STUDY OF COST EFFECTIVE ECO FRIENDLY STRUCTURES TO CONVENTION BUILDINGS

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ABSTRACT

In today's world, it is more than essential to create an enabling environment for affordable housing for one and all in a manner as sustainable as possible without degrading the environment and natural surroundings around us. In this project an attempt is made to propose and estimate the cost of a cost-effective eco-friendly alternative to conventional houses which deals with materials and design rather than energy efficient fixtures to contribute to energy efficiency of the buildings. The reason for this is the cost intensive nature of energy efficient fixtures when compared to that of conventional fixtures. Hence, the aim of this project is to propose an eco-friendly building just based on design and construction materials to be used. Eco friendly trails like Rammed Earth walls, Filler slabs, Bamboo flooring and UPVC Doors and Windows have been analysed and proposed as alternatives to conventional materials as they are locally available, cheap, and durable and strong for use in construction. Detailed quantity & cost estimation of a conventional house has been carried out to enable comparison of the same with the proposed eco-friendly building.An overall reduction of 46% in the cost was reported for the proposed house when compared to the conventional one.

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INTRODUCTION

1.1 GENERAL

A house with basic amenities of water, sanitation and domestic energy, offering a sense of privacy, safety and dignity is the right of every individual in society.The access to and the quality of housing directly influence the quality of life of people, their productivity levels and growth potential.Housing also holds the key to accelerate the pace of economic & social development. Investments in housing have a multiplier effect on income and employment. It is estimated that overall employment generation in the economy due to additional investment in the housing/construction is eight times the direct employment. The construction sector is growing at the rate of 7% and it provides employment for 16% of the work force. Out of this, housing sector alone accounts for 85.5 lakh workers, which include poor people.

According to the report of the Technical Group on Estimation of Housing Shortage constituted in the context of preparing 11th Five Year Plan document, the housing shortage in urban areas as of 2007 is estimated to be around 24.71 million. Most of the housing shortage is for Economically Weaker Section (EWS) and Lower Income Group (LIG) Sections which does not seem to be getting translated into economic demand due to lower affordability by the poor. A sizeable number of this requirement leads to squatting and slums.

1.2 OBJECTIVES

After an initial literature review of the project and after identifying the general scope of the project, the following objectives were set up:

- To suggest an eco-friendly house (a mix of natural and green building), which is cost-effective and the cost of which is comparable to or lower than that of a conventional house.

- To suggest/propose eco-friendly building materials or techniques for each structural element which satisfies the criteria of utility, serviceability, easy & local availability, eco-friendliness, ease of construction, eco-friendliness & low embodied energy to the maximum extent possible without compromising on cost & economy of the project.

- To study the energy efficiency of a building without any additional energy efficient fixtures & only by replacing the construction materials for each structural element with eco-friendly building materials or methods thus resulting in overall cost-effectiveness

2.0 LITERATURE REVIEW

2.1 JOURNAL ON LOCAL GREEN BUILDING MATERIALS by *Nura S Mohammed*

Abstract: Materials that are eco-friendly but are not found locally add cost to transportation and indirect costs of consumption of fuel, release of carbon dioxide and other gases in turn harming the environment. Transportation of eco-friendly materials is not by itself eco-friendly. Hence, Local green building materials should be available in good quality. They should be found in vicinity of the place we want to use. The materials should be acceptable in their physical and chemical state. The materials should not compromise on mechanical strength.Effects of climatic conditions should be known. Procedures used or manufacturing must be simple and not in need of high-tech or expensive equipment.They should have an aesthetic standpoint.

2.2 JOURNAL ON BENEFITS OF GREEN BUILDINGS by *MoncefKrarti*

Abstract: The most fundamental benefit of Green Building is that it is environmental friendly and safe for people occupying the building. A well designed and constructed green building is well integrated into the environment in which it is built and does not detract from it. It is pleasant and safe for people who use the building on a daily basis. Its aesthetic appeal of carefully designed and well integrated architectural features, such as efficient use of space, intuitive layouts and [pleasant lighting offers psychological benefits to people. While, elements such as clean air monitoring and circulating systems, handicap access, clean water and other elements make it safe and beneficial to human health.Another important benefit of Green Building is Energy Efficiency, which results in reduced energy consumption for AC and Heating needs. It may feature elements like effective use of natural lighting, cool roof and wall panels, and green energy generating systems all aimed reducing energy consumption, which results in cleaner environment and direct cost savings to the building owners.

