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Experimental analysis on properties of M15 and M20concrete brick sample with partial replacement of sand by crumb rubber and coarse aggregate by expanded polystyrene

by

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A THESIS

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled **"Experimental analysis on properties of M15 and M20concrete brick sample with partial replacement of sand by crumb rubber and coarse aggregate by expanded polystyrene**" submitted by Samiksha Dhakal, in partial fulfilment of the requirements for the degree of Master of Science in Technology and Innovation Management.

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ABSTRACT

The suitability of crumb rubber and EPS as an alternative to sand and coarse aggregate in concrete production was researched here. Sand and coarse aggregate were partially replaced by crumb rubber and EPS in different percentages like 0%, 10%, 20% and 30% for Grade M20 and M15 concrete samples. The sample of size (240 × 115× 57) mm for M15 and M20 grade of concrete were prepared for the test. Various properties like Compressive strength, Bulk density and water absorption of the concrete brick prepared were determined. The normal consistency, initial and final setting time and compressive strength of cement used for the experiment were determined as 27%, 120 minutes, 290 minutes and 40.34 N/mm^2 respectively before carrying out the experiment. The nominal maximum size of sand, coarse aggregate, crumb rubber and EPS used for the preparation of concrete brick sample were found as 2.36 mm, 12.5mm, 2.36 mm and 4.75 mm respectively from the sieve analysis. Impact value of coarse aggregate obtained was 17.06 %.

The experimental results showed that water absorption of prepared M15 and M20 concrete brick samples increased whereas compressive strength and bulk density decreased with increase in percentage replacement of sand by crumb rubber and coarse aggregate by EPS. The results obtained from the experiment showed that concrete brick made with partial replacement of sand and coarse aggregate y crumb rubber and EPS respectively had sufficient compressive strength compared to common brick. The research recommended that upto 30% replacement of sand and coarse aggregate by crumb rubber and EPS respectively, the concrete brick so produced could be used for masonry unit in building construction.

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LISTOF ACRONYMES AND ABBREVIATIONS

BDW	: Brick Dust Waste
CA	: Coarse Aggregate
CB	: Common Brick
CR	: Crumb Rubber
Cum	: Cubic meter
EPS	: Expanded Polystyrene
FA	: Fine Aggregate
IS	: Indian Standard
ISSCS	: Indian Standard Soil Classification System
Kg	: Kilo gram
M	: meter
Mm	: millimeter
MPa	: Mega Pascal
M20	: Mix of Characteristic Strength of 20 N/mm2
M15	: Mix of Characteristic Strength of 15 N/mm2
N	: Newton
NS	: Nepal Standard
OPC	: Ordinary Portland Cement
PET	: polyethylene terephthalate
Sqm	: Square meter
W/C	:WaterCementRatio

CHAPTER ONE: INTRODUCTION

1.1 Background

Bricks have been around for a long time. The earliest known bricks have been dated to about 7000 BC. In the Middle Ages, bricks were made by workers who mixed clay and put it in wooden timber. Bricks were made by hand until 1885. The industrial revolution changed everything and increased production capacity and consequently reduced production and construction costs. By the 1920's brick-making machines were capable of producing up to 12,000 bricks a day.

In current time, bricks are the most widely used building materials. Bricks are prepared by molding clay into rectangular blocks of the same size followed by drying and burning. The main types of bricks commonly used in masonry are Common Burnt Clay Bricks, Sand Lime Bricks (Calcium Silicate Bricks), Engineering Bricks, Concrete Bricks and Fly ash Clay Bricks.

Concrete is a composite and versatile material. Being one of the most popular building materials in the world, there is a high demand for the constituent materials of concrete. Cement, sand and aggregate are the main constituent materials of concrete. River sand in Nepal has been used as one of the major components of concrete as it is easily accessible in nature. River sand is widely used in various kinds of civil engineering constructions.With the increase in construction of structures, the use of river sand has increased excessively. The excessive mining of river sand is becoming a serious environmental concern. In addition, most of the aggregates are obtained from the environment and numerous environmental problems and natural disasters are occurred due to high extraction of aggregate and sand.It is therefore necessary to explore another possible solution to reduce the use of these basic constituent materials. Therefore, replacement of materials for natural river sand and aggregate in concrete is the requirement of time.

One of the potential marginal materials suitable for replacing sand in concrete is crumb rubber which is a recycled rubber produced from automotive and truck scrap tires. The number of discarded waste tires has become a serious ecological and environmental problem. Decay of waste tire rubber can take more than 50 years, and every year the number of discarded tires is rapidly increasing. Hence there is a need for reutilizing more and more waste material. The commonly used fine aggregate for making concrete is the natural sand extracted from the riverbeds. But, the availability of river sand for the preparation of concrete is decreasing due to the excessive nonscientific method of excavating from the riverbeds, lowering of water table, sinking of the bridge piers, etc.Thus, there is high demand for the identification of substitute materials for the river sand for making concrete.The choice of materials to replace sand in concrete depends on a few factors such as their availability, physical properties, and chemical ingredients.

The present demands identification of substitute materials for the river sand for production of concrete. A recent successful study on the use of crumb rubber as a new brick material supplement appears to be viable solution not only to the environmental problem but also to the problem of to economic design of building. Huge quantity of wastes used in this research is presently disposed in sanitary landfills or open dumped into uncontrolled waste pits and open areas.

Similarly, Expanded polystyrene (EPS) can be used as a replacement for coarse aggregate. EPS refers to a strong, durable and lightweight thermoplastic product. EPS is usually white and is made of expanded polystyrene beads. EPS is suitable for the packaging and construction industries due to its light weight, high strength and excellent thermal insulation properties. EPS is highly resistant to biological corrosion. It also reduces the effects of moisture and water vapor, so it is used as a insulation product. EPS is posing a threat to waste disposal as well as for waste management. This material is a reason of concern to environmentalists.

The advantages of replacing sand by crumb rubber for the production of concrete brick are:

- Lightweight
- Low thermal conductivity
- Good sound absorption
- High flexibility

Similarly, the advantages of replacing coarse aggregate by EPS for the production of concrete brick are:

- Extremely durable
- High thermal insulation

- Resistance to moisture
- Easily recyclable
- Versatile in strength
- Light weight and portable
- High shock absorbency characteristics
- Compression resistance

These replacement exhibits many advantages over the traditional concrete including weight reduction of the structure by reducing the dead loads transmitted to the foundation. Replacement of coarse aggregate by EPS becomes more economical as compared to using sand and aggregate in concrete brick. So, in this study, it is attempted to partially replace fine aggregate by crumb rubber and coarse aggregate by EPS beads.

1.2 Problem Statement

The increase in development activities around the world has led to an increase in demand for building materials. Most of the building materials for construction activities are found in the nature and many environmental problems and natural disasters occur due to the excessive extraction of those materials from nature. Therefore, it is necessary to focus on future development, while protecting the environment. There is a strong need to use other alternative materials for the sustainable development. The problem of waste products such as sandpaper, tires, sawdust, fly ash, silica fume, plastic bottle and others can cause pollution and health problems in the community. Steps must be taken to determine the best way to make garbage useful and recyclable. Expanded polystyrene foam (EPS) is widely used as packaging, building materials, and household appliances and much more. EPS has caused pollution because it is difficult to decompose. Therefore, this study has been designed to study the use of EPS waste and crumb rubber in concrete technology.

There is a great demand for building materials in the domestic market, which is becoming scarce day by day. At this point researchers and engineers who have the vision of keeping track of development projects and reducing costs should look at other building materials. Currently millions of tons of rubber tire and polystyrene waste are produced worldwide. This has ultimately created pollution and is harmful to the ecosystem. National and international environmental laws have become so inflexible that it has become increasingly difficult to get rid of them.

Therefore, the use of polystyrene waste and rubber waste in concrete production not only solves the problem of waste disposal but also helps to conserve natural resources.

1.3 Scope

The main scope of my work will be as follows:

- Analyzing suitability of crumb rubber and EPS in concrete brick production
- Evaluating the effect of crumb rubber and EPS in properties of concrete brick
- Comparing strength of concrete brick made by partial replacement of sand by crumb rubber and coarse aggregate by reused EPS with common brick.
- Establish as a guideline for future reference study.

1.4 Research Objectives

1.4.1 Main Objective

The main objective of this thesis is to investigate experimentally the effect of the partial replacement of sand by crumb rubber and coarse aggregate by EPS on compressive strength, bulk density and water absorption properties of the resulting concrete brick.

1.4.2 Specific Objectives

The specific objectives are:

- To determine compressive strength of concrete brick sample with 0%, 10%, 20% and 30% replacement of sand and coarse aggregate by crumb rubber and EPS respectively.
- To determine water absorption of the prepared concrete brick sample.
- To determine bulk density of the prepared concrete brick sample.
- To compare the strength of concrete brick made by partial replacement of sand by crumb rubber and coarse aggregate by reused EPS with common brick.

1.5 Limitations of the Study

While carrying out this research, there were various limitations. Due to this, the accuracy of the results obtained is limited. Some of them are:

- Compressive strength test was carried out only for the samples cured for 28 days.
- Among various tests only bulk density, water absorption test, compressive strength test were performed to check the effect of crumb rubber and EPS on the properties of concrete.
- Mixing was performed manually with hand.
- Crumb rubber by cracker Mill process is only used for experiment .
- Crumb rubber was assumed to be homogeneous.

CHAPTER TWO: LITERATURE REVIEW

2.1 Research Gap

P. Rohit, S.K. Alisha, P.V.S.S.P. Ganesh Varma (P. Rohit, 2020)studied Partial Replacement of Fine Aggregate with Crumb Rubber in Concrete. The main aim of this study was to investigate the potential use of recycled tyre rubber in concrete mixture. Partial fine aggregates replacement in concrete mix by powdered rubber leads to a reduction in the density of the final product, because the specific gravity of rubber used was less than that of fine aggregates. The addition of powdered rubber to the concrete mix results in a negative effect on the modulus of elasticity. The decrease of elasticity reflects the capability of rubberized concrete to behave in an elastic manner when loaded in tension, thus improving the failure manners of typical concrete.

Mandlik et al., (2013) studied about the EPS concrete. The main aim of this study was to achieve a mix design for Lightweight EPS Concrete with density lesser than 1800kg/m^3 and enough high compressive strength so that it can be used in construction purpose. The study concluded that expanded polystyrene concrete has scope for nonstructural applications, like wall panels, partition walls, etc.

Gawale et al., (2016)developed a new structural light weight concrete by completely replacing coarse aggregate in concrete by expanded polystyrene (EPS) beads. Their findings have shown that the lightweight concrete using EPS beads has a desirable strength to be an alternative construction material for the construction of partition wall, foot path, parapet wall, bed concrete.

Pradhan and Maharjan, (2016) study the effect of expanded polystyrene beads and aggregate ratios in compressive strength and thermal insulation of light weight concrete bricks. Compressive strength, thermal conductivity and density of light weight concrete brick with partial replacement of coarse aggregate by EPS are their major findings.

Poudyal and Jha, (2017) focused on experimental study on the properties of concrete with the partial replacement of sand by rice husk. Workability, compressive strength, bulk density, flexural strength and water absorption of lightweight concrete with partial replacement of sand.

Oyedepo et al.,(2014) investigated the properties of concrete using sawdust as partial replacement for sand. The concrete mix ratio of 1:2:4 was prepared using water/cement of 0.65 with 0%, 25%, 50%, 75% and 100% sawdust as partial replacement for fine sand. Using sawdust in a proportion greater than 25% replacement of sand is detrimental to strength and density properties of concrete.

Cammille A Issa, et alconducted research on recycled crumb rubber as a substitute for fine aggregate in concrete at 0% to 100% replacement to crushed sand in concrete mix. The result of research showed that 25% Replacement of crushed sand gives good compressive strength and by using crumb rubber up to 25% results in 8% decrease in density of concrete and ductilityof concrete increases therefore it is useful in shock resisting element , highway barrier etc. And also damping properties improves.

F pache co- Torgal et al studied the effect on fresh and hardened concrete properties by using polymeric waste like tyre rubber and PET bottles in concrete mix. The research result showed that with increase in rubber content workability (slump) increases, and the properties like compressive strength, split tensile strength, flexural strength and modulus of elasticity decreases. However,the toughness of concrete mix increases with the higher content of tyre rubber.

In another similar research, Ghaly and Cahill carried out experiments with 5%, 10%, and 15% by volume of rubber aggregates in concrete with water and cement ratios of 0.47, 0.54, and 0.61. Around 180 samples were tested for compressive strength. Test results showed that compressive strength reduces for rubber mix concrete by 10-30%. The author suggests that such rubber mix concrete is not suitable for critical building components. However, this can have application in non-load bearing structures androad paving works.

(Ghimire,2018) experiment on the properties of Concrete brick with partial replacement of Sand by Saw Dust and Partial Replacement of Coarse Aggregate by Expanded Polystyrene. The final result of experiment showed that water absorption of prepared M15 and M20 concrete brick samples increased with increase in percentage replacement of sand by saw dust and EPS by coarse aggregate. Compressive strength and Bulk density of prepared M15 and M20 concrete brick sample decreased with increase in percentage content of saw dust and EPS. The result of the experiment show that partial replacement of sand by saw dust and coarse aggregate by EPS in concrete brick sample had sufficient strength as compared to common bricks.

(Bhatta,2019)experiment on properties of concrete brick with complete replacement of sand by Brick Dust Waste and Partial Replacement of Coarse Aggregate by EPS. The final result show that with increased in percentage of EPS, compressive strength of the Brick sample decreased. The result showed that concrete brick made with replacement of sand by BDW and partial replacement of coarse aggregate by EPS had enough compressive strength as compare to common brick. The result obtained from research show that with whole replacement of sand by brick dust and upto 30% partial replacement of coarse aggregate by expanded polystyrene,the concrete brick so produced can be used for masonry unit in construction of building.

2.2 Waste Materials Used

The waste material used in this experimental research is locally available and these include crumb rubber and EPS beads.

2.2.1 Crumb Rubber

The processing of the tire into fine granular or powderedparticles using mechanical or cryogenic processes is known as crumb rubber. During this process, the steel andfabric component of the tires are also removed. Crumb rubber contains particles ranging in size from4.75mm to less than 0.075mm. Generally, three methods are usedto convert scrap tires into crumb rubber. Methods are:

1. Cracker mill process

2. Granular process

3. Micro mill process.

By performing cracker mill process, we can obtain particle sizesranging from 5mm to 0.5mm and are commonly known asground crumb rubber. By performing granular process, we canobtain particle size ranging from 9.5mm to 0.5mm. In the research, crumb rubber is used for the partial replacement process. The specific gravity ofcrumb rubber is about 1.15.

2.2.2 Expanded Polystyrene

Extended polystyrene (EPS) refers to a strong, durable and lightweight thermoplastic product. EPS is usually white and is made of expanded polystyrene beads. EPS is ideal for the packaging and construction industries because of its light weight, strength and excellent thermal insulation properties.

EPS is a solid foam or thermoplastic product that has characteristics such as low weight, insulation properties and durability. The thermal qualities of EPS improve with its strength. Expanded polystyrene has a variety of applications such as for thermal insulation boards in building constructions and packaging products. It is the common choice for electronic goods cushioning and packaging. Manufacturers depend heavily on EPS due to its insulation and shock absorption capacity, as well as its ability to prevent or minimize product damage during the transportation of sophisticated equipment.

Expanded polysterene is easy to install on the construction site. Other than construction and packaging, EPS is also used to make protective crash helmets for sports personnel and others.

