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Use of Recyclable Material in Civil Construction

Arpit Mathur[1], R. C. Patil[2]

[1]PG Student, [2]Assistant Professor,

[1,2]School of Research & Technology, People's University Bhopal, Madhya Pradesh, India

ABSTRACT

In today's scenario the cement concrete is one of the most widely used construction material in the world. Increase in the population growth is leads to increase in the demands of various fields like cultivation, transportation and building construction etc. Nowadays, there is a very much increase in the demand for construction works like residential buildings, commercial buildings, bridges, dams, roads etc. and because of this increase in demand the availability of resources for the cement concrete ingredients is getting very complex. Hence people are looking for the alternative resources for the concrete ingredients in order to meet their requirements. This thesis work deals with the study of physical properties of the cement concrete with using Used Aggregate in the cement concrete mixture. The major objective of this research work is to determine that what percentage of Used Aggregate can be utilized in the cement concrete mixture to achieve its target mean strength. In this research work it is concentrated on the use of Used Aggregate in the cement concrete mixture. A series of tests were carried out to determine the compressive strength, split tensile strength with and without addition of Used Aggregate. The use of recyclable material in cement concrete mixture also helps in preservation of the environment by saving the natural resources. However, in coming few decades, it can raise new challenges for the construction industry. It is essential to investigate the properties of fresh and hardened concrete to encourage and escalate its application in the civil engineering construction industry. This research investigates the properties of fresh and hardened concrete made with different quantity Used Aggregate in the cement concrete mix.

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KEYWORDS: *Used Aggregate Concrete, Recycled Aggregate, Workability*

1. INTRODUCTION

1.1. GENERAL

The quantity of generated scrap and waste materials has been increased rapidly due to the development of urbanization and industrialization. Today, most of the waste material is disposed in land filling and spreading on agriculture land. The large volume of waste material is produced, increasing of environmental concerns and the shortage of landfill site made land filling are limited.

So, new alternative applications have to be considered for the disposal of waste material diverted away from the landfills and agriculture. One of these alternatives is the use of waste material in construction materials field. The possible use of scrap and waste material as construction and building materials would provide a new option of alleviating the sludge in significant quantity. Also this option has an economic and energy saving advantages.

Development of infrastructural facilities is accompanied by construction, remodeling and demolition of buildings, roads, bridges, flyover, subways, runways, factories and other similar establishments. The waste generated mainly consists of inert and non-biodegradable materials such as concrete, plaster, wood, metal, broken tiles, bricks, masonry etc. These wastes are heavy, having high density, very often occupy considerable storage space either on road sides or communal waste bin. In most part of the world, on travelling a few kilometers by road, it is not uncommon to see huge piles of such waste, which is heavy as well, stacked on roads especially in large projects, resulting in traffic congestion. Such stacks of wastes choke the surface drains very often causing flooding of roads and low lying areas. Waste from small generators like individual house construction or demolition; find its way into the nearby municipal bin, waste storage depots, making the municipal waste heavy and unsuitable for further treatment like composting or energy recovery. Sometimes the wastes from small projects are buried in the site itself, forming an impervious layer, which adversely affect the growth of vegetation, prevent the infiltration of surface run off into the ground water table and lead to high level of environmental imbalance.

The waste materials that are commonly known are blast furnace slag, fly ash, silica fume (from Power Plants) recycled aggregates (from Demolition sites), solid waste, plastic waste (Domestic waste) and rubber waste (commercial waste). Partial replacement of Portland cement with waste materials like blast furnace slag, fly ash, silica fume (from Power plants), recycled aggregates (from Demolition sites), solid waste, plastic waste (Domestic waste) and rubber waste (commercial waste) will be a great help in reducing environmental pollution and also in reduction in manufacturing of cement and other material that required for the construction activities. One of the major challenges of our present society is the protection of environment.

Any construction activity requires several materials such as concrete, steel, brick, stone, glass, clay, mud, wood, and so on. However, the cement concrete remains the main construction material used in construction industries. For its suitability and adaptability with respect to the changing environment, the concrete must be such that it can conserve resources, protect the environment, economize and lead to proper utilization of energy. To achieve this, major emphasis must be laid on the use of wastes and byproducts in cement and concrete used for new constructions. The utilization of recycled aggregate is particularly very promising as approximately 75 per cent of cement concrete is made of aggregates. The huge quantities of demolished concrete are available at various construction sites, which are now posing a serious problem of disposal in urban areas. This can easily be recycled as aggregate and used in concrete.