2.3 JOURNAL ON GREEN BUILDING MATERIALS by *Heide G. Schuster*

Abstract: Sustainability and environmental friendliness are two key requirements to green building materials. Many green building materials also offer energy efficiency benefits. For instance, use of metal in residential and commercial construction is considered environmentally friendly because metal is recyclable and long lasting building material that also offers excellent solar reflective benefits making it an energy efficient choice for roofing and wall panels when constructing a building envelope.Bamboo is another green building material because it grows quickly and thus can be easily sustained. Specially grown Cedar can be considered sustainable building material when it is grown locally and cut in a sustainable manner that will ensure future growth and availability.

3.0 RESEARCH METHODOLOGY

The scope of the project lies in the study & comparison of various eco-friendly building materials available in India. It also deals with the proposal of a cost-effective & eco-friendly alternative to conventional houses and analysing their life-cycle cost. The project also deals with the design of the conventional building and a cost comparison between the conventional & the proposed eco-friendly house.

- The energy efficiency of a building made of eco-friendly materials and sans (without) any energy efficient fixtures will be within the project
- A study of the general constraints or limitations or problems in widespread implementation and acceptance of eco-friendly houses was done through literature review.
- The project necessitates an understanding of energy consumed by a building. This includes both the embodied energy and the energy for maintenance of a building during its lifecycle.
- A quick study of the locally available eco-friendly materials/methods of construction (technique) has already been done. Based on this, the

material/method of construction (technique) for each structural element will be chosen giving preference to the material which was the cheapest, strong, durable and easily available.

- Detailed quantity & cost estimation of a conventional house will be carried out to enable comparison of the same with the proposed eco-friendly building.
- A study and estimation of cost of the eco-friendly materials will also be carried out.

The primary focus of the project will be more on natural buildings rather than green buildings i.e. the project deals with materials and design rather than energy efficient fixtures although the materials and techniques to be chosen will contribute to energy efficiency of the buildings.

The two major reason for this being –

a) Energy efficient fixtures & fixtures which tap into renewable energy are being promoted both commercially and by the government of India. The government has focussed a lot on these and have initiated several initiatives to promote these fixtures. A slew of players in the market are also promoting these in a big scale. Hence enough information and studies on their costs, benefits and other aspects are available. Action towards this end has been satisfactory as well. Contrary to this, not enough study has gone into the construction materials. Their role in the performance of a building on the energy side and their effect on the impact of building towards environment have been neglected & not fully understood. Neither enough study on their suitability and performance has been done nor has enough information on their costs and economic justification been carried out.

b) Energy efficient fixtures are cost intensive. The energy efficiency of buildings made with the right building materials is satisfactory or comparable to that of a building with only energy efficient fixtures (This statement has also been justified in the project). Hence it adds unnecessarily to the total cost of buildings.

Thus, energy efficient fixtures & fixtures which tap into renewable energy fall outside the purview of the project

4.0 PROPOSED ECO-FRIENDLY MATERIALS

4.1 RAMMED EARTH FOR WALLS

4.1.1Introduction

Rammed Earth is a wall-building technique, by which a certain mixture of mud, chalk, lime, gravel and water, is forcibly tamped inside formwork. The resulting wall has high mass, so it works well in hot climates. It often needs no exterior or interior covering, thus saving materials.

