Studies on Eco-Friendly Soil and Sawdust Filled Plastic Bottles to Promote Sustainable Development for Partition Walls

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Abstract— Alarming volume of plastic in urban waste is an indication of peak pollution that will lead to global warming to different elevations. Also the rapidly increasing rate of building materials is necessary to be controlled. Also the materials used for construction are big contributors for the environmental degradation that ultimately hinders sustainable development. Here in this study we have found an alternative of brick wall which is a soil filled plastic bottle block bonded together with cement sand mortar of two different proportions. The arrangement of plastic bottles is tested both for parallel to the axis of loading and perpendicular to the load axis. The concept of plastic bottle block can also be used for the load bearing walls, since the blocks are capable enough to withstand significant loads after 28 days of curing. The compression test results showed that the blocks with plastic bottle arrangement perpendicular to the load axis has more strength than that of parallel arrangement. The arrangement of plastic bottles is tied together with nylon rope to prevent slipping of bottles over one another while casting. The soil filled plastic bottles of similar size are tied together in different types of arrangements and casted in mortar cubes of 1:4 and 1:6 cement sand mix mortar. After proper curing, the casted specimens are tested for compression under universal testing machine on 7th, 14th and 28th day after casting and curing. There were two types of arrangements of bottles made, first in which the bottles are kept parallel to the load application and second, in which the plastic bottle is kept perpendicular to the axis of loading. Different results were observed and comparison is plotted on various days for specifies loadings and mortar mixes. As Per the results obtained, it has been proved that the plastic bottle bricks are a sustainable material for construction in the modern world. The suggested blocks are low cost and an innovative construction material.

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

I. Introduction

Plastic material is any of a wide range of synthetic, semi-synthetic or organic solids used in the manufacturing of industrial products. The word plastic is derived from the Greek (plastikos) meaning capable of being shaped or moulded.

The raw materials needed to make most plastics come from petroleum and natural gas. Plastic packaging is growing due to the cost effectiveness and the demand due to the population pressure on planet earth.

Plastic is one of the most disposable materials in the modern world. Plastic bottles are increasingly becoming a menace to the environment due to the chemicals used in the manufacture, improper use and disposal. Waste plastic bottles are used for filling up landfills which polluted to soil, choking water bodies and causing serious environmental consequences. On the other hand, world human population continually increase so needed more houses and land for construction. Now a day, it is difficult to make own house for poor people of the world by using costly construction material. Can we use waste bottles for construction? Yes, it is difficult to think of a bottle as a brick. But a mud-filled bottle is as strong as a brick and whatever you can do with a brick; you can do with a bottle, too. When the bottles are filled with soil or sand they work as bricks and form a framework for walls or pillars. 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. Our project intends to investigate the application of waste plastic bottles as one of the urban wastage in buildings construction and that how it can lead to sustainable development. In this project, we try to different patterns for construction of plastic bottle masonry and compare various factors like as compressive strength, durability and construction cost with normal brick masonry.

A. *Benefits of Bottle Construction*

1) *Waste management*

To build a small house one can use as many as 10,000 used bottles which are readily available. Waste that would otherwise be deposited in a landfill can now help solve other social problems like housing, schools and clinics. If the communities want to get rid of other plastic waste the bottles can be filled prior to construction. Waste like paper and plastic is then permanently removed from the environment.

2) *Environmental benefits*

Unlike "traditional" bricks, bottle bricks are not fired, this as well as the weight consideration in terms of transport contributes to a more eco- friendly building system.

3) *Provide structures*

Any statistic would have to be an educated guess, since in many parts of the world homeless people are considered outside normal society. Approximately 1 billion people do not have suitable housing and 500 million have no housing whatsoever.

4) *Cost effective*

The use of recycled material makes it more affordable than conventional building methods and will increase the accessibility to suitable housing. It is a well-insulated solution that will reduce energy consumption to control temperatures. 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 walls 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.

5) 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 as a bulletproof shelter.

6) 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.

7) Absorbs abrupt shock loads

Flexibility is a characteristic which makes the buildings 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 buildings bearing capacity against the earthquake.

8) 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

B. Housing Problems

1) The world is experiencing a global housing crisis.

- About 1.6 billion people live in substandard housing and 100 million are homeless.
- Each week, more than 1 million babies are born in, or move to, cities in the developing world.
- One billion people live in urban slums.
- If no serious action is taken, the number of slum dwellers worldwide would increase over the next 30 years to nearly 2 billion.

2) Clean, decent, and stable housing provides more than just a roof over persons' head.

- Stability for families and children.
- Sense of dignity and pride.
- Health, physical safety, and security.
- Increase of educational and job prospects.

3) Improved housing leads to improved lives.

