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Recycling of Scrap Tires

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1. Introduction

As Rachel Louise Carson (1907-1964) successfully noted in her phrase "The human race is challenged more than ever before to demonstrate our mastery - not over nature but of ourselves", we are challenged to find ways to produce more energy, reduce our waste production while minimizing use of limited natural resources. Although recycling of materials has a history going back to the times of Plato BC400 and collecting scrap bronze & metals in Europe in pre-industrial times (Wikipedia, 2011), the demand roar for raw materials in the 19^{th} and 20^{th} centuries with industrial development caused cheaper alternative of reusing scrap material rather than mining them out. Interestingly, 21^{st} century's major driving force has additional items on top of the existing reasons of using recycled material, such as reducing consumption of limited natural resources and lowering carbon dioxide emissions against the greenhouse effect. The increasing demand for energy production and dealing with larger amounts of waste contaminating the nature, forces mankind to find innovative ways to deal with the produced pollutant waste, emit lesser amounts of CO_2, and generate more energy. Recycling of scrap tires turns out to be a perfect match for the recent requirements of the 21^{st} century. This chapter discusses various ways of recycling scrap tires and how they relate to the recent energy, material, and nature needs of our times.

Recycling of scrap tires until the 1960's in the US can be taken as an example; about half of the manufactured automobile tires used to be recycled since only synthetic or natural rubber was used in the tire manufacturing process and tires could have been directly used without major processing. Recycling of used tires was further encouraged by the fact that these materials were also expensive. The increasing use of the synthetic rubber, however, lowered the manufacturing costs and reduced need for recycling. Moreover, the development of steel belted tires in the late 1960's was almost the end of tire recycling since additional processing of tires was needed. Consequently, by 1995, the rate of rubber recycling fell to only 2% [Reschner].

Highway construction industry is a big alternative market for recycling scrap tires. Many studies have been carried out on crumb rubber modified asphalt. In 1995, it was required by all federal states in the U.S. to fund paving projects with tire modified asphalt. After that, the consumption rate of wasted tires in modified asphalt projects was increased, and in some states a maximum recycling rate of 20% was reached [Sheehan]. Other methods to gain the raw material and energy available inside scrap tires are further discussed under each heading below. The outcomes of scrap tire recycling are not only limited by easy access to cost-efficient material such as rubber and steel, but also have positive effects on the environment: Recycling of scrap tires on a global scale can drastically reduce waste yards, soil and atmospheric contamination caused by dump yards and large scale tire fires.

Fig. 1. Scrap tire storage areas and fires.

2. Brief history and production technology of tires

Automotive tires are made of synthetic rubber which is obtained from petroleum. The development of tires was based on improving the performance of natural rubber which is obtained from the liquid latex secreted by certain plants. At the beginning, natural rubber was used to produce waterproof fabrics and to make balls, containers and shoes by Pre-Colombian people in South and Central America. Until the 18th century, Europeans did not make use of rubber except that they utilized it for manufacturing elastic bands and pencil erasers. Joseph Priestley, a founder of the modern study of chemistry, named the substance "rubber" for its use as an eraser (Oven, 2004).

During the 19th century, Charles Goodyear studied on making rubber more resistant to various chemicals. He started his working by mixing rubber with various dry powders, and aimed to find a way to make natural rubber stickier. In 1839, he achieved to obtain the best product by applying steam heat under pressure, for four to six hours at 132 Celsius (270 Fahrenheit) degrees (Goodyear, 2011).

Following the discovery of vulcanization, manufacturers began producing tires from solid rubber which yielded a strong material to resist cuts and abrasions. Although this was a great progress, the tires were too heavy and rigid. In order to decrease vibration and improve traction, Robert W. Thomson, first produced the pneumatic rubber tire which consisted of rubber filled in with air. His idea could not a commercialized since it was introduced too early for its time. John Boyd Dunlop from Ireland, who did not know about Thomson's earlier invention, once more introduced the pneumatic tire to the market in 1888. This time, pneumatic tire caught the public's attention because bicycles were becoming extremely popular and the lighter tire provided a much better ride (Rubberis, 2011).

In early 19th century, manufacturers started producing vehicle tires comprising two parts, i.e., an inner part and an outer part. The inner part, called the inner tube, contained compressed air and the outer part was a casing protecting the inner tube and providing the tire with a better grip. An important element of the outer part were the layers called plies which were made of rubberized fabric cords embedded in the rubber and they were strengthening the casing. They were known as bias-ply tires because the cords in a single ply run diagonally from the beads on one inner rim to the beads on the other rim. The orientation of the cords change from ply to ply so that the cords crisscross each other (Rubbentire, 2011).

The steel-belted radial tires were first produced in 1948 by the Europeans. In those first tires, the ply cords radiate at a 90 degree angle from the wheel rim. Together with this, a belt of steel fabric that wrapped the circumference of the tire reinforced its casing. Radial tire ply cords are composed of nylon, rayon or polyester. The advantages of radial tires include longer tread life, better steering and less rolling resistance. On the other hand, radials have a harder riding quality, and are about twice as expensive as the tires without radials. The production sequence of steel-belted radial tires is briefly illustrated in Fig. 2.

3. Scrap tire disposal related problems

Massive disposal sites of scrap tires is common in many cities of modern times as about 1 scrap tire is produced per person every year. The stored used tires slowly degrade under the effects of solar radiation as well as rusting of steel takes place. Degraded material would slowly contaminate soil and underground water over years. The disposal sites waiting under the sun for extended periods of time might catch on fire either by accident or because of bottles or broken glass focusing sunlight. Tires burn with thick black smoke and heat, quickly spreads over the whole disposal area, and leaves oily residue contaminating the soil. Such fires are difficult to put off and generates significant amount of air pollution.

One of the overseen problems of scrap tire disposal yards is that these areas become breeding places for rodents and mosquitoes. Stagnant water that collects inside tires is a suitable breeding place for mosquitoes. Elimination of scrap tire disposal sites by proper recycling would also have secondary advantages of eliminating disposal related problems.