4.1.2 Brief Description

It is an ancient building method that has seen a revival in recent years as people seek more sustainable building materials and natural building methods. Because of the nature of the materials used, it is incombustible, thermally insulating and very strong and hardwearing. It also has the added advantage of being a simple way to construct walls. Traditionally, rammed earth buildings are common in arid regions where wood is in scarce supply. Rammed earth is based on naturally damp and crumbly earth which is compressed into a form and left to dry and harden. With densities ranging from 1700 to 2200 kg/m^3 it is the heaviest form of earthen building. Rammed earth structures can therefore be load bearing. The earth is filled into a form and compressed in layers similar to conventional in-situ concrete. Alternatively large rammed earth blocks can be pre-cast in moulds and then assembled on site much like brickwork on large scale.For rammed earth construction, soil selection and composition is critical. The basic soil composition for rammed earth is roughly 70% sand and gravel, the structural filler, and 30% clay and silt, the binder. If the clay content is too high, sand can be added to the mixture. This will also increase the compressive strength of the material. If the clay content is too low, high clay soils can be mixed in to make an optimum mix.

5.0QUANTITY & COST ESTIMATION OF CONVENTIONAL BUILDING

A 60’*40’ site was selected and a suitable plan for a single storied residential house was prepared by giving a setback of 10’ in the front and a setback of 5’ all around.

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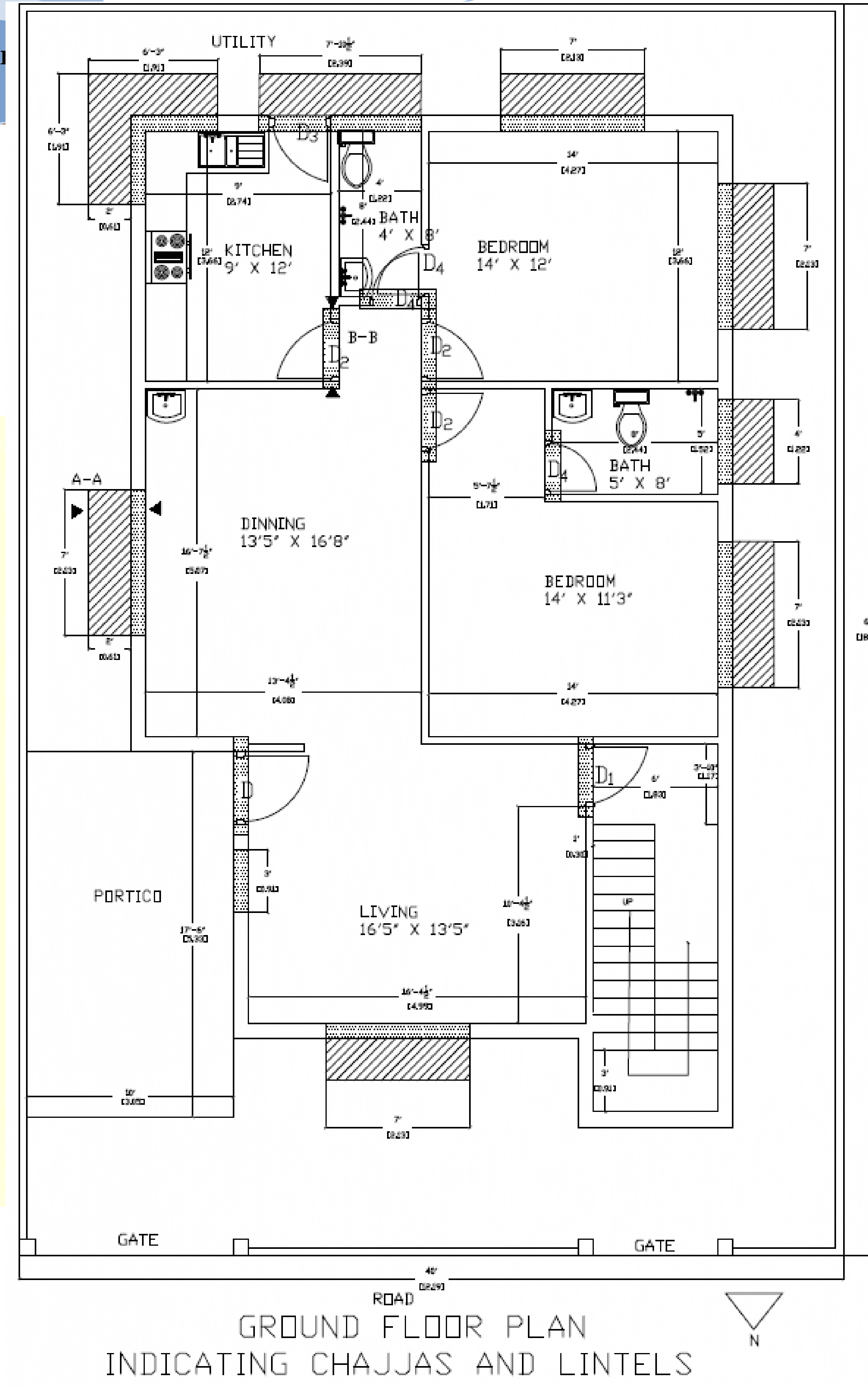
UTILITY
KITCHEN
9' X 12'
BATH
4' X 8'
BEDROOM
14' X 12'
B-B
A-A
DINNING
13'5" X 16'8"
BATH
5' X 8'
BEDROOM
14' X 11'3"
PORTICO
LIVING
16'5" X 13'5"
UP
GATE
GATE
ROAD
N
GROUND FLOOR PLAN
INDICATING CHAJJAS AND LINTELS