EPS is produced through a polymerization process and is a derivative of ethylene and benzene. EPS uses two molding processes:

- Block molding – produces large blocks of EPS that is later cut into shapes or sheets for using packaging and building/construction applications.
- Shape molding – produces parts that are prepared as per custom design; used mainly for the packaging of electronic products.

Expanded Polystyrene is classified as high expansion, medium grade, fast cycling, high ratio flame retardant and low pentane flame retardant (Hangzhou Epsole Technologies Co.,LTD., 2015).

2.3 Concrete Constituents

Concrete is a mixture of cement, fine and coarse aggregates and water, which are mixed in a particular proportion to get a particular strength. The cement and water react together to form a paste, which binds the aggregate particles together. The mixture is then sets into a rock-like solid mass, which has significant compressive strength butless resistance in tension (Agbede&Monash, 2009). However, the construction industry depends heavily on conventional materials such as cement, granite and sand for the manufacturing of concrete. As the infrastructure of the entire world isemerging, the construction industry is in need of large amount of raw materials. As the consumption of raw materials increases the demand increases material (Murali&kumar, 2012). The growing concern of resource exhaustion and global pollution has challenged many researchers and engineers to seek and develop new materials relying on renewable resources. These comprise the use of by-products and waste materials in building construction. Most of these by-products are used as aggregate for the makingaccomplishedfor the making of concrete is the natural sand mined from the riverbeds. But, the accessibility of river sand for the production of concrete is becoming threatened due to the excessive nonscientific methods of mining from the riverbeds, lowering of water table are becoming common treats(Mageswari&Vidivelli, 2010). The worldwide consumption of sand as fine aggregate in concrete production is huge in amount, and many developing countries have encountered some strain in the supply of natural sand in order to accomplished the increasing demand of infrastructural development in recent years (Divatar, et al.,2012). Nevertheless, accumulation of unmanaged wastes especially in developing countries has resulted in an increasing environmental concern. However, the increase in the popularity of using environmental friendly, lightweight construction materials in building industry has brought about the necessity to investigate how this can be achieved by benefiting environment as well as maintaining the material requirements stated in the standards. Thus a large demand has been placed on building material industry especially in the last decade owing to the increasing population that result a prolonged shortage of building materials, (Turgut, 2007).

2.3.1 Cement

Cement is a binding material manufactured with very detailed processes. It has the property of setting and hardening when mixed with water to achieve strength. The cement may be natural or artificial. Natural cement is mass-produced by burning and then crushing natural cement stones, which contain argillaceous and calcareous matter. Artificial cement is made by burning correctly proportioned mixture of argillaceous and calcareous materials at a very high temperature and resulting mixture is grinded to fine powder. Ordinary Portland Cement is generally use in concrete construction and according to IS 4031:1988 the Ordinary Portland Cement has been classified into three grades- 33 grades, 43 grades and 53 grades respectively. The content of cement highly affects the strength and performance of the concrete depending upon the hydration of cement including its chemical and physical properties.

2.3.2 Aggregates

Aggregates are granular materials such as sand, gravel, or crushed stone that, along with water and cement, are an essential ingredient in concrete. Aggregates should be clean, hard, strongand free from chemicals and other fine materials that could cause the deterioration of concrete. Aggregates, are divided into two major categories that are:.

a) Fine aggregates

The material which is passed through 4.75mm size IS test sieve is termed as a fine aggregate. Commonly natural river sand is used as a fine aggregate.

b) Coarse aggregates

The material which is retained on 4.75mm size IS test sieve is termed as a coarse aggregate. Broken stone is usually used as a coarse aggregate.

2.3.3 Water

This is the most important ingredient of concrete. Water used for making concrete should be free from harmful impurities such as oil, alkali, acid,etc. In general, clean water which is fit for drinking should be used for making concrete.

2.4 Laboratory Test

For material test, sieve analysis, normal consistency test, impact value test, compressive strength test is performed. For prepared concrete brick sample compressive strength test, water absorption test and bulk density test is performed.

2.4.1 Grading

In order to determine the particle size distribution of specific aggregates which on plotting gives a grading curve, grading is performed. Gradation is find out by passing the material through a series of sieves stacked with progressively smaller openings from top to bottom and weighing the material retained on each sieve. Particle size distribution shows what sizes of particles are present in what proportions. Sieve analysis is necessary to be performed to obtain grading of aggregate. A set of IS Sieves of sizes – 80mm, 63mm, 50mm, 40mm,31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm,4.75mm, 3.35mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm and 75µm are used as per requirements. Apparatus required for the sieve analysis includes- set of sieves, tightly fitting pan and lid for the sieves, mechanism of shaking sieves, electronic balance, brushes, test data sheet for recording results, and others

2.4.2 Fineness Modulus

Fineness modulus is defined as index to particle size and mathematically obtained by adding the cumulative percentages of aggregate retained on each of the standard sieves used in the experiment and dividing this sum by 100. Fineness modulus is generally used to know howcoarse or fine the aggregate is. Coarser aggregate means higher value of fineness modulus where as small value of fineness modulus refer that the aggregate is finer. Fineness modulus of fine aggregate varies from 2.2 to 3.2 and fineness modulus of coarse aggregate varies from 5.5 to 8.0

2.4.3 Impact Value Test

The degree of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load is known as aggregate impact value. The property of aggregate to resist impact is known as toughness. Aggregate impact value lesser than 10% is exceptionally strong. Impact value (10% - 20%) is strong, (20% -30%) is satisfactory and greater than 35% is weak. (IS 2386- Part IV-1963).

2.4.3 Compressive Strength Test

Compressive strength of a brick is determined by testing the brick under standard conditions by means of a Compression testing machine. The process as mentioned in IS 3495 (Part-2) shall be used to find out the compressive strength of brick. Compressive Strength of bricks is determined in lab by placing brick in compression testing machine. After placing the brick in compression testing machine, load is applied on it until brick breaks. Note down the value of failure load and find out the compressive strength value of brick. The minimum compressive strength for common brick must be 3.5 N/mm^2. If it is less than 3.50 N/mm2, then it is not useful for construction purpose.

2.4.4 Water Absorption Test

The strength of a brick is depended upon its Water Absorption capacity. Water Absorption of Bricks is caused due to the presence of voids in the bricks. The brick will absorb more water if it has more voids reducing the load carrying capacity. So, the bricks are verified to determine their water absorption capacity before using them in construction activities. Water absorption test is conducted by saturating brick sample specimens by immersion in potable water for 24 hours. The brick sample specimens are then allowed to drain for a minute before wiping off visible surface water using a damp cloth. The saturated specimens are then oven-dried at a temperature of 105°C for not less than 24 hours but until a constant dry mass is obtained. Finally, the water absorption is calculated using the following expression:

$$\text{Water Absorption (\%)} = \frac{(M_s - M_d)}{M_d} \times 100$$

Where, Ms and Md are the mass of the saturated and dry concrete brick specimens,respectively.

2.4.5 Bulk Density Test

Bulk Density is defined as the ratio of weight to volume of a substance. Prepared concrete bricksample is kept in the ventilated oven and then sample isdry at a temperature of 105°C to 115° C. Then concrete brick samples are cooled down in roomtemperature and its mass (M) is recorded. After that, dimension of the brick is measuredand volume is calculated. Finally, bulk density is calculated using the followingexpression: Bulk Density = Weight/Volume

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Research Design

A research design is a structure that has been created to find answers to research question. All the research carried out here is centered on laboratory experimentation so the research method adopted can be consideredas the experimental study.

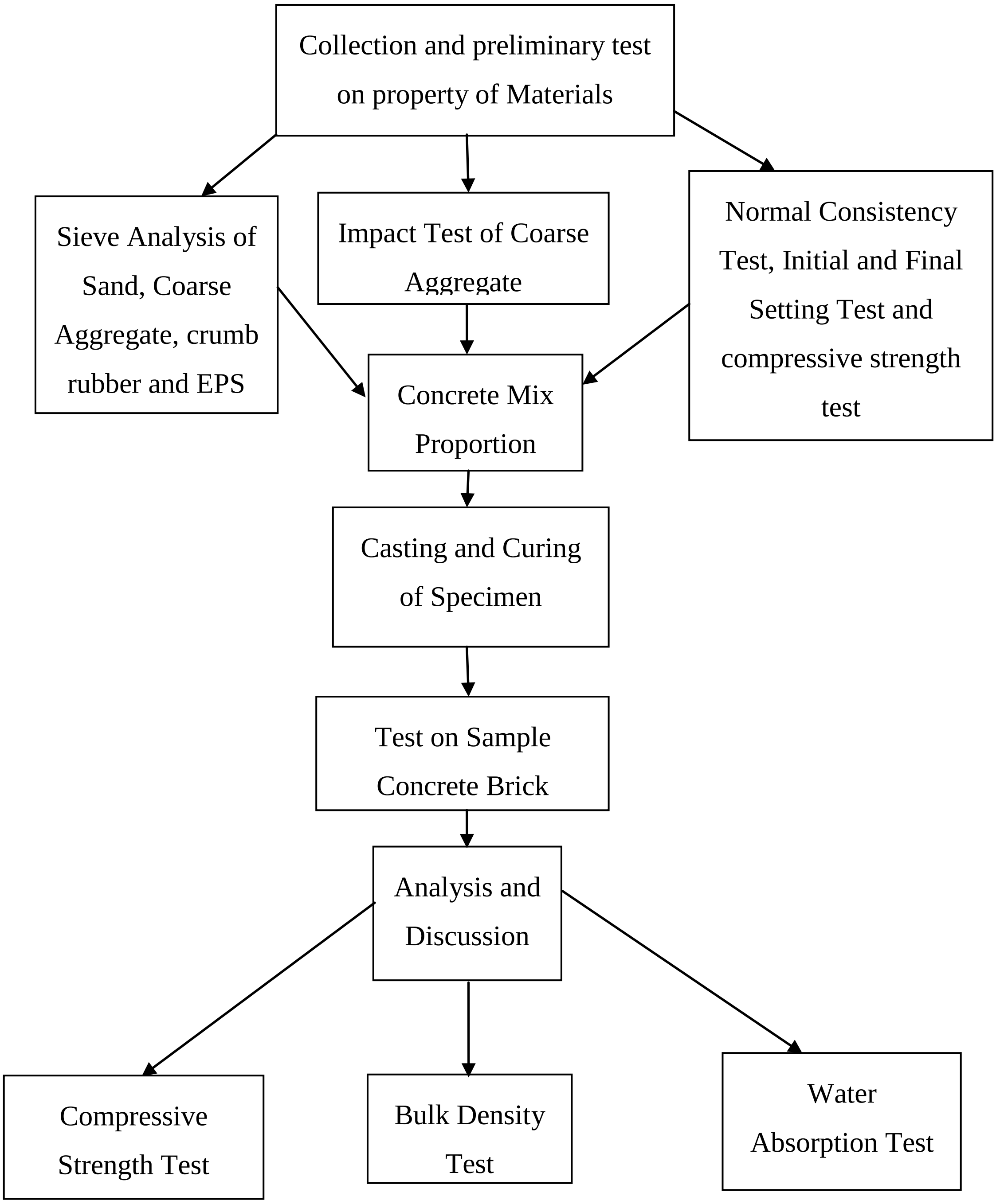

Figure 1: Methodological Framework

3.2 Material Collection

Following materials were used in this research work:

- OPC cement
- Sand
- Coarse aggregates
- EPS
- Crumb rubber and
- Water

Figure 1shows the material used in this research work.

Figure 1 Cement, Coarse aggregate, EPS, Sand, Crumb Rubber

Following equipment/machines available in Central Material Testing Lab in Instituteof Engineering, Pulchowk Campus were used for the experimental works:

☐ Sieve sets as per Indian Standard

☐ Sieve Shaking Machine

☐ Volumetric Flask

☐ Vicat Apparatus

☐ Buckets

☐ 240*115*57 mm brick moulds

☐ Curing tank

☐ Electronic Balance

☐ Compressive Strength Testing Machine

☐ Others

Figure 2 Sieve sets as per IS standard, sieve shaking machine and compressive strength testing machine

3.3 Physical Properties of Materials

3.3.1 Properties of Cement

OPC cementwas used for the experimental works. The following properties were testedand determined as mentioned below.

i) Normal Consistency Test

Vicat's apparatus with 10mm diameter plunger was used to determine the normalconsistency of cement pastes which on penetration about 33-35mm of cement paste fromtop gives the percentage of water essential to make a standard paste of cement.

ii) Initial and Final Setting Time

Vicat's apparatus was used to determine the initial and final setting time. Cement paste was made and kept in vicat'smould. The square needle of cross section 1mm X 1mmwas attached to movable rod of vicat's apparatus. The needle was allowed to quicklyrelease and allowed to penetrate in the cement paste. In initial stage, the needle penetratedcompletely. It was then taken out and dropped at a fresh place. The test procedure wasrepeated at regular intervals till the needle didn't penetrate completely. The time at which water was added to make cement paste to elapsed time at which 1mm X 1mm squareneedle penetrate 5mm measured from bottom of test specimen was noted .This time interval between the addition of water to cement and stage at which the needle stop topenetrate 5mm measured from bottom was termed as initial setting time.Annular collar was used instead of square needle to find final setting time. The annularcollar was attached to the movable rod of Vicat's apparatus. The annular collar wasgently released and the time at which annular collar didn't make an impression in testspecimen was noted. The time interval between additions of water to cement and stage atwhich annular collar impression was not found in test specimen was considered as finalsetting time of cement.

iii) Compressive Strength Test

Nine cubes of size 70mm*70mm*70mm were prepared with 1:3 cement and sand mortar according to IS 4031-Part 6. Prepared sample of cubes were cured for 3 days, 7 days and 28 days in curing tank. Then compressive strength of three cubes was determined with the help of compression testing machine at 3 days, 7 days and 28 days ofcuring.

3.3.2 Properties of Sand

Well washed and dried sand was used for the study. Various physicaland mechanical properties of sand were determined as discussed below:

i) Particle Size Distribution (Grading)

According to IS 2386 (Part I)-1963, the sieve of various opening sizes 4.75mm, 2.36mm, 1.18mm, 0.60mm, 0.30mm, 0.15mm and 0.075mm were used in sieve analysis of fine aggregates. Sample weighing 530gm was sieved for the period of 15 minutes in ashaking machine and the weight retained on each sieve was determined.

From the percentage finer obtained, the maximum nominal size of sand was found out.

ii) Fineness Modulus

Fineness modulus is defined as index to particle size and mathematically obtained by adding the cumulative percentages of aggregate retained on each of the standard sieves used in the experiment and dividing this sum by 100. Fineness modulus is usually used to get an idea of how coarse or fine the aggregate is. More fineness modulus value denotes that the aggregate is coarser and smaller value of fineness modulus denotes that the aggregate is finer. Fineness modulus of fine aggregate varies from 2.2 to 3.2 and fineness modulus of coarse aggregate varies from 5.5 to 8.0

3.3.3 Properties of Coarse Aggregates

The coarse aggregate of nominal size 12.5mm were considered for the experimental works. The mechanical and physical properties of coarse aggregate will be determined byParticle Size Distribution (Grading) and Impact test as discussed below:

i) Particle Size Distribution (Grading)

According to IS 2386 (Part I)-1963, the sieve of various opening sizes 20mm, 16mm,12.50mm, 10mm, 4.75mm were used in the sieve analysis of coarse aggregates. Sampleweighing about 5 kg was sieved for the period of 15 minutes in a shaking machine andthe weight retained on each sieve was determined.

ii) Impact Test of coarse Aggregate

Impact tests are performed to study the toughness of material. For the impact test of coarse aggregate three sample weighing 500 gm was taken.

