Feasibility Study of Material Filled Plastic Bottles as Partition Wall Units

Dropsingh Turkar[1] Prof. Rajesh Joshi [2]
[1]M.Tech. Student [2]Head of the Department
[1,2]Department of Civil Engineering
[1,2]Rajiv Gandhi Proudyogiki Mahavidyalaya, Bhopal, M.P, India

Abstract— Rapidly increasing rate of plastic usage is in alarming situation in the present scenario. Plastic is one of the major cause of elevated global warming. Uncontrolled plastic waste disposal is leading to the conditions where the landfill sites will only have plastics into it. Also the environmental hazards caused by plastic are numerous. On the other hand, construction industry is flourishing day by day, but the homeless people are not getting affordable shelter. To maintain the personal hygiene and to improve the living standards, housing is the main necessity. In the current study, an alternative to the burnt clay bricks used in partition walls is suggested. A low budget housing has majority of its cost on partition walls made of traditional bricks. Also the manufacturing of bricks requires valuable top soil and fossils for its preparation and improvement. Plastic bottles filled with soil and sawdust is proposed to be used as partition wall blocks. The plastic bottles of similar sizes are sorted from the waste disposal site and filled with material and tied together to form a stable structure and bound together with 1:4 and 1:6 cement sand mortar mix. The cube casted is treated as single block of wall and is subjected to compressive loads parallel and perpendicular the axis of plastic bottles in the blocks. Compressive strength of designed blocks is tested on 7th, 14th and 28th day of curing and results are compared. The results clearly approved the use of plastic bottles in partition walls, as the strengths obtained were within the range and the material filled inside the plastic bottles were found to have no effect on the compressive strength of the cubes.

Key words: Global Warming, Plastic Bottles, Load Bearing Partition Walls, Sustainable Material, Compressive strength, Low Cost Construction Material

I. INTRODUCTION

Plastic material used in the manufacturing of industrial products. It is mainly found in form of synthetic, semi-synthetic &organic solids. Plastic is a Greek word derived from plastikos which means a material that can be easily shaped or moulded into a desired product. Plastic is a polymeric by-product of petroleum and natural gas refinery process. Cost effectiveness of plastic makes it an easy and readily available choice for the increasing population.

Plastic is among the most disposable waste materials in the modern scenario. Plastic bottles are hindrance to the environmental health due to its chemical composition, non-biodegradable properties, uncontrolled use and improper disposal. Waste plastic bottles are disposed of into the barn landfills which pollute the soil, choke nearby water bodies and cause serious environmental consequences.

Housing is a main problem of the current days, increasing population is struggling to afford a house because the cost of construction is very high. More population triggers the requirements of more houses. Also the building material involved in construction has got high carbon footprints. Especially, the manufacturing of bricks, the basic building block or the widely used material used in partition walls requires ample amount of energy for its better performance. It will be very eco-friendly solution, if the building blocks are arranged to be replaced with some material which is a complete wastage and may facilitate with various other advantages like sound insulation and thermal insulation. Plastic bottles can serve the purpose effectively and also they can be filled with some cheap and easily available material like soil and saw dust to attain stability within the structural use. Yes, it is not easy to assume of a bottle as a brick. But a soil filled plastic bottle can be as stable and reliable as a burnt clay brick. Infact soil filled plastic bottles more cheap than bricks and can be easily worked on with unskilled labour.

When soil & saw dust is filled inside the plastic bottle, they act as bricks and make a framework for walls or pillars. Due to cylindrical shape of bottle, there are chances that they slide over one other, but when the bottles are arranges in a compact manner and if they are tied together with a rope, slipping or sliding of bottles may be avoided. Cement-sand mortar can be used to provide bonds between the bottle units and fills the space between all bottles. Walls of non-load bearing nature can be made with plastic bottles, where the roof of the structure is made of wood or corrugated metal sheet or any other light material.

Current set of experiments conducted in favour of the dissertation intends to investigate the feasibility of using one of the major causes of pollution, i.e., waste plastic bottles in buildings construction to promote sustainable development. In this dissertation, plastic bottles are filled with local soil and saw dust and a rope bound set of plastic bottles will be casted into cubes filled with 1:4 and 1:6 cement sand mortar and its mechanical properties are observed in order to identify its applicability. The results are also compared with the strength parameters of conventional bricks used in construction to establish the suitability of soil or sawdust filled plastic bottle blocks over brick.

