ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

# Basalt Aggregate as Coarse Aggregate in High Strength Concrete Mixes

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## ABSTRACT

***Concrete technology has been changing rapidly and constantly since its discovery. The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The scope of this work is limited to the development of a suitable mix design to satisfy the requirements of workability and strength of the concrete mix using basalt aggregate as a coarse aggregate. To evaluate the workability of concrete mixes using basalt aggregate as coarse aggregate. To evaluate the strength of hardened concrete using basalt aggregate as coarse aggregate The results of the compressive strength tests will be conducted on the trial mixes containing 0%,25%, 50%,75% and 100% basalt, respectively. The compressive strength will be tested as the percentage of basalt content in the mix is increased. Five mixes were prepared; namely 0% basalt (as a control mix), 25% basalt, 50% basalt, 75% basalt and 100% basalt for each set of design mix. The composition of each mix was 60% coarse aggregate of 20 mm size and 40%coarse aggregate of 10mm size. Fine aggregate confines to zone-I.***

## INTRODUCTION

Cement is the most regularly utilized material as a part of different sorts of development, from the deck of a hovel to a multi storied skyscraper structure from pathway to an airplane terminal runway, from an underground passage and remote ocean stage to skyscraper fireplaces and TV Towers [1]. In the most recent thousand years concrete has requesting prerequisites both as far as specialized execution and economy while extraordinarily differing from building perfect works of art to the least complex of utilities. It is hard to call attention to another material of development which is as adaptable as concrete [2].

Cement is one of the flexible heterogeneous materials, structural building has ever known. With the approach of cement structural designing has touched most noteworthy pinnacle of innovation. Cement is a material with which any shape can be thrown and with any quality. It is the material of decision where quality, execution, strength, impermeability, imperviousness to fire and scraped area resistance are required. It is very much perceived that coarse total assumes a critical part in cement.

Coarse total commonly possesses more than 33% of the volume of cement, and research demonstrates that progressions in coarse total can change the quality and crack properties of cement. To anticipate the conduct of cement under general stacking requires a comprehension of the impacts of total sort, total size, and total substance. This comprehension must be increased through broad testing and perception [3].

There is solid proof that total sort is a component in the quality of cement. Ezeldin and Aitcin (1991) contrasted cements and the same blend extents containing four distinctive coarse total sorts. They inferred that, in high-

**Cite this article as:** M.Satheesh & Dr.K.Rajasekhar, "Basalt Aggregate as Coarse Aggregate in High Strength Concrete Mixes", International Journal & Magazine of Engineering, Technology, Management and Research, Volume 5 Issue 6, 2018, Page 240-247.

quality cements, higher quality coarse totals commonly yield higher compressive qualities, while in typical quality cements; coarse total quality has little impact on compressive quality. Other exploration has looked at the impacts of limestone and basalt on the compressive quality of high-quality cement (Giaccio,Rocco, Violini, Zappitelli, and Zerbino 1992). In cements containing basalt, load incited breaks grew basically at the framework total interface, while in cements containing limestone; about the majority of the coarse total particles were broken. Darwin, Tholen, Idun, and Zuo (1995, 1996) watched that cements containing basalt coarse total showed higher bond qualities with fortifying steel than cements containing lime stone. There is much debate concerning the impacts of coarse total size on cement, mainly about the consequences for crack vitality.

A blend proportioning [4] just gives a beginning blend outline that will must be pretty much altered to meet the fancied solid attributes. Regardless of the way that blend configuration is as yet something of a craftsmanship, it is undeniable that some key investigative standards can be utilized as a premise for computations. Creation of cement and usage of cement has quickly expanded, which brings about expanded utilization of common total as the biggest solid segment. It is all around perceived that coarse total assumes a critical part in cement. Coarse total normally possesses more than 33% of the volume of cement, and research demonstrates that progressions in coarse total can change the quality and break properties of cement. To anticipate the conduct of cement under general stacking requires a comprehension of the impacts of total sort, total size, and total substance. This comprehension must be increased through broad testing and perception. It is standard to utilize limestone totals which are additionally accessible in incredible plenitude.