Procedure

1. Coarse aggregate was sieved through 12.5 mm and 10.0mm IS sieves. Theaggregates passing through 12.5mm sieve and retained on 10.0mm sieve was taken as the test material.
2. 500 gm of coarse aggregate retained on 10.0mm sieve was taken on cup as a sample.
3. Impact machine was kept on floor in such a way that hammer guide column was vertical.

4. The cup was fixed firmly in position on the base of machine and hammer was raised until its lower face was 380mm above the surface of aggregate sample in the cup and allowed to free fall on aggregate sample for 15 times.
5. Crushed aggregate was removed from the cup and sieved through 2.36 mm ISsieve and retained weight of aggregate was weighted.
6. Impact value was calculated.

3.3.4 Properties of crumb rubber

Various mechanical and physical properties of crumb rubber were determined as described below:

i) Particle Size Distribution (Grading) of crumb rubber

According to IS 2386 (Part I)-1963, the sieve of various opening sizes 4.75mm, 2.36mm,1.18mm, 0.60mm, 0.30mm, 0.15mm and 0.075mm will be used in sieve analysisof fine aggregates. Sample weighing 200 gm was sieved for the period of 15 minutes in a shaking machine and the weight retained on each sieve was determined. The percentage finer was then obtained to find out the maximum nominal size of crumb rubber.

3.3.5 Particle Size Distribution of Expanded Polystyrene

Medium grade Electronic packaging Expanded Polystyrene beads was used in concrete mix. Electronic packaging Expanded Polystyrene were broken down into small pieces and sieve analysis of these expanded polystyrene beads was done. According to IS 2386 (Part I)-1963, the sieve of various opening sizes 20mm, 16mm, 12.50mm, 10mm, 4.75mm were used in the sieve analysis of coarse aggregates.Sample weighing about 200gm was sieved for the period of 15 minutes in a shaking machine and the weightretained on each sieve was determined.

3.4 Sample Preparation

The dimension of common standard brick found in Nepal is 240 mm x 115 mm x 57 mm. So, six moulds of same dimension were prepared for sample production in order to compare their properties with brick practice in Nepal. Various samples of M15 and M20 grade concrete brick were made by partial replacement of sand by crumb rubber and coarse aggregate by EPS.Volume batching was used for the mix.

Figure 3 Wood moulds (240 mm x 115mm x 57mm) and batched materials

Three samples for each sample type A, B, C and D were made for M15 grade concrete brick. Thus, in total twelve samples were made for M15 grade concrete brick. Sample type A was considered as control sample of M15 grade whereas sample type B, C, D were made by replacing 10%, 20% and 30% of sand by crumb rubber and coarse aggregate by EPS respectively. Calculation for different mix proportion of M20 grade is given in Table C1of annex C.

Figure 4 concrete mix in the mould

Table 1 shows the variouscompositions of M15 grade concrete bricks for sample type A, B, C and D.

Table 1 Composition of various M15 grade brick samples

Cement:(Sand and crumb rubber): (Coarse aggregate and EPS)	Sand Replacement by coarse Aggregate (%)	Coarse Aggregate Replacement by EPS (%)	Sample Type	Sample
1:2:4 (By Volume)	0	0	A	A1
				A2
				A3
	10	10	B	B1
				B2
				B3
	20	20	C	C1
				C2
				C3
	30	30	D	D1
				D2
				D3

Three samples for each sample type E, F, G and H were made for M20 grade concrete brick. Thus, in total twelve samples were made for M20 grade concrete brick. Sample type E was considered as control sample of M20 grade whereas sample type B, C, D were made by replacing 10%, 20% and 30% of sand by crumb rubber and coarse aggregate by EPS respectively. Calculation for different mix proportion of M20 grade is given in Table C2of annex C.

Table 2 shows the various compositions of M20 grade concrete bricks for sample typeE, F, G and H.

Table 2 Composition of various M20 grade brick samples

Cement:(Sand and crumb rubber): (Coarse aggregate and EPS)	Sand Replacement by coarse Aggregate (%)	Coarse Aggregate Replacement by EPS (%)	Sample Type	Sample
1:1.5:3 (By Volume)	0	0	E	E1
				E2
				E3
	10	10	F	F1
				F2
				F3
	20	20	G	G1
				G2
				G3
	30	30	H	H1
				H2
				H3

Thus, all together 24 concrete brick samples were prepared in the laboratory for the research.

3.5 Concrete Mix Proportion

Correct concrete mixing ratio is necessary to produce a strong, durable concrete mix. The four basic materials required to make concrete block are cement, fine aggregate, coarse aggregate and water. Although various grade of concrete can be prepared by varying the ratio of coarse aggregate, fine aggregate and cement, only M15 and M20 grade concrete has been considered in this research work.

The ratio of cement, fine aggregate and coarse aggregate for M15 grade of concrete is 1:2:4 i.e. one part of cement, two part of fine aggregate and four part of coarse aggregate. Similarly, the ratio of cement, fine aggregate and coarse aggregate for M20 grade of concrete is 1:1.5:3 i.e. one part of cement, one and half part of fine aggregate and three part of coarse aggregate. In all type of mix both fine and coarse aggregate was replaced by 0%, 10%, 20% and 30% crumb rubber and EPS respectively. Different proportions of cement, sand, coarse aggregate, crumb rubber and EPS for M15 and M20 gre20 grade along with the composition of different type of sample are shown in table C1 and C2 of appendix C.

All the 24 samples (A, B, C, D, E, F, G, H) ready for compressive strength test after curing are shown in figure 7 below.

Figure 5 Prepared and cured dry 24 sample (A, B, , D, E,F, G, H) ready for compressive strength test

3.6) Experimental Test

Compressive strength test, Water absorption test and bulk density test were carried out on the prepared sample to determine its properties.

3.6.1) Compressive Strength Test

Compressive Testing Machine was used to determine the compressive strength of the concrete brick sample. The test was performed after 28 days of curing. The test was performed at Central Material Testing Lab of Institute of Engineering, Pulchowk Campus. IS 3495-Part II was considered for the procedure to test compressive strength of brick.

Compressive strength value for different proportion of mixes of concrete brick samples of M15 and M20 grade shown in Table B1 and B2 of Appendix B respectively.

Procedure:

1. The samples prepared were cured for 28 days before performing the compressive strength test.
2. The sample was placed between two 3 mm metal sheets and centered between plates of the compressive testing machine.
3. Load was applied uniformly till the failure of the sample occurred.
4. Breaking load was noted when the crack was seen on the test specimen.

3.6.2) Water Absorption Test

Electric oven was used to perform the water absorption test. The test was performed after 28 days of curing of concrete brick samples.

Procedure:

1. Samples of concrete bricks were stored in the oven for 24 hours, during which a constant temperature of 105°C was maintained.
2. Weight of each brick was noted after cooling the samples in room temperature.
3. All the sample bricks were immersed in the water tank at room temperature for aperiod of 24 hours.
4. Brick samples were extracted from the water tank and wiped all over with a dry cloth and all brick samples were weighed.

5. Percentage of Water Absorption is calculated as shown in Table B3 and Table B4 of Appendix B.

Water absorption percentage was calculated by using the formula:

$$\text{Water absorption percentage} = \frac{\text{Saturated weight of cured brick} - \text{weight of dry brick}}{\text{weight of dry brick}} \times 100\%$$

3.6.3) Bulk Density Test

Bulk density is determined by using the formula:

$$\text{Bulk Density} = \frac{\text{Weight of concrete brick samples}}{\text{Volume of concrete brick samples}}$$

The bulk densityof various concrete brick samples for grade M15 and M20 is shown in Table B5 and Table B6 of Appendix B respectively.

Procedure:

1. Concrete brick sample was stored in the ventilated oven.
2. It was then dried it at a temperature of 105°C.
3. The mass of brick sample were recorded after cooling them in room temperature.
4. The dimension of the brick was measured.
5. Then, the volume of the samples taken were calculated.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Properties of material used

Various experiments were performed in the lab to determine the physical and mechanical properties of constituent materials used in the preparation of concrete brick sample. The important properties of the constituent materials obtained in the lab are discussed below:

4.1.1 Properties of Cement

The properties of cement determined in lab are:

Normal Consistency of cement

The normal consistency of cement used was found to be 28%.Generally, the normal consistency for OPC rangesfrom 26 to 33% (IS, 1998). The results of normal consistency test observed on lab are shown in Table A1 of Appendix A.

Initial Setting Time and Final Setting Time of cement

The initial setting time of cement used for the experiment was found to be 120 minutes whereas the final setting time was obtained as 290 minutes. The result of initial and final setting time of cement are shown in Table A2 of Appendix A. According to IS 8112:1989, the initial setting time should not be less than 60 minutes and final setting time should not be more than 600 minutes. Thus, the observed values were within the requirements of IS 8112: 1989.

Compressive Strength of cement

The average compressive strength of three cement cubes at 3 days, 7 days and 28 days of curing were obtained as 19.6 N/mm^2, 30.1 N/mm^2 and 39.5 N/mm^2 respectively. The results of compressive strength test are shown in Table A3 of Appendix A.

Particle Size Distribution of sand

Particle size distribution of sand, coarse aggregate, crumb rubber and EPS were performed using Sieve analysis. The nominal maximum size of sand was found to be

2.36 mm. Sieve analysis of sand is shown in Table A4 of Appendix A. The particle size distribution curve for sand is shown in figure 6.

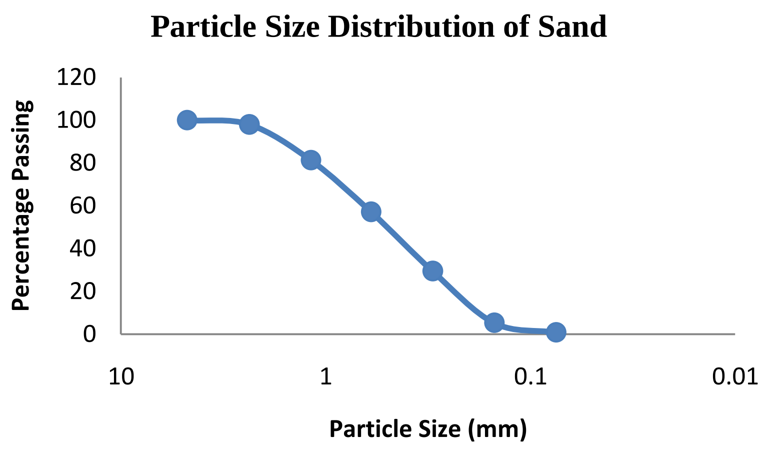

Figure 6 Particle size distribution of sand

From the Table A4 of Appendix A, the fineness modulus was found to be 2.29, which means the average size of particle of given fine aggregate sample was between 0.3mm to0.6mm. And from the result of sieve analysis, the fine aggregate falls into category ofGrading Zone II according to the clause 4.3 of IS 383:1970.

4.1.2 Properties of Coarse Aggregate

Particle Size Distribution of Coarse Aggregate

The nominal maximum size of coarse aggregate was found to be 12.5mm. The sieve analysis of coarse aggregate is shown in Table A5 of Appendix A. The particle size distribution curve for coarse aggregate is shown in figure 7 below.

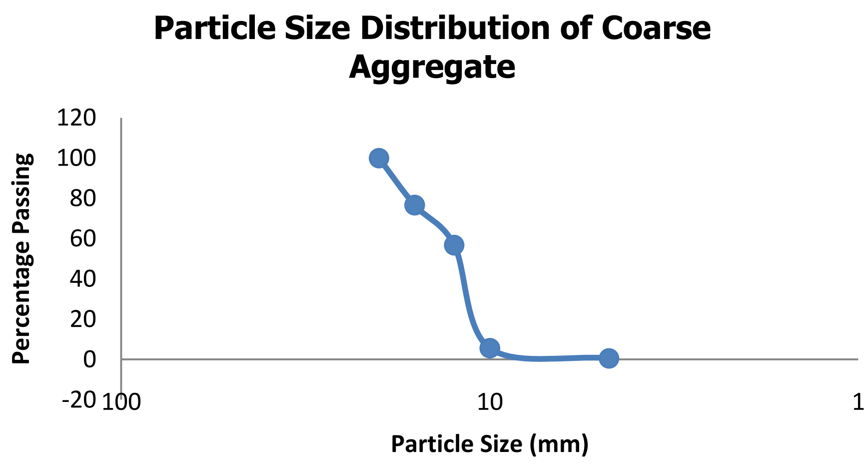

Figure 7 Particle size distribution of coarse aggregate

Impact Value of Coarse Aggregate

The impact value of coarse aggregate was obtained as 17.06%. The result of impact value test of coarse aggregate is shown in Table A6 of Appendix A.

Properties of Crumb Rubber

The nominal maximum size of crumb rubber was found to be 2.36 mm. Sieve analysis of crumb rubber is shown in Table A7 of Appendix A. The particle size distribution curve for crumb rubber is shown in figure 8 below.

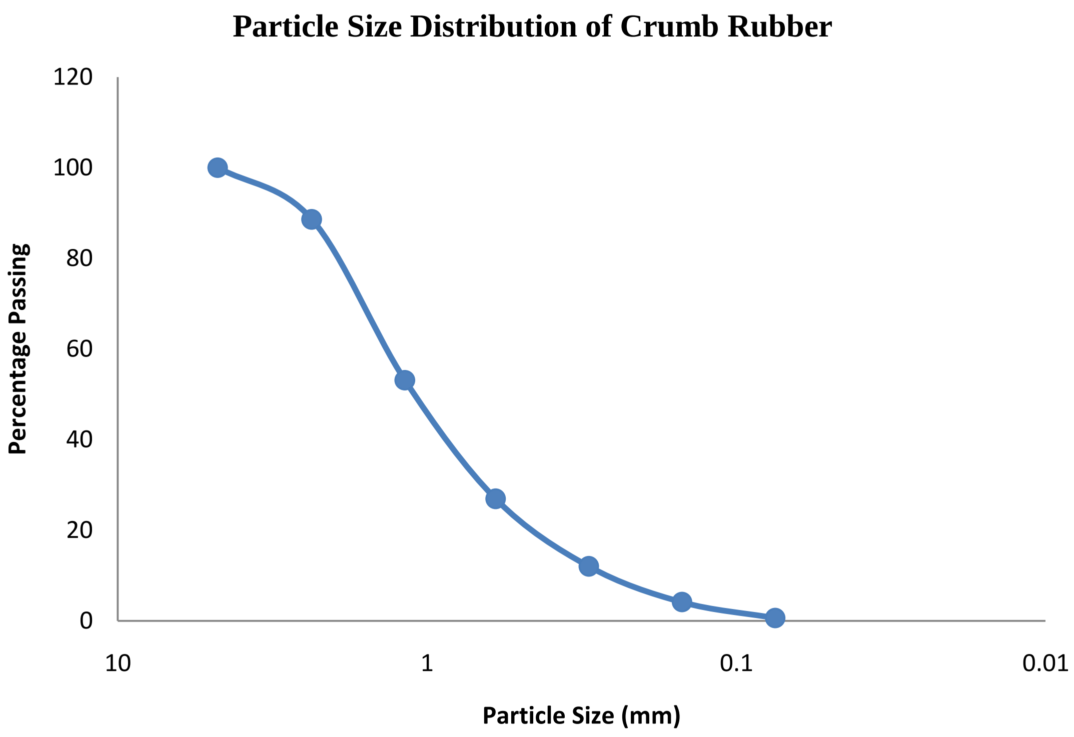

Figure 8 Particle size distribution of Crumb Rubber

From the Table A7 of Appendix A, the fineness modulus was found to be 3.15, whichmeans the average size of particle of given fine aggregate sample was between 0.3mm to0.6mm. And from the result of sieve analysis, the fine aggregate falls into category ofGrading Zone II according to the clause 4.3 of IS 383:1970.

