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Grancrete-An Innovative Building Construction Material

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Abstract

Nowadays, there is a rising need to construct houses or buildings of good quality at minimal expense, and in a more eco-friendly way, thereby dealing with the concern of global pollution, as well as resource depletion. In order to face this challenging task, the paper proposes a new eco-friendly construction technology, named grancrete. Grancrete is a constructing material, that is composed of sand, ash and some binding materials. It is sprayed onto the Styrofoam panel to withstand both tropical as well as below freezing temperature, and offers a good resistance to fire. In this paper several advantages of grancrete, its importance and the dominance of its compressive strength over traditional concrete were experimentally verified. Thus it ensures an opportunity to have adequate housing plans opting for longer and healthier lives of buildings.

Keywords: Grancrete, Eco-friendly construction, Compressive strength, Binding material, Styrofoam panel.

INTRODUCTION

Houses and buildings are an essential entity, which each and every human being needs for their safe living. These buildings also reflect the living standard of a society. In today's world the construction methodologies are often being appended with modern innovative ideas which are more cost effective and efficient. For example, small dimension lumbers have replaced the usage of heavy timbers, depending upon the building size. Even conventional building materials are modified and are used nowadays. The production of these conventional materials requires lots of electrical as well as thermal energy, which in turn initiate various types of pollutions. [1] In olden days, people used clay and stone to build their houses and other buildings. Constructing a house with stone is not an easy process as it needs to be cut into several pieces and has to be smoothened and designed till it attains desired shapes. This process consumes more construction time, requires huge man power for chiseling, rubbing and polishing the stone. In totality it is a challenging gigantic task. [2, 3] In rural areas only two to three local masons, or people themselves build their houses using burnt bricks for wall, and coconut leaves\thatches for roof. The thatched houses are more vulnerable to fire and during wet climate it would lead to fungal attacks. Due to these reasons several precautionary measures are needed to reduce such risks.

[4] revealed that large groups of people use timber or wood for constructing their houses, which would result in deforestation. It leads to the loss of forest diversity which in turn significantly increases the greenhouse gases, influences climatic changes and paves a way for environmental pollution. [5] explained about buildings that are constructed using fired bricks manufactured from the top layers of soil. Bricks are treated with fire to receive their strength. Thus it would possess a huge footprint of carbon. Due to the usage of outdated technologies and poor quality testing facilities, irregular dimensions and cracks in the bricks would sometimes create serious problems such as poor resistance to water. It would even result in the collapse of the entire building due to the decrease in the compressive strength. [6] used air lime in historical buildings as a protective coating. But due to some climatic and environmental interaction, it would cause severe superficial cracks and detachments in the constructed building.

[7] proposed the usage of Lime-Pozzolana (LP) cement for construction purposes. The combination of lime and pozzolans in the presence of water produces hydraulic cement, which has the ability to set under water and was used as a mortar binder for construction works. The cementitious properties of pozzolana mixtures are unpredictable and also in some situations it would act as a poor resistant to erosion as well as climatic changes. [8] The problem in LP cement has been overcome by the introduction of Portland cement in the year 1824. Even though it is used as a dominant binding material in the construction industry, it has high permeability allowing water and other aggressive media into building parts finally resulting in the emission of greenhouse gases, carbonation and corrosion problem. [9, 10] used no-fine concrete mixtures to increase the mechanical and durability related properties of conventional carbon steel bars. It reduced the corrosion behaviour of conventional steel bars that are covered by a cement paste layer. Though it is corrosion resistant this type of concrete needs extra coating of mortar, owing to its permeable nature. [11] relied on stainless steel for its fire resistance and mechanical properties. It uses Continuous Strength Method (CSM) to achieve significant strain hardening, thereby ensuring consistency with carbon steel design expressions. Even though it is advantageous, it gets affected by pitting and galvanic corrosion when it comes in direct contact with lead, nickel, copper etc.

[12] uses Nano-crystalline powder that are sprayed on the stainless steel coating in order to increase the hardness of steel surface and to provide better corrosion resistance. Possibility

