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Optimization of Concrete Aggregates by Iteration method of Analysis Using Python Program

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Abstract*— Concrete is an essential part of most of the civil engineering works. Aggregates are the main constituents of the concrete. An aggregate occupies about 70% to 80% of the total volume of the concrete and also they highly affect the fresh and hardened properties of the concrete. The concrete mix optimization implies selection of the most suitable cost of raw materials, quantity of aggregate packing, water and cement consumption. Optimization of aggregates can be achieved by using optimized techniques such as Maximum density line or Power curve, Coarseness factor chart, Fineness modulus and Surface area. By using optimization of aggregates technique we can reduce the cement content and also it gives the dense packing arrangement in between aggregate particles in total volume of concrete. Finally optimization improves the properties of concrete such as workability, durability, compressive strength and decreasing drying shrinkage etc,. This work also includes the development of computer based program for calculating optimization of aggregate proportions of different sizes of aggregates used in concrete mix design by using optimized techniques. The optimized aggregates proportions are calculated by the use of iteration method. This paper most useful to calculate optimized combined aggregates mix proportions for generating optimized concrete by using computer based program.

***Keywords*— Maximum density line or Power curve, Coarseness factor and workability factor, Fineness modulus.**

I. INTRODUCTION

In construction field mostly used material is concrete. In that cement content is about 60%. In fresh concrete, cement paste occupies 25% to 40% and total aggregates occupies up to 70% to 80% of its total volume. By the increasing the paste of cement the total cost will be adequate. Some quantity of cement can be replaced by the cementanoius materials like fly ash, GGBS, RHA etc…, reduced quantity of cement can be achieved by optimizing the combined aggregate phenomenon while making the mixes. We can achieve the parameters like

1) Reducing voids between aggregate particles
2) Reducing cost of cement by reducing the cement content
3) Increasing durability by decreasing permeability for drying shrinkage cracking.
4) Increasing the structure performance by decreasing porosity and increasing the total aggregate volume.

By the shape and texture of aggregate the packing ability of individual aggregates and strength for optimizing blended aggregates will have significant increment.

The second most expansive material in concrete is aggregate. It occupies 60% to 90% of its total volume. The type and size distribution of aggregate will affect the properties of concrete such as durability, workability, permeability, mechanical strength and also cost of hardened concrete. By this we can state that aggregates are essential for optimizing concrete mix design.

A. MAXIMUM DENSITY LINE OR POWER CURVE

In 1907, Thompson and fuller developed that the ideal concept of gradation curve shape will produce the best concrete performance. The equation for the maximum density line was shown in below, for concrete mixtures were later developed by Talbot and Richard in 1923. In 1948, nijboer and in 1962 goode and lufsey it was further developed and confirm for various aggregate types. In particle size distribution, the individual aggregate property required to be inputted for this technique. The equation as follows

$$P = \left[\frac{d}{D}\right]^N$$

Where P = Combined percentage passing of aggregates
d = sieve size (or) particle size
D = Maximum sieve size or Largest particle size
N = Grading type factor or Power factor (varies from 0.3 to 1.00)

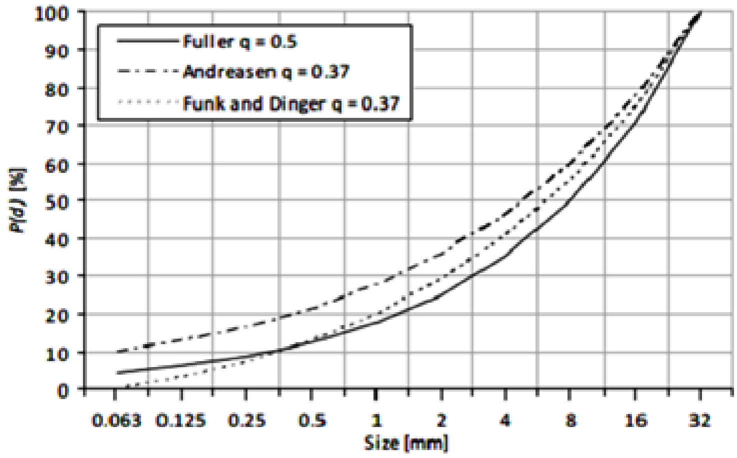

Fig: 1 Ideal distribution curves developed by Fuller, Andreassen, and Funk & Dinger

C. SHILSTON'S COARSENESS FACTOR CHART

Shilstone built up an apparatus for deciding a very much reviewed blend, the Coarseness Factor Chart in 1990. The main individual aggregate property required to be inputted for this system is the molecule estimate circulation.

