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Sudan University of Science and Technology
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Title:

Recycling of EVA Foam Waste as A Constituent of Lightweight Concrete Mixture for Construction Application

إعادة إستخدام مخلفات رغوة الإيفا مُكّوناً لخلطات الخرسانة الخفيفة الوزن في تطبيقات الإنشاءات

A Thesis Submitted in Fulfillment of The Requirements for The Degree of PhD in Plastics Engineering

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Quran


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قال تعالى:

{وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ }

صدق الله العظيم

التوبة – الأية 105

DEDICATION

To my Mother's Soul

To my Father's Soul

To my wife

To my children's

To my Brother's and Sister's

To my Friends

Acknowledgement

First and foremost ,I would like to thank God Almighty for giving me strength, knowledge, secondly, I would like to express my sincere gratitude to my supervisor Prof. **Ahmed Ibrahim Ahmed Seed Ahmed** for the continuous support of my PhD and related research. for his patience, motivation and immense knowledge. His guidance helped me in all the time of research and writing of this thesis .

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ABSTRACT

The amount of waste has increased year by year and the disposal becomes serious problem. Particularly, recycling EVA waste in life and industry is low.

This study presents a simple way of recycling EVA waste in the field of civil engineering as constituent in mix of light weight concrete, and to evaluate its efficiency to produce a concrete with high strength and lightweight .Also this work aim to study of permeability, sound insulation property for concrete samples with different densities. Experimental study was carried out by preparing different test samples using various proportions of EVA waste (10%, 25%, 40%, 55%, and 70%) in the mix and a blank sample of concrete of grade M25. Samples and Blank were cured in water tanks for 7 days and 28 days. Resulted samples were then tested for compressive strength of concrete and slump value, and then the results were compared with the normal conventional concrete. Results showed that using10% EVA gave the best performance. Accordingly it was concluded that there is an indirect relationships between the amount of the EVA in the mix and the weight of the product. Same relation was notices against compressive strength.

An empirical formula to determine the sound insulation of this concrete blocks by using the UPV, The sound insulation of concrete blocks calculated according to a proposed empirical formula made in this work. Finally the results of permeability decrease with increase in replacement percentage of EVA waste compared with the normal conventional concrete, Results showed that using 10% EVA gave the lowest permeability and the best performance. Results of sound insulation showed transmission losses increased with decreased the average weight per area unit for concrete mixtures. Accordingly it was concluded that there is an indirect relationships between the amount of the EVA in the mix and the sound insulation of the product. Same relation was notices against compressive strength . Study is recommended. to use of industrial EVA waste as replacement of aggregate is better for non loads structure members for examples light weight blocks ,tiles and interlock ,also EVA waste can be used in thermal and water insulation, sound insulation as studio, halls of universities, conference hall , schools.

الملخص

أن كميه المخلفات في تزايد مستمر سنه تلو الاخري ورميها اصبح مشكله جديه وخطيره . خصوصا إعاده التدوير لمخلفات مادة الإيفاEVA في الحياة والصناعه قليلة .

تعرض هذه الدراسه طريقه بسيطه لاعادة استخدام مخلفات ماده الايفا في مجال الهندسه المدنيه كمكّون في الخلطه للخرسانيه خفيفه الوزن، وتقييم كفاءتها لانتاج خرسانة ذات وزن خفيف ومقاومة عالية. أيضا هذا البحث يهدف لدراسة النفاذية ، و خاصية العزل الصوتي لنماذج خرسانية ذات كثافات مختلفة. الدراسات والتجارب التي أجريت علي الخرسانة تمت بإستخدام نسب مختلفة من مخلفات مادة الإيفا EVA (10%, 25%, 40%, 55%, and 70%) في الخليط الخرساني والعينة المرجعية لعيار M25 .تم غمر العينات للنسب المختلفة من الخلطة الخرسانية والعينة المرجعية في خزان ملئ بالماء لمدة 7و28يوم .

تم الحصول علي نتائج للعينات بإستخدام إختباري مقاومة الضغط وقيم الهبوط للخرسانة، ثم تم مقارنة النتائج مع العينة المعيارية الخالية من الايفا.اوضحت النتائج أن نسبة 10%من مادة الإيفا تعطي افضل أداء .و قدتم تلخيص ذلك بالعلاقة العكسية مابين كمية من مادة الايفا المضافة للخليط الخرساني كبديل للركام ووزن الخرسانة المنتجة .ايضاً يلاحظ أنه توجد علاقه مابين الوزن ومقاومة الضغط.

أجريت فحوصات مختبرية على النماذج الخرسانية لتحديد العزل الصوتي باستخدام تقنية الموجات فوق الصوتيةUPV . تم حساب العزل الصوتي لجدران خرسانية باعتماد معادلة مقترحة في هذا البحث .

نلاحظ ان نتائج النفاذية تنقص مع إزدياد نسبة مخلفات الايفا المستبدله مقارنة بالخرسانةالتقليدية الطبيعية بدون اضافات وتوضح النتائج أن استخدام 10%من مخلفات الايفا تعطي أقل نسبة نفاذية وأعلي أداء .كما أن نتائج العزل الصوتي تعطي إزدياداً مع إنخفاض متوسط الوزن لكل وحدة مساحة من خلطات الخرسانة.وفقاً لتلك العلاقة العكسية يلاحظ أن هنالك علاقة مابين كمية الإيفا في الخليط والعزل الصوتي للمنتج الخرساني . هنالك ايضا علاقة تربط العزل الصوتي مع المقاومة للإنضغاط.

توصي الدراسة بإستعمال مخلفات مادة الإيفا كبديل للركام الطبيعي في أعضاء المنشأت الغير مُحملة كالبلوكات الخرسانية خفيفة الوزن ،البلاط ،الإنترلوك ،ايضاً مخلفات مادة الإيفاتستعمل في العزل المائي والحراري ،العزل الصوتي كما في الاستديوهات وقاعات الجامعات والمؤتمرات والمدارس.

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I List of Abbreviation

ACI: American Concrete Institute

ASTM: American Society of Testing Material

AZC: Azodicarbonamide

C.A: Coarse Aggregate

CBI:China Bank International

CDW: Construction and Demolition Waste

DTA: Different Thermal Analysis

ECC: Engineered Cementitious Composites

ESCR: Environmental Stress Cracking Resistance

EVA: Ethylene Vinyl Acetate

F.A: Fine Aggregate

FTIR: Fourier Transform Infared Spectroscopy

HDPE: high density polyethylene

IR: Infrared

LDPE: low density polyethylene

LWC: Light Weight Concrete

LWAC: Light Weight Aggregate Concrete

LWCB: Light Weight Aggregate ConcreteBlock

MSW: Municipal solid waste

MFR: Melt flow rate

NMR: Nuclear Magnetic Spectroscopy

OPC: Ordinary Portland cement

PCBDM: Portland Cement-Based Decorative mortar

PET: Polyethylene terephthalate

PP: Polypropylene

PS: Polystyrene

PU: Polyurethane

PVA: Poly (Vinyl) Alcohol

PVC: Poly (Vinyl) Chloride

PWF: Poplar Wood Flour

SEM: Scanning Electron Microscopy

SSMO: Sudanese Standards and Meterology Organization

SUST: Sudan University of Science and Technology

SG: Specific gravity

TGA: Thermo Gravimetric Analysis

UPV: Ultrasonic Pulses Velocity

WPC: Wood Plastic Composites

w/c: Water Cement Ratio

Chapter One

Introduction

Chapter One

Introduction

1.1 Polymers and Polyolefin Foams

Polymers are a large class of materials consisting of many small molecules (called monomers) that can be linked together to form long chains, thus they are known as macromolecules. Polymer can be of long chain molecules or branched long chain molecules or molecules of interconnected three dimensional networks.

Atypical polymer may include tens of thousands of monomers. Because of their large size, polymers are classified as macromolecules.

Polymer has been one of the most important materials in human society, with its synthesis technology that had been developed since the early 19th century.

Polymers are used in many applications, which influence every aspect of human life.

The applications of polymer have been directed at replacement of traditional materials, most commonly, metals. Although plastic raw materials can be more costly than metals on a weight basis, they are often more economical in terms of final manufactured cost.

These edge advantages are due to polymers' properties, such as light weight, easy process ability, isolation and other unique properties.

There are many types of polymers depend on sources:

i. Natural of Polymers.
ii. Modified Natural Polymers.
iii. Synthetic Polymers.

Traditionally, plastics are divided into two broad categories, namely, thermoplastic and thermosetting. They are both produced by the petrochemical industries.

Thermoplastic resins, usually obtained as a granular polymer, can be repeatedly melted or solidified by heating or cooling.

Heat softens or melts the material so that it can be formed, and subsequent cooling then hardens or solidifies the material in the given shape.

They are both produced by the petrochemical industries and although there are naturally occurring plastics such as rubber. There are numerous minor classification schemes for polymers.

Thermoplastic resins are, therefore, usually molded by extrusion, injection, blow molding, and calendaring processes as well as by thermoforming.

On the other hand**,** thermosetting resins, which are usually supplied as a partially polymerized molding compound and are cross-linked or “cured” during the fabrication process, are usually shaped by compression molding.

Foam is a substance that entraps on the inside, well-dispersed bubbles/cells. Polymer foams are composed of two phases, in which a blowing agent is used to generate stabilized bubble structures inside the polymer matrix. The foaming technology has been developed, and has been applied with an increasing number of different types of polymers . Polymer industry, accounting for about 10% of total commodity consumption Polyolefin foams are fourth ranked, after polyurethane (PU),polystyrene (PS), and poly (vinyl chloride) (PVC) foams.

Polyolefin foam is one of the most important categories within polymer foams. It had first been marketed in the early 1960*s* and the areas of application include packaging, sports and leisure, toys, insulation, automotive, buoyancy, cushioning and others.

Soft foams made of polyolefin have a wide application, such as cushioned packaging materials, floatation materials, padding in various sports equipment as ski boots, bicycle saddles, hockey pads, boxing and mixed martial arts gloves and helmets, wakeboard boots, fishing rods and fishing reel handles, shock absorbers, and sports shoe soles/slippers/sandals.

In terms of final foam properties, the wide range of polyolefin foams can be divided into hard foams, which are obtained using polypropylene (PP) or other high strength basic polyolefin, and softer foams, which are obtained using co-polymer, such as ethylene vinyl acetate, EVA.

1.2 Ethylene vinyl Acetate (EVA)

Ethylene vinyl acetate (also known as EVA) is the copolymer consist of ethylene and vinyl acetate (VA), it is one of the materials popularly known as expanded rubber or foam rubber. The weight of percent vinyl acetate usually varies from 10 to 40%, with the remainder being ethylene.

EVA is an extremely elastic material that can be sintered to form a porous material similar to rubber, yet with excellent toughness.Soft polyolefin foam from EVA comes with the property of elasticity, which is due to the ability of the long chains to reshape them back to the original configuration after the applied stress is released.The applications for EVA copolymers include wire/cable insulation, packaging film, adhesives/coatings, carpet backing, sandals, sports shoe soles, sports leisure, sound damping sheets. It is also used in the photovoltaics industry as an encapsulation material for crystalline silicon solar cells in the manufacture of photovoltaic modules, EVA is also used in biomedical engineering applications as a drug delivery device EVA copolymers are used principally in specialty applications, competing with plasticized PVC and rubber.

EVA slippers and sandals are currently very popular because of their properties like light weight, easy to form, odorless, glossy finish, and cheaper compared to natural rubber.EVA resin can be used in adhesives, sealants and coatings. It is the basis of many hot melt adhesives when blended with a petroleum wax .EVAs have greater clarity, low-temperature flexibility, stress-crack resistance, and impact strength than LDPE. EVA resins are more permeable to oxygen, water vapor, and carbon dioxide. EVA has good clarity and gloss .Chemical resistance is similar to that of LDPE, with somewhat better resistance to oil and grease for EVA resins of higher VA content. The VA groups contribute to improve adhesion in extrusions or hot-melt adhesive formulations.

The outdoor stability of EVA resins is superior to that of LDPE by virtue of their greater flexibility. Resistance to UV radiation by addition of UV stabilizers can extend the outdoor life of clear compounds to three to five years, depending on the degree of exposure.EVA has a barrier properties, low temperature, toughness, good process ability, flammability ,crosslink able, good stiffness, high elasticity, high impact resistant, high viscosity, high molecular weight, resilient, hot-melt adhesive water proof properties.[1][2].

1.3 EVA Waste Problems:

The use of plastic materials has been growing all over the world in packing, automotive and industrial applications. This results in a great generation of urban and industrial waste that can be stored or eliminated. Due to the low density of plastics, storage or disposition in landfills implies the availability of large surface areas. The elimination of plastics can be done by incineration, however, as the production of plastics involves the use of potentially harmful chemicals, the ashes produced may not always be acceptable in a landfill because of their potentiality to cause groundwater and soil pollution due to leach of heavy metals.

Ethylene vinyl acetate (EVAs) utilized by the footwear industries, EVA cannot be melted through heat because of its molecular chains and hence another recycling process is needed. Currently, 17 billion pairs of shoes are produced worldwide every year, and this creates an enormous amount of post-consumer (end-of-life) shoe waste that is currently being disposed of in landfill sites around the world [3].

The cutting stage of outsole, in sock and reinforcement generates about 25–35% of waste which represents 80 tons of waste/million pairs [4].

The EVA represents 14% of this waste. Therefore 190,400 *tons* of EVA waste are generating worldwide every year needing a large surface for placement and storage, and also generates great costs of management due to its long biodegradation.

In Sudan EVA foam has been used in many plastic companies in footwear application such as (shoes, shoes sole, innersole, sandal , flip–flop) and the annual production of EVA foam products in Sudan about 2400ton.Most of commodity thermoplastics materials classified as easy recyclable materials such as PE, PP and PVC. But EVA foam products and byproducts (EVA foam waste and scrap) difficult to reprocess or recycle due to difficulties of recycling of EVA foam which comes from:

- Complicated process for waste EVA foam due to (Across links between internal molecular) that make the waste of EVA foam is cheap compared (virgin EVA).
- High cost of additives (Blowing agent and cross linking agent).
- High cost of virgin EVA foam because the process of EVA has many stages, According to Mills, N.J.(2007,p42),the Monomer prices are determined by the raw material and energy costs, the number of stages in their manufacture and the scale of manufacture.

- High cost of pyrolysis recycles (chemical recycling technique) compare to physical recycling (Thermo mechanical recycling technique) for EVA foam which comes from footwear industries.
- The composition of EVA foam depends on the amounts of EVA and additives, if the amount of EVA is relatively low the material will be soft, if it is high the material will be relatively hard.
- Moreover short life of EVA foam products cycle.

Due to difficulties of recycling of EVA foam based on the above mentioned factors.

The main target of this proposal to increase the life cycle of EVA foam (recycle) more than one year by use EVA foam as a constitute in light weight concrete (Engineering recycle technique) when will be mixed based on a stress crack resistance, water proof properties and flexibility of Eva foam.

1.4 Objectives of the study:

1. To study the chemical and physical properties of EVA foam waste compared to virgin EVA.
2. To mix EVA foam waste with concrete compounds for construction applications and optimized the ratio of the composites
3. To investigate the performance of the concrete/EVA composites compared with blank.
4. The main objective of this research is studying how to reduce the pollution which comes from accumulation of EVA foam waste that was used in footwear companies (shoe sole /sandal/sports shoes - flip flop).

Chapter Two

Background and Literature Review

Chapter Two

Background and Literature Review

2.1 Introduction

Polymer has been one of the most important materials in human society, with its synthesis technology that had been developed since the early 19th century. Polymers are used in many applications, the products made of polymers range from disposable items like tea cups to high strength composites used in aircraft industry. These edge advantages are due to polymers' properties, such as light weight, easy processability, isolation and other uniqueproperties. To pursue lower density, better isolation and other related properties, foam in technology has been applied into polymers since the 1930s [4][5].

Polymer are classified into three groups, thermoplastics, thermosets and elastomers. In addition,thermoplasticare divided into amorphous,crystalline and liquid crystalline polymer.

Thermoplastics are linear or branched polymers which can be melted uponthe application of heat. They can be moulded and remoulded using conventional techniques.

Thermosetting plastics or thermosets are heavily cross-linked polymer which are normally rigid and intractable. They consist of adense three-dimensional molecular network and like rubbe, degrade rather than melt on application of heat.

Elastomers or rubber are polymeric materials which display elastomeric properties ,they can be stretched easily to high extensions and will be spring back rapidly when the stress is released.

Based on the type of monomer Polymer is divided into homo polymers and copolymers.

Homo polymers are formed by polymerizing only one type of monomers like polyethylene (PE),poly vinyl chloride (PVC), polypropylene(PP),polystyrene (PS). Whereas copolymers are formed by polymerizing two or more than two types of monomers together like Ethylene vinyle acetate(EVA), Acrylonitrile butadiene styrene(ABS).

Polyolefin foams are fourth ranked, after polyurethane (PU), polystyrene (PS), and poly (vinyl chloride) (PVC) foams. The increasing demand for cross linked polyolefin foams makes polyolefin foams have one of the highest growth rates.

Polyolefin foam is one of the most important categories within polymer foams. It had first been marketed in the early 1960s and the areas of application include packaging, sports and leisure, toys, insulation, automotive, buoyancy, cushioning and others [6].

2.2Plastic Foams

Plastic foams are polymers that contain cells dispersed throughout the polymer matrix .Polymer foam can be viewed from different perspectives, such as product dimension, foam density, cell size, cell density, foam morphology, and foam property [7].

Foam is a substance that entraps on the inside, well-dispersed bubbles/cells. Polymer foams are composed of two phases, in which a blowing agent is used to generate stabilized bubble structures inside the polymer matrix [8].

Foamed plastics have a wide density range from about 1.6 kg/m^3 to over 960 kg/m^3.

Based on the average cell size and cell density, they can be divided into three main categories:

i. conventional foams($<10^6$ *cells/cm*^{3}), fine-celled foams (10^6 to 10^9 *cells/cm*^{3}),

ii. Microcellular foams ($>10^9$ *cells/cm*^{3}).

iii. In terms of the foam expansion ratio, plastic foams can also be classified into:

  - High density foam (<4 folds).
  - Medium density foam (4-10 folds).
  - Low density foam (10-40 folds).
  - Very low density foam (>40 folds)[9].

Because of less material cost, Plastic foams are more environmentally friendly compared with unformed ones. Furthermore, plastic foams also have many advantages, such as: lightweight, insulating abilities (sound and heat), energy absorption (shock, impact, and vibration, buoyancy), and elastic properties in certain cases. Because of the desirable range of densities and application requirements, plastic foams can be used in products suchas: packaging, sports، construction, automotive/transportation, insulation, wires/cables.

Generally speaking, higher density foams are used in construction, automotive/transportation applications; while lower density foams are used in insulation, and packaging applications.

Plastic foams can also be divided into thermoset foams and thermoplastic foams depending on the polymer matrix. In terms of foam morphology, plastic foams can also be classified as open-cell foams and closed-cell foams. Open-cell foams are widely used in sound insulation and water purification technology[10][11].

2.3EthyleneVinyl Acetate EVA

EVA is a co-polymer made from two different monomers:

i. Ethylene monomer.
ii. Vinyl acetatemonomer.

In a foam state, EVA has rubber like properties, making it useful where cushioning is important such as in. midsoles, sock liners, and unit soles in footwear

In EVA, the relative amount of vinyl acetate to ethylene influences polymer properties. Higher vinyl acetate content tends to make the polymer softer and more rubbery, while lower vinyl acetate content tends to make the polymer harder and more crystalline, Figure 2.1 illustrates the molecular formula of EVA[1].

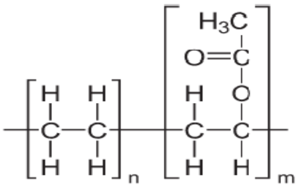


Figure 2.1EVA molecular formula

The weight of percent vinyl acetate usually varies from 10 to 40%, with the remainder being ethylene, Figure 2.2 presents the relationship between maximum molecular weight and vinyl acetate content for EVA[11].

EVA has a relatively low softening temperature, which ranges around 60-100°C. EVA approaches elastomeric materials with rubberlike properties of softness and flexibility, and has the process ability of other thermoplastics.

according to global high EVA copolymer markets ,technology and trends from 2011-2020 [12], Ethylene vinyl acetate (EVA) copolymers are often considered an extension of LDPE with high VA content, which provide impact strength, clarity, and blending characteristics that traditional LDPEs cannot provide. EVA copolymers are classified by their vinyl acetate (VA) content. Typical VA content ranges include: 0-6% VA, 7-16% VA, 17-24%

VA, and >25% VA. Lower EVA is classified as having a VA content less than 18%, and are predominantly used in commodity film markets, such as bakery bags, ice bags, frozen food bags, overwrap, and fresh produce wrap. High EVA copolymers have a VA content of 18% and less than 40% as a co monomer.

High EVA copolymers command a price premium over commodity LDPEs because of their special performance properties, such as impact strength, puncture resistance, excellent clarity, heat seal properties, and flexibility. Lower VA contents are typically more vulnerable to substitution from competing materials, including other polyolefin's, and mostly compete on a price basis with other materials. Higher VA content applications are less susceptible to competition from competing materials. The price premium also encourages a fierce intermaterial competition to replace high EVA copolymers. Acid copolymers and monomers succeeded in providing properties better than high EVA copolymers, but are more expensive [13][14].

The high EVA market amounted to about 1.6 *million tons* in 2011 with applications in:

(1) foam, (2) film, (3) hot melt adhesives, (4) wire & cable, (5) carpet backing, (6) molding & profile extrusions, (8) solar encapsulation, and others. As the market is dominated by the foam for footwear production, which has largely shifted over to China and other Asian countries, the market in this region has developed significantly.

High EVA is expected to maintain their higher growth and specialty status. While EVA has been used in solar encapsulation for the past twenty years, the market has begun to experience extraordinarily high growth rates due to the increasing interest in using renewable energy. The majority of demand is shifting to Asia for solar encapsulation, as China has become the largest supplier to PV cells and protective films.

As high demand growth is being seen in Asia, new LDPE/EVA capacity is announced for Asia, and producers have expressed interest in producing EVA with higher VA contents. Currently, there is a tight supply for high EVA. The addition of new high EVA production will impact the high growth expected in this market.

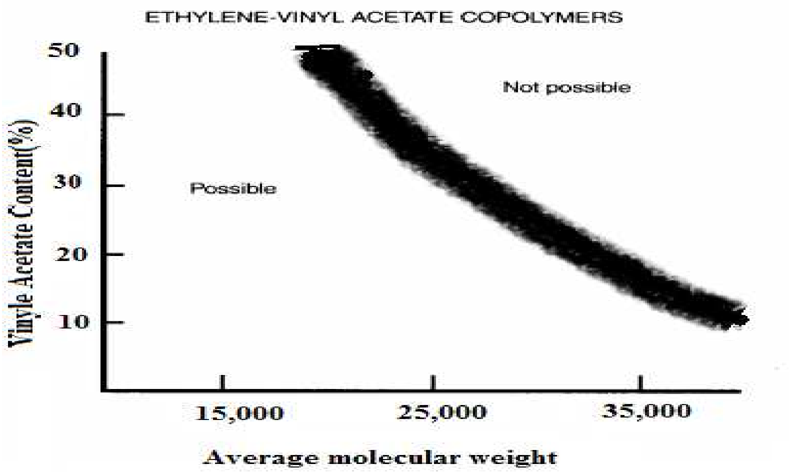


Figure 2.2 Relationship between maximum molecular weight and vinyl acetate content for EVA

2.3.1 EVA foam

EVA foam is closed cell made from Ethylene vinyl acetate and blended copolymers, it produced under pressure by copolymerization, it has a high level of chemical cross linking.

The EVA foam made from the conventional process has acellular structure that contains cell which are mostly closed cells (90%closed cell and 10% open cells)[15][16].

EVA foam is prepared by completely filling a preheated mould with an foam able composition ,which usually contains EVA resin, a foaming agent, and crosslinking agent apply pressure to the composition and allowing foaming and curing of composition to take place. Ethylene vinyl acetate (EVA)foam widely used for toys, doll parts, foot wear items (shoes insoles and slippers).

2.3.2Advantages,Properties of EVA foam

EVA foams provide ideal mechanical and physical properties for many structural materials. Because of their low densities, foams have a very large properties-to-weight ratio which make them an idealchoice for several industrial applications such as thermal and sound insulators and lightweight materials for the automotive industry and construction. The copolymer containing high levels of vinyl acetate isprimarily used as a component in adhesives andcoatings but can be vulcanized to obtain usefulphysical properties. As vinyl acetate content increasespolymer flexibility, toughness, solubility in organicsolvents and clarity increase.

The properties of EVA will be described. Table 2.1 shows some properties of the homopolymers and their copolymer[17].

Table 2.1: Properties of the homopolymers and their copolymer.

Property	LDPE	VA	EVA
Density(kg/m^3)	910-925	1050-1280	930-950
Melting point(^0C)	122-124	-	47-100
Softening temp(^0C)	-		
Elongation at break(%)	150-600	10-20	300-750
Tensile strength(mPa)	22-31	29.4-49	15-28
Thermal expansion coeff(K^{-1})	$10*10^{-5}$	$7\text{-}22*10^{-5}$	16-25*10-5

2.3.4 Physical properties of EVA foam

The properties of ethylene-vinyl acetate copolymer vary depending primarily on the level of vinyl acetate in the copolymer. At lower levels of vinyl acetate, the copolymer is a thermoplastic with properties similar tolow density polyethylene. As the vinyl acetate contentis increased, the copolymer takes on the performance characteristics of a thermoplastic elastomer until thecrystallinity drops so low that the copolymer forms asoft rubbery material with minimal physical strength, the lowered crystallinitycaused by the addition of the vinyl acetate contributes[9][10].

- Density nominal value at 23^0C 940-960 kg/m^3 according to ASTM D150.
- The material has good clarity and gloss.
- EVA foam is softer and more resilient than PE foam.
- Hot-melt adhesive.
- Light weight.
- High Resistance for electricity
- Good processability.
- Weather resistant and can be washed in dishwashers (taking the maximum service temperature into account).
- Yellow and red colored products are however more likely to decolorize due to UV radiation.
- High viscosity.
- High molecular weight.
- Easy to form and allow great design flexibility, as they can be easily modeled in complex geometric parts
- Waterproof properties.

- Resistance to UV radiation.
- Acoustic and thermal insulation properties.
- Buoyancy with low water absorption.
- Suitability for thermo-forming and thermo-moulding.
- EVA is cheaper compared to natural rubber.
- The density of Ethyl Vinyl Acetate at 200-500 kg/m^3, the relation between expansion and density for EVA as shown in Table 2.2, Due to the foaming and crosslinking the material expands to 1.2 - 1.75 times the original volume. According to ASTM D792 [18][19].

