CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

India is a developing country, it proposes multipurpose development projects. Every budget proposal involves large construction of roads, bridges, dams, irrigation schemes, public health engineering schemes, educational buildings and residential buildings etc. all these construction schemes demand optimum and efficient use of construction resources. Most of the modern heavy constructions require huge quantity of cement concrete incurs depletion of natural resources such as river sand and rock strata. Cost of river sand and crushed rock particles is rapidly increasing because of inadequate raw materials and rise of transport cost due to the hike in fuel price and other inputs. Further mining of river sand causes severe environmental damage by lowering ground water table and disintegration of rock strata causes landslide and earthquake. This emerging problem obliges contemporary material usage to balance the ecology. In this essence the abundant availability of waste tyre rubber can be utilized as an effective replacement for natural aggregate which will be beneficial for both circumstances. Hence this research project investigates the use of waste tyres in various aspects of construction. There has been a few number of rubber based concrete projects developed in all the corners of Civil Engineering. A critical review of the existing literature on the utilization of waste rubber is presented in the following areas:
i) Civil Engineering Applications of Scrap (Waste) Tyres

ii) Waste Tyres in Road Construction

iii) Waste Tyres in Concrete

iv) Waste Tyres in Hollow Blocks

v) Applications and Advantages of Tyre Rubber Aggregate Concrete (TRAC)

2.2 CIVIL ENGINEERING APPLICATIONS OF WASTE TYRES

Scrap tyre chips and their granular parts such as ground rubber and crumb rubber; have been used in a number of Civil Engineering applications. Tyre chips which is roughly shredded into 2.5 to 30 cm lengths have been researched extensively as lightweight fill for embankments and retaining walls, but it has also been used as drainage layers for roads and in septic tank leach fields (Humphrey 1999).

According to Humphrey (1999), some of the advantageous properties of tyre chips include low material density, high bulk permeability, high thermal insulation, high durability, and high bulk compressibility. In many cases, scrap tyre chips may also represent the least expensive alternative to other fill materials. Crumb rubber has been successfully used as an alternative aggregate source in both asphalt concrete and PCC. This waste material has been used in several engineering structures like highway base-courses, embankments, etc.

2.2.1 Sub grade Insulation for Roads

Excess water is released when sub grade soils thaw in the spring. Placing a 15 to 30 cm thick tyre shred layer under the road cab prevents the
sub grade soils from freezing in the first place. In addition, the high permeability of tyre shreds allows water to drain from beneath the roads, preventing damage to road surfaces (ASTM D6270-98).

2.2.2 Sub grade Fill and Embankments

Tyre shreds can be used to construct embankments on weak, compressible foundation soils. Tyre shreds are viable in this application due to their light weight. For most projects, using tyre shreds as a lightweight fill material is significantly a cheaper alternative (Tyres Manufacture's Association 2003).

2.2.3 Backfill for Walls and Bridge Abutments

Tyre shreds can be useful as backfill for walls and bridge abutments. The weight of the tyre shreds reduces horizontal pressures and allows for construction of thinner, less expensive walls. Tyre shreds can also reduce problems with water and frost build-up behind walls because tyre shreds are free draining and provide good thermal insulation.

Recent research has demonstrated the benefits of using tyre shreds in backfill for walls and bridge abutments. (Tyres Manufacture's Association 2003).

2.2.4 Landfills

Landfill construction and operation is a growing market application for tyre shreds. Scrap tyre shreds can replace other construction materials that would have to be purchased. Scrap tyres may be used as a lightweight backfill in gas venting systems, in leachate collection systems, and in operational liners. They may also be used in landfill capping and closures, and as a material for daily cover. (Tyres Manufacture's Association 2003).
2.2.5 Other Uses

Fattuhi and Clark (1996) have suggested that TRAC could possibly be used in the following areas:

i) Where vibration damping is needed, such as in foundation pad for rotating machinery and in railway stations,

ii) For trench filling and pipe bedding, pile heads, and paving slabs, and

iii) The resistance against impact and blast is required such as in railway buffers, jersey barriers (a protective concrete barrier used as a highway divider and a means of preventing access to a prohibited area) and bunkers. TRAC, because of its light unit weight (density ranges from 900 to 1600 kg/m$^3$) may also be suitable for architectural applications such as: (1) Nailing concrete, (2) False facades, (3) Stone backing and (4) Interior construction.