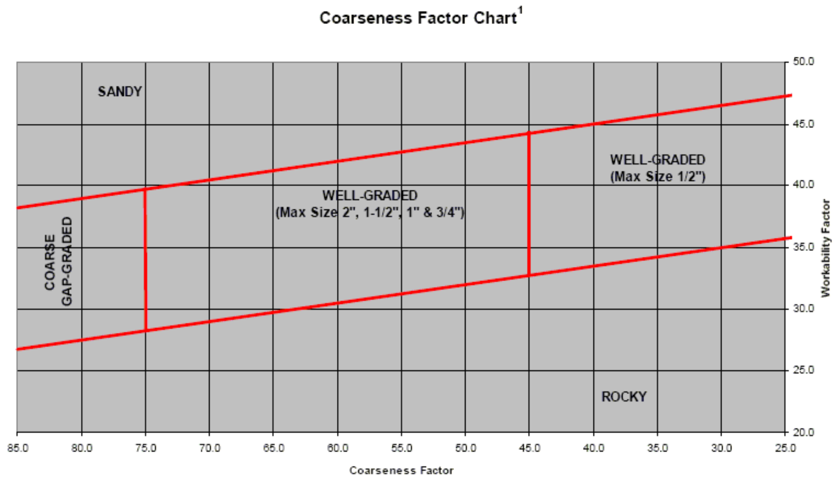

Fig: 2 Shilstone's Coarseness Factor Chart

The coarseness factor (CF) and workability factor (WF) values can be calculated by using the following equations

Coarseness Factor (CF) = $\frac{\%\ Cumulative\ Retained\ on\ 10mm\ \ IS\ sieve}{\%\ Cumulative\ Retained\ on\ 2.36mm\ IS\ sieve}\ x\ 100$

Workability Factor (WF) = % cumulative Passing on the 2.36 mm IS sieve

D. SHAPE AND SIZE OF AGGREGATES

Clearly the pressing is a component of the molecule shape and the size circulation. It very well may be reasoned that the normal aggregate went (0-27 mm) gives pressing qualities higher than of squashed aggregate for a similar aggregate blend extents for all exploratory and hypothetical examinations. It is additionally discovered utilization of three sorts of aggregate or more gives ideal pressing and great cement.

II. MATERIALS

A. CEMENT

Cement is used as the basic binding material for making any type concrete with including raw materials like fine aggregate, coarse aggregates, required quantity of portable water and admixtures. Basically cement is manufactured by using raw materials like clay, lime and some other chemicals required for fulfil construction needs. Manufacture of cement done on the basis of wet and dry process, but now way days wet process mostly used for manufacturing of cement in industries.

In this experimental study we are using PPC type cement (IS 1489 part- 1) manufactured by Bharathi cement private limited. The specific gravity property of cement determined by the procedure described in the IS: 4031(part II)-1988 code provisions.

The value of specific gravity of cement is obtained as 3.10.

B. COARSE AGGREGATES

In this project, we have used 20mm, 10mm and 5mm HBG metal, these materials brought from the Chandragiri quarry near Chandragiri Kota in Chittoor district. The physical properties of coarse aggregate of different sizes are shown in Table 1.

Table 1. Physical properties of coarse aggregates of different sizes

Sl.No	Nominal size of Aggregates in (mm)	Specific gravity value	Water absorption in percentage (%)
1	20	2.65	0.50
2	10	2.65	0.50
3	5	2.65	0.50

The sieve analysis of coarse aggregate of different sizes of 20mm, 10mm and 5mm are done as per IS: 2386 (Part I) – 1963codal procedure. The sieve analysis values obtained for 20mm, 10mm and 5mm size coarse aggregate are shown in Table 2, Table 3and Table 4 respectively.