2. LITERATURE REVIEW

2.1. Background

One of the most common environmental issues in the contemporary world is related to the management they are of pneumatic tyre, which is not readily biodegradable. Every year, approximately 800 million new tyres are produced in every region of the world, in various sizes and types (Serumagard, 1999). Although the lifetime of some tyres are prolonged, but ultimately they will be discarded as waste materials. Majority of such tyres will end up in the already congested landfill or they become mosquito breeding places and give the worst effects when burnt. The melting tyres also produced large quantities of oil, which will contribute to the contamination of soil and ground water.

Recent statistics in Malaysia indicated that there is an increase of more than 100 % in the number of registered vehicles within these ten years. The current thirteen million vehicles are producing a large number of scrap tyres. Therefore, the Department of Environmental has put a stop to the open burning and burying of waste tyres as they will cause air pollution and land instability. Even though several agencies and municipal councils are involved in waste management, they often have no clear direction in relation to waste management. Only a few companies take the shredding process further by producing crumb rubber and rubber powder. The cost of crumb rubber is about RM 1000 (1 US dollar = RM 3.5) per ton. Therefore, as an engineer and researcher, there is a need to seek and identify economic and environmental friendly methods to manage these tyres in different civil engineering applications.

For the last 20 years, introduction of scrap tyres rubber into asphalt concrete pavement has solved the problem of waste tyres. Several investigations showed that strength and compressibility of shredded tyres in concrete form can be engineered to meet the requirements by increasing the cement content. On the other hand, owing to the unique characteristic of tyre (rubber), it is expected that by adding crumb rubber into concrete mixture, it can increase the toughness (energy absorption capacity) of concrete considerably (Toutanji, 1996, Naik & Siddique, 2004, Li, et al., 2004, Hermandez-olivares et al., 2002, Lingand Nor, 2007). However, the initial cost of rubberized asphalt is 40 to 100 % higher than that of conventional asphalt, moreover, its long term benefits are uncertain (Fedroff et al., 1996).

Limited laboratory tests results have shown that the incorporation of waste tyre rubber (crumb rubber) in concrete pedestrian block, reduces the weight and considerably increases toughness and skid resistance (Sukonrasukkul & Chaikaew, 2006). However, such combination causes less abrasion resistant and is not as strong as the conventional block. Hence, the blocks produced are considered not applicable for trafficked pavement.

To resolve these problems (low strength and slow production by hand-pressed method), various means are attempted to improve the strength and to reduce tyre wastes in a massive quantity. This study is aimed to promote a practical use and acceptance of using crumb rubber in CPB by potential end users. Therefore, an investigation of manufacturing processes and feasibility of producing CPB incorporating crumb rubber in a commercial plant setting is carried out. In addition to that, the CPB quality and strength are expected to be improved by using specialised manufacturing equipment (under vibration and extreme pressure) based on formulations developed in laboratory trials (Ling et al., 2009).

2.2. Previous work in this field

There have been countless number of studies which have looked at the properties of concrete containing various types and quantities of recycled coarse and fine aggregate. Properties such as chemical stability [I. B. Topc, u and M. Canbaz, 2004], physical durability [S. M. Levy and P. Helene, 2004], workability [C. S. Poon, Z. H. Shui, L. Lam, H. Fok, and S. C. Kou, 2004], strength [T. C. Hansen and H. Narud, 1983], permeability [T. C. Hansen, 1986], and shrinkage resistance [J. M. Khatib, 2005] have been examined. A general consensus between these studies is that concrete containing recycled coarse aggregate which are properly cleaned, and in quantities no more than 50% replacement of virgin aggregate would have adequate durability, workability, and strength when compared with concrete containing 100% virgin aggregate. Concrete containing recycled aggregate is expected to display slightly more shrinkage than that containing virgin aggregate only [J. M. Khatib, 2005]. Permeability of concrete containing recycled aggregate at w/c ratios same as that of concrete containing only virgin aggregate is also expected to increase [T. C. Hansen, 1986]. With regards to chemical stability, it is important that waste aggregates being used do not contain reactive silica in order to avoid alkali-silica reaction (ASR) in the final product.