Table 2.2: Relation between expansion and density for EVA

Expansion low	1.2	Density low* Expansion low=	200*1.2=	240
Expansion high	1.7	Density low* Expansion high=	500*1.5=	600
Density low	200	Density low* Expansion high=	200*1.7=	340
Density high	500	Density high* Expansion high=	500*1.7=	850

According to P. Viot1et al (2011**)** had studied the influence of the density and the walls of beads, For morphology properties they are one study, The objective of this study is to estimate the influence of the cell microstructure and the bead wall structure on the macroscopic response of the foam and moreover to explain the phenomena of bead wall buckling and strain localization bands observed experimentally.

The objective of this study is precisely to reveal this effect on the macroscopic response of the cellular material and furthermore to explain the phenomena of bead wall buckling and strain localization bands observed experimentally, this study had concluded on two steps, first step of this study, multi scale physical phenomena observed experimentally in dynamic compression of polymeric foams have been reproduced in using simple models representing the two scales of the foam. Strain localisation has been highlighted in considering the porous interior of beads as a homogeneous material.

The second step of the numerical approach will be to introduce the heterogeneity of the microstructure of the cellular beads in modeling variability in the cell size and defaults such as large bubbles [20].

Other work about physical properties of ethylene-vinyl acetate foams containing calcium carbonates outlined by Manoel Alpire et al (2014),This work studied the effect of type (natural or precipitated) and content of calcium carbonate in ethylene-vinyl acetate foams produced by compression moulding.

The fillers are added to reduce cost but have a direct influence also in ultimate properties and even in processing conditions of the foams However, the precipitated $CaCO_3$ yields better properties to the EVA foams due to the higher purity, lower particle size and much less abrasiveness. The calcium carbonate act in the foam both as a filler and as a cell nucleating agent.

This processing technique generates various types of heterogeneities in the product, like differences between the skin and the core.

The results of this study showed clearly that EVA foams are highly heterogeneous. And the differences in temperature on the mould surface also have a major influence in foam properties.

The hardness was shown to vary widely from place to place in moulded samples, and this was related to local variations in temperature. The analysis of the effect of calcium carbonate showed that the precipitated one yield better physical properties like density, hardness and elastic modulus. of EVA foams[21][22].

EVA has many properties one of them EVA foam have high dielectric strength compare with other types of plastics as example LDPE .the Dielectric Constant or (Relative Permittivity) for EVA about 2.8, and Dielectric Strength (Breakdown Potential) 21 *kV/mm* (0.8 *V/mil*)compared with LDPE has Dielectric Constant 2.3.Dielectric Strength(27*MV/m*).that concluded by Hojjat, Amrollahi et al (2015) studied the Low density polyethylene (LDPE) blends with different percentages of ethylene vinyl acetate polymermembranes10%-20%-30% were prepared by a hot press casting method. The effects of EVA content on the electrical properties of LDPE were studied. The results on the electrical properties revealed that the surface resistance, volume resistivity, and break down voltage of the LDPE decrease with EVA content and reach a minimum at a 30 wt% of EVA. Dielectric constant and dielectric loss factor were increased with increasing EVA content up to 30 wt% of EVA compared to the purred LDPE, while the permittivity and loss factor increase. As concluded the electrical properties of LDPE are improved by blending with EVA [23].

2.3.5 Thermal properties of EVA foam

EVA foam has many thermal properties as follow

- Vicat softening temperature 95^0C according to ASTM D1525
- Low-temperature Melting point 52^0C.-(47-100)
- Melt flow rate (MFR) nominal value 2.0*g*/10 *min* according to ASTM D1238.
- Melt index (1900C/ 2.16*kg*) 65-85*g*/10*min* according to ASTM D1238.

Some researchers investigated and studied the affect of thermal properties on mechanical properties and creep response of EVA foam .Raquel Verdejo (2003) state the effects of gas diffusion on the mechanical response of polymeric foams subjected to periodic loads and studies their durability. A repeat impact machine was developed to analyze changes in the mechanical response of ethylene vinyl acetate copolymer foams used in running shoes, the diffusion coefficients of Ethylene-Vinyl Acetate (EVA) foams were measured using a microbalance where the pressure and the temperature were controlled. Theoretical analysis of gas diffusion in foams subjected to repeat impact was carried out and confirmed a negligible gas loss due to diffusion in foams under cyclic loads, the main goal of this research was to identify the factors affecting the foam fatigue under repeated loads. Hence, the main conclusion achieved is that foam fatigue is due to the compression and recovery processes of the cellular structure and not to a change in the air content.

- The compressive mechanisms are valid at vary temperatures well as the blow Figure 2.3 shown Creep response of an EVA foam to a constant load of 300 *kPa* at different temperatures. The creep properties depend on the temperature, the stress applied and on the type of polymer [24].

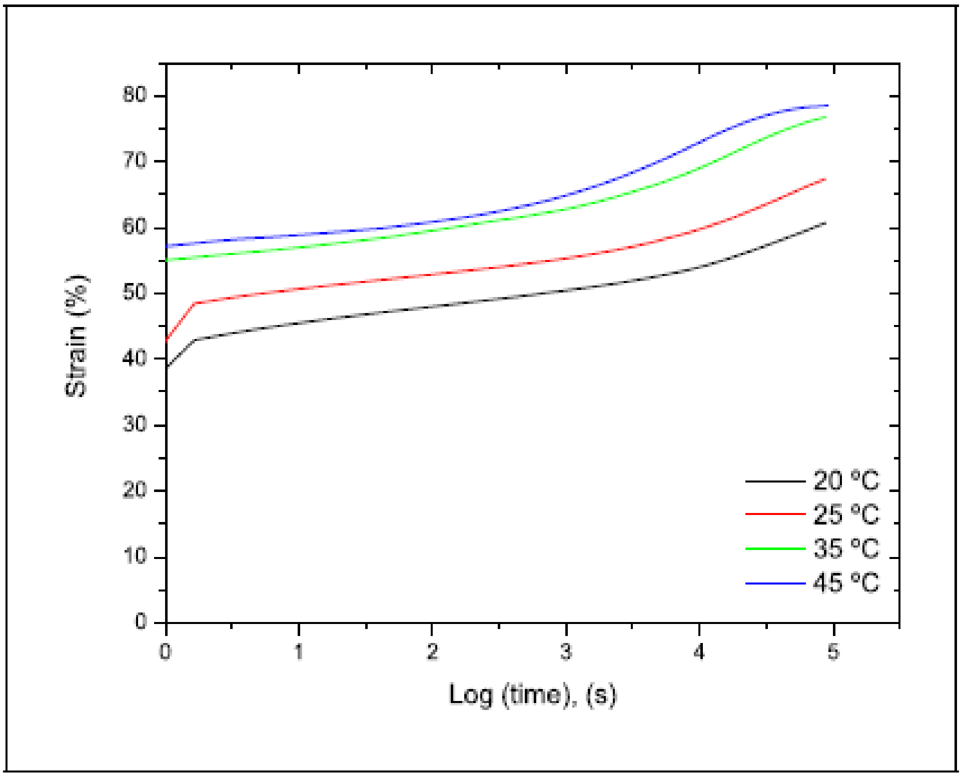


Figure 2.3: Creep response of an EVA foam to a constant load of 300 kPa at different temperatures.

2.3.6 Mechanical properties of EVA foam

The mechanical properties of EVA foams depend not only on the base polymer and their cellular structure .The composition of EVA foam varies.

- Increase of VA content lead to decrease degree of crystallinity,
- Increase of VA content lead to increase polarity.
- Decrease Degree of crystallinity lead todecreasemelting Temp-decrease chemical resistance-decrease surface hardness.
- Decrease Degree of crystallinity lead todecrease stiffness modulus.
- Decrease Degree of crystallinity lead toincrease impact resistant.-increase friction factor.

- Increase Degree of polarity lead toincrease compatibility with other polymers-increase adhesion -increase printing ability.

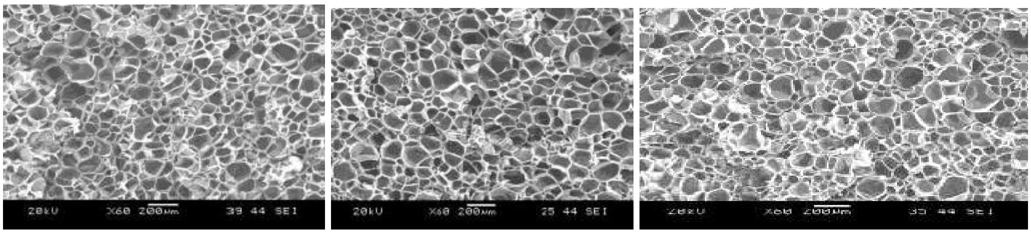
High amounts of EVA will produce a harder material with different mechanical properties than foams with a lower amount of EVA.

- EVA foam generally has a high tearing strength of 8 - 14 *kN /m*.

The tearing strength of EVA foam is quite high for foam. Most foams, especially foams with an open cell structure, tear relatively easy, Generally, materials with more cross-links have a higher tearing strength.

- EVA foam has a minimum service temperature of about -76 °*C* and a maximum service temperature of about 70 °*C*. This makes the material suitable for most consumer appliances in- and outside.
- EVA foam will shrink 0.3 – 5 % when it is heated to 70 °*C* for 40 *minutes*. It can shrink 2 – 10*%* when it is heated to this temperature for 24 *hours*. This means that it should be avoided to EVA foam near certain heat sources [6][11][20].
- The compression set for EVA foam is 18 – 23 *%* when the material is stressed for 24 *hours* at a temperature of 23 °*C* and 64 – 68 *%* when the material is stressed for 6 *hours* at a temperature of 50 °*C*. This means the material springs back quite a lot.
- Stress-crack resistance.
- Impact and vibration absorption.
- Good toughness.
- Tensile strength at break 5*mPa* according to ASTM D638.[8]
- Elongation at break 900-1100*%* according to ASTM D638.
- Hardness Shore A <40 according to ASTM D2240.
- Flexural modulus 51.7Mpaaccording to ASTM D970.

A Rizvi et al (2011), they discussed the mechanical properties of cross linked Ethylene vinyl acetate (EVA) foams. An extensive range of mechanical tests with varied conditions were carried out. Scanning electron microscopy (SEM Analysis), SEM it can magnify a sample up to 50.0000time, results revealed the effect of different processing conditions on the foam morphology. The effect of cell density and the foam expansion ratio were then correlated with the mechanical properties of the foam. In this work the cellular morphology developed in cross linked EVA foams prepared at 170°C, 180°C and 190°*C* for 6 *min* are illustrated in Figure 1. Cells of larger average diameter were produced at 180°*C* when compared to 170°*C*. This is because at a higher temperature the rate of gas diffusion is accelerated, which favors bubble growth. This article had concluded a correlation between mechanical properties of cross linked EVA foams and foam morphology under different processing conditions. Inherently, foams have a large void fraction which jeopardizes their mechanical properties. But having a qualitative relationship between important mechanical properties such as tensile strength, compression modulus and hardness with morphological factors such as expansion ratio and hardness, an estimate can be drawn about the processing conditions required to produce foams that will fulfill the mechanical needs of a specific application [25].



(a) (b) (c)

Figure 2.4SEM micrographs of crosslinked EVA foamed at (a) 170°C (b) 180°C (c) and 190°C for 6 min

Also Nan Chen (2012) studied the effects of cross linking on EVA foaming .and conducted a fundamental approach was applied to describe the influences of cross linking on EVA/gas viscosities, gas solubility and diffusivity in EVA, EVA foaming nucleation and early stage of bubble growth, which leads to a better understanding of the plastic foaming mechanism. The cross linking also has effects on the diffusivity and solubility of a blowing agent inside EVA. The solubility and the diffusivity of the blowing agent in the EVA decrease with the cross linking degree increases. The diffusivity decrease makes more gas is utilized for the foaming rather than leak out of the polymer matrix quickly. This study concluded the following:

- Both shear and extensional viscosities of cross linked EVA have been experimentally measured. Cross linking increases the viscosity of the EVA matrix, under both circumstances, with and without the blowing agent being dissolved. The strain hardening and viscosity enhancement, especially the extensional viscosity enhancement caused by cross linking, helps maintain the bubble structures with fewer bubbles that can collapse or coalesce.
- Compression molding foaming experiments are carried out using EVA .chemical blowing agents, and chemical cross linking agents
- A visualization batch foaming system is used to study the early stage of the bubble growth in the cross linked EVA[11].

2.3.7 Chemical properties and properties of EVA foam based on structure.

The gas bubbles in the EVA foam have a closed cells structure. In contrast, sponges are made of a material with an open cell structure. This allows the sponges to absorb fluids. Because of the closed cell structure that EVA foam has, the material isn't able to absorb fluids. This makes EVA foam a suitable material for different appliances. Figure 2.4 presents the Open cell structure and closed cell structure, the seat of a bicycle made of EVA foam will not be wet when you sit on it after it has rained.

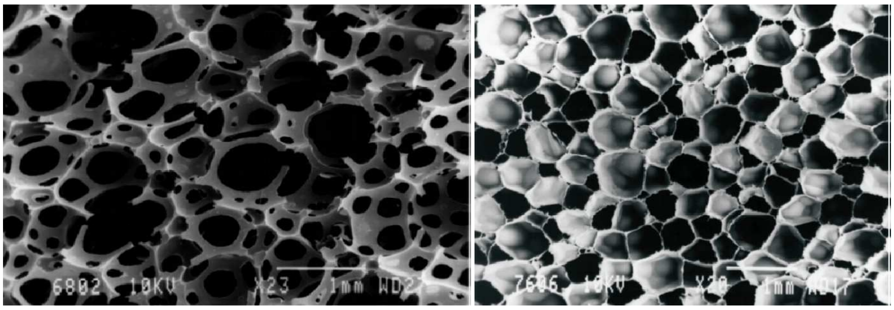


Figure2.4: Open cell structure and closed cell structure

- Other benefits of this closed cell structure are that the material is dirt repellent and easy to clean. Dirt cannot settle itself in the cells because they are closed[6].
- The smooth surface makes it easy to clean the material. There is no need to post process the material to make it dirt repellent and easy to clean, which is a benefit compared to materials with an open cell structure. The combination of these two factors makes EVA foam a hygienic material. Besides the hygienic benefits of the closed cell structure, this structure also offers.
- The benefit of the possibility to create textures on the material.
  - The use of foamed materials result in a significant improvement in the passive safety of the vehicle, owing to their excellent energy dissipation properties.
  - EVA foam is resistant against almost all chemicals. Most alkalis, bases, oils and acids do not form a threat for EVA foam.
  - EVA has a distinctive "vinegar" odor.
  - EVA is competitive with rubber.

- EVA has good resistance to salt water and bases, but is not compatible with strong oxidizers.
- EVA copolymers are generally readily soluble in a wide range of aliphatic, aromatic and chlorinated solvents.
- EVA has good resistance to oils and fuels.

2.3.7Disadvantage of EVA foam

When the materials are formed, chemical connections are created. These chemical connections cannot be easily broken. When the material is heated after it is formed it will not melt, but it will burn. Because of this the material is not recyclable. Ethylene Vinyl Acetate (EVA) is the one of light weight garbage, examples, slippers, sport shoe sole, plastic cones etc.

This EVA products makes EVA foam an environment unfriendly material. But it is sustainable in a way because it has a high resistance against abrasion and therefore has a long life cycle.

Alvarez et al (2008), outlined the following disadvantages of Human Health and Environmental concerns for EVA foam.[13][14]:

- EVA Produces toxic chemicals in fires.
- Uses carbon monoxidein production.
- Risk of fire due to pellets or powder plastic.
- Chloride catalyst is used in some vinyl acetate production.
- Risk of children choking from small parts due to product breakage
- Incomplete combustion produces carbon monoxide and low molecular weight aldehydes.
- Incomplete combustion produces carbon monoxide and low molecular weight aldehydes.
- Environmental Concerns from Ideal disposal method is in landfill.

- Byproducts of ethylene production. Chloride catalyst used in some vinyl acetate production [15].

There are many works studied Effect of environmental and chemical material like mineral acids, ketones, and aromatic or chlorinated hydrocarbonson EVA foam one of them done by .Ing et al. (2003) suggest that Polymeric materials are sensitive to processing and affected by the environment, time and temperature during storage, transportation and service. Especially the long-term properties are frequently unpredictable can match the flexibility of EVA they also have better environmental stress cracking resistance. This work, investigations on environmental stress cracking resistance (ESCR) were carried out on polyethylene compounds comprising low density polyethylene (LDPE) and different amounts of ethylene-vinyl acetate random copolymer (EVA). Work had concluded that a strong interplay exists between composition, morphological features and the ESCR behavior of PE/EVA blends. Obtained results demonstrate that EVA containing 28 wt.-% VA vinyl acetate is a very effective copolymer for the retardation of ESC in LDPE. Samples containing 8.9 wt.-% EVA always pass the ESCR test at all temperatures up to 1000 *h*. When the EVA content is 7.1 wt.-% and less, the affinity of polyethylene to ESC can be clearly seen. In most of the cases, cracking starts on both sides in a direction perpendicular to the notch as expected from the finite element calculations.

The ESC behavior of a polymer is strongly dependent on:

The concentration of the stress-cracking agent, exposure temperature, exposure time, and most of all, the level of strain on/in the polymer.

As a result of the long thermal treatment of the samples during the Bell telephone test, different reorganization processes can occur. Therefore, any changes in the thermal properties are detected by differential scanning calorimetry (DSC). Wide- and small angle X-ray scattering investigations are carried out for determination of any changes in the crystal structure and lamellae arrangement as a result of the long thermal treatment in the Ideal surfactant during the Bell telephone test. Relevant microscopic techniques (atomic force microscopy, transmission electron microscopy, scanning electron microscopy, high voltage electron microscopy) are applied for morphology characterization, monitoring the process of brittle failure and micromechanical deformation mechanism. The morphological data should be then correlated with the results of the ESCR test and the mechanical tests in order to create a correlation model for morphology and (ESCR)in plastics means the failure at about room temperature due to continuously acting external and/or internal stresses in the presence of surface active substances (known as stress cracking agents) such as alcohols, soaps, dyes, agents containing moisture behavior ,of polyethylene compounds.

Mechanical properties of PE/EVA samples had investigated at room temperature, 50 and 70°*C* by using Instron test machine. The results show that the increased temperature reduces the stiffness of the polymer as observed from the decreased Young’s modulus. Both Young’s modulus and yield stress fell monotonically with increasing temperature.

EVA is resistant to dilute mineral acids, alkaline substances, alcohols, fats, oils and detergents but not to concentrated mineral acids, ketones, and aromatic or chlorinated hydrocarbons. The resistance to ESC increases with increasing VA content and decreasing melt index. It is significantly higher for EVA copolymers than for comparable LDPE .It is well known that EVA has been used in the modification of PE for better flexibility, toughness, and resistance to environmental stress cracking [26].

2.3.9 Properties of EVA foam composite with other material

Polymeric materials have Properties different from each other and sometimes are similar, to get mixed polymers with new-modified polymers or composite, there are many articles studied that composites of EVA.

Thai Hoang, Vu Dinh et al (2014), focused in their research on the Tensile, rheological properties, thermal stability, and morphology of ethylene vinylacetate copolymer/silica nanocomposites using EVA-g-maleic anhydride ,EVA-g-maleic anhydride with 0.5 wt% maleic anhydride groups was added to all ethylene vinyl acetate/silica nanocomposites. Fourier transform infrared, field emission scanning electron microscopy, rheology behavior, and thermo gravimetry analysis were used to characterize the structure, morphology, rheological, and thermal properties of the nanocomposites, respectively. The Fourier transform infrared spectra and field emission scanning electron microscopy micrographs showed that the hydroxyl groups on the surface of silica nanoparticlesinteract with maleic anhydride groups in EVA-g-maleic anhydride and lead to a finer dispersion of individual silica nanoparticles in the ethylene vinyl acetate matrix. The rheological properties and thermal stability of ethylene vinylacetate/silica nanocomposites were significantly increased after adding EVA-g-maleic anhydride into the nanocomposites.Mechanical properties including tensile strength and elongation at break of the nanocomposites were mainly affected by the content of silica nanoparticles. For the tensile strength as well as elongation at break of the nanocomposites, amaximum value was observed at the content of 0.5 wt% of silica nanoparticles. The addition of EVA-g-maleic anhydrideinto ethylene vinyl acetate/silica nanocomposites resulted in a further improvement of mechanical properties of thenanocomposites[27].

Dongfang Li, et al (2012) ,investigated the effects of different ethylene vinyl acetate EVA contents on the performance of wood plastic composites WPCs made from poplar wood flour PWF and high density poly ethylene HDPE, physical properties tests, mechanical properties test, and scanning electron microsope SEM tests were employed .the thermal and functional groups of PWF treated by EVA were evaluated by thermo gravimetric analysis TGA ,different thermal analysis DTA, and fourier transform infared spectroscopy FTIR espectively . Figure 1(a)-(b) show the results hardness, densities ,water uptake,and thickness welling of the WPCs was reduced with increasing content of EVA. the MOR and tensile strength of the WPC treated by 15%EVA content were enhanced by17.48% and 9.97%,respectivelyhad shown in figure 1 – (c), compared with those of WPC without EVA .TGA results showed thermal stability of PWF treated by EVA was improved ,FTIR analysis indicated that PWF was reacted and coated with EVA. SEM results showed that gaps and voids hardly existed in the sections of the WPCstreated byEVA.This article had shown the following result the best condition of EVA content could be 15% to improved the flexibility and mechanical properties of WPCs [28].

A.M. Betioli et al (2009), over research has been conducted to the ethylene/vinyl acetate (EVA) copolymer, it had used as latex or powder, is added to mortars and concrete to improve the fracture toughness, impermeability and bond strength to various substrates. The physical and chemical interactions were already proved after one day of hydration but during the first hour just the physical interaction was identified and some evidences of a chemical interaction.

The aim of this work was to evaluate the chemical interaction between EVA and Portland cement during the first hours of hydration in the thermo gravimetric analysis. EVA added two percentage 5% and 10% to modified cement paste or blended Portland cement with 10% calcareous filler was used, according to brazilian Standard (CPII F 32).This work leads to the following conclusions:

EVA copolymer reduced the calcium hydroxide in the cement paste due to the chemical interaction between Ca^{2+} ions and anions acetate, released in the EVA alkaline hydrolysis. This interaction was verified at the first 15 *min* by the absence of the dehydration peak in thermo gravimetric analyses until 5 and 6 *h* in EVA-modified pastes with 5% and 10% EVA, respectively; the new peak observed at 380 ^0C, referred to the first calcium acetate decomposition and, the increase in CO_2 release, due to its calcium carbonate formed during the decomposition of the calcium acetate.This chemical interaction probably decreases the EVA flexibility, thus promoting the elasticity modulus of cement-based materials increases[29].

Other work related to interaction between EVA and hydrating Portland cement done by D.A. Silva, H.R. et al (2002) concluded use of ethylene/vinyl acetate copolymer (EVA) in mortar and concrete production, there is no agreement among various researchers about the kind of interaction that is developed between cement and polymeric phases. The purpose of this research is to fill this lack of knowledge through the micro structural characterization of cement pastes modified with EVA copolymer. Portland cement pastes were prepared with different EVA contents. The water/cement ratio was kept constant. The pastes were submitted to two different curing conditions, and analyzed at 28 *days* old. Thermal analyses (differential thermal analysis [DTA] and Thermo gravimetric [TG] analysis, Fourier-transform infrared spectroscopy (FT-IR) and scanning electron microscopy (SEM) tests were performed, which permitted the evaluation of the EVA effects on the cement hydration. Some evidences of chemical interactions between cementitious and polymeric phases were identified. The actual EVA contents in the mixtures were 10% and20% by cement weight. These contents were corrected due to the presence of inorganic compounds in the copolymer powder, measured by the ash content consequently; EVA copolymer/cement ratios of 10% and 20%were obtained by adding, respectively, 10.8% and 21.6% of EVA. The water/cement ratio was kept constant at 0.4, in weight basis.

From the micro structural tests performed with pure and EVA-modified cement pastes it was possible to conclude that:

- There are evidences of chemical interaction of acid groups released by alkaline hydrolysis of EVA with Ca^{2+} ions in the pore water of the cement pastes.The products of this interaction are calcium acetate and polyvinyl alcohol.
- Calcium acetate is an organic salt with high hygroscopicity, and polyvinyl alcohol is water soluble. These two factors can impair the performance of EVA-modified mortars and concretes when saturated by water.EVA copolymer changes into a polymer formed by ethylene, vinyl acetate and polyvinyl alcohol.
- EVA retards the whole cement hydration reactions and leads to the formation of Hadley’s grains and big rods. The quantity of calcium hydroxide in cement pastes is decreased also because EVA consumes Ca^{2+} ions from the solution.
- EVA-modified cement pastes showed expressive formation of polymeric film deposited on the surface of an hydrous and hydrated cement phases, and also partially ling pore walls.

The results showed that the acetate groups of EVA copolymer undergo alkaline hydrolysis and interact with Ca^{2+} ions of the pastes to form an organic salt (calcium acetate). The calcium hydroxide content is decreased, the crystals appear to be well formed and many Hadley's grains were observed. A calcium-rich, porous and hexagonal structure phase was detected, probably due to acetic acid attack on calcium hydroxide crystals [30].

2.4 Procedure of Plastics foam

The plastic foaming procedure generally has four basic steps [6]:

1) Polymer and blowing agent mixing. Azodicarbonamide (AZC) is one of the widely used blowing agent, It generates 65% N_2, 32% CO_2.

2) Polymer/blowing agent solution formation.

3) Bubble nucleation.

4) Cell growth and stabilization. Figure (2.5) presents basic steps of cellular plastics processing [8].

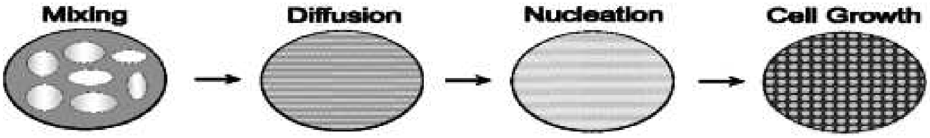


Figure 2.5Basic steps of cellular plastics processing

2.4.1 Production of EVA foam

EVA foams used in running midsoles are mainly made by two different processes:

1. Compression moulding.
2. Injection-moulding .

2.4.2 Production of EVA foam by Compression moulding

The foams were made by compression moulding had a two-stage process:

- Firstly, the extrusion (one or two extruder).
- Secondly, the compression moulding, as shown in figure (2.6.)