A. Environmental Harms Cause by Plastic Bottles:

Plastics are long lasting resistant to natural processes of degradation. Thermoplastics can be re-melted and re-used; unfortunately, recycling of plastics has proven to be a difficult process. The biggest problems are the collection and transport of plastic to recycling depots. Also the deficiency of automated sorting facilities for plastic wastes, making it labours intensive.

Environmental concerns are the release of harmful pollutants, toxic gas, litter, biodegradable and non-biodegradable landfill impact as a result of the production and disposal of petroleum and petroleum-based plastics. Of particular concern ocean gyres has been the recent accumulation of enormous quantities of plastic trash.

1) *Effect of plastic waste on wildlife:*
   - Birds plastic bags caught up and ultimately dies due to starvation
   - Plastic bags , one ingested cannot be digested or passed by animals so it stays in the gut , leading to the very slow and painful death of the animals
   - More numbers of whales, birds, seals and turtles are killed every year from plastic litter as they mistake plastic bags for food such as jellyfish.
2) *Impact of plastic waste on surrounding environment:*
   - Harmful chemicals are released into the soil from chlorinated plastic waste, which can seep into groundwater bodies or other adjacent water sources or ecosystem. Seeped chemicals into water or soil can root serious spoil to the species that drink the water.

B. Housing Problems

Housing crises are experienced by the whole world. More than a hundred million people in the world are shelter less. Also the birth rate is getting higher with around a million babies born every week. More than a billion people are forced to live in urban slums to support their livelihood. If not any big action is taken, the number of slum dwellers worldwide would increase over the next 30 years to nearly 2 billion.

A clean, decent, and stable housing not only provides a roof to live inside but also is a responsible for providing stability to the families, a sense of dignity and pride, a proper healthy, physically safe and secure place to live in, where one can look forward for good educated and job.

Good housing facilities attract the economic investors and contribute to the development of an individual as well as nation. Safe homes and vicinity help to make social stability and secure community-based organizations.

Housing must become a priority because percentage of people with no proper access to decent and stable housing is intensifying. Housing supplies must be increased essentially to meet the demands of growing populations. World health marked adequate housing as a vitally important factor for economic and health development. Poverty can be successfully fought by providing aspects of housing practices and policies.

C. Benefits of bottle construction

Around 10,000 plastic bottles can be readily used for the construction of even a small house. These plastic bottles will otherwise be disposed off into the landfill deposits. Building houses with bottles can solve many social struggles like housing, housing cost and more. If the locality wants to eliminate other wastes the bottles can be filled with the waste prior to construction. Municipal waste like papers, dust, glasses, etc can then be eternally disconnected from the environment.

- Waste management
- Benefits to environment
- Provides affordable structures
- Cost effective
- Good construction abilityNon-brittle characteristic
- Absorbs abrupt shock loads
- Green Construction

D. Challenges in Plastic Bottle Construction

- The ineffective shape of the bottles.
- The waste of time to fill bottles with sand.
- The amount of clay required to bond the bottles together.
- The on-going maintenance.
- General lack of education concerning the environment and the impact of waste.

E. Objective of the Dissertation:

The alarmed increase of plastic waste in the form of plastic bottles has created an urgent requirement for the suitable disposal so that the environment does not face the adverse effects. Also to attain a proper housing is an issue of concern for most of the areas in the world, because of the raised prices of conventional building material. Both the problems can be simultaneously resolved if we prepare a building block by making use of useless plastic bottles.

Hence the objective of the dissertation is to prepare 15 cm x 15 cm blocks of cement mortar strengthened with soil sawdust filled plastic bottles. Total 72 blocks will be prepared, 36 with parallel soil and sawdust filled plastic bottle arrangement and 36 with perpendicular soil and sawdust filled plastic bottle arrangement, each for 1:4 and 1:6 cement mortar and the compression test will be carried out on 3 blocks each of 7th, 14th& 28thday after curing.

Following is the objective of the project:

- To test the compressive strength of 1:4 and 1:6 cement sand mortar blocks strengthened with soil and sawdust filled plastic bottles on 7th, 14th& 28thday, when load is applied parallel to the bottle cross-section.
- To test the compressive strength of 1:4 and 1:6 cement sand mortar blocks strengthened with soil and sawdust filled plastic bottles on 7th, 14th& 28thday, when load is applied on the perpendicular axis of bottle.
- Compressive strength of perpendicular and parallel arrangement is compared.
- Changes is compressive strength due to different filler materials will be Plotted.

