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VISVESVARAYA TECHNOLOGICAL UNIVERSITY
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A PROJECT REPORT ON

"USE OF WASTE PLASTIC BOTTLES IN CONSTRUCTION"

Submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF ENGINEERING
IN
CIVIL ENGINEERING

Submitted by:

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LOCHANA POUDYAL (1BO10CV035) ZOUHAIB NAZIR SHAH (1BO10CV099)

Under the Guidance of

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DEPARTMENT OF CIVIL ENGINEERING
BRINDAVAN COLLEGE OF ENGINEERING
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BENGALURU-560063, MAY 2014

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CERTIFICATE

This is to certify that the project work entitled **"USE OF WASTE PLASTIC BOTTLES IN CONSTRUCTION"** is a bonafide work carried out by out by

KUSHAL ADHIKARI	**USN: 1BO10CV034**
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of 8th semester in partial fulfillment for the award of degree of Bachelor Of Engineering in CIVIL of the Visvesvaraya Technological University, Belgaum during the academic year 2013-2014. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited to the Departmental library.

The project report has been approved as it satisfies academic requirements in respect of project work prescribed for the Bachelor of Engineering Degree.

SIGNATURE
HOD and GUIDE
(Dr.K.U.MUTHU)

SIGNATURE
PRINCIPAL
(NOOR AHMED)

Examiner

1.

2. 10/6/14

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We consider our privilege to express our gratitude and thanks to the following persons for the help and encouragement in completing this project successfully.

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Finally we wish to thank and acknowledge the help given by **our parents** and **friends** which helped for the completion of the project successfully.

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INDEX

ABSTRACT

One of the main disadvantages of constructing world house is high cost of the building. High cost of primary requirements for constructing the houses in places where people are under poverty line, is forming one of the most significant problems of people. On the other hand, urbanization growth will increase waste especially non-renewable ones. A suitable approach for this situation is using some part of urban waste as required materials for building construction and also providing comfortable situation and suitable thermal for building residents. Plastic bottles are considered as an urban junk with sustainability characteristic which can be used as a material instead of some conventional material such as brick in building construction. This work intends to investigate the application of plastic bottles as one of the urban wastage in buildings construction and that how it can lead to sustainable development. It also mentions some ways for self-standing and insulating them in thermal and sound points of views and some positive points which this material have versus others. At the end, it is concluded that in different factors such as time of execution, cost, load capacity, flexibility, reducing waste and energy efficiency, plastic bottles can be more effective compared to some conventional building materials such as brick, concrete and ceramic block.

Group members of the project

1. INTRODUCTION

Nowadays, human apply all of its potentiality to consume more. The result of this high consumption is nothing but to deplete the initial resources and increasing the landfill. In recent times, human from the one hand is always seeking broader sources with lower price and from the other hand is following the way to get rid of the wastes. The waste today can be produced wherever humans footprints be existed, and remind him that they have not chosen the appropriate method for application of the nature. At the present time, the possibility of utilizing the renewable resources such as solar, wind, geothermal has been provided for us more than before, and development of this science is making progress. But those energies can be chosen as one of the renewable and alternative energies instead of fossil fuels which are cheap as possible and have fewer environmental impacts. Since no attention to economic issues lead to that the use of these energies be just for groups dedicated to specific segments of society. Whilst many renewable energy projects are large-scale, renewable technologies are also suited to rural and remote areas, where energy is often crucial in human development. With population growth in today's world, the need to the building has increased and to respond to this demand, the countries tend to use the industrial building materials and decline the use of indigenous and traditional materials. These factors in spite of increasing the energy consumption in the industry section; they can also raise the cost of homes and are considered as the barrier for users to obtain the basic needs of the life.

The problem of users is losing the power and ability of design and building their own homes by themselves. Two factors that prevent aboriginal people from building their homes are high cost of building materials and labor and also maybe long transportation. One of the solutions for this problem can be using following factors

1. Use of affordable recycled materials in building

2. Using the method of regenerating through proper education to people.

In the past, the glass was common in packing some foods such as milk and etc. They could be returned to the factory for using again for the same purpose. But now by changing the human's disposal culture, glass bottles have been replaced by plastic bottles, as they have increasingly become one of the substances of destruction of the landfills because they decompose in a long time. Two alternative solutions against the plastic bottle disposal are recycling and reusing process.

Recycling needs additional energy to treat the materials for producing something usable. Moreover, the recycling process produces wastewater and air pollutants. So the best solution is reusing for which no additional energy is required and does not contribute to pollution. Indeed, when we reuse junk, we are helping to save the obtained energy which would otherwise be wasted. It is focused on not only the financial aspect but also the environmental aspect. Plastics are produced from the oil that is considered as non-renewable resource. Because plastic has the insolubility about 300 years in the nature, it is considered as a sustainable waste and environmental pollutant. So reusing or recycling of it can be effectual in mitigation of environmental impacts relating to it. It has been proven that the use of plastic bottles as innovative materials for building can be a proper solution for replacement of conventional materials. The use of this material has been considered not only for exterior walls but also for the ceiling of the building.

The objective of this project is to investigate the using of plastic bottles as municipal wastes in the buildings, the key and positive characteristics of this product and the benefits obtained by using it in building. It also intends to compare the characteristics of some construction materials such as brick, ceramic and concrete block with bottle panel.

2. LITERATURE REVIEW

Nowadays, large amount of plastic bottles are wasted and disposed every day. People are throwing away them without considering that what those plastic bottles can have impact on the humans and/or environment. Andreas Forese, the founder of Eco-Tec Environmental Solution, in searching for finding an inventive solution to junk, established the innovation of building plastic bottle houses. The first bottles house was built using 10000 glass beer bottles by William F. peck in 1902 in Tonopha, Navada. After that the newer innovative concept has been using plastic bottle instead of glass bottles in constructing the houses. This innovative idea took to account for some reasons such as providing a cost-efficient construction method for third-world countries, reusing the plastic bottles due to their not indecomposable characteristic, and etc.

The first plastic bottles house in Africa was constructed in the village of Yelwa in Nigeria by Andreas Forese. Forese used the plastic bottles instead of bricks, bound the bottles together with string and at the end applied the plaster. Anyway beside the Eco-Tec, various other institutions and groups have initiated the concept of reusing the plastic bottles for building construction. However nowadays, the concept has spread to countries all over the world. Various kinds of homes have been built from plastic bottles such as: ecological house constructed using 8000 bottles in Honduras, an Eco-Tec home in Bolivia constructed using the PET and wine bottle, a house of waste plastic bottles built in Serbia by Tomislav Radovanic, Taiwan's plastic bottle building, ecological bottle house built using 1200 PET plastic bottles for the walls near the Iquazu Falls, Misiones, Argentina etc. The purpose of this paper is to look into the using of plastic bottles as a municipal waste in the buildings, the key and positive characteristics of this product and the benefits obtained by using it in building. It also intends to compare the characteristics of some construction materials such as brick, ceramic and concrete block with bottle panel.

3. CASE STUDY

3.1 ECO-TECH

Figure 3.1.1.First house built with plastic bottles

The following picture is of an ecological house constructed in Honduras using some 8,000 PET bottles, in the process freeing up an estimated 12 cubic meters (m3) in the local landfill.

The house also features a living roof (sometimes called a green roof) of sod and turf. Such roofs not only have aesthetic appeal, but tend to insulate the house better than conventional roofs, lowering heating and cooling costs. They are also cheaper than conventional roofs.

3.2 SAMARPAN FOUNDATION, CHENNAI

When plastic bags and pet bottles are being banned worldwide, here is the organisation in India which promotes it for a cause – building homes with pet bottles!

Samarpan Foundation, a non-governmental and non-profit organization, has set out an agenda to build 'green house' with pet bottles. "What we are setting out to do is to build an entire house with PET bottles at our forest nursery site in Chennai which will consume approximately one lakh bottles. This is to demonstrate to the people of Chennai and world at large that though PET bottles are considered a 'necessary' evil, they can be put to good use," says Romaine San Francesco, project coordinator.

