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COMPRESSION ANALYSIS ON POLYETHYLENE TEREPHTHALATE (PET) MATERIALS

[1]Dr.K.Vinaygar, [2]G.Nanthakumar, [3]B.Parthiban, [4]N.Ramanathan
[1]Associate Professor, Department of Mechanical Engineering,
Final year students, Department of Mechanical engineering,
Sethu Institute of Technology, pulloor – 626 115, kariappati , virudhunagar, India

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ABSTRACT

Road accident is a major problem in the country and should be dealt with an effective ways. Road furniture is one of the factors that contributing an accidents than other factors. Therefore, this study focuses on waste material such as recycle plastic bottle that potential to be used as a road barrier and crash cushion. The objective of this study are to investigate the potential of plastic bottles filled with sand as crash cushion, examine the impact strength of plastic bottles and designing crash cushion by using recycled materials. Some plastic bottles of soft drinks containing ordinary sand was prepared and undergone experimental and simulation works. Free fall Impact test that imposed on the plastic bottles has been carried out to identify the strength and its energy absorption. The numerical simulation of impact test was conducted using Finite Element Method to obtain impact failure and to observe its details response under low velocity impact loads. The numerical results by employing FEM well agreed with practical works. Where, the absorption of energy from the impact test shows that the difference does not exceed 50%. In addition, the deformation of both test are almost similar. Therefore, the use of recycled materials such as plastic bottles filled with sand as crash cushions that can be considered as alternative and environmentally friendly materials.

I. INTRODUCTION

Road accident occurs when two more vehicles collided by themselves or the vehicle collide with some object on the road. The accident cause injuries even death of vehicle's occupants. In Europe countries, the road accidents has been brought to the attention that incidence is one of the major problems and influence in various aspects of socio-economic development . One of the cause accidents is the use of inadequate attribute of road furniture. The road or highway should be completed by road furniture which to facilitate the road safety and gave protection to road users. In addition, it's also to increased road safety and as a warning about the dangers ahead. The road furniture such as curb, guardrails and concrete barriers, are used as a safety barrier.

The safety barrier often comes with the crush cushion to optimize the barrier from impact and hazardous errant vehicle. Usually, crash cushion is made from metal, rubber, or plastic arranged to reduce an accident from any diversion or crossing a road vehicle without endangering other vehicle. Various types of crash cushion depend on types of vary in terms of installation cost, size, ease of repair and maintenance. These aspects should be assessed carefully to select the appropriate cushion violations. However, the crash cushion least preferred due to expensive and less expertise to design it. This process is costly and time consuming.

The plastic waste is a quite problematic for its non-biodegradability and therefore can stay in the environment for a considerable length of time carrying all sorts of problems. Meanwhile in the world, total plastic bottles disposal increase every year, more than 121 million tons, the plastic bottle give contribution of waste per year, which more than 75% of plastic water bottles cannot be re-cycled and to be disposal. Usually, the type of waste bottle is Polyethylene Terephthalate (PET or PETE or Polyester). The properties of this bottle are toxic and it has materials component may contaminate water by a diffusion process or called migration. However, the physical properties of this bottle type are a high degree of impact resistance and tensile strength, besides good chemical resistance. Therefore, this investigation re-used plastic bottle which modified as a crash cushion is a potential material to reduce the cost of crash cushion production and its maintenance, also to reduce the timing installation. Additionally, utilizing the waste bottles reduce the pollution problem.

Therefore, the bottle plastic had been modified as crash cushion or Modified Bottle Crash Cushion (MBCC) and was tested by the drop weight impact method. This method produced the high impact energy to hit the MBCC, furthermore the characteristic and behavior impact failure of MBCC would be obtained. The high

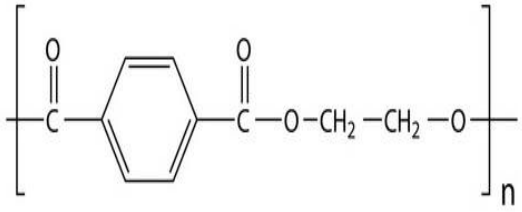
impact generated from the kinetic energy was produced by the height and velocity of impactor. The test determined energy absorption of modified bottle crash cushion. According to conservation energy law, the energy absorption can be calculated correspond to the deformation of MBCC. Furthermore, the Finite element method conducted to validate the result test. ELFEN software simulated the modified plastic bottle crash cushion subjected to impact loading. The results show that the modified plastic bottle can absorb energy impact. This test result agrees with the simulation model that the energy impact of modified plastic bottle no exceed to 35%. The investigation presented that the modified plastic bottle can be considered as road crash cushion.

