INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & MANAGEMENT

LIFE CYCLE COST EVALUATION OF USING EXPANDED POLYSTRENE FOR RESIDENTIAL BUILDINGS

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ABSTRACT

As the world population continues to grow exponentially, disequilibrium has been created in the demand and supply of houses. Most developing nations of the earth today including Nigeria are exposed to the phenomenon of population growth and scarcity of houses. Therefore, there is need to explore alternative approaches to improve the availability of houses for low income citizens. One of the alternatives available is the adoption Expanded Polystyrene (EPS) for mass housing scheme. For that, this paper examines the cost effectiveness of Expanded Polystyrene as an alternative building material to the conventional Portland cement concrete and sandcrete blocks most used in Nigeria. Life Cycle Cost (LCC) model of cost comparison among project alternatives is adopted for the comparison of Expanded Polystyrene buildings with the Sandcrete blocks buildings. Net Present Value is adopted for the economic evaluation. The result of this research proves that the use of EPS for residential building construction is more economical in the long run and that much benefit will accrue to the stake holders in the built environment if LCC is applied in the early design stage to gauge and manage maintenance budgets and the overall life cycle costs of buildings.

Keywords: Expanded Polystyrene, Sandcrete Blocks, Life Cycle Costing, Net Present Valu.

INTRODUCTION

In all nations of the earth, the population is on the increase and so do the demand for housing facilities. Since economic laws must find equilibrium, the cost of houses for rent and for acquisition is gradually getting out of the reach of common man. In view of the fact that housing is one of the most basic needs of man, the necessity for adequate and affordable housing for all cannot be over emphasized. This means that as the population continues to increase, there is need to start anticipating future problems that will emerge around housing programs. Lack of affordable house has been identified as the cause of various educational, family, health and economic problems of the low-income earners1-5. Some of the reasons for the housing emergency in underdeveloped nations are high cost of conventional building materials such as Portland cement concrete, steel, neglect of traditional building technologies and poor technological knowhow. As the use of conventional building materials such as Portland cement is becoming unsustainable due to its major contribution to the global change in climate, there is need to use more environmentally friendly materials.

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The building construction industry is known to be responsible for the annual consumption of approximately 40% of the aggregates used for concrete (raw stone, gravel, and sand) globally with about 25% of fresh un-seasoned wood. Global energy usage is not left out, as over 40% is consumed by the buildings industry just as about 16% of global water usage is for building works6. These materials are becoming scarce and very expensive to produce which in turn transfers the high cost to the building industry. The high cost and depleting nature of many building materials remain fundamental limiting factors to sustainable housing development in the world today. As the world population continues to grow, the demand for houses is destined to become overwhelming unless appropriate steps are taken towards addressing them. One of such steps will be the sourcing of alternative materials to concrete products which is the most used building material around the world. The acceptable alternative materials must be economically viable, easily available and environmentally friendly. Expanded Polystyrene (EPS) represent one of the options available as its use is emerging as one of the breakthroughs in the construction industries. This research therefore considers the economic viability of Expanded Polystyrene (EPS) wall and slab panels as an alternative to a combination of conventional Portland cement concrete and sandcrete blocks which is typical in Nigerian built environment for residential buildings.

The most commonly adopted construction material for Nigerian residential buildings are reinforced concrete for framing members and hollow-sandcrete blocks for wall panels and slabs. The high demand for these construction materials and the intensive labour required for site placement have all contributed to very high cost of buildings today. More so, the durability of concrete structures is beginning to pose a problem in some developing nations because low expertise and numerous conflicting local factors. The frequent cases of collapsed concrete buildings in Nigeria confirms this phenomenon7,8.

Historically, building materials have developed due to advances in knowledge and technology, from the mud for adobe huts of the Middle East to the development of concrete, steel, then reinforced concrete, to the arrival of fiber reinforced concrete and plastics, and a lot of other breakthroughs in building materials and civil engineering applications. Though the basic construction materials continue to be in use over successive ages, the technological advancement made in each successive ages depended mostly on how these materials are combined to the advantage of the society in terms of safety, economy and functionality of built structures. These rapid advances in construction materials technology have led to better health and good standard of living for mankind. This research falls in line with the trends of advancing the benefits already achieved through the use innovative building materials worldwide. This will open the door for less dependency on the environmentally non-friendly concrete material and more exploration into other affordable alternative and locally available and environmentally friendly options such as wood, bamboo and innovative materials. Expanded Polystyrene (EPS) is one material which can contribute towards a better environment in the field of building construction. The American Society for Testing and Materials (ASTM)9 defines EPS as a type of foamed plastic formed by the expansion of polystyrene resin beads in a molding process. EPS is used in engineering to produce EPS block geofoam embankment10, for roofing11, for producing insulation board and for producing wall and slab panels12.Some of the characteristics of EPS include its lightweight, thermal and sound insulation capacity and aesthetically-pleasing for decoration. EPS is used as a building system made up of structural panels of undulated foam polystyrene with a base reinforcement placed against the sides with high resistance steel mesh and each side joined to one another by means of electro-welded steel connectors. These panels are used for slabs, walls, partitions and ceilings. The EPS project is finished on-site by applying concrete/sandcrete with pneumatic devices. In this way, the panels form the principal vertical and horizontal structural elements of a building. The potentials of EPS justifies it's choice as the focus of this research on alternative, economically viable and environmentally acceptable option against concrete/sandcrete blocks materials for mass housing scheme in a developing nation like Nigeria.