Basaltic rock totals are like limestone totals in numerous perspectives. Basalt is a hard, thick volcanic molten rock that can be found in many nations over the globe. For a long time, basalt has been utilized as a part of throwing procedure to make tiles and sections for structural applications. Also, cast basalt liners for steel tubing show high scraped area resistance in modern applications [5].

## BASALT AGGREGATE

Basalt is a common extrusive igneous rock formed by the rapid cooling of basaltic lava exposed at or very near the surface of Earth.


Fig: 2.1.Basalt rock

Basalts are dull, dark shaded, fine-grained volcanic rock. The mineral grains of the basalt are fine to the point that they can't bed is tinguished by the stripped eye or even by an amplifying glass. Basalt is the most well-known sort of extrusive volcanic rock and the most widely recognized rock sort at the Earth's surface. Most basalt are volcanic in cause and were framed by the fast cooling and solidifying of the magma streams. Albeit, most basalts are extrusive rocks, cooled at Earth's surface, there are some meddlesome basalts, having cooled inside the Earth's inside. Basalt is low in silica content, and nearly rich in iron and magnesium .Basalts show an assortment of structures for the most part related totheir situations of solidification. Basalt happens as pumice and bombs and in addition magma streams. Basaltic pumice canhave more than 95% porosity. Bombs are generally smooth, round bodies up to around 1 m in width whose normally are split as an aftereffect of extension of the inside material which stays liquid longer than the immediately cooled surface [6].

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The mineralogy and surface of basalts shift with cooling history and with substance creation. With moderate cooling, precious stones develop to vast sizes coming to couple of millimeters.

## COMPOSITION OF BASALTIC AGGREGATES

The principle mineral constituents of basaltic rocks incorporate calcic plagioclase and augite, with various frill minerals deciding their careful obsessive name. In designing terms, these mineralogical contrasts are not generally critical with the exception of in the way they impact adjustment. For instance, olivine is a high temperature mineral and is more defenseless to change than augite. In this way olivine basalt is liable to be more modified than olivine free basalt. Different variables of essentialness to the architect are the varieties in the physical properties of the stone, specifically grain size, surface, porosity, discontinuities and other variety in quality [7]. Commonly the minerals that structure basaltic rocks are lengthened and frame an interlocking system that is held together by the groundmass. In magma, fast cooling may give a microcrystalline or even smooth surface. The resultant rock is hard and has no favored planes of shortcoming. Where polished or microcrystalline minerals frame most of the stone mass, it frequently breaks with a lustrous crack and creates a flaky total. Discontinuities in the stone mass may frame amid the way toward cooling.

## EXTRACTION OF BASALTIC AGGREGATES

Basaltic aggregates may be quarried as a conventional bedrock quarry (usually homogeneous rock type) or dug as gravel from pits (usually heterogeneous material of a variety of rock types). Its composition can vary both within a quarry, a pit and between pits. This affects the overall quality of the aggregate produced [8]. The variation is a reflection of the structure and composition of the original rock and also of its alteration history.

## USE OF BASALT IN ASPHALT CONCRETE MIXES

Basalt is utilized as a part of numerous nations around the globe in interstate and landing strip asphalt development. For instance, in one of the basalt crushers in Poland, the creation limit of the crusher is 1,300,000 tons for every year. Streets represent 70% of this yield. The fine items are utilized as a part of black-top surfacing and the coarse items are usedin the fundamental asphalt layers. Different markets incorporate railroad weight and Rockwool protection .Aggregates utilized as a part of the black-top solid surface layers ought to be more grounded than totals in the lower layers. Surface layers are subjected to high hassles because of activity stacking, and totals are uncovered at the surface, in this way, they require extraordinary properties that are entirely superfluous in the basic asphalt layers [10].

These properties incorporate imperviousness to cleaning and scraped spot by activity, and imperviousness to weathering and substance assault. To these ought to be included the more broad characteristics of satisfactory quality and reasonable reviewing and shape. Hence, for additional solidness, and because of the way that basalt is twice as hard as the limestone total as measured by Mohs hardness test, basalt can be utilized to supplant the coarse total part of the black-top solid surface layers. For black-top cement blends, hard totals, for example, basalt, are alluring in light of the fact that they have a tendency to contain lengthened particles which increment the fine total angularity(FAA) and the blend voids in mineral total (VMA) [9].One hundred percent pulverized and cubical limestone sands produce FAA values in the low forties.