Properties of EPS

The nominal maximum size of EPS used for preparing concrete brick sample was obtained as 4.75mm. The sieve analysis of EPS is shown in Table A8 of Appendix A.The particle size distribution curve for crumb rubber is shown in figure 9 below.

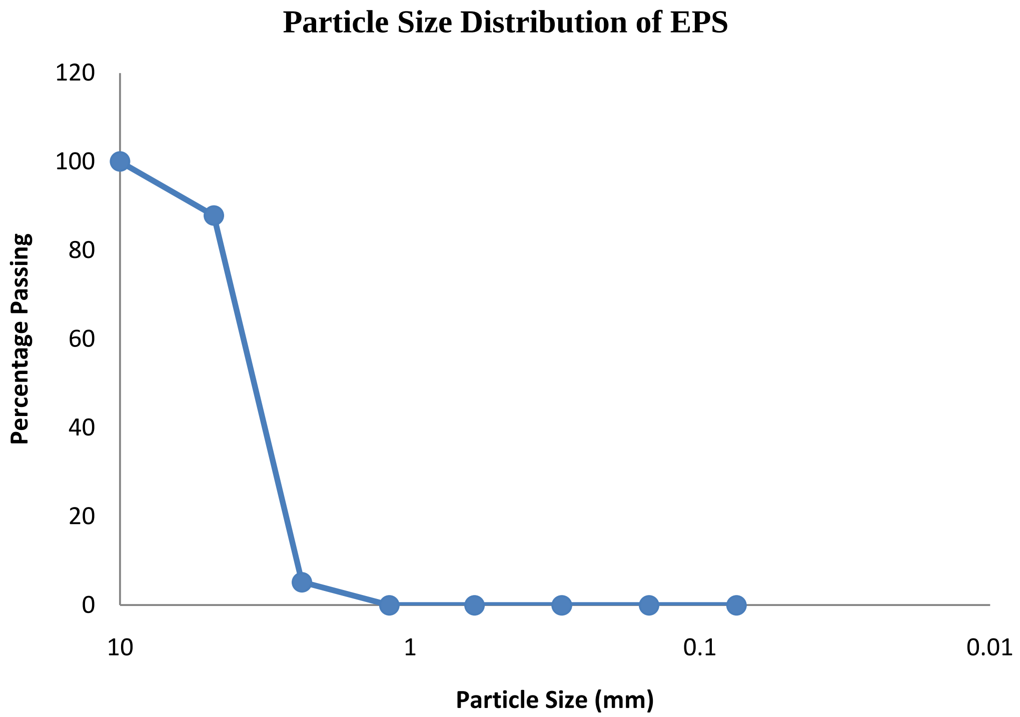

Figure 9 Particle size distribution of EPS

4.2 Compressive Strength

The result obtained from compressive strength test for all concrete brick sample of different proportion of crumb rubber and EPS after 28 days of curing for M15 grade is shown in Table 3.

The average compressive strength for M15 grade concrete brick sample type A, B, C and D were obtained as 19.08 N/mm^2, 16.85 N/mm^2, 13.24 N/mm^2, and 9.41 N/mm^2 respectively.

Table 3 Compressive Strength of Concrete Brick Sample of M15 Grade

Sample Type	Sample	SandReplacement by Saw Dust (%)	Coarse Aggregate Replacement by EPS (%)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
A	A1	0	0	19.01	19.08± 0.27
	A2	0	0	19.38	
	A3	0	0	18.85	
B	B1	10	10	17.02	16.85± 0.14
	B2	10	10	16.80	
	B3	10	10	16.75	
C	C1	20	20	13.50	13.24± 0.27
	C2	20	20	13.28	
	C3	20	20	12.95	
D	D1	30	30	9.42	9.41± 0.36
	D2	30	30	9.78	
	D3	30	30	9.05	

Three samples of concrete brick were made for each of M15 grade concrete brick. All the three samples were tested in compressive testing machine individually to find their compressive strength. Then, their mean value was calculated to obtain the average compressive strength. The graph of average compressive strength at different percentage of EPS and crumb rubber is shown below in figure 10.

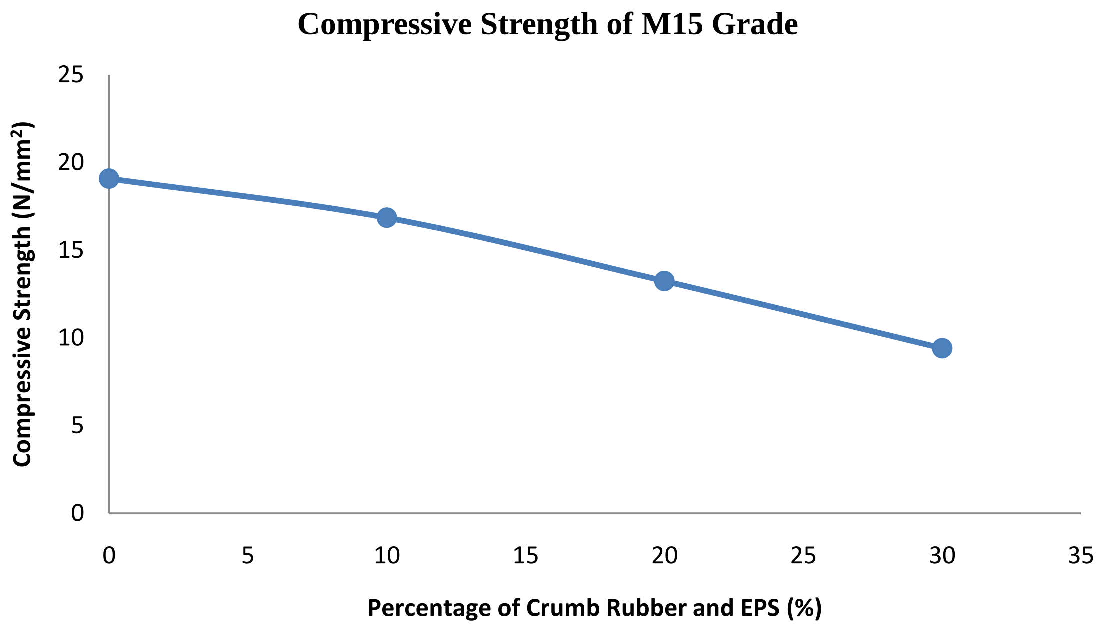

Figure 10 Variation of Compressive Strength of M15 Grade Concrete containing different percentage of crumb rubber and EPS

From the graph shown in figure 3, it was observed that the compressive strength decreased with the increase in percentage of crumb rubber and EPS in the mix. The compressive strength of sample type A, B, C and D was found to be in decreasing order. The compressive strength was maximum for the control sample i.e. sample A.However, compressive strength of all the prepared samples was greater than the minimum compressive strength requirement of brick for construction of load bearing wall according to NS code. According to Nepal National Building Code 109:1994, Minimum compressive strength of Brick for load bearing construction in Nepal is 3.5 N/mm^2. (NS, 1994)

The result obtained from compressive strength test for all concrete brick sample of different proportion of crumb rubber and EPS after 28 days of curing for M20 grade is shown in Table 4.

The average compressive strength for M20 grade concrete brick sample type E, F, G and H were obtained as 26.08 N/mm^2, 18.05 N/mm^2, 15.45 N/mm^2, and 13.76 N/mm^2 respectively.

Table 4Compressive Strength of Concrete Brick Sample of M20 Grade

Sample Type	Sample	SandReplacement by Saw Dust (%)	Coarse Aggregate Replacement by EPS (%)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
E	E1	0	0	25.36	26.08± 0.72
	E2	0	0	26.08	
	E3	0	0	26.81	
F	F1	10	10	18.47	18.05±0.57
	F2	10	10	18.28	
	F3	10	10	17.40	
G	G1	20	20	15.21	15.45±1.11
	G2	20	20	16.67	
	G3	20	20	14.49	
H	H1	30	30	14.49	13.76±0.65
	H2	30	30	13.60	
	H3	30	30	13.21	

Three samples of concrete brick were made for each of M20 grade concrete brick. All the three samples were tested in compressive testing machine individually to find their compressive strength. Then, their mean value was calculated to obtain the average compressive strength. The graph of average compressive strength at different percentage of EPS and crumb rubber is shown below in figure 11.

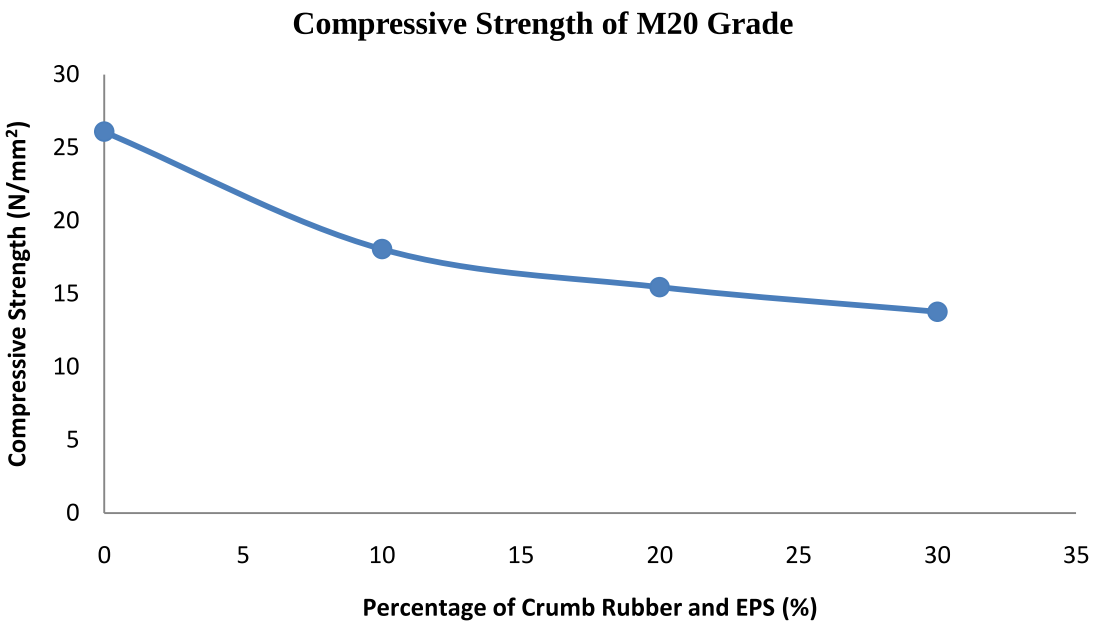

Figure 11Variation of Compressive Strength of M20 Grade Concrete containing different percentage of crumb rubber and EPS

From the graph shown in figure 4, it was observed that the compressive strength of prepared concrete blocks decreased with the increase in percentage of crumb rubber and EPS in the mix. However, the average compressive strength of all the prepared samples was greater than the minimum compressive strength requirement of brick for construction of load bearing wall according to NS code.

4.3 Water Absorption

The result obtained from water absorption test for various test samples of M15 grade is shown in Table 5. The average water absorption of sample type A, B, C and D were found to be 2.63%, 2.97%, 3.24% and 3.56% respectively.

Table 5 Water Absorption Percentage of Sample for M15 Grade

Sample Type	Sample	Sand Replacement by Crumb Rubber (%)	Coarse Aggregate Replacement by EPS (%)	Water Absorption (%)	Average Water Absorption (%)
A	A1	0	0	2.63	2.65±0.14
	A2	0	0	2.53	
	A3	0	0	2.81	
B	B1	10	10	3.10	2.97±0.13
	B2	10	10	2.98	
	B3	10	10	2.84	
C	C1	20	20	3.34	3.24±0.24
	C2	20	20	2.97	
	C3	20	20	3.43	
D	D1	30	30	3.42	3.56±0.17
	D2	30	30	3.52	
	D3	30	30	3.75	

Figure 12, shows the graph of water absorption value of M15 grade concrete brick at different percentage crumb rubber and EPS.

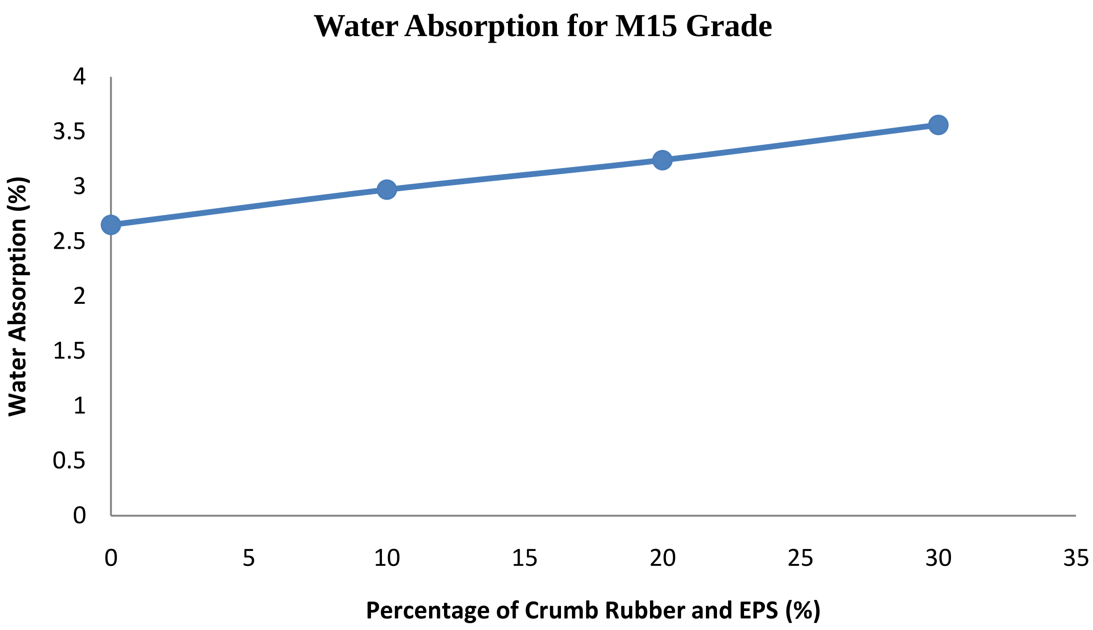

Figure 12 Variation of Water Absorption of M15 grade Concrete containing different percentage of Crumb rubber and EPS

Average value of water absorption of three concrete brick sample type A, B, C and Dwere plotted against percentage replacement of sand and coarse aggregate with crumb rubber and EPS respectively.From the above graph, it was observed that water absorption value of M15 grade concrete brick sample increased with increase in percentage replacement of sand and coarse aggregate by crumb rubber and EPS respectively. The water absorption value of concrete brick sample prepared was found less than common brick.

Similarly, the result obtained from water absorption test for various test samples of M20 grade is shown in Table 6. The average water absorption of sample type E, F, G and H were found to be 2.31%, 2.47%, 2.67% and 2.71% respectively.

Table 6 Water Absorption Percentage of Sample for M20 Grade

Sample Type	Sample	Sand Replacement by Crumb Rubber (%)	Coarse Aggregate Replacement by EPS (%)	Water Absorption (%)	Average Water Absorption (%)
E	E1	0	0	2.37	2.31±0.19
	E2	0	0	2.47	
	E3	0	0	2.10	
F	F1	10	10	2.24	2.47±0.16
	F2	10	10	2.56	
	F3	10	10	2.36	
G	G1	20	20	2.89	2.67±0.18
	G2	20	20	2.52	
	G3	20	20	2.67	
H	H1	30	30	2.52	2.71±0.18
	H2	30	30	2.87	
	H3	30	30	2.76	

Figure 13, shows the graph of water absorption value of M20 grade concrete brick at different percentage crumb rubber and EPS.