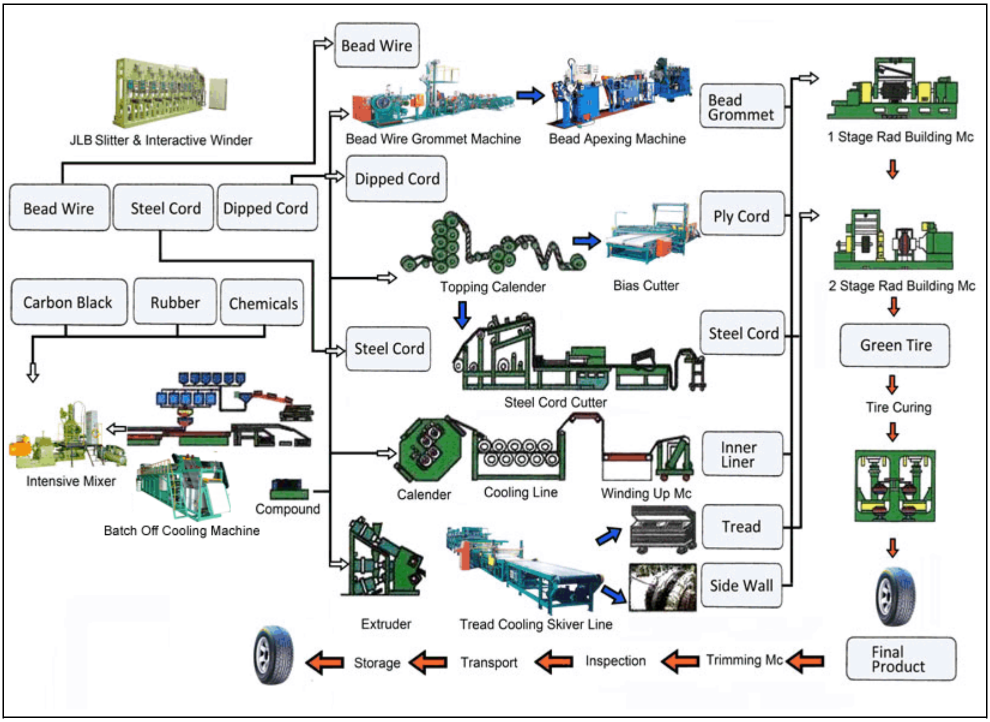

Fig. 2. Tire production line (Courtesy of PHT, Pam Hsiang Trading Co., Ltd.).

4. Major methods and reasons of recycling tires

The recycling of scrap tires may be defined under two different categories: i) using the scrap tires as whole or mechanically modified shapes (in crumps or shredded), and ii) chemical decomposition or separation of scrap tire contents into different materials.

Recycling as-is or after mechanical process has the advantages of directly using scrap tires without major investment. For example, scrap tires can be directly used as boat bumpers at marinas to protect ships from scratching or hitting at the side of wharf (Fig. 3). Similarly, old tires can be placed side by side in half tire shifted pattern for slope stability or under roads for improved stability (Mechanical Concrete®). Ripped tire pieces in large chunks can be directly used as light weight infill material at embankments. Smaller scrap tire pieces (Fig. 4) can be used as mixture in concrete as gravel substitute to improve tensile capacity or in asphalt paved roads for better traction. Smaller crumbs can be bonded together to generate walking or running mats or soft surfaces for playgrounds. Drainage around building foundations, erosion control for rainwater runoff barriers, wetland establishment, crash barriers at sides of race tracks are other uses of scrap tires without much modification.

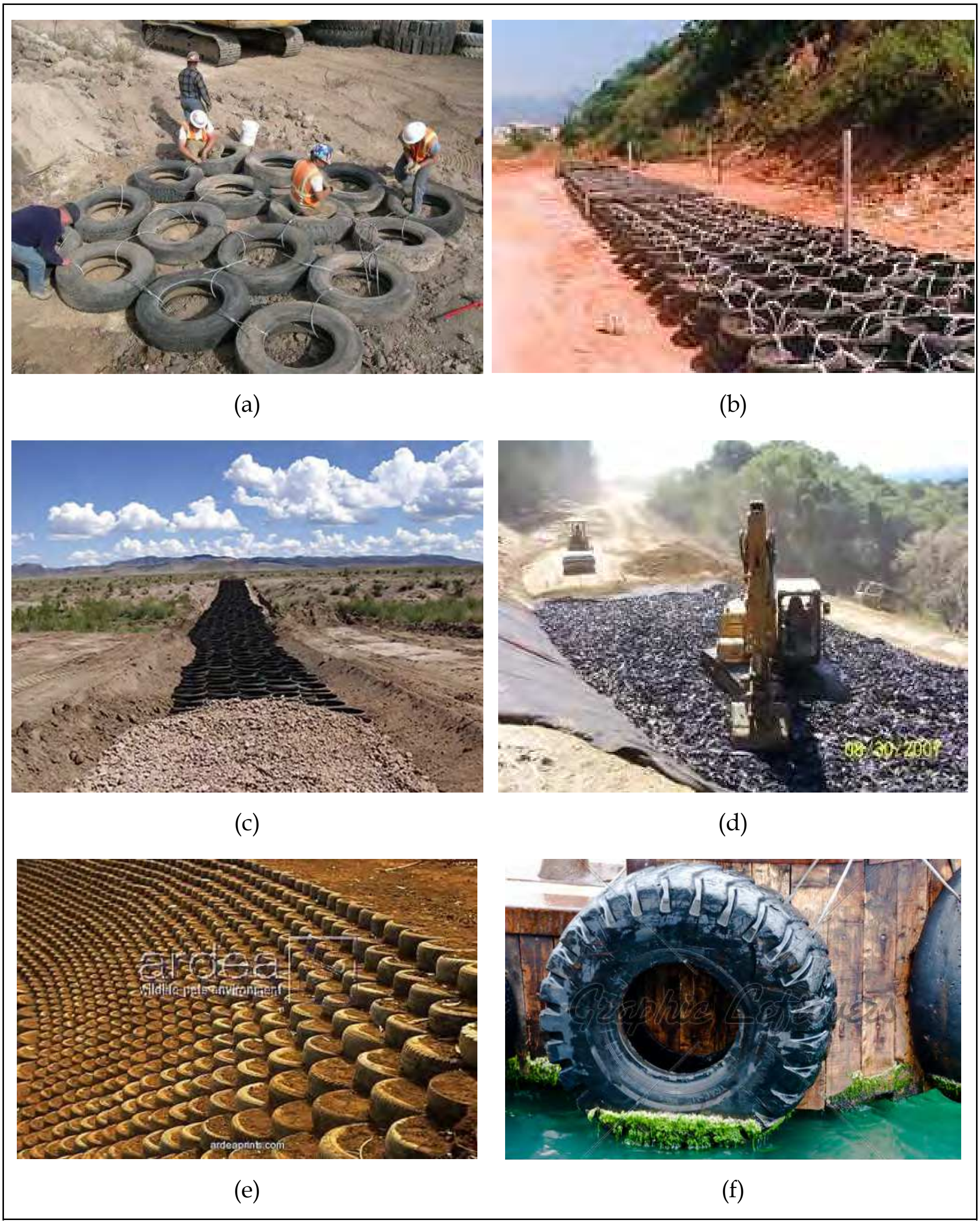

Fig. 3. Innovative uses of scrap tire (a,b,c) road sublayer stability, (d) tire pieces as fill material, (e) slope stability, (f) ship bumper at warf.