Figure2.4 Protocol of finished lightweight concrete precast wall

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## LIGHT WEIGHT AGGREGATE CONCRETE

In the late years inferable from the gigantic advancement in the development business, the utilization of total of the sum total of what sorts have been expanding impressively. At that point the expense of falsely made total is more, the general expense is less as the transportation and taking care of expense is less. The utilization of falsely delivered total is urged inferable from financial and biological issues of humanity .Light weight total can be comprehensively arranged in the two classifications in particular characteristic Light weight total and counterfeit light weight total [11].

## HIGH STRENGTH CONCRETE

As of late there has been extensive thoughtfulness regarding the generation what's more, utilization of high quality focus, quality more noteworthy than 48Mpa at 28 days (14 ). This kind of solid which is a specific case of consolidated viable utilization of different admixtures and water diminishing admixtures has discovered application in the section of elevated structure. For high quality cements fly cinder prompts extended quality at later periods of curing which can't be accomplished using additional Portland concrete [7-9].

## MATERIALS

The material utilized as a part of the test examination incorporate

1. 53 evaluation Bharathi common Portland cement (opc)
2. Aggregate

A) Fine total

B) Coarse total

3. Water
4. Basalt Aggregate

### Compressive Strength

Compression test is done as per IS 516-1959. All the concrete specimens were tested in a 2000KN capacity compression-testing machine. Concrete cubes of size 15mm x 15mm x15mm are tested for crushing strength;crushing strength of concrete is determined by applying load at the rate of 140kg/sq.cm/minute until the specimens failed [10]. The maximum load applied to the specimens has been recorded and dividing the failure load by the area of the specimen the compressive strength has been calculated. Variations of the compressive strength with various variables studied are examined. The 2000KN capacity compression-testing machine with specimen.

$$\text{Compressive strength} = \frac{Load}{Area} \text{ in N/mm}^2$$

## SPLIT TENSILE STRENGTH

This test is conducted in a 2000KN capacity compression-testing machine by placing the cylindrical specimen horizontally direction, so that its axis is horizontal between the plate's of the testing machine. Narrow strips of the packing material i.e., ply wood is placed between the plates and the cylinder, to receive compressive stress [11]. The load is applied uniformly at a constant rate until failure by splitting along the vertical diameter takes place. Load at which the specimens failed is recorded and the splitting tensile stress is obtained using the formula based on IS 5816-1970. The splitting of cylinder.

The following relation is used to find out the split tensile strength of the concrete.

$$F_t = \frac{2p}{\pi DL} \text{ in N/mm}^2$$

Where $p$ = Compressive load on the cylinder

L = Length of the cylinder

D = Diameter of the cylinder

## RESULTS

The purpose of this research is to investigate the feasibility of using basalt aggregates in concrete mixes. The researcher has designed an elaborate experimental program that included a variation of basalt percentages in concrete mixes. The laboratory investigation included measurements of compressive strength, indirect tensile strength, flexural strength,. Two different sets of specimens are prepared using design mixes M50 and M60 for each set respectively .In each set, the specimens are casted by varying the percentage of replacement of coarse aggregate (limestone) with basalt aggregate starting from 0 to 100%with an increment of 25% by weight of coarse aggregate and they are represented as0%,25%,50%,75%,100% respectively. In the second set, the former procedure is followed; in addition to that mineral admixture of 7.7% by weight of cementis replaced. Cubes with size 150mm X150mm X150 mm, are prepared.

## COMPRESSIVE STRENGTH TEST RESULTS (M 50)

This test was performed according to the British Standard (B.S. 1881, part 3).Table5 to table 8 and Figure 2 show the results of the compressive strength tests that were conducted on the trial mixes containing 0%,25%, 50%,75% and 100%basalt, respectively. In general, the compressive Strength increased as the percentage of basalt contentin the mix is increased.