Topcu and Avcular (1997) suggested that TRAC may be used in highway construction as: (1) Shock absorber in sound barriers, (2) Sound boaster (which controls the sound effectively), and (3) in buildings as an earthquake shock-wave absorber. However, research is needed before definite recommendations can be made.

Pierce and Blackwell (2003) highlighted the use of crumb rubber in flowable fill. In their investigation, they replaced sand with crumb rubber to produce flowable fill. Experimental results indicated that crumb rubber can be successfully used to produce a lightweight (1.2–1.6 g/cm$^3$) flowable fill which can able to excavate at 28-day compressive strengths ranging from 0.02 to 0.09 MPa. Their research concluded that a crumb rubber-based flowable fill
can be used in a substantial number of construction applications, such as bridge abutment fills, trench fills and foundation fills.

The following are also some examples of using scrap tyres:

- Playground surface material.
- Gravel substitute.
- Drainage around building foundations and building foundation insulation.
- Erosion control/rainwater runoff barriers (whole tyres).
- Wetlands/marsh establishment (whole tyres).
- Crash barriers around race tracks (whole tyres).
- Boat bumpers at marinas (whole tyres).
- Artificial reefs (whole tyres).

2.3 WASTE TYRES IN ROAD CONSTRUCTION

The use of rubber waste shredded tyres in road construction was studied in the past by many researchers. Chunk rubber from recycled tyres was used as a road construction material; the feasibility of using large rubber chunks from shredded tyres as aggregates in cold-mixes for road construction was investigated (Hossain et al 1995). The research was directed toward development of a chunk rubber asphalt concrete mix design for low volume road construction using local aggregate, shredded tyre rubber chunks and a cationic emulsion. A set of mixes using different combinations of chunk rubber content, emulsion content and fly ash content were tested. Based on the Marshall Stability results, some of these mixes appeared to be suitable as binder courses or stabilized drainable bases for low volume roads (Design of Normal Concrete Mixes 1975).
Amirkhanian et al (1994) has tested the use of crumb rubber-asphalt concrete in road pavement at several areas to determine the economic and engineering feasibilities of these materials. They concluded that the road section paved using wet process has been performing satisfactorily to this point. The test result coring that it indicates the asphalt rubber mixture is producing higher wet indirect tensile strength and tensile strength ratios than control mixture. Larson (2003) found that crumb rubber in concrete could reduce thermal expansion, contraction, drying shrinkage, ride noise, freeze-thaw damage, brittleness and weight in road pavements.

A research in construction of a test embankment using a sand–tyre shred mixture as fill material was made (Sherwood 2005). Use of tyre shreds in construction projects, such as highway embankments, is becoming an accepted way of beneficially recycling scrap tyres. Another research work was made for the determination of the optimum conditions for tyre rubber in asphalt concrete (Ahmed 1993, Ahmed and Lovell 1992). Tyre rubber waste recycling in self-compacting concrete, the rubber waste tyre was used in this kind of concrete and the mechanical and micro structural behavior were investigated in the study.

2.4 WASTE TYRE RUBBER IN CONCRETE

2.4.1 Fresh Concrete Properties

Previous investigations have shown that the Tyre Rubber Aggregate Concrete (TRAC) possesses good aesthetics, acceptable workability and a smaller unit weight than that of ordinary concrete.

2.4.1.1 Aesthetics

Eldin and Senouci (1993) reported that TRAC showed good aesthetic qualities. The appearance of the finished surfaces was similar to that
of ordinary concrete and surface finishing was not problematic. However, the authors reported that mixes containing a high percentage of larger sized rubber aggregate required more work to smooth the finished surface. They also found that the colour of rubberized concrete did not differ noticeably from that of ordinary concrete.

2.4.1.2 Workability

Khatib and Bayomy (1999) investigated the workability of TRAC. They observed a decrease in slump with increased rubber aggregate content by total aggregate volume. Their results show that for rubber aggregate contents of 40% by total aggregate volume, the slump was close to zero and the concrete was not workable by hand. Such mixtures had to be compacted using a mechanical vibrator. Mixtures containing fine crumb rubber were, however, more workable than mixtures containing either coarse rubber aggregate or a combination of crumb rubber and tyre chips.