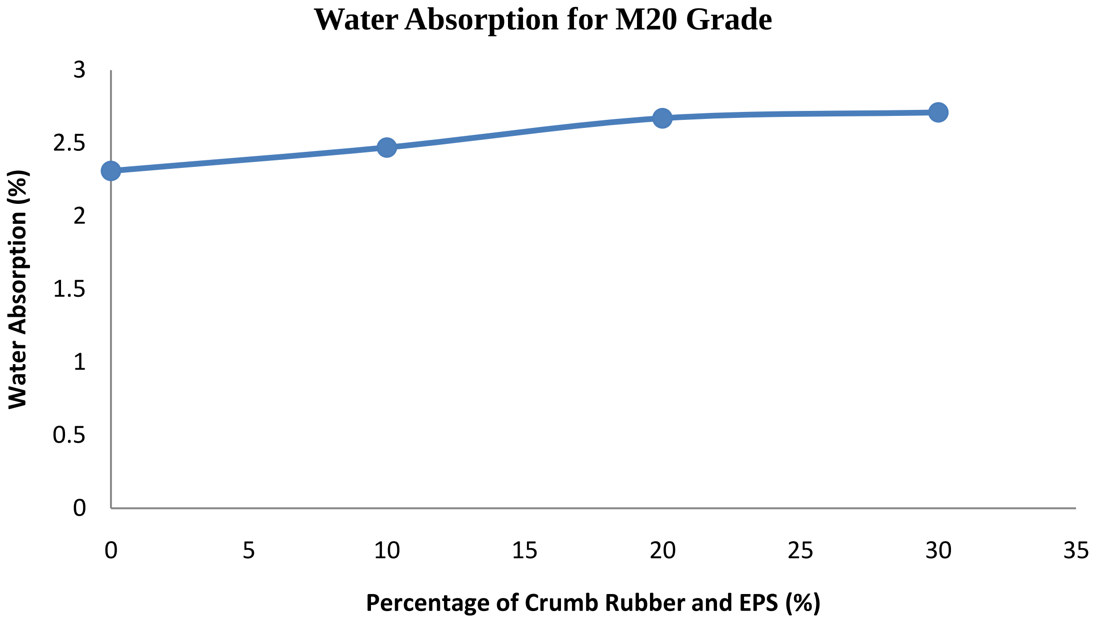

Figure 13 Variation of Water Absorption of M20 grade Concrete containing different percentage of Crumb rubber and EPS

Average value of water absorption of three concrete brick sample type E, F, G and H were plotted against percentage replacement of sand and coarse aggregate with crumb rubber and EPS respectively.From the above graph, it was observed that water absorption value of M20 grade concrete brick sample increased with increase in percentage replacement of sand and coarse aggregate by crumb rubber and EPS respectively. The water absorption value of concrete brick sample prepared was found less than common brick. Hence the prepared brick samples are suitable to use as they have low water absorption value.

4.4 Bulk Density

Table 7 shows the bulk density for M15 grade concrete brick sample. The average bulk density of sample type A, B, C and D were obtained as were 24 KN/m^3, 22.73 KN/m^3, 21.14 KN/m^3, and 20.09 KN/m^{3}respectively.

Table 7The Bulk Density of Sample for M15 Grade

Sample Type	Sample	Sand Replacement by Crumb Rubber (%)	Coarse Aggregate Replacement by EPS (%)	Bulk Density (KN/m^3)	Average Bulk Density (KN/m^3)
A	A1	0	0	24.47	24.36±0.11
	A2	0	0	24.25	
	A3	0	0	24.38	
B	B1	10	10	22.99	22.56±0.59
	B2	10	10	21.89	
	B3	10	10	22.80	
C	C1	20	20	21.71	21.63±0.08
	C2	20	20	21.64	
	C3	20	20	21.54	
D	D1	30	30	20.27	20.3±1.19
	D2	30	30	21.54	
	D3	30	30	19.16	

Figure 14, shows the graph of bulk density value of M15 grade concrete brick at different percentage crumb rubber and EPS.

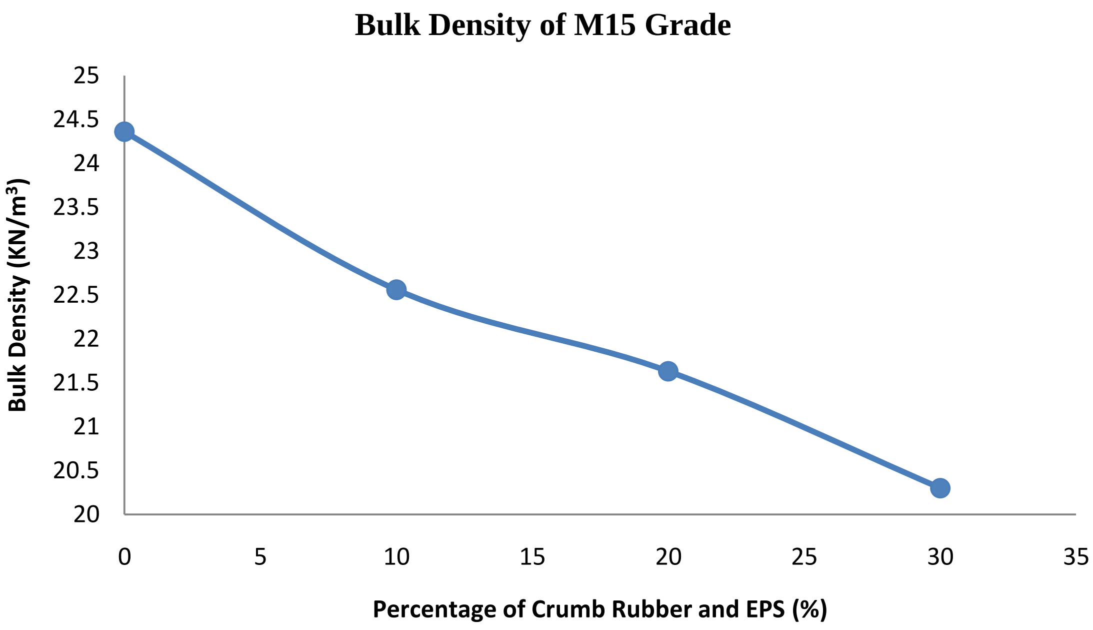

Figure 14 Variation of Bulk Density of M15 grade Concrete containing different percentage of crumb rubber and EPS

Average value of bulk density of three concrete brick sample type A, B, C and D were plotted against percentage replacement of sand and coarse aggregate with crumb rubber and EPS respectively.From the above graph, it was observed that bulk density of M15 grade concrete brick sample decreased with increase in percentage replacement of sand and coarse aggregate by crumb rubber and EPS respectively.

Similarly, Table 8 shows the bulk density for M20 grade concrete brick sample. The average bulk density of sample type E, F, G and H were obtained as were 24.23 KN/m^3, 23.90 KN/m^3, 21.14 KN/m^3, and 20.09 KN/m^3respectively.

Table 8The Bulk Density of Sample for M20 Grade

Sample Type	Sample	Sand Replacement by Crumb Rubber (%)	Coarse Aggregate Replacement by EPS (%)	Bulk Density (KN/m^3)	Average Bulk Density (KN/m^3)
E	E1	0	0	24.06	24.23±0.19
	E2	0	0	24.44	
	E3	0	0	24.18	
F	F1	10	10	24.06	23.90±0.30
	F2	10	10	23.55	
	F3	10	10	24.09	
G	G1	20	20	23.14	22.61±0.53
	G2	20	20	22.62	
	G3	20	20	22.08	
H	H1	30	30	21.35	21.21±0.16
	H2	30	30	21.03	
	H3	30	30	21.25	

Figure 15, shows the graph of bulk density value of M20 grade concrete brick at different percentage crumb rubber and EPS.

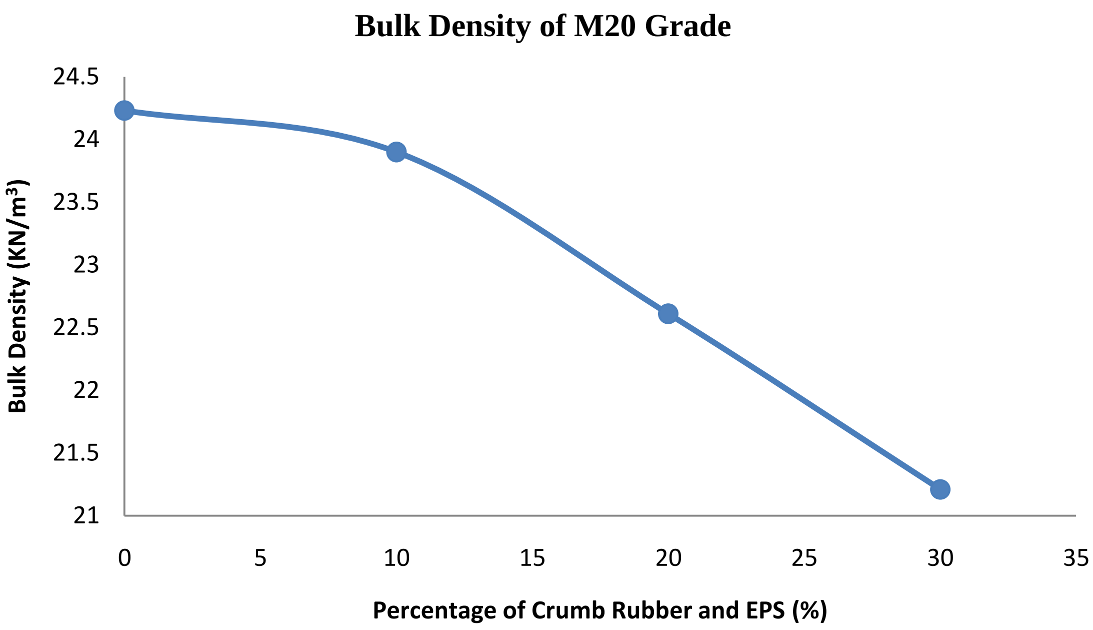

Figure 15 Variation of Bulk Density of M20 grade Concrete containing different percentage of crumb rubber and EPS

Average value of bulk density of three concrete brick sample type E, F, G and H were plotted against percentage replacement of sand and coarse aggregate with crumb rubber and EPS respectively.From the above graph, it was observed that bulk density of M20 grade concrete brick sample decreased with increase in percentage replacement of sand and coarse aggregate by crumb rubber and EPS respectively.

Thus, from the above analysis it was concluded that the concrete brick produced by partially replacing sand by crumb rubber and coarse aggregate by EPS results a concrete brick sample lighter in weight compared to that of control sample.

4.5 Variation of compressive strength with bulk density

Figure 16 shows the graph between Compressive strength and bulk density of M15 grade sample. The graph shows that the compressive strength of concrete brick sample increases with increase in bulk density.

Variation for M15 Grade concrete brick

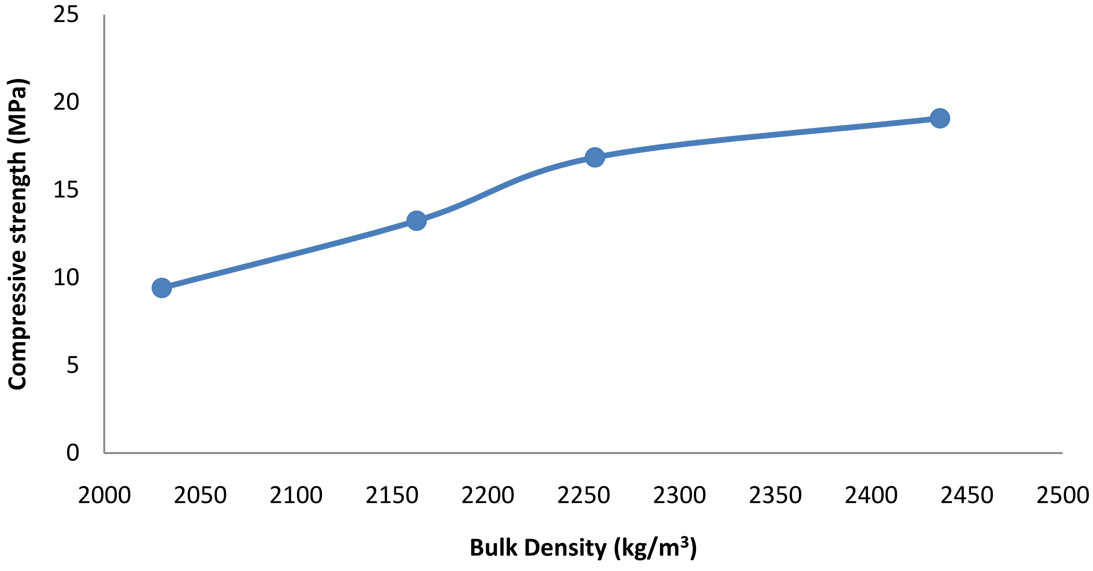

Figure 16 Variation of Compressive strength with bulk density of M15 grade sample

Average value of compressive strength and bulk density of M15 grade concrete bricksample type A, B, C and D were plotted. Henced, the result obtained shows that compressive strength is directly proportional to bulk density.

Variation for M20 Grade concrete brick

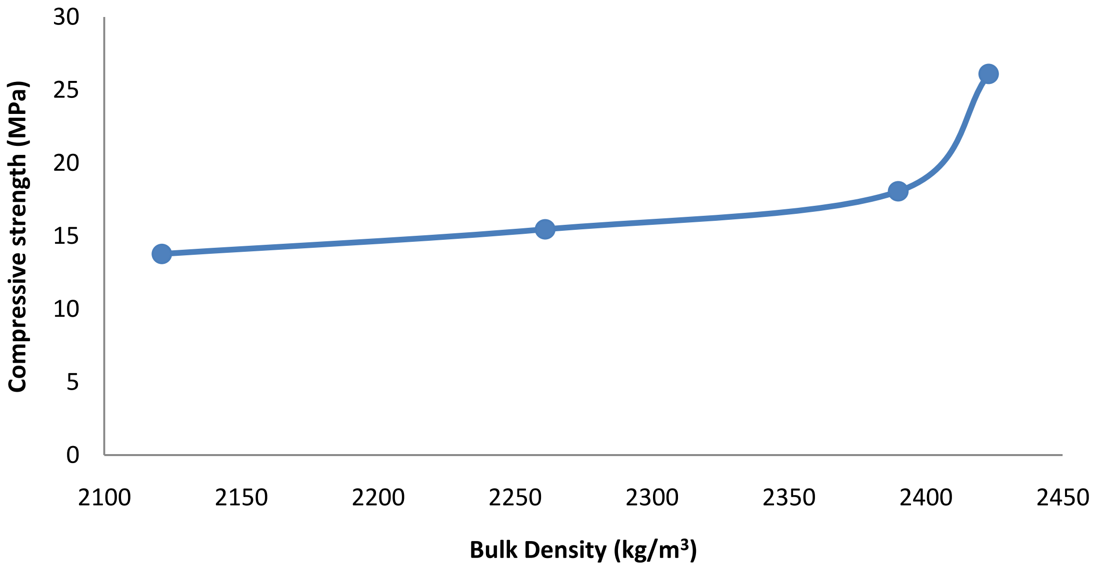

Figure 17 Variation of Compressive strength with bulk density of M20 grade sample

The graph of figure 17 shows that compressive strength increases with increases in value of bulk density.

4.6 Variation of compressive strength with water absorption

Figure 18 shows the relation between average value of compressive strength and water absorption for M15 grade concrete brick. The graph was plotted from the experimental results obtained for the sample type A, B, C and D. Thus, the result obtained shows that compressive strength decreased with increased in water absorption value.

