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SPATIAL DISTRIBUTION AND CHARACTERISTICS OF TEN HIGH MASS EARTH MATERIALS FOR PASSIVE SOLAR SYSTEMS IN THE SOUTHWEST

BY

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SPATIAL DISTRIBUTION AND CHARACTERISTICS OF TEN HIGH MASS EARTH MATERIALS WITHIN THE STATE OF TEXAS

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ABSTRACT

Passive solar design depends on inexpensive and highly available high mass materials. This paper spatially demonstrates their existence and inter-compares their basic potential for doing work as heat storage systems. Particular emphasis is placed on transportation costs related to the density and BTU capacity, exhibited by each material, setting up an argument for more on site excavation and fabrication. Some basic equipment for on site fabrication is outlined showing some results that this author knows of from personal experience and local people as to fabrication performance. Our portable earth lab developed by Howard Scoggins is outlined and a photograph of its basic parts is given.

INTRODUCTION

On site or localized use of building materials in many parts of the world is the norm and not the exception. This norm is probably based on an evolution that includes together the laws of physics, the inherent economics of transport and the need for a population to self maintain its building superstructure over time. An inevitable solution in more arid lands is for these materials to be based on earth not only because of its high availability but also due to the constant deforestation process that man has helped augment for many thousands of years within these regions. Even though this paper deals primarily with the physics and economics of earth as a building material in Texas, the background for this study lies in a concern for a region very similar to many ancient parts of the world, particularly from the standpoint of its biogeographical makeup. The primary difference between our region and those others in the midst of a desertification process is that Texans refuse to accept many of the longlasting stable non-energy intensive ways of building that these other cultures exemplify. It is this combination of a typical semi-arid transitional zone so typically dealt with perhaps a little too late by many ancient civilizations along with the ravages that epitomize our post-industrial society that initiated work in earth and other appropriate technologies by the Center for Maximum Potential Building Systems.

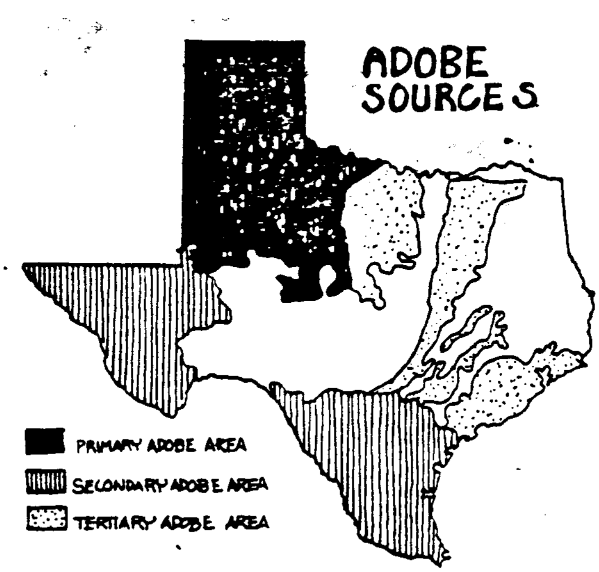
PROCEDURE

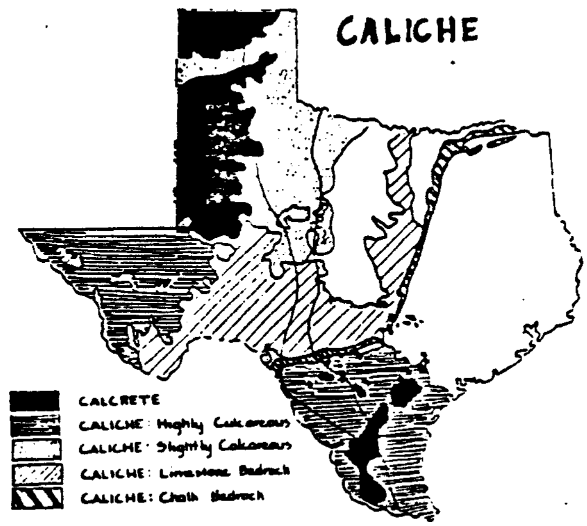
This paper deals with the characteristics of ten different high mass building techniques within the political boundaries of the state of Texas. Eight of these materials have been mapped spatially.