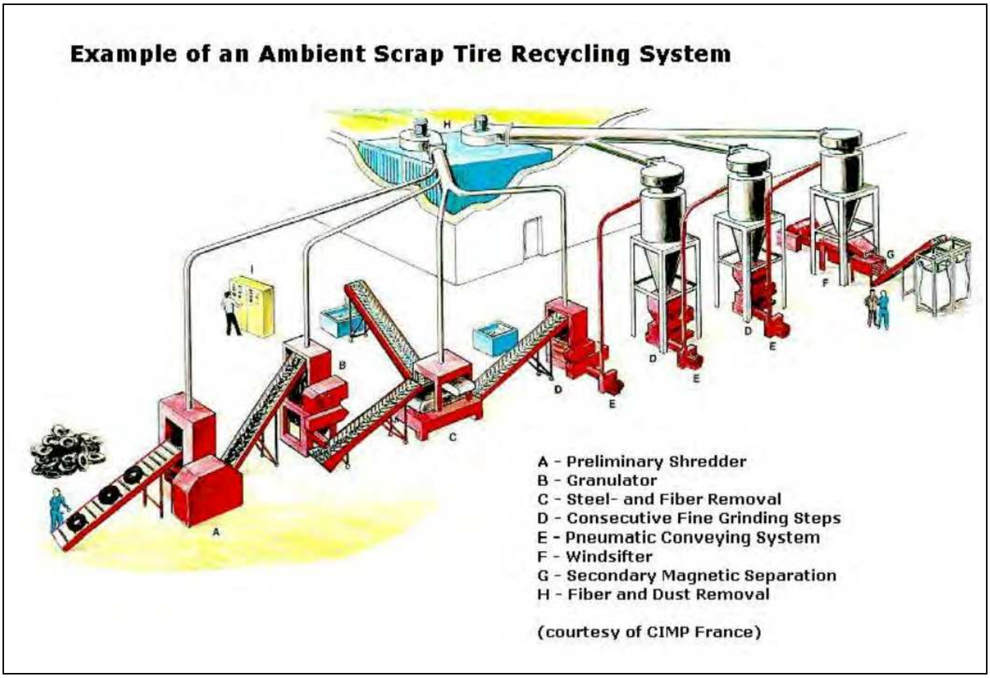

Fig. 4. Example scrap tire recycling system (courtesy of CIMP France).

Recycling of scrap tires at element level that includes some form of chemical decomposition or transformation is different than the mechanical process. Chemical recycling has additional advantages of obtaining well defined building blocks of a tire separately (such as steel wires, natural gas, oil, carbon black, charcoal etc.). The process in a way reverses the manufacturing process and obtains the elements forming a tire backwards. The materials then can be directly sold or used for energy in factories or diesel cars. Alternatively, burning scrap tires may also be included as a chemical process since long chained carbon based molecules are divided into smaller molecules and carbon forms new bounds with oxygen generating heat and carbon dioxide (CO_2). Additionally, hydrogen in the molecules also forms bounds with oxygen forming water (H_2O). Further details of the chemical process can be found in the literature [Murugan et., al., Wikipedia cement kiln].

4.1 Separation of scrap tire contents by thermo-chemical decomposition (Pyrolysis)

Pyrolysis is the common name used for decomposing organic material at elevated temperatures in the absence of oxygen. The oxygen needs to be absent otherwise organic material may burn. Typically the process takes place under pressure and operating temperatures above 430 °C (800 °F). The word is originated from Greek based words "pyr" and "lysis" meaning "fire" and "separating", respectively.

Initial studies on pyrolysis of scrap tires have shown that tire-derived activated carbon, carbon black, boudouard carbon, and fuel gas are obtained. Considering recycling of scrap tires in the road industry couldn't pass much beyond 2% of available scrap tire production; therefore, pyrolysis of scrap tires have enough resources to keep the system running. Gas obtained from the decomposition of scrap tires can directly be used in the pyrolysis process itself; therefore, the production can support the process for energy saving and sustainability. Economical evaluation of the pyrolysis have shown that when tipping fee for collecting scrap tires (F), revenue received from sale of products (R), processing cost for operating the facility (C), cost for transportation of tires (T), cost of tire shredding (S), cost of disposal of waste products (D) are considered with the assumption of 35% char, 20% gas, 45% oils, and using 50% of char burn-off during activation, net profit (P) is found to be USD 1.5/tire (1996 prices) with about 6 million USD/year gross income with investment payback of about 3.3 years (Marek, 1996).

$$P = F + R - C - T - S - D \tag{1}$$

Recent evaluation of scrap tires pyrolysis by Rubber Manufacturers Association in 2009 contains some disheartening comments. Even after the increase in oil prices reaching USD 150 per barrel, the market did not support this technology. Carbon black, charcoal, and waste oils demand would determine if the operation is viable. Although methane gas is produced during the process and can be used to operate the pyrolysis facility, the manufactured amount is not large volumes enough to sell economically. The excessive gas is usually flared off. Pyrolysis produces pyrolytic carbon char, often confused as carbon black.

Although pyrolytic carbon char has a high carbon content, it is dissimilar to carbon black, which is a highly engineered product. Pyrolytic carbon char is said to have limited market as a filler in some materials and as a colouring agent for some plastics after extensive refining and cannot be easily sold in carbon black markets where there is a lot of competition. The liquid hydrocarbon material obtained from pyrolysis unfortunately contains some contamination and may not be suitable to be directly used as diesel fuel or in home heating; it should be either used as waste oil or further refined. As a result, pyrolysis technology today could not reach its intended target yet. If it comes to the choice between either dumping the scrap tires to large storage areas as housing to rodents and mosquitoes every often catching fire and polluting air, soil, water or pyrolysis to melt down the scrap tire stocks while obtaining less than perfect charcoal, gas, and oil to be further refined is a relatively easy choice. It would be easier if the process can become environmentally friendly and profitable without government subvention.

4.2 Burning scrap tires for energy

Another chemical process on scrap tires is burning in high temperature ovens for energy. The burning is usually carried out at thermoelectric power plants and cement production in kiln with clinkers. Although burning a tire usually produces a dark heavy smoke, burning at high temperature furnaces with proper chimney filtering achieves a complete burning without similar smoke. Using scrap tires as fuel is referred as TDF (tire derived fuel) by Scrap Tire Management Council, which was established in 1990 by the North American tire manufacturers.

