



Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-360

Proposal Title: Sustainable Bricks Using Minnesota Clay and Recycled Aggregate

Project Manager Information

Name: Mohammad Yamin

Organization: Minnesota State Colleges and Universities - Minnesota State University Mankato

Office Telephone: (507) 389-1058

Email: mohammad.yamin@mnsu.edu

Project Basic Information

Project Summary: The main objective of this research proposal is to develop sustainable, stronger and more affordable green construction bricks using Minnesota clay and recycled aggregate stabilized chemically and mechanically.

Funds Requested: \$123,000

Proposed Project Completion: 2023-06-30

LCCMR Funding Category: Small Projects (H)

Secondary Category: Air Quality, Climate Change, and Renewable Energy (E)

Project Location

What is the best scale for describing where your work will take place?

Region(s): SW, SE,

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

The construction sector, where the earth bricks are considered one of its main building units, contributes to 23% of air pollution, 50% of the climatic change, 40% of drinking water pollution, 50% of landfill wastes, and 40% of worldwide energy usage according to research by the U.S. Green Building Council (USGBC). According to test results by Auroville Earth Institute, fired bricks (bricks made from firing clay) use significant amount of natural resources, consume energy and release CO₂ emissions more than four times the unfired bricks. For example, air pollution emissions in kg of CO₂/m³ are 57 and 230 for unfired and fired bricks, respectively. In addition to that, initial embodied energy in MJ/m³ can be approximated to 2,356 for fired brick compared to 631 for unfired brick. The initial embodied energy is the non-renewable energy consumed in the acquisition of raw materials, their processing, manufacturing, transportation to site, and construction. The development of sustainable, stronger and more affordable unfired bricks is vital for the future of green construction worldwide. This brick will contribute at reducing greenhouse gas emissions and re-using of wasted material which in turn improves the air quality of Minnesota climate.

What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.

The proposed solution is to make bricks utilizing chemical (adding cement of less than 15%) and mechanical (applying high pressure compaction of 16 MPa) stabilization techniques. The main ingredient of the mix consists of Minnesota Clay and recycled aggregate that is abundantly available as a result of highway maintenance. This proposed approach will significantly reduce (1) the air pollution emissions and (2) the required natural resources (initial embodied energy). This reduction is expected to be 70 – 80% compared to the conventional production of clay bricks. This significant reduction in air pollution and energy used will considerably impact the lives of people. Additionally, the proposed approach will enable the production of a non-traditional brick shape (e.g., a brick with two holes in the middle). This non-traditional compressed stabilized earth brick (CSEB) which can be considered as a lego-brick will allow at time of construction for an easy stacking of brick, simple placement of reinforcement and pouring of concrete in the holes when needed. This advantage will allow unskilled people to build a wall with ease and at a very low rate. A small research was performed at MSU Mankato on pure Kaolin with the use of a custom manufactured compactor.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

One of the main outcomes from this research proposal is to prepare useful design charts for making durable, strong and affordable compressed stabilized earth bricks (CSEBs). The design charts will summarize the relationships between the various percentages of clay, recycled aggregates, and cement contents with a number of engineering properties such as: strength, durability, and absorption.

Activities and Milestones

Activity 1: Project Preparation Phase

Activity Budget: \$53,000

Activity Description:

In this phase, literature review will be performed to improve the understanding of compressed stabilized earth brick. In addition to that, acquiring of materials (clay, recycled aggregate, cement) and equipments (clay pulverizer/crusher, soil sifter, cone penetrometer, hydraulic cement brick testing machine, ASTM compliant bench top soil mixer) will be performed in this phase. This phase will also include recruiting of undergraduate students to carry out the research tasks. Clay soil will be collected from three different locations in Minnesota (North, Middle, and South). One truck load from each location will be needed. Recycled aggregate will be obtained from materials and recycling companies. A near by material company has been already identified that can supply our research with the amount needed. Five truck loads of recycled aggregate will be needed. Regular cement Type I will be used in this research.