II. LITERATURE REVIEW

Mojtaba et al. [1] concluded that 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 when it is warm it is cold inside. 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.

Shilpi et al. [2] concluded that by utilizing PET bottles in construction recycled materials, thermal comfort can be achieved in very low cost housing, benefit in residents for those who cannot afford to buy and operate heating and cooling systems. Plastic is non- biodegradable, tosxic, highly resistant to heat and electricity (best insulator) and not recyclable in true sense, plastic PET bottles use in bottle brick technique. This gives relief for the poor people of India to provide cheap and best houses for living.

Puttaraj et al. [3] examined that efficient usage of waste plastic in plastic-soil bricks has resulted in effective usage of plastic waste and thereby can solve the problem of safe disposal of plastics, also avoids its wide spread littering and the utilization of quarry waste has reduced to some extent the problem of its disposal. 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.

Pratima et al. [4] studied that plastic bottles wall have been less costly as compare to bricks and also they provide greater strength than bricks. The PET bottles that are not recycled end up in landfills or as litter, and they take approximately 1000 years to biodegrade. This has resulted in plastic pollution problems in landfills, water ways and on the roadside, and this problem continues to grow along with the plastic bottle industry.

Arulmalar et al. [5] studied that the initial perception on the use of PET bottles in construction is changing day by day. A paradigm which emerged as PET bottle bricks in the construction of load bearing walls with steel trusses and prefabricated metal sheet is at present witnessing flat roofs with nylon 6 replacing steel reinforcement and intuitive vault construction. Even though research on the effective use PET in developing new material as an option, solutions exploring the application of PET bottles as structural members, foundation, retaining walls and secondary elements like street furniture, road dividers, pavements and other landscape elements is to be looked in to. The Governing bodies shall formulate policies to propagate this eco centric approach via appropriate practices, research investigations on the properties of the materials and construction techniques.

VikramPakrashi et al. [6] examined Eco-brick is a viable resource for construction purposes with a number of possible applications. The bricks are relatively easily manufactured with controlled weight and packing. Eco-bricks have relatively good compressive strength, with values matching that of basic concrete cubes. The weight of Eco-brick was observed to hold a nearly relationship with load at failure and with specific strength. Eco-bricks have a relatively good specific strength. They are lightweight but strong for the weight they bear.

Andreas Froese et al. [7] concluded that when the bottles are filled with soil or sand they work as bricks and form a framework for walls or pillars. Different types of walls varying in size and orientation of the bottles are built. The compression strength and fracture behaviour of each wall are measured and compared. PET bottle walls can bear up to 4.3 N/mm² when the bottles are filled with sand which is the weakest filling material. The bottles bear one third of the load while the plaster bears two thirds. Plaster made of clay or a cement mixture fills the space between all bottles while a roof made of wood or corrugated metal completes the house. As only regional products are used the houses are cheap and can be afforded even by poor families. Additionally the method has so far proven to be earthquake resistant and allows short construction periods.

YahayaAhmade et al. [8] said that the structure has the added advantage of being fire proof, bullet proof and earthquake resistant, with the interior maintaining a constant temperature of 18 degrees C (64 degrees F) which is good for tropical climate.

Seltzer et al. [9] revealed that the first example of known structures built with bottles is the William F. Peck's Bottle House located in Nevada (USA). It was built around 1902, and it required 10,000 beer bottles to be built. These buildings were primarily made out of glass bottles used as masonry units and they were bound using mortar made out of adobe, sand, cement, clay and plaster.

Job Bwire and AritheaNakiwala et al. [10] suggested that, baked bricks, tiles, concrete and rocks, among other construction materials, have been essentials in construction. But did you know that a house constructed using plastic bottles can save you more and be just as strong as or even stronger than brick homes? Water bottle housing is an innovation aimed at providing low cost housing, while contributing to environment management.

William F. Peck [11] 1902 suggest the first bottle built by him at Tonopha, Navada by using 1000 glass beer bottles. After this innovative concept the use of plastic bottle got promoted instead of glass bottles which were cost efficient in construction.

Andreas Forese [12] was the first to construct plastic bottle house in village of Yelwa of Nigeria. He used this bottle as brick and made the bonding with help of strings and plastered it. Mojtaba et al. [1] concluded that there is huge effect on saving energy and reduce CO2 emission by using small percentage of cement.