Explaining the reason for using PET bottles which are considered to be a threat to environment due to its non-bio-degradable nature, Romaine said, "The reason PET bottles are a menace is because of their longevity. We at Samarpan have taken the extreme native aspect of a PET bottle, ie. Its longevity and converted into positive. We have already built a room out of such bottles in one of our schools in New Delhi."

Revealing his green initiatives, Romaine added, "Besides building this house with PET bottles, we are also going to power it using solar cells which have been modified to enhance their output."

To help his novel effort to paint green, Romaine has been asking people to bring their unused pet bottle filled with mud for his housing project in Red Hills.

Samarpan Foundation, is a Non-Profit, non-governmental organisation, registered in New Delhi and carrying out activities nationwide, wherever there is a humanitarian, ecological or environmental need. These include orphanages, aged homes, tree planting drives, rainwater harvesting, eradication of mosquitoes, food kitchens for the poor, free schools for slum children, housing for victims of natural disasters, building free hospitals, rehabilitation of bonded labourers, revival of tribal arts and cultures, vocational training centres, among other social causes. Unique to the Foundation, is it Waste Management Programme, where a school building has been constructed in New Delhi using PET water bottles.

Samarpan Foundation was established office in Chennai in June 2010. Presently, the Chennai Chapter focuses certain key environmental issues such as raising forest tree nurseries and transplanting them in the city, building a model "Green House" made of used PET bottles,running 100% on solar power without the use of batteries, novel plan to convert the Buckingham Canal into a "freshwater Canal", blueprint for rain harvesting on city roads; replanting of Mangroves on the coast and back waters, Malaria awareness and eradication campaign, village adoption programme aimed at healthcare, education, (academic, computer, vocational), economic resurgence and empowerment and providing support and assistance to old age homes by giving medicines, food items, clothing etc.

Figure3.2.1:School built by Samarpan Foundation using waste bottles

3.3 NIGERIA'S STEP TOWARDS ECO-CONSERVATION – PLASTIC BOTTLE HOUSE

Figure3.3.1. Homeless people in Nigeria

On the western coast of Africa lies one of the most populous countries in the world. Nigeria - a country with a rich natural and cultural heritage, a fast growing economy, yet plagued with violence, health problems, poverty and some serious environmental issues. Many non-governmental organizations strive hard to make the life of Nigerians a bit better and this time

they have hit the bull's eye by creating something unique and path breaking - A house built of recycled plastic bottles!

With poor hygiene provisions, drinking tap water is considered unsafe in Nigeria and hence, many people prefer consuming bottled water. This surge, in use of bottled water, has led to a huge waste of plastic bottles. Every year, millions of plastic bottles are dumped into landfills and waterways causing erosion, pollution, irrigation blockages and health problems. So, an NGO decided to take matter into their hands and put these environmental hazards into something useful. Building houses of recycled plastic bottles is their initiative and it is proving very successful and gaining lot of popularity amongst the Nigerians as well as globally.

The project was started in northern Nigeria, in a village named Yelwa, which is garnering a lot of attention due to these "magic" houses. A sturdy concrete foundation is laid to make sure that the structure will be stable and firm. After that, plastic bottles are filled with dry soil or construction waste and then laid in rows like bricks. The bottles are bound together with mud and walls are constructed. Around 8000 bottles are used for each house, which consists of a living room, bedroom, kitchen and a toilet. The houses are built in a typical North Nigerian circular style and look beautiful from outside as a lovely design is created by the round bottoms of the exposed bottles.

The best thing about the plastic bottle houses is that they are well insulated, sturdy and inexpensive. The compact dry soil filled in the bottle makes the houses almost 20 times stronger than brick constructions, making it resistant even to earthquakes. The sand also insulates the houses from the scorching heat by maintaining a low room temperature, ideal for the hot Nigerian climate. Also, the construction of plastic bottle houses cost one third less than house built by bricks and concrete. Another special feature the house boasts is that it is bullet proof. People from most part of the world will find this amusing, but for the violence stricken Northern Nigeria, it can be a blessing in disguise.

The bottles are collected from hotels, restaurants, embassies and homes and then used for the construction. There is some criticism regarding the use of discarded plastic bottles, which are used by many people for storage purpose and by street vendors to sell products like peanuts. Also, it is said that the use of sand in bottles shall increase its demand and consequently the price.

Nevertheless, the project is a huge success and has got more pros than cons. Apart from the eco-conservation; this project also aims to uplift the street children from the life of poverty. Instead of begging, the children fill the bottles with soil and get paid for it. There are also plans to make houses completely energy autonomous, i.e. fuel efficient cooking stoves, water purification tanks, urine filtration fertilization systems, etc. Other countries should get inspiration from this African country and take a step forward towards environment conservation.

Fig:3.3.2 Plastic Bottle House in Nigeria

Fig:3.3.3 Plastic Bottle House in Africa

4. SUSTAINABLE DEVELOPMENT (SD)

Sustainable Development (SD) is the development which meets the needs of the present without compromising the needs of future generations. Some purposes of SD can be as following:

 Resource conservation: To conserve the non-renewable resources such as fuel, mineral and etc to ensure sufficient supply for present and future generations.

 Built development: To integrate environmental considerations into planning and development to respect the natural environment.

 Environmental quality: To prevent or reduce processes such as land filling which can lead to environment degradation and develop the culture of reusing and recycling process.

 Social equity: To impede development that increases the gap between the rich and the poor, and to encourage for reach to the social equality.

Inhabitation needs of the sustainability are based on three aspects including environmental, social and economical. At current time, the SD can be achieved through the partial integration of these three aspects. But the alternative face of SD is the full integration of these aspects such that:

 Economic exists entirely within the society as all parts of the human economy are achieved through interaction among people.

 Economy and society merely depend on the environment because if something is un-environmental then the society will be affected.

 When the society affected, then it will be uneconomical for the nation to create sustainable development.

Plastic bottle is considered as a sustainable material which can help in achieving the SD. Using the plastic bottle can follow the objectives of SD. It can abstain from the resource depletion, assist in protecting the environment; prevent or reduce the environmental degradation process such as land filling through reusing process and it can assist to obtain a social equity by avoiding the gap between the rich and the poor people in the society.

Figure4.1.and4.2. indicate the face of SD at current time and

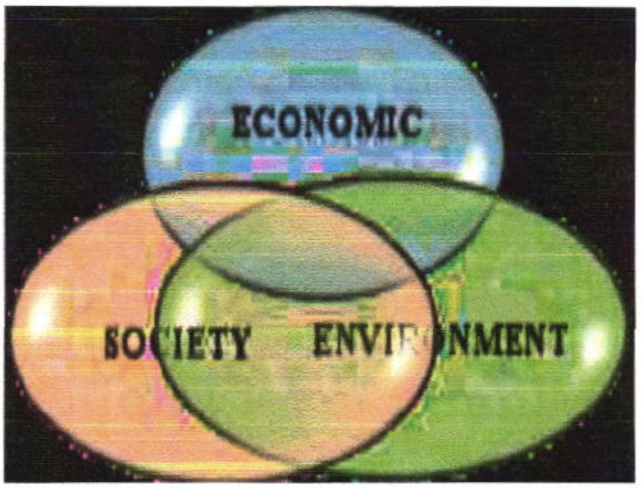


Figure 4.1. Face of SD at current time

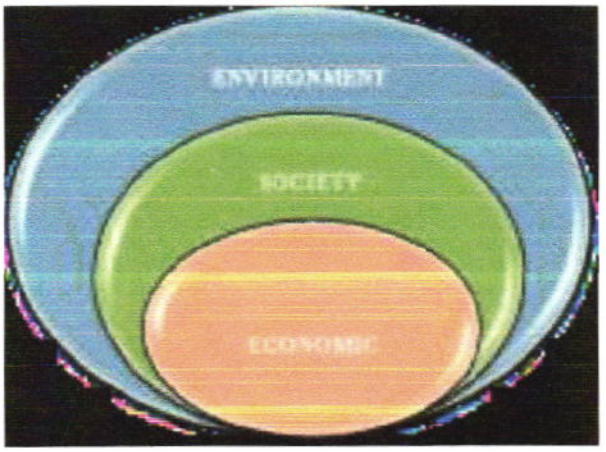


Figure 4.2. Alternative face of SD in future

5. SUSTAINABLE AND GREEN BUILDING

Green building is defined as an environmentally sustainable building constructed and operated with the aim of mitigation of environmental impacts such as natural resource depletion as well as CO2 emission. It addresses sustainable site planning, energy efficiency, conservation of material and resources by using renewable resources as well as recycling and reusing and indoor air quality (US green building design).