Activity Milestones:

Description	Completion Date
Recruiting of Student Researchers	2021-08-31
Literature Review	2021-11-30
Acquiring of Equipments	2022-01-31
Acquiring of Materials	2022-05-31

Activity 2: Analysis and Preparation of Clay Phase

Activity Budget: \$35,000

Activity Description:

In this phase, the acquired clay will be dried and pulverized. Then, several analyses will be performed on the clay. X-ray diffraction tests will be performed to determine the chemical composition of the clay minerals. Atterberg limits will also be determined using cone penetrometer. The soil used will have to be passed sieve #40. This will be performed using the soil sifter.

Activity Milestones:

Description	Completion Date
Drying of Clay	2022-07-31
Pulverizing of Dried Clay	2022-08-31
Soil Analysis	2022-09-30

Activity 3: Making and Testing of CSEBs and Project Finalizing Phase

Activity Budget: \$35,000

Activity Description:

In this phase, CSEBs for the various design mixes will be prepared. The bench top mixer will be utilized to thoroughly mix the soil. In this phase, compaction tests will be performed to determine the optimum moisture contents of the water for the various mixes. The CSEBs will be prepared by adding the optimum percentage of water to obtain a brick with the highest density (i.e., the least voids). After preparation of CSEBs, the CSEBs will be cured for two days. Curing will be

performed by sprinkling water three times a day. The CSEBs will be kept in a plastic bag during the curing stage. Then, the various engineering properties of CSEBs will be investigated. Strength, durability and absorption tests will be performed on the various CSEBs. After the testing is completed, the findings will be summarized and organized in tables and charts. The project report will be also prepared and finalized at the end of this phase. Travels to disseminate the project findings at a conference and to annually update the responsible committee of the project are included in this activity.

Activity Milestones:

Description	Completion Date
Making of CSEBs	2023-01-31
Testing of CSEBs	2023-02-28
Summarizing and Organizing the findings in Design Charts	2023-05-31
Travel for annual project update (two updates)	2023-06-30
Travel for dissemination of results at a conference	2023-06-30
Preparation of Project Report	2023-06-30

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this be funded?

The results of this research proposal will contribute to the green brick making industry. The optimum percentages of various components (clay, recycled aggregate, water and cement) found in this research will be utilized to make strong, durable and affordable. Yet, this brick will be significantly less harmful to our environment. The findings will be shared with the brick making industry and published to make it useful to educators in general. The end of this research will establish the basis for the next phase of continuous improvement of the CSEBs to make it match or even better the existing less-friendly brick.

Project Manager and Organization Qualifications

Project Manager Name: Mohammad Yamin

Job Title: Assistant Professor

Provide description of the project manager's qualifications to manage the proposed project.

Mohammad Yamin is an Assistant Professor of Civil Engineering joined the Department of Mechanical and Civil Engineering at MSU Mankato Fall of 2017. Mohammad holds a Doctorate degree in Civil Engineering with emphasis on Geotechnical Engineering applications from the University of Akron, Ohio. He obtained his Bachelor and Master degrees in Civil Engineering from Jordan University of Science & Technology, Jordan. Mohammad is a licensed Professional Engineer (P.E.) in the States of Minnesota and Ohio. Prior to joining MSU Mankato, Mohammad served as an Assistant Professor at Bradley University in Peoria, IL and a visiting Assistant Professor at the American University of Sharjah in United Arab Emirates. In 2013 while at Bradley University, Mohammad has received the Teaching Excellence and Innovation award from Bradley University. This award has enabled him to develop an educational windows-oriented computer software in foundation engineering (foundationPro). This award has enabled him to publish his book entitled "Problem Solving in Foundation Engineering using foundationPro" with Springer. Finally, He worked as a design engineer at California Department of Transportation, Sacramento, CA. He also worked as an Engineering Manager at Gulf Engineering House – a consulting firm in Saudi Arabia.