for spallation would arise during high temperature. [13-15] Glass Fiber Reinforcement Polymer (GFRP) has been used to increase the compressive strength of concrete and its corrosion resistance nature. However it is highly resistant to fire. It generated some hazardous waste when it was cut into several shapes. Instead of disposing plastic wastes, [16] recycled the waste to produce new materials like concrete mortar or concrete production. Plastic cement is a blend of Portland cement designed to use with the plaster sand, but the practitioners must be careful in selecting the type of plastic as it might be burned in the kiln leading to environmental pollution while producing cement mortar or concrete. [17] utilized magnesium based cements, which is more stronger than that of the conventional cements due to its high compressive strength. Due to its non-conducting nature of electricity, it has been used as a constructing material for constructing floors in hospitals operating room and in radar stations. Durability problems were initiated, when it is directly exposed to acids and sustained contact with water. It would finally result in expansion and leaching of building material. Rubberized Asphalt Concrete (RAC) [18] acts as an effective resistance to reflective cracking for a flexible pavement surface. When comparing with other construction materials RAC has long lasting nature. But during sunny days it would cause weather pollution due to the melting of surface asphalt, which produces harmful greenhouse gases too. [19] In early periods of 1996, an Argonne scientist made use of cement like material called ceramicrete, which prevents the intrusion of radioactive wastes as well as hazardous materials into the environment. Ceramicrete is nothing but the mixture of magnesium oxide, phosphate and water. When it is sprayed on the building's exterior surface it acts as a good resistant to fire [20] whereas it would suffer by high leach rates due to the rapid structural degradation of ceramic products.

Hence it is necessary to develop a pollution free environment to lead a healthy and peaceful life along with nature. Thus the project aims to meet the rising needs and demands of the current generation by constructing buildings or housing in an efficient, cost effective as well as eco-friendly manner by upgrading technologies using the locally available tough ceramic material called grancrete to compete with erosion caused by the acidic properties of nature. In spite of these characteristics, it is proven that it is suited best in terms of reliability.

METHODOLOGY

Grancrete is proposed as a locally available material, to build an inexpensive house that suits people of different economic groups. It is an Argonne material similar to shotcrete or ceramicrete, which is a combination of ceramics and concrete used in the form of spray-foaming concrete. The ceramic composites and the biodegradable ingredients of grancrete provide strength to build a very strong housing structure. It is a type of spray that can used with any aggregate, so that a simple wooden panel sprayed with grancrete becomes a very strong panel of concrete.

Composites

Grancrete is a mixture of locally available materials including sand, ash and binding material composites in various ratios. Different composites that are used in the preparation of grancrete and its compositions are represented by the table 1.

Table 1. Composites of grancrete

Composite	Range (percentage)
Sand	50%
Ash	25%
Binding material	25%

Binding materials that are used in the preparation of grancrete are composed of magnesium oxide and potassium phosphate. The composition of various composites used in this case of preparation of grancrete includes 50 parts of sand, 25 parts of ash and the remaining is 25 parts of the binding material. Amount of water should be available in the range between 8 to 12 pounds per 100 pounds of dry mix and sand. The equipment used for

the preparation of grancrete is shown in figure 1.

Figure 1. Pumper and grancrete mixer

The mixture of sand, ash and the binding material is then poured into the grancrete mixer and is pumped through the hoses to a spray nozzle. It is then sprayed over the vertical walls made of Styrofoam panel and the roofs made of wooden material, to which it adheres and gets dried within a certain period of time.

Styrofoam is an Expanded Polystyrene sheet, widely used as an ideal solution for various building applications. It is a lightweight, strong and clean material that provides insulation from temperature and noise thereby ensuring an insulating panel for heating and cooling. It is a recyclable and eco-friendly product usually used with concrete forms for efficient

building construction. As an alternate to the Styrofoam panel, woven fiber mats can also be used as a raw material as and when required.

Secondly, the frames required for windows and door openings were cut down from the foam and are fixed to the Styrofoam panel. Finally, grancrete is sprayed over each and every corner of the roofs, frames, exterior and interior walls of the house. All these process was conducted at 40^0 F. Thus the process of mixing and spraying of slurry would take an approximate time of about ten minutes for the whole set-up.

Within an hour the mixture gets warmed up, thereby indicating the occurrence of chemical reaction within the wall. When the grancrete mixture gets dry, it forms a light hard surface. This is because the chemicals create a locking connection that makes the grancrete structure very strong. Hence the Styrofoam remains as an effective insulator to deal with pollution in the surrounding environment. This process of housing has been accomplished only with two persons working for one full day. Moreover, the entire house was sprayed within 4-5 hours. Soon after spraying the grancrete over entire house, a trowel has been used to smooth the sprayed mixture. All these process should be completed within certain period of time.

Features of Grancrete

Grancrete differs from ordinary conventional building material by means of several discriminative features which include:

- Curing time is very short i.e. between 15 to 20 minutes.
- It is impervious to water including salt water and will cure easily even under water.
- Its life span extends to more than100 years and has a longer life time than the conventional cement.
- It can tolerate temperatures up to 2200◦F and it sets in cold temperatures at 30◦F.
- Grancrete can be sprayed, poured, troweled or painted in the building.
- The time taken to construct a grancrete house is relatively very low.
- It is a form of Reinforced Concrete (RC) and is remarkably fire resistant.
- If it gets decomposed, it can be restored back into the soil.
- Withstands both tropical as well as below freezing temperatures.