Siddique and Naik (2004) and Senthil Kumaran et al (2008) presented an overview of some of the research published regarding the use of scrap tyres in the manufacture of concrete. Studies indicate that good workable concrete mixtures can be made with scrap-tyre rubber.

Eldin and Senouci (1992) reported that, in general the TRAC batches showed acceptable performance in terms of ease of handling, placement and finishing. However, they found that increasing the size or percentage of rubber aggregate decreased the workability of the mix and subsequently caused a reduction in the slump values obtained. They also observed that the size of the rubber aggregate and its shape (mechanical grinding produces long angular particles) affected the measured slump. The slump values of mixes containing long, angular rubber aggregate were lower than those for mixes containing round rubber aggregate (cryogenic grindings).
Round rubber aggregate has a lower surface/volume ratio. Therefore less mortar will be needed to coat the aggregates, leaving more to provide workability. They suggested that the angular rubber aggregates form an interlocking structure resisting the normal flow of concrete under its own weight; hence these mixes show less fluidity. It is also possible that the presence of the steel wires protruding from the tyre chips also contributed to the reduction in the workability of the mix.

2.4.1.3 Concrete Density

The replacement of natural aggregates with rubber aggregates tends to reduce the density of the concrete. This reduction is attributable to the lower unit weight of rubber aggregate compared to ordinary aggregate. Previous studies have found that the unit weight of TRAC mixtures decreases as the percentage of rubber aggregate increases. Topcu (1995) included low volumes of rubber aggregate during the preparation of the concrete, while Rostami et al (1993) appeared to use larger volumes of rubber aggregate. Their results indicated that concrete densities were reduced to 87% and 77% of their original values, respectively, when the maximum amounts of rubber aggregate were used in the investigations.

Eldin and Senouci (1993) reported a reduction in density of, up to 25% when ordinary aggregate was replaced by coarse rubber aggregate. Li et al (1998) found that the density of TRAC was reduced by around 10% when sand was replaced by crumb rubber to the amount of 33% by volume.

2.4.1.4 Air Content

Ali et al. (1993) reported that when rubber aggregate was added to the concrete, the air content increased considerably (up to 14%). Fedroff et al (1996) and Khatib and Bayomy (1999) observed that the air content increased
in TRAC mixtures with increasing amounts of rubber aggregate. Although no air-entraining agent (AEA) was used in the TRAC mixtures, higher air contents were measured as compared to control mixtures made with an AEA (Fedroff et al. 1996).

The higher air content of TRAC mixtures may be due to the non-polar nature of rubber aggregates and their ability to entrap air in their jagged surface texture. When non-polar rubber aggregate is added to the concrete mixture, it may attract air as it repels water. This increase in air voids content would certainly produce a reduction in concrete strength, as does the presence of air voids in plain concrete (Benazzouk et al. 2007).

Since rubber has a specific gravity of 1.14, it can be expected to sink rather than float in the fresh concrete mix. However, if air gets trapped in the jagged surface of the rubber aggregates, it could cause them to float (Nagdi 1993). This segregation of rubber aggregate particles has been observed in practice.

2.4.2 Hardened Properties

Several studies had been carried out to describe the use of tyre rubber aggregate in concrete. Results had indicated about the size, proportions and surface texture of rubber particles that noticeably affect the compressive strength of rubber concrete mixtures.

Goulias et al (1998) conducted an experimental study incorporating crumb rubber, as fine aggregate with Portland cement. Test results showed modifications in the brittle failure of concrete, which indicates that rubber concrete specimens exhibited higher ductility performance than normal concrete. Results showed large deformation without full disintegration of concrete.
Chou et al (2007) investigated Rubber replaced concrete for various applications and has shown promising results. The addition of rubber particles leads to the degradation of physical properties, particularly, the compressive strength of the concrete. Chung et al (1999) introduced rubber concrete using waste rubber using the dry process. The compressive strength of rubber concrete was about 89 MPa and the Poisson’s ratio, which is the ratio of compressive-to-tensile strength, was 5.5%.

