td>
</tr>
<tr>
<td>Rice Peel</td>
<td>8</td>
</tr>
<tr>
<td>SawDust</td>
<td>6</td>
</tr>
<tr>
<td>Plastic Fibers (Polysters)</td>
<td>6.7</td>
</tr>
<tr>
<td>Polystering Fibers</td>
<td>4.7</td>
</tr>
<tr>
<td>Basaltic Pumice</td>
<td>2.8</td>
</tr>
<tr>
<td>Copper Tailings</td>
<td>18.6</td>
</tr>
<tr>
<td>Bauxite</td>
<td>19.7</td>
</tr>
<tr>
<td>Waste Gypsum+Cement</td>
<td>17.4</td>
</tr>
<tr>
<td>Jarosite (Red Mud)</td>
<td>13.8</td>
</tr>
<tr>
<td>Treated Sludge</td>
<td>16</td>
</tr>
</tbody>
</table>

This matrix shows how each addition, according the experiments had influenced the compressive strength of the brick. It is found the synthetic materials, hazardous, and non-hazardous materials made the highest levels of compressive strength. The brick made in the United States ranges between 7 to 105 N/mm². Many of the materials stated above could be a potential great additive.
Leading Brands
Masonry made out of recycled materials industry is still considered taking its baby steps to be become mainstream. Many companies had started working in that field, however, they are all focusing on recycling the built material, or in recycling non-hazardous materials. Brick made out of Hazardous material is still not favored in the market. Moreover, there are many difficulties facing it since brick factory is needed to be near the treatment plant which adds difficulties in managing/distributing the product later on.

Eco Block
The Eco-Block is a brick made from recycled glass and construction waste. Professor Poon and his team say the blocks work by catalysing nitrous oxides, a major greenhouse gas contributor in the atmosphere, into non-hazardous substances.

Focusing on Using Fly Ash as the main substance to make bricks. These brands rely on the Calcium Carbonate, an essential component of Fly Ash, with other binders to make pressured brick without the need for firing, making the brick 85% less reliable on heat strengthening.
Conclusion

Compressive strength is the most important factor to qualify a brick, since it measures the ability of this building material to resist earthquakes which is common in many parts of the world were mud and clay bricks are used solely for construction. The studies had proven innovations on using additive material in brick mixture can enhance its compressive strength. Several additives were experimented, and were found that natural additives coming from the agricultural waste increased the thermal resistance, and oppositely it lowered its compressive strength. On the other hand, Synthetic materials and by products coming from mining industry had proven that they could be furtherly used to increase the compressive strength of the brick since they provided better consistency. Stabilizers such as cement, basaltic pumice, Gypsum, were used as well, and fly Ash was needed to contain the toxic material in non hazardous by products. It is expected in the coming years to see a change in the industry from using the natural resources for building to recycling by products. This will create secondary industries that rely on recycling those materials, and will also help to create better environments with less pollution.
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Books