Cement is produced in high temperature kilns as the raw materials are placed in cement kiln and heated to a temperature range of 1455 to 1510 °C (2650 to 2750 °F). At this temperature the formation of tricalcium silicate (ALITE), the principal compound of portland cement clinker, occurs. A flame temperature of 1925ºC (3500ºF) is necessary to arrive at this temperature. Scrap tires (TDF) can be completely destroyed in cement kilns since the temperatures are extremely high along with a positive oxygen atmosphere and relatively long periods of 4 to 12 seconds at the elevated temperatures ensures the complete combustion of the scrap tire; therefore, incomplete combustion (PICs) or black smoke or odors release is prevented.

When tires are burned in the cement production, the production rates may increase in preheater kilns. This is made possible as the preheater calcination rate is increased in the preheater when burning tires compared to the normal calcination rate when burning coal only. Calcination rates were reported to be increased from 45% to 56% when burning tires instead of burning coal. The carbon dioxide transported by the kiln is reduced when scrap tires are burned in kilns; in this way, additional oxygen be used in the kiln, which allows for the burning of additional clinker (Scrap Tire Management Council, 1992).

Burning scrap tires raises some concerns from environmental point of view since tires include up to 17 heavy metals (e.g., lead, chromium, cadmium, and mercury) in addition to natural rubber from rubber trees, synthetic rubber made from petrochemical feedstocks, carbon black, extender oils, steel wire, other petrochemicals and chlorine. Synthetic rubber often contains the organic chemicals styrene and butadiene. Styrene, a benzene derivative, is a suspected human carcinogen. Butadiene is known to cause cancer in laboratory animals and is a suspected human carcinogen. Studies show a strong association between leukemia and butadiene. Extender oils contain benzene based compounds which cause cancer in laboratory animals but totally burnt at high temperatures. A coal and tire chlorine content comparison showed that tires may contain as much as 2 to 5 times the chlorine level of coal. The coal averaged a chlorine weight of 0.04% and tires showed a weight range of 0.07% to 0.2%. (CIWMBA, 1992). Most of the mentioned toxic material are in low percentages and remain in the burnt wastes or bound inside the cement. Factories and power plants that burn tires must therefore have proper filtering at chimneys in case the pollutants remain in the ashes or emitted gasses (Page, 1980). The non-condensable gases are filtered (using a demister filter) and are passed through a wet scrubbing system to remove acid components by NaOH (4%) injection (Sharma et. al.).

Typical composition of fuel derived from tyres have Sulphur <1.8%, Chlorine 0.07, Mercury <2mg/kg, Cadmium and thallium <79mg/kg, Antimony, arsenic, chromium, cobalt, copper, lead, manganese, nickel, tin and vanadium <640mg/kg while control limits are <2%, <0.2%, <10mg/kg, <80mg/kg, <1200mg/kg, respectively (European Commission 2003, Castle Cement 1996 reported by EA 2001a).

4.3 Use of scrap tires as a whole or after mechanical processing

Scrap tires can be utilized by making use of their sturdy nature and steel reinforcement inside the rubber. The steel wires are usually protected inside the rubber if the rubber is not severely cracked or eroded. Therefore, the tires can survive for long periods of time even under harsh environments such as as a boat bumper in salty sea water, under a paved road with heavy traffic, or constant pressure of unstable slopes (Fig. 3). The tires can be used at the edge of sloped soil to maintain the soil at the edge from washing away with rainwaters. The reduced erosion at the edges help the soil to maintain its slope and integrity for extended periods of time. When tires are placed side by side and connected each other by clamps or wires, they help to keep the soil together as shear locks. The soil or gravel fill are trapped inside the tires, cannot expand due to high strength steel wires inside the tires and stabilizes the medium.

When tires are shredded or crumb size divided, they can be used as mixture to concrete for additional tension material and making lightweight concrete. Also, can be mixed with asphalt for extra traction and tensile capabilities. Smaller size crumbs are used to make children play grounds and running track surface finishing.

4.4 Strengthening structures using scrap tires, structural engineering applications

In a recent study of using scrap tires as confinement material for concrete columns (Abdulmoula and Saatcioglu, 2009), the tires were used as peripheral material to confine concrete. When concrete is axially loaded, it tends to expand defined by Poisson's ratio. If the lateral expansion is prevented, axial compressive strength of concrete is significantly increased. In the mentioned study, a series of concrete columns were cast inside scrap tires which were placed on top of each other. The cylindrical shape formed by carefully and centrally alined pile of scrap tires have also formed a natural form to be easily filled by concrete. Following the strength gain of concrete in 28 days, the steel wires and rims inside the scrap tires served as horizontal confinement for the columns. It was shown both experimentally and analytically that steel-belted tires can be used effectively to confine concrete in reinforced concrete columns. The exterior scrap tire also protects the column and steel reinforcement inside the column from corrosion.

4.4.1 STP scrap tire pads for seismic base isolation

Seismic base isolation is the placement of a laterally flexible system between the footing (ground) and upper structure to isolate earthquake induced seismic forces. The natural vibration periods of the suspended building or structure shifts towards larger values in the response spectrum causing reduction in the forces and accelerations in the suspended building. The accelerations that correspond to the natural period of the structure decrease, therefore the demand of the earthquake on the structure reduces. Inter-storey drifts decrease considerably and the superstructure on isolation system behaves similarly to a rigid body during earthquake motions.

Seismic base isolation systems can be studied in two main groups: elastomer-based and sliding-based systems. Elastomeric bearings are the most common isolators used in the design of seismically isolated structures. Among the most common types of elastomeric isolators are the low-damping rubber with damping ratio (ξ) about 2% to 3%, high-damping rubber (ξ=10%-20%), lead-plug, and the fibre-reinforced elastomeric bearings. The high vertical stiffness of elastomeric bearings is provided by horizontal steel or fiber reinforcement whereas the low horizontal stiffness is provided by flexible laminated rubber layers. Elastomeric-based isolators may be mimicked using pads made out of scrap tires which are called Scrap Tire Pads (STPs).

Since automobile tires are produced by vulcanizing steel mesh and cords with the rubber, when the part that touches the ground is removed from the sidewalls of the tire and piled on top of each other as rectangular rubber sheets, they form an STP. Steel cords inside tire layers have similar effect as the steel layers inside an elastomeric isolator. The terminology used for STP includes; disposed scrap tires (Fig. 6a); a tire ring is the tread part of a tire that touches the ground and is obtained after cutting off the sidewalls of the tire (Fig. 6b). Tire band is the same part after cutting the ring in transverse direction (Fig. 6c). Tire layers are about 0.20m long pieces of scrap tire bands (Fig. 6d). The scrap tire pad, i.e., the STP, is formed when a set of scrap tire layers are placed on top of each other (Fig. 6e).