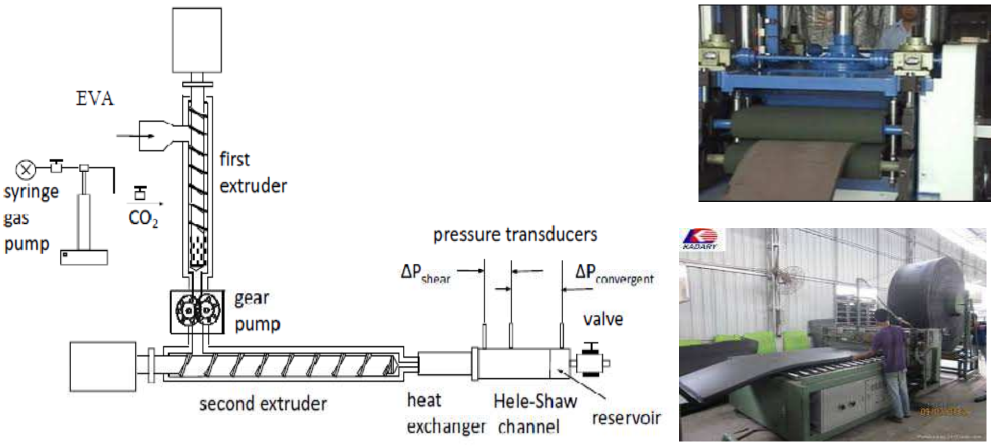


Figure2.6: Production of sandal made by extrusion and compression moulding

EVA foam compositions are compounded to carefully balance the decomposition of the peroxide. EVA foam products are compounded by:

- Batch mixing in an ammeter.
- Cooling and dispersal mixing on open mills, and
- Calendaring or granulation to make a final mixed compound ready for production of foam.

The Slab stock foam is used for die-cut EVA midsoles, and sock liners. Large steam heat presses are used to make slabs of EVA foam. The slabs are then mechanically skived, cut and shaped to the final parts.

According to D. Eaves, Ed (2004), and Stephen Moore (2012),They titled the foaming process is as follows :[8][19].

1. The EVA, the blowing agent, peroxide and the rest of the ingredients in table 2.3 are mixed together and introduced into a mill to get a homogeneous mixture.

Table 2.3: Formulation for a EVA foam with 15 to 18 % VA content. □ phr denotes grams of component per 100 g of dry resin

Ingredient	Content (*phr*)
EVA	95
Rubber	5
Crosslinking	0.75
Foaming Agent	4
Zinc Oxide(ZnO)	1
Calcium stearate	1
Megnesium Carbonate ($MgCo_3$)	1
Magnesium Carbonate	8
Titanium dioxide (TiO_2)	1

.

2. The extrusion stage takes place by introducing the mix into a calender, which consists of four horizontal robust counter-rotating steel rolls where the mix is formed into a sheet of uniform thickness [8][9]. The sheet is cut and pile up to a certain thickness, which depends on the volume of the cavity of the mould.
3. The slab is heated in a compression mould and expanded by a release of pressure.
4. The foam slab is moved into a cool flat place for at least three days until its dimension is stabilized.
5. The skin is removed and the foam slab is cut into a fixed thickness and then trim to a specific contour.
6. This perform is then heated in the mould until the surface is melted.
7. Then the foam is subjected to a change of temperature, by turning off the heat source and on a cooling system, and its dimension is stabilized.

8. The edges are trimmed to get the finished product.

2.4.3 Production of EVA foam by injection moulding

EVA foam injection molding is a relatively new production process. There are only a few companies ' worldwide that produce products using this process. EVA foam products in the form of slabs and plates have been known for a few years. Looking at 3D-shape with EVA foam, there is a whole new world to discover.

EVA injection moulding machine (ethylene vinyl acetate foam injection moulding machine) is specialized in producing plastic products. It has two main parts, namely:

- Injection unit.
- Clamping unit.

EVA (Ethylene Vinyl Acetate) foam injection molding is the production of EVA foam products using a special form of injection molding. Melted EVA foam material is forced into a shape because of an injection force. The amount of material and the used pressure are enough for the material fill the shape completely. Final products by EVA injection molding machine are EVA slippers, sandals, clogs and sneaker soles and various EVA toys for children.

The EVA material, a chemical blowing agent, and a chemical curing agent are mixed into many small pellets, which are poured into an injection machine hopper. The pellets are then injected into the shrink mold in a semi-melt situation (screws to 120°C). The pellets are then heated to 175°C for 400 s using the heating plate at the top and bottom. The mold is then released after packing for 400 s, and the shoe sole inside freely expands to a large shoe sole product (Fig. 2.7)

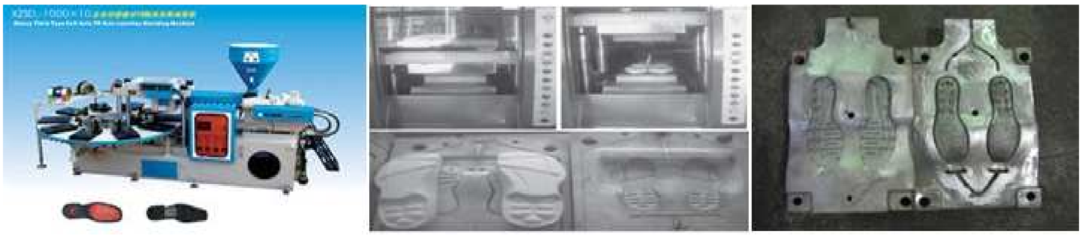


Figure.2.7: After packing for 400 s at a high temperature, the mold was released and the shrunk shoe sole inside freely expanded to a large 3D product

Using an oven system to gradually cool the material to room temperature from 175°C solidifying the finished product.To produce the shoe sole product shape accurately by using the EVA foam material, the manufacturing procedure is the crucial step.

The products that are created using this production process are not just solid EVA products, but foam products. There are gas bubbles inside the material that make the product foam. These gas bubbles are created through the chemical reaction of EVA with a foaming agent and a cross-linking agent. There are also cross-links which give the material better mechanical properties. The chemical reactions occur around170 °*C*, so the material has to be heated [17].

The composition of the two additives varies for each company and is mostly secret. A possible foaming agent is ADC, azodicarbonamide or azobisformamide. This is a synthetic chemical with the moleculeformula $C_2H_4O_2N_4$. It is a yellow to orange red, odorless, crystalline powder. The thermal decomposition ofazodicarbonamide results in the emerging of nitrogen, carbon monoxide, carbon dioxide, and ammoniavgases, which are trapped in the polymer as bubbles to form a foamed product.

Heated EVA foam material wants to expand because gas bubbles with a greater volume are formed, but the pressure of the mold on the material prevents the material from expanding. When the mold is opened, the pressure on the material will be relieved and the material can finally expand up to 1.75 times its original size. Due to the loss of heat the material will also shrink for about 5 % afterwards.

Obviously the product itself is a very important factor that determines the costs. The amount of products that is requested is decisive for the final product price. A good marketing plan with a good balance is very important. Making a few products results in unacceptable prices for the customers. But making too many products could result in over-producing, which is a waste of material, time and money as well. The size of the product will affect the amount of material used and the number of products that can be made by one mold and both affect the production costs. The number of products that can be made by one mold is determined by the size, but also by the complexity of the product and has a direct relationship to the productivity and cost of manufacturing the product. Obviously, using thicker walls also means using more material, but because the material is heated inside the mold, the thickness of the product seriously affects the cycle time and therefore the production costs as well. So it is preferred to maintain one wall thickness for most of the product. Different colors have a different price[19].

Advantages of IMM injection moulding machines:

1. EVA injection moulding machines function stably under Siemens industrial PC controlling. They show advantages of low malfunction rate and high efficiency. Besides, products moulded by our machines are nice in appearance, and they have low inferior-quality rate.
2. The injection machine can hold 4/6/8 workstations at the same time to meet different production needs.

2.4.4 Usage and Applications of EVA foam

There are a lot of different applications of foams depending on the different types of production and properties of EVA foam as mechanical properties of foams are related to their complex microstructure and to the properties of the material of which the cell walls are made, and foam density, cell size, cell density, foam morphology.

Due to the foaming and cross linking the material expands to 1.2 - 1.75 times the original volume.EVA is widely used at the footwear industry as a material for shoes' sole. EVA slippers and sandals are currently very popular because of their properties like light weight, easy to form, odorless, glossy finish, and cheaper compared to natural rubber [8][9].

Polymer foam can be viewed from different perspectives, such as product dimension, , and foam property, in here a solid polymeric material Polymer foams as EVA are used in a number of applications of passive safety for consumer goods (packaging for electronic equipment...) or for consumers themselves (helmets, knee pads) because of their good energy absorbing a shock. It is typically used as a shock absorber in sports shoes. EVA foam is used also as padding in equipment for various sports such as:

- Ski boots, Bicycle saddles, Hockey pads, Boxing and Mixed martial arts gloves and Wakeboard boots, Fishing rods-Fishing reel handles.

There are many other applications for EVA foam as examples:

- Freezer door gaskets, convoluted tube for vacuum cleaners.
- Electrical: Foams for static sensitive devices**.**
- Industrial : Hoses, tubes**.**
- Packaging Shrink wrap film**.**
- EVA is also used in biomedical engineering applications as adrug delivery device.

- Medical: Disposable gloves, an aesthesia face masks and hoses.
- Miscellaneous: Adhesives, coatings, sealants,solar cell, in capsulation, baby bottlenipples .deferent's applications of EVA.[8][12][17].shown in fig(2.8).

Figure2.8 :Applications of EVA foam

2.4.5 Product of EVA Copolymer according to Weight % Vinyl acetate

There are many types of EVA copolymer according to weight percentage of Vinyl acetate (Wt. % VA) as follows[19]:

1. **Very Low EVA** 1 - < 7% Commodity films, e.g., Bakery bags, ice bags, frozen food bags, overwrap and fresh produce wrap.
2. **Low EVA** 7 - < 17% Blow molding, foam applications, extrusion / lamination, injection molding, industrial stretch wrap and wire and cable.

3. **Mid EVA** 17 - < 25% Extrusion coating, injection molding, lamination film, heat seal layers,hot melt adhesives, agricultural films.
4. High EVA 25 - 35% Carpet backing, hot melt adhesives, injection molding, wax blended coatings,extrusion, solar panels and photovoltaic cells.
5. Ultra High EVA 36 - 45% hot melt adhesives, coating, polymer modification, grafted polymers.

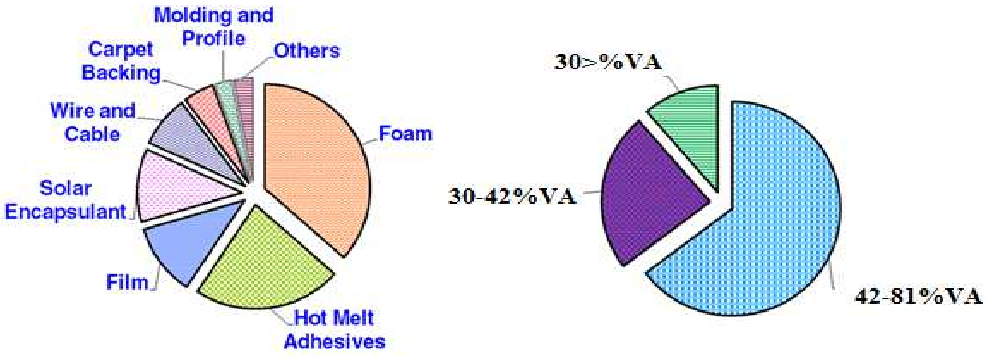


Figure2.9:Applications of EVA foam made from different % of VA

2.5 General Plastics Recycling

Waste is now a global problem, and one that must be addressed in order to solve the world's resource and energy challenges. Plastics are made from limited resources such as petroleum, and huge advances are being made in the development of technologies to recycle plastic waste among other resources. Mechanical recycling methods to make plastic products and feedstock recycling methods that use plastic as a raw material in the chemical industry have been widely adopted, and awareness has also grown recently of the importance of Thermal recycling as a means of using plastics as an energy source to conserve petroleum resources. According to Figure

(2.10), plastics compose about 12 % of the total Municipal Solid Waste (MSW) generated, which is about 29.5 *million tons* annually [21].

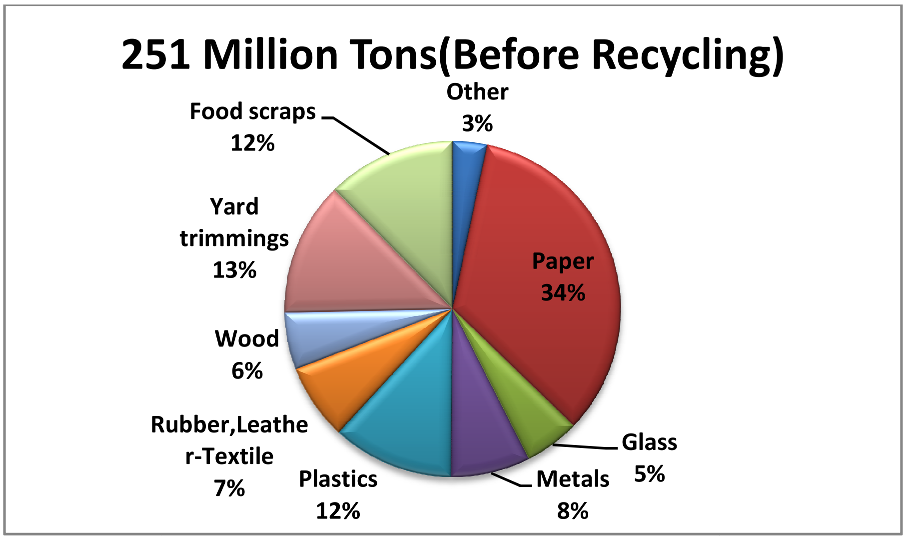


Figure 2.10 the % of plastics compose of total Municipal Solid Waste (MSW) generated

Generally Recycling of plastics is a process to change materials into new products to prevent waste of potentially useful materials, reduce the consumption of fresh raw materials, reduce energy usage, reduce air pollution (from incineration) and water pollution (from land filling) by reducing the need for "conventional" waste disposal, and lower greenhouse gas emissions as compared to plastic production.

These problems have increased the use of recycled thermoplastics such as polyethylene, polypropylene and polyamide, which can be melted for recycling in the plastic industry,

Identification marks or plastics recycling codes are assist to sorted collection, containers and packaging .Because of the wide variety of materials from which plastic products are made, it is recommended that such products also bear a (material mark), figure (2.11) presented the plastics recycling codes, As well as the identification and material marks specified by the Container and Packaging Recycling Law, the symbols below are sometimes seen [19] [20][21].

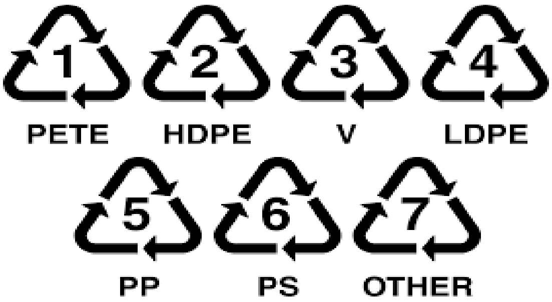


Figure2.11 Plastics Recycling Codes

1 = Polyethylene Terephthalate 2 = High Density Polyethylene
3 = Vinyl 4 = Low Density Polyethylene 5 = Polypropylene
6 = Polystyrene
7 = OTHER - all other resins and multi-materials

The use of plastic materials has been growing all over the world in packing, automotive and industrial applications. This results in great generation of urban and industrial waste that can be stored or eliminated. Due to the low density of plastics, storage or disposition in landfills implies the availability of large surface areas. The elimination of plastics can be done by incineration, however, as the production of plastics involves the use of potentially harmful chemicals, the ashes produced may not always be acceptable in a landfill because of their potentiality to cause groundwater and soil pollution due to leach ate carrying heavy metals[12][16].

2.5.1General Step of Plastic Recycling

There are five steps process for plastics recycling:

2.5.1.1Collection

The recycling facilities gather available recyclable plastic material in their area, such as from roadside collections, special recycling bins, or even directly from industries. In this way, both post-consumer and post-industrial plastic items are collected.

2.5.1.2Manual Sorting

All plastic items that are collected are then sorted according to the various plastic types indicated by the plastic recycling symbols and codes on them. Unwanted non-plastic materials found in the piles are promptly taken out.

2.5.1.3Chipping

After sorting, the sorted plastic products are prepared for melting by being cut into small pieces. The plastic items are fed into a machine which has sets of blades that slice through the material and break the plastic into tiny bits, commonly known as regrind or granules,as shown in fig(2.12).

2.5.1.4Washing

At this step in the process of recycling plastic, all residue of products originally contained in the plastic items and various other ‘contaminants’ (e.g. paper labels, dirt) are removed. A particular wash solution consisting of an alkaline, cationic detergent and water are used to effectively get rid of all the contaminants on the plastic material, making sure that all the plastic bits are clean and ready for the final step. During washing, the wash tank agitator serves as an abrasive, stripping the adhesive off any labels and shredding any paper mixed in with the plastics. The alkaline, cationic detergent (which is similar to the formulas used in shampoos and fabric softeners) is used because plastic materials have a positive surface charge, and only positively-charged chemical compounds (which in this case are cationic detergents) can properly clean them, and effectively remove dirt and grease from the positively charged plastic surfaces.

2.5.1.5Pelletizing

The cleaned and chipped pieces of plastic are then melted down and put through a machine called an ‘extruder’ in this stage of the recycling plastic process. The extruder shapes the melted plastic into thin noodle-like tubes. The plastic tubes are then cut into small pellets by a set of rotating knives. The pellets are then ready to be reused and remade into new items.

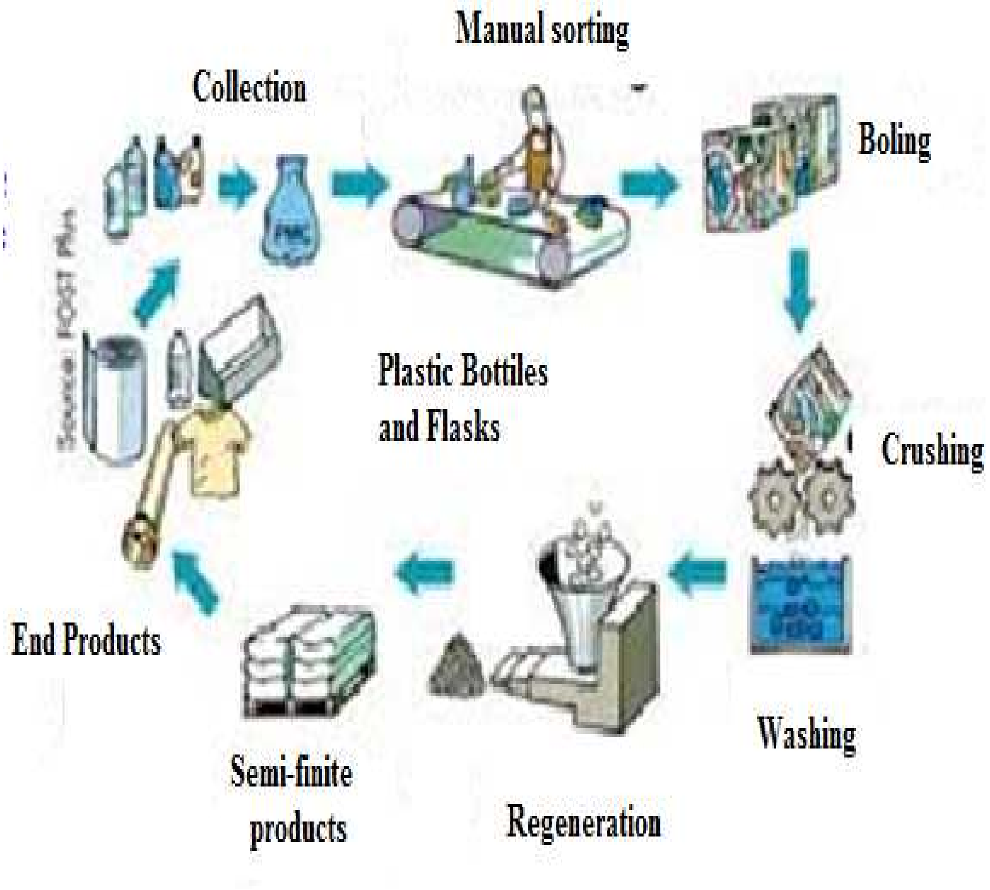


Figure2.12 steps process for plastics recycling

2.5.2 Methods of recycling of Plastics

Internationally there are many methods for recycling scrap of plastics, one of them is the chemical recycling and the other is physical recycling. Another process involves the conversion of assorted polymers into petroleum by a much less precise thermal depolymerization process. Such a process would be able to accept almost any polymer or mix of polymers, including thermoset materials such as vulcanized rubber tires and the biopolymers in feathers and other agricultural waste. Like natural petroleum, the chemicals produced can be made into fuels as well as polymers. On the other hand compositions and methods for incorporating high levels of scrap EVA foam into molded articles made of virgin EVA are based on the discovery that certain compatibilizers can be used to increase the physical properties of the molded articles.

The methods of recycling currently recognized by the Container and Packaging Recycling Law are mechanical recycling, feedstock recycling (monomerization, liquefaction, use as a blast furnace reducing agent, coke oven chemical feedstock recycling and conversion to chemical feedstock by gasification) and thermal recycling (liquefaction and gasification). Under the amendment in 2006, RDF and other forms of thermal recycling were added as supplementary methods, albeit with Plastic Waste Management Institute (2009) concluded the methods of recycling category in Japan and other method in Europe as shown in table (2.6):

Table2.4 Recycling category in Japan and other method in Europe

Category (in Japan)	**Method of Recycling**		**Method of Recycling Category (in Europe)**
Material recycling	Recycling to make Plastic raw materials- plastic products).		Mechanical recycling Recycling to make: Plastic raw materials Plastic products
Chemical recycling	Monemertization		Monmerization Feedstock recycling
	Blast furnace reducing agent		
	Coke oven chemical feedstock recycling		
Thermal recycling	Gasification- Liquefaction	Chemical feedstock	Thermal recycling
		Fuel	
	Cement kiln Waste power generation RDF *[1] RPF *[2]		

1: Refuse Derived Fuel (solid fuel made from burnable waste, plastic waste, etc.) 2* : Refuse Paper & Plastic Fuel (high-calorie solid fuel made from waste paper and plastic).*

Recycling technology has advanced tremendously and its use is spreading, but recycling is not an end in itself. As the Basic Law for Promoting the Creation of a Recycling-oriented Society enacted in 2000 made explicit, the purpose of recycling is to curb consumption of finite natural resources such as oil and minimize the burden on the environment through the cyclical use of resources. This means it is necessary to carefully consider whether the method used reduces inputs of new resources or limits the burden on the environment when promoting recycling.

It is important to select the recycling method for plastics that imposes the least social cost as well as limiting environmental impact given the situation of the plastic waste to be recycled[22][23].

2.5.2.1 Mechanical Recycling:

Mechanically recycled waste has until now consisted largely of industrial plastic waste. Industrial plastic waste generated in the manufacture, processing and distribution of plastic products is well suited for use as the raw material for mechanical recycling thanks to clear separation of different types of resins, a low level of dirt and impurities and availability in large quantities. Used plastics from households, stores and offices are now being mechanically recycled as a result of the entry into effect of the Container and Packaging Recycling Law and the Home Appliance Recycling Law. All kinds of recycled products are made from industrial plastic, presented in fig (2.13).

Fig 2.13: Kinds of recycled products are made from industrial plastic

Mechanical recycling of plastic waste follows the same basic process of raw materials:

1. **Extrusion moulding**

   Resin is melted and continually extruded through a mold by a screw to form a molded product. Products include pipes, sheets, film and wire covering [4].

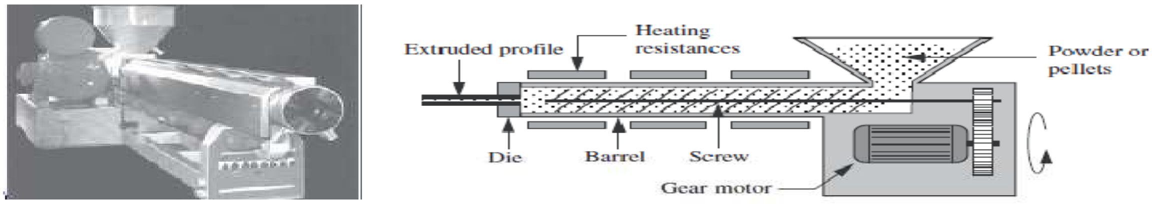


Figure 2.14Extrusion machine

2. **Injection moulding:**

   Heated melted resin is injected into a mold and solidifies to form a molded product. Products made this way range from washbowls, buckets and plastic models to larger products such as bumpers and pliers [4].

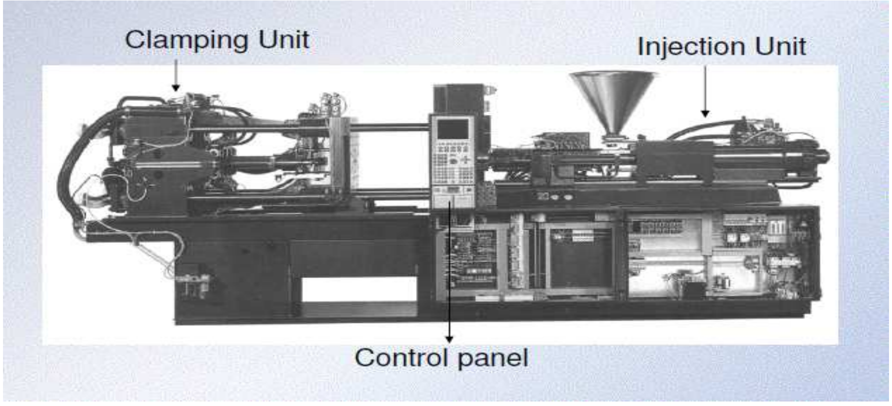


Figure 2.15Injection machine

3. **Blow Moulding :**

   A parison obtained by extrusion or injection molding is clamped into a mold and inflated with air to make bottles for all kinds of uses, such as shampoo bottles. They are made by stretch blow molding so as to make them less likely to rupture [4].

Figure 2.16 Blow moulding machine

4. **Vacuum Moulding:**

A heat-softened sheet is sandwiched in a mold and the space between the sheet and mold sealed and evacuated to form products such as cups and trays.

5. **Inflation Method :**

a cylinder to form a film. This method is used to make products such as shopping. some limitations,[22].

2.5.2.2 Chemical Recycling by Monomerization

Monomerization is technique used for manufacturing resin by breaking it down into high-puritymonomer.

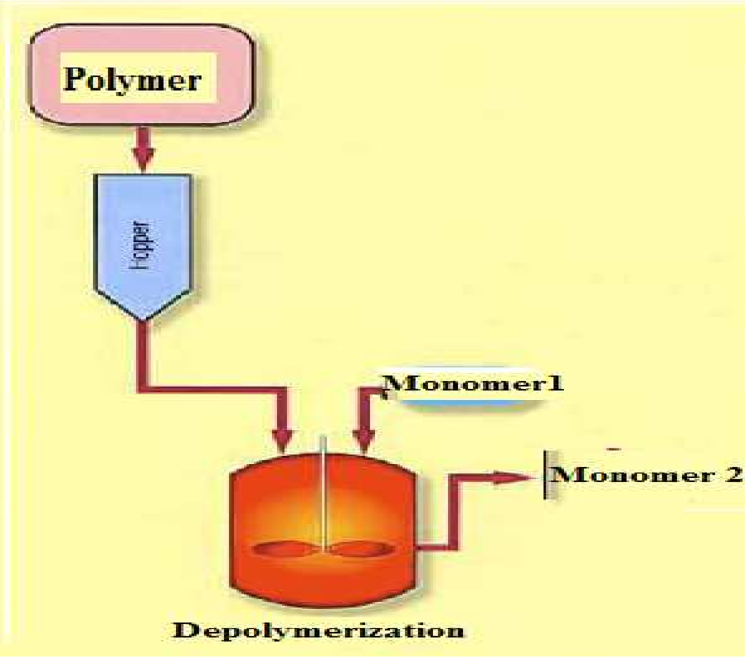


Figure 2.17 Recycling by Monomerization method

2.5.2.3 Thermal Recycling (Gasification)

Plastics are converted to gas for use as a raw material in the chemical industry.