Waste glass constitutes a problem for solid waste disposal in many municipalities. The current practice is still to landfill most of it. Since glass is usually not biodegradable, landfills do not provide an environment-friendly solution. Consequently, there is a strong need to utilize/recycle waste glasses. One option is to crush and grade it and use it as a replacement for fine aggregate in a concrete mix. As with waste recycled aggregates, it is very important that the glass used be silica-free in order to avoid ASR in the final composite. If this basic criterion is met, past studies indicate that recycled waste glass is an acceptable material to be used in concrete. There tends to be a slight decrease in compressive strength as the fraction of recycled glass is increased in a mix, and other properties such as air content and mix are dependent on the shape of the individual grains of the crushed glass [S. B. Park, B. C. Lee, and J. H. Kim, 2004, T. R. Naik and Z. Wu, 2001].

3. MATERIALS AND METHODOLOGY USED

3.1. Introduction:-

To efficient research the enhancement in the mechanical properties of the fibre reinforced concrete, preliminary planning, procedures and methods must be wisely selected. The criteria to evaluate mechanical properties are based on the activities to plan and preparation, which carried out by before the testing of the fresh and hardened properties of Fibre reinforced concrete (FRC). These various activities are as follows:

1. Aggregate Impact Value test
2. Water absorption test on aggregate
3. Sieve analysis test on aggregate (Coarse and Fine)
4. Fineness test on cement
5. Setting time test on cement
6. Selection of dosages of fibre in concrete
7. Selection of the mix
8. Concrete mixing
9. Preparation of the test samples.

Testing is an activity required in the majority of the engineering research work, where it comprises or consists all preparation and plan of action to be taken and being situated into performance subsequently. This chapter describes preliminary design and planning such as experimentation of the coarse and fine aggregates, selection of fibres with fibre volume dosage rate, target strength of concrete specimens, mix proportioning and number of mix batches and concrete specimens required to meet up the scope of this thesis work.

3.2. Materials Used In Our Work:-

The materials those were used in our thesis work are as follows:-

1. Binding material i.e. Cement
2. Fine aggregate (Sand)
3. Used Aggregate in Concrete
4. Potable water.

3.2.1. Binding Material:-

Cement is a binding material which founds in the powder form that is made by calcinations process of lime and clay, mixed with potable water to form mortar or mixed with sand, stone and water to make concrete. General materials used to manufacture the cement includes limestone, chalk and shells combined with blast furnace slag, silica sand shale, clay, slate, and iron ore. Cement is mainly consists of silicates and aluminates of lime obtained from limestone and clay. Cement is made by heating these materials those are listed above at 1450 °C in a kiln and this process is known as calcination. This result in the hard substance called clinker which is then ground with a small amount of gypsum into a powder to make OPC, the most commonly used type of cement. The different types of cement as classified by Bureau of Indian Standards (BIS) are as follows:

1. Ordinary Portland Cement
2. Portland Pozzolana Cement
3. Rapid Hardening Portland Cement
4. Portland Slag Cement
5. Hydrophobic Portland Cement
6. Low Heat Portland Cement
7. Sulphate Resisting Portland Cement.

Generally OPC is used in common concrete construction where there is no exposure to sulphates in the soil or in ground water. This cement is obviously produced in the maximum quantity than other cements. OPC is classified into three grades namely 33 grade, 43 grade and 53 grade depending upon the compressive strength of cement at 28 days. OPC 43 grade was used in this study as shown in Figure-3.1. The properties of cement were determined and are given in the next Chapter.

3.2.2. Fine Aggregate:-

During the experimental process of sieving the aggregates most of which passes through 4.75 mm BIS Sieve known as fine aggregates.

1. **Natural Sand** - Fine aggregates resulting from the natural disintegration of rock and which have been deposited by rivers or glacial agencies.
2. **Crushed Stone Sand** - Fine aggregates produced by crushing hard stone is known as crushed stone sand.
3. **Crushed Gravel Sand** - Fine aggregates produced by crushing natural gravel is known as crushed gravel stone.

