Benha University | Faculty of Computers & AI

Simulation Models of Sustainable Building Materials using Optimization Techniques and Machine Learning

Proposal for a research project submitted to

IbTIECar

Track: **Machine learning**

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1. Abstract

The agro and solid waste pollutes land, water and air in Egypt. Recycling of them into sustainable materials is the optimal solution to avoid their environmental damage and serve the Egyptian society. This paper proposes an approach to develop a sustainable building material using agro and solid waste. Rice straw, furnace slag, cement and lime are used to develop sustainable bricks. A mathematical model is designed to determine the optimal mix of these raw materials to achieve the maximum compressive strength. The optimal solution is determined using Optimization solver (LINGO). Machine learning methods are used to determine the optimal solution too. Finally, the results are compared. The cost of these sustainable bricks is effective as compared to other commercial bricks.

2. Introduction

The current trend in the world is recycling waste into sustainable materials to provide alternative raw materials and preserve natural resources for the future. Waste management will help in sustainable development in Egypt .Materials such as rice straw, rice husk ash, wheat straw ash, cotton waste, wood sawdust, processed waste tea, furnace slag, sugarcane bagasse ash and others were used to develop sustainable materials such as bricks and thermal insulation boards.

The main ingredients used are rice straw, furnace slag, cement and lime. Rice straw is abundant in Egypt and burning it after harvesting rice causes serious environmental damage such as black cloud in the sky for many weeks whack affects human health badly. Instead of burning rice straw, we can reuse it to develop new sustainable and efficient materials such as bricks. One advantage of rice straw is being suitable for thermal insulation because it contains Fiberglass. So, we can conclude that rice straw is a wasted wealth.

To optimize our resources we need to find out the best mix of these ingredients. For this purpose, a mathematical model was formulated to estimate the best mix of these ingredients to maximize the compressive strength of a brick. The presented approach has many benefits for the appropriate usage of natural resources and the purpose of sustainability.

3. Background Research and Related Work

The manufacturing process of conventional building materials consumes energy and natural resources [1]. Building bricks and blocks are one of the important materials for construction industry. The annual consumption of burnt clay bricks in India is around 150 x 109 no's which requires an estimated 500x106 tones of top fertile soil and 600 x 106 GJ of energy [2]. Over exploitation of raw material resources and extensive use of energy intensive materials creates an adverse impact on the environment. On the other hand, disposal of solid waste generated from agricultural and industrial production activity is another serious problem in developing countries like India. The major quantities of waste generated from agricultural sources are sugarcane bagasse, paddy & wheat straw, jute fibre, coconut husk, cotton stalk etc. Reuse of such wastes into energy efficient, environmental friendly and sustainable building alternatives appears to be techno-economic viable solution [3]. Non-linear programming (NLP) is the process of solving an optimization problem defined by a system of equalities and inequalities, collectively termed constraints, over a set of unknown real variables, along with an objective function to be maximized or minimized, where some of the constraints or the objective functions are non-linear. Lingo is a comprehensive tool designed to make building and solving linear, nonlinear (convex & non convex/Global), quadratic, quadratically constrained, stochastic, and integer optimization models faster, easier and more efficient. Alabi et al. [4] developed a linear optimization model for mix proportioning for minimum concrete strength using akure pit sand as fine aggregate. Linear programming technique was applied to a concrete mix design having objective function as least cost of concrete per cubic meter while satisfying given water-cement ratio, the specified limits for the range of acceptable workability, absolute volume constraint and the specified compressive strength. The design variables in the optimization process were cement, aggregate (fine and coarse) and water. Ibearugbulem et al. [5] developed a new regression model with 21 mix ratios for optimizing concrete mixes. This model was satisfactorily tested through laboratory experiments on concrete. The Fisher f-test revealed that the values of compressive cube strength predicted by the new regression model are very close to those from the experiment, with 95% confidence level. Shariq et al. [6] considered the variables for optimization such as 28 days cube compressive strength, water to cement ratio (w/c), coarse aggregate to total aggregate ratio (CA/TA) and total aggregate to cement ratio (TA/C). The influence of w/c ratio, CA/TA ratio and TA/C ratio on compressive strength was experimentally carried out and analysed using polynomial regression analysis. Mathematical polynomial model was developed for compressive strength of concrete as a function of mix proportions. Based on the statistical analysis, optimum concrete mix for different mix proportions was proposed using full factorial experimental technique. Ahmad et al. [7] develop a polynomial regression model for compressive strength considering factors water/binder ratio, binder content, and fine/total aggregate ratio to obtain optimum proportioning of concrete mix. Soudki et al. [8] developed mathematical polynomials for concrete strength as a function of temperature and mix proportion. The influences of the water/cement ratio, coarse aggregate/total aggregate ratio, total aggregate/cement ratio, and temperature on compressive strength were characterized and analyzed using polynomial regression. In the present paper, a multi objective nonlinear optimization of mix proportion was carried out for the design of sustainable brick which consists of Sugar Bagasse Ash (SBA) as the principal raw material. The bricks developed from sugarcane bagasse ash, quarry dust (QD) and lime (L) with various mix proportions were used for optimization [9]. LINGO software was used for the optimization of mix proportion which satisfies the strength and energy criteria of sustainable brick

