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Analysis of Overburned Brick in Concrete as a Coarse Aggregate

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ABSTRACT: *The research was conducted to study the possibility of utilizing the crushed over burnt brick as an aggregate that can be used in the place of natural stone aggregate. The compressive strength of the concrete is the major concern of this study by replacing the natural aggregate through crushed over-burnt brick aggregate. Trial mixes were prepared using the crushed over burnt bricks in place of coarse aggregates for M20 concrete to study the compressive strength parameters. The result of 28 days compressive strength of natural stone aggregate concrete at 0.45 and 0.5 water-cement ratio has 21.9 MPa and 20.2 MPa respectively. Similarly, the result of 28 days compressive strength of crushed over-burnt brick aggregate concrete at 0.45 and 0.5 water-cement ratio has 24.9 MPa and 22.4 MPa respectively. The result of partial replacement of natural stone aggregate by crushed over-burnt brick aggregate indicates that there has the significant increment on compressive strength of concrete. The result also specified that due to the decrement of water-cement ratio there have the increment in compressive strength of concrete. Based on the research data the use of crushed over burnt brick coarse aggregate for structural concrete has strongly recommended.*

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I. INTRODUCTION

1.1 Background

Concrete is the most widely used construction material for the development of different infrastructures project. Due to required strength properties, long life and sustainability the use of concrete is increasing day by day but for effective utilization of concrete, the required properties has changed along with technological advancement. Generally, concrete is prepared by mixing cement, fine aggregate, coarse aggregate, and water in required proportions. Concrete is a composite construction material composed of coarse granular material embedded in a hard matrix of material that fills the space among the aggregate particles and binds them together. These days the properties of aggregate has improved by using appropriate use of admixtures. Concrete is widely used for making architectural structures, civil structures like foundation construction, retaining structures, pavement construction, highways, runways, parking structures , dam construction, reservoirs formation, pipes and poles. Concrete technology was introduced by Romans and was widely used within roman Empire-Colosseum is largely built of concrete and the concrete dome of the Pantheon is the world's largest structure. After the Empire, use of concrete became inadequate until the mid-18th century. The famous concrete structures include like Burj Khalifa (world's tallest building), Hoover Dam, the Panama Canal were constructed by concrete.

The basic ingredients of concrete are cement, fine aggregate, coarse aggregate and water. In simplest form, concrete is a mixture of cement binder, aggregate, sand with water. The paste, composed of Portland cement and water, coats the surface of the fine and coarse aggregates.Through a chemical reaction called hydration, the paste hardens and gains strength to form the rock-like mass known as concrete.Within this process lies the key to a remarkable trait of concrete: it is plastic and malleable when newly mixed, strong and durable when hardened.

The key and major material for the concrete production is the aggregate that leads the total volume of the concrete. Aggregates impart higher volume stability and better durability than hydrated cement paste in concrete leads the economy of the concrete.The type and size of the aggregate mixture depends on the thickness and purpose of the final concrete product. Due to the limited source of aggregate production, it is assumed that there may be the scarcity of aggregate for the production of concrete. The increasing rate of concrete consumption and limited natural resources of aggregate mining it is the time to think on the alternate material for the production of concrete. The high value of soil around the globe provides that it be used as aggregate production by proper technological advancement i.e. using over-burnt brick as an aggregate.

The water is also the influencing ingredient for the concrete manufacturing and development. Almost any natural water that is drinkable and has no pronounced taste or odor may be used as mixing water for concrete. Excessive impurities in mixing water not only may affect setting time and concrete strength, but also may cause efflorescence, staining, corrosion of reinforcement, volume instability, and reduced durability.

Supplementary cementing materials, also called mineral admixtures, contribute to the properties of hardened concrete through pozzolanic activity. Typical examples are natural pozzolans, fly ash, ground granulated blast-furnace slag, and silica fume, which have used individually with Portland cement or in different combinations. These materials react chemically with calcium hydroxide released from the hydration of Portland cement to form cement compounds. These materials often added to concrete to make concrete mixtures more economical, reduce permeability, increase strength, or influence other concrete properties. The proper use of all these materials provides the consistent material for the construction of different civil engineering infrastructures.