1.1 OBJECTIVE

Road accident is a major problem in the country and should be dealt with an effective ways. Road furniture is one of the factors that contributing an accidents than other factors. Therefore, this study focuses on waste material such as recycle plastic bottle that potential to be used as a road barrier and crash cushion. The objective of this study are to investigate the potential of plastic bottles filled with sand as crash cushion, examine the impact strength of plastic bottles and designing crash cushion by using recycled materials. Some plastic bottles of soft drinks containing ordinary sand was prepared and undergone experimental and simulation works. Free fall Impact test that imposed on the plastic bottles has been carried out to identify the strength and its energy absorption. The numerical simulation of impact test was conducted using Finite Element Method to obtain impact failure and to observe its details response under low velocity impact loads. The numerical results by employing FEM well agreed with practical works. Where, the absorption of energy from the impact test shows that the difference does not exceed 50%. In addition, the deformation of both test are almost similar. Therefore, the use of recycled materials such as plastic bottles filled with sand as crash cushions that can be considered as alternative and environmentally friendly materials.

1.2 POLYETHYLENE TEREPHTHALATE

Polyethylene terephthalate (PET or PETE) is a general purpose thermoplastic polymer which belongs to the polyester family of polymers. Polyester resins are known for their excellent combination of properties such as mechanical, thermal, chemical resistance as well as dimensional stability.



Molecular Structure of Polyethylene Terephthalate

PET Chemical Formula: $(C_{10}H_8O_4)_n$. Recycled PET can be converted to fibers, fabrics, sheets for packaging and manufacturing automotive parts. Chemically, Polyethylene terephthalate is very much similar to Polybutylene Terephthalate.

PET is highly flexible, colorless and semi-crystalline resin in its natural state. Depending upon how it is processed, it can be semi-rigid to rigid. It shows good dimensional stability, resistance to impact, moisture, alcohols and solvents. Commercially available PET grades include un-reinforced to glass reinforced, flame retardant and high flow materials for various engineering applications that typically require higher strength and or higher heat resistance. Addition of fillers like glass fibers, CNTs etc. help improve impact strength, surface finish, reduce warpage and several other benefits.This plastic database is available to all, free of charge. You can filter down your options by property (mechanical, electrical…), applications, conversion mode and many more dimensions.There are two basic molding methods for PET bottles, one-step and two-step. In two-step molding, two separate machines are used. The first machine injection molds the preform, which resembles a test tube, with the bottle-cap threads already molded into place. The body of the tube is significantly thicker, as it will be inflated into its final shape in the second step using stretch blow molding.

In the second step, the preforms are heated rapidly and then inflated against a two-part mold to form them into the final shape of the bottle. Preforms (uninflated bottles) are now also used as robust and unique containers themselves; besides novelty candy, some Red Cross chapters distribute them as part of the Vial of Life program to homeowners to store medical history for emergency responders.In one-step machines, the entire process from raw material to finished container is conducted within one machine, making it especially suitable for molding non-standard shapes (custom molding), including jars, flat oval, flask shapes, etc. Its greatest merit is the reduction in space, product handling and energy, and far higher visual quality than can be achieved by the two-step system

Figure 1.1 Pet Bottles

1.3 ENVIRONMENTAL AND SOCIAL IMPACT

Life Cycle Assessment (LCA) was induced to examine the environmental impacts in the life cycle of polyethylene terephthalate (PET) package of milk, and to compare the environmental impacts from different treatments. In the comparison of landfill, incineration and recycling of PET package, the environmental impact in landfill treatment was the highest, and then was incineration and recycle which were beneficial effects on environment.Compared to the environmental impacts before PET package come into waste management, landfill could append 3.5% additional environmental impacts and incineration could reduce 22.2%. In contrast, recycling could reduce 61.7% of environmental impacts more significantly.