- Clean, warm housing is essential for the prevention and care of diseases like HIV/AIDS, tuberculosis, diarrhoea, and malaria, suffered in poverty stricken countries
- Children under five, living in Malawi, residing in suitable homes have a 44 % lower chance of contracting malaria, respiratory or gastrointestinal diseases compared to children living in traditional houses.

4) Good housing attracts economic investment and development.

- Contributes to thriving school systems and community organizations.
- A catalyst for civic activism and a stimulus for community-based organizations.
- Safe homes and neighbourhoods help to build social stability and security.

5) Housing must become a priority

- The percentage of people without access to decent, stable housing is rising.
- Increasing the housing supply across the globe is essential.
- Adequate housing is vitally important to the health of the world's economies, communities, and populations.
- If we are to succeed in the fight against poverty, we must support the expansion of housing both as policy and in practice.

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.

Vikram Pakrashi 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.

Yahaya Ahmade 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 Arithea Nakiwala 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 CO_2 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).

Fig. 1: Plastic Bottles Selected for experiment

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	31	32	31	39	39	38
Average %	31.5			38.5		

Table 1: Water Requirements for Standard Consistency

B. *Compression Test on Cubes*

Total of 72 samples were prepared 36 each for soil filled and sawdust filled plastic bottles, with 18 each for parallel and perpendicular arrangement of bottles in mortar cubes, 9 for 1:4 mortar and 9 for 1:6 mortar. The results of the tests performed are as follows:

Specification	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	178	1978	2004
	II	0.09	182	2022	
	III	0.09	181	2011	
14 days	I	0.09	219	2433	2433
	II	0.09	220	2444	
	III	0.09	218	2422	
28 days	I	0.09	239	2656	2663
	II	0.09	239	2656	
	III	0.09	241	2678	

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

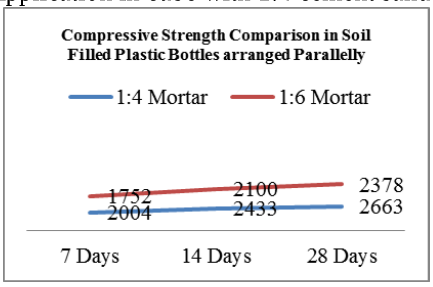

Fig. 6: Comparison of compressive strength of 1:4 and 1:6 cubes with bottles arranged Parallel to the direction of load application

Specification	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	162	1800	1819
	II	0.09	164	1822	

	III	0.09	165	1833	
14 days	I	0.09	192	2133	2167
	II	0.09	197	2189	
	III	0.09	196	2178	
28 days	I	0.09	217	2411	2444
	II	0.09	221	2456	
	III	0.09	222	2467	

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

Specification	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	156	1733	1752
	II	0.09	158	1756	
	III	0.09	159	1767	
14 days	I	0.09	186	2067	2100
	II	0.09	191	2122	
	III	0.09	190	2111	
28 days	I	0.09	211	2344	2378
	II	0.09	215	2389	
	III	0.09	216	2400	

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

Specification	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	156	1756	1774
	II	0.09	158	1778	
	III	0.09	159	1789	
14 days	I	0.09	186	2089	2122
	II	0.09	191	2144	
	III	0.09	190	2133	
28 days	I	0.09	211	2367	2400
	II	0.09	215	2411	
	III	0.09	216	2422	

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

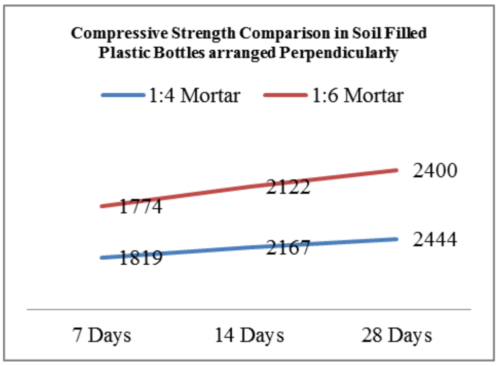

Fig. 7: Comparison of compressive strength of 1:4 and 1:6 cubes with bottles arranged Perpendicular to the direction of load application

Specification	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	170	1888.88	1881
	II	0.09	168	1866.66	
	III	0.09	170	1888.88	
14 days	I	0.09	210	2333.33	2359
	II	0.09	215	2388.88	
	III	0.09	212	2355.55	
28 days	I	0.09	232	2577.77	2596
	II	0.09	170	1888.88	
	III	0.09	168	1866.66	

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

Specification	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	159	1766.66	1785
	II	0.09	162	1800	
	III	0.09	161	1788.88	
14 days	I	0.09	186	2066.66	2062
	II	0.09	187	2077.77	
	III	0.09	184	2044.44	
28 days	I	0.09	212	2355.55	2366
	II	0.09	217	2411.11	
	III	0.09	210	2333.33	