1.2 Statement of the problem:

Rapid increase in construction activities leads to shortage of conventional construction materials in the various regions of the globe. Concrete is most widely used construction material for different infrastructure development. Researches are inventing for cheaper materials that can be used as substitute for these materials. In this context an experimental study carried out to find the suitability of the alternate construction materials such as, rice husk ash and over burnt brick aggregate as a partial or fully replacement for cement and conventional aggregates. In Nepal, bricks can be produced in the large scale and are easily available and much reliable material as crushed stone aggregate. Among the wastage or over burned bricks would help in the protection of environment as well as replaced of stone aggregate by over burned brick aggregate may yield cost-effectiveness in making concrete structure through quarrying would be significantly reduced.

1.3 Objective of the study:

The objectives of the studyare:

(i) To analysisthe compressive strength of crushed over burnt brick aggregate concrete.

(ii) To compare the compressive strength of natural stone aggregate with over burnt brick aggregate at different proportion.

1.4 Significant of the study:

We know that the source of stone aggregate is constant but the materials have quarried day by day that will result in the decrement of stone aggregate. After some decades, natural rock deposits will be scarce, burnt-clay bricks will be an alternative source of coarse aggregate. The construction of rigid pavement, small-to medium-span bridges and culverts and buildings up to six stories high using crushed brick concrete is quite common. In Nepal, bricks can be produced in the large scale and are easily available and much reliable material as crushed stone aggregate. Due to the fewer unit weight of brick aggregate concrete has reported to be much lighter than that of stone aggregate concrete. The use of brick aggregate instead of stone aggregate in various components of a building structure can result in a significant reduction of dead load on column as well as foundation. Hence, the replacement (partly or fully) of stone aggregate by brick aggregate may yield cost-effectiveness in making concrete structure.

1.5 Operational Definitions and Assumptions

The concrete design mix is the basic requirement of this research. The research has been done on M20 concrete using locally available aggregate and over burnt brick of Nepal. The design mix is prepared as per the properties of different constituents of concrete. The design mix is constant and the water-cement ratio has varied considering the natural aggregate has replaced partially or fully.

II. LITERATURE REVIEW

The demand of infrastructure construction for the country like Nepal is essential part of the development. The construction of road, bridges, hydropower, tunnel, buildings, and airport are in primary demand list. We can found the following uses of concrete in infrastructure development.

Uses of Concrete:

- While approaching from the street, our driveway is the first thing we notice that it is made up of concrete.
- Our sidewalk is the next thing we see that is made up of concrete.
- Upon entering the house, our friends become impressed by the look of the decorative concrete flooring in our entryway. We appreciate the ease of cleaning and maintenance.
- In the living room, we are thoroughly impressed by the fireplace surround constructed entirely of concrete.
- Moving to the kitchen, we are stricken by the uniqueness of the concrete countertops that perfectly complement our home’s decor.