Construction of buildings demand a large and long-term investment for which the client must be assured of the profitability of the investment before venturing in. Therefore, cost effectiveness of investing in a new building model is of ultimate interest for the client, the user and society. Generally, production cost is the main cost factor considered in the construction industry and the operators are obliged to setting it to minimum as to make it attractive to the investors. Procurement costs are widely used as the primary criteria for project selection without considering the hazards posed by hidden costs associated with the life cycle maintenance of buildings. Life cycle costs are the total costs estimated to be incurred in the design, development, production, operation, maintenance, support, and final disposition of a major system over its anticipated useful life span13. Life cycle cost analysis is an important tool that can be used to educate the client in the early stage of design decisions. It is important, to show the client in the early design phase of the relationship between design choices and the resulting lifetime costs14. Therefore, to prove the suitability of the EPS for mass provision of houses in developing nations like Nigeria, Life Cycle Cost (LCC) model of cost comparison among project alternatives is adopted for the comparison of EPS buildings with the traditional Sandcrete Blocks (SCB) buildings. As sandcrete blocks is the most commonly adopted building material in Nigeria, it becomes imperative to compare it with EPS which has a potential for adoption for mass housing production. LCC model of cost comparison is adopted because good engineering proposals without economic justification may often end up uneconomical15. LCC model of cost comparison provides better assessment of long-term cost effectiveness than can be obtained from only prime costs decisions.

METHODS

Life Cycle Costing In The Construction Industry

Life cycle cost analysis was conceived in the mid-1960s for the US Department of defense and have been successfully and frequently used effectively in the industries and many commercial areas. It has experienced limited applications in the building construction sector. The minimal application in the built environment is related to the scarcity of data needed for the objective application of the method. The goal of LCC analysis is to choose the most cost effective approach from a series of alternatives so that the least long term cost of ownership is achieved16. LCC analysis helps engineers justify project selection based on total costs rather than the initial purchase price since the cost of operation, maintenance, and disposal usually exceed procurement costs many times over. Construction clients and end users can use life-cycle costs to measure and compare competing projects, and quantify maintenance demands and costs. Life cycle cost (LCC) is the total cost of ownership of equipment or projects, including its cost of acquisition, operation, maintenance, conversion, and/or decommission17.

A broad variation of economic evaluation methods for LCC abounds in the literature, but the most suitable approach for LCC in the construction industry is the Net Present Value (NPV) method14. NPV is the result of the application of discount factors, based on a required rate of return for each year of projected cash flow discounted to present value. In LCC, the focus is on cost rather than on income, therefore, the usual practice is to treat cost as positive and income as negative. Consequently the best choice between two competing alternatives is the one with minimum NPV18. The reason for adopting NPV is that it takes the time value of money into account and generates the return equal to the market rate of interest19.

This research adopts the Net Present Value (NPV) method of economic evaluation for the implementation of the Life Cycle Cost (LCC) model of cost comparison of Expanded Polystyrene (EPS) buildings with the traditional Sandcrete Blocks (SCB) buildings.

Once all the relevant costs have been established and discounted to their present value, the costs are summed to generate the total life cycle cost of the project alternative. After this has been done for all the project alternatives, a summary of the results is prepared.

The summary of this research will compare the total life cycle costs of initial investment, operations, maintenance/repair/replacement, and residual value of the two competing alternatives.

RESULTS AND DISCUSSION

Life Cycle Costing Implementation And Data Analysis

The life cycle cost implementation proceeds as defined in the following 7 steps.

Step 1: Problem formulation

Conventional low-income residential buildings in Nigeria are built with Sandcrete Blocks (SCB) as wall panels. As the Nigerian population is exponentially increasing, the demand for housing units is getting very high and the cost of buildings in sandcrete block buildings is getting ever more expensive. The research question is to find an effective LCC alternative for an interval of 20 years.