Eldin and Senouci (1993) conducted experiments to examine the strength and toughness of rubberized concrete mixtures. Three sets of experiments were performed, the first set using coarse rubber aggregate (chipped tyres) of 19-38 mm size and the second and third sets using smaller diameter chips of 6 mm and 2 mm respectively. The results found that the specimen containing rubber when loaded in compression exhibits more gradual failure, either of a splitting (for coarse rubber aggregate) or a shear mode (for fine crumb rubber).

Norman (1992) used carbon black as filler in rubber concrete and found the increase in structural flexibility. Test results show significant improvement in the results of elongation, modulus of elasticity, hardness and tensile strength of the rubber concrete. The results shows increase in tensile strength, elongation varies from 440% – 730% for various carbon blacks. Fairburn and Larson (2001) investigated the use of concrete derived from shredded rubber from old tyres for resurfacing a cracked pavement. He found that the concrete was more slip resistant, highly elastic, lighter in weight, and could be used for fireproofing and insulation.

Toutanji (1996) conducted experiments to investigate the effect of the replacement of coarse aggregate by rubber aggregate. Four different contents of rubber aggregate with a maximum size of 12.7 mm were used to replace the coarse aggregate at 25, 50, 75 and 100% by volume and
discovered that the incorporation of the rubber aggregates in concrete produced a reduction in compressive strength of up to 75% and a significantly smaller reduction in flexural strength of up to 35%. The reduction in both strengths increased with increasing the rubber aggregate content. It is observed that the specimens containing rubber aggregate exhibited a ductile mode of failure as compared to the control specimens.

In Biel and Lee (1996) used recycled tyre rubber in concrete mixes made with magnesium oxychloride cement, where the aggregate was replaced by fine crumb rubber up to 25% by volume. The results of compressive and tensile strength tests indicated that there is better bonding when magnesium oxychloride cement is used. The researchers discovered that structural applications could be possible if the rubber content is limited to 17% by volume of the aggregate.

Schimizze (1994) developed two TRAC mixes using fine rubber granulars in one mix and coarse rubber granulars in the second. While these two mixes were not optimized and their design parameters were selected arbitrarily, their results indicate a reduction in compressive strength of about 50% with respect to the control mixture. The elastic modulus of the mix containing coarse rubber granular was reduced to about 72% of that of the control mixture, whereas the mix containing the fine rubber granular showed a reduction in the elastic modulus to about 47% of that of the control mixture. The reduction in elastic modulus indicates higher flexibility, which may be viewed as a positive gain in rubberized PCC (RPCC) mixtures used as stabilized base layers in flexible pavements.

Topcu (1995) investigated the effect of particle size and content of tyre rubbers on the mechanical properties of concrete. The researcher found that, although the strength was reduced, the plastic capacity was enhanced significantly.
Khatib et al (1999) concluded that RPCC mixtures can be made using ground tyre in partial replacement by volume of CA and FA. Based on the workability, an upper level of 50% of the total aggregate volume may be used. Strength data developed in their investigation (compressive and flexural) indicates the systematic reduction in the strength with the increase of rubber content. From a practical viewpoint, rubber content should not exceed 20% of the aggregate volume due to severe reduction in strength. Once the aggregate matrix contains nontraditional components such as polymer additives, fibers, iron slag, and other waste materials, special provisions would be required to design and produce these modified mixes. At present, there are no such guidelines on how to include scrap tyre particles in PCC mixtures.

Segre and Joekes (2000) worked on the use of tyre rubber particles as addition to cement paste. In their work, the surface of powdered tyre rubber (particles of maximum size 35 mesh, 500 m) was modified to increase its adhesion to cement paste. Low-cost procedures and reagents were used in the surface treatment among that sodium hydroxide (NaOH) solution gave the best result. The particles were surface-treated with NaOH saturated aqueous solutions for 20 minutes before using them in concrete. The test results showed that the NaOH treatment enhances the adhesion of tyre rubber particles to cement paste, and mechanical properties such as flexural strength and fracture energy were improved with the use of tyre rubber particles as addition instead of substitution for aggregate. The reduction in the compressive strength (33%) was observed, which is lower than that reported in the literature.