- While having cocktails in your basement bar, we all marvel at the concrete bar top and acid stained floor.
- After a couple of eating, we point the direction to the washroom. Our guests are in awe of the shower and vanity top with an integral sink.
- After dinner and washing, we retire to our new backyard patio. It resembles random pieces of flagstone but is, of course, stamped concrete.
- In fact, we enjoy our (nearly) maintenance-free backyard so much that we were considering adding a swimming pool. Then your home would be like your own private resort. For comfort and appearance, you wouldnot dream of having the pool deck built of anything but decorative concrete.
- Because your guests have all been so enamored with your amazing concrete, at the end of the evening we cannot resist showing them out through the garage. The stained & polished concrete floor make your garage and workshop look like a showroom.
- The major structures like beam, column, basement, and slab are of course made up of concrete.
- Concrete spring (innovation): the concrete spring has strength of over 200 N/mm2. David Bennett, a consultant on architectural concrete, predicts concrete will overtake plastics and ceramics, with applications such as thin staircases and even telephones.
- Concrete is an integral component in the construction of public transit. Due to its superior strength, durability, versatility, economy, and availability, concrete is commonly used in the construction of transit guideways, subways, stations, maintenance.
- Concrete provides a highly durable, strong, fuel resistant, deformation-free surface, with excellent load-bearing capacity for airport runways and taxiways.
- An alternative concrete product, Roller compacted concrete, or RCC, can also be used for industrial pavements. RCC has the same basic ingredients as conventional concrete, but uses much less water.
- From dams and bridges to commercial and residential buildings and modern agricultural complexes above ground, to culverts, sewers and gray water management systems below ground, concrete structures define our society and make our activities possible.
- Dams may well be the best showcase for how versatile, strong and enduring concrete is as a building material. Depending on the purpose of the dam and the configuration of the site where it will be built, engineers can select the type of cement that has properties uniquely suitable for that use and combine it with the correct type of aggregate to create the best concrete for the situation.
- High Performance Concrete (HPC) is used to build bridges of superior durability and low maintenance that stand up to harsh weather and corrosive chemicals.
- Concrete once again turns out to be best suited for drainage and pollution control applications. Not only does concrete pipe meet hydraulic and structural design criteria, but also it is superior in performance, durability and service life.
- Concrete can be delivered to site as precast units that have been made in a factory. This facilitates greater quality control in producing the product, and a more consistent material. Precast units can range from beams and slabs to entire housing units.

Overburnt brick aggregate is the alternate sources of material in concrete in place of stone aggregate. So we can test the basic charecteristics of concrete by using the over burnt brick as aggregate. The following properties are essential part of the study to determine the quality of concrete.

Consistency of concrete: The concrete slump test is an empirical test that measures the workability of fresh concrete. More specifically, it measures the consistency of the concrete in that specific batch. This test has performed to check the consistency of freshly made concrete. It refers to the ease with which the concrete flows. It is used to indicate the degree of wetness. Workability of concrete has mainly affected by consistency i.e. wetter mixes will be more workable than drier mixes, but concrete of the same consistency may vary in workability. The IS standard can be adopted for the conformation of concrete performance on consistency. According to European Standard EN 206-1:2000 five classes of slump have designated, as tabulated below:

SLUMP CLASS	SLUMP IN MM
S1	10 – 40
S2	50 – 90
S3	100 – 150
S4	160-210
S5	≥220

Density of concrete: The unit weight of concrete has primarily affected by the unit weight of the aggregate, which varies by geographical location and increases with concrete compressive strength depending on the added pozzolans. The density of concrete normal strength Portland cement lies between 2240 - 2400 kg/m^3.

Compressive strength of concrete: A concrete mixture has designed to provide a wide range of mechanical and durability properties to meet the design requirements of a structure. The compressive strength of the concrete is the most common performance measure used bythe engineer in designing buildings and other structures.The compressive strength is measured by breaking specified (cubes, prism or cylinder) concrete specimens in a compression-testing machine.The compressive strength has calculated from the failure load divided by the cross-sectional area resisting the load and reported in Mega-pascal (MPa) in SI units. Concrete compressive strength requirements can vary from 17 MPa for residential concrete to 28 Mpa and higher in commercial structures. Higher strengths up to and exceeding 70 MPa has specified for certain applications.Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test, one can judge that whether concrete withstand the design loading or not. For cube test two types of specimens, both cubes of 15×15×15 cm.The designed proportion of cement, sand, aggregate and water has poured in the mould. After 24 hours, these moulds are removed and test specimens are put in water for curing. The top surface of these specimens should have made even and smooth. These specimens are tested by compression testing machine after 7 days curing, 14 days curing, or 28 days curing. Load should be applied gradually until the specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Gradation of Aggregate: Sieve Analysis (or Dry Mechanical Analysis) is the method of grading of the construction material (aggregate). It has called particle size distribution of aggregate. The aggregate can be graded as: well graded, poorly graded and gap graded.For the construction purpose,well-graded material either for fine aggregate or for coarse aggregate is preferred as it consist almost all size of grains and gives compact or dense concrete. However, poorly graded aggregate consist same size of grains, so it has not considered as a good materials. Whereas gap graded consist the presence of some size of particles.