Advantages of grancrete

Some of the advantages of grancrete over the other construction materials are as follows:

- The house can be constructed and maintained at low cost.
- It is an eco-friendly construction material.
- It is an alternative to concrete and is stronger than the conventional Portland cement.
- Time consumption is very low while setting up a grancrete building.
- It acts an excellent fire resistant.
- Grancrete is a biodegradable building material.
- It prevents salt water intrusion.
- Prevents leaching of hazardous contaminants into the environment and ensures high durability even in the aqueous system.
- No reinforcement is required.
- It keeps the houses in the arid regions as cool and the houses in frigid regions as warm.

All these advantages reveal that grancrete is an excellent building material used in the construction process, which ensures low cost and of high quality.

RESULTS AND DISCUSSION

This section summarizes the experimental result, which shows the procedure for building a house using grancrete as a construction material. Grancrete is considered as an advanced from of concrete for an inexpensive means of housing.

Figure 2 shows the styrofoam panel or Expanded Polystyrene (EPS) foam that is used to design the vertical walls of grancrete housing. The roof was constructed from the wooden material.

Figure 2. Styrofoam panel

After constructing the wall and roof using styrofoam panel, the slurry composed of sand, ash and binding material are mixed well by the grancrete mixer. The grancrete slurry is then pumped through the hose and is sprayed by the spray nozzle all over the walls and roof of the house, so that it becomes a water tight part of the home.

Finally the frame for the windows and doors openings are cut out of the foam and then the frames are installed. The grancrete slurry was then sprayed onto the interior and exterior walls and also around the windows and doors to ensure a weather proof seals, which is represented in figure 3.

Figure 3. Spraying the grancrete mixture

Within several hours, the ceramic structure occupies the overall building structure; finally it gets hardened and is dried to provide a good building support to strengthen the building for many years.

Table 2. Engineering performance for cementitious/grancrete fills

Material properties	Recommen -dations	Test	Basis
Setting time	Within several hours	ASTM C 403-99	Strength measured on cured material
Total shrinkage	< 0.01 vol.%	TBD	Cracking due to shrinkage is very low
Leaching index	< 1%	EPA draft method 1316 (EPA 2009a)	Prevents leaching of hazardous material, hence durability is high

Table 2 describes the various engineering performance measures taken for cementitious fills. After performing several testing criteria, it ensures that the leaching index and the setting time is very low for the grancrete cement, when comparing it with all the other building materials such as, Portland cement, lime cement etc. Hence the durability of the grancrete houses is expected to be hundred plus years more than the conventional cement.

The compressive strength of grancrete is more because of its high bonding strength and is calculated for different hours. The compressive strength of grancrete in 2 hours is 3000psi. In 24 hours the compressive strength is 6000psi, 6500psi in 7 days and 6500-8000psi in 28 days as shown in the table 3.

Table 3. Compressive strength of grancrete

Hours	Compressive strength(psi)
2hrs	3000psi
24hrs	6000psi
7days	6500psi
28 days	6500-8000psi

When comparing with the other conventional construction materials, the water absorption capacity of grancrete is greater than 1%. In freeze thaw resistance, the durability factor is 81 at 300 cycles. The real conductivity is 0.53w/m.k. During its setting time, its expansion is around 1%. The density of grancrete is 2.1g/cc. The fracture toughness is 0.6 - 0.7 Mpa. The water content of grancrete is at pH 3-11. High structural tolerance was experienced.

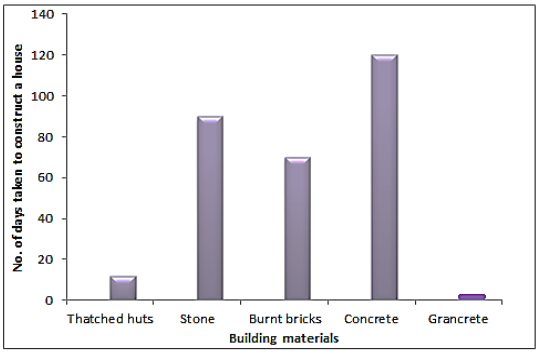

Figure 4. Comparision of conventional building materials with grancrete

Figure 4 compares the time span taken by the workers to construct a normal house with the conventional building materials such as thatched roofs, stone, burnt bricks and concrete with the proposed grancrete. The figure shows that the house constructed using cement would take more time than all other types and also it has high impact of erosion. But in terms of grancrete, it takes only single day by two persons to construct a house, which also acts as an effective resistant to fire and erosion.