Plastics are composed mainly of carbon and hydrogen and therefore normally produce carbon dioxide and water when combusted. The gasification process involves heating plastics and adding a supply of oxygen and steam. The supply of oxygen is limited, which means that much of the plastics turn into hydrocarbon, carbon monoxide and water. Sand heated to 600-800^{0}C is circulated inside a first-stage low-temperature gasification furnace. Plastics introduced into the furnace break down on contact with the sand to form hydrocarbon, carbon monoxide, hydrogen and char. If the plastics contain chlorine, they produce hydrogen chloride. If plastic products contain metal or glass, these are recovered as non-combustible matter.

The gas from the low-temperature gasification furnace is reacted with steam at a temperature of 1,300-1,500^{0}C in a second-stage high-temperature gasification furnace to produce a gas composed mainly of carbon monoxide and oxygen. At the furnace outlet, the gas is rapidly cooled to 200^{0}C or below to prevent the formation of dioxins. The granulated blast furnace slag alsoproduced is used in civil engineering and construction materials.

The gas then passes through a gas scrubber and any remaining hydrogen chloride is neutralized by alkalis and removed from the synthetic gas. This synthetic gas is used as a raw material in the chemical industry to produce chemicals such as hydrogen, methanol, ammonia and acetic acid.

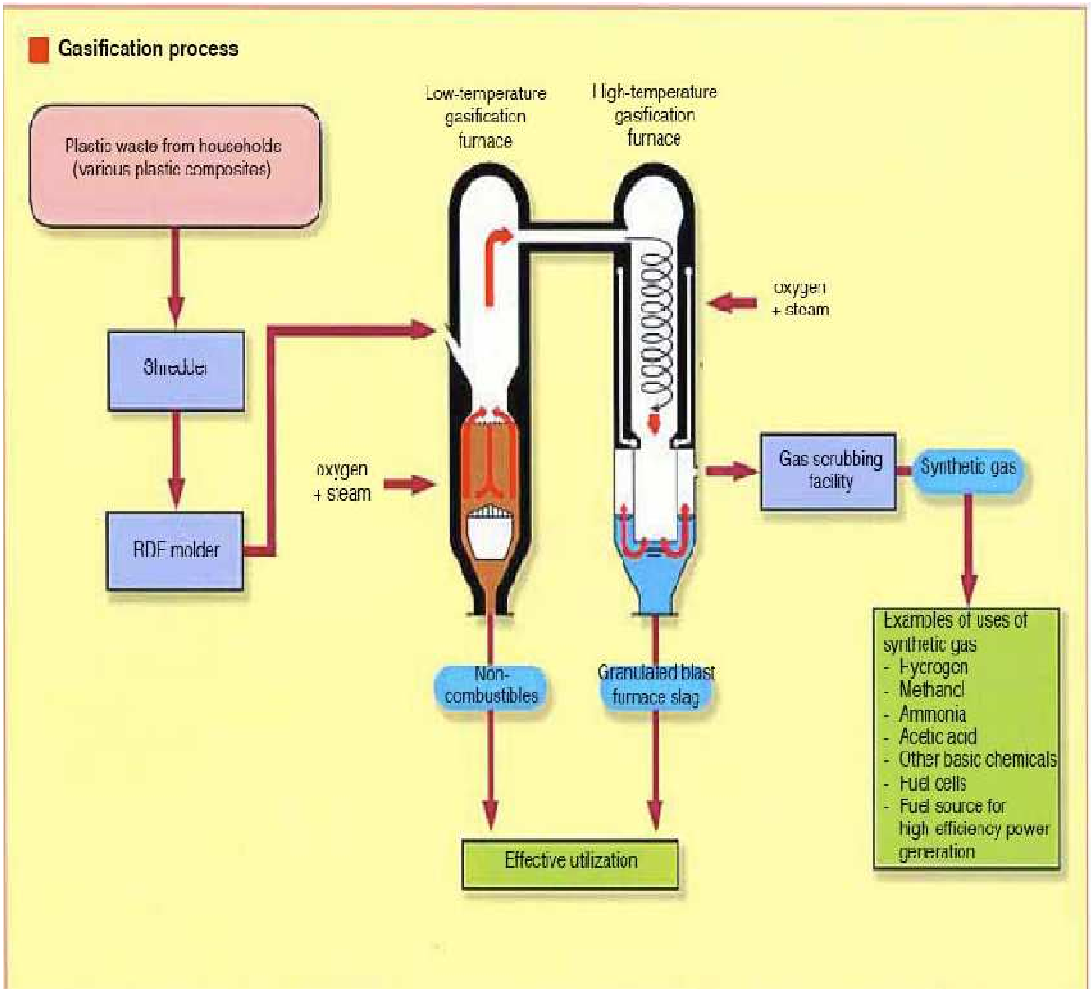
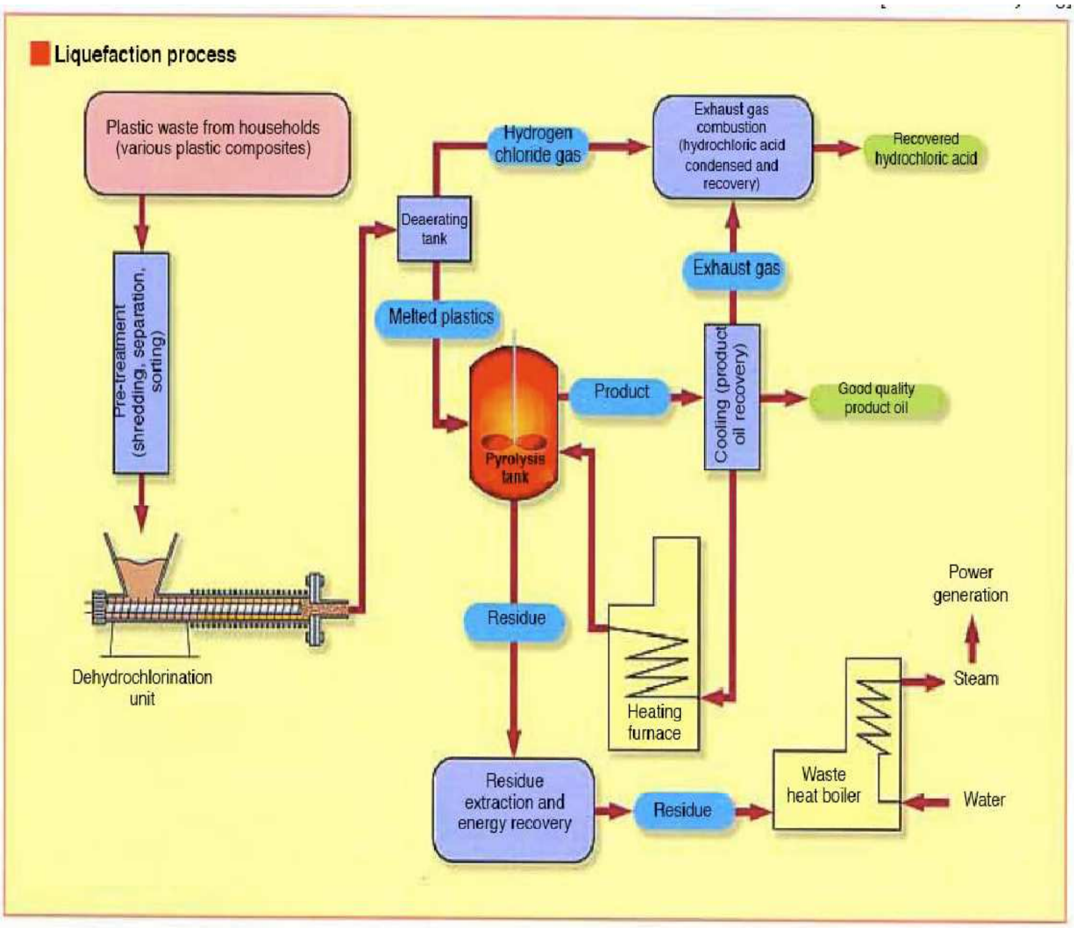


Figure 2.18Gasification and melting furnace power generation system

2.5.2.4Thermal Recycling(Liquefaction) Waste Plastics Converted Back Tooil.

Plastics are produced from petroleum, it should be possible to produce petroleum from them by reversing the process by which they are manufactured.

The Plastic Waste Management Institute has established a technique to convert plastic waste back to oil following development 2work initiated in the late 1970s [21]



Source: Plastic Waste Management Institute

Figure 2.19Recycling method by Liquefaction

2.6 Recycling of EVA foam

EVA foam have one of the highest growth rates of plastics materials , EVA is widely used at the footwear industry as a material for shoes´ sole.EVA cannot be melted through heat because of its molecular chains and hence another recycling process is needed, they do not decompose easily.Currently, 17 *billion pairs* of shoes are produced worldwide every year, and this creates an enormous amount of post-consumer(end-of-life) shoe waste that is currently being disposed of in landfill sites around the world [11].

As example in 2006, the US consumed 2,403,137,000 *pairs* of shoes .There are many efforts have been made to minimize the impact of industrial rejects. Total EVA demand grows by an estimated 645.7*kT* over 5*years* of an annual growth rate of 3.5%/*year*. The following table presents recycling of EVA foam.

Figure 2.20Recycling of EVA

HVEA demand grows by anestimated 208 *kT* or comprise 32.2% of new growth (6.4%AAGR).

MEVA demand grows by anestimated258.9*kT* (leads all EVAs)or comprise 40.1% of new growth. As shown the annual consumption of EVA in the world from 2011 up to 2016 by *kTonn* .total EVA demand grows by an estimated 645.7*kT* over an annual growth rate of 3.5%,summarizes in table (2.4) [18].

Barrett, J. R. (2005). Concluded the cutting stage of outsole, in sock and reinforcement generates about25–35% of waste which represents 80 *tons* of waste/million pairs [12].

The EVA represents 14% of this waste. Therefore, 190, 400 *tons* of EVA waste are generating worldwide every year needing a large surface for placement and storage, and also generates great costs of management due to its long biodegradation period.

Table2.5 Total EVA Capacity Utilization 2011-2016

Process	**Market**	**Global Summary-2016KTA**					**Global Summary 2011-2016%AAGR**				
		VLEVA	**EVAL**	**MEVA**	**HEVA**	**Total EVA**	**VLEVA**	**EVAL**	**MEVA**	**HEVA**	**Total EVA**
Extrusion	film					1,555.2	2.0%	2.6%	3.4%	2.5%	2.6%
-	coating					145.4	1.9%	1.4%	3.2%	11.6%	2.4%
Injection	footwear					874.7	8.2%	2.5%	3.1%	6.9%	3.4%
Compound -other	Wire-cable-photovoltaic cells					604.9	6.0%	2.4%	5.8%	10.1%	6.7%
Other Extrusion	Hoses-Tubing-Profile					240.5	3.0%	3.1%	4.3%	3.0%	3.5%
Other Non-Extrusion	Hot melt Adhesives -foam					644.6	9.2%	2.9%	3.0%	3.8%	3.4%
Total EVA						4,065.3	2.3%	2.5%	3.3%	6.4%	3.5%

According to CBI China Presented by Stephen Moore (2012) concluded the total consumption of EVA in the world from 2011-2016, shown in table (2.5).Africa are the largest importers of EVA in this order. Other Asia/Pacific (OAP), Western Europe and North America (NA) are the largest exporters of EVA in this order China, Middle East (ME)[19].

The following table (2.6) presented EVA Capacity by Region / Country

Table (2.6) EVA Capacity By Region /Country

Region /Country	Total EVA *k Ton*
North America	1982
Central /South America	232
Western Europe	1062
Central/Europe	20
Japan	763
China	305
Other Asia/Pacific	584
Middle East	220
Africa	0
South Korea	692
Total	5878

Demand in EVA market did not materialize as forecasted several years ago. Forecasts were for a 5.7*%/ year* growth while the industry exhibited a 1.5*%/year* growth rate.

Table2.7 Total consumption EVA in the world from 2011-2016

	North America	Central South America	Western Europe	Central East Europe	Japan	China	Other Asia Pacific	India	Middle East	Africa	Total
2011											
Consumption	**1084**	**100**	**480**	**51**	**190**	**722**	**304**	**85**	**275**	**129**	**3,419**
Net Trade	150	20	219	68	53	446	538	87	210	129	0
Calculated Production	1234	80	699	17	243	276	842	2	65	0	3419
Average Capacity	1978	232	1055	20	763	305	1236	15	220	0	5824
Capacity Utilization	62.4%	34.4%	66.3%	NA	31.8%	90.5%	68.1%	NA	29.4%	0.0%	58.7%
2016											
Consumption	1121	122	527	72	222	921	402	99	412	168	4065
Net Trade	171	36	199	65	48	268	386	94	157	168	0
Calculated Production	1292	86	726	7	270	657	788	5	255	0	4065
Average Capacity	1982	277	1117	20	823	887	1711	15	620	0	7402
Capacity Utilization	65.2%	37.8%	65%	37%	32.8%	74.1%	46%	30.7%	41.1%	0.0%	54.9%

2.7 Concrete Definition

Concrete is the most widely used material in the world. It plays an important role in infrastructure and private buildings construction. Concrete is a manmade building material that looks like stone.

The word concrete is derived from the Latin concretus, meaning(to grow together).

Concrete is the name given to a mixture of particles of stone bound together with cement. Because the major part of concrete is of particles of broken stones and sand, it is termed the aggregate. the material which binds the aggregates is cement and this is described as the matrix.

Concrete is broadest sense, is any product or mass made by the use of a cementing medium. The simplest definitionof concrete can be written as

Concrete = filler + binder

Fig2.21 Concrete mixture

Generally this medium is the product of reaction between hydraulic cement and water. In these day a new definition for concrete cove a wide range of products, concrete is made from with several types of cement and also containing pozzolan, fly ash ,blast furnace slag a regulated set additives, sulpher, polymers, fibers and soon, and these concrete can be heated, vacuum treated, hydraulically pressured shock-vibrated, extruded mixture, and spray[31].

2.1.17 Component of concrete

1. **Aggregate(Gravel/sand)**

The materials commonly used as the aggregate for concrete sand and gravel. The grains of natural sand and particle of gravel are very hard and insolublein water and can be economically dredged or dug from pits and rivers.

The material dug from many pits and river beds consists of a mixture of sand and particles of gravel and is called ballast, or all in aggregate.

All in aggregate is one of the cheapest materials that can be used for making concrete and was used for mass concrete work such as large open foundations. The proportion of fine to coarse particle in all in aggregate cannot be vaied and the proportion may vary from batch to batch so that it is not possible to control the mix and therefore the strength of concrete made with all in aggregate.

Fine aggregate is natural which has been washed and sieved to removed all particles larger than 5 and coarse aggregate is gravel which has been crushed, washed and sieved so that the particles vary from 5to 6, and up to 12 to 19 in size.

Fig2.22: (Fines –coarse) aggregate

The fine and coarse aggregate are delivered separately .because they have to be sieved, a prepared mixture of fine and coarse aggregate is more expensive than natural than natural.

There are two types of aggregate:

a. **Sand (fine aggregate):**

A natural sediment of granular, mainly siliceous products of rock weathering .particles are smaller than 2mm,are visible to the naked eye and the smallest size is 0.06*mm*.sand is gritty, it has no real plasticity and can be easily powdered by hand when dry.

b. Gravel(coarse aggregate) :

a natural coarse grained deposit of rock fragments and finer sand, many of the particles are larger than 2*mm*.

2. **Cement :**

The cement commonly used is ordinary Portland cement .it is manufactured by heating a mixture of finely powdered clay and limestone with water to a temperature of about 1300^0C ,at which the lime and clay fuse to form a clinker .this clinker is ground with addition of little gypsum to affine powder of cement according to (ASTM C150-92).cement powder reacts with water and its composition grandually changes and the particles of cement bind together and strongly to materials with which they mixed cement.

Fig2.23Ordinary Portland cement

3. Mixing Water ,Water to Cement (W/C) ratio :

In many specifications, the quality of water is covered by a clause saying that water should be fit for drinking.

The materials used for making concrete are mixed with water for two reasons.

- Firstly to cause the reaction between cement and water which results in the cement acting as a binding agent ,
- Secondly to make material of concrete sufficiently plastic to be placed in position .the ratio of water to cement used in concrete affects its ultimate strength ,and a certain water –cement ratio produces the best concrete.

If too little water is used ,the concrete is too stiff that in cannot be compacted and if too much water is used the concrete does not develop full strength .The amount of water required to make a concrete sufficiently plastic depends on the position in which the concrete is to be placed.

2.7.2 Lightweight Concrete

The use of lightweight (LWAC) can be traced to asearly as 3,000*BC*, Earlier lightweight aggregates (LWAs) were of natural origin, mostly volcanic.

Lightweight concrete is characterized by the use of low density aggregates with high amount of voids between the particles or by the replacement of solid material by air, which can be achieved through the incorporation of air or foam, or a low specific mass can be achieved producing concrete without fines**.**

American Concrete Institute [ACI213R], (2003). Early notable LWC structures include the Port of Cosa, the Pantheon Dome, and the Coliseum.

In modern times, structural LWC structures are widely used but to a much lesser extent than normal weight concrete. With the current emphasis on upgrading structures, LWC will be very beneficial since it provides improvements in the superstructure such as wider shoulders and more lanes without the necessity of any major improvements to the substructure. LWC can also provide longer life with low maintenance [32]. There are many examples of the successful use of LWC in and outside the United States (Fidjestol, 2003; Ramirez et al., 2000).

2.7.2.1Advantages of LWC

- Purity of aggregate: man-made
- Lower dead load.
- Better physical properties: lower modulus, lower coefficient of thermal expansion, easier drilling.
- Improved durability: This is because of the reduced likelihood of shrinkage and early thermal cracking,
- Lower permeability and etc.
- Environmental problems: The benefit can be significant of industrial waste products are used to manufacture LWA.
- Offshore Platforms construction: additional buoyancy,etter cracking behavior, lower permeability, improved freeze-thaw resistance, savings on transport, etc.
- Demolition.

2.7.2.20Disadvantagesof LWC:

- Reduced resistance to locally concentrated loads.
- More brittle.

- Greater care is required in controlling water content, mixing, and supervision.
- Special measures for pumping concrete.[33]

2.2.7.2.3 Advantage of using plastics waste in concrete

The growth in the use of plastics is due to it is beneficial properties, which include.

- Extreme versatility and ability to be tailored to meet specific technical needs.
- Lighter weight than competing material reducing fuel consumption during transportation.
- Durability and longevity.
- Resistance to chemicals, water and impact.
- Excellent thermal and electrical insulation.

2.7.2.4 Disadvantages of using plastics waste in concrete:

The following are the main dis advantage of using the plastics in concrete are as following:

- Plastics are having low bonding properties so that the strength of concrete get reduced such as compressive .tensile and flexural strength.
- It is melting point is low so that it cannot be used in Furnace because it gets melt as it is comes in contact with the heat at high temperature.

2.7.3 Lightweight Concrete blocks:

Masonry is a common component with low cost, low maintenance, good durability and aesthetics and can be used exploring its acoustic properties.

The use of masonry units as sound absorber or sound isolators is increasing on buildings applications or as sound barriers along roads.

One of the raw materials that can be used in masonry units is the lightweight concrete. Lightweight concrete blocks are a good masonry material because they are lighter and easier to lay than standard concrete blocks. Otherwise they can have good behavior under thermal and mechanical points of view.

At the moment there is, in Portugal, a lightweight expanded clay aggregate factory belonging to a world leader in the production of these aggregates. The aggregates are used mainly in light infilling and precasting of lightweight concrete products.

Nowadays almost 10 % of the 220 factories of vibrocompressed products existents in Portugal use lightweight expanded clay aggregates in their products. Between these products the most important are the masonry blocks. The most frequently used applications are:

- building enclosures, using multi chamber blocks, normally with thickness equal or greater than 0.25 m, used in single leaf walls, with or without thermal insulation, because they have a good thermal behaviour. The acoustic insulation is also good. The mechanical resistance is low, and the structural utilization is limited to small buildings;
- Internal partition walls, according to the light character of the units;
- Walls of industrial, store and agricultural buildings;
- Free standing masonry boundary walls.

The authors have already designed an absorvative lightweight concrete block that is now used in many applications throughout the country, Fig.(2.23) (Sousa and Carvalho, (1998).

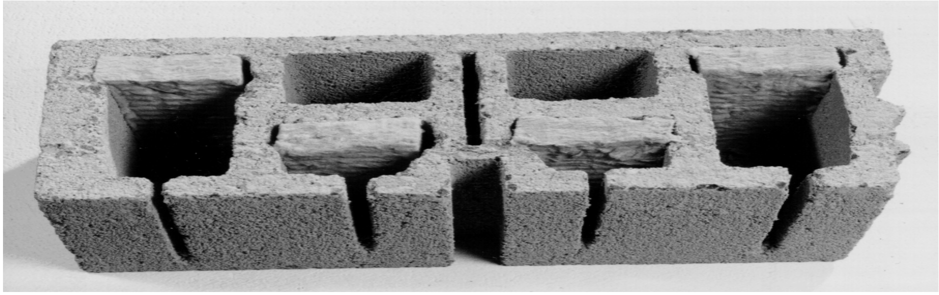


Figure2.24 Photograph of a new sound absorbing lightweight concrete sound absorbing masonry block

A Portuguese manufacturer of lightweight concrete products-PAVILECA, S.A, challenged again the Faculty of Engineering of Porto University to develop a new lightweight concrete sound absorbing masonry block for improved sound insulation between dwellings.

Nowadays infilling walls used between dwellings are generally ceramic units in cavity walls, with acoustical material in the middle according to standard requirements.

The aim of the lightweight concrete masonry block manufacturer was to have a single wall, easier and quicker to lay, without acoustical insulator and more economic.

Under an acoustic point of view there are two different areas of analysis related to its acoustic behavior:

- Sound isolation;
- Sound absorption.

The sound isolation in single walls is fundamentally function of the known mass law. Several studies in different countries allow to say that masonry made with lightweight concrete units, if conveniently plastered to be airtight, has a better behaviour than the suggested by the mass law (Short and Kinniburgh 1978, Cormon 1973).

Sound absorption is a different property and is related with the decreasing of sound reflection from a surface. Most lightweight concrete surfaces, if unplastered, have a quite good sound absorption[34].

2.8 Previous Work

2.8.1 Previous work related to methods of recycling EVA foam

Many researchers have proposed alternative approaches to solve environmental problems due to the progressive rate of waste generation. Some of them studied physical recycling and that means EVA are re melted to form new plastic objects, and other in chemical recycling, it means possible to convert the copolymer of EVA and back into monomers and also study the mechanical properties of EVA recycle compare with EVA virgin.

First article related to pyrolysis recycling of EVA and application of photovoltaic modules done by ZENG De-Wen et al (2004),this research interest in behavior of EVA copolymer, which is often used as a lamination agent in solar modules ,was investigated in thermo gravimetry differential thermal analysis DTA and thermo-volumetry .The TG analysis shown that the EVA pyrolsis can be accelerated under the partial oxidizing atmosphere but the end pyrolsis temperature must be higher than in nitrogen's,a strong exothermal peak occurs at about 450^0C under air condition and gets weaker at oxygen content lower than 10%vol .the massbalance of EVA pyrolysis was given through the thermo volumetry with out put of 10wt % permanent gas 89.9wt % condensate and 0.1% residual coke besides ,the composition of the permanent gas and condensate at different pyrolysis stage were analyses and interpreted on the known pyrolysis mechanism tin this research some information about EVA pyrolysis ,which is necessary for the design recycling of the solar modules ,such as the gas volume of EVA pyrolysis [34].

Another work in Eva recycling method done by NIKE, INC(2014) , this paper interest in a method of recycling scrap ethylene-vinyl acetate (EVA) foam involves foaming and cross linking a blend containing virgin EVA resin and scrap EVA foam, as well as a cross linking agent and blowing agent for the EVA resin. The blend Further contains a compatibilizers, which is a hydrogenated petroleum resin, that means using the compatibilizers, suitable foamed articles can be made that contain up to 30 parts of recycled foam per 100 parts of virgin resin, In addition to the improved aesthetic appearance, improves shrinkage and elongation of the resulting foamed articles, and also improves the split tear performance, as measured by standard industry tests.

A method of recycling EVA foam involves combining virgin EVA resin, scrap EVA foam, blowing agent for the EVA resin, organic peroxide, and a compatibilizers to form a blend.EVA is commonly used in midsoles ofshoes. As such, the application requires a good aesthetic appearance and retention of physical properties while achieving as high content as possible of recycled scrap foam. Up to 30 parts of scrap EVA foam can be incorporated into newly [37].

Joson Lin (2006), studied process for recycling formed EVA waste, this process comprises the following steps:

- Step1: preparing the raw material of formed EVA waste.
- Step2: cutting the formed EVA waste into the pieces(small blocks or pellets) before being processed.
- Step3: heating the formed EVA waste.
- Step4: rolling the formed EVA waste.

- Step5: taking out the stripes of semi –final products, figure (2.20) showing the process for recycling formed EVA waste

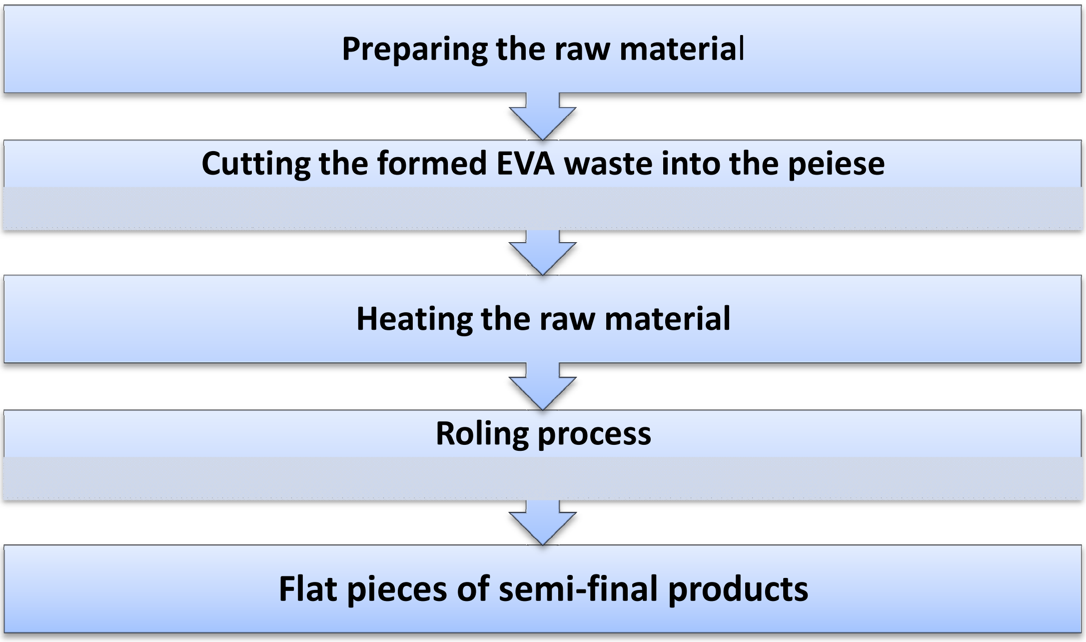


Fig 2.25Process for recycling formed EVAwaste

Initially prepared the formed EVA waste and then heat them to the range from 80to200^{0}C,it would be the best if the temperature can be controlled within the range of (80-120^{0}C).so as to soften the formed EVA waste .after this ,putting the soft formed EVA wastes in rolling machines for repeated rolling so as to integrate them together ,and finally the formed EVA wastes can be rolled into semi-final products in form of flat pieces, which can be applied to the carpet ,mat or the shell of traveling case [26].