### Table 4.1 3 days compressive strength test results for M 50 grade concrete mix in N/mm$^2$

| Specimen | 0% basalt | | 25% basalt | | 50% basalt | | 75% basalt | | 100% basalt | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load |
| 1 | 28 | | 32.56 | | 34.66 | | 38.33 | | 40.66 | |
| 2 | 30.45 | **29.81** | 33.25 | **33.39** | 36.55 | **36.10** | 40.88 | **39.88** | 42.11 | **42.18** |
| 3 | 31.00 | | 34.36 | | 37.11 | | 40.44 | | 43.77 | |

### Table: 4.2 7 days compressive strength test results for M 50 grade concrete mix in N/mm$^2$

| Specimen | 0% basalt | | 25% basalt | | 50% basalt | | 75% basalt | | 100% basalt | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load |
| 1 | 39.83 | | 40.26 | | 41.25 | | 42.15 | | 42.98 | |
| 2 | 40.56 | **40.86** | 41.25 | **41.58** | 43.56 | **42.35** | 42.28 | **43.09** | 45.36 | **45.3** |
| 3 | 42.15 | | 43.25 | | 42.25 | | 44.86 | | 47.56 | |

### Table: 4.3 28 days compressive strength test results for M 50 grade concrete mix in N/mm$^2$

| Specimen | 0% basalt | | 25% basalt | | 50% basalt | | 75% basalt | | 100% basalt | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load |
| 1 | 60.25 | | 62.33 | | 66.78 | | 66.45 | | 68.56 | |
| 2 | 59 | **60.75** | 63.86 | **63.46** | 64.18 | **64.94** | 69.45 | **65.56** | 69.45 | **66.33** |
| 3 | 63 | | 64.21 | | 63.86 | | 67.6 | | 67.6 | |

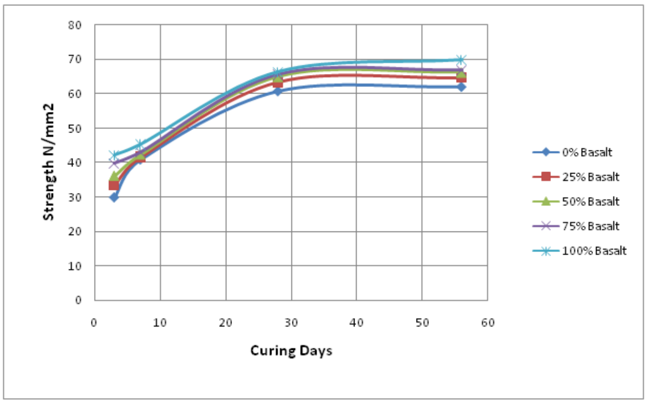
### Table 4.4 :56 days compressive strength test results for M 50 grade concrete mix in N/mm$^2$

| Specimen | 0% basalt | | 25% basalt | | 50% basalt | | 75% basalt | | 100% basalt | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load |
| 1 | 61.51 | | 63.59 | | 68.04 | | 67.71 | | 69.82 | |
| 2 | 60.26 | **62.01** | 65.12 | **64.72** | 65.44 | **66.2** | 66.61 | **66.82** | 70.71 | **69.79** |
| 3 | 64.26 | | 65.47 | | 65.12 | | 66.15 | | 68.86 | |

### Table 4.5 Curing days for compressive strength test results for M 50 grade concrete mix in N/mm$^2$

| S.No: | Curing Days | Compressive strength (N/mm2) | | | | |
|---|---|---|---|---|---|---|
| | | 0 % of basalt | 25 % of basalt | 50 % of basalt | 75 % of basalt | 100 % of basalt |
| **1** | **3** | 29.81 | 33.39 | 36.10 | 39.88 | 42.18 |
| **2** | **7** | 40.86 | 41.58 | 42.35 | 43.09 | 45.3 |
| **3** | **28** | 60.75 | 63.46 | 64.94 | 65.56 | 66.33 |
| **4** | **56** | 62.01 | 64.72 | 66.2 | 66.82 | 69.79 |

### Graph 4.1 Curing days for compressive strength test results for M 50 grade concrete mix in N/mm$^2$



ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

From the results its seen that the compressive strength of the concrete ay 3 days curing period, the concrete which contains basalt compressive strength is more than the conventional concrete(0% basalt).As well from the 7 days curing period the values of compressive strength of concrete which contains the basalts gives better results than the conventional concrete.

