CONSTRUCTION OF EARTHEN HOUSES USING CSEB: BANGLADESH PERSPECTIVE

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ABSTRACT

In a country like Bangladesh, endeavors to find a low cost, eco-friendly and sustainable building material that mitigates the problems caused by construction materials such as Fired Clay Bricks (FCB), Corrugated Iron Sheet (CI), concrete, wood, bamboo, etc is of paramount importance. This study aims to investigate the effect of different stabilizers on engineering properties of Compressed Stabilized Earth Blocks (CSEB). Blocks were prepared using local soil collected from Savar. In addition, compressed blocks containing three different stabilizers (lime, cement and jute-lime mixture) at various percentages were also prepared. After a 28 days curing period, it was observed that unstabilized and lime stabilized blocks had undergone significant cracking. It was found that blocks stabilized with a combination of jute fibre (0.3% w/w) and lime (5% w/w) can withstand large deformations. Although cement is effective in increasing the strength, it is not as effective in improving the ductility of the blocks. From the investigation, it was concluded that jute-lime mix stabilized CSEB can be used as a cost effective earthquake resistant building material.

Keywords: CSEB; earthen block; shrinkage; lime; jute fibre

INTRODUCTION

About one third of the world's populations live in some form of earthen construction (Houben and Guillaud, 1994). Raw earth was one of the first, oldest and most traditional building materials to be used by man and it has a heritage dating back over at least 10,000 years (Islam, 2010; Hossain, 2015). Sustainability of such earthen houses gained the attention of developed countries in the past 40 years (Islam et al., 2006; Islam, 2010). However, this interest is not growing in developing countries like Bangladesh. As a low income country, the common people of Bangladesh can only dream of building a decent shelter for themselves at a low cost. Therefore, a need arises to find a feasible building material which is not only locally available and economical, but is also a way towards sustainable development. As such, it could be hoped that if local people understands the feasibility and economy of earthen houses, its use would be maximized in the near future.

Earthen buildings have the benefit that they can be built from on-site materials rather than materials with high carbon footprints (Holliday et al., 2016). However, there are few undesirable properties such as loss of strength when saturated with water, erosion due to wind or driving rain and poor dimensional stability (Islam and Haque, 2009; Islam and Iwashita, 2010). Durability and strength are also major problems. Another severe problem of earthen building is its vulnerability to earthquake loading. Various researches have been carried out around the world to alleviate these problems. One such form of earthen building material is Compressed Earthen Block (CEB). When stabilizers such as cement, lime or jute are added in certain proportions to form CEB, then it is called Compressed Stabilized Earthen Block, CSEB (Mesbah et al., 2004; Marin et al., 2010; Ming, 2011). The numbers of factors influencing the properties of such blocks are many. Not only the stabilizers but also the clay content has significant effect on strength and erosion properties of CEB/CSEB (Walker, 2004). Due to affordability, local availability and ease of construction, earth blocks have huge potential as a low-cost building construction material in Bangladesh. This study focuses on improvement of earth block as a building construction material, determining the factors that drive environmental and economic impact and analyzing the tradeoff of properties germane to different earth blocks. The primary objective of this research is to determine the properties of lime stabilized clay and to obtain the influence of stabilizers on strength properties of earthen block.

Advantages over other construction materials

Bangladesh needs an alternative building material to Fired Clay Bricks (FCB), Corrugated Iron Sheet (CI), concrete, wood, bamboo, etc. that is both cost effective and environment-friendly. CSEB can be a good alternative. Not only CSEBs are 25-30% cheaper than FCB, but also produce 70% less CO_2 emissions per m^2 wall than that of FCB. In addition, there is no deforestation for firewood, neither any top soil depletion. For the production of CSEB, mainly subsoil is needed and the abundant supply of riverbed sand in this region can also be used. Moreover, hollow-interlocking CSEBs allow for horizontal and vertical reinforcement for earthquake resistant construction. For constructing affordable, safe and eco-friendly housing, CSEB is a strong alternative in Bangladesh.