Using renewable resources and also some unusable things in building construction can help in conserving the nonrenewable resources and obtaining to the green building. Plastic bottle is considered as a kind of junk which can be used in construction of some parts of the building such as wall, roof and etc. By using this kind of junk as the material, we can help in saving the energy consumed in the factory for baking the bricks; saving the energy and reducing the CO2 emission by reducing the amount of cement usage and so on.

6. MATERIOLOGY AND TESTING

6.1. MATERIALS

- ✓ BOTTLE
- ✓ SAND
- ✓ EARTH
- ✓ WOOD DUST
- ✓ CEMENT

6.1.1. BOTTLES

Waste plastic bottles were used for this project. Plastic bottles thrown away after use were collected from the college premises as well as the local area nearby the college. The bottles used in the project were mainly drinking water bottles and coke bottles. These bottles were used as Building Materials in substitution of bricks.

6.1.2. SAND

Sand used for this project was the river sand. This is the cheapest sand available. Sand was kept in the plastic bottles in three layers. Due compaction was given after putting each layer.

Fig: 6.1.2.1 Sand

6.1.3. EARTH

Earth was also used in substitution of sand. Earth obtained from the college area was used in the bottles. Use of unattended earth not only makes the college area cleaner but also it made the project more economical.

Fig 6.1.3.1 Earth

6.1.4. WOOD DUST

Wood dust obtained from the local furniture shop was used to fill the bottles. Use of wood dust makes the structure thermally more comfortable. It helps to cool the interiors of the building.

6.1.5. CEMENT

Ordinary Portland cement (43 grades) was used for the project. Cement was used to make the mortar. Here, mortar was used as the binding material. Minimum possible use of cement was done during the project. Clay can be used as a substitute for cement but because of unavailability cement was used.

6.2. TEST CONDUCTED

- ✓ Compression test on Bricks and Bottles.
- ✓ Flexural test.
- ✓ Durability test.

6.2.1. COMPRESSION TEST ON BRICKS AND BOTTLES

A test was conducted in the compression machine to compare the compressive strength of bricks with bottle filled with sand. Three trials were performed to obtain the strength values for both bricks and plastic bottles for which the results are as shown in the table below. Table 1 gives the results for plastic bottles and table 2 gives the results for conventional bricks.

Table 1: COMPRESSION TEST ON PLASTIC BOTTLES

Trial No.	Area(mm^2)	Peak Load(N)	Max. Stress(N/mm^2)
1	2375	142500	60
2	2375	140125	59
3	2375	144875	61

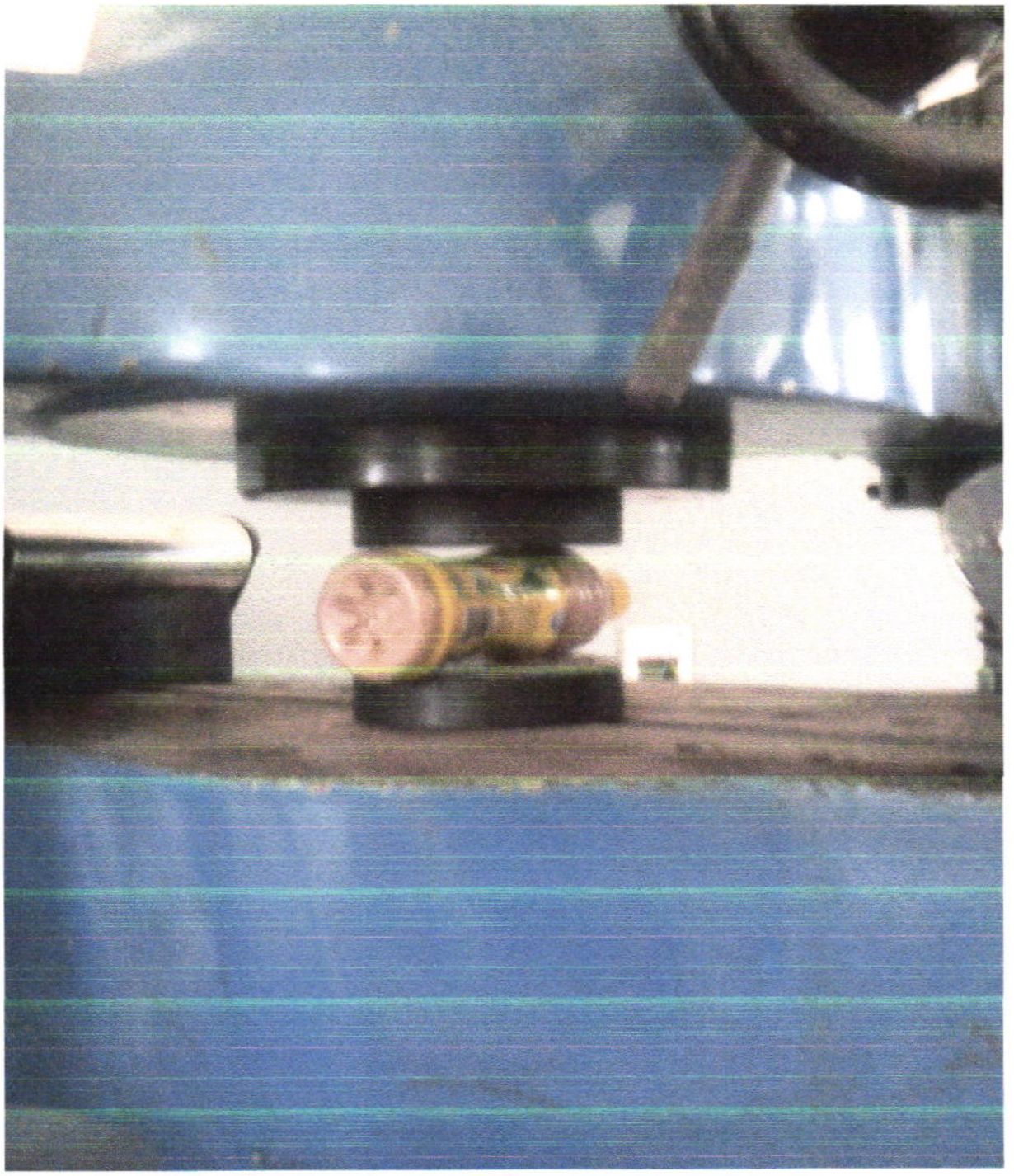


Figure6.2.1.1. Compression test on bottle

Table 2: COMPRESSION TEST ON BRICK

Trial No.	Area(mm^2)	Peak Load(N)	Max. Stress(N/mm^2)
1	6500	24700	3.8
2	6500	26000	4
3	6500	27300	4.2

Thus, the compressive strength of brick was found to be 4 $N/mm^2$and, strength of bottle filled with compacted sand was found to be 60 N/mm^2.

Hence, we concluded that the plastic bottles have high compressive strength than bricks and it can be used as building material in place of bricks.