5.2 DETAILED QUANTITY ESTIMATE

Sl. No.	Item of Work	No.	L (m)	B (m)	H (m)	Quantity (m^3/m^2)
1	Earth Work Excavation					
	a) For Foundation	1	46.51	1.22	1.22	69.13
	b) For Sump Tank	1	3.66	2.44	2.13	19.03
						88.16
2	P.C.C. bed with 1:4:8 mix	1	46.51	1.22	0.25	14.40
3	Size Stone Masonry in C.M. 1:6					
	Course - I	1	46.51	0.91	0.36	15.12
	Course - II	1	46.51	0.76	0.30	10.80
	Course-III	1	46.51	0.61	0.30	8.64
	Course-IV	1	46.51	0.46	0.43	9.18
						43.75
4	Damp Proof Course (D.P.C.)	1	46.51	0.46	0.15	3.24
5	Plinth Filling using Local soil					
	a) Kitchen l=2.7432-0.1143=2.6289m b=3.6576-0.1143=3.5433m	1	2.63	3.54	0.46	4.26
	b) Bathroom-1 l=1.2192m b=2.4384-0.1143=2.3241m	1	1.22	2.32	0.46	1.30
	c) Bedroom-1 l=4.2672-0.1143=4.1529m b=3.6576-0.1143=3.5433m	1	4.15	3.54	0.46	6.73
	d) Bathroom-2 l=2.4384-0.1143=2.3241m b=1.524m	1	2.32	1.52	0.46	1.62

Sl. No.	Item of Work	No.	L (m)	B (m)	H (m)	Quantity (m^3/m^2)
5	e) Bedroom-2					
	Portion-A l=4.2672-0.1143=4.1529m b=3.429m	1	4.15	3.43	0.46	6.51
	Portion-B l=1.7145m b=1.6383m	1	1.71	1.64	0.46	1.29
						7.80
	f) Staircase Room					
	i)l=1.8288-0.1143=1.7145m b=4.3053m	1	1.71	4.31	0.46	3.37
	ii)l=1.8288-0.1143-0.1143=1.6002m b=0.1651+0.9144-0.1143=0.9652m	1	1.60	0.97	0.46	0.71
						4.08
	g) Living Room l=4.9911-0.1143=4.9797m b=4.0767-0.1143=3.9624m	1	4.98	3.96	0.46	9.02
	h) Dining					
	i)Portion A: l=4.0767-0.1143=3.9624m b=5.0673-0.1143-0.1143=4.8387m		3.96	4.84	0.46	8.77
	ii)Portion B: l=4.0767-1.524=2.5527m b=0.2286m	1	2.55	0.23	0.46	0.27
	iii)Portion C: l=4.0767-1.524-1.0668=1.4859m b=0.1143m	1	1.49	0.11	0.46	0.08
						9.11
	i) Passage l=1.22m b=1.22m	1	1.22	1.22	0.46	0.68
						44.60