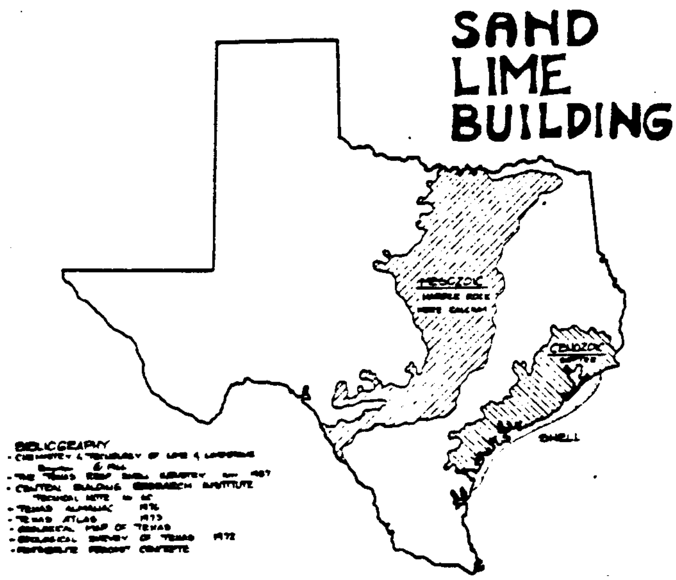
The materials themselves are all well proven building components some of them such as pozzolan and adobe quite ancient in origin particularly on a global scale. Most of the materials have been used in the United States and many within the state of Texas. Of primary importance in this paper is a comparison not only in general distribution but also in the particular characteristics these materials exhibit when compared to basic transportation parameters. Basic assumptions regarding availability, specific heat and density are outlined and used to compare the amount of potential work done by a material once used as mass heat storage walls in building. This potential heat storage work or heat capacity is then compared to cost of shipping that particular material.

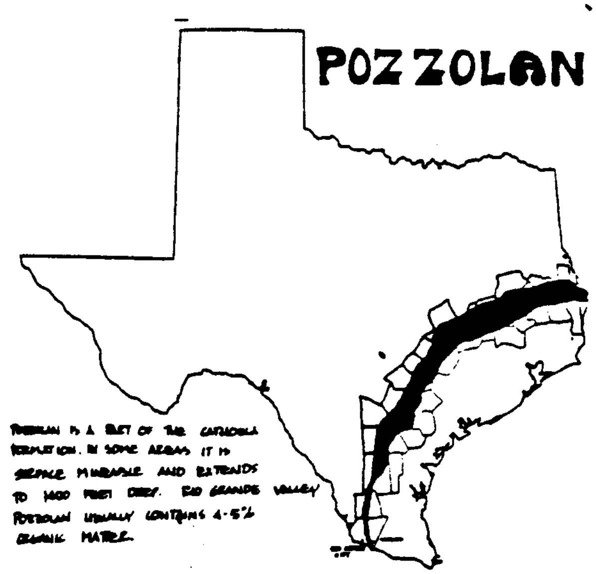
SPATIAL DISTRIBUTION

Spatial distribution within the state of Texas is quite encouraging. According to maps our center has produced (summary small maps are shown below) approximately 60-80% of the state fits into areas that can be easily served by on site or near on site sources. Many of these materials require no firing or initial high energy processes: adobe caliche, alumina clay, surface sulfur, diatomaceous earth. Other materials that are not obtainable directly require some preliminary preparation before they can be used. This preparation usually utilizes some high temperature energy expenditure for dehydration. These actual on site energy costs would be important comparisons between materials but are difficult values to find and have not been included in this paper.