1.4 SAFETY

Commentary published in Environmental Health Perspectives in April 2010 suggested that PET might yield endocrine disruptors under conditions of common use and recommended research on this topic.[26] Proposed mechanisms include leaching of phthalates as well as leaching of antimony. An article published in Journal of Environmental Monitoring in April 2012 concludes that antimony concentration in deionized water stored in PET bottles stays within EU's acceptable limit even if stored briefly at temperatures up to 60 °C (140 °F), while bottled contents (water or soft drinks) may occasionally exceed the EU limit after less than a year of storage at room temperature.

1.5 PROPERTIES OF PET MATERIAL

Polyethylene terephthalate polyester (PETP) is the most common thermoplastic polyester and is often called just “polyester”. This often causes confusion - not only is the chemically similar polybutylene terephthalate (PBT) also a (thermoplastic) polyester, the most common resin system used in GRP is also a polyester system - and also often called just “polyester”. (In this latter case, however, the polyesters are chemically unsaturated and are “free-radical polymerized” into a thermo set).

Polyethylene terephthalate polyester (PETP) is a hard, stiff, strong, dimensionally stable material that absorbs very little water. It has good gas barrier properties and good chemical resistance except to alkalis (which hydrolyse it).

Its crystallinity varies from amorphous to fairly high crystalline. Polyethylene terephthalate polyester (PETP) can be highly transparent and colourless but thicker sections are usually opaque and off-white.

Uses

Plastic bottles made from PET are widely used for soft drinks (see carbonation). For certain specialty bottles, such as those designated for beer containment, PET sandwiches an additional polyvinyl alcohol (PVOH) layer to further reduce its oxygen permeability. Biaxially oriented PET film (often known by one of its trade names, "Mylar") can be aluminized by evaporating a thin film of metal onto it to reduce its permeability, and to make it reflective and opaque (MPET). These properties are useful in many applications, including flexible food packaging and thermal insulation (such as space blankets). Because of its high mechanical strength, PET film is often used in tape applications, such as the carrier for magnetic tape or backing for pressure-sensitive adhesive tapes.

Non-oriented PET sheet can be thermoformed to make packaging trays and blister packs. If crystallizable PET is used, the trays can be used for frozen dinners, since they withstand both freezing and oven baking temperatures. Both amorphous PET and BoPET are transparent to the naked eye. Color-conferring dyes can easily be formulated into PET sheet. When filled with glass particles or fibres, it becomes significantly stiffer and more durable.

PET is also used as a substrate in thin film solar cells.
Terylene (a trademark formed by inversion of (polyeth)ylene ter(ephthalate)) is also spliced into bell rope tops to help prevent wear on the ropes as they pass through the ceiling.
PET is used since late 2014 as liner material in type IV composite high pressure gas cylinders. PET works as a much better barrier to oxygen than earlier used (LD)PE.
PET is used as a 3D printing filament, as well as in the 3D printing plastic PETG.

Advantages

It has higher strength and stiffness than PBT
It is very strong and lightweight & hence easy and efficient to transport
It is known for its good gas (oxygen, carbon dioxide) and moisture barrier properties
It exhibits excellent electrical insulating properties
PET has broad range of use temperature, from -60 to 130°C
As compared to PBT, it also has higher heat distortion temperature (HDT)
It has low gas permeability, in particularly with carbon dioxide
PET is suitable for transparent applications, when quenching during processing
PET doesn't not break or fracture. It is practically shatter-resistant and hence, a suitable glass-replacement in some applications
It is recyclable and transparent to microwave radiation
PET is approved as safe for contact with foods and beverages by the FDA, Health Canada, EFSA & other health agencies.

1.6 MERITS AND DEMERITS

(a) MERITS:

1) Light Weight

2) Chemically stable

3) Minimizes Thermal Shock

4) Versatility

5) Rigidity

6) Flexibility

7) Ease of maintenance

8) Eliminates flashing leaks

(b) DEMERITS:

Durability is less.

In this project,the Polyurethane Foam was choice for the experiment because of its good air sealant and good structural advantage. Foam adheres to steel decking on flat roof structures providing effective insulation where venting is impossible and there is no framing cavity to support other types of insulation.