A. Marcilla et al (2005) investigated the evolution of gas during the catalytic pyrolysis of three commercial ethylene vinyl acetate copolymers in the presence of mesoporous MCM-41 has been studied by TGA/FTIR.

Fourier transform infrared spectrometry (FTIR)has been used by many authors for the study, analysis and identification of polymers. This technique has also been combined with other equipment to carry out the pyrolysis of the polymer, studying the absorption bands of the products formed. Other technique is Thermo gravimetric analysis (TGA), TGA is also useful for compositional analysis of multi-component materials and used to examine the kinetics of the physio-chemical processes occurring in the sample.

These techniques studied the changes of the composition of the gas evolved during the thermal pyrolysis of three commercial ethylene vinyl acetate copolymers (EVA) Also study showed the well known two main events of decomposition:

- The first corresponding to the loss of the acetoxy groups, from the vinyl acetate (VA) co monomers, yielding ‘‘polyene domains’’ in the polymer chain.
- The second, which takes place at higher temperatures, is formed by two separated processes, one corresponding to the decomposition of these ‘‘polyene domains’’, and another to the decomposition of the ‘‘polyethylene (PE) domains’’, corresponding to the initial ethylene units.

The results have been compared with those corresponding to the thermal pyrolysis carried out under the same experimental conditions, and showed that the formation of alkenes and aromatics and shorter and/or more branched hydrocarbons is favoured in the presence of the catalyst[38].

The results obtained previously works for the thermal pyrolysis of EVA done by A. Marcilla et al (2005) , showed that in the VA groups’ pyrolysis, the elimination of acetic acid occurs, plus some formation of CO, CO_2 and CH_4 as minor products. In the second decomposition step, however, the cracking of the polymeric chain resulting from the previous step yields mixtures of alkenes and alkanes, which also include aromatic compounds, According to the TGA and the GS curves , in spite of the fact that the temperature of maximum decomposition rate for the first decomposition step is not affected by the presence of the catalyst, an early beginning of the process, which results ina widening of the range of temperatures for the first decomposition step. This phenomenon, which has not been observed in the thermal pyrolysis [39].

Eunha Kim et al.(2015) investigated Vinyl acetate (VA) contents of poly(ethylene-co-vinyl acetate) (EVA) analyzed by infra red spectroscopy (IR),nuclear magnetic spectroscopy (NMR), and thermo gravimetric analysis (TGA) were compared. Four grade EVAs supplied by Aldrich Co. and four grade EVAs manufactured by DuPont Co. were used. For IR analysis, VA contents were determined using calibration curve (absorbance ratio of 1739 cm−1/2922 cm−1 or 609 cm^{-1}/1464 cm−1) of reference EVAs. Correlation coefficients of the calibration curves were not sufficiently high (r2 ≤ 0.96). For NMR analysis, VA contents were determined using peaks of CH_3, CH_2, and CH. VA contents determined by NMR analysis were less than those marked by suppliers more than 10%. For TGA, VA contents were determined using weight loss through deacetylation. VA contents determined by TGA were slightly different with those marked by suppliers. Difference in the VA contents determined by different analytical methods was discussed, and difference in the analytical results according to the EVA suppliers was also examined [40].

2.8.2 Previous work related to using composite of EVA foam Waste with LWC mixtures

There are many previous works studied mechanical as compressive strength and physical properties as insulation of sound also reducing of density had come from used of EVA waste as an ingredient in concrete mixtures with different proportions of water and EVA foam and other filler.

one of them named lightweight concrete with EVA recycled aggregate for impact noise attenuation concluded by B. F. Tutikianet al (2012),Their purpose was study and evaluate the acoustic performance of lightweight concrete with ethylene vinyl acetate copolymer (EVA) residues to reduce impact noise on floors. Three types of concrete with three different mix proportions were evaluated. The method adopted includes the characterization of water absorption, voids and density of the samples.

The experimental study of noise impact followed the procedures of ISO 140. The samples made with natural coarse aggregate obtained values between 71 and 72 *dB*. but their results concluded that the lightweight concrete with EVA recycled aggregate can reduce impact noise levels by up to 15 *dB* and the highest percentage of coarse aggregate EVA does not entail a higher acoustic. The concrete molded with EVA presented lower levels of bulk density of fresh concrete in comparison to the concretes with natural aggregates. It can be followed that the higher the percentage of lightweight aggregate added to the mix, the lower values of density [41].

Another work related to insulation of sound by used EVA waste with lightweight concrete by Nunes, M. F et al (2010) focused in their research on Impact Sound Insulation of Lightweight Concrete Floor with EVA Waste. The work conducted in this research leads to the following conclusions the concrete molded EVA had lower levels of density of fresh concrete in comparison with the reference mix proportion. It can be argued that the higher the percentage of lightweight aggregate added to the mix, the lower values of density.

In testing, the impact noise lightweight concrete achieved the best acoustic performances, with satisfactory performance for structural slabs. In the case of coverage available, the classification of acoustic performance decreased. However، other available coatings that can help with soundproofing should be considered in roof.

It was noted that the incorporation of EVA material as resilient in the sub floor to break the rigidity of floors in the system has good efficiency. However, it also shows that the highest percentage of coarse aggregate EVA does not match the performance of acoustic noise impact; the noise in buildings can spread through the air, when they receive the name of airborne noise, or through the structures themselves, when they are called impact noise.

The impact noise is produced by percussion of solid bodies and transmitted through the air (e.g. falling objects, footsteps, hammering, percussion instruments, etc. In the samples studied the reduction of 80% to 60% of coarse aggregate resulted in better acoustic performance, with 15 *dB* in noise levels reduction measured, and 77 *dB* to 62 *dB*.The relationships obtained between the measured sound levels, voids and bulk density indicate that the major benefit in reducing the weight provided by the light weight aggregate structures could be a higher acoustic quality in concrete floors [41][42].

Other work outlined by Paulo Roberto et al (2010), had shown the Recycled lightweight concrete made from footwear industry waste and CDW, In this paper had two types of recycled aggregate, originated from construction and demolition waste (CDW) and ethylene vinyl acetate (EVA) waste, were used in the production of concrete. The EVA waste results from cutting off the EVA expanded sheets used to produce insoles and innersoles of shoes in the foot wear industry. The goal of this study was to evaluate the influence of the use of these recycled aggregates as replacements of the natural coarse aggregate, upon density, compressive strength, tensile splittingstrength and flexural behavior of recycled concrete. The experimental program was developed with three water to cement (w/c) ratios: 0.49, 0.63 and 0.82. Fifteen mixtures were produced with different aggregate substitution rates (0%, 50% EVA, 50% CDW, 25% CDW–25% EVA and 50% CDW–50% EVA), by volume.

EVA is a lightweight aggregate whose particles float in water, a specific method (Santiago et al., 2009) was used to determine it specific gravity. This method was also used to determine the specific gravity of CDW aggregate. The Fractions of EVA aggregate:

(a) >9.5 *mm*; (b) >6.3 *mm*; (c) >4.8 *mm* and (d) <4.8 *mm* .

The results showed that it is possible to use the EVA waste and CDW to produce lightweight concrete having semi-structural properties,Basedon the results, the following conclusions can be drawn:

- The density of recycled concrete was reduced. The lowest densityvalues belong to concrete with the highest replacement level of EVA.
- A reduction of compressive strength with the addition of recycled aggregate is verified. However, it was possible to obtain, to mix with a/c ratio equal to 0.49, a structural lightweight concrete made from 50% (25% CDW–25% EVA) of recycled aggregate.
- Influence of w/c ratio, age of concrete and type of recycled aggregate, and their interactions on compressive strength are significant statistically. A minor influence of addition of recycled aggregate on compressive strength with increment of w/c ratio is observed.

- The indirect tensile strength accompanied the compressive strength results with a reduction of mechanical property values with an increment of recycled aggregate addition. [43].

There are still many works that involve Effects of Two Redispersible Polymer Powders on Efflorescence of Portland Cement-based Decorative Mortar, by Huimei ZHU, Peiming WANG et al (2013), The purpose of this article studied The effects of redispersible polymer powders of ethylene/Vinyl acetate copolymer (EVA) and ethylene/vinyllaurate/vinyl chloride terpolymer (E/VL/VC) on the efflorescence of Portland cement-based decorative mortar (PCBDM).

The results showed that EVA slightly prolongs the efflorescence duration of fresh PCBDM; and exacerbates efflorescence of hardened PCBDM, because it increases the content of soluble salts such as Ca^{2+}, K^{+}, Na^{+}ions in hardened PCBDM and promotes their migration. E/VL/VC exacerbates efflorescence of fresh PCBDM due to it easily dissolves in the surface water; but reduces efflorescene of hardened PCBDM, which is attributed to that it decreases the soluble salts content in hardened PCBDM and prohibits salts migration.

They rare many benefits can be achieved by using recycled waste as raw material for construction some of them are:

1. The reduction of the total cost of the construction,
2. The reduction of the consumption of energy.
3. The decrease in the use of natural materials.

For example Paulo Roberto et al(2009) reported on Mechanical behavior of recycled lightweight concrete using EVA waste and CDW under moderate temperature, In this work two types of recycled aggregate were used in construction and demolition waste (CDW) and EVA, the Ethylene Vinyl Acetate (EVA). EVA aggregate is obtained by cutting off the waste of EVA expanded sheets used to produce insoles and innersoles of the shoes.

The aim of this work was to study the influence of the use of these recycled aggregates, as replacement of the natural coarse aggregate, on mechanical behavior of recycled concrete.

The experimental program was developed with two w/c ratio: 0.49 and 0.82. Four mixtures with produced with different aggregates substitution rates (050%EVA, 50% CDW and 25% EVA-25% CDW), by volume. Compressive tests were carried out to evaluable the influence of recycled aggregate on strength, elastic modulus and Poisson coefficient. In addition, it was evaluated the effect of the moderate temperatures (50, 70 and100^0C) on stress-strain behavior of concretes studied.

The results of analysis for used EVA aggregate in construction considering that no special treatment processes steps are required to production of recycled lightweight aggregate of EVA, their use as aggregate to production of concrete has economical and ecological advantages as compared with others lightweight aggregate. Despite the reduction in compressive strength and elastic modulus, the combination of recycled aggregates to permit the production of a structural lightweight concrete. From stress-strain curves for EVA concrete it was observed that the slope of descending branch decreased, when compared with conventional concrete, indicating an increment of toughness of material.

The effect of temperature it is more important on elastic modulus of concrete. To temperatures of 50, 70 and 100^0C it was verified a reduction this property of recycled concrete, as relation of conventional concrete.

However, studies on the influence of elevate temperature (higher than $410^{0}C$) must be performed to verify the release of anytoxic gas into the recycled concrete in situation of fire [44].

Suitable example for used of EVA waste in concrete block done by Prachoom .K et al (2014), this research studied the used of Para-rubber (vulcanized latex) as an admixture for improving the properties of EVA plastic waste concrete block. In mix design, cement per EVA plastic waste per quarry dust per water ratio is 1:0.5:4:1.6 by weight, vulcanizedlatex per cement ratios are 0.00, 0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, and 0.45 respectively (by weight of cement), no charge surfactant is 4*%* (by weight of vulcanizedlatex).no charge surfactant is 4*%* (by weight of vulcanizedlatex). The suitable ratio of vulcanized latex per cement in this testing is 0.15 (by weight of cement).Because of low density, sound absorption and thermal insulation properties of the EVA, the researcher did an experiment by mixing the small crushed the EVA in concrete block. The result showed that the EVA with proper size and strength had good adhesion with cement. Therefore this concrete had higher properties than the general concrete; their weight is only 3 *kg per piece* and the density is 640 kg/m^3, while the general concrete has weight about 8*kg* per piece and the density is 1,700 kg/m^3. That is similar as light weight concrete and this concrete could be used together with plaster as same as general concrete block.

This article had concluded the Vulcanized latex could help to develop some property of the EVA concrete block; reducing of density, The EVA concrete block mixed much vulcanized latex had the low density. The EVA concrete block mixed with less vulcanized latex or without vulcanized latex had the high density, water absorption, drying shrinkage and thermal conductivity coefficient and adding some property of sound absorption, thermal insulation and non flammability. Nevertheless the mixing of vulcanized latex overmuch could make the compressive strength reduced and the costs of EVA concrete block would be higher. The vulcanized latex volume about 0.05 of cement weight (ratioP0.15) had a good property reached TIS standard 58-2533 (TIS, 1990) and the cost was not so high.After comparing with the wall materials in the construction market; concrete block and lightweight, block the EVA concrete block mixed with vulcanized latex had better property than the general concrete block. This EVA concrete block had similar property with light weight block but their costs were less than light weight block. Moreover the vulcanized latex could reduce water absorption problem. That made the EVA concrete block easy to plaster and mortar [43].

Lightweight concrete blocks with EVA recycled aggregate titled by A. B. De Melo et. al. (2013), this article presents an evaluation of thermal performance with measurements of temperature variation in mini walls (1 m^2) built with different materials, including various kinds of EVA block and ceramic bricks. Tests have shown efficient thermal performance for masonry blocks with EVA.

These results and supplementary estimates contribute to add value to the EVA block, considering that there are good expectations that the component, with the new geometry proposed, can contribute to the energy efficiency of buildings, EVA block 80% 12.5, which satisfies the requirement of mechanical performance for non-structural masonry، suggested in previous studies, also had good thermal performance that was similar to EVA blocks14-60 %and EVA blocks 60 % 9 that prsented the greatest difference between the temperatures of the faces (exposed and opposite to heat) of small masonry evaluated, The influence of the amount of EVA was confirmed by the good thermal performance of the EVA block 80% with 12.5 compared to the other evaluated, the void (air chamber) inside the EVA block 80% 12.5 is considered small compared to the other EVA blocks،which influence their thermal performance, suggesting that other evaluations could perform in order to change the design of the component, maintaining the balance between lightness (using 80% EVA in the composition of concrete) and its their mechanical performance minimum compressive strength of 1.2 *mPa* compatible for use in nonstructural masonry. Based on the characterization of the thermal performance of the EVA blocks and performed in cases of hot climate region, where cooling is the main goal of thermal comfort in architectural design, it can be stated that there are good expectations that the proposed component (EVA block 60% 12.5 or EVA block 80% 12.5) can contribute to the energy efficiency of buildings[44].

P. Khamput et al (2014) studied physical, mechanical, and thermal insulation properties of light weight concrete block products mixed with ethylene vinyl acetate plastic scrap (EVA) from shoe factories, and they concluded the least density of light weight concrete block mixed with waste of ethylene vinyl acetate plastic products is 640 kg/m3. The appropriate mixtures of light weight concrete block mixed with EVA plastic scrap can reach the required values from the standard of TIS 58-2533 and can be used as a thermal insulation wall [45].

Nopado S et al (2014). Conducted in this work used waste plastic EVA from footwear industry to substitute the parts of aggregates (sand content) and aluminum powder in concrete block manufacturing. With lighter weight and lower density, the LWC with EVA waste encompass low thermal conductivity property and becomes an excellent insulating material for building. The optimum ratios of waste content and other components; EVA sizes, Al powder addition, etc. were examined. The study tested the physical and mechanical properties including weight, density, humidity, shrinkage, and compressive strength. The values of material thermal conductance were tested by using Thermal Constant Analyzer (Hot Disk TCA). To evaluate the heat transfer though materials and the insulation property, the field experiment was conducted by facing one side of LWC to the sun during the day for 6 *hours*. The results showed that the higher content of EVA and larger size could contribute to lower in strength. Al powder addition was also found to cause the weakness in LWC. Thermal conductance of smaller EVA sizes of 4-5 *mm*. possessed the relatively low thermal conductance in all EVA content percentages. Data from field testing showed that the LWC without Al addition demonstrated the comparable value of temperature difference with the LWC with Al. Smaller EVA-size (4-5 *mm*.) tended to provide more insulation performance to the concrete blocks. The data also showed that the higher EVA content in LWC, the better insulation property. The results retrieved from the study can be used to set the manufacturing recommendation of LWC with EVA content. The production process of this construction material which involves the recycling of EVA waste could be further developed and scaled-up to a mass commercial production in the later state [46] .

Last but not least work done by Singhirunnusorn, W. et al(2013), This study aims to promote the energy efficiency in a building by integrating the technological approach of waste utilization with the perspective of architectural design. Follow-up the authors' previous study, this research applies the prototype materials, lightweight concrete with Ethylene Vinyl

Acetate (EVA) waste content from footwear industry, to demonstrate the applicability of those energy-friendly building materials and their advantageous properties for building energy conservation. With its good properties of lighter weight and low conductivity, the lightweight concrete with EVA content should be used as insulating materials and suitable for walls against strong solar radiation [47].

This study proposed LWC with EVA manufacturing recommendations based on three major selection criteria:

1) Thermal insulation property,

2) Lighter weight,

3) Compressive strength (Thailand industrial standard). For this research, the manufacturing process combine the substitute part of aggregates with the smaller EVA size approximately 4-5 *mm* and 30% of EVA content.

Chapter Three

Materials and Methods

Chapter Three

Materials and Methods

3.1Introduction

This chapter contains a description of EVA waste were considered for beneficial reuse in civil engineering applications and component materials of concrete mixes. EVA waste selected based on availability in Sudan, and difficult recycling.

The experimental work and full study of this research was conducted at the laboratories of the civil engineering department of sudan university of science and technology and shwahig company.

3.2 Materials Used:

There are many materials used in this work .

3.2.1Prepartion of EVA foam waste (EVA aggregates)

For the present study, EVA waste was obtained by collected from local footwear industry (shahata industry) like runner shoes as shown in figure (3.1) and then EVA waste were cut into pieces of different length between (2*mm*-15*mm*) EVA waste having average width from (1*mm*-10*mm*) as presented in figure(3.2) by using cutter machine as shown in figure (3.3)

Fig3.1 EVA waste (runners shoes) in local footwear industry before cutting

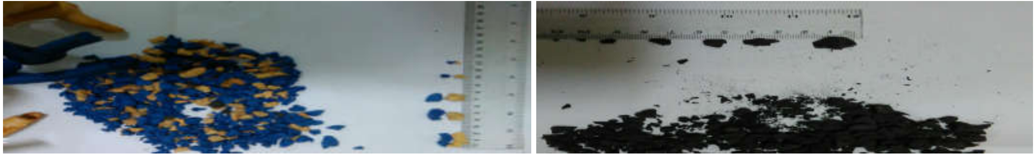


Fig 3.2 Fractions of EVA aggregate from(2mm-15mm) after cutting

Fig3.3 Specimens preparation by hredder/crusher machine for industrial EVA waste

EVA waste was used to replace coarse aggregate for making concrete specimens .These EVA aggregates were available in size between 2-15*mm* as shown in fig 3.2 the sieve analysis of these aggregate were carried out individually in table 3.1.

Table 3.1: Sieve analysis test for EVA aggregate according to ASTM D1921

U.S. Standard sieve No. In	Sieve opening *Mm*	Mass of EVA retained on each sieve, *g*	Cumulative mass of EVA retained, *g*	Cumulative mass of EVA passing each sieve, *g*	Percent finer %
3/2	38.40	0	0	500	100
3/4	19.05	0	0	500	100
3/8	9.53	0	0	500	100
3/16	4.76	383.15	383.15	116.85	23.37
No 10	2.00	87.92	471.07	28.93	5.79
No 16	1.19	16.5	487.57	12.43	2.49
Pan		12.43	500	0	0

*Mass of total dry EVA = 500g

$$\text{Percent finer} = \frac{\textbf{cumulative mass of EVA passing each sieve}}{\textbf{mass of the total dry EVA}} \times \mathbf{100}$$

3.2.2 Ordinary Portland Cement (OPC), Type I

Cement is a fine, grey powder. it was standardized according to(Sudanese Standard 39998,2008)and (BS12:1996) .it is mixed with water and materials such as sand ,gravel to make concrete .The cement and water form paste that binds the other materials together As the concrete hardens. The ordinary cement contains two basic ingredients namely argillaceous and calcareous. In argillaceous materials clay predominates and in calcareous materials calcium carbonate predominates .Basic composition of cement are shown in table 3.3 [48].

Table3.2 Composition limits of Portland cement

Ingredient	%Content
CaO (lime stone)	60-67
SiO_2 (Silica)	17-25
Al_2O_3(Alumina)	3-8
Fe_2O_3 (Iron Oxide)	0.5-6
MgO (Magnesia)	0.1-4
Alkalies	0.4-1.3
Sulphur	1-3

The cement has uniform color i.e grey with a light greenish shade and was free from any hard lumps .

3.2.3 Fine Aggregates (Sand)

The sand used for the experimental work was locally procured and conformed to British Standard Institute (ASTM C-128) [49], the sand was first sieve through 4.75mm sieve to remove any particles greater than 4.75mm and then was washed to remove the dust. The aggregate used in the experimental work are tabulated in table (3.5).

Table 3.3 Properties of fine aggregates

S.NO	Characteristics	Value
1	Type	Uncrushed(Natural)
2	Specific gravity	2.5
3	Total water absorption (%)	0.8
4	Sieve 200 (%)	3.21
5	Organic Impurities test (%)	3.07

The aggregates were sieved through a set of sieves as shown in fig 3.4 to obtain sieve analysis and the same is persent in table 3.4.

Table 3.4: Sieve analysis test for fine aggregate

U.S. Standard sieve no.	Sieve opening *mm*	Mass of soil retained on each sieve, *g*	Cumulative mass of soil retained, *g*	Cumulative mass of soil passing each sieve, *g*	Percent finer %
4	4.76	0	0	1500	100
8	2.38	0	0	1500	100
10	2.00	528.4	528.4	971.6	64.8
20	0.85	390.4	918.8	581.8	38.76
40	0.425	222.8	1141.6	358.4	23.9
60	0.25	91.4	1233	267	17.8
100	0.15	43.6	1276.6	223.4	14.9
200	0.075	175.5	1452.1	48.1	3.21
Pan		48.1	1500	0	0

*Mass of total dry soil = 1500g

$$\text{Percent finer} = \frac{\textbf{cumulative mass of soil passing each sieve}}{\textbf{mass of the total dry soil}} \times \mathbf{100}$$

Fig3.4 Sieve analysis tests

3.2.4 Coarse aggregates

The material which is retained on BIS test sieve no 882 termed as a coarse aggregate. Locally available coarse aggregate from western Omdurman uncrushed aggregated (Mark heat) having the maximum size 15*mm* was used in this work and satisfying ASTM C-127[4].The aggregates were washed to remove dust and dirt and were dried to surface dry condition as shown in fig 3.5.the aggregate were tested per Sudanese Standard specifications[50].

Table 3.5 Properties of coarse aggregates

S.NO	Characteristics	Value
1	Type	Uncrushed(Natural)
2	Specific gravity	2.5
3	Total water absorption (%)	0.7
4	Sieve4 (%)	6.3

The coarse aggregates were sieved through a set of sieves as shown in fig 3.4 to obtain sieve analysis and same. the same is persent in table 3.6.

Table 3.6: Sieve analysis test for coarse aggregate

U.S. Standard sieve no.	Sieve opening *mm*	Mass of soil retained on each sieve, *g*	Cumulative mass of soil retained, *g*	Cumulative mass of soil passing each sieve, *g*	Percent finer %
3/2	38.40	0	0	1493	100
3/4	19.05	0	0	1493	100
3/8	9.53	178.6	178.6	1314.4	88.04
No 3	6.35	649.1	827.7	665.3	44.56
No 4	4.76	571.2	1398.9	94.1	6.3
Pan	-	94.1	1493	0	0

*Mass of total dry soil = 1493g

$$\text{Percent finer} = \frac{\textbf{cumulative mass of soil passing each sieve}}{\textbf{mass of the total dry soil}} \times \mathbf{100}$$

3.2.4 Water:

Water is one of the most important materials required to produce mortar paste and concrete. Tap water from Khartoum city water network was used for the production and curing of the concrete and mortar cubes.

3.3 Preparation and testing of concrete, hollow blocks

3.3.1 Mix Design for Concrete

- The materials used in this work are OPC, EVA waste, fine and course Aggregates, the tests carried out on 0.5 water-cement ratio. firstly cement ,fine and course aggregate were manually mixed in ratio (1:2:4) for 5 minutes, then the water added ,and all materials mixed according to1881 British method . This pure mix without EVA waste is consider as control sample.
- The percentage replacements of course aggregates by industrial EVA waste, this are calculated by using the specific gravity of EVA aggregates, in place of specific gravity of course aggregates were 10%, 25%, 40%, 55% and 70%. This was done to determine the proportion that would give the most favorable result. The 0% replacement was to serve as control for other sample which is finally used for the comparison. Samples of concrete mixes

were prepared and tested in civil engineering laboratories at SUST (College of Engineering, civil Engineering Department) and Shawahig Company .

- The mix of six proportions studied for the EVA waste concrete are as shown in Table 3.7.