Step 2: Alternative Choice

An alternative model in Expanded Polystyrene (EPS) wall panel is considered. The cost of acquisition is 12,942,193 Naira for the SCB model and 13,159,197 Naira for the EPS model. Components of acquisition cost are shown for SCB and EPS buildings in figures 1 and 2 respectively.

Step 3: Preparation of cost breakdown structure

Each of the building models will incur acquisition costs and sustaining costs. Acquisition costs include research and development, engineering data (for EPS model only), engineering design, facility and construction and supervision. Sustaining costs comprise maintenance cost, replacement/renewal/modification cost, energy cost and facility usage cost, operational/management cost.

Step 4: Choice of analytical cost model

Net Present Value (NPV) analytical cost model is used for the implementation of LCC in the two competing housing models. Sustaining costs are prorated into each year since the specific costs are chance events.

Figure 1: Capital cost of the SCB building model

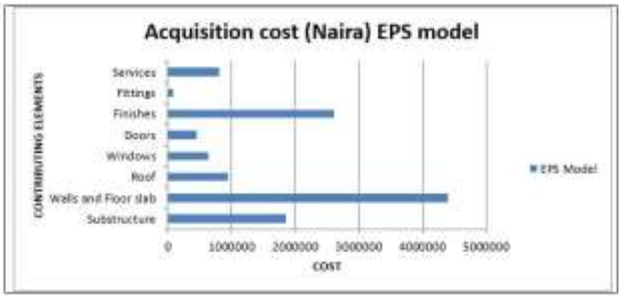

Figure 2: Capital cost of the EPS building model

Step 5: Gathering of cost estimates and cost model

The capital cost is equal to the cost of acquisition of SCB model (12,942,193 Naira) while the capital cost for the EPS model is equal to the cost of acquisition plus engineering data collection cost (about 10% of cost of acquisition) for the perfection of the relatively new EPS building technology (13,159,197 Naira). Having examined the local and environmental factors affecting the built industry in Nigeria such as scarcity of data, poor maintenance culture, high incidence of building collapse, high risk of fire in EPS model and the newness of the EPS building technology, the following costs were adopted: cumulative annual maintenance/upgrade (5% acquisition cost), annual power cost for running air conditions in the two house models is 120,000 Naira for the SCB model and 96,000 Naira for EPS model (EPS is a better insulating material when compared to SCB), straight line depreciation for 20 years and a disposal cost (10% acquisition cost). For the implementation of LCC, NPV is applied at 12% discount rate while a tax provision of 15% is assumed.

Step 6: Summary of cost profiles for each alternative

While preparing the cost profile for the two competing alternatives, no revenue stream is included in the calculations so the case with the smallest loss will be the most attractive case. The combined non-annualized and annualized recurring costs are then presented in tables. The Net Present Values are shown in figure 3.

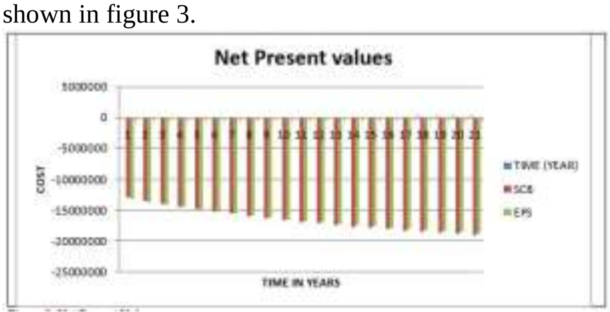

Figure 3: Net Present Values

Step 7: Break-even charts for the alternative building models

The breakeven chart shows the effects of fixed and variable costs. Results for the two alternatives are captured in figure 4 for a quick grasp of how the breakeven points of the EPS building model compares to the SCB building model. The y-axis shows the cumulative present values while time is in the x-axis. It shows the cost of money with time and how the effects of expenditures can play together to induce cost increase or reductions.