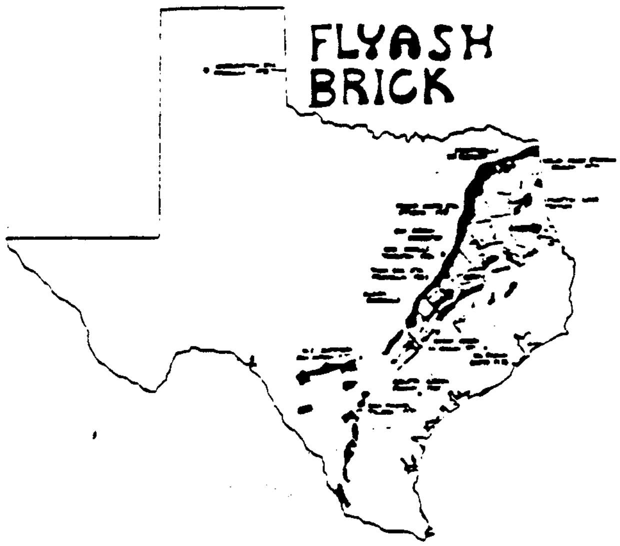




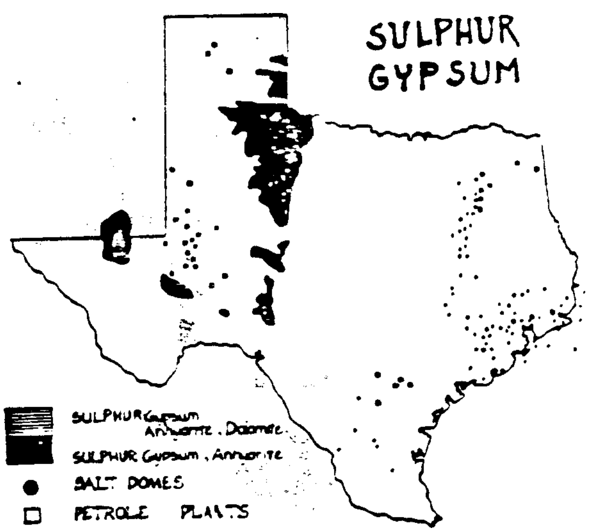


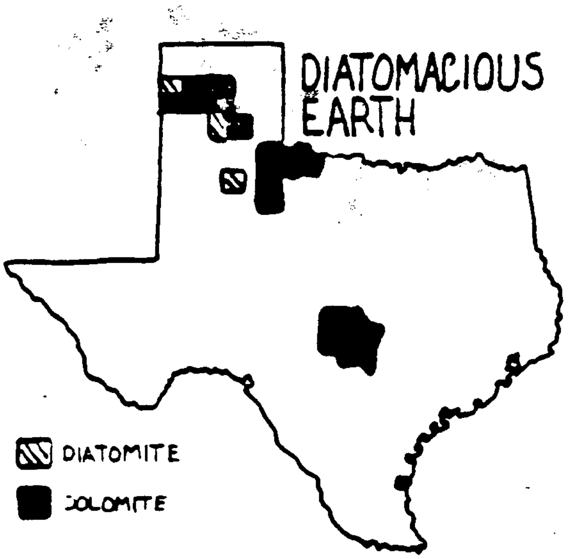


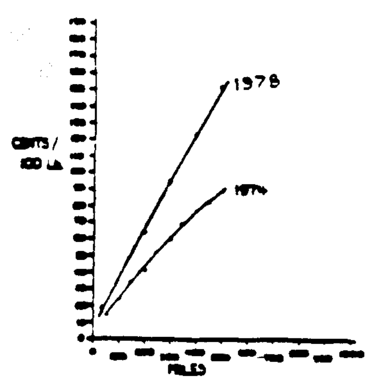
ECONOMIC COSTS OF SHIPMENT

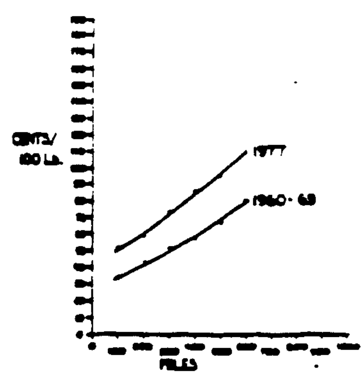


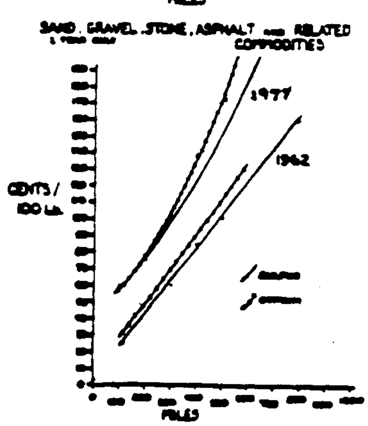
Graphs demonstrating costs per 100 lb. for shipment from 30 to 800 miles are given below for a range of years in order to show price changes. These graphs were developed from data from the Texas Railroad Commission and are set so that the carrier gains a "sensible" profit from his own expenditures. Observing these graphs, it is obvious that costs increase with distance but it is also important to note that an appreciable percent increase over the years specified has occurred at the lower end of all the graphs-that is distances in the order of 15 to 50 miles. Those materials that fit into the category of earth moving (tariff #2A,E) adobe, caliche, alumina clay, diatomaceous earth, have increased within only a 4-year period (1974-78) of 161.8% while flyash, pozzolan, and cement have increased 161.1% over an eleven-year period for distances that fit within 30 miles. These were compared according to cents/100 lb. The least increase was gypsum at 83.6% over a 15-year period and sand lime (lime) at 147.6% over a 17-year period. Wood was placed in as a comparative value and came out 117.6% increase over a 5-year period. All costs for 200 miles, which was once used as a HUD guideline for industrial building firms to not distribute beyond, came out with approximately the same percent increases.