Table 3.7 Mixes proportions for Concrete according to the1988British method

		Mass of Quantities (*Kg*)				
Samples	**EVA%**	**EVA Agg,*kg***	**Coarse agg,*kg***	**Fine agg,*kg***	**Water, *kg***	**Cement , *kg***
S_1	0	0	11.26	6.34	1.80	3.60
S_2	10	0.225	11.035	6.34	1.80	3.60
S_3	25	0.630	10.63	6.34	1.80	3.60
S_4	40	0.910	11.35	6.34	1.80	3.60
S_5	55	1.24	10.02	6.34	1.80	3.60
S_6	70	1.58	9.68	6.34	1.80	3.60

- British method (BS 1881) of mix design was used for mix design for concrete cubes ,test, the cube specimens has standard size(100mm×100mm×100mm)were casted for concrete as shown in fig3.5. After 24hourse the specimens were de-molded various percentages of EVA mix proportions for different replacement levels of Aggregate by EVA waste and cured concrete specimens in water for 7and 28day,and tested .[51]

Fig 3.5Cubse test for concrete mixes BS1881

3.3.2 Mixes for EVA Concrete Hollow Blocks

Concrete hollow block have standard mix according to ASTM C 140-08a and SSMO 2011/4918 [52],i.e.1:7:7 (cement :sand :aggregates) was used for pure concrete hollow blocks. Batching was by weight and constant 0.5 w/c ratio was used, the concrete mixture was done manually on smooth concrete pavement. The coarse aggregates and fine aggregates were mixed thoroughly. To this mixture cement was added .these were mixed to uniform color .then water was added carefully. For forming of EVA concrete block repeated the above mix design with different proportions of EVA aggregates as replacement for coarse aggregates to ensure homogeneity. Thirty Hollow concrete blocks of size ($400mm \times 200mm \times 200mm$) were used produced in locally factory,(ALOMDAH) by hydraulic concrete blocks machine as shown in fig 3.6, the concrete blocks produced on six batch depend on percentage of EVA aggregate any batching had produced five blocks as shown in fig3.7, twenty five blocks for replacement 10%-25% - 40% - 55% - 70% EVA, and five blocks without replacement i.e. 0 % EVA to serve the control .the mix proportions are presented in Table 3.8.

Table 3.8 Mixes proportions for Concrete Hollow Blocks according ASTM C 140-08a and SSMO 2011/4918 by Mass.

		Mass of Quantities(*kg*)				
Samples	**EVA%**	**EVA Agg,*kg***	**Coarse agg, *kg***	**Fine agg, *kg***	**Water, *kg***	**Cement *kg***
S_{01-05}	0	0	44.00	44.00	3.00	6.00
S_{11-15}	10	0.88	39.60	44.00	3.00	6.00
S_{21-25}	25	2.20	33.00	44.00	3.00	6.00
S_{31-35}	40	3.50	26.40	44.00	3.00	6.00
S_{41-45}	55	4.90	19.80	44.00	3.00	6.00
S_{51-55}	70	7.20	13.20	44.00	3.00	6.00

Fig 3.6 Hydraulic concrete blocks machine

Fig 3.7 Batch from Hollow Concrete blocks

3.4 Methods

3.4.1 Materials Tests

3.4.1.1Determination of Specific Gravity

Specific gravity is ratio of the weight of a given volume of aggregate to the weight of an equal volume of water, the specific gravity of an aggregate is considered to be a measure of strength quality of the material, the tests were conducted at SUST soil lab .according to ASTM C127 [52].

3.4.1.2Determinations of   General properties of EVA waste aggregates

The EVA waste has properties, such as impact strength, puncture resistance, excellent clarity, heat seal properties, and flexibility colour lumps.

The following tests were done to determine the properties of EVA in Table 3.9.[53][54][55][56].

Table 3.9 properties of EVA waste aggregates

S.NO	Characteristics	Value
1	Specific gravity(ASTM D792)	0.5
2	Total water absorption (%)(ASTM D570)	1.03
3	Sieve 4 (%) (ASTM D1921- Sieve Analysis)	23.37
4	Break strength (MN/m^2) (ASTM D638-Tensile Test)	2.2
5	Minimum breaking load (N)	8.9
6	Maximum load (N)	217

3.4.1.3Determination of Initial ,Final setting time(ASTMC191-70)

The starting of the setting process of blended cement paste is based on this property .The final setting time is used to describe the stiffening of cement paste ,summary of this various tests conducted on cement had been given below in Table 3.10 .

Table 3.10 physical test of Portland cement

No	Types of Test	Results	Requirements of Ref BS12:996
1	Standard of cement paste	33%	W/C not less than 26% more than 33%
2	Initial setting time (*min*)	105*min*	Not less than 45*min*
3	Final setting time (*min*)	2*hr*:35*min*	Not more than10 *hrs*
4	Fineness	1%	Not more than 10%
5	Specific gravity	3.15	

3.4.1.4Determination of Water Absorption Test: ASTM C140:

absorption test one of the most important properties of a good quality concrete is low permeability, especially one resistant to freezing .a concrete with low permeability, for concrete, the test procedure involves drying a specimen to constant weight, weighting it, immersing it in water for specified amount of time, and weighting it again, the increase in weight as percentage of original weight is expressed as its absorption in percent. The average absorption of the test samples shall not be greater than 5% .

the water absorption by immersion is determined according to BS-NBN B15-215 (1989),principally, the test consist of two major steps: saturating the specimens followed by drying .First the concrete specimens are immersed in water until the change in mass during 24 *hours* is less than 0.1% .The obtained saturated mass called M_s. afterwards ,the specimens are dried in a ventilated oven at temperature of 105±5C^ountil the difference in mass during 24*houres* is less than 0.1%.The dry mass is called M_D the water absorption by immersion (W) is expressed as water uptake relative to dry mass:[56]

$$W = \frac{M_S - M_D}{M_D} \text{........................} \quad (3.1)$$

3.4.2Concrete Tests

3.4.2.1Determination of Compressive strength

Compressive strength is the most important test because it gives an indication of mechanical strength of hardened concrete, the compressive strength was determined after 7 and 28 *days*, three cubes the test for each period and the average was reported as the compressive strength. the concrete cube were tested by applied axial loads on the area of cube face(100×100 mm^2) at the constant rate within the range(0.2 to 0.4 *mPa/s*) and the crushing strength is reported to the nearest 0.*5mPa/s* [58].

Fig 3.8 compression testing machine

3.4.2.2Determination of Workability (Slump test)

The workability of concrete is assessed by slump test ,this test measure of workability and it used in different countries ,the mould for slump test is a cone ,the dimension as follow: high 305*mm* ,the base 203*mm* ,diameter is placed on smooth surface with smaller opening of 102*mm*,diameter at the top. And the container is filled with concrete in three layers. each layer is tamped 25times with standard 16*mm* diameter steel rod, rounded at the end ,and the top surface is struck off by means of screening and rolling motion of the tamping rod. The mould must firmly held against its base during the entire operation by handles, immediately after filling ,the cone is slowly lifted and unsupported concrete will slump, the decrease in the height of center of slumped concrete is called slump[59].

Fig 3.9 slump test

3.4.2.3Ultrasonic pulse velocity test (UPV)

UPV test can be considered as one of most promising methods for evaluation the concrete structures, once it makes possible an examination of the material homogeneity. The UPV results can be used for diagnosis, prognosis and quality control. The method is based on the propagation of a high frequency sound wave which passes through the material. The speed of the wave varies in function of the density of the material, allowing the estimation of the porosity and the detection of discontinuities after 7and 28 *days*.

The idea is to project the sound inside a material and measure time, the time taken by the pulse travel through the concrete is measured by electrical timing- unit with an accuracy of ±0.1 microsecond and ,knowing the length of path travelled through the concrete, the pulse velocity can be calculated[55][60]. According to rules:

$$V=L/T \ldots\ldots\ldots\ldots\ldots \quad (3.2)$$

V=the pulse Velocity,$km/\mu\ sec$, L=thickness of sample (Path length), km,($10cm=10^{-4}km$), T= time of pulse transmission, micro second ,$10^{-6}Sec$

Fig 3.10 ultrasonic pulse test, direct transmission

Table 3.11 show the higher of elastic modulus ,density and integrity of mortar,the higher is the pulse velocity.in this study UPV is used as nondestrictive testing parameters such as transducer frequency and specimen geometry on cement mortar

Table 3.11: Genral guide lines for mortar quality based on UPV

Mortar Quality	Pulse velocity (*km/sec*)
Very good to excellent	> 4.0
Good to excellent	3.5-4.0
Satisfactory but loss of integrity	3.0-3.5
Poor and loss of integrity exit	<3.0

3.5 Concrete blocks (ASTM C129)

3.5.1Classification of concrete Hollow blocks (SSMO: 2011/3947)

Hollow block(open or closed cavity) is a block having on ore more large holes or cavities which either pass through the block open cavity or do not pass through the block closed cavity and having the solid material between 50to75 percent of total volume of the block calculated from overall dimensions (IS2185:2015),The external dimensions of the units should respect modular co-ordination size principles [61][62]. In Sudan the current co-ordinations sizes of blocks are shown in table 3.12:

Table 3.12: General Dimension of concreteblocks according to SSMO:2011/3947

Length, *mm*	**Width, *mm***	**Height, *mm***
400	200	100
400	200	120
400	250	120
400	200	200
390	190	190
400	150	100
400	200	150

Usually the current thickness - e - of blocks is multiple of ±20 *mm*, the hollow blocks shall conform to the following grades and minimum average compressive strengths as shown in table 3.13:

Table 3.13: compression strength of concrete blocks according to ASTM-C140-75

Type	**Minimum Compression strength C.S(N/mm^2) at28days**			
	Load bearing units		**Non load bearing units**	
	Average C.S for units	**Test of one unit**	**Average C.S for units**	**Test of one unit**
Hollow block	*7*	*5.5*	*3.2*	*2.6*
Solid block	*12*	*10*	*4.0*	*3.5*

The nominal dimension of concrete block (fig3.11) are shown as follows: Length 400 *mm*, width 200 *mm*, height 200*mm*,thickness 30 *mm*[63].

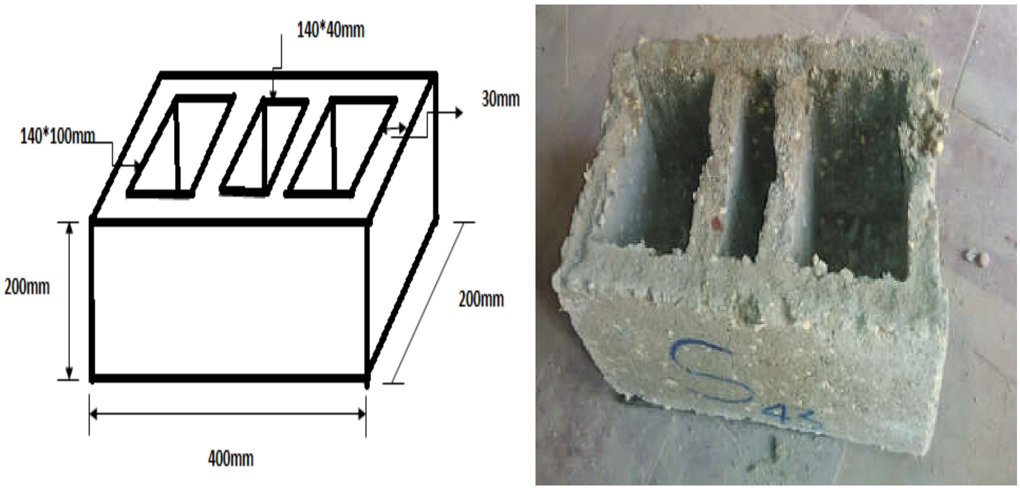


Fig3.11: Dimension of concrete hollow blocks used in this work

Chapter Four

Results Analysis and Discussion

Chapter Four

Results Analysis and Discussions

4.1Introduction

The results of strength , average densities and soundless of concrete cubes and adsorption of hollow blocks thoroughly stated and discussed to evaluate the optimum replacement percentage of EVA aggregate.

The effect of this replacement on cost saving of blocks concrete beside reduction the accumulation EVA waste in Sudan .

4.2 Specific Gravity (SG) result:

Table 4.1: SG results of aggregates and cement

Types of Aggregate	Specific Gravity
Course Aggregate	2.47
Fine Aggregate	2.50
EVA Aggregate(ASTM D792)	0.50
Ordinary portland cement	3.15

Table 4.1 show specific gravity for ordinary portland cement,sand,coarse aggregate ,EVAwaste, EVA samples have SG less than SG of coarse aggregate by five times.

4.3 Absorption test: BS 1881: Part 122

Table 4.2: Absorption results of aggregates

Types of Aggregate	Absorption %
Course Aggregate	0.7
Fine Aggregate	0.8
EVA Aggregate	1.03

Table 4.2 presented absorption percentage for course and EVA waste.

4.4 Average Density and weight of concrete mixes: B.S1881

The weight was measured for cubes taken from water tank .the value of densities obtained to for blank (0%EVA) and other percentage 10%-70% is shown in table 4.3 and fig 4.16 for 0.5W/C ratio. It is found from testing the unit weight of there is considerable decrease in unit weight when compared with the control concrete (blank) without EVA waste replacement. for the accuracy of results three samples of control concrete and three samples of EVA waste replaced concrete were casted and tested and average of three are taken for accuracy of results. The weight and density of concrete decreased with increasing amounts of EVA waste and it found can be used as light weight concrete. The results of densities of control and EVA replaced concrete are shown in table 4.4 and fig 4.2 according to formula:

$$Density = \frac{Average\ Weight\ of\ concrete\ samples(kg)}{Volume\ of\ sample\ \ (m^3)} \ldots\ldots\ldots\ldots\ldots (4.1)$$

Table 4.3: Average weight for concrete mixtures for samples S_1, S_2, S_3, S_4, S_5 and S_6 at 7 and 28 days age:

Mixes	**Average Weight *kg***	
	7days	**28days**
Concrete mix with zero EVA	2.52	2.54
Concrete mix with 10% EVA	2.45	2.49
Concrete mix with 25% EVA	2.22	2.41
Concrete mix with 40% EVA	2.1	2.12
Concrete mix with 55% EVA	2.03	2.09
Concrete mix with 70% EVA	1.91	1.94

Table 4.4: Average density for concrete mixtures for samples S_1, S_2, S_3, S_4, S_5 and S_6 at 7 and 28 days age:

Mixes	Average Density Kg/m^3	
	7days	**28days**
Concrete mix with zero EVA, S_1	2520	2540
Concrete mix with 10% EVA, S_2	2450	2490
Concrete mix with 25% EVA, S_3	2220	2410
Concrete mix with 40% EVA ,S_4	2100	2120
Concrete mix with 55% EVA, S_5	2030	2090
Concrete mix with 70% EVA, S_6	1910	1940

- According to rules of Density=Mass/Volume (kg/m^3)
- Volume = volume of cube=10*10*10=1000cm^3=0.001m^3

In table 4.4 observe the values of average density for different propositions from EVA waste, the lowest density values belong to concrete with the highest replacement level of EVA. The mixtures 70% EVA, can be classified as lightweight concrete.

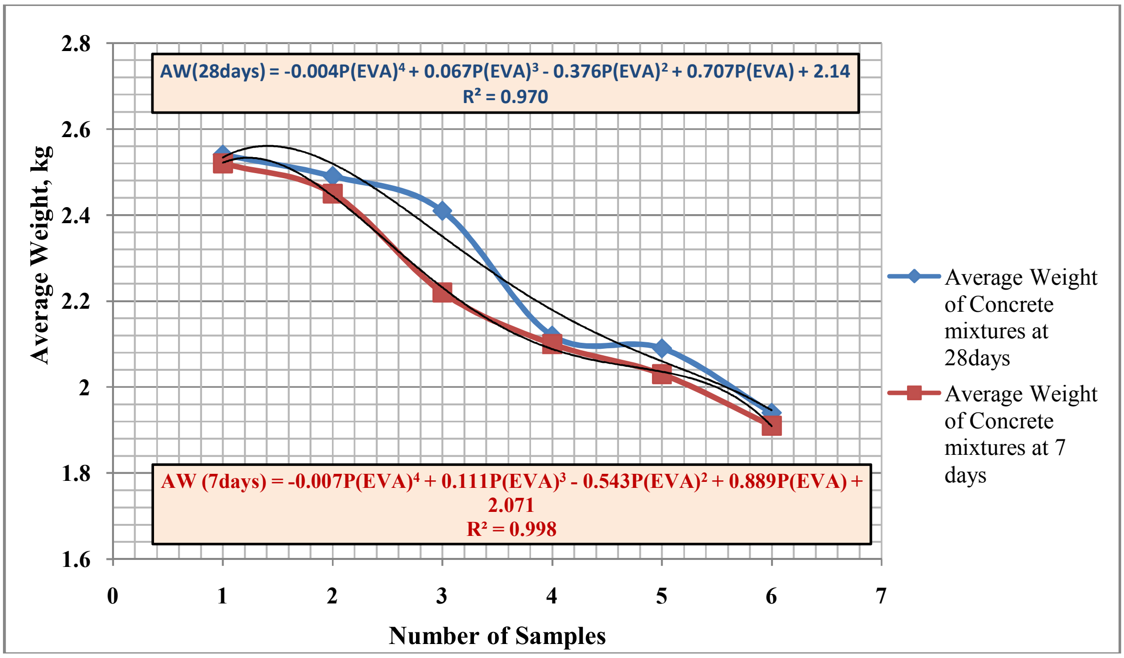


Fig 4.1: Average weight of concrete mixtures at 7 and 28 days

Equation 4.2 and 4.3 are predicted by excel sheet to determine the average weight of concrete at 7 and 28 days depend on the percentage of EVA

$$AW\ (_{7days}) = -0.007P(EVA)^4 + 0.111P(EVA)^3 - 0.543P(EVA)^2 + 0.889P(EVA) + 2.071 \quad (R^2 = 0.998) \ldots\ldots (4.2)$$

$$AW\ (_{28days}) = -0.004P(EVA)^4 + 0.067P(EVA)^3 - 0.376P(EVA)^2 + 0.707P(EVA) + 2.14 \quad (R^2 = 0.970) \ldots\ldots (4.3)$$

Where: AW: Average weight and P(EVA): Percentage of EVA waste.

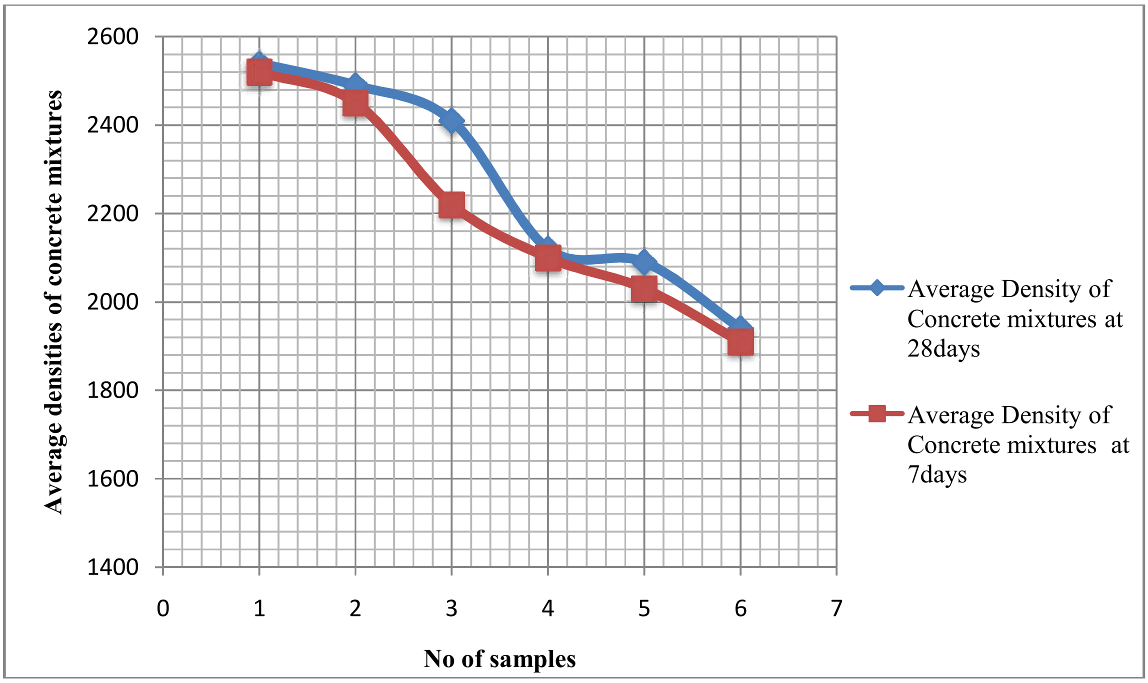


Fig 4.2: Average density of concrete mixtures at 7 and 28 days

4.2 Compressive Strength of Concrete Samples

Compressive strength of concrete mixtures is determined at the 7, and 28 *days* for all samples **S_1, S_2, S_3, S_4, S_5 and S_6**. There were three samples for each test and the average results were be taken. The effect of age of mix concrete and propositions of EVA waste on compressive strength can be observed from table 4.5 to 4.17.

Table 4.5: Compressive Strength Test for sample S_1 with 0% EVA waste (Blank)

Age	Load (*kN*)	Area (mm^2)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)	Slump (*mm*)
7days	290	100×100	29	27	**10**
	260		26		
	260		26		

Table 4. 6: Compressive Strength Test for sample S2 with 10%EVA waste

Age	Load (*kN*)	Area (mm^2)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)	Slump (*mm*)
7days	138	100×100	13.8	15.1	**8**
	149		14.9		
	167		16.7		

Table: 4. 7 Compressive Strength Test for sample S_3 with 25%EVA waste

Age	Load (*kN*)	Area (mm^2)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)	
7days	140	100×100	14	12.2	**5**
	105		10.5		
	120		12		

Table 4. 8: Compressive Strength Test for sample S_4 with 40%EVA waste

Age	Load (*kN*)	Area (mm^2)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)	Slump (*mm*)
7days	80	100×100	8	7	**5**
	50		5		
	80		8		

Table 4.9: Compressive Strength Test for sample S_5 with 55%EVA waste

Age	Load (*kN*)	Area (*mm²*)	Compressive strength (*N/mm²*)	Average compressive strength (*N/mm²*)	Slump *(mm)*
7days	50	100x100	5	4.6	**0**
	50		5		
	40		4		

Table 4.10: Compressive Strength Test for sample S_6 with 70%EVA waste

Age	Load (*kN*)	Area (*mm²*)	Compressive strength (*N/mm²*)	Average compressive strength (*N/mm²*)	Slump *(mm)*
7days	37.38	100x100	3.74	2.93	**0**
	23.5		2.35		
	27		2.7		

Table 4.11: Compressive Strength Test for sample S1 with 0%EVA waste (Blank)

Age	Load (*kN*)	Area (*mm²*)	Compressive strength (*N/mm²*)	Average compressive strength (*N/mm²*)	Slump *(mm)*
28 days	260	100×100	26	27	**10**
	300		30		
	250		25		

Table 4.12: Compressive Strength Test for sample S_2 with 10%EVA waste

Age	Load (*kN*)	Area (*mm²*)	Compressive strength (*N/mm²*)	Average compressive strength (*N/mm²*)	Slump *(mm)*
28 days	222.9	100×100	22.3	20.53	**8**
	197		19.7		
	195.6		19.6		

Table: 4. 13: Compressive Strength Test for sample S_3 with 25%EVA waste

Age	Load (*kN*)	Area (*mm^2*)	Compressive strength (*N/mm^2*)	Average compressive strength (*N/mm^2*)	
28 days	80	100×100	8	10.3	**5**
	90		9		
	140		14		

Table 4.14: Compressive Strength Test for sample S_4 with 40%EVA waste

Age	Load (*kN*)	Area (*mm^2*)	Compressive strength (*N/mm^2*)	Average compressive strength (*N/mm^2*)	Slump *(mm)*
28 days	53.9	100×100	5.39	5.84	**0**
	61.57		6.16		
	59.7		5.97		

Table 4.15: Compressive Strength Test for sample S_5 with 55%EVA waste

Age	Load (*kN*)	Area (*mm^2*)	Compressive strength (*N/mm^2*)	Average compressive strength (*N/mm^2*)	Slump *(mm)*
28 days	56.9	100×100	5.69	5.02	**0**
	45.1		4.51		
	48.7		4.87		

Table 4.16: Compressive Strength Test for sample S_6 with 70%EVA waste

Age	Load (*kN*)	Area (*mm^2*)	Compressive strength (*N/mm^2*)	Average compressive strength (*N/mm^2*)	Slump *(mm)*
28 days	30.3	100×100	3.03	2.68	**0**
	26.7		2.67		
	23.4		2.34		

The value of compressive strength when add 10% EVA waste after 28day gave good strength compared to blank sample and when add 70% EVA waste gave low strength. The values of Compressive strength of concrete decreased with increasing amounts of EVA waste as summarized in table 4.17 and Fig 4.1

Table 4.17: Compressive Strength for all samples at 7 and 28 days

Mixes	Compressive strength N/mm^2	
	7days	28days
Concrete mix with zero EVA	27	27
Concrete mix with 10% EVA	15	20.5
Concrete mix with 25% EVA	12.2	10.3
Concrete mix with 40% EVA	7	5.84
Concrete mix with 55% EVA	4.6	5.02
Concrete mix with 70% EVA	2.93	2.68

4.3 Workability, Slump Test: ASTM C143-90

The results of workability test are presented in table 4.14 used slump test. gave a true slump three mixes had a zero slump, so that the degree of workability is very low(0-25mm) according to (A.M.Nevile ,concrete technology ,table5.1,p85.That indicated to use this mix in suitable application as concrete block [55] [59].

Table 4.18: Slump test for concrete mixtures for samples S_1, S_2, S_3, S_4, S_5 and S_6 at 7 and 28 days age:

Mix	Slump
Concrete mix with zero EVA ,S_1	10
Concrete mix with 10% EVA , S_2	8
Concrete mix with 25% EVA , S_3	5
Concrete mix with 40% EVA , S_4	0
Concrete mix with 55% EVA ,S_5	0
Concrete mix with 70% EVA ,S_6	0

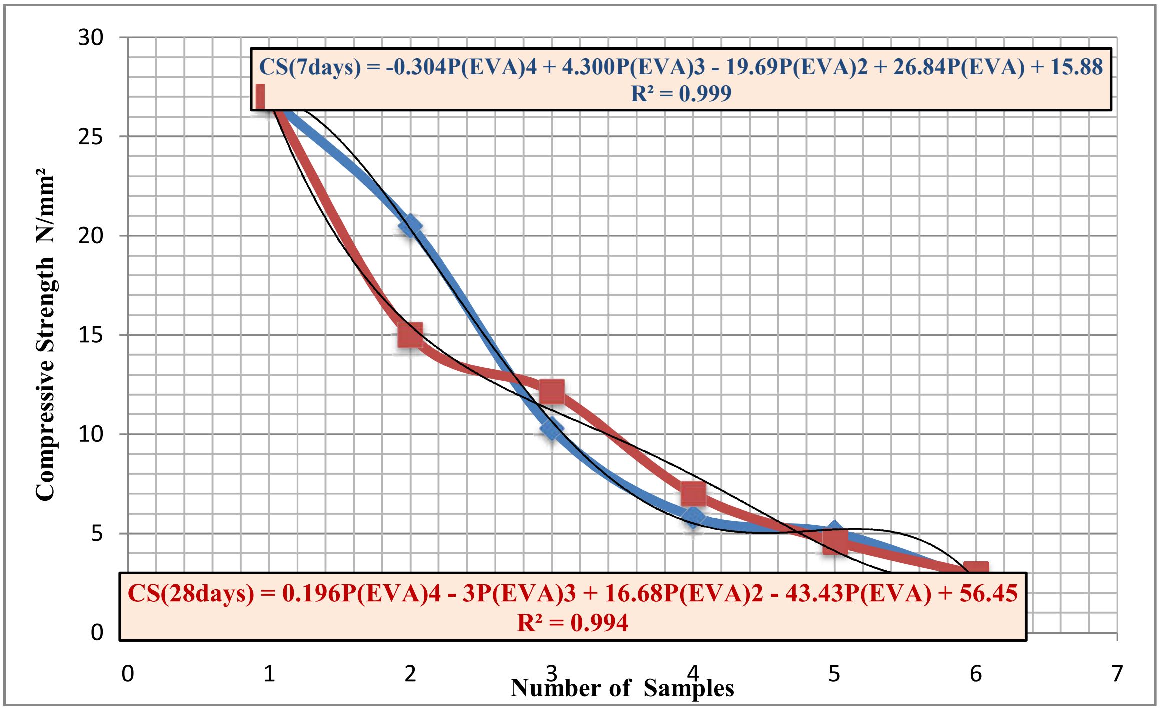


Fig 4.3: Average compressive strength for concrete mixes

Equation 4.4 and 4.5 are predicted by excel sheet to determine the average weight of concrete at 7 and 28 days depend on the percentage of EVA waste

$$CS_{7days} = -0.304P(EVA)^4 + 4.300P(EVA)^3 - 19.69P(EVA)^2 + 26.84P(EVA) + 15.88 \quad (R^2 = 0.999) \quad (4.4)$$

$$CS_{28days} = 0.196P(EVA)^4 - 3P(EVA)^3 + 16.68P(EVA)^2 - 43.43P(EVA) + 56.45 \quad R^2 = 0.994 \quad (4.5)$$

Where: CS: compressive strength and P(EVA): Percentage of EVA waste

4.4 Ultra SonicPulse Velocity Test (UPV):

Table 4.19 to table 4.24, presented the mean ultrasonic Pulse Velocity (UPV) of cubical specimens. All of these specimens were tested at 28days. According to ASTM C597-97 and standard table 3.11chapter three [60]. Mixes quality in table 4.19 for blank 0% EVA waste was very good to excellent ,the quality for 10% EVA waste was good to very good ,that means the quality reduced when increased the EVA waste replacement presented from 10% to 70% as shown in table from 4.20 up to table 4.24.