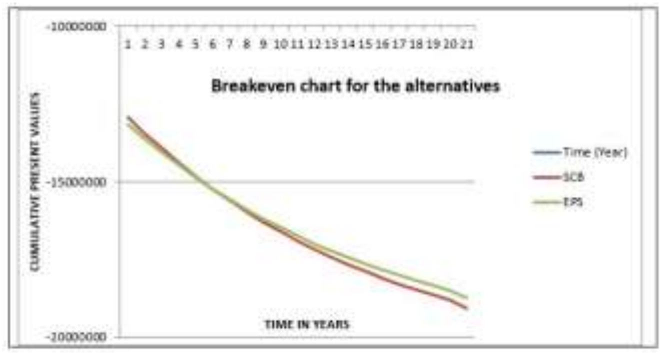

Figure 4: Breakeven chart for the 2 alternative models

CONCLUSION

From the breakeven chart, the effects of fixed and variable costs are confronted for the SCB and EPS building alternatives. The EPS line crossed that of SCB at about 7th year and continues to have a smaller cost all through the period of consideration. From these results, it is proven that the EPS model is more economically viable than the SBC model. From the 7th year to the end of the period of consideration, it maintained a lower cost. This proves that good cost effective building project alternatives can be achieved through LCC analysis. Much benefit will definitely accrue to the stake holders if LCC is applied in the early design stage when creativity can be employed in making the right choice that will guarantee overall better life cycle performance of a selected project alternative. Devising a better alternative outside the design phase will be difficult as it will be employed too late in the improvement cycle. Therefore, LCC provides a good tool for all stake holders in the building industry to gauge and manage maintenance budgets and the overall life cycle costs of buildings. EPS model is therefore proven to be more economically viable than the SBC model.

REFERENCES

[1] Crowley, S. The Affordable Housing Crisis: Residential Mobility of Poor families and School Mobility of Poor Children, Journal of Negro education, 72(1), 2003, 22-38.

[2] Bartlett, S. N. Housing as a factor in the socialization of children: A critical review of the literature, Merrill-Palmer Quarterly, 43(2),1997, 169-198.

[3] Bartlett, S. N. Does inadequate housing perpetuate children's poverty? Childhood, 5, 1998, 405-428.

[4] Scanlon, E. & Devine, K. Residential mobility and youth well-being: Research, policy, and practice issues, Journal of Sociology and Social Welfare, 28(1), 2001, 119-138.

[5] Sharfstein, J.; Sandel, M.; Kahn, R. & Bauchner, H. Is child health at risk while families wait for housing vouchers? American Journal of Public Health, 92, 2001, 1191.

[6] D. M. Roodman and N. Lenssen, A Building Revolution: How Ecology and Health Concerns are Transforming Construction, Worldwatch Paper 124, Worldwatch Institute,Washington, DC, 1995.

[7] Ede, A. N. (2010): "Building Collapse in Nigeria: the Trend of Casualties in the Last Decade (2000 -2010)". International Journal of Civil & Environmental Engineering, Vol: 10 No: 06, pp32-42

[8] Ede, A. N. and Adegbite, A. A. (2014). Effects of limestone and super-plasticizer on the fresh properties of self-compacting concrete, IISTE Civil and Environmental Research, Vol.6, No.2.

[9] ASTM 2007. Terminology for Geosynthetics, American Society for Testing and Materials, D 4439, West Conshohocken, PA.

[10] Arellano, D. & Stark, T. D. Load bearing analysis of EPS-block geofoam embankments, In: Bearing Capacity of Roads, Railways and Airfields, edited by Tutumluer & Al-Qadi, Taylor & Francis Group, London, 2009, 981-990.

[11] EPS Industry Alliance. Technical Bulletin, EPS Roofing Solution, EPS Industry Alliance, Crofton, 2008.

[12] Ogundiran, I. A. & Adedeji, Y. M. D. Urban housing delivery: Expanded polystyrene panels initiative in Abuja, Nigeria, In: Laryea, S., Agyepong, S.A., Leiringer, R. and Hughes, W. (Eds) Procs 4th West Africa Built Environment Research (WABER) Conference, 24-26 July 2012, Abuja, Nigeria, 1033-1042.

[13] DOE (1995). "Practical Machinery Management for Process Plants: Volume 1: Improving Machinery Reliability". http://www.em.doe.gov/ffcabb/ovpstp/life.html, posted 4/12/1995 on the world wide web, accessed 20th September, 2013.

[14] Schade J. (2007). "Life Cycle Cost Calculation Models for Building",in proceedings of 4th Nordic Conference on Construction Economics and Organisation: Development Processes in Construction Mangement. Atkin, B. & Borgbrant, J. (eds.). Luleå: Luleå tekniska universitet, p. 321-329.

[15] Barringer, H. P. (2003). "A Life Cycle Cost Summary", International Conference of Maintenance Societies (ICOMS) http://www.icoms.org.au.

[16] Barringer H. P. and Weber, D. P. (1996). "Life Cycle Cost Tutorial", Fifth International Conference on Process Plant Reliability, Gulf Publishing Company, Houston, TX.

[17] SAE (1999). "Reliability and Maintainability Guideline for Manufacturing Machinery and Equipment", Society of Automotive Engineers, M-110.2, Warrendale, PA.

[18] Kishk, M., Al-Hajj, A., Pollock, R., Aouad, G., Bakis, N. & Sun, M. (2003). "Whole Life Costing in Construction: A State of the Art Review", RICS Foundation Research Papers.

[19] Flanagan, R., Norman, G., Meadows, J. & Robinson, G. (1989). "Life Cycle Costing Theory and Practice". Oxford: BSP Professional Books.