Organization: Minnesota State Colleges and Universities - Minnesota State University Mankato

Organization Description:

The Mechanical and Civil Engineering department is made up of experienced faculty members who take pride in teaching and enjoy being in the classroom. We maintain small classes which provide opportunities for students to connect with the faculty, allowing a heightened learning experience both inside and outside of the classroom. Faculty members strive to bring practical knowledge to the classroom, in addition to connecting students to engineering practice. Our close ties with the local and regional engineering community have allowed many of our students and alumni to obtain internship and full-time positions with a broad range of engineering firms and public agencies. Many of these groups have specifically sought our students, recognizing the applied education they have received in our program.

In addition to traditional opportunities in the classroom, many faculty members are involved in a range of research opportunities which provide students with research experience both at the undergraduate and graduate level. Whether pursuing advanced degrees or joining the engineering community, engineers leave our program "shovel-ready", capable of contributing to mechanical engineering practice, and prepared to make a positive impact in the region, the state, and throughout the world.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount
Personnel								
Mohammad Yamin		Project Manager			40%	0.6		\$22,000
Student 1		Student Researcher			7.65%	0.6		\$15,000
Student 2		Student Researcher			7.65%	1		\$15,000
Student 3		Student Researcher			7.65%	1		\$15,000
Student 4		Student Researcher			7.65%	1		\$15,000
							Sub Total	\$82,000
Contracts and Services								
Chemistry	Professional or Technical Service Contract	X-ray diffraction tests of clay samples				0		\$700
							Sub Total	\$700
Equipment, Tools, and Supplies								
	Equipment	Clay pulverizer	to pulverize/crush the dried clay					\$5,000
	Equipment	Cone Penetrometer	to determine the Atterberg limits of clay					\$3,500
	Equipment	Hydraulic brick cement compression testing machine	to test the strength of the CSEBs					\$4,500
	Equipment	silent soil sifter	to sieve the crushed clay and obtain the minus 40 sieve					\$3,000
	Tools and Supplies	6 truckloads of clay soil	needed for the CSEBs					\$7,000
	Tools and Supplies	12 truckloads of recycled aggregate	needed for the CSEBs					\$6,000
	Tools and Supplies	cement	needed for the CSEBs					\$1,000
	Tools and Supplies	Safety masks	to be used in the labs for safety purposes					\$600

	Tools and Supplies	safety glasses	to be used while in the laboratory for safety purposes					\$200
							Sub Total	\$30,800
Capital Expenditures								
		ASTM compliant bench top soil mixer	to mix the soil (clay, RA, cement, water) thoroughly according to ASTM standards					\$7,000
							Sub Total	\$7,000
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								
	Miles/ Meals/ Lodging	2	annual project update					\$600
	Conference Registration Miles/ Meals/ Lodging	1	dissemination of project results at a conference					\$1,400
							Sub Total	\$2,000
Travel Outside Minnesota								
							Sub Total	-
Printing and Publication								
	Publication	1	publication of project results					\$500
							Sub Total	\$500
Other Expenses								
							Sub Total	-

							Grand Total	\$123,000
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Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
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Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	-
Non-State				
			Non State Sub Total	-
			Funds Total	-

Attachments

Required Attachments

Visual Component

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Alternate Text for Visual Component

The 16-MPa hydraulic pressure soil compactor as shown in picture below will be used in this project. This equipment was manufactured for the purpose of compacting the soil samples as part of a faculty research grant that was received from Minnesota State University Mankato. The equipment is available in the Geotechnical Engineering Laboratory at Trafton Center North 361 in the Engineering building at MSU Mankato. The equipment can compact specimens in 2 seconds leaving very limited voids. Two mold shapes were designed and available to utilize, the solid and the solid with two holes in the middle. The solid with two holes in the middle can allow the brick to be stacked easily as interlocking bricks. The two holes in the middle will allow reinforcement installation and concrete pouring if needed.

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

No

Does your project include research?

Yes

Does the organization have a fiscal agent for this project?

No

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