Aggregate Impact Value: This test is done to determine the aggregate impact value of coarse aggregates as per IS 2386 (Part IV) – 1963. The aggregate impact value has calculated by the ratio of weight retained in 2.36 mm sieve and total weight of sample expressed in the percentage.

Aggregate Crushing Value: This test helps to determine the aggregate crushing value of coarse aggregates as per IS 2386 (Part IV) – 1963. The aggregate impact value has calculated by the ratio of weight retained in 2.36 mm sieve and total weight of sample expressed in the percentage.

For lower strength, concrete production the alternate construction material can be used. However, due to the lack of research activity and data it is impossible to use the over-burnt brick as an aggregate.In developing countries, numbers of bricks (approximately 13%) are severely over-burnt due to the uncontrolled distribution of temperature in the kiln (1). These bricks have considered as useless and has not allowed in construction purpose. Nevertheless, different studies around the globe considered that these bricks can be utilized in the production of concrete for construction purpose. The different properties of concrete using partial and full content of over-burnt brick coarse aggregate indicates that the use of over-burnt brick aggregate in concrete production is useful (2).Experimental investigation has done to achieve higher strength concrete using crushed brick aggregate. It has found that even recycled brick has used as coarse aggregate in concrete. The research showed that concrete can be successfully produced by using recycled aggregates that have been produced from demolition and construction waste (3).Some investigation indicates the properties of higher strength concrete made with crushed brick as coarse aggregate and found that higher strength concrete (fcu = 31.0 to 45.5 N/mm^2) with brick aggregate is achievable whose strength is much higher than the parent uncrushed brick (4).

It was found that the unit weight of the crushed brick concrete ranged from (1685-1760) kg/m3 and its compressive strength was about 61% of that of the natural aggregate concrete while the flexural strength was 70% of natural aggregate concrete (5).The use of brick aggregate as a replacement of stone aggregate resulted reductions in unit weight, compressive strength, and modulus of elasticity of concrete by about 14.5%, 33%, and 28% respectively. Different relations for determination of compressive strength, splitting tensile strength, and modulus of elasticity of mix-aggregate concrete have been tentatively proposed (6). The measured compressive strength of the cubes shall be calculated by dividing the maximum load applied to the cubes during the test by the cross-sectional area, calculated from the mean dimensions of the section and shall be expressed to the nearest 0’5 N/mm^2(7). The shape of the coarse aggregate particles does not directly enter the relation because, for instance, a crushed aggregate as a greater bulk volume for the same mass (that is, a lower bulk density) than a well-rounded aggregate (8).

Use of broken over burnt bricks as coarse aggregate for structural concrete is recommended when natural aggregate is not easily available, high strength of concrete is not required and the bearing capacity of the soil is low.The research was conducted to study the suitability of crushed over burnt bricks as alternative coarse aggregates for concrete production. Tests were carried out to determine the physical properties of the crushed over burnt bricks aggregates. Values of 22.8%, 28.2% and 4.4% were obtained for aggregate crushing value, aggregate impact value and aggregate water absorption respectively. The concrete mixes were prepared using crushed over burnt bricks as coarse aggregates at water – cement ratios of 0.40, 0.50, 0.55 and 0.60. Cubes of concrete were prepared and tested to study the compressive strength. The results were compared with concrete made with river wash gravel as coarse aggregates which at present is the only coarse aggregate in Makurdi, Nigeria and its environs. The results indicate that crushed over burnt bricks – sand concrete is medium light weight concrete having a density between 2000-2200 kg/m^3 and compressive strength of up to 29.5 N/mm^2 compared to grave l – sand concrete having density between 2300-2400 kg/m^3 and compressive strength of up to 30.8 N/mm^2. It can be concluded that by reducing the water-cement ratio from 0.60 to 0.40 the compressive strength of crushed over burnt bricks – sand concrete and gravel – sand concrete increase by more than 30%(9).