Sl. No.	Item of Work	No.	L (m)	B (m)	H (m)	Quantity (m^3/m^2)
6	Burnt Brick Masonry in CM 1:6					
	a) Exterior Walls including Parapet wall h=3.048+0.696=3.6576m	1	46.51	0.23	3.66	38.89
	b)Interior Walls					
	i)Kitchen/Dining	1	2.74	0.11	3.05	0.96
	ii)Kitchen/Bath-1 & Passage	1	3.66	0.11	3.05	1.27
	iii)Bath-1 & Passage/Bedroom-1	1	3.66	0.11	3.05	1.27
	iv)Bath-1/Passage	1	1.22	0.11	3.05	0.42
	v)Bedroom-1/Bath-2 & Bedroom-2	1	4.27	0.11	3.05	1.49
	vi)Bedroom-2/Bath-2	1	1.52	0.11	3.05	0.53
	vii) Bedroom-2/Bath-2	1	2.44	0.11	3.05	0.85
	viii)Bedroom-2/Dining	1	5.07	0.11	3.05	1.77
	ix)Bedroom-2/Staircase room & Living room	1	4.27	0.11	3.05	1.49
	x)Staircase room/ Living room	1	4.08	0.11	3.05	1.42
	xi)Living room/ Dining	1	1.07	0.11	3.05	0.37
						11.84
	c) Stair room in terrace l=2(3.3528+0.2286+1.8288+0.2286) =11.2776m	1	11.28	0.23	2.44	6.29
	d)Deduction for Openings					
	i)Door, D	1	1.07	0.23	2.13	0.52
	ii)Door, D_1	2	0.91	0.11	2.13	0.45
	iii)Door, D_2	3	0.91	0.11	2.13	0.67
	iv)Door, D_3	1	0.76	0.23	2.13	0.37
	v)Door, D_4	3	0.76	0.11	2.13	0.56
	vi)Window, W	1	1.83	0.23	1.68	0.70
	vii)Window, W_1	2	0.91	0.23	1.68	0.70
	viii)Window, W_2	4	1.83	0.23	1.37	2.29
	ix)Window, W_3	2	0.91	0.23	0.76	0.32
	x)Ventillator, V	2	0.91	0.23	0.46	0.19
						6.77

COST ANALYSIS OF ALTERNATIVE MATERIALS & COST ESTIMATION OF PROPOSED BUILDING

6.1 GENERAL

Costs of certain materials proposed which are commercially available were procured directly from dealers. Principles of Rate Analysis were applied for materials produced in-situ and rough estimations of savings in materials and costs were done for special construction techniques proposed.

6.2 COST OF RAMMED EARTH

It is proposed to construct in-situ walls using Rammed Earth. Previous studies were referred to get an idea of labour requirements.

The quantity/weight of earth required for constructing one cubic metre of rammed earth wall = $\frac{7}{0.15*0.15*0.15}$ = 2074kg

Density of earth available at the site = 23 kN/m^3 ≈ 2300 kg/m^3

Volume of earth required to construct 1m^3 of rammed earth wall = $\frac{2074}{2300}$ = 0.9017m^3

Total quantity of B.B.M (i.e. total volume of wall) = 44.2 m^3

Therefore total quantity of earth required = 0.9017 * 44.2 = 39.86 m^3

Earth available = Earth excavated- Earth to be filled back = 88.16 – 20.16 = 68m^3> 39.86m^3

Hence, enough Earth is available at the site for constructing rammed earth walls.