METHODOLOGY

Soil sample was collected from Christian Commission for Development in Bangladesh Human and Organizational Potential Enhancement Centre (CCDB HOPE CENTRE) which is located at Baroipara, Savar. All soil samples were collected from 15 cm below the ground surface. New soil samples underwent an initial visual inspection after being received in the laboratory. The amount of organic material in each of the sample along with the sample's in-situ moisture content has been determined. Tests pertaining to the engineering and index properties of soil have also been conducted following ASTM standards (ASTM, 2006). The soil used for CSEB production has been found to contain primarily silt and clay. Particle size distribution of the soils is presented in Fig. 1. The clay component provides the cohesion or binding forces necessary to hold the particles comprising the block together. Silt, sand and gravel particles contribute to the structural strength by combining to create a compact matrix with little void spaces. Lime was selected primarily for soil stabilization. Soil sample was first stabilized with different lime contents (3%, 6% and 9%) to observe the behavior of lime stabilized soil.

Soil mix was watered until it was plastic enough to mould. Water content less than optimum moisture content of the soil by weight has been used. The water and soil was thoroughly mixed. As the blocks may develop some cracks, to reduce the number of cracks and also to make the blocks more weatherproof, stabilizing materials have been added to the mix.

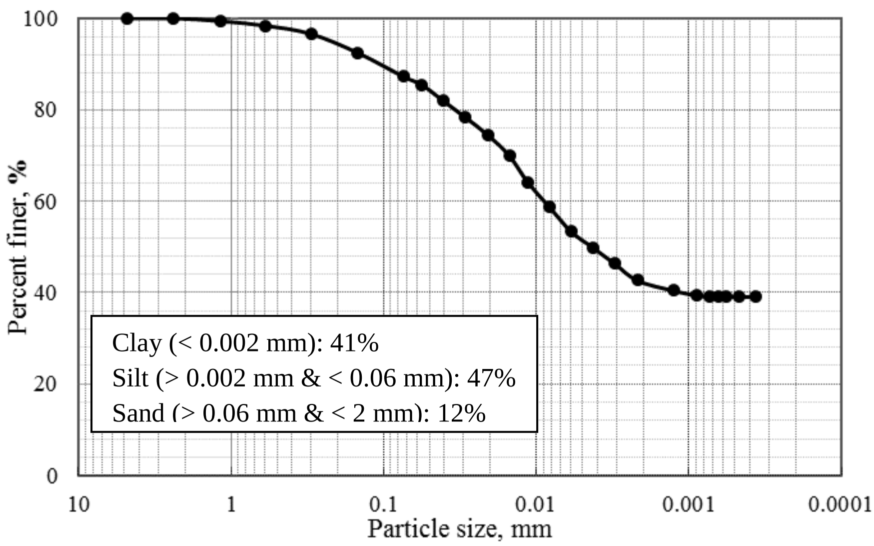


Fig. 1: Particle size distribution of the soil used for making CEB/CSEB

Here, soil samples were stabilized using either cement and sand, only lime, or a combination of lime and jute together. Another sample where no stabilizers were used was also prepared. Five blocks of each set were prepared using earthen block preparation machine (Press 3000 Multi-Mould Manual Press). Four groups of earth blocks were prepared for testing, unstabilized block (USB), blocks at field condition (HOPE Centre)/cement and sand stabilized CSEB (CSSB), lime stabilized CSEB (LSB) and lime-jute stabilized CSEB (LJSB). The combinations of various constituents of each type of block are given in Table 1. These blocks were cured for 28 days before testing for compressive strength. Blocks were cured by keeping them at room temperature (25°-30°C) and spraying water on them at two days interval. Fig. 2 shows the blocks after one day of production at the time of curing. After curing period, unconfined compressive strength (UCS) test was performed using Universal Testing Machine to study the strength and ultimate failure strain of different blocks. The strain rate used did not allow for the stress rate to surpass the rate given by the code.