According to the particle size, the fine aggregates may be classified as coarse, medium or fine aggregates. Depending upon the particle size distribution, the fine aggregates are divided into four grading zones as per **(13) BIS: 383-1970** that are zone I, zone II, zone III and zone IV. The grading zones become finer from grading zone I to grading zone IV. The sand confirming to **zone II** was used in this study shown in Figure-3.2. The properties of fine aggregates such as specific gravity and fineness modulus were determined and are given in the next chapter.

3.2.3. Used Aggregate in Concrete

The main source of used concrete aggregate was demolished structures waste concrete mainly the slabs, columns and beams which were free from any reinforcement or other contaminants, cubes from this material were casted and tested in the laboratory. The local crushing plants were not able to crush the concrete waste and thus the crushing and sieving had to be done manually. The demolished waste concrete (Fig 3.3) were broken initially manually and then sieving was done using IS sieves. The process produced, used concrete aggregate of sizes 10.

3.2.4. Potable Water

For making of our cement concrete mixture we use potable water i.e. the water which is use to drinking purpose.

3.3. METHODLOGY ADOPTED

The main aim was achieved through the following objectives:

1. To study the influence of recyclable materials on fresh and hardened concrete properties.
2. To determine the optimum recyclable materials to cement ratio which can be used in concrete mix?
3. To examine the effect of recyclable materials on interlock brick properties as an example of non-structural elements made with recyclable materials concrete.
4. To assess the environmental safety and the stability of incorporating recyclable materials in concrete mixtures.
5. An integrated approach is required in an attempt to manage such large quantities of a diverse, contaminated mixture of plastics in an energy efficient and environmentally benign manner. This would require examining critically various steps in the life of the plastics such as the raw materials for their manufacture, the manufacturing processes, design and fabrication of the finished products, possible reuse of those items, and

the proper disposal of the wastes, in totality. Such an integrated waste management concept comprises:

A. Source reduction;
B. Reuse;
C. Recycling;
D. Landfill and
E. waste-to-energy conversion.

4. EXPERIMENTAL WORK

4.1. Casting of Concrete Cubes

Proportioning of concrete

Before having any concrete mixing, the selection of materials and their proportion must be determined through mix design. There are various methods to determine concrete mix design. Five batches of mixtures were determined in our thesis.

The initial mix batch is using 100% natural aggregate and then we use four different mixes prepared using variable percentage of used aggregate in the mixture.

First batch of the mix called a control mixture used only natural aggregate and four successive mixtures with increasing percentage of used aggregate corresponding decrease of natural aggregate from 25% to 100% by weight. All these mixtures were prepared with cement and aggregate in the proportion by weight, and were expected to achieve a target compressive strength. The Table no. 5.1 shows the various prepared mixtures of cement concrete.

Table 4.1 Percentage of aggregate used in all 5 batches of mixes

Material	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5
Natural Aggregate (%)	100	75	50	25	0
Used Aggregate (%)	0	25	50	75	100

4.2. Water Absorption test for both types of aggregate

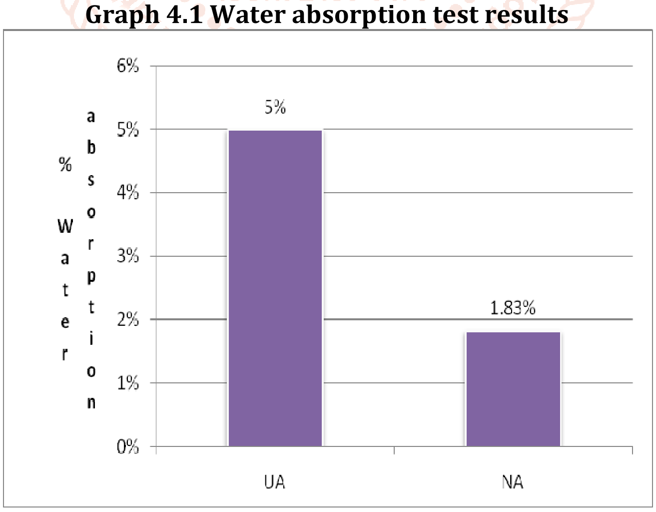
Water absorption is the amount of moisture absorbed by the aggregate. The water absorption capacity is based on saturated surface dry condition and oven dried condition. The amount of water in a concrete mix has direct effect on the setting time and compressive strength of concrete. Moisture content of the aggregate has to determine first before preparing a mix for a particular aggregate. Before making mix either the aggregate has to be moistened to surface dry condition or extra water as per the percentage, has to be added to the mix.