Table 2. Sieve Analysis values of 20 mm size Coarse Aggregate

Sl.No	IS sieve size in (mm)	Cumulative percentage passing
1	25	100.00
2	20	79.53
3	12.5	10.47
4	10	1.27
5	4.75	0.17
6	2.36	0.03
7	1.18	0.03
8	0.60	0.03
9	0.30	0.03
10	0.15	0.03
11	Pan	0.00

Table 3. Sieve Analysis values of 10 mm size Coarse Aggregate

Sl.No	IS sieve size in (mm)	Cumulative percentage passing
1	25	100.00
2	20	100.00
3	12.5	85.35
4	10	40.90
5	4.75	12.10
6	2.36	0.95
7	1.18	0.35
8	0.60	0.30
9	0.30	0.25
10	0.15	0.20
11	Pan	0.00

Table 4. Sieve Analysis values of 5 mm size Coarse Aggregate

Sl.No	IS sieve size in (mm)	Cumulative percentage passing
1	25	100.00
2	20	100.00
3	12.5	66.67
4	10	66.67
5	4.75	0.00
6	2.36	0.00
7	1.18	0.00
8	0.60	0.00
9	0.30	0.00
10	0.15	0.00
11	Pan	0.00

C. FINE AGGREGATE

If the aggregate particles passing through the 4.75mm IS sieve and retained on 75 micron IS sieve then the material is classified as Fine aggregate. It is formed by the decomposition or weathering action of sand stone.

Table 5. Physical properties of fine aggregate

Sl.No	Description of material	Specific gravity value	Water absorption in percentage (%)
1	Fine aggregate	2.65	1.20

The sieve analysis of fine aggregate is done as per IS: 2386(Part I) – 1963 codal procedure and the values are shown in Table 6. After comparing the obtained fine aggregate results with standard values Shown in Table 6 in IS: 383-1970, we then conclude that fine aggregate used for this project work is belongs to Zone II grading of aggregates.

Table 6. Sieve Analysis values of fine aggregate

Sl.No	IS sieve size in (mm)	Cumulative percentage passing	IS 383-1970 (Zone II)
1	25	100.00	100
2	20	100.00	100
3	12.5	100.00	100
4	10	100.00	100
5	4.75	98.40	90-100
6	2.36	92.30	75-100
7	1.18	76.60	55-90
8	0.60	49.10	35-59
9	0.30	13.20	8-30
10	0.15	2.90	0-10
11	Pan	0.00	---

III. METHODOLOGY

We are considered experimental investigations already done on optimized techniques by the Tolbot's grading curve or power curve, Shilston's developed coarseness factor chart, fineness modulus and IS: 10262-2009 code procedure for preparing the concrete cubes of grade M20 for investigation the result which are obtained on after tests conducted in laboratory on the hardened concrete cubes at 7 days and 28 day's curing completed.
First we are preparing target values of different N values by using mathematical relation developed by the Fuller and Thompson in 1907, then in 1923 Talbot's and Richart developed as follows

$$P = 100 \text{ x } \left[\frac{d}{D}\right]^{N}$$

Where P = % passing (by mass)
d= sieve size in mm
D = max. Sieve size in mm
N = grading type factor

After preparing the target values we are developing a target curve by considering target values on X- axis and respective sieve sizes on Y- axis, and then we are calculating the actual proportions required for the optimized aggregate gradation by using Iteration method of analysis. In this method we are dividing the total proportion of different size of aggregate materials are in the unity. After we are increment and decrement done on the proportions of respective aggregates and also simultaneously calculate the actual values obtained for different new proportions. Then we prepare the plot for actual values and sieve sizes, after we calculating the standard deviation value for each curve. Then finally compare with the target curve, which curve gives the least value of standard deviation that respective curve proportions gives the required optimized aggregate grading proportions.

The above procedure repeated for all possible proportions among the given different sizes of aggregates with different N values. The manually calculation for all different N values is very difficult job to overcome these difficulty we are developed a computer based programme in python language. Developed Python programme takes time (approximately greater than 15 minutes) for calculating the actual value of single iteration for one N value.