III. RESEARCH METHODOLOGY

3.1 Research Design and Study Variables:

The purpose of this study is to evaluate the compressive strength of the concrete at different proportion of stone aggregate and over-burnt brick aggregate as coarse aggregate of locally available materials from Nepal. The design mix is prepared as per standard norms for M20 (1:1.57:2.93) concrete. The cube test has adopted for the compressive strength test of concrete. The stone aggregate has replaced partially or fully with over burnt brick aggregate of different size and proportion as per the norms. The replacement of stone aggregate has aimed as 0%, 10%, 25%, 50%, 75%, and 100%. For this at least 9 numbers of concrete cubes should be prepared for each proportion. The physical and mechanical properties of each proportion should be tested and examined. The compressive strength of each proportion have estimated and examined for 7, 14, and 28 days of curing.

3.2 Study Area:

There is no specific study area for the research though Kotre, Tanahun stone quarry site has chosen for the stone aggregate and Janune, Tanahun has chosen for the over burnt brick aggregate. The overall research has conducted in the university premises and reliable laboratories for testing.

3.3 Limitations/ Exclusion and Inclusion Criteria

The following are the limitations of the research:

- The sample has prepared only for one design mix M20 and its proportion. For data that are more reliable the design mix has done for design mix and proportion.
- The lack of well-equipped laboratory for the testing (Control of Temperature and Humidity)
- Source of bricks (only Jamune and Kotre is taken as the source of over burnt brick aggregate and stone aggregate)
- Manufacturing of over burnt brick (special order should be given for the manufacturing)
- Limited time period for research work

3.4 Sample Size and Sampling Procedure / Materials Used:

Sample size: The major test has conducted based on the standard norms and specification provided in the codes. This is the laboratory-based research work. Therefore, the data are produced from laboratory testing.

The following are the material used and final product of the research work:

Cement: In the most general sense of the word, cement is a binder, a substance that sets and hardens independently, and can bind other materials together.

Aggregate: Construction aggregate, or simply "aggregate", is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geo-synthetic aggregates. The sand and gravel are used in concrete production.

Water: Combining water with a cementations material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and makes it flow more freely.

3.5 Data Collection tools/ Techniques/ Methods:

The research is purely laboratory based and utilizes the primary data obtained during the testing procedure. The tests on cement, aggregate and concrete had adopted in the laboratory. The test has conducted based on the standard norms and specifications and hence the results have compared on the limit provided on the standard norms and specifications.

3.6 Validity and reliability:

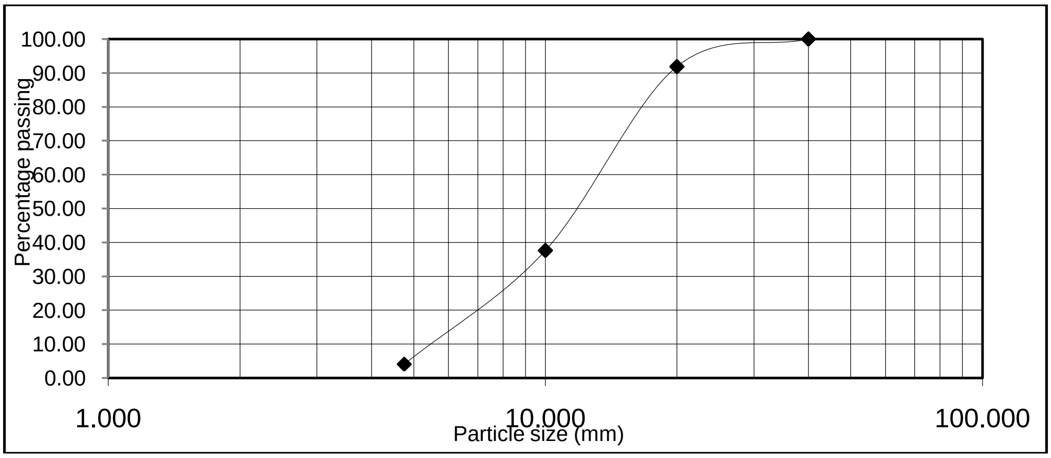
The research data has compared based on the standard data developed by IS code and compared with other similar research conducted by different researchers. The testing equipmentare well tested and calibrated in line with standard provided by British and Indian guidelines. Such equipment data has found close to standard and hence the data obtained from testing are reliable and valid.