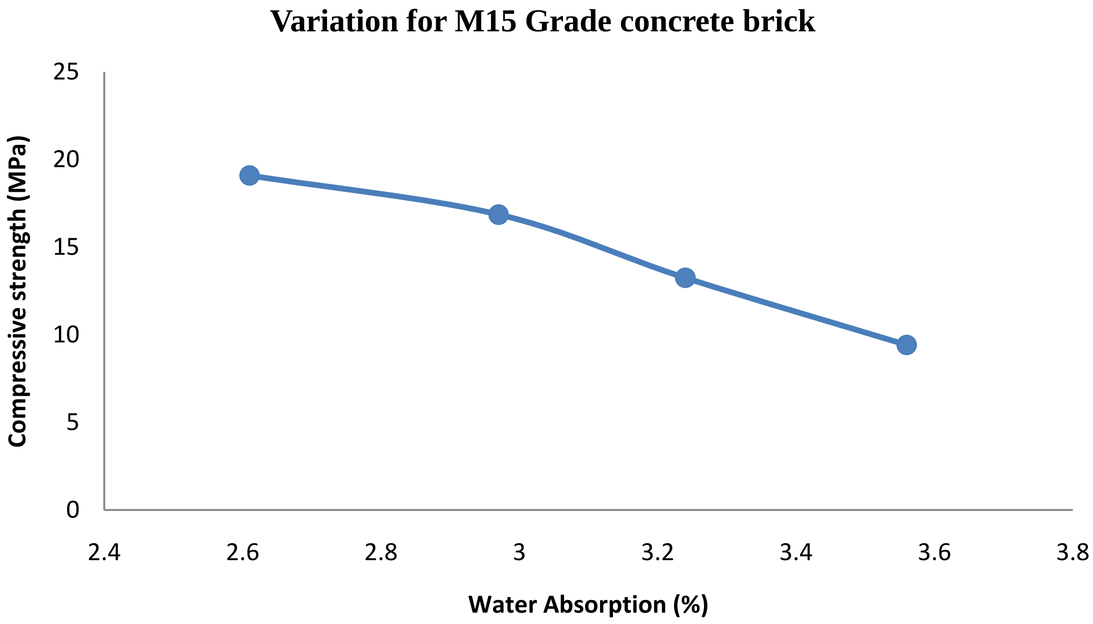

Figure 18 Variation of Compressive strength with water absorption of M15 grade sample

Similarly, Figure 19 shows the relation between average value of compressive strength and water absorption for M20 grade concrete brick. The graph was plotted from the experimental results obtained for the sample type E, F, G and H. Thus, the result obtained shows that compressive strength decreased with increased in water absorption value.

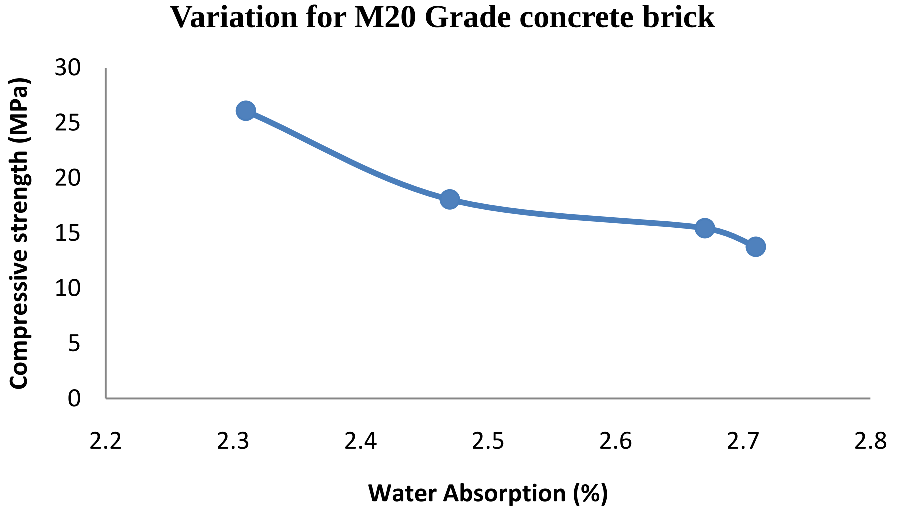

Figure 19 Variation of Compressive strength with water absorption of M20 grade sample

4.7 Variation of bulk density with water absorption

Figure 20 shows the relation between average value of bulk density and water absorption for M15 grade concrete brick. The graph was plotted from the experimental results obtained for the sample type A, B, C and D. Thus, the result obtained shows that bulk density decreased with increased in water absorption percentage.

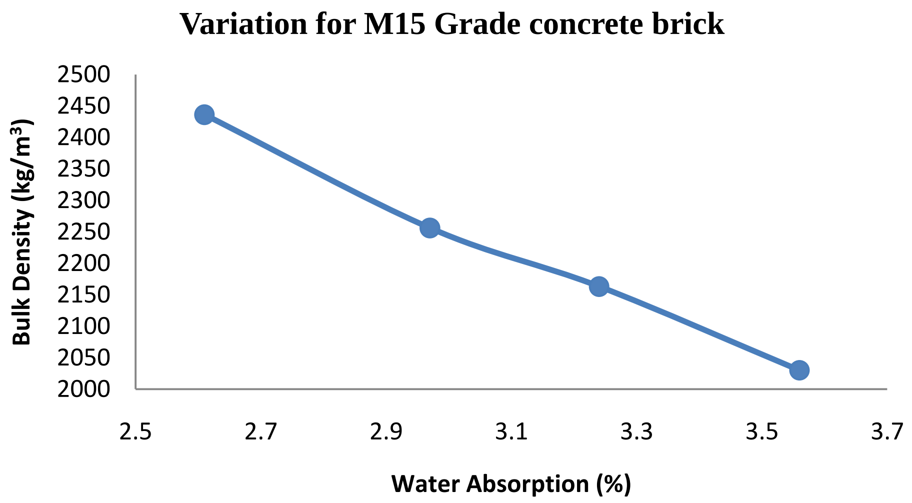

Figure 20Variation of bulk density with water absorption of M15 grade sample

Similarly, Figure 21 shows the relation between average value of bulk density and water absorption for M20 grade concrete brick. The graph was plotted from the experimental results obtained for the sample type E, F, G and H. Therefore, the result obtained shows that bulk density decreased with increased in percentage of water absorption.

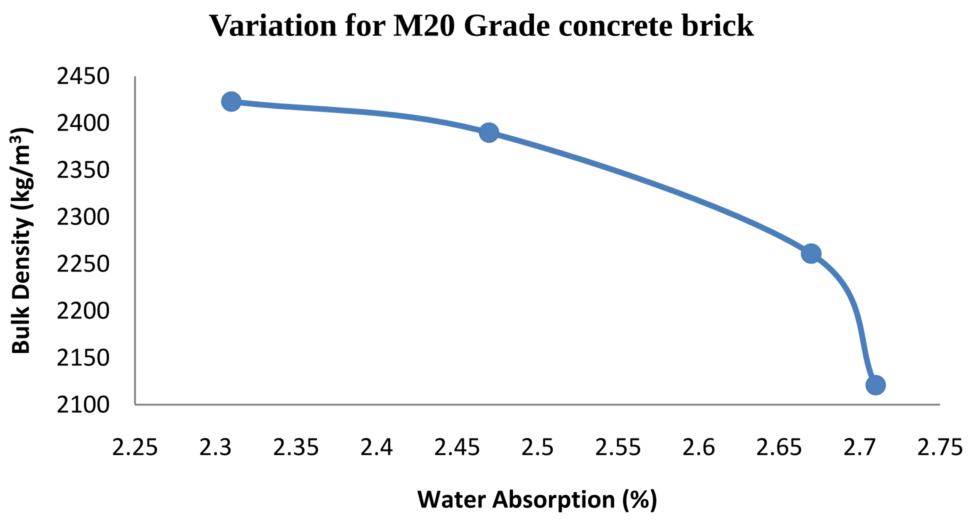

Figure 21 Variation of Bulk Density with water absorption of M20 grade sample

The graph shows that water absorption increase with the decrease in bulk density of concrete brick sample.

4.8 Superimposed Curves

Superimposed curve is used to show the effect of partial replacement of sand by crumb rubber and coarse aggregate by EPS on bulk density, water absorption and compressive strength on a single graph.

The figure 22 shows the result obtained from the laboratory test of M15 Grade concrete brick sample by plotting the curves with common X-axis i.e with partial replacement of sand by crumb rubber and coarse aggregate by EPS.

The experimental results i.e. compressivestrength , bulk density and water absorption were plotted in Y-axis with change in percentage of crumb rubber and EPS respectively in X-axis.

Thus, the graph shows value of water absorption of concrete brick sample increased with the increased in the percentage of crumb rubber and EPS where as compressive strength and bulk density decreased with increased in the percentage of crumb rubber and EPS

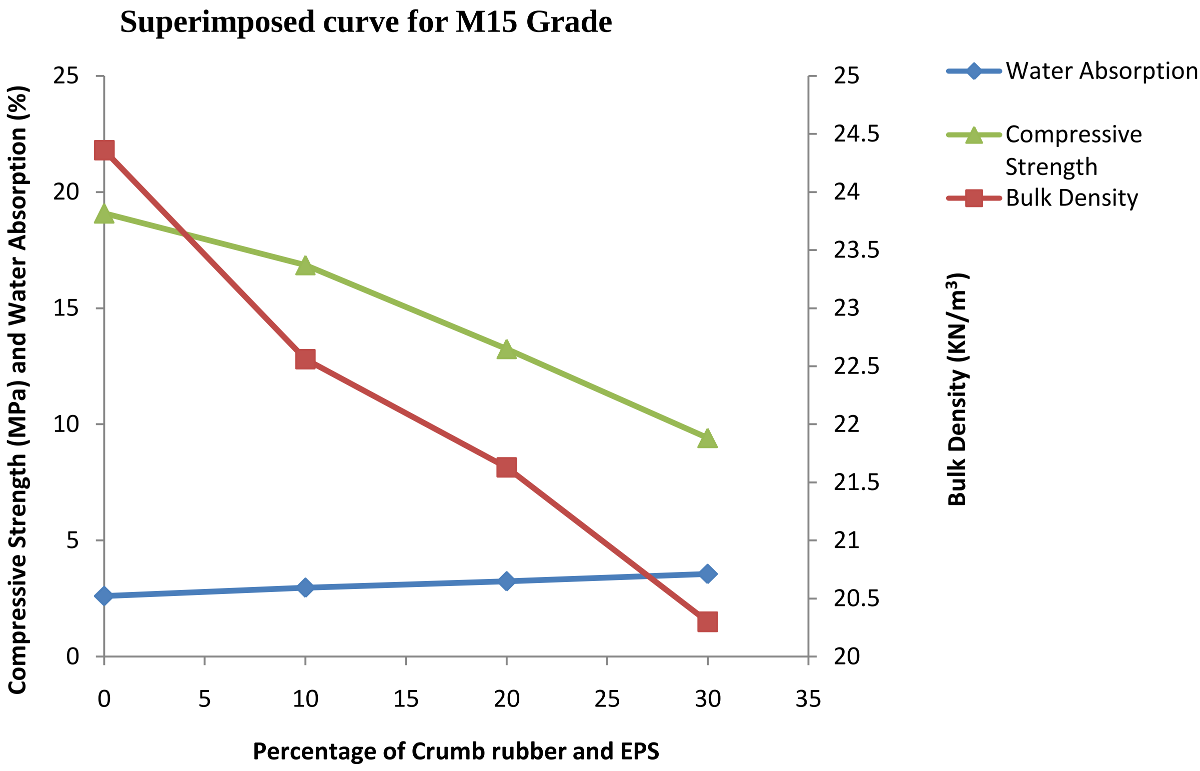

Figure 22 Superimposed curves of obtained results of M15 grade sample

The figure 23 shows the result obtained from the laboratory test of M20 Grade concrete brick sample by plotting the curves with common X-axis i.e with partial replacement of sand by crumb rubber and coarse aggregate by EPS.

The experimental results i.e. compressive strength , bulk density and water absorption were plotted in Y-axis with change in percentage of crumb rubber and EPS respectively in X-axis.

Thus, the graph shows value of water absorption of concrete brick sample increased with the increased in the percentage of crumb rubber and EPS where as compressive strength and bulk density decreased with increased in the percentage of crumb rubber and EPS.

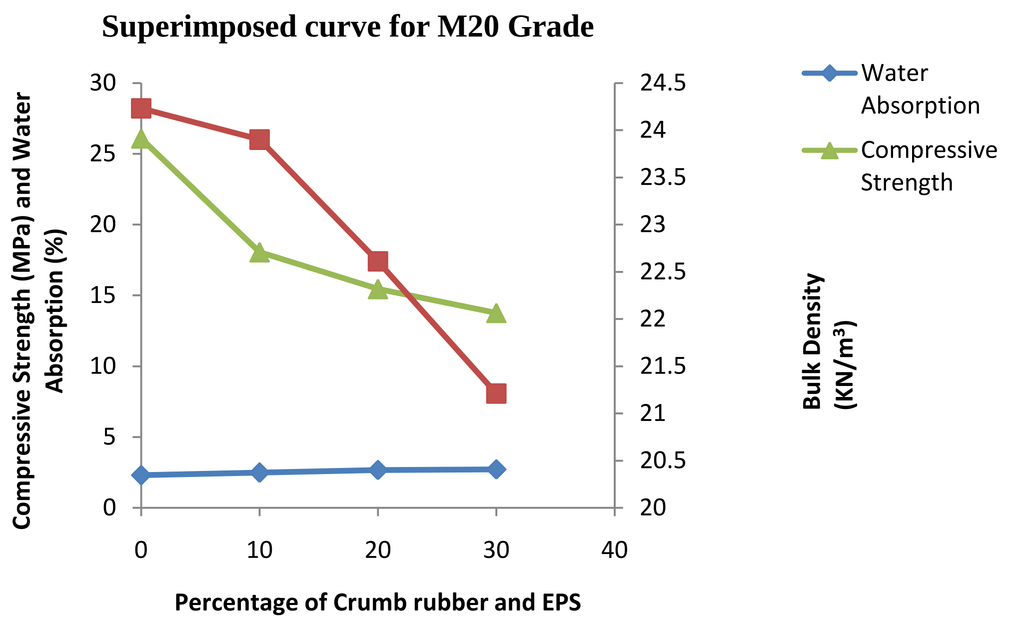

Figure 23 Superimposed curves of obtained results of M20 grade sample

The overall experimental result obtained from the tests carried out in lab is shown in table below:

Table 9 Overall result of M15 and M20 concrete brick

Sample Type	Compressive Strength (N/mm^2)	Bulk Density (KN/m^3)	Water Absorption (%)
For M15 Grade concrete			
A	19.08	24.36	2.61
B	16.85	22.56	2.97
C	13.24	51.63	3.24
D	9.41	20.3	3.56
For M20 Grade Concrete			
E	26.08	24.23	2.31
F	18.05	23.9	2.47
G	15.45	22.61	2.67
H	13.76	21.21	2.71

4.9 Discussion

4.9.1 CostAnalysis

Cost Analysis of M20 and M15 grade concrete mix were done. Cost per one cubic meter concrete of M15 grade sample is shown in Table 10. Rate Analysis is on the basis of Kathmandu Rate 2078/2079.

Table 10 Cost of 1 cum M15 concrete

Description	Various sample of M15 concrete brick			
	A	B	C	D
Cost per 1 cum concrete, NRs	10,142	9,650.2	9,159.04	8,667.56

Cost of sample type A was Rs10,142and that of sample type B, C, and D were Rs 9,650.2, Rs 9,159.04 and Rs 8,667.56 respectively for one cubic meter quantity of M20 grade concrete.