II. LITERATURE SURVEY

Accessing the literature survey guides the specimen of thin walled may be prepared readymade or tailors made should be of ratio L/D should be equal or above to 2 or else there will be the effect of buckling in the axial loading. For form filling in many cases which aluminum foil is only used to improve the specific energy absorption of thin walled structure in its inner filling. For quasi static the impact loading mass will be varied and for dynamic the quasi static the variability is the impact velocity. The load versus deflection curve is obtained to find the mean load and the peak load of the thin walled specimen. then their energy absorbed and specific energy absorption were also find to make a note on the composite material formed.

Sullman, M.J.M., Gras, M.E., Cunill, M.O., Planes, M., Font-Mayolas, S., "Driving anger in Spain", (2007). Road accident occurs when two more vehicles collided by themselves or the vehicle collide with some object on the road. The accident cause injuries even death of vehicle's occupants. In Europe countries, the road accidents has been brought to the attention that incidence is one of the major problems and influence in various aspects of socio-economic development.

Ambak, K., Bajuri, F.A.A., Yusoff, N.A., Madun, A., Prasetijo, J. Green and sustainable median on a divided multilane highway, (2017). One of the cause accidents is the use of inadequate attribute of road furniture. The road or highway should be completed by road furniture which to facilitate the road safety and gave protection to road users. In addition, its also to increased road safety and as a warning about the dangers ahead. The road furniture such as curb, guardrails and concrete barriers, are used as a safety barrier.

Road Traffic Act 1961. Administrative provisions— Part 2 General enforcement powers for Australian road laws. Australia, (2014). The safety barrier often comes with the crush cushion to optimize the barrier from impact and hazardous errant vehicle. Usually, crash cushion is made from metal, rubber, or plastic arranged to reduce an accident from any diversion or crossing a road vehicle without endangering other vehicle. Various types of crash cushion depend on types of vary in terms of installation cost, size, ease of repair and maintenance. These aspects should be assessed carefully to select the appropriate cushion violations. However, the crash cushion least preferred due to expensive and less expertise to design it. This process is costly and time consuming.

Consolazio, G. R., Chung, J. H., & Gurley, K. R. Impact simulation and full scale crash testing of a low profile concrete work zone barrier. Journal of Computers and Structures, (2003), pp. 1359–374.The plastic waste is a quite problematic for its non biodegradability and therefore can stay in the environment for a considerable length of time carrying all sorts o f problems. Meanwhile in the world, total plastic bottles disposal increase every year, more than 121 million tons, the plastic bottle give contribution of waste per year, which more than 75% of plastic water bottles cannot be re-cycled and to be disposal.

Mokhatar, S. N., Sonoda, Y., Kueh, A.B.H. and Jaini, Z. M. (2015). Usually, the type of waste bottle is Polyethylene Terephthalate (PET or PETE or Polyester). The properties of this bottle are toxic and it has materials component may contaminate water by a diffusion process or called migration. However, the physical properties of this bottle type are a high degree of impact resistance and tensile strength, besides good chemical resistance then their energy absorbed and specific energy absorption were also find to make a note on the composite material formed.

Habeeb, S.A., Latiff, A.A.A., Daud, Z. & Ahmad, Z. The start-up of hybrid, anaerobic up-flow sludge blanket (HUASB) under a range of mesophiclic and thermophilic temperatures. EnvironmentAsia, (2011). Therefore, this investigation re-used plastic bottle which modified as a crash cushion is a potential

material to reduce the cost of crash cushion production and its maintenance, also to reduce the timing installation. Additionally, utilizing the waste bottles reduce the pollution problem.

Daud, Z., Awang, H., Kassim, A.S.M., Hatta, M.Z.M. & Aripin, A.M., Comparison of pineapple leaf and cassava peel by chemical properties and morphology characterization. Advanced Materials Research, (2014). Therefore, the bottle plastic had been modified as crash cushion or Modified Bottle Crash Cushion (MBCC) and was tested by the drop weight impact method. This method produced the high impact energy to hit the MBCC, furthermore the characteristic and behavior impact failure of MBCC would be obtained. The high impact generated from the kinetic energy was produced by the height and velocity of impactor. The test determined energy absorption of modified bottle crash cushion.