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

Specification	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	150	1666.66	1662
	II	0.09	149	1655.55	
	III	0.09	150	1666.66	
14 days	I	0.09	170	1888.88	1988
	II	0.09	183	2033.33	
	III	0.09	184	2044.44	
28 days	I	0.09	207	2300	2277
	II	0.09	205	2277.77	
	III	0.09	203	2255.55	

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

Specification	Sample No.	Surface Area (m2)	Load at Failure (kN)	Compressive Strength (kN/m2)	Average Compressive Strength (kN/m2)
7 days	I	0.09	148	1644.44	1637
	II	0.09	146	1622.22	
	III	0.09	148	1644.44	
14 days	I	0.09	176	1955.55	1992

	II	0.09	180	2000	
	III	0.09	182	2022.22	
28 days	I	0.09	219	2433.33	2377
	II	0.09	210	2333.33	
	III	0.09	213	2366.66	

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

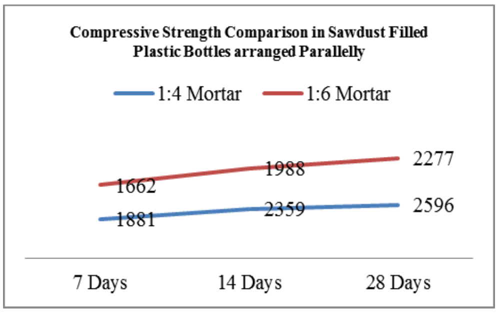

Fig. 8: Comparison of compressive strength of 1:4 and 1:6 cubes with bottles arranged Parallel to the direction of load application

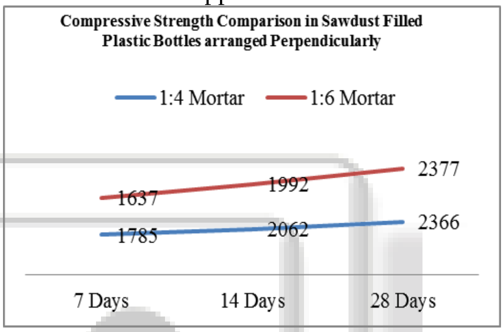

Fig. 9: Comparison of compressive strength of 1:4 and 1:6 cubes with bottles arranged Perpendicular to the direction of load application

VII. CONCLUSION

The results of the study show that there are good As obtained by the results the following conclusions have been obtained:

- The compressive strength of 1:4 cement mortar blocks strengthened with soil filled plastic bottles on 7th day, when load is applied parallel to the bottle cross-section is 2004 kN/m^2.
- The compressive strength of 1:4 cement mortar blocks strengthened with soil filled plastic bottles on 14th day, when load is applied parallel to the bottle cross-section is 2433 kN/m^2.
- The compressive strength of 1:4 cement mortar blocks strengthened with soil filled plastic bottles on 28th day, when load is applied parallel to the bottle cross-section is 2663 kN/m^2.
- The compressive strength of 1:4 cement mortar blocks strengthened with soil filled plastic bottles on 7th day, when load is applied on the perpendicular axis of bottle is 1819 kN/m^2.
- The compressive strength of 1:4 cement mortar blocks strengthened with soil filled plastic bottles on 14th day, when load is applied on the perpendicular axis of bottle is 2167 kN/m^2.
- The compressive strength of 1:4 cement mortar blocks strengthened with soil filled plastic bottles on 28th day, when load is applied on the perpendicular axis of bottle is 2444 kN/m^2.
- The compressive strength of 1:6 cement mortar blocks strengthened with soil filled plastic bottles on 7th day, when load is applied parallel to the bottle cross-section is 1752 kN/m^2.
- The compressive strength of 1:6 cement mortar blocks strengthened with soil filled plastic bottles on 14th day, when load is applied parallel to the bottle cross-section is 2100 kN/m^2.
- The compressive strength of 1:6 cement mortar blocks strengthened with soil filled plastic bottles on 28th day, when load is applied parallel to the bottle cross-section is 2378 kN/m^2.
- The compressive strength of 1:6 cement mortar blocks strengthened with soil filled plastic bottles on 7th day, when load is applied on the perpendicular axis of bottle is 1774 kN/m^2.
- The compressive strength of 1:6 cement mortar blocks strengthened with soil filled plastic bottles on 14th day, when load is applied on the perpendicular axis of bottle is 2122 kN/m^2.
- The compressive strength of 1:6 cement mortar blocks strengthened with soil filled plastic bottles on 28th day, when load is applied on the perpendicular axis of bottle is 2400 kN/m^2.

Hence proved, with the increased percentage of cement in the mortar mix the strength of the cube increases and also the strength of the cube is much more in the arrangement of plastic bottles parallel to the subjection of load, than in the arrangement of plastic bottles perpendicular to the load of action.

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