The cost required to build a house using conventional building material is several times more expensive than the home built with grancrete. One can construct grancrete houses for about 10,000 labourers within 800 square feet, whereas in case of using conventional building materials it is possible only to build a single apartment within a 400 square feet area. More over the maintenance cost as well as the construction cost will be very less for grancrete housing, when compared with other construction using conventional building materials.

CONCLUSION

This paper proposes a new framework using grancrete as the building material. It provides an overview of preparing grancrete and the procedure for the construction of house or building using grancrete as the construction material. Thus the paper proves that grancrete is the best choice to construct a house in future and this new technology can lead to affordable housing for the people. There will be no loss in usage of cement during the construction process. These new emerging materials should replace the old ones to improve the construction styles and to help in recycling the construction materials, which would save energy and thereby ensuring a pollution free country. The grancrete spray-on cement now offers the opportunity to several hundreds of people to have

adequate housing. In future, grancrete will be used by all sectors in the construction field and even the homeless can own them at very less cost, which is demonstrated by figure A1. Meanwhile, advanced techniques were used to improve the performance of grancrete under various climatic changes.

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APPENDIX A

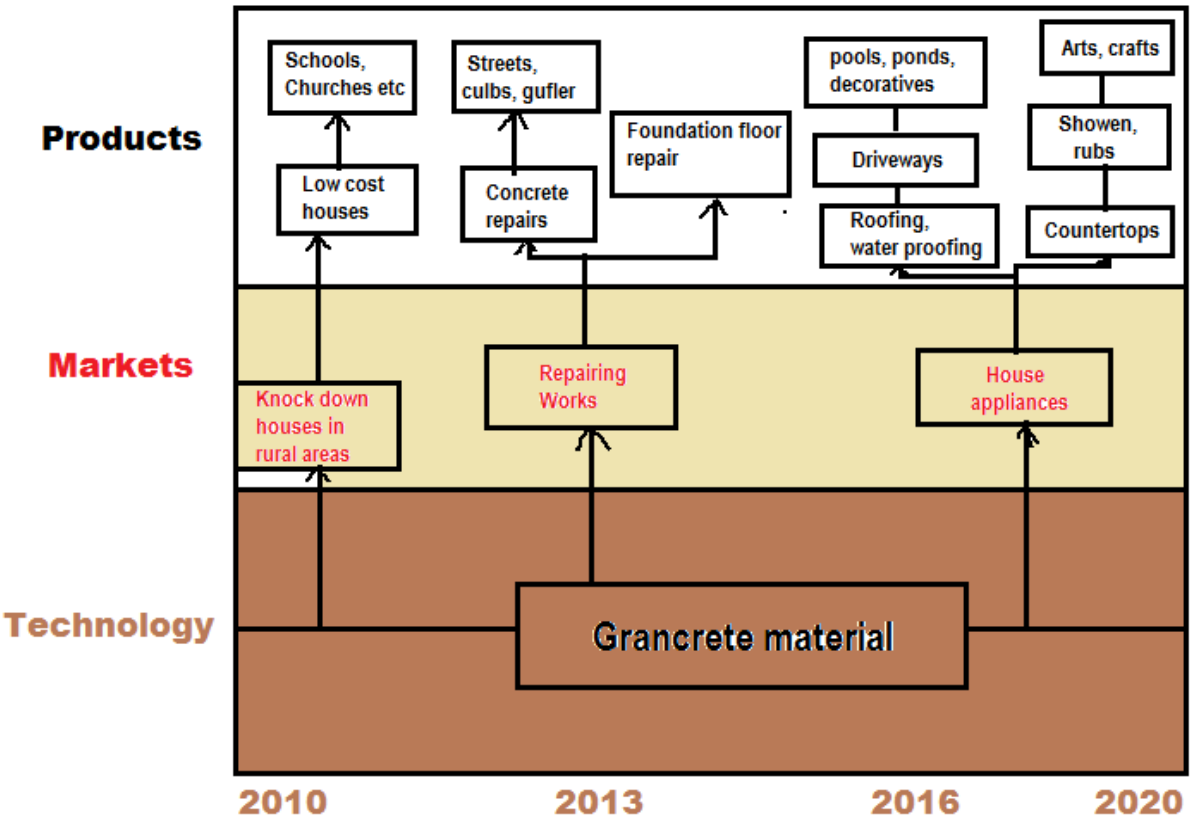

Figure A1. Grancrete in Future