Lee et al (1998) developed “tyre-added latex concrete” to incorporate recycled tyre rubber as a part of concrete. Crumb rubber from used tyres was used in tyre-added latex concrete (TALC) as a substitute for
fine aggregates or styrene–butadiene rubber (SBR) latex while maintaining the same water cementitious materials ratio. TALC showed higher flexural and impact strengths than those of Portland cement, latex modified concrete and rubber added concrete. TALC showed its potential as a viable construction material, that is less brittle than other types of concrete.

Gregory Grrick (2004), showed the analysis of waste tyre modified concrete used 15% by volume of coarse aggregate when replaced by waste tyre as a two phase material as tyre fiber and chips dispersed in concrete mix. The result is that there is an increase in toughness, plastic deformation, impact resistance and cracking resistance. But the strength and stiffness of the rubberized sample were reduced. The control concrete disintegrated when peak load was reached while the TRAC had considerable deformation without disintegration due to the bridging caused by the tyres. The stress concentration in the rubber fiber modified concrete is smaller than that in the rubber chip modified concrete. This means the rubber fiber modified concrete can bear a higher load than the rubber chip modified concrete before the concrete matrix breaks.

Kamil et al (2004), analyzed the properties of Crumb Rubber Concrete, The unit weight of the CRC mix decreased approximately 6 pcf for every 50 lbs of crumb rubber added. The compressive strength decreased as the rubber content increased. Part of the strength reduction was contributed to the entrapped air, which increased with the rubber content. Investigative efforts showed that, the strength reduction could be substantially reduced by adding a de-airing agent into the mixing truck just prior to the placement of the concrete.

Guoqiang Li (2004) conducted investigation on chips and fibers. The tyre surfaces are treated by saturated NaOH solution and physical anchorage by drilling hole at the centre of the chips were also investigated
and they concluded that fibers perform better than chips. NaOH surface treatment does not work for larger sized tyre chips using physical anchorage has some effect.

A systematic experimental study was performed recently for improving strength and toughness of Rubber Modified Concrete (RMC) (Li et al 2004). Two types of rubber particles of different sizes (large and small) were used to study the size effect on mechanical properties of RMC. Result of tension test, fatigue test, and ultrasound velocity test showed that the RMC has higher energy dissipation capacities than regular concrete. The failure modes of the RMC indicate that the RMC samples can withhold very large deformation and still keep their integrity.

Waste tyre steel beads were also used in PCC. The experimental results indicate that although the compressive strength is reduced when steel beads are used, the toughness of the material greatly increases. Moreover, the workability of the mixtures fabricated was not significantly affected (Bignozzi and Sandrolini 2006)

2.4.3 Toughness and Impact Resistance

Tantala et al (1996) investigated the toughness (toughness is also known as energy absorption capacity and is generally defined as the area under load deflection curve of a flexural specimen) of a control concrete mixture and TRAC mixtures with 5% and 10% buff rubber by volume of coarse aggregate. They reported that toughness of both TRAC mixtures was higher than the control concrete mixture. However, the toughness of TRAC mixture with 10% buff rubber (2 to 6 mm) was lower than that of TRAC with 5% buff rubber because of the decrease in compressive strength. Based on their investigations on use of rubber shreds (having two sizes which were, nominally, 5.5 mm to 1.2 mm and 10.8 mm to 1.8 mm) and granular (about 2
mm in diameter) rubber in mortar, Raghavan et al (1998) reported that mortar specimens with rubber shreds were able to withstand additional load after peak load. The specimens were not separated into two pieces under the failure flexural load because of bridging of cracks by rubber shreds, but specimens made with granular rubber particles broke into two pieces at the failure load. This indicates that post-crack strength seemed to be enhanced when rubber shreds are used instead of granular rubber.

Khatib and Bayomy (1999) reported that as the rubber content is increased, TRAC specimens tend to fail gradually and failure mode shape of the test specimen is either a conical or columnar (conical failure is gradual, whereas columnar is more of shreds having two sizes which were, nominally, 5.5 mm to 1.2 mm and 10.8 mm to 1.8 mm (length diameter) sudden failure). At a rubber content of 60%, by total aggregate volume, the specimens exhibited elastic deformations, which the specimens retained after unloading.