Table 4.19: ultra sonic Pulse Velocity Test for sample S_1 with 0%EVA waste (Blank)

Age	Distance (10^{-4}*Km*)	Transmit Time (10^{-6}*sec*)	Average Transmit Time(10^{-6} *sec*)	Average pulse Velocity (*Km/sec*)
28days	1	24.5 23.8 25.5	24.6	4.1

Table 4.20: ultra sonic Pulse Velocity Test for sample S_2 with 10%EVA waste

Age	Distance (10^{-4}*Km*)	Transmit Time (10^{-6}*sec*)	Average Transmit Time(10^{-6} *sec*)	Average pulse Velocity (*Km/sec*)
28days	1	27.3 27.3 26.9	27.2	3.68

Table 4.21: ultra sonic Pulse Velocity Test for sample $S_3$with 25%EVA waste

Age	Distance (10^{-4}*Km*)	Transmit Time (10^{-6}*sec*)	Average Transmit Time(10^{-6} *sec*)	Average pulse Velocity (*Km/sec*)
28days	1	31 28 31	30	3.33

Table 4.22: ultra sonic Pulse Velocity Test for sample S_4 with 40%EVA waste

Age	Distance (10^{-4}*Km*)	Transmit Time (10^{-6}*sec*)	Average Transmit Time(10^{-6} *sec*)	Average pulse Velocity (*Km/sec*)
28days	1	34.1 34.2 34.2	34.2	2.92

Table 4.23: ultra sonic Pulse Velocity Test for sample S_5 with 55%EVA waste

Age	Distance (10^{-4}*Km*)	Transmit Time (10^{-6}*sec*)	Average Transmit Time(10^{-6} *sec*)	Average pulse Velocity (*Km/sec*)
28days	1	34 35 35	34.7	2.89

Table 4.24: ultra sonic Pulse Velocity Test for sample S_6 with 70%EVA waste

Age	Distance (10^{-4}*Km*)	Transmit Time (10^{-6}*sec*)	Average Transmit Time(10^{-6} *sec*)	Average pulse Velocity (*Km/sec*)
28days	1	41.7 40.7 41.5	41.3	2.42

The permeability of concrete of the concrete mixes was evaluated by using Average of ultrasonic Pulse Velocity test at age 28 *days*, permeability decreased with the increase in replacement percentage of EVA waste, as shown in table 4.25 and fig 4.4

Table 4.25: Average Pulse velocity for concrete mixtures for samples S_1, S_2, S_3, S_4, S_5 and S_6 at 28 days age .

Mixes	**Average Pulse Velocity (*Km/sec*)**
	28days
Concrete mix with zero EVA	4.1
Concrete mix with 10% EVA	3.68
Concrete mix with 25% EVA	3.33
Concrete mix with 40% EVA	2.92
Concrete mix with 55% EVA	2.89
Concrete mix with 70% EVA	2.42

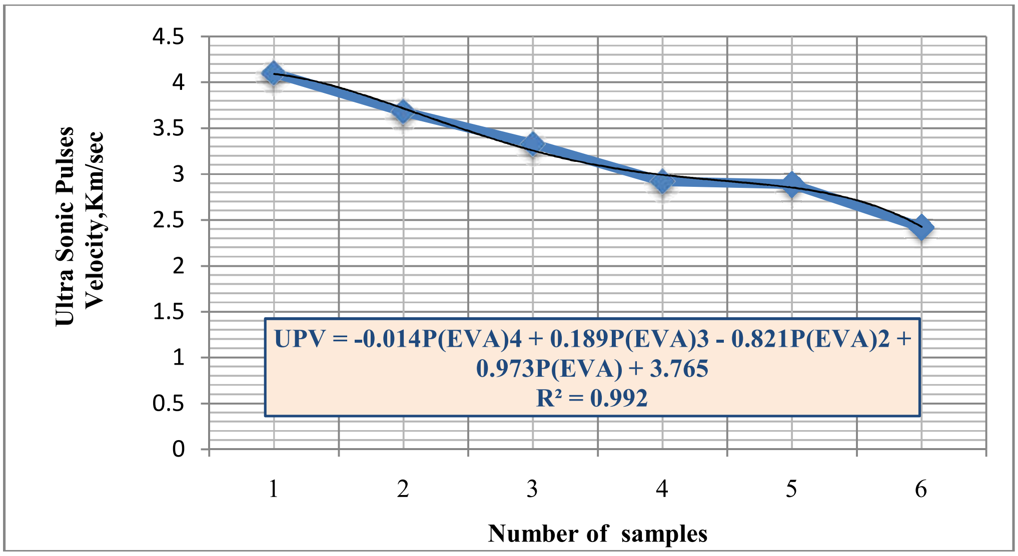


Fig 4.4: Average ultrasonic pulses velocity for concrete mixtures at 28 days

Equation 4.6 predicted by excel sheet to determine the USV of concrete at 28 days depend on the percentage of EVA waste

$$UPV = -0.014P(EVA)^4 + 0.189P(EVA)^3 - 0.821P(EVA)^2 + 0.973P(EVA) + 3.765 \quad (R^2 = 0.992) \ldots\ldots(4.6)$$

Where: USV: Ultra sonic velocity and P(EVA) : Percentage of EVA waste

4.5 Relation between Ultrasonic Pulse velocity and Density

Table 4.26 presented the results of relation between the average density for different propositions from EVA waste with UPV, when the values of concrete density decreased, UPV also decreased, the lowest density S6 70% EVA gave the lowest UPV by (km/sec), that means the permeability was low because it had avoids in concrete for this reason got low UPV .The results was obtained from the relation between average densities and UPV of concrete mixes s are summarized as following:

Table 4.26: Relation between ultrasonic pulses velocity UPV and density for concrete mixtures, samples S_1, S_2, S_3, S_4, S_5 and S_6 at 28 days age

Mix	**Ultrasonic Pulses velocity (UPV)** ***Km/sec***	**Density, ρ** ***Kg/m³***
Concrete mix with zero EVA, S_1	4.1	2540
Concrete mix with 10% EVA, S_2	3.68	2490
Concrete mix with 25% EVA, S_3	3.33	2410
Concrete mix with 40% EVA, S_4	2.92	2120
Concrete mix with 55% EVA, S_5	2.89	2090
Concrete mix with 70% EVA, S_6	2.42	1940

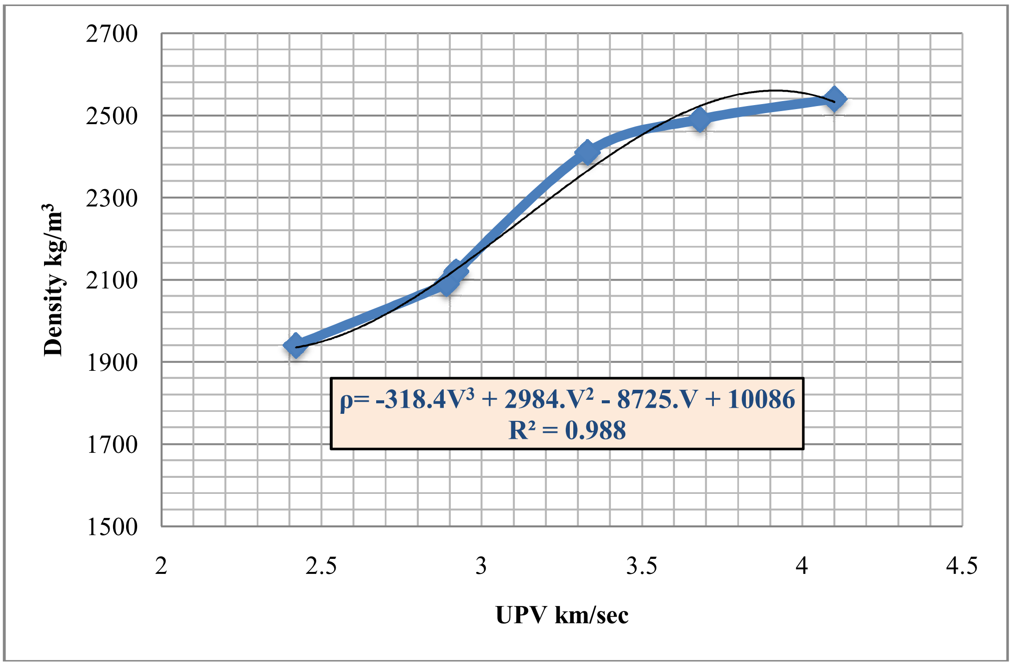


Fig4.5: Relation between Average densities and ultra sonic pulses velocity of concrete mixtures at 28 days

The experimental equation was derived from results between the density for different values from EVA waste of concrete with UPV to got a new density of concrete by knew UPV, as follow:

$$\rho=-318.4V^3+2984\ V^2-8725\ V+10086 \qquad (4.7)$$

The equation (4.7) is empirical formula done by using Microsoft Excel. It is (Polynomial equation-third Order).

- ρ, density of concrete(kg/m^3)
- V, Ultrasonic pulse velocity(km/sec)

4.6 Relation between Ultrasonic Pulse velocity and Compressive strength:

Table 4.27 present the relation between ultrasonic pulses velocity UPV and Compressive strength for concrete mixtures, samples S_1, S_2, S_3, S_4, S_5 and S_6 at 28 *days* age.

Table 4.27: Relation between ultrasonic pulses velocity UPV and Compressive strength for concrete mixture, samples S_1, S_2, S_3, S_4, S_5 and S_6 at 28 days age

Mix	**Ultrasonic Pulses velocity (UPV)** ***Km/sec***	**Compressive strength** ***N/mm²*** **at 28 days age**
Concrete mix with zero EVA, S_1	4.1	27
Concrete mix with 10% EVA, S_2	3.68	20.5
Concrete mix with 25% EVA, S_3	3.33	10.3
Concrete mix with 40% EVA, S_4	2.92	5.84
Concrete mix with 55% EVA, S_5	2.89	5.02
Concrete mix with 70% EVA, S_6	2.42	2.68

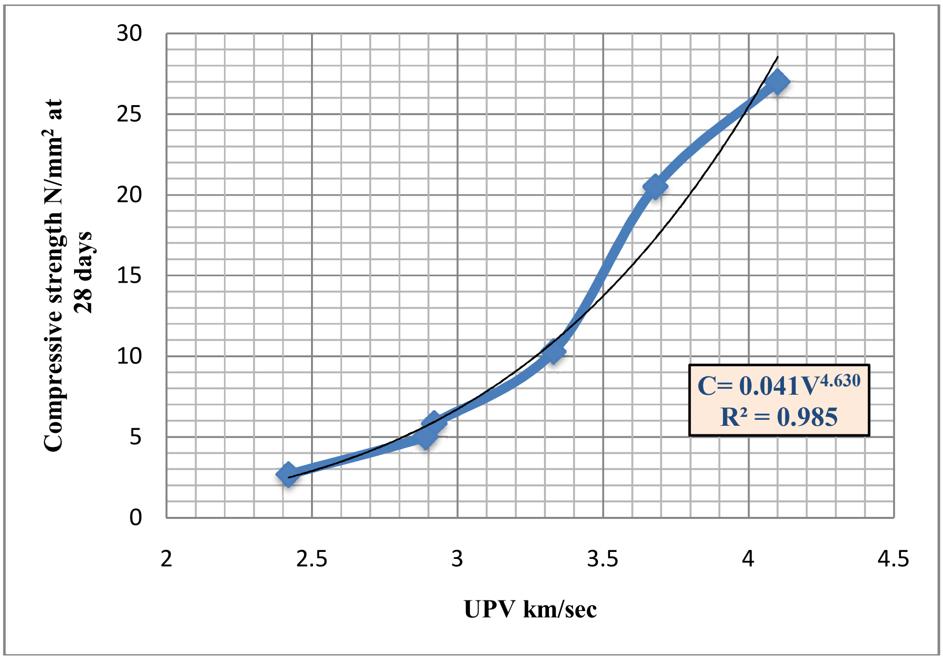


Fig 4.6: Relation between ultra sonic pulses velocity and Compressive strength for concrete mixtures at 28 days

The results which obtained from this relation between compressive and average pulse velocity for light weight concrete in fig 4.4 and table 4.27.It can be seen from this table that, the UPV increases when the percentage of EVA waste from local factory increased that means density was decreased, Another experimental equation was derived from result between Compressive strength C.S and UPV to estimate compression strength for known UPV for light weight concrete.

$$C.S = 0.041V^{4.630} \quad \text{……….....…..……(4.8)}$$

The equation (4.8) is empirical formula done by using Microsoft Excel. It is (Power equation)**.** This formula takes into consideration pulse velocity V, Ultrasonic pulse velocity (*km/sec*) to get:

C.S, compressive strength. (*mPa*).

This equation used to studied mechanical properties of light weight concrete or for casting the values of *C.S* on different densities as shown in table 4.27.

4.7New formula to determine the sound insulation (Transmission losses) of light weight concrete

One aim of this work study of sound insulation property of concrete samples with different densities. Experimental tests on concrete samples were made by using the ultrasonic instrument, the sound insulation of concrete specimens in this work calculated according to a proposed empirical formula for Transmission losses (TL) done by (Harris, C.M., and Yousif .K[64][65].

$$TL = 20\log(f \times m) - 48 \text{……… (Harris equation)………………(4.9)}$$

This formula takes into consideration pulse velocity, wall width in this case used specimen face, and frequency as follow:

TL= Transmission losses, dB

f =frequency, 54 kHz

m =W/A Mass per Area unit, kg/m^2

A= Area=$0.1^2\ m^2$

Table 4.28: Transmission losses TL and Average Weight per Area unit ,m for concrete mixtures ,samples S_1, S_2, S_3, S_4, S_5 and S_6 at 28 days age

Mix	Transmission Losses (TL), dB	Average Weight/Area (m),*Kg/m²*
Concrete mix with zero EVA, S_1	94.74	254
Concrete mix with 10% EVA, S_2	94.57	249
Concrete mix with 25% EVA, S_3	94.29	241
Concrete mix with 40% EVA, S_4	93.17	212
Concrete mix with 55% EVA, S_5	93.05	209
Concrete mix with 70% EVA, S_6	92. 40	194

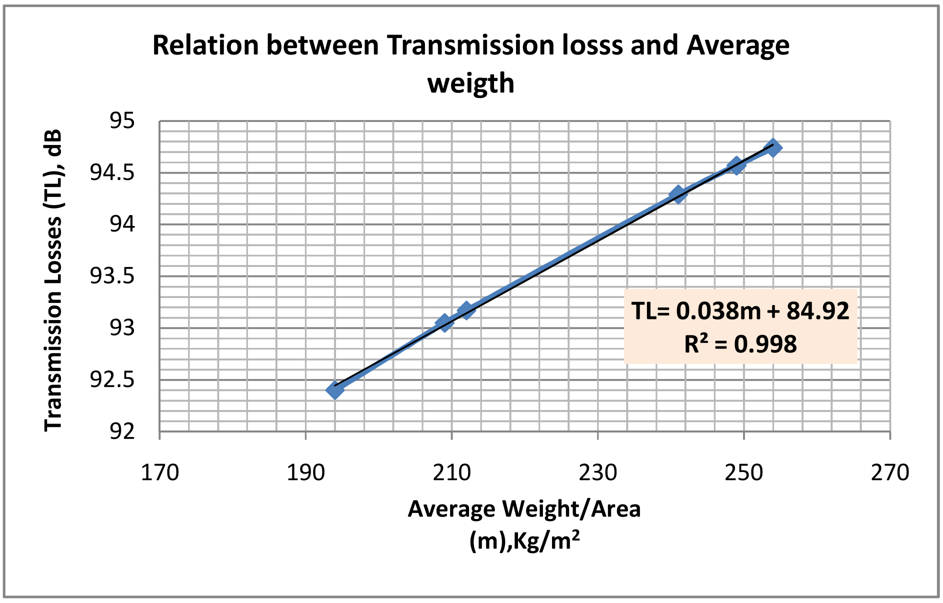


Fig 4.7: Transmission losses and Average Weight per area unit for concrete mixtures at 28 days

$$TL=0.038m+84.92 \quad (R^2=0.998) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.10)$$

This empirical formula done by using Microsoft Excel.(Linear equation) .

Transmission losses increased with decreased the average weight per area unit for concrete mixtures.

4.8 Water Absorption Results of Hollow concrete Blocks:

Table 4.29 presented the results of water absorption at 28 *days* for the average density of different propositions of hollow concrete blocks. Samples S_1, S_2, S_3, S_4, S_5 and S_6. There were three samples for each test and the average results were taken .

Table 4.29: Average water absorption Test for Hollow concrete mixtures, S_1, S_2, S_3, S_4, S_5 and S_6 at 28 days age .

Mixes	Average Water Absorption (%)
	28 *days*
Concrete mix with zero EVA, S_1	5.40
Concrete mix with 10% EVA, S_2	5.50
Concrete mix with 25% EVA, S_3	5.60
Concrete mix with 40% EVA, S_4	6.40
Concrete mix with 55% EVA, S_5	7.20
Concrete mix with 70% EVA, S_6	7.40

The effect of age of mix concrete and proportions of EVA waste on water absorption can be observed in above table (4.29), the value of water absorption when add 10% EVA waste after 28 *day* gave the lowest water absorption and when add 70% from EVA waste gave small increase according to percentage value of EVA waste which added, this test showed a direct relation.

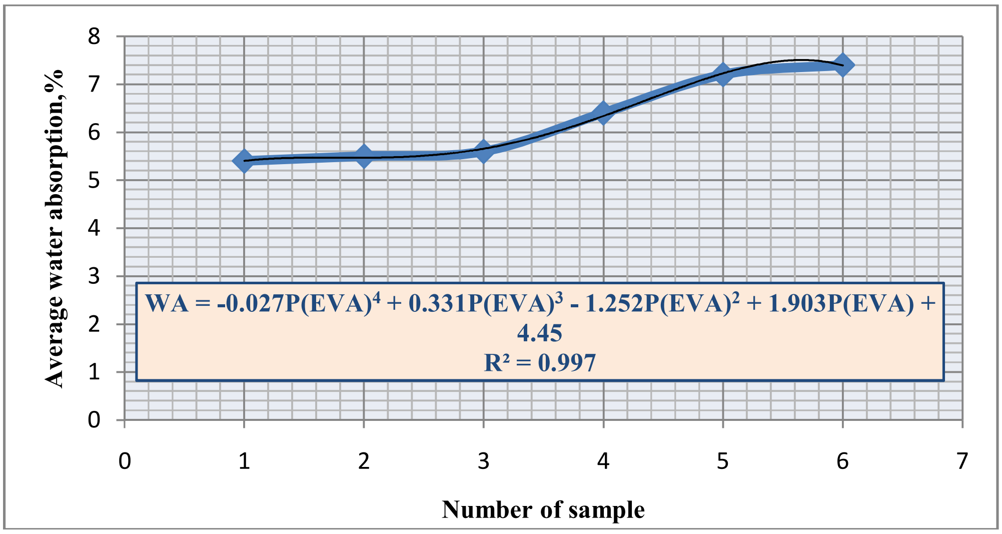


Fig 4.8: Average Water absorption for s hollow concrete block mixtures at 28 days

Equation 4.11 obtained by excel sheet to determine the average water absorption for shallow concrete blocks product by different percentage of EVA waste

$$WA = -0.027P(EVA)^4 + 0.331P(EVA)^3 - 1.252P(EVA)^2 + 1.903P(EVA) + 4.45 \quad (R^2 = 0.997) \ldots\ldots (4.11)$$

Where WA: average water absorption and P(EVA): percentage of EVA waste

4.9 Compressive strength Results of Hollow concrete Blocks

The individual hollow concrete blocks were tested for compression under Compressive Testing Machine as shown in fig4.8.

Fig 4.9Compressive Testing Machine

Fig 4.10 Crack in hollow concrete block

The compression strength values were obtained from applied load by (*kN*) from compression machine on net area of sample from hollow concrete blocks (rips) mm^2, average compressive strength for each mixtures by unit (*mPa* or N/mm^2) which shown in fig 4.9 and fig 4.10, and compared and are represented in tables 4.30to 4.35.The average compressive or crushing strength for hollow concrete blocks of size (400x200x200). There were four samples for each test and the results would be taken as the average of these four blocks, after 28 *days*.

Net area of Block (Rips) = (400×200)-(2×140×120)-(140×40)= 40800 mm^2

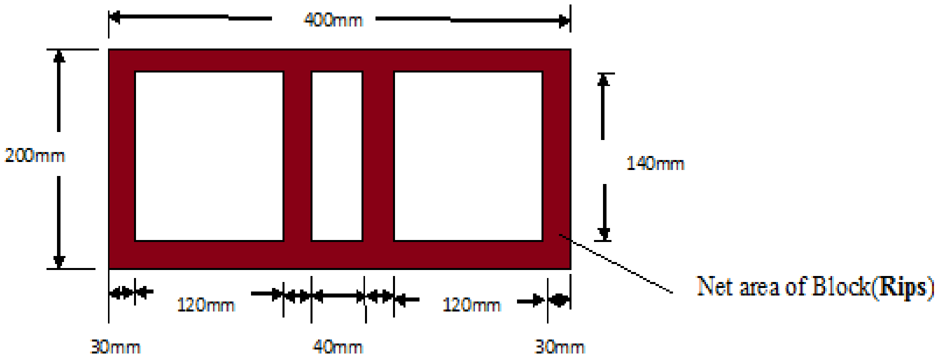


Fig 4.11 Plan of hollow concrete Blocks explain the net area

Table 4.30: Compressive Strength Test for sample with 0%EVA waste (Blank)

Samples	Load (*kN*)	Net Area Rips (*mm^2*)	Compressive strength (*N/mm^2*)	Average compressive strength (*N/mm^2*)	Age
S_{01}	60	40800	1.47	**1.50**	28 days
S_{02}	60		1.47		
S_{03}	55		1.35		
S_{04}	70		1.72		

Table 4.31: Compressive Strength Test for sample with 10%EVA waste

Samples	Load (*kN*)	Net Area Rips (*mm^2*)	Compressive strength (*N/mm^2*)	Average compressive strength (*N/mm^2*)	Age
S_{11}	40	40800	1.00	**1.29**	28 days
S_{12}	60		1.47		
S_{13}	60		1.47		
S_{14}	50		1.23		

Table 4.32: Compressive Strength Test for sample with 25%EVA waste

Samples	**Load (*kN*)**	**Net Area Rips (*mm^2*)**	**Compressive strength (*N/mm^2*)**	**Average compressive strength (*N/mm^2*)**	**Age**
S_{21}	50	40800	1.23	**1.26**	28 days
S_{22}	55		1.35		
S_{23}	55		1.35		
S_{24}	45		1.10		

Table 4.33: Compressive Strength Test for sample with 40%EVA waste

Samples	**Load (*kN)***	**Net Area Rips (*mm*^{2})**	**Compressive strength (*N/mm*^{2})**	**Average compressive strength (*N/mm*^{2})**	**Age**
S_{31}	55	40800	1.35	**1.20**	28 days
S_{32}	50		1.23		
S_{33}	40		1.00		
S_{34}	50		1.23		

Table 4.34: Compressive Strength Test for sample with 55%EVA waste

Samples	Load (*kN)*	Net Area Rips (*mm*^{2})	Compressive strength (*N/mm*^{2})	Average compressive strength (*N/mm*^{2})	Age
S_{41}	45	40800	1. 10	**1.17**	28 days
S_{42}	45		1.10		
S_{43}	50		1.23		
S_{44}	50		1.23		

Table 4.35: Compressive Strength Test for sample with 70%EVA waste

Samples	Load (*kN)*	Net Area Rips (*mm*^{2})	Compressive strength (*N/mm*^{2})	Average compressive strength (*N/mm*^{2})	Age
S_{51}	45	40800	1. 10	**1.08**	28 days
S_{52}	45		1.10		
S_{53}	45		1.10		
S_{54}	42		1.03		

The value of compressive strength for hollow concrete blocks when add 10% from EVA waste after 28day give us good strength compare with blank sample and when add 70% from EVA waste gave low value of compressive strength.

The values of Compressive strength for concrete decreased with increasing the percentage of EVA waste replacement in the mixes ,this results are summarized in table 4.36 and Fig 4.11.