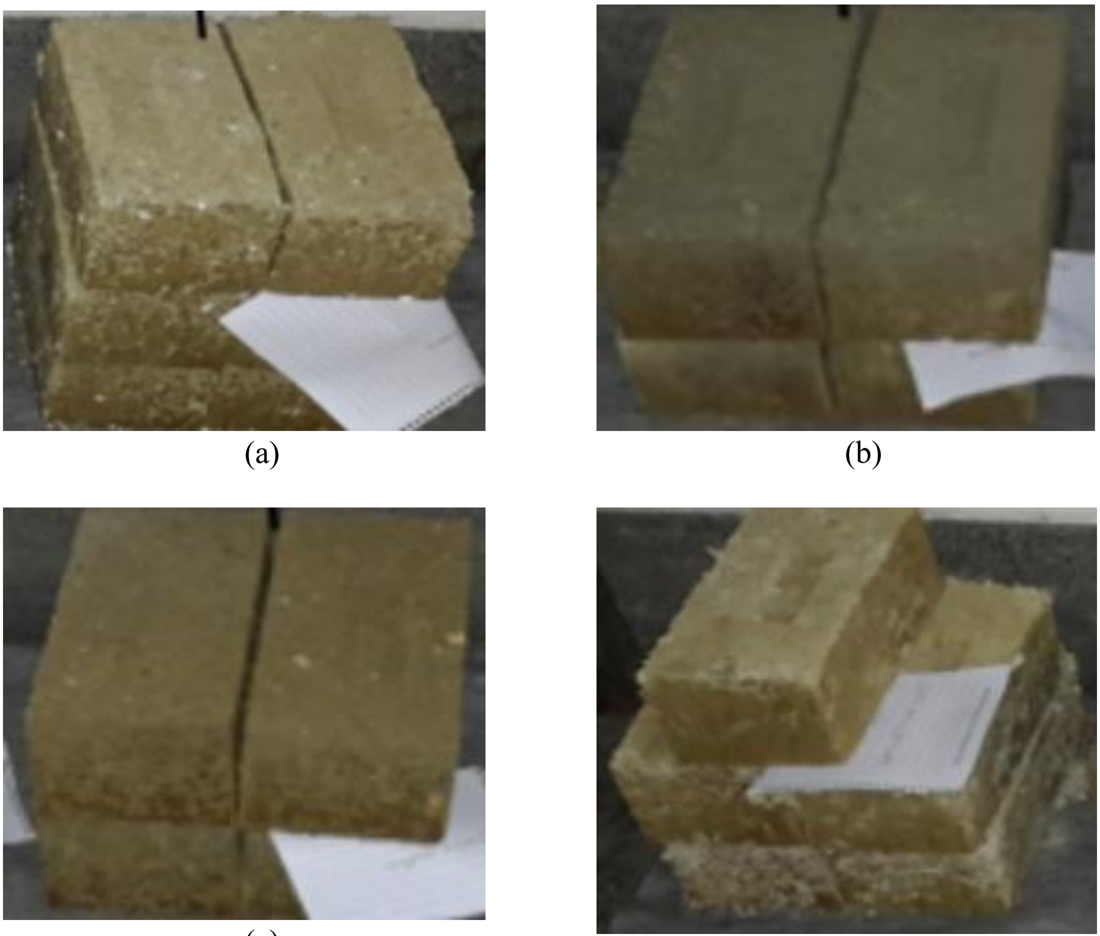
To calculate UCS, Equation 1 was used.

$$UCS = P/A \qquad (1)$$

Here, P = Force at failure (lbs)

A = Cross sectional area of top face of specimen (According to ASTM D143, ASTM, 2006)

After selecting the desired soil mix ratio, several trials were given by producing the blocks and testing them. If, at any point during the process, the proposed soil or soil mixture did not comply to the requirements, the soil sample was reselected and/or the sample modified.



(a) (b) (c) (d)

Figure 2: (a) Unstabilized CEB (USB); (b) lime stabilized CSEB (LSB); (c) cement and sand stabilized CSEB (CSSB) and (d) lime-jute mix stabilized CSEB (LJSB) samples during curing period.

Table 1 Combinations used for preparing earthen block

Group Name	Soil		Cement		Coarse Sand		Lime		Fiber (Jute)		Water		Number of block produced
	kg	%	kg	%	kg	%	kg	%	kg	%	Lit	%	
USB	16	91	-	-	-	-	-	-	-	-	1.5	9	5
CSSB	15	67	2	9	3	13	-	-	-	-	2.5	11	5
LSB	25	86	-	-	-	-	1.5	5	-	-	2.5	9	5
LJSB	20	82	-	-	-	-	1.2	5	0.07	0.3	3.0	12	5

RESULTS AND DISCUSSIONS

By performing soil identification tests, according to USCS the soil was found to be CL. After performing Atterberg limit tests of lime stabilized (3%, 6% and 9%) soil and unstabilized soil, a detailed comparison could be made based on their different properties as shown in Fig. 3.