Daud, Z., Abubakar, M.H., Kadir, A.A., Latiff, A.A.A., Awang, H., Halim, A.A. & Marto, A., Adsorption studies of leachate on cockle shells. International Journal of GEOMATE, (2017). According to conservation energy law, the energy absorption can be calculated correspond to the deformation of MBCC.Furthermore, the Finite element method conducted to validate the result test. ELFEN software simulated the modified plastic bottle crash cushion subjected to impact loading. The results show that the modified plastic bottle can absorb energy impact. This test result agrees with the simulation model that the energy impact of modified plastic bottle no exceed to 35%. The investigation presented that the modified plastic bottle can be considered as road crash cushion.

Kamarudin Ambak, (2018) Sand as filler in bottle increase the strength of PET bottle under impact loading, it potentially as crash cushions (MBBC). Re-use the bottle for crush cushion help to solve the environmental problem. Experimentally, results showed that the MBCC withstand the compressive stress of impact due to high elastic and plastic strain of bottle, beside sand as stress 'reinforcement'.

Josef Hadipramana (2015) The deformation occurred in three dimensional, however the critical in impact or direction, i.e. Depth-Z for horizontal position and Height-Z for vertical position. The displacements generally represent the actual collide accident of crash cushion by errant vehicle. The simulation shows that displacement had similar trend with the experimental results. The load versus deflection curve is obtained to find the mean load and the peak load of the thin walled specimen. then their energy absorbed and specific energy absorption were also find to make a note on the composite material formed.

Xiong zhang,Hoon Hug (2012): investicates the energy absorption characteristics of longitudinally grooved square tubes under axial compression by using explicit nonlinear element code LS-DYNA. The grooves are fabricated by stamping process are considered in the following Crash analyzes. From the simulation results, when grooves are introduced on the side walls, the specific energy absorption of conventional tubes can be increased by up to 82.7% and the peak force can be reduced by up to 22.3%. The load versus deflection curve is obtained to find the mean load and the peak load of the thin walled specimen. then their energy absorbed and specific energy absorption were also find to make a note on the composite material formed.

Kh.Fallah Nejadb ,H.Badnavab , H.R.Farhoudib (2012) done process in thin walled structures usually collapse in Eulerian buckling mode under oblique loads. Energy absorption capacity and crush force efficiency of the structure in this type of collapse are low. collapse initiators are used to improve these properties. In this research, effect of collapse initiators on energy absorption characteristics of square tubes under oblique quasi-static loads is investigated both experimentally and numerically. Initiators are in the form of cutting on the tube corner.

Lion Kok Hao,Amir Rdzi Abdul Ghani,Prasetyo Edi,Khairi Yusuf (2007) Non linear finite element code ABAQUS/Explicit was employed to evaluate the energy absorption characteristics of concentric circular tubes subjected to impact in the axial direction. Thin walled circular tube plays a vital role as energy absorber due to its high energy absorption capacity. However, the main drawback of existing tube type energy absorber is the high initial peak load. This work evaluates the capability of concentric circular tubes in reducing the peak load that is exerted to the protected structures and occupants during impact.

Samer F,F.Tarlochan,Pooria Khalili,Hatam Samaka (2005) presents their work using of non linear finite element simulations on the crash behavior and to enhance the energy absorption of the thin walled hexagonal tube subjected to dynamic loading and to decrease the peak load to ensure the occupants safety during front collision.

Wilhelm Rust,Karl Schweizerh of (2002) After discussing general properties of implicit FE analyses using ANSYS and explicit analysis using LS-DYNA it is shown when and how quasi-static limit load analyzes can be performed by a transient analysis using explicit time integration. Then we focus on the remaining benefits of implicit analysis and how a proper combination of ANSYS and LS-DYNA can be used to prepare the transient analysis by common preprocessing and static analysis steps.

R.Velmurugan, R.Muralikannan (2009) Thin walled tubes are used as energy absorbing elements in automobile applications. The circular tube proves to be a popular energy absorber because it provides a reasonably constant operating force which is the prime characteristics of the energy absorber. Square and rectangular tubes are widely used in automobile structures as these cross sections are suitable for welding with other components in the structure and hence highly preferred.