Eldin and Senouci (1993) demonstrated that the failure mode of specimens containing rubber particles was gradual as opposed to brittle. Biel and Lee (1998) reported that failure of concrete specimens with 30, 45, and 60% replacement of fine aggregate with rubber particles occurred as a gradual shear that resulted in a diagonal failure, whereas failure of plain (control) concrete specimens was explosive, leaving specimens in several pieces.

Goulias and Ali (1997) found that the dynamic modulus of elasticity and rigidity decreased with an increase in the rubber content, indicating a less stiff and less brittle material. They further reported that dampening capacity of concrete (a measure of the ability of the material to decrease the amplitude of free vibrations in its body) seemed to decrease with an increase in rubber content. However, Topcu and Avcular (1997)
recommended the use of rubberized concrete in circumstances where vibration damping is required.

Similar observations were also made by Fattuhi and Clark (1996), and Topcu and Avcular (1997) reported that the impact resistance of concrete increased when rubber aggregates were incorporated into the concrete mixtures. The increase in resistance was derived from the enhanced ability of the material to absorb energy. Eldin and Senouci (2002), and Topcu (1995) also reported similar results.

Zhu (1999) presented the flexural toughness and impact resistance of steel fibre-reinforced light-weight concrete, and the results indicate that the high compressive strength and density are desirable for good impact resistance of plain concrete and also reported that the incorporation of steel fibers improved the impact resistance substantially.

Hernandez-olivares et al (2002) reported that addition of crumb tyre rubber volume fractions up to 5% in a cement matrix did not yield a significant variation of the concrete mechanical features, either maximum stress or elastic modulus.

2.5 WASTE TYRE IN CONCRETE HOLLOW BLOCKS

Another research was done using Chopped Worn-Out Tyres in production of light weight concrete masonry units (Al-Hadithi et al. 1999). This research, generally aimed at defining the possibility of using chopped worn-out tyres to produce lightweight concrete building units. Many experimental mixtures were made with different percentages of chopped worn-out tyres after identifying the importance of produced characteristics of the mixtures. For producing lightweight Chopped worn-out tyres concrete
mixes, many trials were adopted in selecting the required mixes. The methodology of aggregate replacement was to substitute a certain volume of aggregate by the same volume of Chopped worn-out tyres, but with different partial replacement ratios (PRR’S) for the sand and the gravel. For production and testing Chopped worn-out tyres in Hollow- Concrete blocks units with a new suggested geometry, in addition to the conventional units, to enhance the structural properties of walls and the other properties which are provided by using Chopped worn-out tyres, five short walls were built from fine-block using both Chopped worn-out tyres (concrete and mortar) mixes with their corresponding plain mixes (without Chopped worn-out tyres). Also two short walls were built from traditional Hollow-Concrete block with two holes using plain mixes (without chopped worn-out tyres).

These walls were tested to study the structural behavior of such walls. All the mixes used Ordinary Portland Cement. The sand was a washed and dried natural river sand with a size range of (0.15-4.75mm), with bulk specific gravity 2.6. The gravel was washed and dried natural gravel with a size range of 1.18 to 9.5 mm, with specific gravity of 2.7. The Chopped worn-out tyres used in this work had a maximum size of 6.35mm and a specific gravity of 0.95. The dry constituents were initially mixed for 1.0 minute with Chopped worn-out tyres mixes, the Chopped worn-out tyres were then incorporated into the dry mix through a dispenser, and the mixing continued for another 1.0 minute to allow uniform distribution of the Chopped worn-out tyres in the mixture. After adding the water, the constituents were then mixed for a further 2.0 minutes to produce a homogeneous mixture. Different specimens were prepared and a number of tests were made, the tests included compressive strength, axially load capacity of walls and prisms, measurement of longitudinal and traverse strains were made on both faces of walls using mechanical extensometers with high sensitivity.
The conclusions arrived from this investigation were, incorporating Chopped worn-out tyres into the mortar and concrete mixes as a partial replacement of aggregate reduced its unit weight, compressive strength and flexural strength and increased its thermal insulation significantly. The Chopped worn-out tyres concrete masonry wall had numerous benefits, especially in the reduction of the dead loads, improvement of thermal insulation by providing a satisfactory structural function. The absorption of the Chopped worn-out tyre concrete units was within the range of ACI 531-83 requirements for the corresponding lightweight masonry unit. The performance of fin-blocks was superior as compared with that of conventional blocks and cracks occurred simultaneously in masonry units and mortar, these cracks which developed in a masonry wall before failure are visible to the naked eye.