Although layers forming an STP can be glued together using epoxy, the friction between tire layers is large enough to keep STP layers intact and working together. The mechanical and dynamic properties of various brand STP samples used in this study were obtained using axial compression, static shear, dynamic (impact), and shaking table experiments.

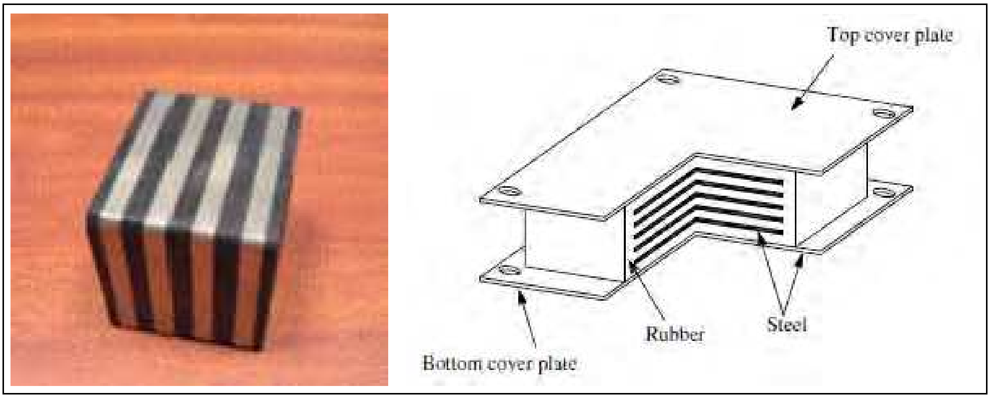

Fig. 5. Seismic isolator, laminated rubber bearing (LRB).

Lateral dynamic tests were conducted on different height of STP specimens and horizontal stiffness values of STPs were found to be linearly decreasing as the number of STP tire layers increased (Fig. 7). The reduction in stiffness with the increase in number of layers was similar to the behaviour of common elastomeric isolators as indicated by Equation 2.

$$K = G \cdot \frac{A}{t_r} \qquad (2)$$

where, K is the stiffness of isolator, G is the shear modulus of isolator material, A is the isolator contact surface area, and t_r is the thickness (height) of the isolator. Nonlinearities in Fig. 7 are observed as more than 8 layers of tire were used, and therefore accepted as an indication of a stability problem. The linear relationship between horizontal stiffness and number of layers (up to 10 layers) implies that the stiffness of STPs can easily be adjusted by changing the number of tire layers. The transverse and the longitudinal direction stiffness graphs are parallel to each other (up to the 10-layer mark) and decline linearly as the

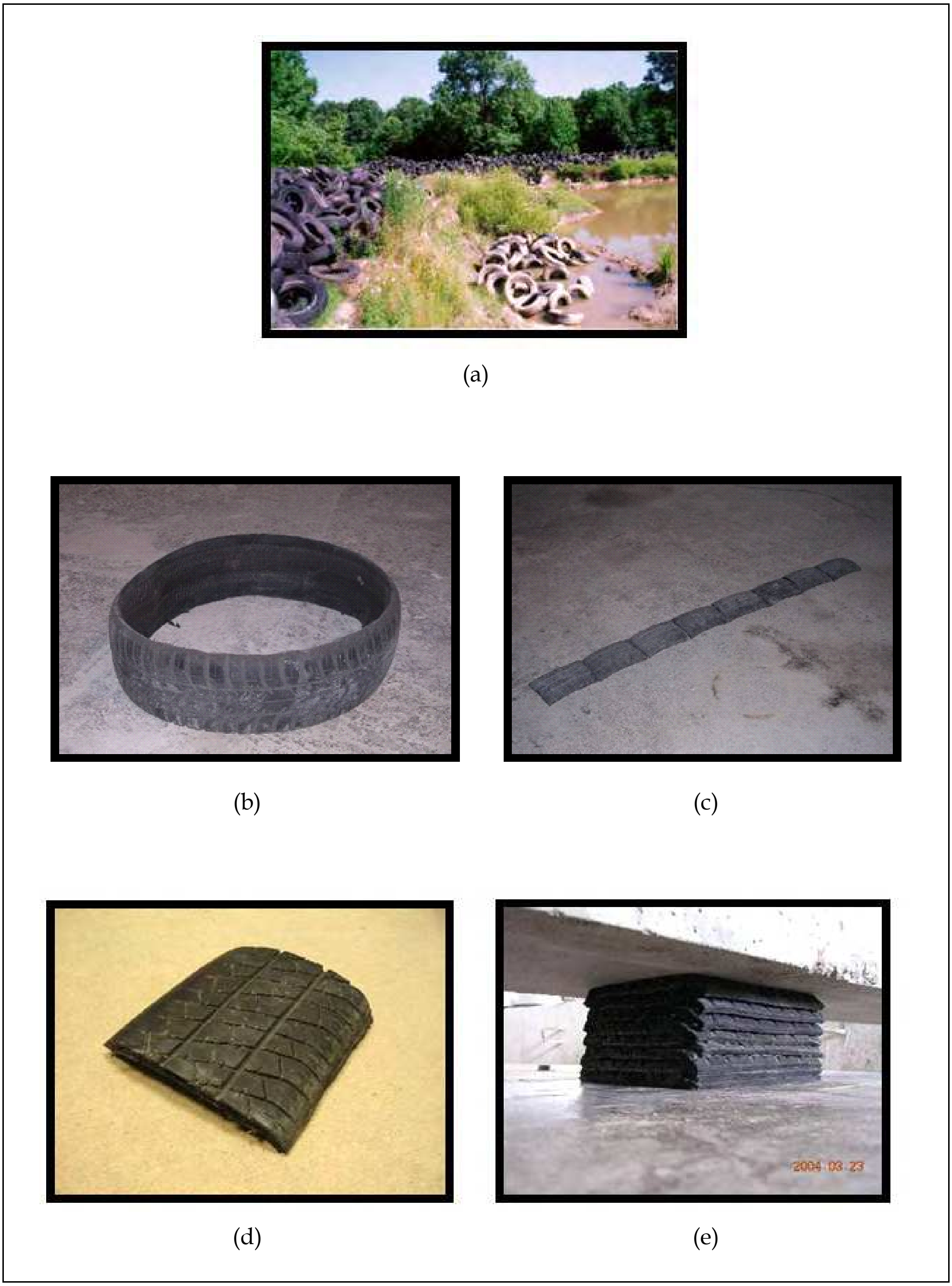

Fig. 6. Scrap a) tire, b) ring, c) band, d) layer, and e) scrap tire pad (STP).