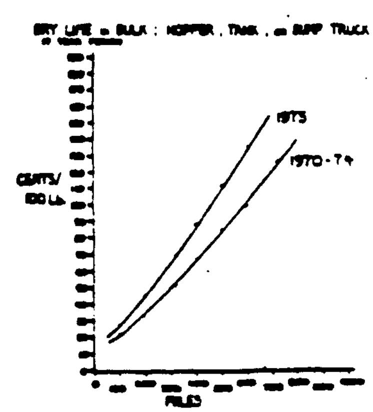












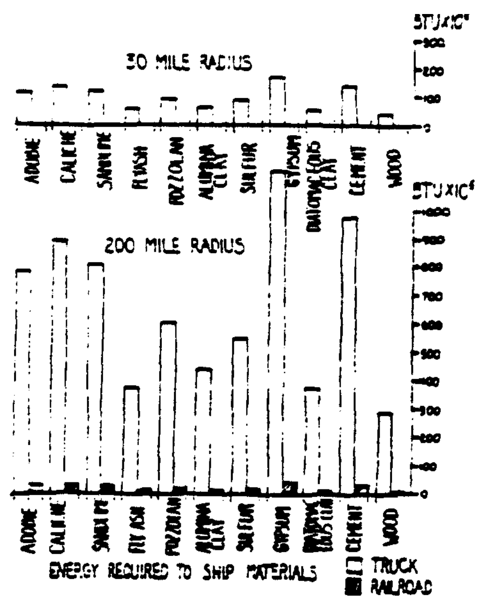
EARTH MIX DENSITY AND SPECIFIC HEAT

In order to develop a reference point to compare various materials we placed available data as to density and specific heat onto the actual building product in order to see how this effected our choice of one material over another when compared to shipment costs per lb. In other words, how much potential work could be done by using that material in a building compared to how much it cost to get it there. The latter will be discussed in the next section. Below in chart form we show the values we used and the earth mix that ends up to be the actual building product. All values were adjusted to include this mix within the calculations.

Earth Building Material	Density lb/cu. ft.	Specific Heat btu/lb/F°	Remarks Assump
Adobe	126	.20	30% Cl; 70% Sd.
Caliche	124	.21	8 Sd, 9 Ca. 1 Cement
Sandlime	112	.206	1 Sd.1 Lim
Flyash	52	.21	60% Flyash 40% Clay
Pozzolan	84	.21	7 Pozzolan 1 Lime
Alumina Clay	62	.20	30% Cl; 70% Sd
Sulfur	86	.19	40% Sulfur 60% Sd.
Gypsum	159	.259	Block dipped in water for surface crystali-zation
Diatoma-ceous Earth	52	.451	3 Sawdust, 3 Shavings 1 Cement 1 Diatomit 1 Clay
Cement	135	.271	Mortar Const.
Wood	40	.60	Avg. Wood Found in Bldg.