SjoerdNienhuys Kathmandu, Nepal November2014 [13] Concluded that plastic can be used as good thermal insulation as it can easily insulate water piping of solar water heaters and warm water piping inside houses.

Singh Rawat, R. Kansal Aditya [14] investigated the mechanical behaviour of the unit and compare the compressive strength of brick bottle with brick and concluded that using the concept of brick bottles is cost effective, energy efficient and commercially feasible and termed as Green construction.

VikramPakrashi et al. [15] examined Eco-brick and concluded that the Eco brick have good compressive strength than the concrete cubes. They appear to have light but have high bearing strength. The template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities.

III. OBJECTIVE OF STUDY

Following is the objective of the project:

- To test the compressive strength of cement mortar blocks strengthened with soil and sawdust filled plastic bottles on 7th, 14th & 28th day, when load is applied parallel to the bottle cross-section.
- To test the compressive strength of cement mortar blocks strengthened with soil and sawdust filled plastic bottles on 7th, 14th & 28th day, when load is applied on the perpendicular axis of bottle.
- Comparison of strengths in both type of arrangements.
- Comparison of strengths with different filler materials.

IV. MATERIAL

This construction require some of the basic materials which ensures a stable, eco-friendly structure and also results in cheap construction as compared to brick wall. Materials uses for Bottle wall masonry construction are:

- Soil
- Plastic bottles
- Cement
- Nylon rope
- Water

V. METHOD

Method for testing the strength suitability of plastic bottle block as a partition material for the construction purpose includes following steps:

1) Used PETE plastic is sorted and collected from the MSW dump yards.
2) Plastic bottles are arranged in different patterns and their necks are tied properly in their respective places by means of nylon rope.
3) The tied arrangement of plastic bottles is placed centrally in the greased wooden mould.
4) The mould is then with the designed cement - sand mortar mix and compacted properly.
5) The mould is kept aside for 24 hours for drying and then kept inside the curing tank, few for 7 and few for 28 days.
6) The compressive strength of the prepared blocks is tested under Universal Testing Machine (UTM).
7) Soil and wood saw dust compatible as a filler material is selected and filled in the plastic bottle to provide bottle some mass and stability in terms of strength and density. The bottle caps are tightened firmly.

Fig. 2: Material Filled Plastic Bottles

Fig. 3: Mould Preparation

Fig. 4: Placing of Bottles and Mortar

Fig. 5: Complete Plastic Bottle Cubes

VI. OBSERVATION

A. Standard Consistency Test:

Cement : Sand	1 :4			1 :6		
	I	II	III	I	II	III
Water content for standard consistence %	31	32	31	39	39	38
Average %	31.5			38.5		

Table.1. Water Requirements for Standard Consistency

B. Compression Test on Cubes:

Age	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	178	7.91	8.01
	II	0.09	182	8.09	
	III	0.09	181	8.04	
14 days	I	0.09	219	9.73	9.73
	II	0.09	220	9.78	
	III	0.09	218	9.69	
28 days	I	0.09	239	10.62	10.65
	II	0.09	239	10.62	
	III	0.09	241	10.71	

Table.2. Soil Filled Plastic Bottles Arranged Parallel to the Load Application in cube with 1:4 cement sand mortar

Age	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	162	7.20	7.27
	II	0.09	164	7.29	
	III	0.09	165	7.33	
14 days	I	0.09	192	8.53	8.67
	II	0.09	197	8.76	
	III	0.09	196	8.71	
28 days	I	0.09	217	9.64	9.78
	II	0.09	221	9.82	
	III	0.09	222	9.87	

Table.3. Soil Filled Plastic Bottles Arranged Perpendicular to the Load Application in cube with 1:4 cement sand mortar

Age	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	156	6.93	7.01
	II	0.09	158	7.02	
	III	0.09	159	7.07	
14 days	I	0.09	186	8.27	8.40
	II	0.09	191	8.49	
	III	0.09	190	8.44	
28 days	I	0.09	211	9.38	9.51
	II	0.09	215	9.56	
	III	0.09	216	9.60	

Table.4. Soil Filled Plastic Bottles Arranged Parallel to the Load Application in cube with 1:6 cement sand mortar

Age	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	145	6.44	6.53
	II	0.09	146	6.49	
	III	0.09	150	6.67	
14 days	I	0.09	174	7.73	7.87
	II	0.09	180	8.00	
	III	0.09	177	7.87	
28 days	I	0.09	210	9.33	8.96
	II	0.09	199	8.84	
	III	0.09	196	8.71	