6.2.2. FLEXURAL TEST

Further, a similar test was conducted in an UTM to study the flexural behavior of the plastic bottles and bricks .Three trials were performed for each of the specimen, the results of which are as below:

Table 1: Flexural behavior of conventional bricks

Trial No.	Load (N)	Span (mm)	Width (mm)	Depth (mm)	Flexural strength($fp=1.5wl/bd^2$) (N/mm^2)
1	7110	190	100	65	4.19
2	7600	190	100	65	5.12
3	7900	190	100	65	5.32

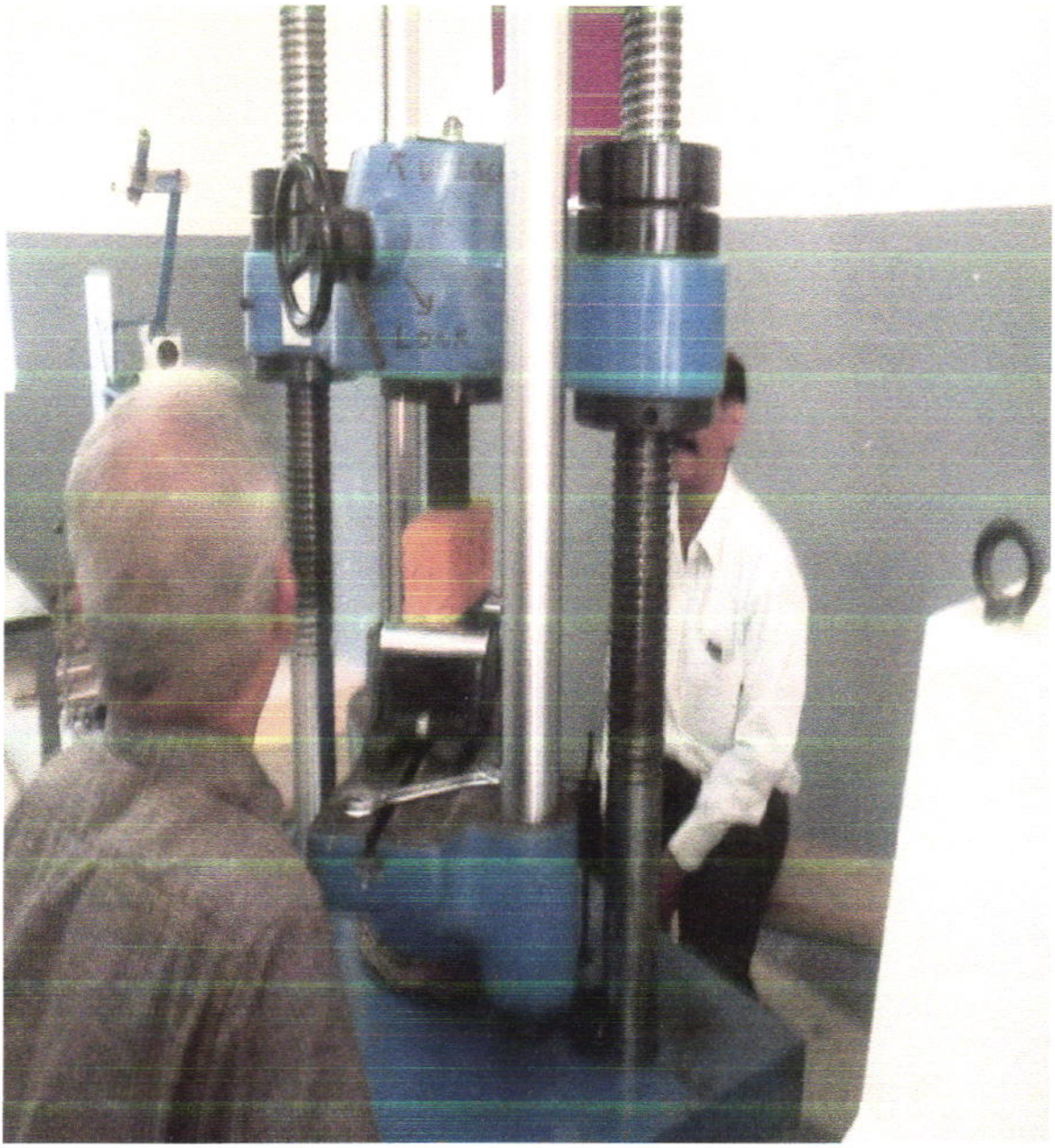
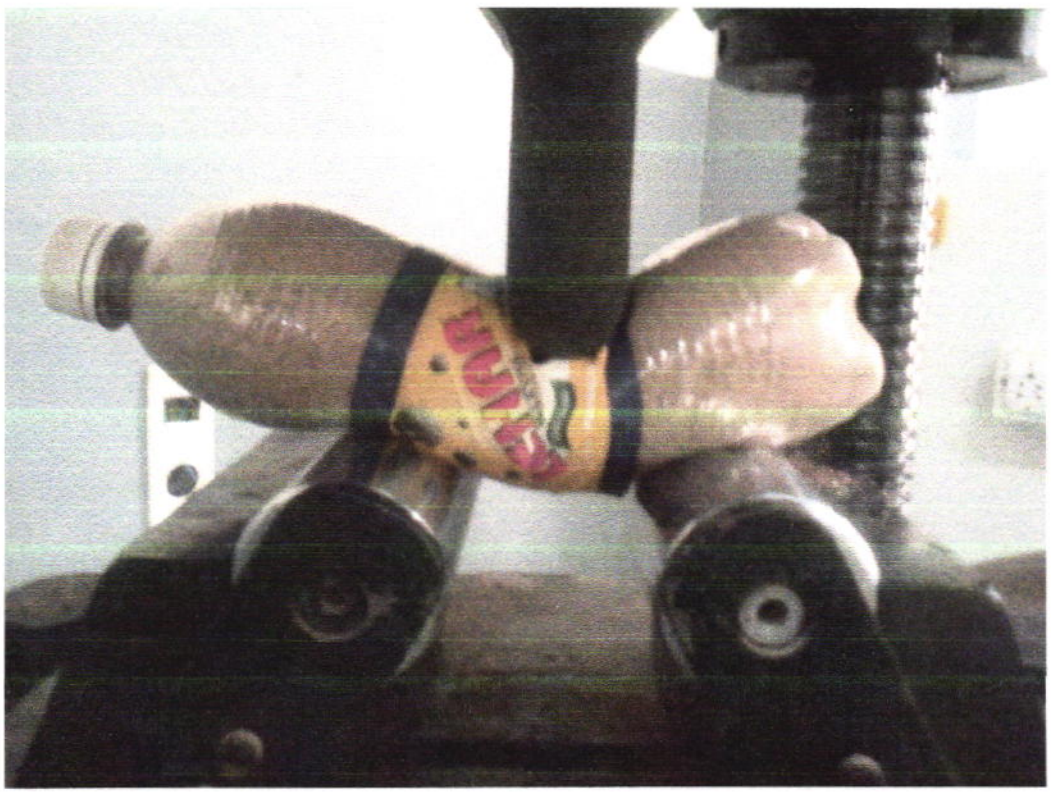


Figure 6.2.2.1.Flexural test on brick

Table 2: Flexural behavior of plastic bottles filled with sand

Trial No.	Load (N)	Span (mm)	Moment(M) =(Wl/4) (Nmm)	Dia(D) (mm)	$Z=\pi d^3/32$ (mm^3)	$Fp=M/Z$ (N/mm^2)	Displacement (mm)
1	13280	190	315400	55	16333.82	19.3	39.2
2	13700	190	325375	55	16333.82	19.92	40
3	13100	190	311125	55	16333.82	19.04	38