As per a study conducted by Auroville based on practical experience on executing several projects using rammed earth, it has been found that a team of 5 labourers (Unskilled) has an output capacity of 8m^2 (for a wall of 24cm thickness)

Therefore, the output of 5 labourers in terms of volume = 8*0.24 = 1.92m^3

Output per labourer = $\frac{1.92}{5}$ = 0.384m^3

Total no. of labourers required = $\frac{44.2}{0.384}$ = 115.104 ≈ 116

Salary for unskilled labourers per day = Rs. 150-200

But, since construction of rammed earth involves a lot of human effort in terms of ramming the salary is assumed to be higher and taken as Rs.250

So Labour cost = 116*250 = Rs. 29000

Cement required per m^3 = 0.05*2074 = 103.7kg

Cost of cement per bag i.e. per 50kg = Rs. 250

Cement cost for rammed earth construction for giving project = $\frac{250}{50}$ * 103.7 * 44.2

Cost of cement required = Rs 22917

Assuming a Lump sum of Rs.5000 for formwork,

Total cost for rammed earth construction = 29000+22917+5000

Total cost for rammed earth construction = Rs. 56917

Total cost of construction using B.B.M. (excluding plastering & painting) = Rs. 150946

Therefore savings by using rammed earth = 148274 – 56917= Rs.93, 119

i.e. a saving of (100 - [$\frac{56917}{148274}$ *100]) = 61.63 ≈ 61 %

If cost of plastering and painting are also considered to calculate the savings since rammed earth does not require plastering or painting,

Savings = 148274 + 97236 + 72927 - 56917 = Rs. 2, 61, 520 or a % saving of 82%

Cost of Rammed earth construction per $m^3 = \frac{56917}{44.2}$ = $Rs.1287.7/m^3$

Cost of rammed earth construction per cubic feet = $1287.7 * 0.3048^3$ = Rs. 36.46/cu-ft which is cheaper than B.B.M. by over 50% the cost of which is Rs. 95/cu-ft

6.3 COST OF BAMBOO FLOORING

Bamboo flooring is available in a range of prices depending on the finish required. The cheapest variant is priced at Rs.50/- per sq-ft (exclusive of labour) and the costliest variant is priced at Rs.150/- per sq-ft (exclusive of labour). The labour charges vary between Rs.15-25 per sq-ft.

Hence total cost of bamboo flooring (cheapest variant) = 50+25 = Rs.75/sq-ft which is less than half the price of granite flooring (Rs.160/sq-ft)

Total cost of bamboo flooring (costliest variant) = 150+25= Rs.175 which is slightly higher but still comparable to the price of granite flooring.

Since the scope of the project is to promote cost effectiveness the cheapest variant is proposed.

Hence total cost of flooring using bamboo flooring = 75 * 1040 = Rs 78000

Savings = 166400 – 78000 = Rs. 88400

% Savings = $100 - \frac{78000 * 100}{166400}$ = 53.125%

6.4 COST OF uPVC DOORS AND WINDOWS

UPVC doors & windows are slightly cost-intensive in comparison to other materials proposed in the project. But they are an excellent replacement for wood & highly energy efficient and help in maintaining the indoor temperatures stable.

The cost of UPVC windows and doors vary a lot depending on its utility, variants and finish.

CHAPTER 7

RESULT

Cost Comparison

Cost of conventional building = Rs 11, 66, 974

Cost of Proposed building = Rs 6, 39, 815

Overall reduction/saving in costs = 1166974 - 639815 = Rs 5, 27, 159

% reduction/saving $= 100 - \frac{639815*100}{1166974} = 45.17\ \%$

CONCLUSIONS

The primary objective of proposing a cost-effective building was fulfilled. Even though the objective set was to arrive at a proposed building whose costs are comparable to that of a conventional building if not cheaper, the efforts resulted in a proposed building whose cost is only about 55% of that of the conventional building. Thus, it resulted in a low-cost building rather than a cost-effective building.The money saved could further be utilized for fitting solar systems, for grey water harvesting etc. thus making it more environment-friendly without increasing the cost of the project.

This project disproves the general argument that green buildings are cost-intensive and that their costs are 3-5% more than conventional buildings.The results show that careful selection of materials based on local availability and site condition can go a long way in saving money and saving the environment at the same time.The alternate methods of construction methods proposed not only resulted in reduction in cost and lesser impact on the environment, but also resulted in a more energy efficient building, particularly in terms of lesser dependence on cooling systems due to ambient interior temperatures primarily due to use of filler slabs with a thermal air gap and uPVC windows with double glazing

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