E Ismail (2008) B The structures of the vehicle during the crushing processes or accidents are not only experienced directly or axially collisions but sometimes these structures crushed off-axially. Therfore, it is very crucial things to study whether or not a foam-filled column capable to support the oblique compression forces efficiently and effectively.

III. EXPERIMENTAL DETAILS

3.1 COMPRESSION TESTING

Light-weighting or down-gauging is an important concern for the manufacturers in packaging industries to cut down the cost of production. This can be done by reducing down the volume of the raw materials used in manufacturing. But, it is also true that using less material does not mean that container is of poor quality that usually collapses or fails during their life cycle. To ascertain the quality of the containers such as cans, PET bottles, preforms, plastic containers and related materials can be tested by performing Top Load Testing on these materials. It is one of the highly accurate test methods that accurately determine the integrity and other properties of the container.

The Top Load Tester is designed in compliance with various national and international standard test methods that are provided by different standardization authorities. The integrity, thickness, and quality of the bottles can be tested by measuring the top load strength of the materials. The test is performed on the materials by following a common test compression or top load test method.

3.2 SIZE OF SPECIMEN

Table 3.1 Size of specimen

Bottle description on	Size of specimen in cm
Top & bottom	31
Middle	23
Bottom	19
Full	11

3.3. COMPRESSION TESTING ON SAMPLES

Figure 3.1 Compression test on top and middle

Figure 3.2 Compression test on middle

Figure 3.3 Compression test on bottom

Figure 3.4 Compression test on Full

Table 3.2 Displacement of MBCC at horizontal position

Bottle description on	Velocity					
	4.4 m/s		5.4 m/s		6.3 m/s	
	Before (mm)	After (mm)	Before (mm)	After (mm)	Before (mm)	After (mm)
Height -Y	312	316	312	316.5	312	316.6
Width -X	94	110	94	114	94	117
Depth-Z	94	66.5	94	63	94	60

Table 3.3 Displacement of MBCC at vertical position

Bottle description on	Velocity					
	4.4 m/s		5.4 m/s		6.3 m/s	
	Before (mm)	After (mm)	Before (mm)	After (mm)	Before (mm)	After (mm)
Height-Y	94	94	94	112.5	94	149
Width-X	94	94	94	915	94	745
Depth-Z	312	259.5	312	230	312	214

IV. RESULT AND DISCUSSION

The empty and filled thin walled plastic bottle is examined quasi statically in axial loading on UTM machine. There are two empty specimen which are same dimension 20mm diameter and 200mm length was tested load vs deflection curve was obtained. The deflection between the dimension were neglected with is less than

5%.The area under the curve in the graph is obtained as mean load. The average of the two empty specimens were drawn as a graph to obtain a mean load of deflection or the load the object can absorbed. The load versus deflection curve was obtained using the quasi static loading which is connected with the software which generated the graph according to the real values. The load versus deflection curve was found out for the initial load required to actuate the thin bottle to deform.

4.1 INITIAL COMPRESSION

The Initial load compression between both empty plastic bottle. This initial load actually causes the thin walled plastic bottle to trigger the folding formation and initiate the first folding.

Figure 4.1 Initial compression

The average of empty bottle are taken from the load versus deflection curve. The results are compared together. The parameter which considered here were along with the initial load was working load these results in the energy absorption and specific energy absorption characteristics. As per the experiment the initial value to trigger the regular fold formation the average time required for that is approximately 80sec.From empty fill to the complete filling the initial load required to initiate the displacement of the foam filled thin walled tubes were consistently increasing.