IV. RESULTS AND DISCUSSIONS

Sieve analysis of the particle size distribution of over-burnt brick aggregate hascarried out in accordance with IS (20mm down) has presented below. The assessment of the particle size distribution revealed that the aggregate is well graded. The size of sieve is based on the specification provided for building construction.

S/N	Sieve Size (mm)	Weight Retained (gms.)	% Retained	% Passing	Specification		Remarks
					Upper Limit	Lower Limit	
1	40	0.00	0.00	100.00	100	100	
2	20	648.00	8.10	91.90	100	95	
3	10	4345.00	54.31	37.59	55	25	
4	4.75	2679.00	33.49	4.10	10	0	
5	Pan	328.00	4.10	0.00			
	Total	**8000.00**		233.59			
	FM			**2.34**			%

Table 1: Sieve analysis



Graph 1: Grading of aggregate

Test result for cement:

S/N	Physical Properties	Value	IS Requirement
1	Specific Gravity	3.14	3.15
2	Consistency, %	30	26-33%
3	Initial Setting Time, Minute	40	30 Minutes
4	Final Setting Time, Minute	720	600 Minutes
5	Fineness of Cement, %	9.5	10%

Table 2: Physical properties test of cement

The presented result indicates that the initial and final setting time of cement is not within the specified limit because the cement is not fresh one. The specific gravity and the consistency value are in specified limit.

Test result for fine aggregate:

S/N	Physical Properties	Value	IS Requirement
1	Water absorption, %	1.64	0.1-3%
2	Specific Gravity	2.64	2.4-3.0

Table 3: Physical properties test of fine aggregate

The water absorption limit and the specific gravity of fine aggregate are as per specified limit according as IS.

Test result for coarse aggregate:

S/N	PHYSICAL PROPERTIES	VALUE	IS REQUIREMENT

1	Water absorption, %	1.64	0.1-2%
2	Specific Gravity	2.64	2.4-3.0
3	Abrasion Value, %	31.89	
4	Impact Value, %	23.02	

Table 4: Physical properties test of coarse aggregate

The water absorption limit, the specific gravity, abrasion value and impact value of coarse aggregate are as per specified limit according as IS.

Test result for over-burnt aggregate:

S/N	PHYSICAL PROPERTIES	VALUE	REMARKS
1	Water absorption, %	6.53	Average Value
2	Specific Gravity	2.16	

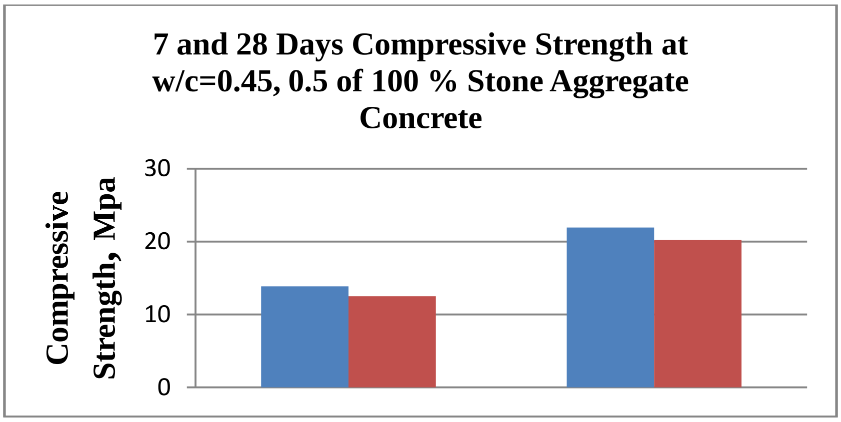
Table 5: Physical properties test of over-burnt brick aggregate