Table.5.Soil Filled Plastic Bottles Arranged Perpendicular to the Load Application in cube with 1:6 cement sand mortar

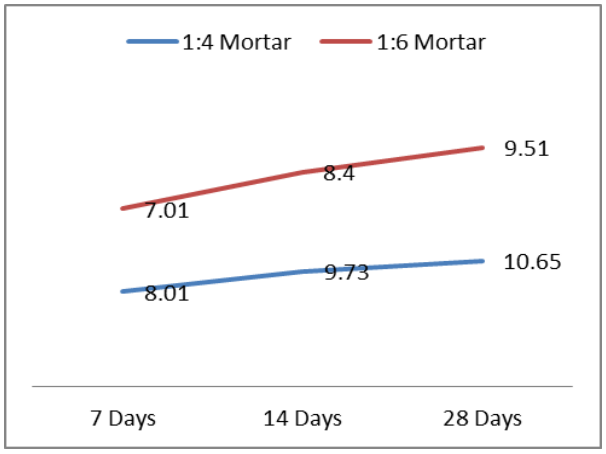

Fig. 6: Comparison of compressive strength of 1:4 and 1:6 cubes with bottles arranged Parallel to the direction of load application

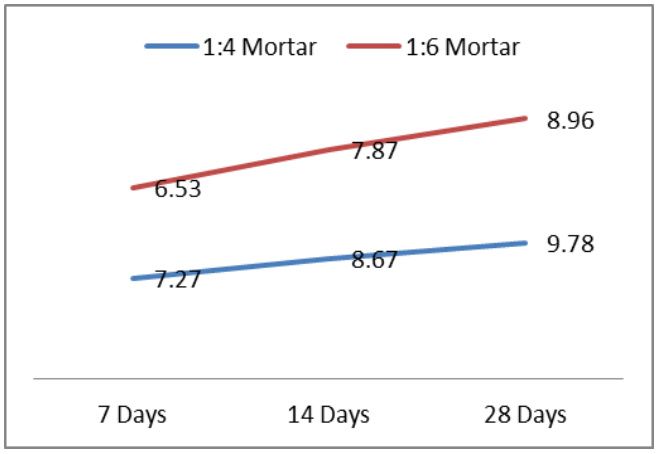

Fig. 7: Comparison of compressive strength of 1:4 and 1:6 cubes with bottles arranged Perpendicular to the direction of load application

Age	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	170	7.56	7.53
	II	0.09	168	7.47	
	III	0.09	170	7.56	
14 days	I	0.09	210	9.33	9.44
	II	0.09	215	9.56	
	III	0.09	212	9.42	
28 days	I	0.09	232	10.31	10.39
	II	0.09	233	10.36	
	III	0.09	236	10.49	

Table 6: Sawdust Filled Plastic Bottles Arranged Parallel to the Load Application in cube with 1:4 cement sand mortar

Age	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	159	7.07	7.14
	II	0.09	162	7.20	
	III	0.09	161	7.16	
14 days	I	0.09	186	8.27	8.25
	II	0.09	187	8.31	
	III	0.09	184	8.18	
28 days	I	0.09	212	9.42	9.47
	II	0.09	217	9.64	
	III	0.09	210	9.33	

Table 7: Sawdust Filled Plastic Bottles Arranged Perpendicular to the Load Application in cube with 1:4 cement sand mortar

Age	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	150	6.67	6.65
	II	0.09	149	6.62	
	III	0.09	150	6.67	
14 days	I	0.09	170	7.56	7.96
	II	0.09	183	8.13	
	III	0.09	184	8.18	
28 days	I	0.09	207	9.20	9.11
	II	0.09	205	9.11	
	III	0.09	203	9.02	

Table 8: Sawdust Filled Plastic Bottles Arranged Parallel to the Load Application in cube with 1:6 cement sand mortar

Age	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	148	6.58	6.55
	II	0.09	146	6.49	
	III	0.09	148	6.58	

14 days	I	0.09	176	7.82	7.97
	II	0.09	180	8.00	
	III	0.09	182	8.09	
28 days	I	0.09	219	9.73	9.51
	II	0.09	210	9.33	
	III	0.09	213	9.47	

Table 9: Sawdust Filled Plastic Bottles Arranged Perpendicular to the Load Application in cube with 1:6 cement sand mortar