2.6 APPLICATIONS AND ADVANTAGES OF TRAC

The TRACs are affordable, cost effective and withstand for more pressure, impact and temperature when compared to the conventional concrete. It is observed that the Rubber Modified Concrete (RMC) is very weak in compressive and tensile strength. But it has good water resistance with low absorption, improved acid resistance, low shrinkage, high impact resistance, and excellent sound and thermal insulation. Studies shows the Crumb Rubber Concrete (CRC) specimens remained intact after failure (did not shatter) compared to a conventional concrete mix. Such behavior may be beneficial for a structure that requires good impact resistance properties. The impact resistance of TRAC was higher, and it was particularly evident in concrete samples aggregated with thick rubber (Kamil et al 2005).

Moreover the unique qualities of TRAC will find new areas of usage in highway constructions as a shock absorber, in sound barriers as a sound absorber and also in buildings as an earthquake shock-wave absorber. It
reduces plastic shrinkage cracking and reducing the vulnerability of concrete to catastrophic failure.

Currently, the waste tyre modified concrete is used in precast sidewalk panel, non-load bearing walls in buildings and precast roof for green buildings (Fuminori et al 2005). It can be widely used for development related projects such as roadways or road intersections, recreational courts and pathways, and skid resistant ramps (Kamil et al 2005). With this new property, it is projected that these concretes can be used in architectural applications such as nailing concrete, where high strength is not necessary, in wall panels that require low unit weight, in construction elements and Jersey barriers that are subject to impact, in rail road’s to fix rails to the ground (Topcu 1995).

TRAC can also be used in non load bearing members such as lightweight concrete walls, building facades, or other light architectural units, thus the waste tyre modified concrete mixes could give a viable alternative to the normal weight concrete (Khatib and Bayomy 1999). Rubberized mixes could be used in places where cement-stabilized aggregate bases are needed, particularly under flexible pavements. The other viable applications well suited for use in areas where repeated freezing and thawing occur, and can also be poured in larger sheets than conventional concrete.

The tennis courts can now be poured in a single slab, eliminating ‘section’ lines which must be smoothed after curing. Roofing tiles and other concrete products can now be made lighter with TRAC (Kamil et al 2004). It may also used in runways and taxiways in the airport, industrial floorings and even as structural member.
2.7 CRITICAL REVIEW

The previous studies have shown that the inclusion of rubber aggregate in concrete as a full or partial replacement for natural aggregates reduces the compressive strength of the concrete. These studies also indicate that the mechanical strength of TRAC is greatly affected by the size, proportion and surface texture of the rubber aggregate and the type of cement used. This strength reduction can be expected primarily because rubber aggregate is much softer (elastically deformable) than the surrounding cement paste. Secondly, the bonding between the rubber aggregate and the cement paste is likely to be weak, so that soft rubber aggregate may be viewed as voids in the concrete mix. It has also been recognized that, the strength of concrete greatly depends upon the density, size and hardness of the aggregates. In addition, the previous studies have shown that the workability of concrete containing rubber aggregate is reduced. This could affect the method of preparation of concrete samples and products and requires further study during the present investigation.

A critical review of literature presented above indicated that the proportion of rubber aggregate in the concrete should be restricted to prevent great loss in mechanical properties. Further there is no specific literature found to analyze the flexural performance, deflection and ductility behaviour of Reinforced Cement Concrete beams made of TRAC. In addition an attempt is also made to make use of rubber strips as rebar in tensile zone. As such, the research focus on waste tyre rubber as material itself is in infant stage. Hardly there is no literature available in the area of structural application. In these circumstances it is important to investigate the relevant properties of tyre rubber aggregate concrete beams to enhance its primary structural applications in concrete construction. The possibilities include reduced weight, enhanced toughness, increased ductility and impact resistance.