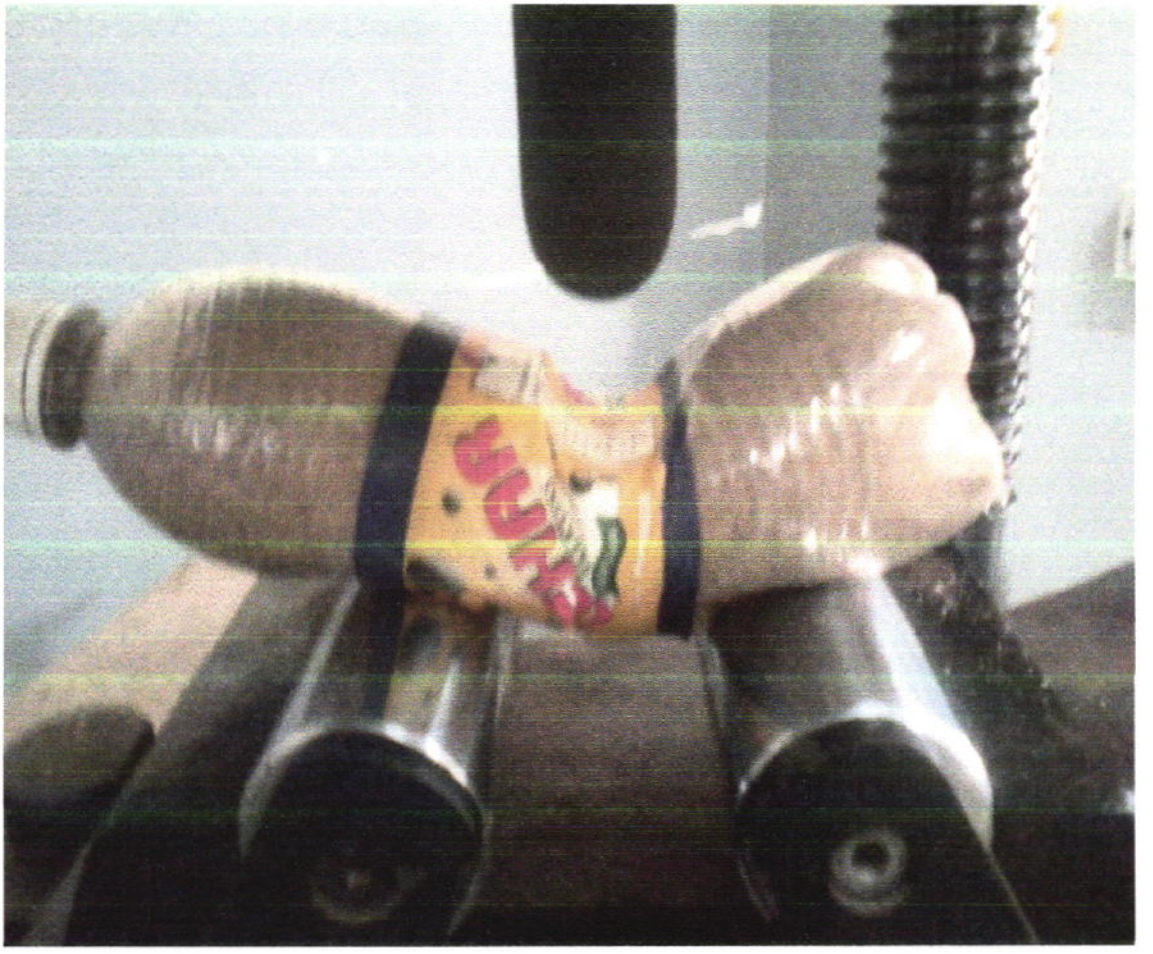


Figure6.2.2.2. Flexural test on bottle

Thus, the flexural strength for plastic bottles were found to be 19 Mpa with a displacement of 39mm before breaking and for bricks it was found to be 5 Mpa without any displacement.

Hence, we can conclude that plastic bottles have good flexural behavior compared to conventional bricks.

6.2.3. DURABILITY TEST

In order to know about the response of plastic bottles in adverse exposure conditions, a durability test was conducted. Three samples of bottles were placed in two different acidic solutions for 7 days and 21 days period respectively.

An acidic solution of sulphuric acid with 5% concentration was made and the bottles were kept in it for the above mentioned no. of days, for which there was no any significant change in its weight and strength.

Further a solution of Nitric acid was prepared with the same concentration and same no. of days. Here also no significant changes were observed.

Thus, we came to a conclusion that the plastic bottles can sustain the adverse exposure conditions too

7. CONSTRUCTION PROCEDURE

- ✓ COLLECTION OF WASTE BOTTLES
- ✓ FILLING THE BOTTLES WITH SAND
- ✓ EXCAVATION
- ✓ FOUNDATION
- ✓ COLUMNS
- ✓ WALL
- ✓ ROOFING
- ✓ FINISHING
- ✓ CURING OF THE STRUCTURE

7.1 COLLECTION OF WASTE BOTTLES

Plastic bottles were collected from the college premises and nearby surroundings. The main source of waste plastic bottles was a café named POTENZA CAFÉ nearby the college. We collected nearly 1200 bottles from the café and about 400 bottles from the college premises.

Fig 7.1.1: Collection of waste bottles

7.2 FILLING THE BOTTLES WITH SAND

The plastic bottles were filled mostly by sand. Soil present at various construction sites within the college was also used .Various construction wastes present near the sites

were also used .But sand was the prime constituent. Sand is filled in the bottles and required compaction is done .It took nearly a week to fill all the bottles.

Fig 7.2.1: Filling the bottles with sand

Fig 7.2.2: Filling the bottles with sand

7.3 EXCAVATION:

The site for the construction of plastic bottle building was fixed. The first step for the construction was excavation at the building site.1 foot deep excavation was carried out around the diameter of 7 feet. Excavation was done for the circular foundation. Approximate time of 3 hours was required for one labor to complete the as mentioned excavation. Some of the figures showing the excavation are as shown below:

Fig 7.3.1: Excavation

7.4 FOUNDATIONS:

Foundation of stone masonry was laid down. Stones were collected from the college premises for the foundation. Initially a layer of concrete mix prepared in the ratio 1:3 was laid down on the ground as the first layer. Above the concrete, stone masonry was laid down. Alternate layer of concrete and stone was laid till the ground level. The topmost layer of concrete

was given a smooth finish. The images of foundation are as shown below:

Fig 7.4.1: Concrete Bed

Fig 7.4.2:Foundation

7.5 COLUMNS

While laying the foundation, a steel rod of 16mm dia was inserted at 3 different locations to serve as the pillars for the structure. Above the ground level, the bottles were laid around the rod in an aesthetic design.

Fig 7.5.1: Column

Fig 7.5.2: Location of Columns

7.6 WALLS

Walls were entirely made of plastic bottles. The bottles were placed horizontally in layers one above the other as in brick masonry. Cement mortar of ratio 1:3 was used as the binding material. The wall was raised up to a height of around 4 feet so as to provide the security personnel to look out.15 layers of plastic bottles were required to reach this height.The total number of bottles used were around 1300 which were mostly the coca cola bottles. In order to enhance the strength of the structure, some reinforcement was provided at certain intervals of layers. And, over the last layer of plastic, cement mortar was placed. Some of the figures captured during the wall construction are as follows:

Fig 7.6: Wall built up using plastics

7.7 ROOFING

A roofing of FRP sheet was provided supported on steel bars placed in a conical shape with a base diameter of 9 feets and slanting height of 5 feets.

Fig 7.7.1: Roofing

7.8 FINISHING

Considering the aesthetic view of the structure, some finishes were given at the end. The interior of the walls were plastered and a layer of granite was placed at the top of the wall, above the cement bed. Wire mesh was provided before plastering to provide better adhesion between the mortar and plastic. Some of the finishing activities are as shown in the figure below.

7.8.1 POINTING:

Pointing was done in order to remove the excess of cement mortar on the surface of the walls to give a beautiful design of bottles base.

Fig7.8.1.1: Pointing

7.8.2 WIRE MESHING:

The wire meshing was provided in order to strengthen the bonding between mortar and the bottle surface.