In linear shrinkage tests, the soil behaved differently for different lime contents. For 3% of lime, the linear shrinkage result was approximately same as the unstabilized soil sample while for 6% and 9% lime contents, one and two cracks formed respectively along the lateral direction of the sample. From the above experiments and observations, it can be inferred that as the soil sample has relatively high amount of clay, it should be stabilized with lime (Ming, 2011; Ogundipe, 2013). Nevertheless, too much lime causes shrinkage crack. Henceforth, 5% lime was mixed with soil for preparing earth blocks. There is a likelihood of shrinkage crack if the soil is only stabilized with lime. Thus, some blocks were made using lime and jute with soil while others were stabilized with sand and cement. Also, some blocks were made using only soil to compare with stabilized bricks.

During the curing period, a lot of shrinkage cracks developed in the unstabilized and lime stabilized blocks and henceforth they were considered unsuitable for the construction of CSEB. The remaining two groups of specimens had undergone no cracks and seemed to have gained sufficient strength. Therefore, CSSB and LJSB blocks were tested using Universal Testing Machine. The average ultimate compressive strength and failure strain of each group of blocks are presented in Fig. 4. Typical condition of specimens before and after the test are depicted in Fig. 5.

It can be deduced from the test results that though the cement and sand stabilized blocks possess high compressive strength, they might not be suitable due to low failure strain and ductility and inadequate resistance against earthquake forces. Addition of small amount of lime and jute reinforcement with soil offers considerable bond strength with the development of no shrinkage crack at the time of curing. Jute and lime stabilized blocks maintained their integrity at the time of loading as they have

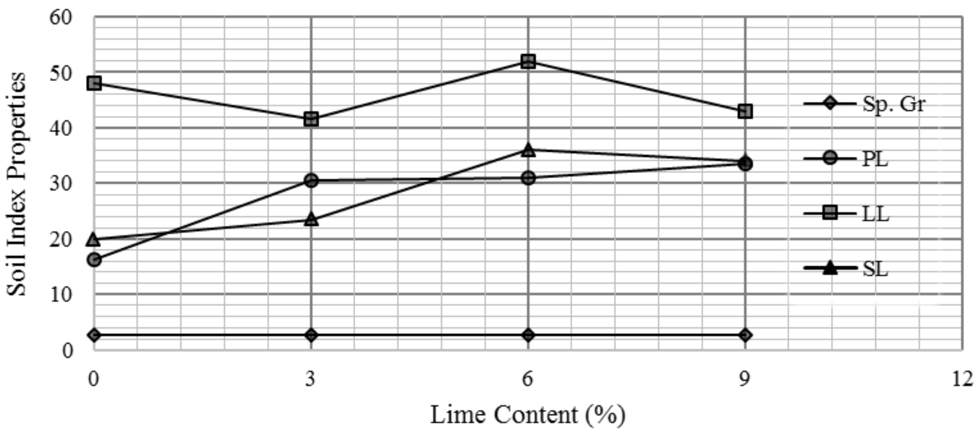
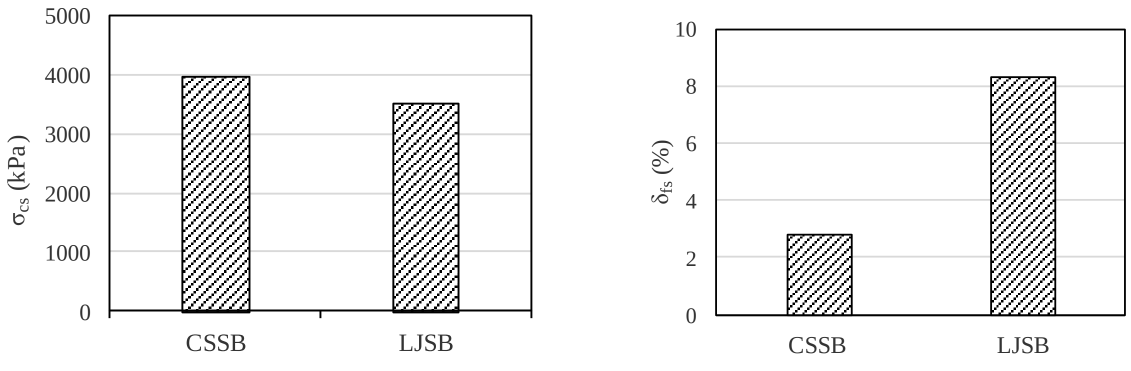