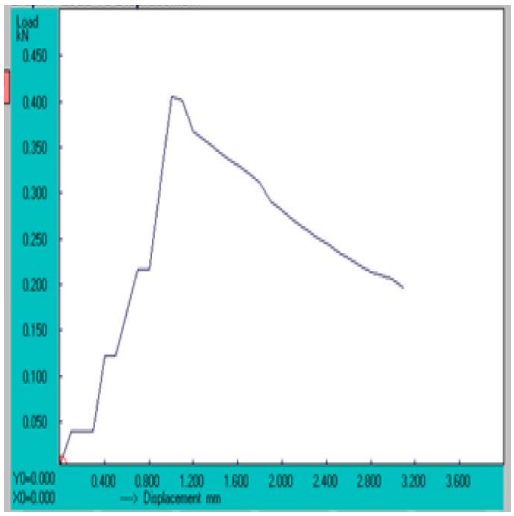


Figure 4.2 Load vs Deflection curve for top and middle

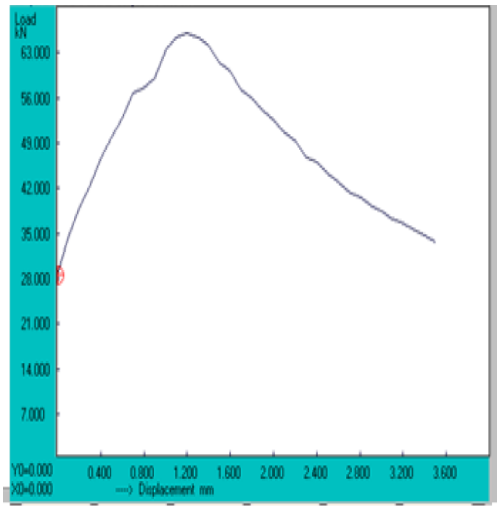


Figure 4.3 Load vs Deflection curve for middle

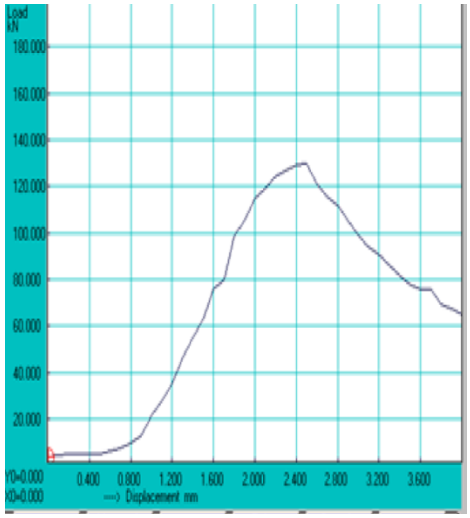


Figure 4.4 Load vs Deflection curve for bottom

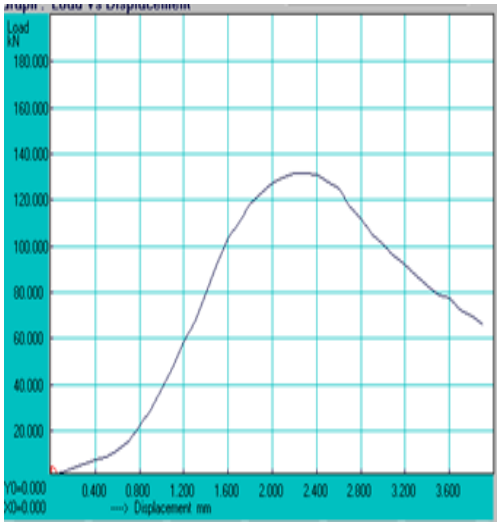


Figure 4.5 Load vs Deflection curve for full

4.2 FINAL COMPRESSION

Here in this work only circular tubes were taken since it has more specific energy absorption the plastic bottle of thin walled tube were tested under quasi static loading and the compressive strength, mean load, peak load and specific energy absorption were find out by means of the experiment and there were consistently increasing as the thickness. These result were tabulated below. So the inclusion of two bottles sections result shows the improve the specific energy absorption characteristics. Even though the there is considerable energy absorption the initial force actually required to trigger the displacement was not too far from the empty tube. Hence the inclusion of the plastic bottle of thin walled tubes were improve the specific energy absorption and cross worthiness of the specimen.