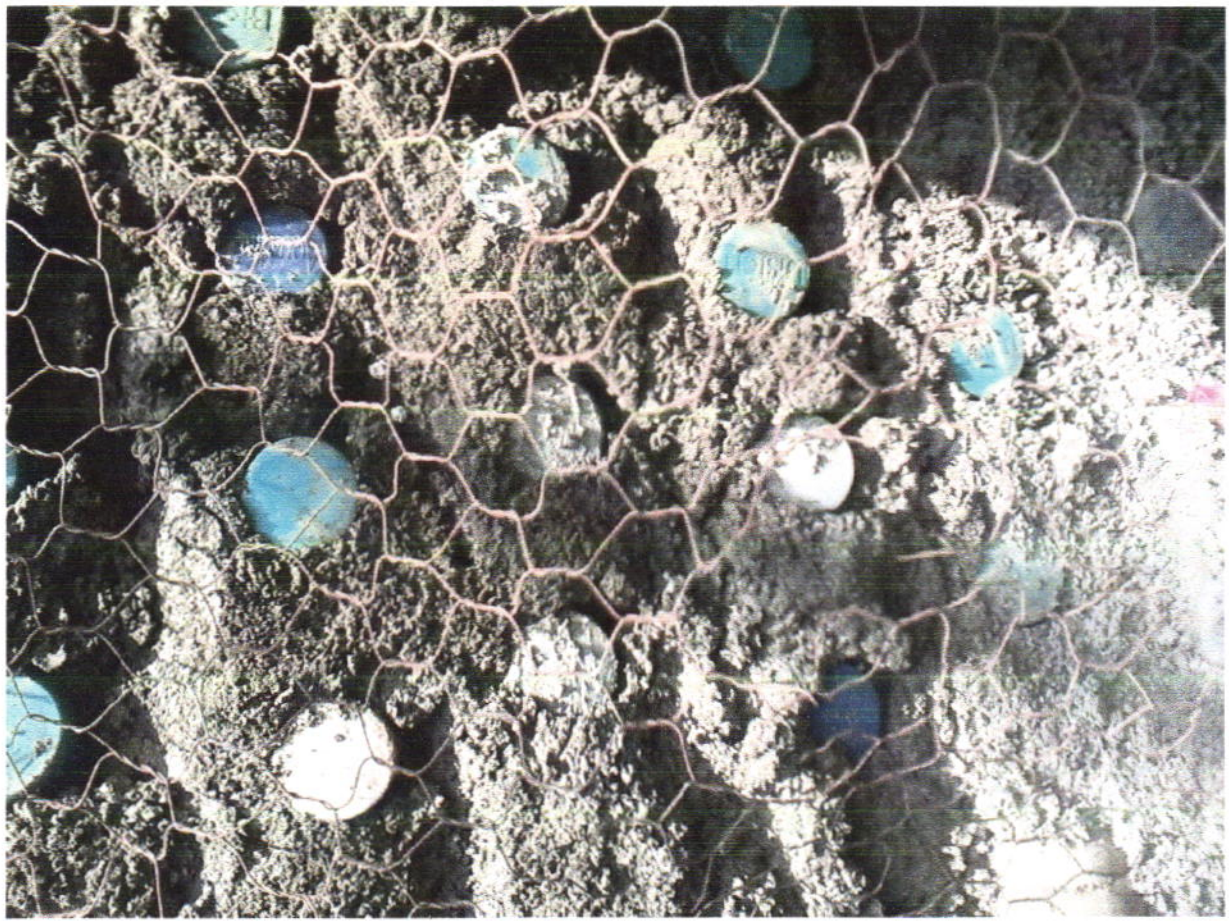


Fig 7.8.2.1 Wire Meshing

7.8.3 PLASTERING:

The inner surface of the walls and pillars were plastered to provide a good look and also to improve the durability of the structure.

. Fig 7.8.3.1:Plastering

7.8.4 PLACING OF GRANITE

The broken pieces of granite were placed at the top of walls.

7.8.5 FLOORING

Flooring of concrete was provided with a smooth finish of cement at the top.

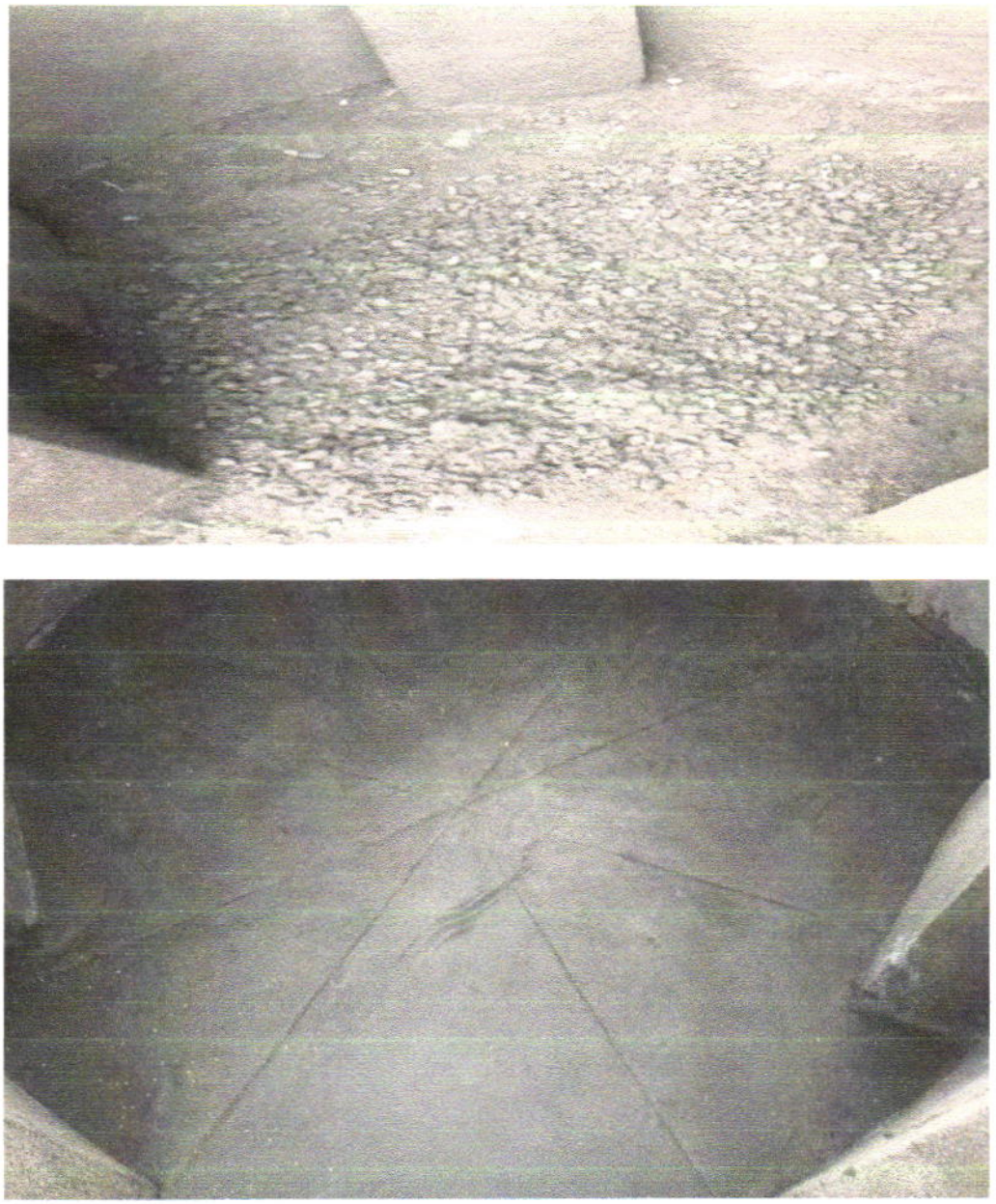


Fig 7.8.5.1: Flooring

7.8.6 PAINTING:

All the exposed steel structures and the pillars were given a paint.At first the primer was given of the redox and then final paint of green colour was given.

Fig:7.8.6.1: Painting

7.9 CURING OF THE STRUCTURE:

The structure was given the sufficient curing at all the stage of construction.

Fig 7.9.1: Curing of the structure

Fig : Finished structure(Security shelter)

8. COMPARATIVE STUDY

Table I indicate the comparison between the wall component built by different kind of materials such as plastic bottle, ceramic and concrete

	Factors	Considerations	Bottle panel	Ceramic block	Concrete block
1	**Time and speed of execution**	5 persons team-one working day	15% faster	120 m2	Less than 100 m2
2	**Material and equipment costs**	Implementation and installation of materials and equipment	Saving in cement, water, grinder and fitting	More weight, more materials	More weight, more materials
3	**Transportation costs**	Displacement in the building	Lighter and higher volume, easy and cheap displacement	Greater weight and less volume, hard and costly displacement	Greater weight and less volume, hard and costly displacement
4	**Execution cost**	Using calculations of panel	Less manpower and indigenous	More human resources- the higher cost	More human resources- the higher cost

5	**Strength and load capacity**	Degree of Strength	20 times more than brick	Greater wall thickness, lower strength	Greater wall thickness, lower strength
6	**Resistance to earthquake**	Earthquake has a direct relationship with the weight of each structure	Low and integrated weight without falling debris	High weight and loss of material	High weight and loss of material
7	**Cleanness and beauty of work**	Aesthetic view and whimsical look	Very clean execution, no construction waste	High volume of construction waste	High volume of construction waste
8	**Flexibility**	Degree of flexibility	High flexibility	Low flexibility	
9	**Material waste**	Construction waste	No wastage	High and unusable	High and unusable

Table 1: Comparison between plastic bottles, ceramic blocks and concrete blocks

9. SPECIFICATIONS OF THE PLASTIC BOTTLE AS A BUILDING MATERIAL

Everyday many junks are produced in various sectors. Plastic bottles as a kind of junk produced a lot everyday can be used instead of some construction materials such as brick. It is so interesting to be stated that the plastic bottles has as same strength as bricks, ceramic block and concrete block but with the difference that the plastic bottle has got lots of advantages too.