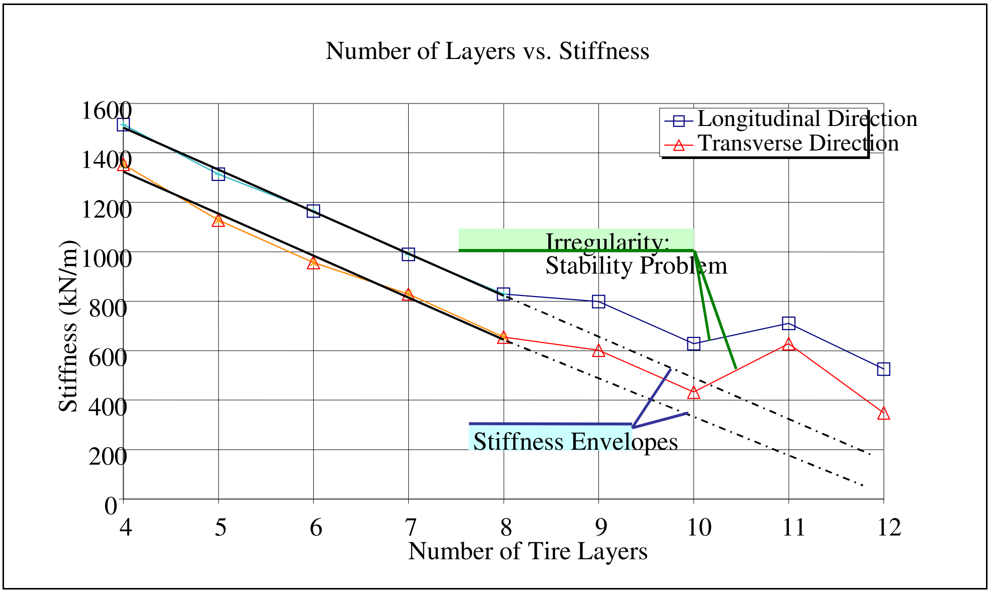

Fig. 7. Stability graph of scrap tire pads (STP).

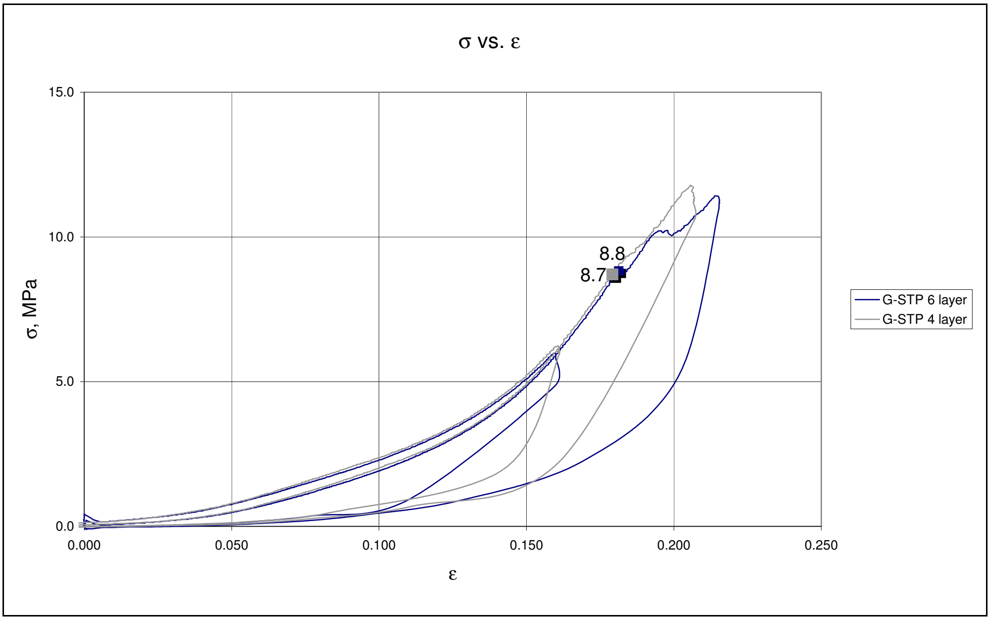

Fig. 8. Stress-strain graph of scrap tire pads (STP) under axial loading.

number of tire layers is increased. The constant 200 kN/m difference between the lateral stiffness terms in the two principle directions is an interesting result and deemed to be a shape factor since the width and length were 0.18m and 0.20m, respectively (Turer, 2008). The axial load capacity of STPs were obtained to be around 8 MPa (Fig. 8), which is relatively low compared to commercially available laminated rubber bearings.

Axial compression tests revealed that the non-linear compressive behavior of STP specimens is close to the compressive behavior of common steel reinforced elastomeric isolators (SREI). The axial compression tests showed that an allowable vertical stress level of 4 MPa for STP specimens can be obtained if a safety factor of 2 is accepted. The free vibration test results showed that the damping values of various STP specimens change between 7% and 14%. For design purposes, taking into account the displacement safety margins, the minimum value of 7% should be accepted as the damping value for the STP specimens. The free vibration tests also showed that, the lateral stiffness of STP specimens can be adjusted by changing the number of tire layers composing the STPs. However, the stability should also be satisfied for higher numbers of tire layers; i.e., larger than 8 layers for 0.18m×0.20m sized STP. The horizontal behavior of STP specimens were determined by conducting static shear tests. Shear modulus values of STP specimens were calculated to be between 0.9 MPa and 1.85 MPa. Relatively high levels of shear modulus values and their dependence on the brand of the tire present difficulty for the design of STPs.

The experimental and analytical program including shaking table tests have shown that STP based base isolation is possible within certain constraints. Softer type of scrap tires, such as winter tires, may be used with additional recycled steel plates placed between each layer would increase the vertical load capacity while maintaining a relatively low horizontal stiffness.

STP based seismic base isolation can be used for rural bridge supports as a low cost and practical material while recycling and reducing pollutants. The STPs would also serve as temperature compensation devices in bridges.

4.4.2 Post-tensioned elastic walls using scrap tires

Post-tensioning is a well-known technique used in modern civil engineering such as light poles and bridge girders spanning relatively larger gaps. The theory is based on applying a compressive stress field on usually a brittle material (such as concrete), which has weak properties under tensile forces. The compressive strength being about 10 times the tensile stress, the structure highly benefits from the even compression field generated by post-tensioning.