Figure 4.6 Final compression

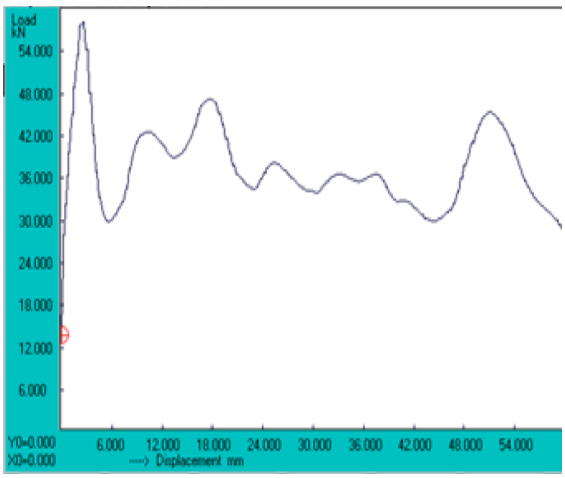


Figure 4.7 Load vs Deflection curve for top and middle

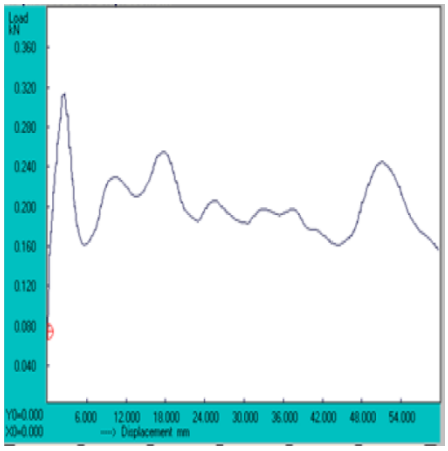


Figure 4.8 Load vs Deflection curve for middle

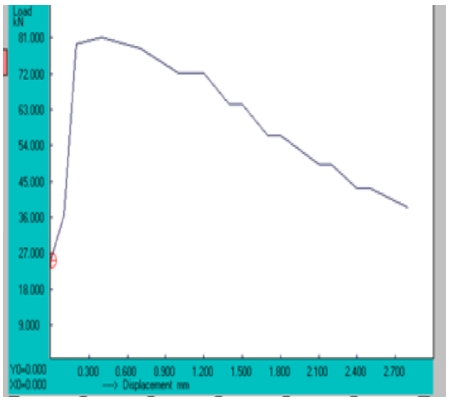


Figure 4.9 Load vs Deflection curve for bottom

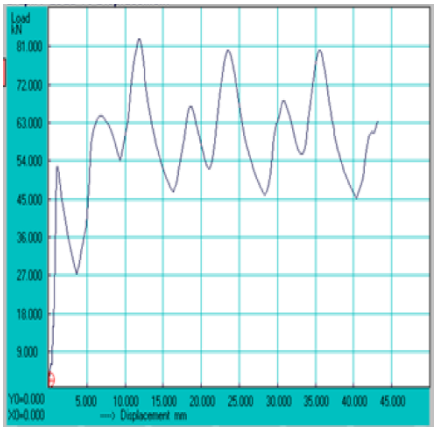


Fig 4.10 Load vs Deflection curve for full

4.3 ANALYSIS OF COMPRESSION TEST

The results are found out by follows:

Specimen	Crush length(mm)	Peak load (N)
Top & middle	35	5.822
Middle	31	6.598
Bottom	27	7.516
Full	25	8.108

Table 4.1 Result for empty bottles

For empty cylinder :

- Average of Peak load = $\frac{5.822+6.598}{2} = 6.21N$
- Compressive strength = $\frac{0.0314+0.0356}{2}$ = 0.0335N/mm^2

For Fully foam cylinder:

- Average of peak load = $\frac{7.516+8.108}{2}$ = 7.812 N
- Compressive strength = $\frac{0.0405+0.0437}{2}$ = 0.0421N/mm^2

Comparison of empty and foam filled cylinder:

- The increase percentage of peak load = $\frac{7.812-6.21}{6.21} \times 100$ = 2.35%
- The increase percentage of compressive strength = $\frac{0.0421-0.0335}{0.0335} \times 100$ = 2.56%

V. CONCLUSION

Sand as filler in bottle increase the strength of PET bottle under impact loading, it potentially as crash cushions (MBBC). Re-use the bottle for crush cushion help to solve the environmental problem. Experimentally, results showed that the MBCC withstand the compressive stress of impact due to high elastic and plastic strain of bottle, beside sand as stress 'reinforcement'.

The deformation occurred in three dimensional, however the critical in impact or direction, i.e. Depth-Z for horizontal position and Height-Z for vertical position. The displacements generally represent the actual collide accident of crash cushion by errant vehicle. The simulation shows that displacement had similar trend with the experimental results.

VI. BIBLIOGRAPHY

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