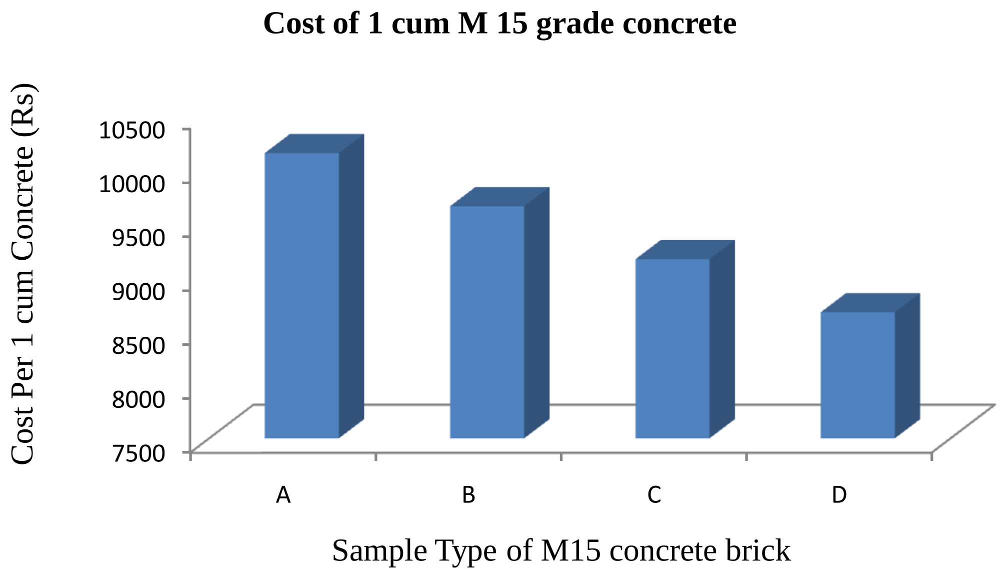

Figure 24 Cost of 1 cum M15 grade concrete

From figure17, it was noted that as percentage replacement of sand by saw dust and coarse aggregate by EPS increased, cost of 1 cum M20 grade concrete decreased.

Detail of cost calculation of M20 concrete brick is shown in Table 1 and Table 2 of Appendix D.

Cost per one cubic meter concrete of M20 grade sample is shown in table 11

Table 11 Cost of 1 cum M20 concrete

Description	Various sample of M20 concrete brick			
	E	F	G	H
Cost per 1m^3 concrete, NRs	11,429.53	10,875.06	10,405.92	9,936.78

Cost of sample type E was Rs11,429.53 and that of sample type F, G, and H were Rs 10875.06, Rs 10,405.92 and Rs 9,936.78 respectively for one cubic meter quantity of M20 grade concrete.

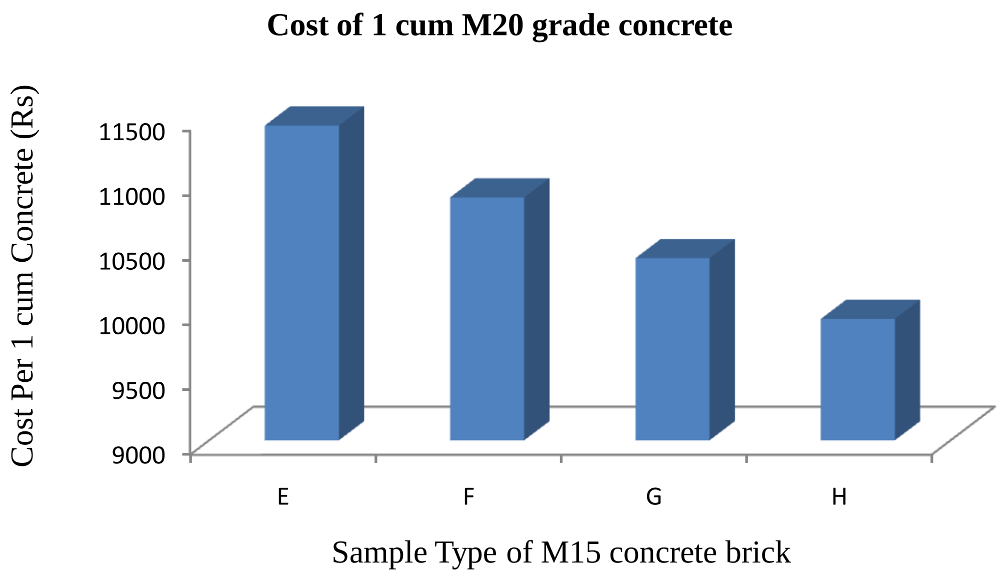

Figure 25 Cost of 1 cum M20 grade concrete

From figure25, it was noted that as percentage replacement of sand by saw dust and coarse aggregate by EPS increased, cost of 1 cum M15 grade concrete decreased. Cost gets decreased due to increase in percentage replacement of sand and coarse aggregate by saw dust and EPS. Here, cost of saw dust and EPS were neglected as they are waste product. Thus, utilization of waste product made concrete brick sample prepared environmental friendly.

4.9.2 Comparative Analysis

Studies to determine the mechanical properties of M15 and M20 grade concrete brick sample by partially replacing sand by crumb rubber and coarse aggregate by EPS have not been done yet.

Some of the studies were carried out by partial replacement of sand with ingredients like crumb rubber, saw dust, rice husk, brick powder, etc. in concrete mix. Similarly, replacement of coarse aggregate was done by EPS in concrete mix.

(Ghimire&Maharjan, 2018), experiment on the properties of Concrete brick with partial replacement of Sand by Saw Dust and Partial Replacement of Coarse Aggregate by Expanded Polystyrene. It was found that with the increase in percentage of sand by Saw Dust and Coarse aggregate by EPS,compressive strength and bulk density decreased.

(Bhatta&Maharjan, 2018), experiment on the compressive strength of concrete brick with complete replacement of Sand by brick dust waste and partial replacement of coarse aggregate by expanded polystyrene. It was found that with thecomplete replacement of sand by brick dust and increase in percentage of coarse aggregate by EPS, compressive strength decreased.

The comparison of compressive strength for M15 and M20 concrete brick sample as per various studies carried out is shown in the table 10.

Table 12 Comparison of compressive strength of M15 and M20 grade brick

Research	Percentage replacement of Sand	Percentage replacement of coarse aggregate	Compressive Strength (MPa)	
			M15	M20
Anjana and Maharjan	0	0	14.73	17.5
	10	10	11.23	13.68
	20	20	7.25	8.21
	30	30	5.92	7.49

Bhatta and Maharjan	100	0	14.87	17.69
	100	10	11.47	12.17
	100	20	8.09	10.35
	100	30	7.37	8.19

Figure 24 shows compressive strength of resulting concrete with various percentage changes of waste materials replacing constituents of concrete.

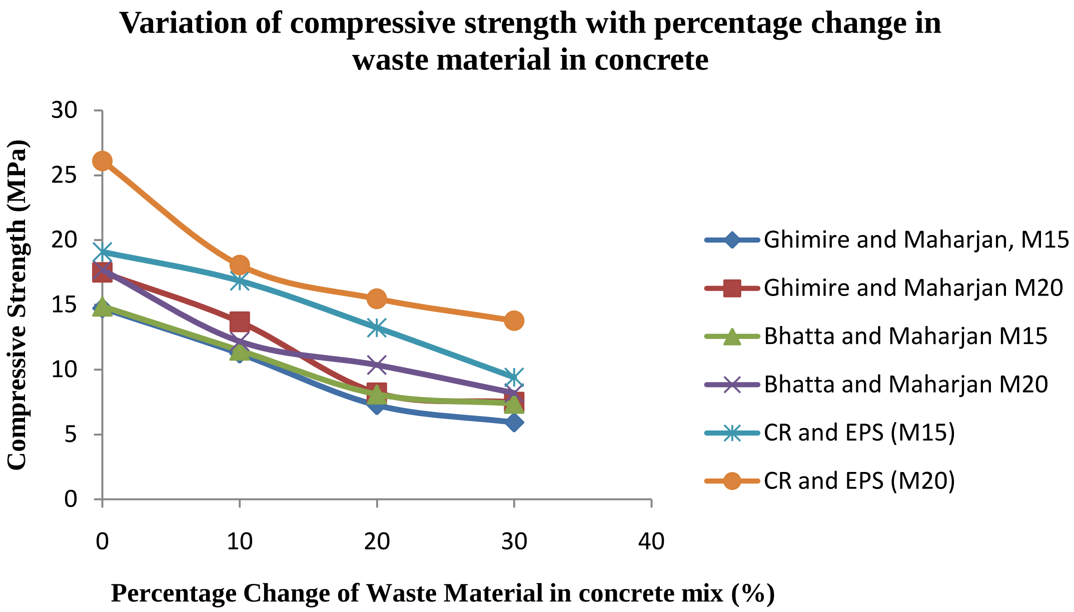

Figure 26Variation of compressive strength with percentage change of waste material in concrete

Comparing the obtained result of compressive strength of M15 and M20 grade concrete brick samples with compressive strength obtained in study of (Ghimire and Maharjan, 2018) ; (Bhatta and Maharjan, 2019), it was found that compressive strength decreaseswith increase in percentage of waste materials in concrete mix. Hence the obtained curve of M15 and M20 grade concrete have same trend as of previous researches.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

1. The compressive strength of M15 and M20 concrete brick decreased from 19.08 to 9.41 MPa and 26.08 to 13.76 MPa respectively while increasing the percentage content of crumb rubber and EPS as partial replacement of sand and coarse aggregate respectively from 0 to 30 %.
2. The bulk density of M15 and M20 concrete brick reduced from 24.36 to 20.3 KN/m3 and 24.23 to 21.21 KN/m3 respectively while increasing the percentage content of crumb rubber and EPS as partial replacement of sand and coarse aggregate respectively from 0 to 30 %. This indicated that the concrete brick becomes light weight with the increase in amount of crumb rubber and EPS.
3. The water absorption of M15 and M20 concrete brick increased from 2.61 to 3.56 % and 2.31 to 2.71% respectively while increasing the percentage content of crumb rubber and EPS as partial replacement of sand and coarse aggregate respectively from 0 to 30 %. The result indicated that water absorption increases with the increase in percentage replacement of sand by crumb rubber and coarse aggregate by EPS.

The results obtained from the experiment showed that concrete brick made with partial replacement of sand and coarse aggregate by crumb rubber and EPS respectively had sufficient compressive strength compared to common brick. The research recommended that upto 30% replacement of sand and coarse aggregate by crumb rubber and EPS respectively, the concrete brick so produced could be used for masonry unit in building construction.

5.2 Recommendation

Some of the recommendations suggested for future studies regarding crumb rubber andEPS concrete brick samples are:

- The effect of additives on mechanical properties of crumb rubber and EPS concretebrick samples can be done.

- The study on properties of crumb rubber and EPS concrete hollow block samples canbe done.
- The study on behavior of brick wallmade by crumb rubber and EPS with its failure mode can be done.
- The study on soundness, hardness and thermal properties of crumb rubber and EPS concrete brick samples can be done.

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APPENDIX A: OBSERVATIONS OF PROPERTIES OF MATERIALS USED

Table A1: Normal Consistency Test Observations

Weight of cement	**% of water added**	**Penetration value**
400 gm	25	20 mm
400 gm	29	40 mm
400 gm	28	34 mm

Table A2: Initial and Final setting time Observations and Calculations

Observation	**Time**
Initial Setting Time	120 min
Final Setting Time	290 min

Table A3: Compressive Strength of 1:3 Cement and mortar cubes

Number of Days	3 Days Result			7 Days Result			28 Days Result		
Sample No.	1	2	3	1	2	3	1	2	3
Dimension (mm)	70.0 × 70.0 ×70.0			70.0 × 70.0 ×70.0			70.0 × 70.0 ×70.0		
Area of Sample (cm^2)	49	49	49	49	49	49	49	49	49
Breaking Load (KN)	90	95	98	148	145	150	198	200	195
Compressive Strength (N/mm^2)	18.37	19.39	20	30.20	29.59	30.61	40.41	40.82	39.79
Average Compressive Strength (N/mm^2)	19.25			30.13			40.34		

Table A4: Sieve Analysis of Sand

Sample Weight = 530 gm					Percentage of weight retained (%)	Cumulative Percentage of Weight Retained (%)	Percentage Passing (%)
Sieve Size (mm)	Weight of Sand Retained (gm)						
	Determination Number						
	I	II	III	Average			
4.75	0.00	0.00	0.00	0.00	0.0	0.0	100.0
2.36	10.00	10.80	11.00	10.60	2.0	2.0	98.0
1.18	88.00	89.00	88.50	88.50	16.7	18.7	81.3
0.6	128.00	127.5	127.9	127.8	24.1	42.8	57.2
0.3	146.50	147.00	147.50	147.00	27.7	70.5	29.5
0.15	128.00	128.50	128.00	128.17	24.18	94.68	5.32
0.075	22.90	23.50	23.90	23.43	4.42	99.1	0.9
On pan	5.00	4.50	4.00	4.50	0.9	100.0	0.0
Total				530.00	100.0		
Therefore, Fineness Modulus = (228.68/100) = 2.2868							
Nominal Maximum Fine Aggregate Size = 2.36							

Table A5: Sieve Analysis of coarse aggregate

Sample Weight = 5 kg							
Sieve Size (mm)	Weight of Coarse Aggregate Retained (gm)				Percentage of weight retained (%)	Cumulative Percentage of Weight Retained (%)	Percentage Passing (%)
	Determination Number						
	I	II	III	Average			
20	0.00	0.00	0.00	0.0	0.0	0.0	100.0
16	1168.00	1166.00	1167.00	1167.0	23.3	23.3	76.7
12.5	990.00	993.00	992.00	992.0	19.8	43.2	56.8
10	2524.00	2527.00	2526.00	2526.0	51.1	94.3	5.7
4.75	254.00	258.00	262.00	258.0	5.2	99.4	0.6
On pan	28.00	32.00	30.00	30.0	0.6	100.0	0.0
Total				5000			
Nominal Maximum Coarse Aggregate Size = 12.5 mm							

Table A6 Impact Value Test of Coarse Aggregate

Description	No. of Test		
	I	II	III
Total weight of aggregate sample (Passing 12.5, Retained 10mm) specimen in gm	500	500	500
Weight of aggregate passing 2.36 mm sieve after test in gm	84	85	87
Aggregate impact value in %	16.8	17	17.4
Average aggregate impact value in %	17.06		

Table A7: Sieve Analysis of Crumb Rubber

Sample Weight = 200 gm					Percentage of weight retained (%)	Cumulative Percentage of Weight Retained (%)	Percentage Passing (%)
Sieve Size (mm)	Weight of Crumb Rubber Retained (gm)						
	Determination Number						
	I	II	III	Average			
4.75	0	0	0	0	0	0	100
2.36	22	22.8	23.6	22.8	11.4	11.4	88.6
1.18	70	72	71	71	35.5	46.9	53.1
0.6	50	55	52	52.3	26.2	73.1	26.9
0.3	29	29.5	31	29.8	14.9	88	12
0.15	17	14.7	16	15.9	8	95.9	4.1
0.075	8	6.5	6	6.8	3.4	99.4	0.6
On pan	1.5	1.4	1.1	1.3	0.7	100	0
Total				200	100	200	
Therefore, Fineness Modulus = (315/100)=3.15							
Nominal Maximum Fine Aggregate Size = 2.36							