After calculating the fineness modulus values for fine aggregate, coarse aggregates, total fineness modulus values of coarse aggregates (TFMVCA) and total fineness modulus values of aggregates (TFMVA) by using following formula

$$\text{Fineness modulus} = \frac{\text{Toatl value of Cumulative retain}}{100}$$

After getting the optimized aggregate proportions for different sizes of aggregates then we calculate the respective Coarseness factor (CF) and Workability factor (WF) values for respective N value by using following formulas

$$\text{Coarseness Factor (CF)} = \frac{\text{\% cumulative retained on 10 mm sieve}}{\text{\% cumulative retained on 2.36 mm sieve}}\, x100$$

Workability Factor (WF) = % Cumulative passing on 2.36 mm sieve

After checking the obtained CF and WF values with the standard values of CF and WF are given by the Shils stones's coarseness Factor chart shown in Fig. 2.
Finally the computer based program developed such a way that it will automatically calculate and display the nearest values of CF and WF with respect to the standard values of CF and WF and also displays the respective optimized aggregate proportions required for making optimized concrete.

At end of the program execution it will also develops the following plots listed below

- Percentage of passing values of aggregates Vs Sieve sizes
- Individual retaining value of aggregates Vs Sieve sizes
- Coarseness factor value Vs Workability factor value

A. MIX DESIGN

The mix design of M20 grade cement concrete was done by using IS: 10262- 2009 and volume of aggregates taken as the proportions obtained in the developed computer based program on optimized aggregate gradation. The raw materials quantities obtained for concrete mix of N=0.45 and N=0.85, S=0.279 are shown in Table 7.

Table 7. Quantities of different raw materials for different N and S values

Sl.no	**Description of materials**		**Quantity of different martial's in (kg/m^3)**	
			N=0.45	**N=0.85 and S=0.279**
1	Cement		322.034	322.034
2	Fine aggregate		744.582 (41.30 %)	804.077 (44.60 %)
3	Coarse aggregate	20 mm	249.816 (13.80 %)	376.232 (20.80 %)
		10 mm	361.762 (20.00 %)	276.748 (15.20 %)
		5 mm	450.394 (24.90 %)	349.101 (19.30 %)
4	Water		195.413	195.572

For M20 grade concrete of N=0.45 value, the mix proportions obtained 1: 2.31: 0.78: 1.12: 1.40 as cement, fine aggregate, coarse aggregate of sizes 20mm, 10mm, 5mm respectively and water cement ratio is 0.60.

For M20 grade concrete of N=0.45 and S=0.279 , the mix proportions obtained 1: 2.50: 1.17: 0.86: 1.08 as cement, fine aggregate, coarse aggregate of sizes 20mm, 10mm, 5mm respectively and water cement ratio is 0.60.

IV. RESULTS AND DISCUSSIONS

The Results obtained of Combined aggregate grading analysis for different N values of 0.40, 0.50, 0.60, 0.70 and 0.80 for given aggregates data as input (as shown in fig 3) to the computer based program developed on the basis of iteration method as shown below.