The water absorption capacity of used aggregate is higher than natural aggregate. The average water absorption of used aggregate is around 5.0%, but water absorption of natural aggregate is only 1.83 %.This shows that water absorption of used aggregate is around 2.5 times of natural aggregate. This result shows that more water needed to be added when using used aggregate in the concrete mixing to get an acceptable workability.

Table 4.2 Water Absorption Test

S. No.	Details	UAC	NA
1)	Wt. of empty Container = W1	2.0	2.0
2)	Wt. of soaked aggregate + Container = W2	3.4	4.3
3)	Wt. of oven dried aggregate + Wt. of container = W3	1.93	1.958
4)	% Water absorption = (W1-W3/W2-W1)*100	5%	1.83%

Graph 4.1 Water absorption test results



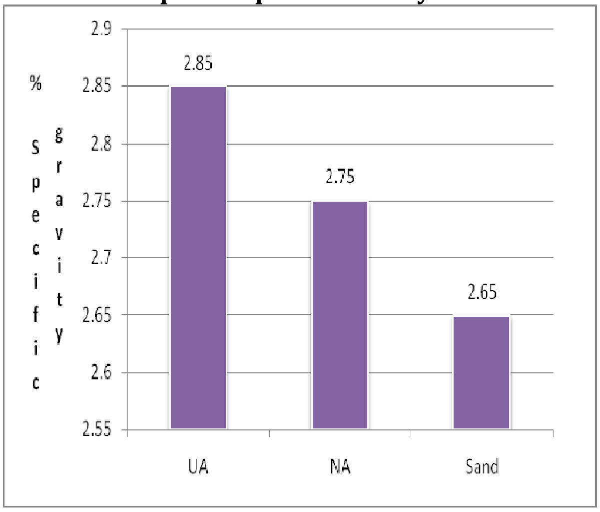
4.3. Specific Gravity test

The specific gravity of natural aggregate is around 2.75 and used aggregate is having 2.85 this means that the used aggregate is stronger than the natural aggregate in this case. Fine aggregate is having the specific gravity value of 2.65.

Table 4.3 Specific Gravity test

S. No.	Details	UAC	NA	Sand
1)	Wt. of empty Pycnometer =W1	0.644 kg	0.644 kg	0.644kg
2)	Wt. of Pycnometer + aggregate/sand =W2	0.844 kg	0.848 kg	0.848kg
3)	Wt. of Pycnometer + aggregate + Water =W3	1.632 kg	1.632 kg	1.629kg
4)	Wt. of Pycnometer + Water = W4	1.502 kg	1.502 kg	1.502kg
5)	Specific Gravity=(W2-W1)/(W2-W1)-(W3-W4)	2.85	2.75	2.65

Graph 4.2 Specific Gravity test



4.4. Aggregate Crushing Value and Impact Value

From the result of crushing value we come to know that the used aggregate is having less resistance to the wear and tear than the natural aggregate. Impact test is the good indicator of strength and durability from the test result we can say that natural and used aggregate are having very less difference in impact and crushing value, which again shows that rock of used aggregate can also used as natural aggregate.

Table 4.4 Aggregate Crushing Value Test

Sample	Total Wt. of dry sample (W1)	Weight of fine passing 2.36mm IS sieve (W2)	Aggregate crushing Value = (W2/W1)*100
Used Aggregate Concrete (UAC)	4 kg	0.90kg	22.50 %
Natural Aggregate (NA)	4 kg	0.814kg	20.02 %