Table A8: Sieve Analysis of EPS

Sample Weight = 200 gm					Percentage of weight retained (%)	Cumulative Percentage of Weight Retained (%)	Percentage Passing (%)
Sieve Size (mm)	Weight of EPS (gm)						
	Determination Number						
	I	II	III	Average			
4.75	24.1	25.3	23.6	24.33	12.16	12.16	87.84
2.36	163.2	166.5	166.2	165.31	82.655	94.815	5.185
1.18	10.3	10.8	10	10.36	5.18	100	0
0.6	0.00	0.00	0.00	0.00	0.00	100	0
0.3	0.00	0.00	0.00	0.00	0.00	100	0
0.15	0.00	0.00	0.00	0.00	0.00	100	0
0.075	0.00	0.00	0.00	0.00	0.00	100	0
On pan	0.00	0.00	0.00	0.00	0.00	100	0
Total				200	100		
Nominal Maximum Size of EPS = 4.75							

APPENDIX B: OBSERVATIONS OF PROPERTIES OF SAMPLES PREPARED

Table B1: Compressive Strength of Concrete Brick Sample of M15 Grade

Sample Type	Sample	Sand Replacement by Crumb rubber (%)	Coarse Aggregate Replacement by EPS (%)	Length (mm)	Breadth (mm)	Area (mm^2)	Breaking Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
A	A1	0	0	240	115	27600	524.68	19.01	19.08
	A2	0	0	240	115	27600	534.89	19.38	
	A3	0	0	240	115	27600	520.26	18.85	
B	B1	10	10	240	115	27600	469.75	17.02	16.85
	B2	10	10	240	115	27600	463.68	16.80	
	B3	10	10	240	115	27600	462.30	16.75	
C	C1	20	20	240	115	27600	372.60	13.50	13.24
	C2	20	20	240	115	27600	366.53	13.28	
	C3	20	20	240	115	27600	357.42	12.95	
D	D1	30	30	240	115	27600	259.99	9.42	9.41
	D2	30	30	240	115	27600	269.93	9.78	
	D3	30	30	240	115	27600	249.78	9.05	

Table B2: Compressive Strength of Concrete Brick Sample of M20 Grade

Sample Type	Sample	Sand Replacement by Crumb rubber (%)	Coarse Aggregate Replacement by EPS (%)	Length (mm)	Breadth (mm)	Area (mm^2)	Breaking Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
E	E1	0	0	240	115	27600	699.94	25.36	26.08
	E2	0	0	240	115	27600	719.81	26.08	
	E3	0	0	240	115	27600	739.96	26.81	
F	F1	10	10	240	115	27600	509.77	18.47	18.05
	F2	10	10	240	115	27600	504.53	18.28	
	F3	10	10	240	115	27600	480.24	17.40	
G	G1	20	20	240	115	27600	419.80	15.21	15.45
	G2	20	20	240	115	27600	460.09	16.67	
	G3	20	20	240	115	27600	399.92	14.49	
H	H1	30	30	240	115	27600	399.92	14.49	13.76
	H2	30	30	240	115	27600	375.36	13.60	
	H3	30	30	240	115	27600	364.60	13.21	

Table B3: Water Absorption of Concrete Brick Sample of M15 Grade

Sample Type	Sample	Sand Replacement by Crumb rubber (%)	Coarse Aggregate Replacement by EPS (%)	Weight of Dry Brick (gm)	Weight of Wet Brick (gm)	Water Absorption (%)	Average Water Absorption (%)
A	A1	0	0	3849	3950	2.63	2.61
	A2	0	0	3815	3911	2.53	
	A3	0	0	3835	3942	2.81	
B	B1	10	10	3931	4053	3.10	2.97
	B2	10	10	3444	3547	2.98	
	B3	10	10	3587	3689	2.84	
C	C1	20	20	3415	3529	3.34	3.24
	C2	20	20	3404	3505	2.97	
	C3	20	20	3388	3504	3.43	
D	D1	30	30	3188	3297	3.42	3.56
	D2	30	30	3388	3507	3.52	
	D3	30	30	3014	3127	3.75	

Table B4: Water Absorption of Concrete Brick Sample of M20 Grade

Sample Type	Sample	Sand Replacement by Crumb rubber (%)	Coarse Aggregate Replacement by EPS (%)	Weight of Dry Brick (gm)	Weight of Wet Brick (gm)	Water Absorption (%)	Average Water Absorption (%)
E	E1	0	0	3785	3875	2.37	2.31
	E2	0	0	3844	3939	2.47	
	E3	0	0	3804	3884	2.10	
F	F1	10	10	3785	3870	2.24	2.47
	F2	10	10	3704	3799	2.56	
	F3	10	10	3790	3879	2.36	
G	G1	20	20	3640	3745	2.89	2.67
	G2	20	20	3559	3649	2.52	
	G3	20	20	3474	3567	2.67	
H	H1	30	30	3359	3444	2.52	2.71
	H2	30	30	3308	3403	2.87	
	H3	30	30	3343	3435	2.76	

Table B5: Bulk Density Test of Concrete Brick Sample of M15 Grade

Sample Type	Sample	Sand Replacement by Crumb rubber (%)	Coarse Aggregate Replacement by EPS (%)	Length (mm)	Breadth (mm)	Height (mm^2)	Volume (mm^3)	Dry Weight of Brick(gm)	Bulk density (KN/m^3)	Average Bulk Density (KN/m^3)
A	A1	0	0	240	115	57	1573200	3849	24.47	24.36
	A2	0	0	240	115	57	1573200	3815	24.25	
	A3	0	0	240	115	57	1573200	3835	24.38	
B	B1	10	10	240	115	57	1573200	3931	24.99	22.56
	B2	10	10	240	115	57	1573200	3444	21.89	
	B3	10	10	240	115	57	1573200	3587	22.80	
C	C1	20	20	240	115	57	1573200	3415	21.71	21.63
	C2	20	20	240	115	57	1573200	3404	21.64	
	C3	20	20	240	115	57	1573200	3388	21.54	
D	D1	30	30	240	115	57	1573200	3188	20.27	20.3
	D2	30	30	240	115	57	1573200	3388	21.54	
	D3	30	30	240	115	57	1573200	3014	19.16	

Table B6: Bulk Density Test of Concrete Brick Sample of M20 Grade

Sample Type	Sample	Sand Replacement by Crumb rubber (%)	Coarse Aggregate Replacement by EPS (%)	Length (mm)	Breadth (mm)	Height (mm^2)	Volume (mm^3)	Dry Weight of Brick (gm)	Bulk density (KN/m^3)	Average Bulk Density (KN/m^3)
E	E1	0	0	240	115	57	1573200	3785	24.06	24.23
	E2	0	0	240	115	57	1573200	3844	24.44	
	E3	0	0	240	115	57	1573200	3804	24.18	
F	F1	10	10	240	115	57	1573200	3785	24.06	23.90
	F2	10	10	240	115	57	1573200	3704	23.55	
	F3	10	10	240	115	57	1573200	3790	24.09	
G	G1	20	20	240	115	57	1573200	3640	23.14	22.61
	G2	20	20	240	115	57	1573200	3559	22.62	
	G3	20	20	240	115	57	1573200	3474	22.08	
H	H1	30	30	240	115	57	1573200	3359	21.35	21.21
	H2	30	30	240	115	57	1573200	3308	21.03	
	H3	30	30	240	115	57	1573200	3343	21.25	

APPENDIX C: CONCRETE MIX PROPORTIONS

Table C1: Concrete Mix Proportion of M15 Grade

Sample Type	Sample	Cement (cc)	Sand (cc)	Crumb Rubber(cc)	Coarse Aggregate (cc)	EPS (cc)	% of Replacement of Sand by Saw dust	% of Replacement of Sand by Saw dust
A	A1	346.1	692.2	0	1384.42	0	0	0
	A2	346.1	692.2	0	1384.42	0	0	0
	A3	346.1	692.2	0	1384.42	0	0	0
B	B1	346.1	622.98	69.22	1245.97	138.442	10	10
	B2	346.1	622.98	69.22	1245.97	138.442	10	10
	B3	346.1	622.98	69.22	1245.97	138.442	10	10
C	C1	346.1	553.76	138.44	1107.53	276.883	20	20
	C2	346.1	553.76	138.44	1107.53	276.883	20	20
	C3	346.1	553.76	138.44	1107.53	276.883	20	20
D	D1	346.1	484.54	207.66	969.09	415.325	30	30
	D2	346.1	484.54	207.66	969.09	415.325	30	30
	D3	346.1	484.54	207.66	969.09	415.325	30	30

Table C2: Concrete Mix Proportion of M20 Grade

Sample Type	Sample	Cement (cc)	Sand (cc)	Crumb Rubber (cc)	Coarse Aggregate (cc)	EPS (cc)	% of Replacement of Sand by Saw dust	% of Replacement of Sand by Saw dust
E	E1	440.50	660.74	0	1321.48	0	0	0
	E2	440.50	660.74	0	1321.48	0	0	0
	E3	440.50	660.74	0	1321.48	0	0	0
F	F1	440.50	594.67	66.074	1189.33	132.15	10	10
	F2	440.50	594.67	66.074	1189.33	132.15	10	10
	F3	440.50	594.67	66.074	1189.33	132.15	10	10
G	G1	440.50	528.59	132.148	1057.18	164.30	20	20
	G2	440.50	528.59	132.148	1057.18	164.30	20	20
	G3	440.50	528.59	132.148	1057.18	164.30	20	20
H	H1	440.50	462.52	198.22	925.04	396.44	30	30
	H2	440.50	462.52	198.22	925.04	396.44	30	30
	H3	440.50	462.52	198.22	925.04	396.44	30	30

APPENDIX D: CALCULATION OF COST OF M20 AND M15 GRADE CONCRETE BRICK PREPARED

Table D1: Cost of M20 Grade concrete brick of sample type E and F

Proportion of Concrete		
Containing 0% crumb rubber and EPS	Containing 10% of crumb rubber and EPS	
1:1.5:3 (cement : sand : aggregate) Total proportion: 1+1.5+3= 5.5	1:0.2:1.75:3.87 (cement : saw dust: sand : EPS: aggregate) Total proportion: 1+0.15+1.35+0.3+2.7=5.5	
Volume of 1 cum dry concrete = 1.54 cum of wet concrete(www.researchgate.net)		
Quantity Calculations		
	Containing 0% Crumb rubber and EPS	**Containing 10% of Crumb rubber and EPS**
Cement (Unit wt. of cement taken = 1440kg/m^3)	0.28 8.064 bags	0.28 8.064 bags
Sand	0.42 0.42 cum	0.378 0.378 cum
Aggregate	0.84 0.863 cum	0.756 0.756cum
Cost Calculations		
	Containing 0% Crumb rubber and EPS	**Containing 10% of Crumb Rubber and EPS**
Cost of cement (Rs.825 per bag (50 kg))	6652.8	6652.8
Cost of sand (Rs.3750 per cum)	1575	1417.5
Cost of aggregate (Rs.3710 per cum)	3201.73	2804.76
Total cost 1 cum M20 grade concrete	**11429.53**	**10875.06**

Table D2: Cost of M20 Grade concrete brick of sample type G and H

Proportion of Concrete	
Containing 20% of Crumb Rubber and EPS	Containing 30% of Crumb Rubber and EPS
1:0.3:1.2:0.6:2.4 (cement :crumb rubber:sand : EPS:aggregate) Total proportion: 1+0.3+1.2+0.6+2.4= 5.5	1:0.45:1.05:0.9:2.1 (cement : crumb rubber: sand : EPS: aggregate) Total proportion: 1+0.45+1.05+0.9+2.1=5.5
Volume of 1 cum dry concrete = 1.54 cum of wet concrete(www.researchgate.net)	

Quantity Calculations		
	Containing 20% of Crumb Rubber and EPS	**Containing 30% of Crumb rubber and EPS**
Cement (Unit wt. of cement taken = 1440kg/m^3)	0.28 8.064 bags	0.28 8.064 bags
Sand	0.336 0.336 cum	0.294 0.294 cum
Aggregate	0.672 0.672 cum	0.588 0.588cum

Cost Calculations		
	Containing 20% of Crumb rubber and EPS	**Containing 30% of Crumb rubber and EPS**
Cost of cement(Rs.825 per bag (50 kg))	6652.8	6652.8
Cost of sand(Rs.3750 per cum)	1260	1102.5
Cost of aggregate(Rs.3710 per cum)	2493.12	2181.48
Total cost 1 cum M20 grade concrete	**10405.92**	**9936.78**

Table D3: Cost of M15 Grade concrete brick of sample type A and B

Proportion of Concrete		
Containing 0% Crumb rubber and EPS	Containing 10% of Crumb rubber and EPS	
1:2:4 (cement : sand : aggregate) Total proportion: 1+2+4= 7	1:0.2:1.8:0.4:3.6(cement : crumb rubber: sand : EPS: aggregate) Total proportion: 1+0.2+1.8+0.4+3.6=7	
Volume of 1 cum dry concrete = 1.54 cum of wet concrete(www.researchgate.net)		
Quantity Calculations		
	Containing 0% crumb rubber and EPS	**Containing 10% of crumb rubber and EPS**
Cement (Unit wt. of cement taken = 1440kg/m^3)	0.22 6.336 bags	0.22 6.336 bags
Sand	0.44 0.44 cum	0.396 0.396 cum
Aggregate	0.88 0.88 cum	0.792 0.792 cum
Cost Calculations		
	Containing 0% crumb rubber and EPS	**Containing 10% of Crumb rubber and EPS**
Cost of cement ((Rs.825 per bag (50 kg))	5227.2	5227.2
Cost of sand(Rs.3750 per cum)	1650	1485
Cost of aggregate(Rs.3710 per cum)	3264.8	2938.32
Total cost of 1 cum M20 grade concrete	**10142**	**9650.2**

Table D4: Cost of M15 Grade concrete brick of sample type C and D

Proportion of Concrete		
Containing 20% of Crumb rubber and EPS	Containing 30% of Crumb rubber and EPS	
1:0.4:1.6:0.8:3.2(cement:crumb rubber:sand :EPS: aggregate) Total proportion: 1+0.4+1.6+0.8+3.2=7	1:0.6:1.4:1.2:2.8(cement : crumb rubber: sand : EPS: aggregate) Total proportion: 1+0.6+1.4+1.2+2.8=7	
Volume of 1 cum dry concrete = 1.54 cum of wet concrete(www.researchgate.net)		
Quantity Calculations		
	Containing 20% of Crumb rubber and EPS	**Containing 30% of crumb rubber and EPS**
Cement (Unit wt. of cement taken = 1440kg/m^3)	0.22 6.336 bags	0.22 6.336 bags
Sand	0.352 0.352 cum	0.308 0.308 bags
Aggregate	0.704 0.704 cum	0.616 0.616 cum
Cost Calculations		
	Containing 20% of Crumb rubber and EPS	**Containing 30% of Crumb rubber and EPS**
Cost of cement((Rs.825per bag (50 kg))	5227.2	5227.2
Cost of sand(Rs.3750 per cum)	1320	1155
Cost of aggregate (Rs.3710 per cum)	2611.84	2285.36
Total cost 1 cum M20 grade concrete	**9159.04**	**8667.56**

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Letter of Acceptance

Ms. Samiksha Dhakal, Mr. Rajendra Shrestha, Mr. Sachin Joshi

The Editorial Board of Journal of Advanced College of Engineering and Management (jacem) (ISSN No: 2392-4853), is pleased to inform you that your manuscript **"Experimental Analysis on Properties of M15 and M20 Concrete Brick Sample with Partial Replacement of Sand by Crumb Rubber and Coarse Aggregate by Expanded Polystyrene"** has been reviewed by the referee and accepted for the publication. Your article will be published in the coming issue of Journal of Advanced College of Engineering and Management, Vol. 7.

We are delighted and thankful for considering this Journal as a venue of your valuable research work.

With Regards

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