As mentioned before, this innovative idea was first introduced by Andreas Froese who also founder of ECO-TEC established with the aim of providing advice on environmental management and utilization of solid waste. The green building ECOTEC technique is used for replacing the brick by disposal plastic bottle. As the plastic can remain as the junk on the earth for a long time due to its slow disintegration process, reusing the plastic can be an effective solution for this problem. The most important benefits of these alternative innovative materials compared to conventional materials such as brick can include:

9.1. Good construction ability

The walls built by these bottles are lighter than the walls built by brick and block, and that makes these buildings to show a good response against earthquake. Due to the compaction of filling materials in each bottle, resistance of each bottle against the load is 20 times higher compared to brick. And these compressed filling materials, makes the plastic bottle to be prevented from passing the shot that makes the building a bulletproof shelter.

The other factor that makes the bottle wall as an ideal wall is its self- supporting property such that the bottles are placed on each other crinkly. A cross-shape cable front and back of the bottle will cause the conflicts among them and this makes the whole unit that causes the cables to create equal forces against each other. The figure9.1.1. And 9.1.2. demonstrate the shape of

bottles and that how they should be put on each other respectively which were simulated in 3D Max Software.

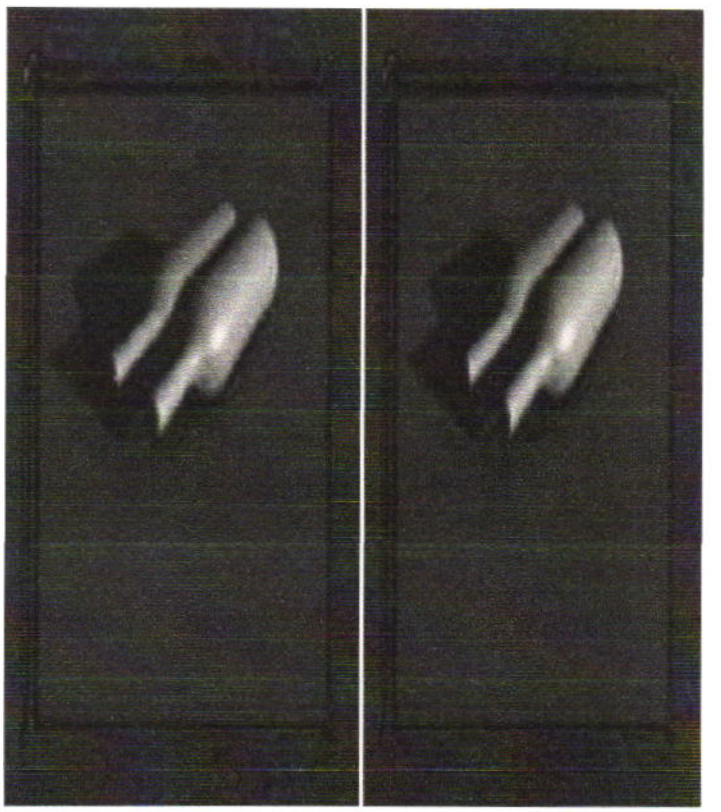


Figure9.1.1. Shape of plastic bottles

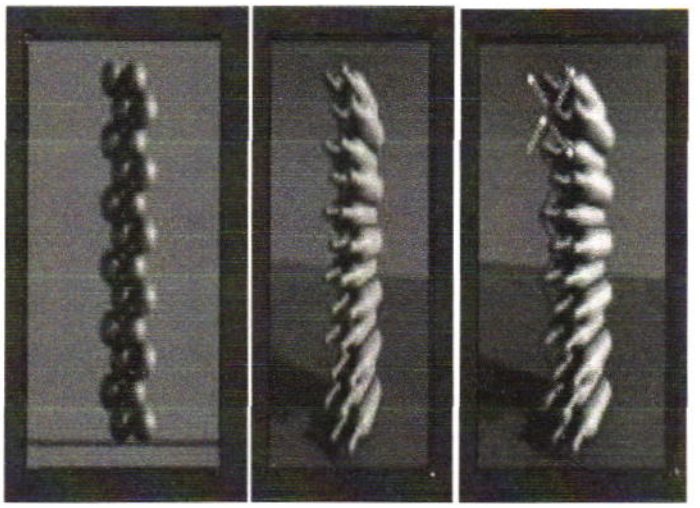


Figure9.1.2. The way of putting the bottles on each other

9.2. LOW COST

Constructing a house by plastic bottles used for the walls, joist ceiling and concrete column offers us 45% diminution in the final cost. Separation of various components of cost shows that the use of local manpower in making bottle panels can lead to cost reduction up to 75% compared to building the walls using the brick and concrete block. It must be noted that the sophisticated manpower can lead to reducing the construction time and the relative costs also become lower.

9.3. SUITABLE THERMAL BEHAVIOR

For insulation of these panels against the exchange of heat, the innovative solution is filling each bottle by three layers. Front and back of the bottle should be filled by sand and

compact gravel and the middle of bottle should be filled by cork or wood particles. Cork is considered as an impenetrable insulation that is used in cylinder parts for blocking the bottle and glass. About 60% of the world total production of cork are used as the bottle caps, and are discarded after being used that can be used as recycled product in these panels which can bring a good and effective work. For building the panel, the variety of materials tailored to desired location can be used. But the material that cause to a good result is mud. The mud can be used as either thatch or mixture of mud and wood particle to fill the pores between the bottles and increase the beauty. Figure7.3.1. demonstrates the method of filling the plastic Bottles