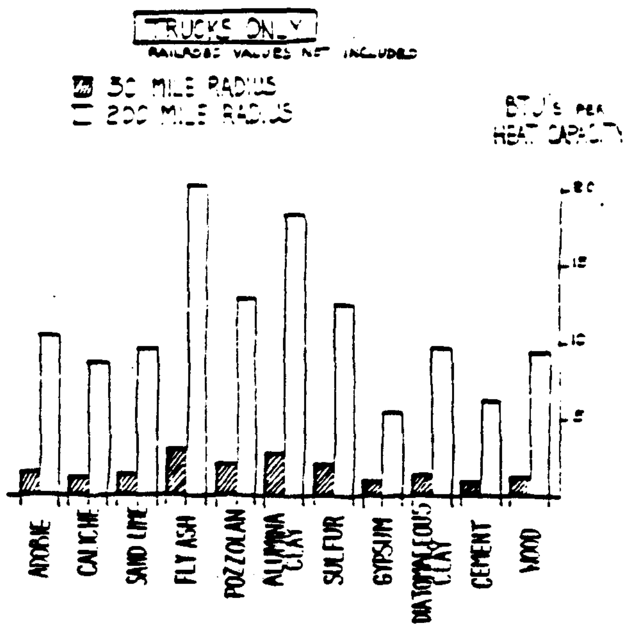
ENERGY COST OF SHIPMENT

The energy cost of truck shipment versus railroad shipment varies due to the relative efficiency of the power/vehicle type. Trucks are much less efficient and run at 2250 BTU/ton mile on the average with a range. of 2000-2500 BTU/ton mile. Railroads operate at about 800 BTU/ton mile. The following bar graph shows only trucks operating at 30 miles and both trucks and railroads operative at 200 miles. The results show the energy cost for gypsum as being the most at 171. $62x10^5$ BTU for 30 miles while cement, sandlime, caliche and adobe are next with cement being the highest at $145.8x10^5$ BTU to run 30 miles with a container car assumed full and measuring 8'xlO'x40'. Diatomaceous earth and flyash are least with alumina clay close by at $66.96x10^5$ BTU for 30 miles. At the 200 mile level considering the same conainer size again gypsum was on top at $1144.8x10^5$ BTU for 200 miles. Others fit into the same catagories as previous with flyash and alumina clay again being least.



COMPARISON OF HEAT STORAGE VALUE TO SHIPMENT COSTS

The present cost associated with delivering a given heat storage potential $/BTU/F° was done comparing all materials for a 30 mile and 200 mile radius. This was accomplished by using a certain shiping size container of 8'xlO'x4O' in order to compensate for various densities of material. For the 30 mile radius adobe, caliche, diatomaceous earth, gypsum and concrete came at at the lowest price per delivered BTU/F° heat storage potential. The worst were sulfur, flyash, and sandlime, with alumina clay and pozzolan in between. It is interesting to note that wood came out about average as well.



BTU's NEEDED IN TRANSPORT RELATIVE TO DELIVERED HEAT CAPACITY

SUMMARY

We have tried to summarize information concerning high mass building materials within Texas from aspects of spatial distribution. This spatial context points at the need or degree with which movement of these materials is required. Since 60-80% of the state possesses building materials literally beneath one's feet, in itself suggests more on site use of these materials, particularly within passive solar design where such material are necessary within the design and engineering process. As we look at the increased cost of transporting these materials due to general inflationary conditions, the need to concentrate more heavily on localized extraction and fabrication is obvious, especially since local transport costs in the order of a 30 mile radius is most common for building construction. We have seen sand lime and flyash stand out in terms of cost per heat capacity (cost/BTU/F°) at a 30 mile radius. However, one of these necessitates special molding equipment (sandlime). Caliche and concrete become most logical in this category of on site molding and availability; however cement reportedly requires large energy expenditures in terms of initial preparation at plant (not included in this report). Adobe, diatomaceous earth and gypsum are also logical cost/BTU/F° candidates but are not nearly the most efficient.

As we look at energy expenditures per heat capacity delivered on site, however the picture changes. Our last bar graph shows the BTUs needed in transport relative to the delivered heat capacity. (It should be emphasized that these figures do not include energy within mining or preparation nor within the fabrication process but only those related to transport). This energy cost figure ultimately represents the actual costs to society. In the long run if we were to combine the total energy cost from excavation to finished building we would obtain an even better figure that would enable us to choose among materials. The bar graph below shows that gypsum and cement are the lowest in BTU/heat capacity with caliche as a close competitor. The worst is flyash construction, while the ever present use of adobe comes out only with mediocre benefits.

BTU/HEAT CAPACITY

	30 miles	200 miles
Adobe	1.561	10.41
Caliche	1.296	8.641
Sandlime	1.436	9.567
Flyash	3.093	20.021
Pozzolan	2.008	12.754
Alumina Clay	2.724	18.146
Sulfur	2.066	12.230
Gypsum	0.816	5.443
Diatomaceous Earth	1.440	9.595
Cement	0.926	6.173
Wood	1.391	9.375

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