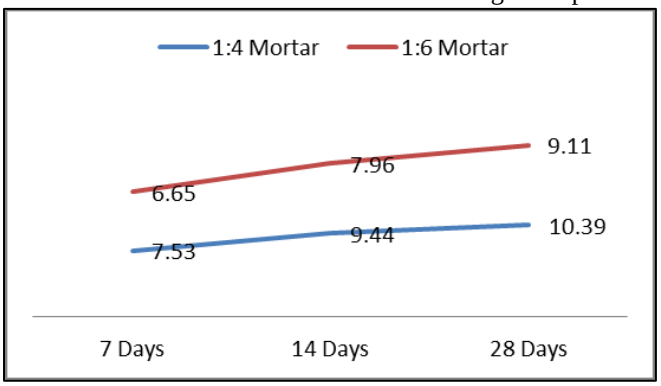

Fig. 8: Comparison of compressive strength of 1:4 and 1:6 cubes with bottles arranged Parallel to the direction of load application

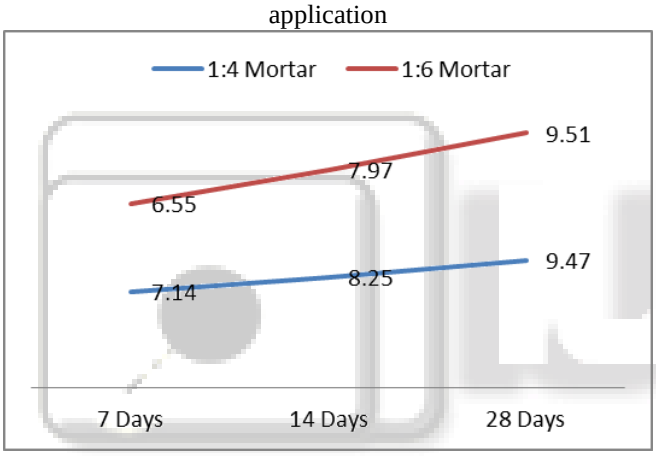

Fig. 9: Comparison of compressive strength of 1:4 and 1:6 cubes with bottles arranged Perpendicular to the direction of load application

VII. Conclusion

As per the experiments conducted on the test cube specimens made of 1:4 and 1:6 mortar with parallel and perpendicular arrangement of soil filled plastic bottles in it, results have been observed that clearly indicates that utility of these blocks as a construction material is truly justified and also the strength of the cubes are desirable for construction of partition walls using this techniques which can also bear significant load liable to get imposed during its service period.

As obtained by the results the following conclusions have been obtained:

- Compressive strength of 1:4 cement sand mortar on 28th day of curing for soil and sawdust filled plastic bottle cubes is found to be 10.65 kN/m2 and 10.39 kN/m2, respectively, when the compressive load is applied parallel to the bottle axis.
- Compressive strength of 1:6 cement sand mortar on 28th day of curing for soil and sawdust filled plastic bottle cubes is found to be 9.51 kN/m2 and 9.11 kN/m2, respectively, when the compressive load is applied parallel to the bottle axis.
- Compressive strength of 1:4 cement sand mortar on 28th day of curing for soil and sawdust filled plastic bottle cubes is found to be 9.78 kN/m2 and 9.47 kN/m2, respectively, when the compressive load is applied perpendicular to the bottle axis.
- Compressive strength of 1:6 cement sand mortar on 28th day of curing for soil and sawdust filled plastic bottle cubes is found to be 8.96 kN/m2 and 9.51 kN/m2, respectively, when the compressive load is applied perpendicular to the bottle axis.
- All the combination of plastic bottle blocks bound together with 1:4 and 1:6 can be recommended for structural use, as the burnt clay bricks used for construction works must not have compressive strength less than 5 kN/mm2 and all the combination of blocks are having compressive strength higher than that.
- Load bearing capacitates are higher in plastic bottle arrangements where the loads are applied parallel to the bottle axis (or perpendicular to the cross-section area of bottle), whereas, in perpendicular loading, the compressive strength is lower because the surface of bottles are liable to slip over each other resulting in failure of block.
- There is no significant difference in the compressive strength of bottles filled with different filler materials (soil or saw dust), indicating the research of filled plastic bottle partition wall panels independent of filler material of bottle.
- The major difference in compressive strengths is due to the arrangement of bottles and the direction of loadings. Therefore, it is suggested that the arrangements of bottles recommended for construction purpose is in standing position.
- The study can conclude that as the cement in the cement in cement sand mortar increases the compressive strength of the bond increases.

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