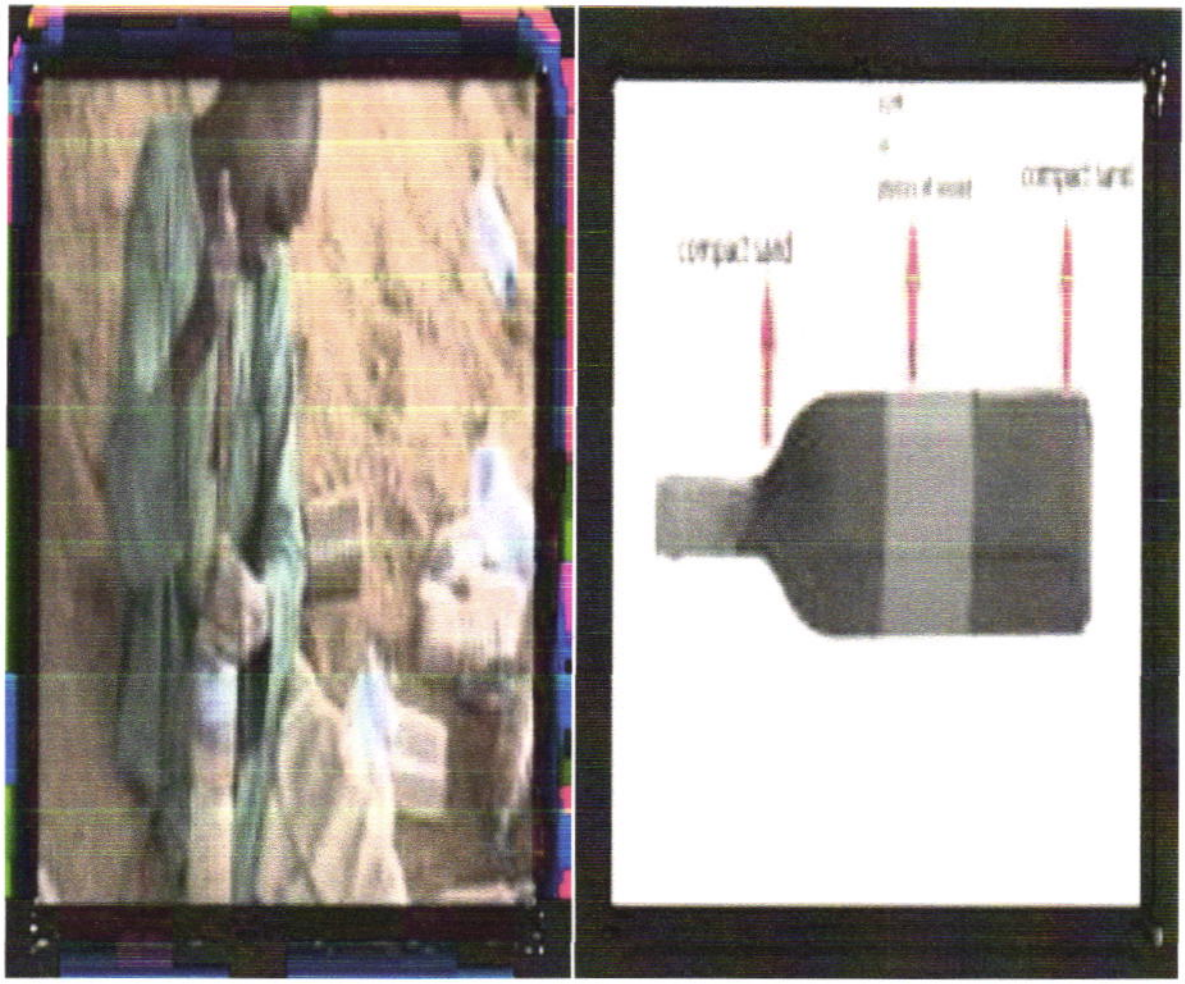


Figure9.3.1. Method of filling the plastic bottles for using in the building

So in the current world economic situation, using these innovative materials can be efficient in reducing the cost of building construction, while the thermal comfort of the building is also supplied and may cause protecting the environment.

9.4. NON-BRITTLE CHARACTERISTIC

Using the non-brittle materials can reduce construction waste. Unlike brick, plastic bottle is non-brittle. So due to the frangibility property, the percentage of producing construction waste in brick is more than plastic bottles. Figure 9.4.1 shows a sample of broken brick used in the walls.

Figure9.4.1. Brittleness characteristic of the brick

9.5 ABSORBS ABRUPT SHOCK LOADS

Flexibility is a characteristic which makes the building's performance higher against the unexpected load. Since the plastic bottles are not fragile, they can be flexible and tolerates sudden loads without failure. This characteristic can also increase the building's bearing capacity against the earthquake.

9.6. GREEN CONSTRUCTION

Plastic bottles can cause the green construction by saving energy and resources, recycling materials, minimizing the emission, having significant operational savings and increasing work place productivity. Figure9.6.1.shows two samples of real green building built using the plastic bottles.

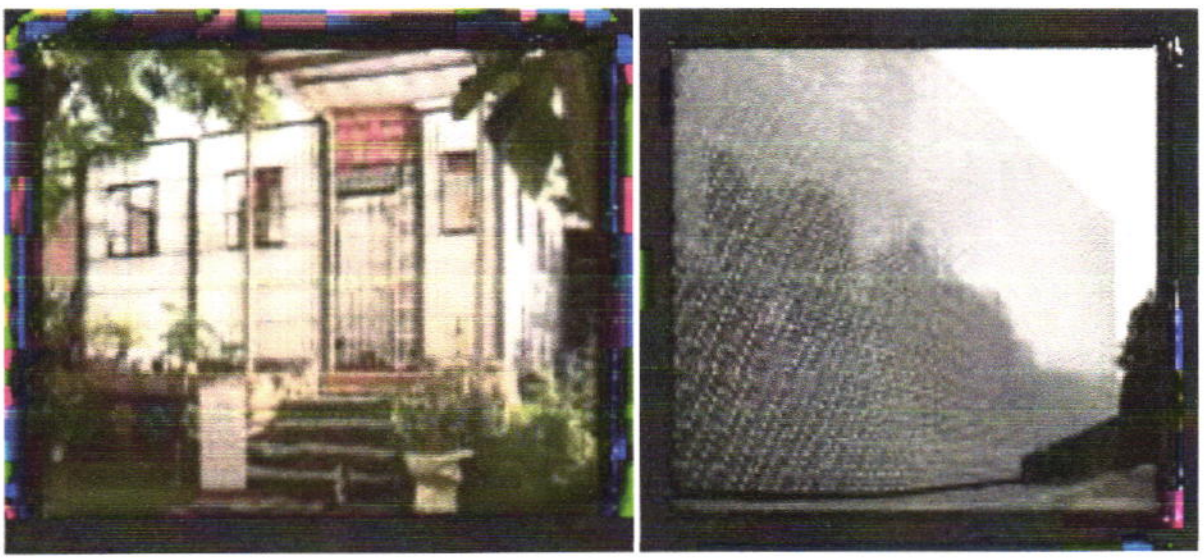


Figure9.6.1. Green buildings built using plastic bottle

10. ENVIRONMENTAL IMPACTS OF REUSING THE BOTTLE PANELS IN BUILDING

Reusing the plastic bottle is considered as sustainable consumption pattern which has a feedback loop after the consumption. The pattern will not lead to the waste which means it follows the reusing and recycling process. Figure10.1. demonstrates the sustainable consumption pattern

Reusing process in sustainable consumption pattern can save substantial amount of embodied energy which would otherwise be wasted. So using plastic bottles in building construction can have significant role in saving high embodied energy due to their reusing. This significant reduction in embodied energy can lead to mitigation of global warming; reducing resource consumption and reduction of biodiversity and in the long term consideration can improve built environment and human health.

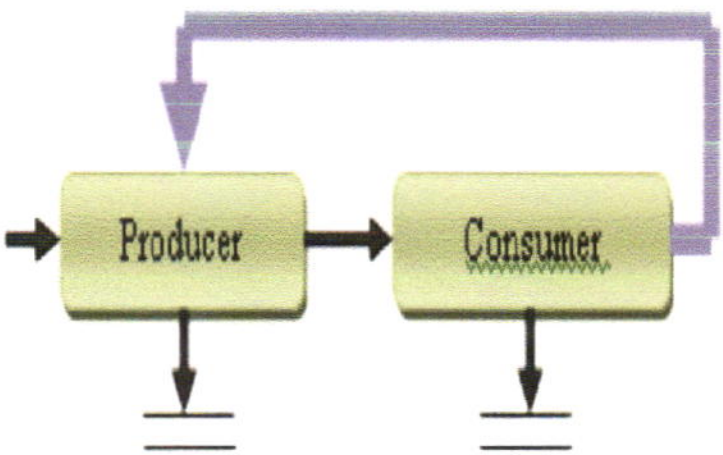


Figure 10.1.Sustainable consumption pattern

The bottle panel technology mitigates the carbon emission emitted during the baking of an ordinary brick. The amount of cement used for the building's wall can be reduced by this technology which can reduce the heat generation from the cement factories. This leads to reducing the emission of greenhouse gases which mitigates the global warming and in the long-term prevents ozone depletion. This material can also be used for the building's roof which leads to a better insulation compared to the conventional roofs. It can cause to lowering heating and cooling cost. Therefore it can be deduced that the bottle brick is much more energy-efficient than the clay brick.

11 CONCLUSION

Plastic bottles are considered as a kind of indecomposable junk which can have substantial dangerous impact on environment. On the other hand using the non-renewable resource cannot lead to sustainable development and causes to the resource depletion which can bring a destructive concern for the future generation. It has been demonstrated that the plastic bottles can be used in some parts of building construction such as walls, roof and etc. Reusing the plastic bottles as the building materials can have substantial effects on saving the building embodied energy by using them instead of bricks in walls and reducing the CO2 emission in manufacturing the cement by reducing the percentage of cement used. It is counted as one of the foundation's green project and has caught the attention of the architecture and construction industry. Generally the bottle houses are bioclimatic in design, which means that when it is cold outside is warm inside and vice versa.

Use of innovative materials with sustainable application such as plastic bottles can have considerable benefits including finding the best optimization in energy consumption of the region, reducing environmental degradation, establishment of the appropriate structural behavior in building such as causing to the light weight structure and can also be applied in a project to construct buildings considered temporary.

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