Table4. 36: Compressive Strength for all samples of hollow concrete block at 28 days

Mixes	Average Compressive Strength for (N/mm^2)
	28days
Concrete mix with zero EVA	1.50
Concrete mix with 10% EVA	1.29
Concrete mix with 25% EVA	1.26
Concrete mix with 40% EVA	1.20
Concrete mix with 55% EVA	1.17
Concrete mix with 70% EVA	1.08

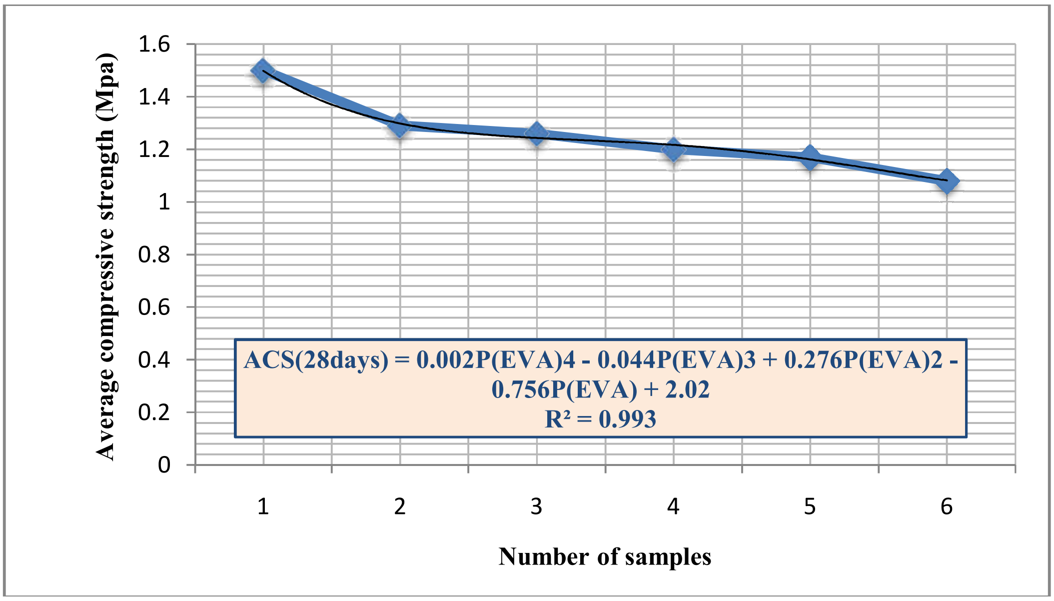


Fig 4.12: average compressive strength for concrete blocks mixes

Equation (4.12)developed by excel sheet to determine the average compressive strength (at 28 days) of hollow concrete depend on the percentage of EVA waste .

$$ACS_{(at\ 28days)} = 0.002P(EVA)^4 - 0.044P(EVA)^3 + 0.276P(EVA)^2 - 0.756P(EVA) + 2.02$$

$$(R^2 = 0.993) \ldots\ldots (4.12)$$

Where ACS: average compressive strength (at 28 days) and P(EVA): Percentage of EVA waste.

4.10Average weight Results of Hollow concrete Blocks

The average weight of at 28days after curing concrete hollow blocks is presented in table 4.37, and fig 4.12 show that all blocks with 70% EVA waste replacement have lowest weight than that of control mix (blank,0% EVA), it also clears that percentage of EVA waste replacement increase the weight of blocks decreases.

Table 4.37: Average weight for Block concrete mixtures for samples S_1, S_2, S_3, S_4, S_5 and S_6 at 7 and 28 days age:

Mixes	**Average Weight (*kg*)**
	28 days
Concrete mix with zero EVA, S_1	19.10
Concrete mix with 10% EVA, S_2	18.3
Concrete mix with 25% EVA, S_3	17.85
Concrete mix with 40% EVA, S_4	16.53
Concrete mix with 55% EVA, S_5	15.93
Concrete mix with 70% EVA, S_6	15.40

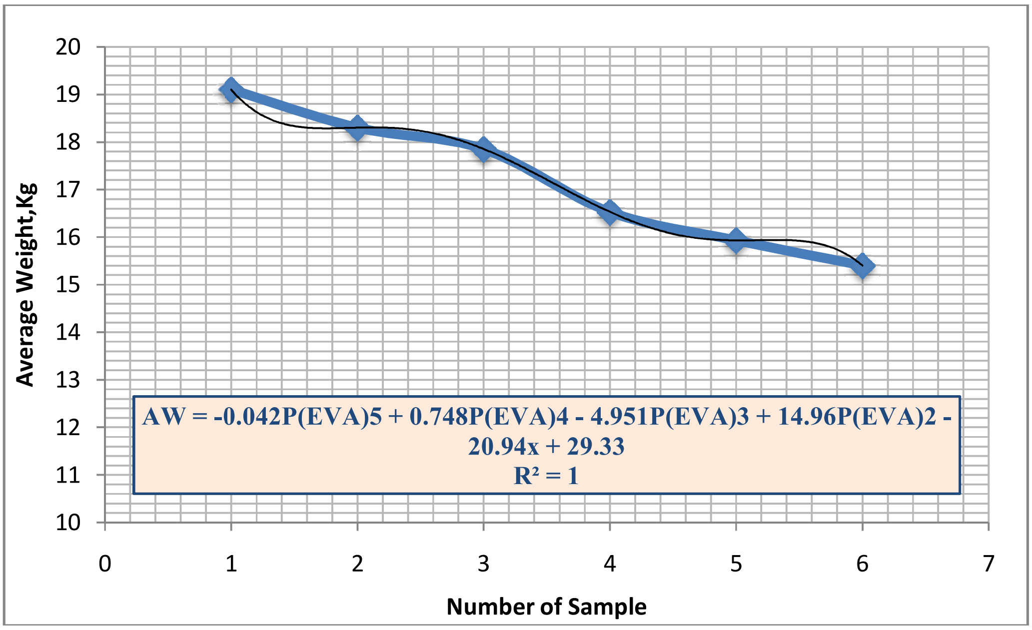


Fig 4.13: average weight for Hollow concrete Blocks mixes

Equation 4.13 predicted by excel sheet to determine the average weight of hollow concrete blocks for different replacement of aggregate by EVA waste

$$AW = -0.042P(EVA)^5 + 0.748P(EVA)^4 - 4.951P(EVA)^3 + 14.96P(EVA)^2 - 20.94x + 29.33 \quad (R^2 = 1) \ldots\ldots (4.13)$$

Where: AW: Average weight of concrete blocks and P(EVA): Percentage of EVA waste replacement

4.11 Cost Saving when use EVA waste as constituent of lightweight concrete mixture for production Hollow concrete Blocks

To evaluate the saving in the cost of hollow concrete block by saving the cost of natural aggregate and reduction of EVA waste accumulation when used as constituent in light weight concrete in this production(Hollow concrete Blocks) , and table 3.38 presented the prices of quantity for concrete mixers, the cost saving of block as shown in table 3.39.

Table 3.38 Prices of constituent concrete

Quantities	Cement, *kg*	Sand, *kg*	Coarse Agg, *kg*	EVA waste, *kg*
Price (SDG)	4.0	0.30	0.55	0.08

Table 3.39 comparisons between hollow concrete block (blank) and lightweight hollow blocks for different replacements of EVA waste

EVA waste, %	Application	Unit Price Of Block (*SDG*)	Saving in Cost of Block (%)
0%(Blank)	Hollow Concrete Blocks	12	0
10%		11.3	5.83
25%		10.9	9.2
40%		10.5	12.5
55%		10.1	15.8
70%		9.7	19.2

From calculations and comparisons carried out it can be said the overall saving in concrete blocks was increased when increases the percentage amount of EVA waste as replacement of natural coarse aggregate as shown in fig 4.13

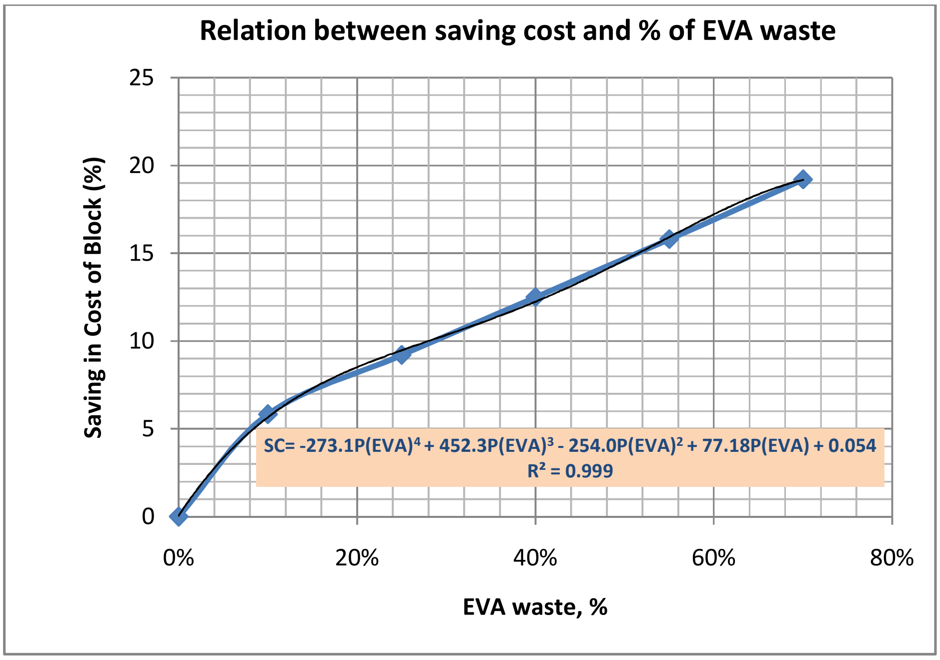


Fig 4.14: Explain saving in cost for Hollow concrete Blocks mixes

Equation 4.14 predicted by excel sheet to determine the saving cost of hollow concrete blocks for different replacement of aggregate by EVA waste.

$$SC = -273.1P(EVA)^4 + 452.3P(EVA)^3 - 254.0P(EVA)^2 + 77.18P(EVA) + 0.054 \quad (R^2 = 0.999) \ldots\ldots (4.14)$$

Chapter Five

Conclusions and Recommendations

Chapter Five

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5.1 Conclusions

According to the laboratory tests conducted to investigate the effect of replacement of various percentages of industrial EVA waste as aggregate for production of lightweight concrete for construction application .The conclusions obtained from different tests are summarized as following:

- Compressive strength of concrete at the age of 7 and 28 days decreased with increased amounts of EVA waste for cube test and concrete blocks. Equations (4.4),(4.5),and (4.12) predicted by excel sheet to determine the compressive strength depend on the percentage of EVA waste.
- The density of concrete decreased with increased amounts of EVA waste .That means the concrete molded with EVA presented lower levels of bulk density of fresh concrete in comparison to the concretes with natural aggregates
- The weight of concrete decreased with increased amounts of EVA waste .This is useful in applications requiring non load bearing light weight concrete, such as hollow concrete blocks. Also equations (4.2),(4.3),and (4.13) predicted by excel sheet to determine the average weight of concrete cubes and blocks depend on the percentage of EVA waste.
- Increased value of slump with increased amounts of EVA waste.

- The cost of light weight concrete blocks mixed with EVA waste was not so high price compared with the general concrete blocks with out EVA waste .

- Water absorption was increased by increasing an amounts EVA waste .That made the EVA concrete block easy to be used as plaster and mortar. Equation 4.11 obtained by excel sheet to determine the average water absorption for shallow concrete blocks product by different percentage of EVA waste.

- Reduced pollution which comes from accumulation of EVA foam waste that used in footwear companies according to the quantities of EVA waste which used in the mix design of concrete blocks when used concrete Block without EVA waste.
- Reduced weight of concrete block with dimensions (400mm*200mm*200mm), the weight of block 19Kg when used 0%EVA waste, but became 15Kg when used 70% of EVA waste.
- The permeability decreased with the increase in replacement percentage of EVA waste.
- Reduced consumption of electricity/energy which used for mixing the composite Concrete because EVA waste had low density .copmared to general concrete which had high density for natural aggregate.
- The ultrasonic Pulse Velocity test increases when the percentage of EVA waste from local factory increased that means density was decreased, at age 28 *days*.
- Sound insulation of light weight concrete can be determined using the ultrasonic instrument .

- Increased the transmission losses with decreased the average weight per unit area for concrete mixtures according to empirical equation (4.10).
- The overall saving in concrete blocks was increased when increases the percentage amount of EVA waste as replacement of natural coarse aggregate.
- Transmission losses decreased with increasing the amount of EVA waste.
- Transmission losses increased with increased the average weight per unit area for concrete mixtures,

5.2 **Recommendation and scope for Future research**

The use of EVA waste in concrete is relatively new development in the world of concrete technology and a lot of research must go in before this material is actively used in concrete construction. The use of EVA waste in concrete lowered the strength of resultant concrete, therefore, the research must be oriented towards ternary systems that help in overcoming this drawback of plastics in concrete

Based on the result of the study performed in this research, the following recommendations can be made:

- Use of industrial EVA waste as replacement of aggregate for other application ,examples light weight blocks ,tiles and interlock.
- Use light weight blocks that contains different ratio of EVA waste to help in the interior sound insulation, as compared to corresponding control concrete, there are many examples for use of LWCB as sound insulation such as: Studio, halls of universities, conference hall ,meeting room, schools.

- Use other types of EVA waste as solid in fresh concrete with optimum values to obtain good workability and high compressive strength. with reduce the accumulation of it .
- Study the use of EVA waste as substitute for sand in concrete mix.
- Study the use of different diameters of EVA waste in concrete mix.
- The EVA waste can be used in installations of radiation.
- The EVA waste can be used in thermal and water insulation.

References

References:

1. Nigel Mills, (2007),polymer foams handbook, engineering and biomechanics applications and design guide,butterworth-heinemann (Elsevier); ISBN 978-0-7506-8069-1.
2. Manas Chanda Salil K. Roy,(2009).Industrial Polymers, Specialty Polymers, and THEIR applications plastics , Taylor & Francis Group (page68).
3. UNIDO, (2000), wastes generated in the leather footwear industry, 14th session of the leather and leather products industry panel, czech republic. [online]: https://www.unido.org.
4. Maurice Reyne (2008),plastic forming processes , hermes science/lavoisier entitled, iste ltd john wiley & sons, inc.27-37 t george's road 111 river street london sw19 4eu hoboken, nj 07030,UK ,USA.
5. J. A. Brydson (1999), plastics materials, 7th ed, Butterworth-Heinemann,Linacre House, jordan hill, oxford.
6. L. J. Gibson and M. F. Ashby,(1998) cellular solids:structure and properties. oxford,pergamon.
7. S.T. Lee and N.S.(2004), polymeric foams. ramesh, eds ,new york: crc press.
8. D. Eaves, Ed.(2004), handbook of polymer foams. crewe, uk: rapra technology limited.
9. D. Klempner and K. C. Frisch, Eds, (1991), handbook of polymeric foams and foamtechnology. new york: hanser.
10. A. H. Landrock, (1995), handbook of plastic foams: types, properties, manufacture and applications. new jersey: noyes publication.
11. Nan Chen, (2012), the effects of crosslinking on foaming of eva, university of toronto, toronto, phd thesis 2012.

12. Globalhighevacopolymersmarkets,technologies, & trends (2011-2016-2020),chemicals/plasticsmarketingresearchwebsite:www.cmrhoutex.com,e mail:cmrinfo@cmrhoutex.co m christian baechler, matthew devuono, and joshua m. pearce, "distributed recycling of waste polymer into reprap feedstock http://dx.doi.org/10.1108.
13. A.M. Henderson, "Ethylene-Vinyl Acetate (EVA) Copolymers: a General Review," IEEE.
14. Barrett, J. R. (2005). Chemical Exposures: The Ugly Side of Beauty Products. Environmental Health Perspectives, 13(1): A24.
15. Alvarez, C., Edwards, S. (2008). Draft Report:The Potential for Use of Biobased Plastics in Toys and Children’s Products.
16. Tickner, J. (1999). A Review of the Availability of Plastic Substitutes for Soft PVC in Toys. Department of Work Environment, University of Massachusetts at Lowell. Available at www.pvcinformation.org/assets/ pdf/PlasticSubstitutesPVCtoys_Tickner.pdf
17. Raquel Verdejo and Mills(2002),performance of EVA foam in running shoes,pp580-587,the engineering of sport4,edsS.Ujihashi and Haake,Blackwell(2002).
18. Delft, (2012),EVA foam injection moulding ,Delft University of Technology Industrial Design EngineeringIO2041 – 5B1.
19. Stephen Moore (2012),EVA Overview: Global Demand,Capacities,Trade & Trends, Sponsored by CBI China,Guilin, China.
20. P. Viot1, L. Mah´eo1 & A. Mercier (2011),the behavior of polymeric multi scale foam under dynamic loading, LMA, H.E. P.-H. Spaak, Brussels, Belgium
21. Porter, Richard C. (2002). . Resources for the Future. ISBN 1-891853-42-2, ISBN 978-1-891853-42-5.

22. Manoel Alpire-Chavez1, Joyce B Azevedo[1],Romulo F Freitas[1] and Marcelo S Rabello[2](2014), Heterogeneities and physical propertiesof ethylene-vinyl acetate foams containing calcium carbonates,Journal of Cellular Plastics2014, Vol. 50(2) 163–177.

23. Hojjat, Amrollahi [*a,b]; Mahmood, Borhani [a] (2015) ,the effect of EVA Content upon the Dielectric Properties in LDPE-EVA Films, a-Department of Physics, Yazd University, Yazd, Iran,b- Imam Javad University College, Yazd, Iran, International Journal of Engineering Research ,Volume No.4, Issue No.2, pp : 69 – 72.

24. Raquel Verdejo (2003) ,Gas Loss and Durabilityof EVA foams used in Running Shoes, , University of Birmingham, PhD Thesis 2003

25. A. Rizvi , N.Chen and C.B in 2011 ,study on the mechanical properties of cross linked Ethylene vinyl acetate (EVA) foams.Electrical Insulation Magazine, vol. 9, no. 1, pp. 30-38, 1993.

26. Doktor-Ingenieurin,J.Piglowski(2003) Investigations on Environmental Stress Cracking Resistance of LDPE/EVA Blends, Ruse, Bulgaria, PhD Thesis 2003.

27. Thai Hoang[1], Trinh Anh Truc[1], Dinh Thi Mai Thanh[1], Nguyen Thuy Chinh[1], Do Quang Tham[1], Nguyen Thi Thu Trang[1], Nguyen Vu Giang1 and Vu Dinh Lam[2] (2014), Tensile, rheological properties, thermal stability, and morphology of ethylene vinyl acetate copolymer/silica nanocomposites using EVA-g-maleic anhydride ,Journal of Composite Materials2014, Vol. 48(4) 505–511.

28. Dongfang Li,Jianzhang Li,Xianohong Hu,LiLi(2012),Effects of ethylene vinyle acetate content on physical and mechanical properties of wood plastic composites,university,Beijing,china.

29. A.M. Betioli [a],*, J. Hoppe Filho a, M.A. Cincotto [a], P.J.P. Gleize [b], R.G. Pileggi (2009)Chemical interaction between EVA and Portland cement hydration at early-age, a,Department of Construction Engineering,

University of San Paulo, Av. Prof. Almeida Prado No. 83, 05508-900 SanPaulo, SP, Brazil,b ,Department of Civil Engineering, Federal University of Santa Catarina, Caixa Postal 476, 88040 900 CEP, Florian polis, SC, Brazil, Elsevier Ltd.

30. D.A. Silva*, H.R. Roman, P.J.P. Gleize(2002), Evidenceschemical interaction between EVA and hydrating Portland cement, Department of Civil Engineering, Federal University of Santa Catarina, Caixa Postal 476, 88040 900 CEP Florianopolis, SC, Brazil.
31. Huimei ZHU, Peiming WANG , Ru WANG , Guofang ZHANG (2014),Effects of Two Redispersible Polymer Powders on Efflorescence of Portland Cement-based Decorative Mortar,ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. 20, No. 3. 2014.
32. Tom Holm,(1994),light weight concrete and aggregate , ,astm169c,chapter 48,astminternational,west conshohocken,pa.
33. American concrete institute ,FamingtoHills,MI,www.concrete.org.Guide for structural light weight aggregate concrete ,AC1213R,
34. Paulo Roberto Lopes Lima *, Mônica Batista Leite, Ediela Quinteiro Ribeiro Santiago,(2010),Recycled lightweight concrete made from footwear industry waste and CDW,S/N – Novo Horizonte, Feira de Santana, Bahia 44036-900, Brazil.
35. Ningwei Li Reduce, Dilasha Mahat Seonhee(2009) ,A Study on Solutions to Plastic Wastes, Worcester Polytechnic Institute.
36. ZENG De-Wen(2004),Pyrolysis of EVA and application of photovoltaic modules ,Manfred Born,Karsten.
37. NIKE, INC (2014),Eva recycling method ,US 20140066530 A1.G. C. Staelm, M. C. G. Rocha, S. M. C. Menezes , N. M.
38. A. Marcilla , A. Gomez. S. Menargues,(2005), TGA/FTIR study of the catalytic pyrolysis of ethyleneevinyl acetate copolymers in the presence of

MCM-41, Elsevier Ltd. Polymer Degradation and Stability 89 (2005) 145-152.

39. Marcilla A, Gomez . S.Menargues (2005), TG/FTIR study of the thermal pyrolysis of EVA copolymers. J Anal Appl Pyrol, in press.
40. Eunha Kim and Sung-Seen Choi (2015)Comparison of Vinyl Acetate Contents of Poly(Ethylene-co-Vinyl Acetate) Analyzed by IR, NMR, and TGA, Elastomers and Composites Vol. 50, No. 1, pp. 18~23 (March 2015).Korea.
41. B. F. Tutikian etal,(2012), Lightweight concrete with EVA recycled aggregateforimpactnoise attenuation, Vol. 63, 310, 309-316.
42. Nunes, M. F. O.; Rauber, J. (2010): EVA waste material to reduce transmission of impact noise, São Paulo, EDUSP .
43. Paulo Roberto Lopes Lima *, Mônica Batista Leite, Ediela Quinteiro Ribeiro Santiago,(2010),Recycled lightweight concrete made from footwearindustry waste and CDW,S/N – Novo Horizonte, Feira de Santana, Bahia44036-900, Brazil.
44. Huimei ZHU, Peiming WANG , Ru WANG , Guofang ZHANG (2014),effects of two redispersible polymer powders on efflorescence of portland cement-based decorative mortar,issn 1392–1320 materials science (medžiagotyra). vol. 20, no. 3. 2014
45. P RACHOOM KHAMPUT,(2014),using of para-rubber to develop propertiesofconcreteblock mixed with ethylene vinyl acetate plastic in masonry, ijerd – international journal of environmental and rural development (2014) 5-2.
46. Nopado Sahachaisaeree[1] Wichitra Singhirunnusorn,2 Anurak Kusolchoo,3 Kanyakorn Kaenwichit 4 Jirawut Ronruengrit ,(2014),thermal condition and insulation properties of lightweight concrete with footwear industrial waste content.

47. Singhirunnusorn, W. & Sahachaisaeree, N. (2013),Interior Thermal Response within Building Evelope Designed from Concrete Blocks Containing Waste Materials, Global Journal on Advances in Pure & Applied Sciences [Online]. 2013, 01, pp 58-64. Available from: http://www.world-education-center.org/index.php/paas.
48. Yadav.I.S,(2008),laborarty investigation of the properties of concrete containing recycled plastic aggregates ,doctoral disseration,thapar universoty patiala.
49. Mills.N.J,(2007),polymer foams handbook,1st Elsevier,oxford.
50. ASTM International (2012),density, ASTM D150,mass flow rate, ASTMD1238,ASTMD638,ASTMD395-03(2008).
51. Shah, Vishu John Wiley & Sons (2007), Handbook of Plastics Testing Technology (2nd Edition).
52. BS12-(1996), specification for Portland cement test, publishing date,15may1996,Cement Tests:SS3998-2008
53. BS EN 933-1,(1997), Tests for geometrical properties of aggregates. Part1: Determination of particle size distribution - Sieving method.
54. ASTM C-127-93 test of specific gravity and absorption of coarse aggregate.
55. Neville, A.M.(1981), properties of concrete , longman publishing, third edition.
56. SSMO ,(2011), Water Absorption Test, Sudanese standards and metrology organization ,4918.
57. ASTM International- C-127-93,(1993), test of specific gravity and absorption of coarse aggregate, annual book of ASTM standards,vol 04.02.3.
58. ASTM International- C39,(1990), Compressive strength test, annual book of ASTM standards,vol 04.02.3.

59. ASTM International -C143,(1990), slump test, annual book of ASTM standards vol04.02.3
60. ASTM International C597-97,(1997),Ultrasonic pulse velocity test UPV,2.annual book of ASTM standards,vol 04.02.3.
61. SSMO,(2011),sudanese specification of concrete (hollow,solid/Brick), Sudanese standards and metrology organization,3947.
62. Yadav, I.S.,(2008), laboratory investigations of the properties of concrete containing recycled plastic aggregates, doctoral dissertation, thapar university patiala.
63. ASTM Intrenational-C140-08a ,(2008),standard test for sampling and testing concrete masonry unit ,edition2008.
64. Harris, C.M.,(1979),handbook, of noise control, mcgraw-hill, u.s.a.
65. Yousif Khalaf Yousif ,(2009), proposed new formula to determine the sound insulation of concrete walls,ajes college of engineering, university of anbara -vol. 2, no. 2.

List of publications :

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Appendix

Abstract of Publish

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USING EVA FOAM WASTE AS THE CONSTITUENT OF LIGHT WEIGHT CONCRETE MIXTURE FOR CONSTRUCTION APPLICATION

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ABSTRACT

This work aimed to study the effects of proportional additions of EVA waste as constituent of lightweight concrete and to evaluate its efficiency to produce a concrete with high strength and lightweight. Experimental study was carried out by preparing different test samples using various proportions (10%, 25%, 40%, 55%, and 70%) of EVA waste in the mix and a blank sample of concrete of grade M25. Samples and Blank were cured in tanks for 7 days and 28 days. Resulted samples were then tested for compressive strength of concrete and slump value. Finally the results were compared with the normal conventional concrete. Results showed that using10% EVA gave the best performance. Accordingly it was concluded that there is an indirect relationships between the amount of the EVA in the mix and the weight of the product. Same relation was notices against compressive strength.

KEYWORDS: EVA, Industrial waste, Fine aggregate (F.A), Coarse aggregate (C.A), Concrete

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STUDY ON PERMEABILITY, SOUND INSULATION FOR LIGHT WEIGHT CONCRETE MIXTURE WITH INDUSTRIAL EVA WASTE

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ABSTRACT

This paper aims to study the permeability and evaluate the concrete structure ,sound insulation property and quality control for proportional additions of EVA waste as constituent of lightweight concrete with different densities .This study also intended to present a proposed empirical formula to determine the sound insulation of concrete cubes by using **UPV**, Samples of various proportions (10%, 25%, 40%, 55%, and 70%) of EVA waste in the mix and a control sample,(0%) were cured in water tanks for 28days. The sound insulation of concrete area calculated according to a proposed empirical formula made in this work . It was found that permeability decrease with increase in replacement percentage of EVA waste compared with the normal conventional concrete, Results showed that using10% EVA gave the lowest permeability and the best performance, Results of sound insulation showed transmission losses increased with decreased the average weight per area unit for concrete mixtures. Accordingly it was concluded that there is an indirect relationships between the amount of the EVA in the mix and the sound insulation of the product. Same relation was noticed against compressive strength.

KEYWORDS: Ultrasonic Pulse Velocity, Industrial Waste, lightweight Concrete, Sound Insulation, Ethylene Vinyl Acetate