From 28 days curing period results it is observed same as previous curing periods the compressive strength increases with increase in the percentage of basalt content in the concrete mix.

From all curing periods it can seen that the compressive strength increased with increase in the basalt percentage.

## SPLIT TENSILE STRENGTH (M 50)

Table 4.6 -3 days Spilt Tensile strengthtest results for M 50 grade concrete mix in N/mm$^2$

| Specimen | 0% basalt | | 25% basalt | | 50% basalt | | 75% basalt | | 100% basalt | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load |
| 1 | 2.97 | | 3.66 | | 4.24 | | 5.65 | | 6.15 | |
| 2 | 3.20 | **3.21** | 3.85 | **3.81** | 4.54 | **4.55** | 5.89 | **5.83** | 6.89 | **6.64** |
| 3 | 3.46 | | 3.94 | | 4.89 | | 5.95 | | 6.89 | |

### Table 4.7 - 7 days Spilt Tensile strength test results for M 50 grade concrete mix in N/mm$^2$

| Specimen | 0% basalt | | 25% basalt | | 50% basalt | | 75% basalt | | 100% basalt | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load |
| 1 | 3.97 | | 4.66 | | 5.24 | | 6.65 | | 7.15 | |
| 2 | 4.20 | **4.21** | 4.85 | **4.81** | 5.54 | **5.55** | 6.89 | **6.83** | 7.39 | **7.36** |
| 3 | 4.46 | | 4.94 | | 5.89 | | 6.95 | | 7.56 | |

### Table 4.8 - 28 days Spilt Tensile strength test results for M 50 grade concrete mix in N/mm$^2$

| Specimen | 0% basalt | | 25% basalt | | 50% basalt | | 75% basalt | | 100% basalt | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load |
| 1 | 4.54 | | 5.20 | | 6.24 | | 7.65 | | 8.15 | |
| 2 | 4.88 | **4.77** | 5.54 | **5.56** | 6.54 | **6.55** | 7.89 | **7.83** | 8.39 | **8.36** |
| 3 | 4.90 | | 5.94 | | 6.89 | | 7.95 | | 8.56 | |

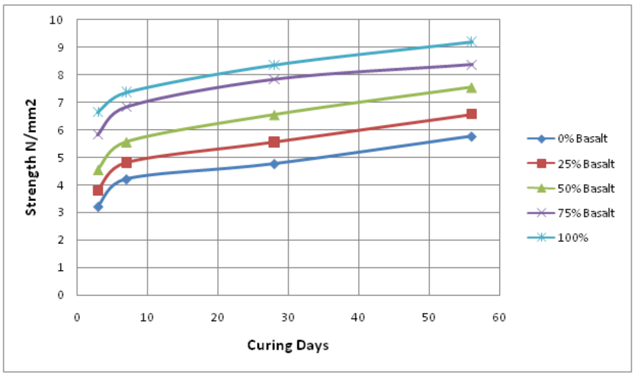
### Table 4.9 - 56 days Spilt Tensile strength test results for M 50 grade concrete mix in N/mm$^2$

| Specimen | 0% basalt | | 25% basalt | | 50% basalt | | 75% basalt | | 100% basalt | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load | Load | Avg Load |
| 1 | 5.54 | | 6.20 | | 7.24 | | 8.15 | | 8.89 | |
| 2 | 5.88 | **5.77** | 6.54 | **6.56** | 7.54 | **7.55** | 8.39 | **8.36** | 9.24 | **9.20** |
| 3 | 5.90 | | 6.94 | | 7.89 | | 8.54 | | 9.49 | |

### Table 4.10 Curing days for Spilt Tensile strength test results for M 50 grade concrete mix in N/mm$^2$

| S.No: | Curing Days | Spilt Tensile strength test strength (N/mm2) | | | | |
|---|---|---|---|---|---|---|
| | | 0 % of basalt | 25 % of basalt | 50 % of basalt | 75 % of basalt | 100 % of basalt |
| **1** | **3** | 3.21 | 3.81 | 4.55 | 5.83 | 6.64 |
| **2** | **7** | 4.21 | 4.81 | 5.56 | 6.83 | 7.36 |
| **3** | **28** | 4.77 | 5.56 | 6.55 | 7.83 | 8.36 |
| **4** | **56** | 5.77 | 6.56 | 7.55 | 8.36 | 9.20 |

### Graph 4.2- Curing days for Spilt Tensile strength test results for M 50 grade concrete mix in N/mm$^2$



From the results of the split tensile strength it can observe that the split tensile strength of the concrete which contain basalt give the greatest values when it compared with the conventional concrete ( 0% basalt).