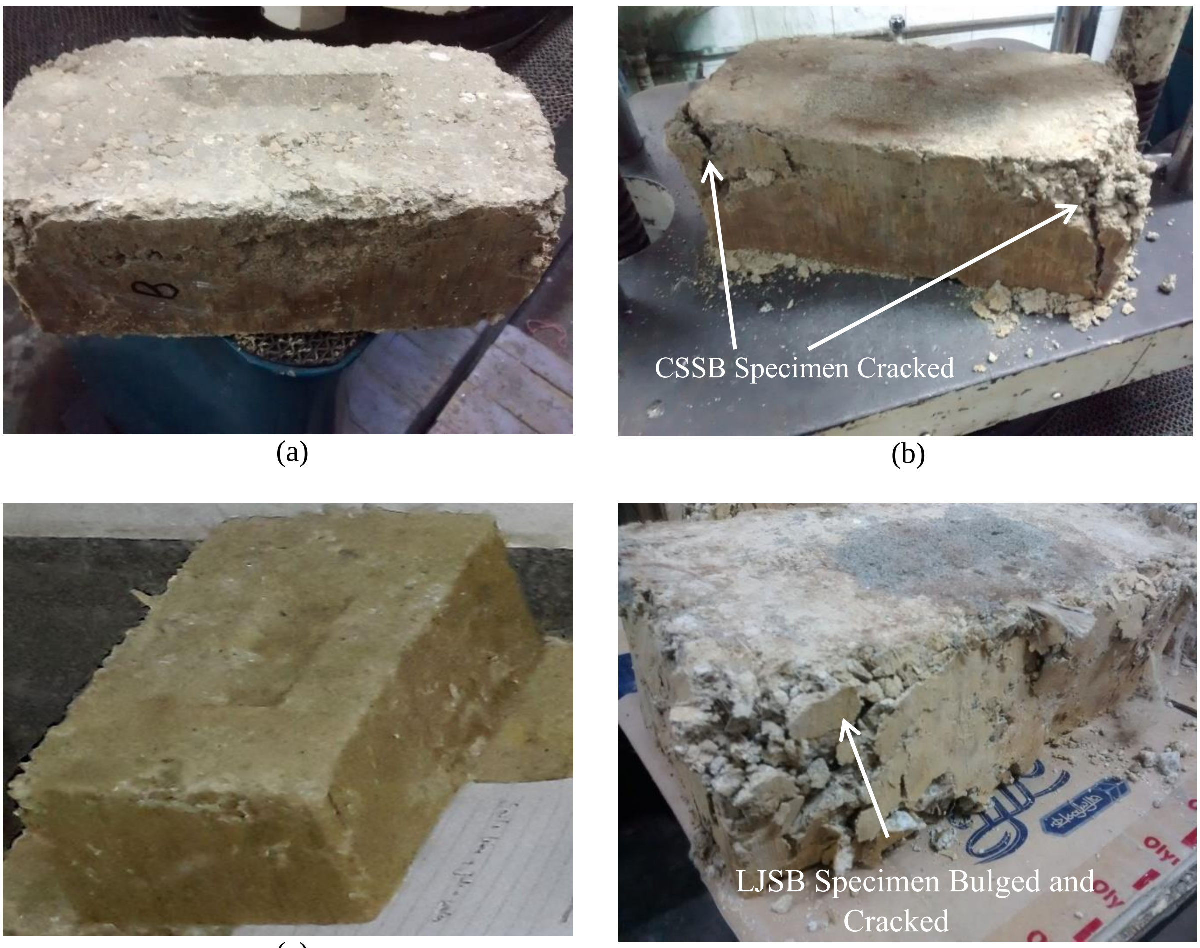
Fig. 3: Variation of index properties with lime content

high failure strength and considerably good ultimate strength. Also, jute and lime stabilized blocks have higher ductility and resistance against earthquake forces. If the jute fibres are mixed at a large scale (around 2%), higher ultimate compressive strength and failure strain can be achieved and the block properties will be enhanced significantly (Islam and Haque, 2009).