Graph 4.3 Aggregate crushing value test results

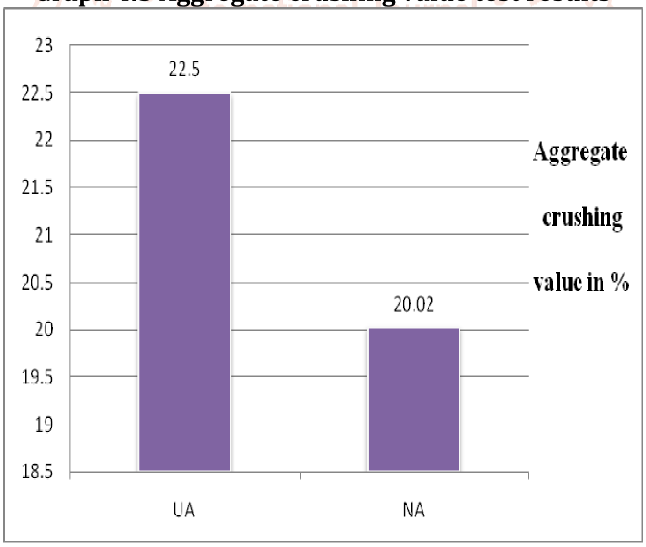
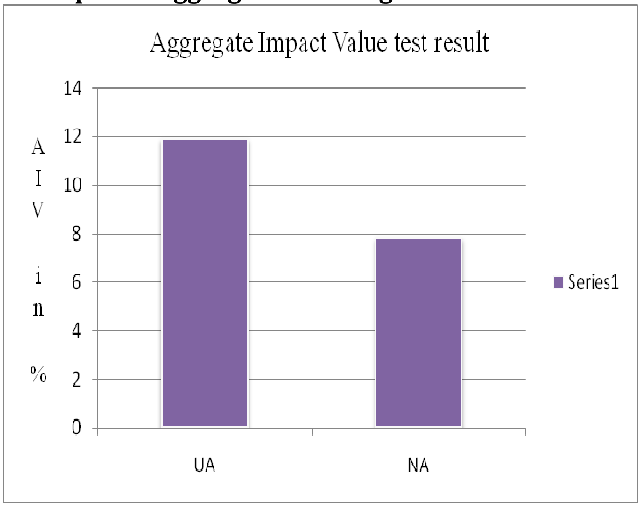


Table 4.5 Aggregate Impact Value (AIV) test results

S. No.	Details	UAC			NA		
		Trial1 (kg)	Trail2 (kg)	Avg. (kg)	Trial1 (kg)	Trail2 (kg)	Avg. (kg)
1)	Total wt. of aggregate sample filling the cylindrical measure= W1	0.546	0.576	11.89%	0.625	0.630	7.81%
2)	Wt. of aggregate passing 2.36mm sieve after the test= W2	0.068	0.060		0.056	0.040	
3)	Wt. of aggregates retained on 2.36 mm sieve after the test = W3	0.478	0.516		0.569	0.590	
4)	Aggregate impact value= (W2/W1)*100	12.45%	10.41%		8.96%	6.66%	

Graph 4.4 Aggregate crushing value test results



5. TEST RESULTS AND ANALYSIS

5.1. Introduction

Series of tests were carried out on materials, fresh and hardened concrete to obtain the strength characteristics of Used Aggregate for potential application as a structural concrete. The results for material test like water absorption, specific gravity, aggregate crushing value and aggregate impact value test are given in Table 5.1. Test results on fresh concrete are arranged in Table 5.2. Compressive strength of hardened concrete is presented in Table 5.3.

Table 5.1 Final result of all tests on Materials

S. No.	Particulars	Natural Aggregate	Used Aggregate	Sand
1	Water Absorption	1.83 %	5 %	-
2	Specific gravity	2.75	2.85	2.65
3	Agg. Crushing value	20.02 %	22.50 %	-
4	Agg. Impact value	7.81%	11.89%	-