The water absorption limit and the specific gravity of over-burnt brick aggregate are as per specified limit according as IS.

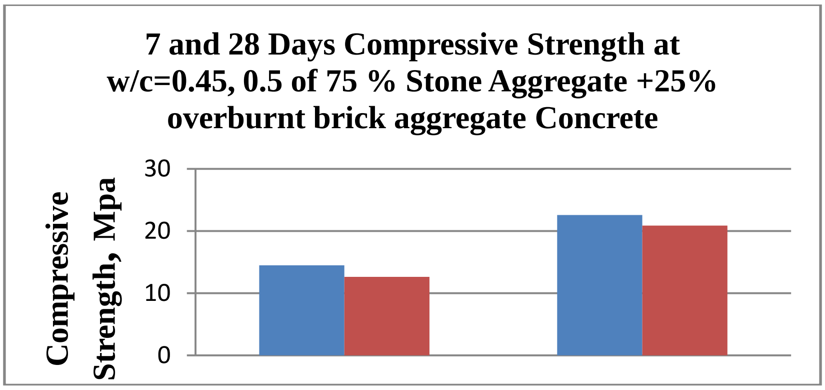
Test result of concrete (M20 of fresh concrete)

S/N	Particular	W/C Ratio	
		0.45	0.50
1	100 % Stone Aggregate		
	Slump Value, mm	35	32
	7 Days' Compressive Strength, MPa	13.9	12.5
	28 Days' Compressive Strength, MPa	21.9	20.2
2	75 % Stone Aggregate+25% Over burnt brick aggregate		
	Slump Value, mm	32	30
	7 Days' Compressive Strength, MPa	14.5	12.6
	28 Days' Compressive Strength, MPa	22.6	20.9
3	50 % Stone Aggregate+50% Over burnt brick aggregate		
	Slump Value, mm	30	29
	7 Days' Compressive Strength, MPa	15	12.6
	28 Days' Compressive Strength, MPa	23	21.2
4	25 % Stone Aggregate+75% Over burnt brick aggregate		
	Slump Value, mm	30	28
	7 Days' Compressive Strength, MPa	15.3	12.7
	28 Days' Compressive Strength, MPa	23.9	21.4
5	100% Over burnt brick aggregate		
	Slump Value, mm	27	25
	7 Days' Compressive Strength, MPa	16.6	12.8
	28 Days' Compressive Strength, MPa	24.9	22.4

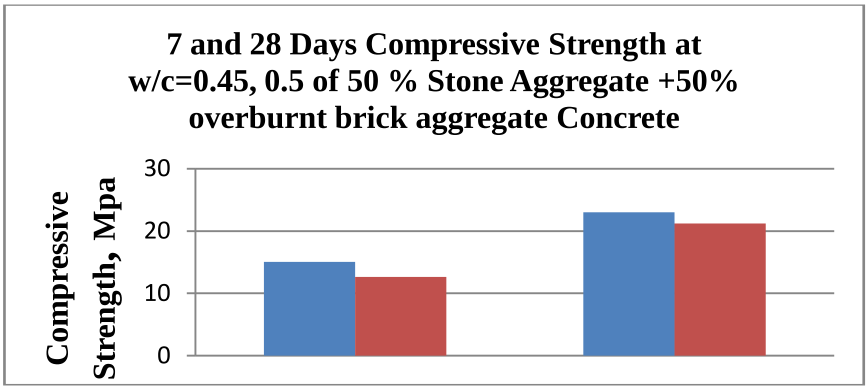
Table 6: Test of compressive strength of concrete