(a) (b)

Figure 4. Comparison of (a) compressive strength and (b) failure strain of: cement and sand stabilized CSEB (CSSB) and lime-jute mix stabilized (LJSB).



(a) (b)

(c) (d)

Figure 5. Photographs of: (a) cement and sand stabilized CSEB (CSSB) specimen before test; (b) cement and sand stabilized CSEB (CSSB) specimen after test; (c) lime-jute mix stabilized CSEB (LJSB) specimen before test; (d) lime-jute mix stabilized CSEB (LJSB) specimen after test.

CONCLUSIONS

Climate change impact on Bangladesh would only reinforce the existing problems that pose serious impediment to the economic development of the country. CSEB is a suitable alternative for constructing affordable, safe and eco-friendly buildings in Bangladesh and can be a positive shift towards a safe and pollution free environment to protect the world from climate change.

From the test results, it can be concluded that silty clay soil with high lime content exhibits high shrinkage crack. Moreover, CSEB blocks made using clay only without any type of stabilizer and blocks made using only lime as a stabilizer are not recommended for construction of any structures. All other clay blocks using sand-cement as stabilizers and using jute-lime as stabilizer may be used for construction works. Jute fiber with lime is found to be better with respect to shrinkage crack control and increased strength and reduced deformation properties of block. In addition, it increases bond strength, has higher ductility and can be considered as a low cost earthquake resistant material for earthen house construction. Due to limitation of scope, analysis of dynamic properties has not been carried out. Dynamic tests, for instance shake table tests of full scale model, are to be shown in authors' future publications.

ACKNOWLEDGEMENT

The study was solely conducted at the Department of Civil Engineering of Bangladesh University of Engineering and Technology (BUET). The authors are grateful to the Hope Centre, Savar for lending the Press (3000 Multi-Mould Manual Press) for making the CSEBs at BUET and providing the necessary soil for making CSEB.

REFERENCES

ASTM.2006. Annual Book of ASTM Standards, Vol. 04.08, Soil and Rock; Building stones; Geotextiles.

Holliday, L, Ramseyer, C, Reyes, M and Butko, D. 2016. *Building with compressed earth block within the building code*. ASCE Journal of Architectural Engineering. 22(3) 1-13.

Hossain, I. 2015. *Compressed earth block stabilization using natural fibre*, BSc. Engg. Thesis, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.

Houben, H. and Guillaud, H. 1994. *Earth construction: A comprehensive guide*, IT Publications, London.

Islam, MS, Honda, K and Iwashita, K. 2006. Improvement of seismic resistance of earthen structures, First European Conference on earthquake Engineering and Seismology, Geneva, Paper No.146.

Islam, MS. 2010. *Present status and problems of earthen architecture in Bangladesh: role of education*, Proceedings of the Seminar TERRA Education 2010, France, held on 24-29 May, 2010, 176–184.

Islam, MS and Haque, I. 2009. *Earthen housing for better adaptation to climate change in Bangladesh*, Conference on Climate Change Impacts and Adaptation Strategies for Bangladesh, Dhaka, Bangladesh.

Islam, MS and Iwashita, K. 2010. Earthquake resistance of adobe reinforced by low cost traditional materials. *Journal of Natural Disaster Science, Japan Society for Natural Disaster and Science, Japan, l.* 32(1) 1-21.

Marin, C, Rivera, G and Petric, J. 2010. Clay based composite stabilised with natural polymer and fibre. *Construction and Building Materials*. 24: 1462-1468.

Mesbah, A, Morel, JC, Walker, P and Ghavami, Kh. 2004. Development of a direct tensile test for compacted earth blocks reinforced with natural fibers. *Journal of Materials in Civil Engineering*. 16(1): 95-98.

Ming, C. 2011. Effect of natural fibres inclusion in clay bricks: Physico-mechanical properties. *Geotechnical and Geological Engineering*. 73: 1-8.

Ogundipe, OM. 2013. An investigation into the use of lime-stabilized clay as subgrade material. *Int. J Sci Technol Res*. 2 (10): 82-86.

Walker, P J. 2004. Strength and erosion characteristics of earth and earth block masonry.*Journal of Materials in Civil Engineering.* 16(5): 497-506.