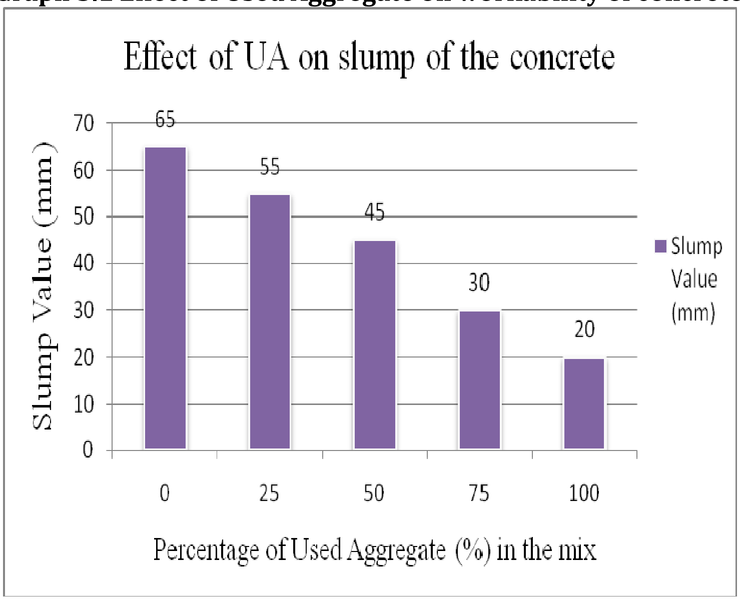
5.2. Slump cone test result and analysis

The slump test indicates a decreasing trend of workability when the percentage of used aggregate increased. Table 5.2 below shows the average slump recorded during the test. Graph 5.1 below shows a graphical representation of slump height.

Table 5.2 The Slump cone test result for each batch of mix concrete

Percentage of Used Aggregate (%)	Water / Cement ratio	Slump (mm)
0	0.55	65
25	0.55	55
50	0.55	45
75	0.55	30
100	0.55	20

Graph 5.1 Effect of Used Aggregate on workability of concrete



According to the result, the highest slump obtained was 65 mm and the lowest slump was 20 mm. From the result it indicates that the workability was tending to harshness with increase in replacement with Used Aggregate because used aggregate are more porous as compared to conventional or natural aggregate.

5.3. Compressive strength test result and analysis

The compression test by CTM (Compressive Testing machine) indicates an increasing trend of compressive strength with age of the concrete specimens. However, it shows that the strength of used aggregate specimens is lower than natural aggregate specimens.

Table 5.3 Variation in compressive strength (Kg/cm^2) with age

% of UA	0 %	25 %	50 %	75 %	100%
7 DAYS	160 kg/cm^2	150 kg/cm^2	145 kg/cm^2	140 kg/cm^2	135 kg/cm^2
28 DAYS	250 kg/cm^2	240 kg/cm^2	235 kg/cm^2	230 kg/cm^2	225 kg/cm^2

5.4. Summary

The experimental results show that increasing the percentage of Used Aggregate influence adversely the properties of fresh and hardened concrete. As the percentage of the Used Aggregate increased, the workability and compressive strength of the concrete decreased so to overcome from this situation we should use superplasticizer in the mixes to improve the workability and the compressive strength of the mix.

6. CONCLUSION AND RECOMMENDATION FOR FUTURE WORK

6.1. Conclusion

These experimental test results indicates that as the percentage of Natural Aggregate decreases by replacing the Used Aggregate, the corresponding compressive strength goes on decreasing, however up to 50% replacement it reduces less compressive strength. Hence, for structural concrete natural aggregate can be replaced by the used aggregate up to 50% limit. The other property like workability of concrete considerably reduces as the amount of used aggregate increases.

This thesis work was targeted to determine the strength characteristics of used aggregate concrete for the potential application in the structural concrete.

One thing should always keep in the mind while using used aggregate that water content in the concrete mix has to be monitored carefully, because used aggregate absorb more water than natural aggregate by this cause it reduces the compressive strength of the mix.

6.2. Future Scope

Further testing and studies on the Used Aggregate Concrete are highly recommended to indicate the strength characteristics for application in the structural concrete. Here are some of the recommendations for further research in this field:

1. The effect of admixtures such as water reducer, accelerator and silica fume can be check to improve the workability of Used Aggregate Concrete.
2. The effect of nylon fiber on the compressive strength of Used Aggregate Concrete can be determined.
3. The effect of waste rubber with their variable percentage on the compressive strength of Used Aggregate Concrete can be determined.
4. The effect of stone dust on the various properties of Used Aggregate Concrete can also be determined.
5. The effect of used aggregate on conventional concrete with proportion like 5 % U.A. + 95 % N.A., 10 % U. A. + 90 % NA etc could also be study.
6. To overcome the problem of water content one should use the super plasticizer in the concrete mix for prominent results.

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