From 3 days, 7days, 28 days and 56 days curing periods of the concrete which contain basalt as 25%,50%,75% and 100% the values of concrete with basalt gradually decreases.

## CONCLUSIONS

Based on the present experimental investigation, the following conclusions are drawn

1. While using the basalt in concrete the original water cement ratio of concrete mix is to be corrected by the amount of water available in basalt aggregate.
2. The laboratory test results in compressive strength, seems to indicate that the increase in basalt percentage enhances the mix strength. This is due to the factthat basalt is denser and more durable and less water absorbing than limestone. Also higher workability is obtained for more basalt aggregate content mix which reduces the cost of labor.
3. As basalt aggregate is a natural aggregate also available in plenty at low cost, an economical and relatively high strength concrete is obtained by using basalt aggregate as coarse aggregate in concrete mixes.
4. Course aggregate replacement with 25% basalt to increase in Compressive Strength, Split Tensile Strength.
5. For M50 Grade with basalt 25%, 50% 75%, 100% the percentage increase in Compressive Strength, Split Tensile Strength are 25.21%, 10.5%.
6. For M60 Grade with basalt aggregate25%, 50% 75%, 100% the percentage increase in Compressive Strength, Split Tensile Strength are 6.46%, 4.62 % respectively.
7. There is an increase in Compressive Strength of Cylinders for M50 & M60 with basalt100% is 27.12 % and 24.91 % respectively higher than Conventional Concrete

## REFERENCES:

[1] Aitkin, P.C., “High-performance Concrete”, E & FN Spoon, UK, 1998

[2] de Garrard, F and Mailer, Y, “Engineering Properties of Very High Performance Concretes” High-Performance Concrete - From Material to Structure,(Editor- Mailer),E&FN Spoon, 1994, London, pp 85 -114.

[3] Had eel Mariah, Ghazi Al-Katie , Effect of basalt and limestone aggregate combinations on Super pave aggregate properties

[4] Hamadallah Mohammad Al-Baja ,The Use of Basalt Aggregates in Concrete Mixes in Jordan, ,Jordan Journal of Civil Engineering, Volume 2, No. 1, 2008

[5] Hamadallah M. Al-Baja Comparison between Composite Beam of Limestone and Basalt Concrete Jordan Journal of Civil Engineering, Volume 3, No. 3, 2009

[6] IS: 456 – 2000 (Fourth Revision) Indian Standard Plainand Reinforced Concrete Code of Practice.

[7] IS: 383-1970 (Second Revision), Specifications forCoarse and Fine Aggregates from Natural Resources forConcrete.

[8] IS: 10262-2009 (first revision), Concrete Mix Proportioning Guidelines

[9] P. D. Lumbar and P. B. Moral ,A New Mix Design Method For High Performance Concrete Under Tropical Concrete, ,Asian Journal of Civil Engineering (BHRC) Vol. 15, No. 3 (2014)

[10] Rosenbaum, M. and Skeen, M. 1995. Airfield Pavement Construction Using Basalt Aggregate, Bulletin-International Association of Engineering Geology, 51:71–79.

[11] Sugarcane Rao.Hunchate, Sashidhar.Chandupalle, Vaishali.G.Ghorpode and Venkata Reddy.T.C, Mix Design of High Performance Concrete Using Silica Fumeand Superplasticizer, International Journal of

Innovative Research in Science, Engineering and Technology, Vol. 3, »» Wu, D., Sofi, M., Mendis, p. High strength concrete for sustainable construction, International Conference onSustainable Built Environment (ICSBE-2010)Kandy, 13-14 December 2010