In the case of scrap tire based post-tensioning, poor housing in the seismically active zones were targeted. Those houses are usually made of masonry and occupants generally have low income and undereducated. The poor economic and social background of the residents also means that masonry constructions do not receive any engineering services and, therefore, are susceptible to heavy damage or total collapse during earthquakes. Earthquake-induced forces cause masonry houses to collapse in a sudden (brittle) manner. In other words, the disintegration of masonry constructions built from adobe, brick, or stone is very quick and it leads to a total collapse of the roof which is traditionally composed of very heavy earth (usually up to 1 meter (3 feet) thick). The sudden disintegration of walls and collapse of the heavy roof of masonry houses kill the residents instantly not leaving any "life pockets" which might be formed during collapse of reinforced concrete houses. The economically constrained residents living in such houses do not have sufficient resources to build their houses from reinforced concrete. Masonry construction in rural areas is traditional and same inferior construction is repeated since losses during earthquakes are perceived as an act of God. In developing countries, the problem of finding an efficient solution to strengthening masonry houses is further exacerbated by the fact majority of the building stock is generally masonry type.

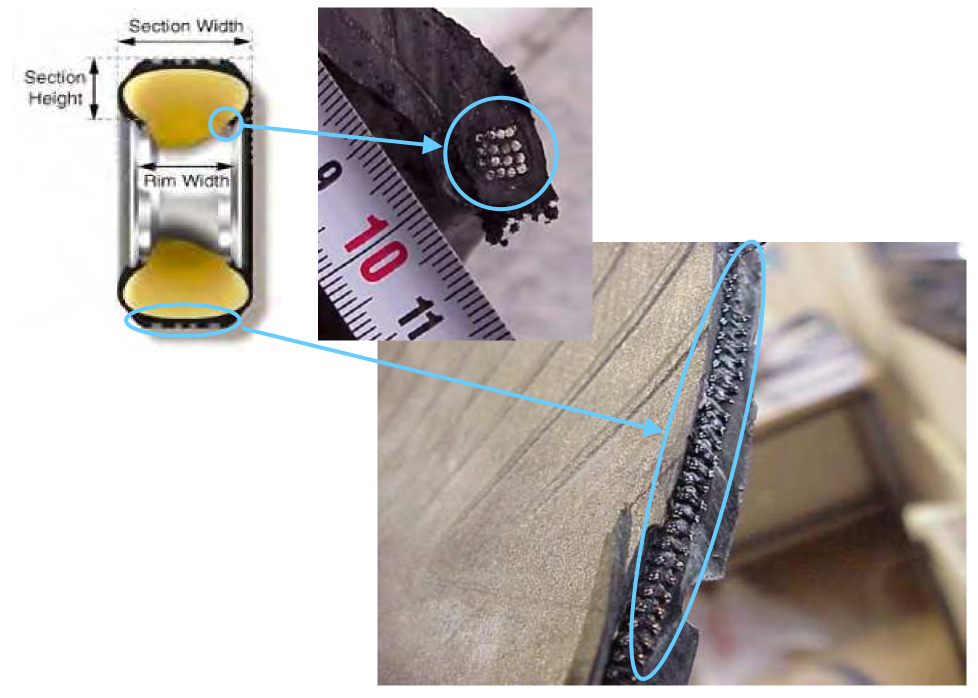

Fig. 9. Typical cross section of a scrap tire.

Implementation of the method is economically affordable and environment-friendly due to the following reasons. First, scrap tires have steel mesh inside with high tensile strength that makes them suitable reinforcement material. Second, except for the low cost of transportation, scrap tires can be obtained free of charge rendering them as low-cost (strengthening) materials. Third, tires can be prepared using simple tools (e.g., a utility knife). Recycling tires has additional advantages preventing waste yards. Finally, the application of scrap tires on walls is simple and easy, and does not require complicated tools and practices. It is believed that the owners of masonry houses in poor countries would be able to implement the strengthening work by themselves since many of them have already built their own houses. Consequently, this will eliminate any workmanship costs thus contributing to the overall affordability and applicability of the strengthening project.

The scrap tire ring test results are obtained in terms of load-displacement curves (Fig. 10). The results indicate that the mean and standard deviation of the ultimate tensile load capacities of scrap tire rings (STRs) were calculated as 133 kN and 32.1 kN. Assuming average weight of a passenger car to be around 12 kN, each single STR can carry more than the weight of 10 cars, which is an amazing performance.

The STRs are placed in the form of chains and tied around the brick walls to generate compression stresses on the masonry wall for post-tensioning. Bolted connections to tie STRs together was used to shorten the distance between tires, in turn, applying force on the system (Fig. 11). The tensile forces generated on the STRs would be in balance with the forces acting on the masonry walls. The walls were tested before and after the post-tensioning application using STRs and performance of the walls were compared for before and after conditions.

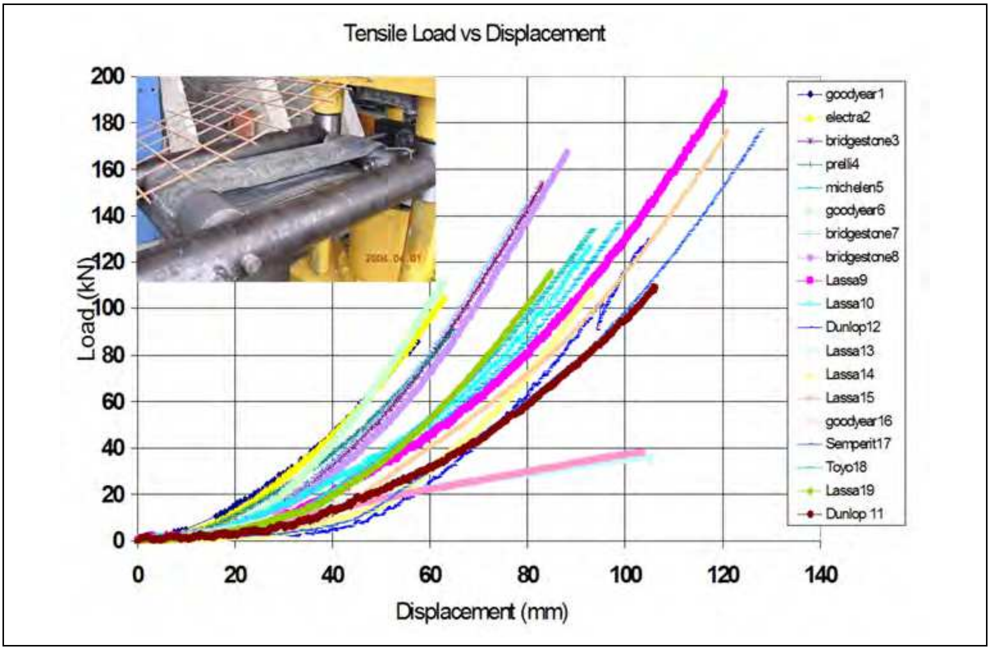

Fig. 10. Load - deflection graph of scrap tire rings (STRs) under axial tension.