x. Novelty

We introduce a new mathematical model for building materials which determine the maximum compressive strength of the bricks. We propose a new hybrid metaheuristic algorithm for the same propose.

x. Methodology

A mathematical model is formulated and machine learning algorithms were used to find out the optimal mix of rice straw, furnace slag, cement and lime that achieves the maximum compressive strength. The estimated results from the mathematical model and the machine learning algorithms are compared to find out which of them are better to maximize the function of compressive strength.

x. Resources

We use the following materials and equipment:

No	Material / equipment	Price	Notes
1-	Rice straw	2000	
2	Cotton waste	2000	
3	Wood saw dust	2000	
4	Furnace slag	2000	
5	Lime	2000	
6	Quarry Dust	2000	
7	Compressive testing Machine	20000	
8	Mix Machine	20000	
9	Some small machines	8000	
10	Total	60000	

x. Test and Results

We product some samples of bricks which has the following properties:

- Meet compressive strength requirements
- Energy efficient
- Cost efficient
- Light in weight
- Thermal insulation efficient

x. Product Features

A brick has the following properties:

- Meet compressive strength requirements
- Energy efficient
- Cost efficient
- Light in weight
- Thermal insulation efficient

x. Practical Development

This project can be widely applied in real life. Building bricks can be replaced with this product to achieve the sustainable development in Egypt.

x. Value

This product is lower in cost than other commercial types of bricks in Egypt. In future, it can be significantly valuable.

x. References

[1] M. Pappu, Saxena, S.R. Asolekar, Solid wastes generation in India and their recycling potential in building materials, Building and Environment, 42 (2007) 2311-20.
[2] B.V. Reddy, Sustainable materials for low carbon buildings, Low-Carbon Technologies, 4 (2009)175-181.
[3] S. P. Raut, R. V. Ralegaonkar, S. A. Mandavgane, Development of sustainable construction material using industrial and agricultural solid waste: a review of waste-create bricks, Construction and Building Materials, 25 (2011) 4037-42.
[4] S.A. Alabi, L.M. Olanitori, J. O. Afolayan, Optimum mix design for minimum concrete strength requirement using akure pit-sand as fine aggregate, Journal of Emerging Trends in Engineering and Applied Sciences, 3(4) 2012 718-724.
[5] O. M. Ibearugbulem, L. O. Ettu, J. C. Ezeh, U. C. Anya, New regression model for optimizing concrete mixes. International Journal of Engineering Sciences & Research Technology, 2(7) (2013) 1735-1742.
[6] M. Shariq, J. Prasad, A. K. Ahuja, Optimization of concrete mix proportioning. International Journal of Emerging Technology and Advanced Engineering, 2(7) (2012) 22-28.
[7] S. Ahmad, S. A. Alghamdi, A statistical approach to optimizing concrete mixture design. Hindawi Publishing Corporation the Scientific World Journal, Article ID 561539, (2014) 7 pages. http://dx.doi.org/10.1155/2014/561539.
[8] K. A. Soudki, E. F. El-Salakawy, N. B. Elkum, Full factorial optimization of concrete mix design for hot climates. Journal of materials in civil engineering, 13 (2001) 427-433.
[9] M. Madurwar, S. Mandavgane, R. Ralegaonkar, Development and feasibility analysis of bagasse ash bricks, J. Energy Engineering (2014) 10.1061/(ASCE)EY.1943-7897.0000200 , 04014022.
[10] Indian Standard: IS 3495 (Part 1 and 2). Methods of tests of burnt clay building bricks. New Delhi: BIS (1992) [Third Revision].
[11] P. Tiwari, Energy efficiency and building construction in India. Building and Environment, 36 (2001)1127–1135.
[12] Guidelines for Manufacturing Quality Fly Ash Brick by NTPC. http://www.ntpc.co.in/images/content/environment/ash_util/2010-11/Fly-Ash-Bricks.pdf
[13] B. V. Reddy, K. S. Jagadish, Embodied energy of common and alternative building materials and technologies, Energy and Buildings, 35 (2003)129–137.
[14] Indian Standard: IS 12894:1990. Fly ash lime brick-specifications. New Delhi: BIS (1990).