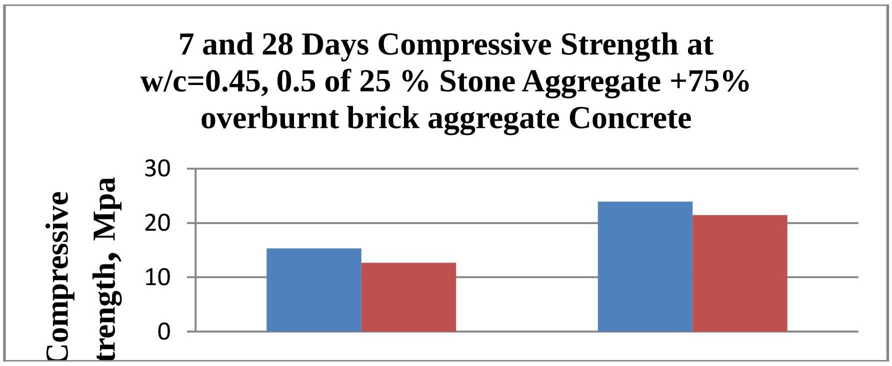
Graph 1: Compressive strength of 100% stone aggregate concrete



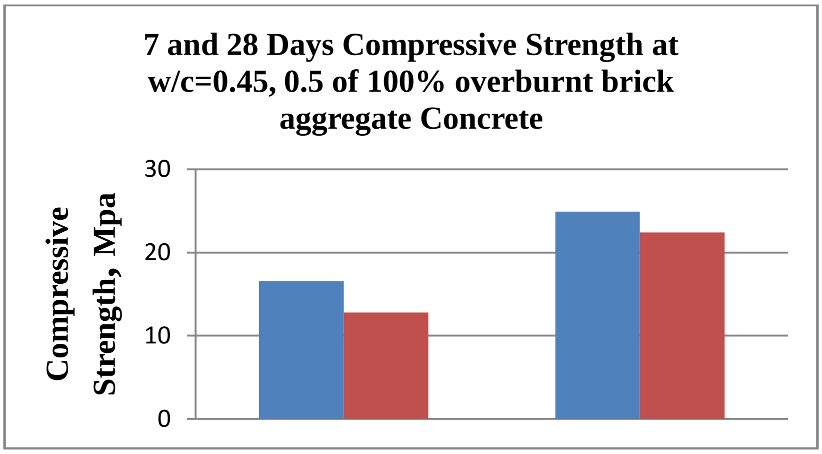
Graph 2: Compressive strength of 75% stone aggregate +25% Over-burnt brick aggregate concrete



Graph 3: Compressive strength of 50% stone aggregate +50% Over-burnt brick aggregate concrete



Graph 4: Compressive strength of 75% stone aggregate +25% Over-burnt brick aggregate concrete



Graph 5: Compressive strength of 100% Over-burnt brick aggregate concrete

V. CONCLUSION

Nepal is developing country and need to build lot of infrastructure by using the massive construction materials. Researcher need to give alternatives of extracted aggregate. The objective of this study was to analysis the compressive strength of crushed over burnt brick aggregate concrete and to compare the compressive strength of natural stone aggregate with over burnt brick aggregate at different proportion. It is concluded the crushed over burnt bricks can be used as replacement for river gravel in concrete production, thetest result of compressive strength of overburnt brick concrete is higher than stone aggregate hence over-burnt brick can be used for the production of low and middle strength concrete. Similarly, the compressive strength of crushed over-burnt brick aggregate concrete has comparatively higher than the normal stone aggregate concrete, Proper grading of crushed over-burnt brick aggregate provides the required compressive strength of concrete with specified water-cement ratio.Increment of over-burnt brick aggregate result in increment of compressive strength of concrete in design mix and the decrement of water-cement ration results in increment in compressive strength of concrete up to specified limit.

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