The experimental studies showed that the nominal lateral load capacities of the brick walls in out-of-plane direction can be improved up to about 10 times by applying 100 kN (per 0.885m of length) axial post-tensioning force using STR chain and about 16 times using hybrid system. The better improvement ratio of the wall post-tensioned with the hybrid system in the third test could have resulted from higher stiffness associated with the STR chain and/or possibility of having a relatively high unintended initial (nominal) strength of the hybrid test's masonry wall.

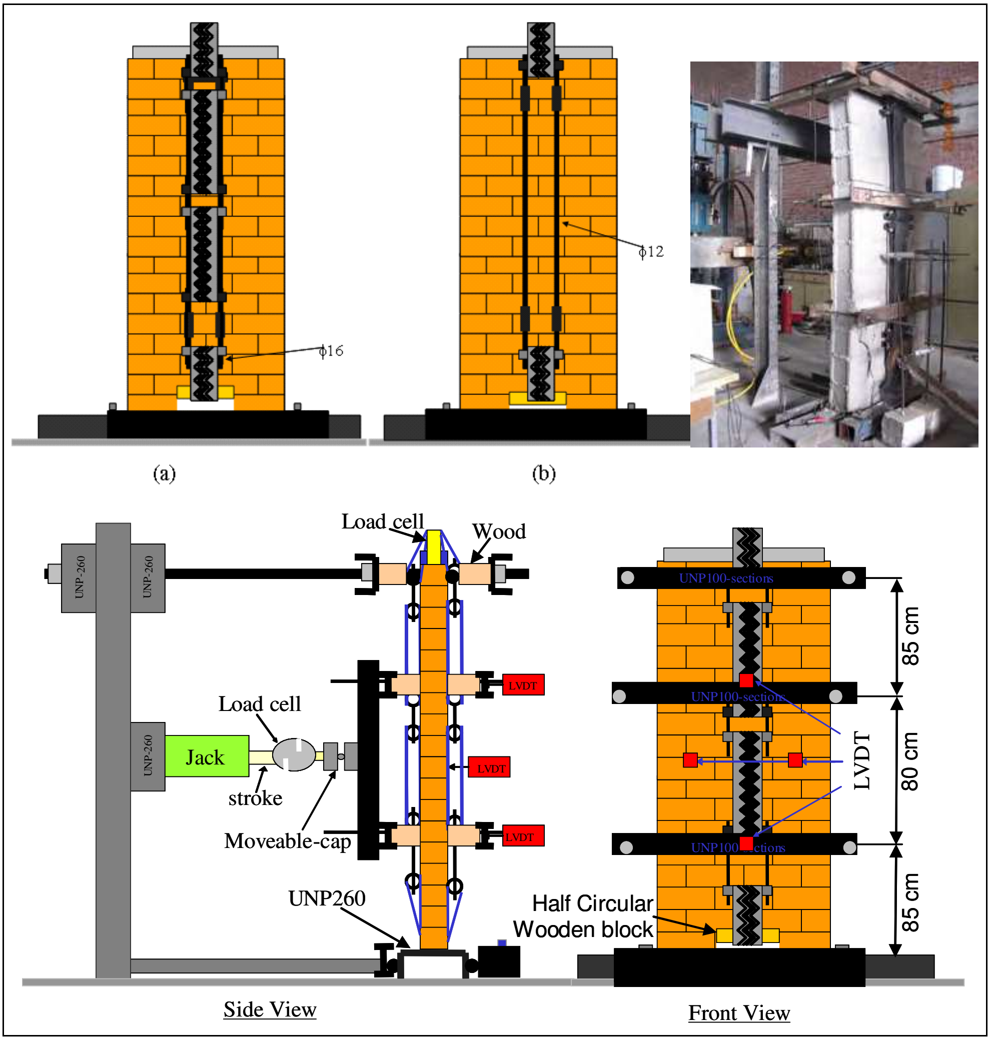

Fig. 11. Application of post tensioning by (a) STR chains, (b) hybrid system, (c) test setup.

5. Conclusions

This chapter illustrated various uses of scrap tires through recycling as a whole, in parts, or after chemically decomposition of materials inside scrap tires. Industrial development brought luxury of cars to our modern lives that produces scrap tires in an increasing rate. As in the cases of other natural resources in the world, we need to learn using less of natural resources while recycling readily available tires by finding ways not to pollute the environment. All cars in the world constantly generating about one scrap tire per person every year causes scrap tires generation in the order of billions on a global scale. The ideal solution would have been recycling each scrap tire to a brand new tire, since when someone throws away a used tire has to buy a new tire.

Using tires on slope stability and land fill, inside asphalt and concrete is not adequately spread enough and in right quantities to use all manufactured tires. Structural uses of scrap tires remain to be at limited instances either enforced by government such as in the case of roads and pavements or experimentally sparse and rare mostly applied by good intentioned environmentalists or low-budgeted projects. Chemical decomposition using pyrolysis is a highly promising approach; however, could not quite reach its full potential yet. On the other hand, burning scrap tires at high temperature furnaces at cement producing kilns and thermo electric power plants as fuel is quite efficient and widely used. Provided that chimney filtering is defined by regulations and rules are properly enforced from toxic material emissions, scrap tire burning seems to be a good source of recycling and transforming otherwise useless and harmful discarded material into energy.

6. Acknowledgment

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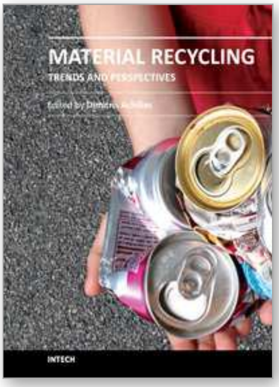

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The presently common practice of wastes' land-filling is undesirable due to legislation pressures, rising costs and the poor biodegradability of commonly used materials. Therefore, recycling seems to be the best solution. The purpose of this book is to present the state-of-the-art for the recycling methods of several materials, as well as to propose potential uses of the recycled products. It targets professionals, recycling companies, researchers, academics and graduate students in the fields of waste management and polymer recycling in addition to chemical engineering, mechanical engineering, chemistry and physics. This book comprises 16 chapters covering areas such as, polymer recycling using chemical, thermo-chemical (pyrolysis) or mechanical methods, recycling of waste tires, pharmaceutical packaging and hardwood kraft pulp and potential uses of recycled wastes.

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