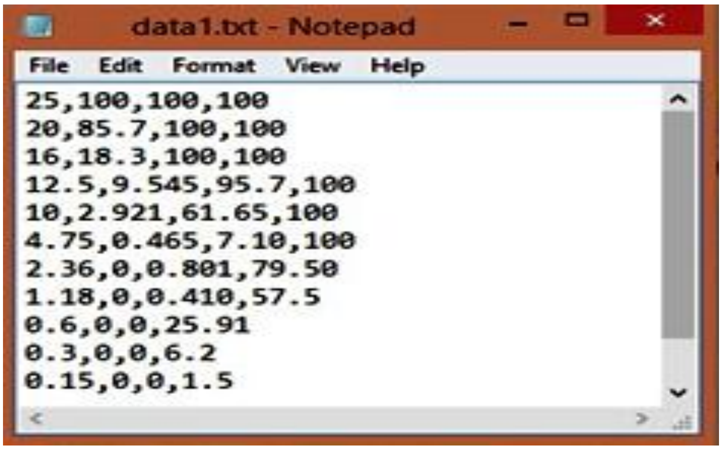

Fig: 3 Input values in text file format

Table: 8 Optimized Mix proportions for different N values

S.No	**N Value**	**Standard deviation value**	**Combined Aggregate mix proportions**		
			20 mm	**12.5 mm**	**Fine aggregate**
1	0.40	6.494	20.50%	26.70%	52.80%
2	0.50	4.689	24.60%	33.10%	42.30%
3	0.60	3.921	28.80%	37.30%	33.90%
4	0.70	3.77	32.90%	39.90%	27.20%
5	0.80	3.877	36.90%	41.20%	21.90%

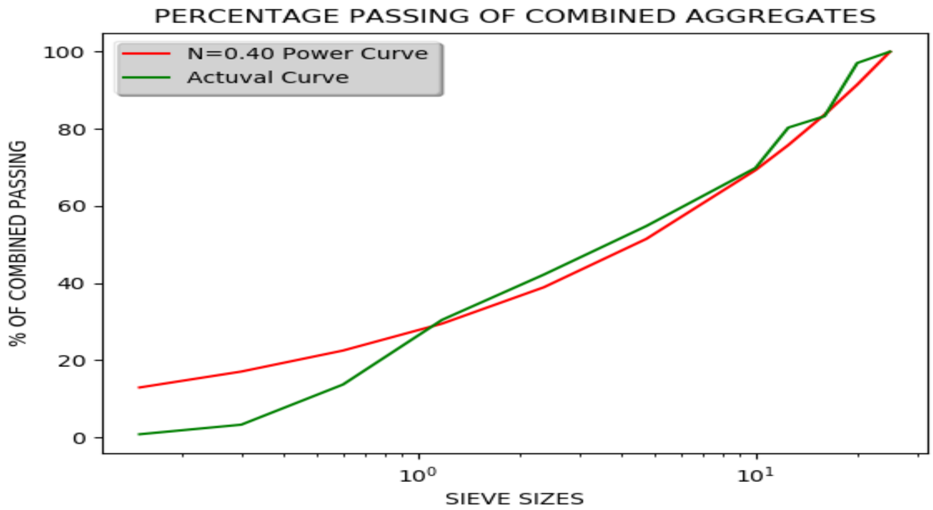

Fig: 4 Percentage passing of combined aggregates for 0.40 power curve

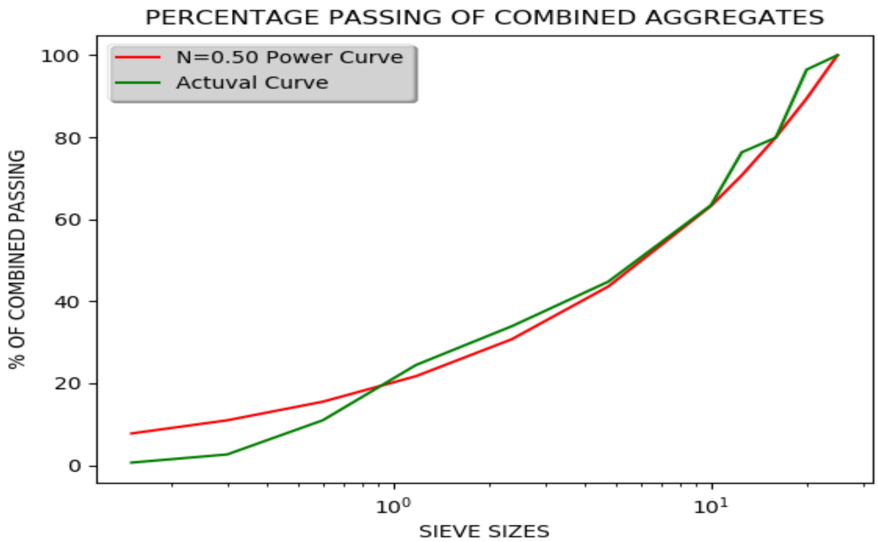

Fig: 5 Percentage passing of combined aggregates for 0.50 power curve

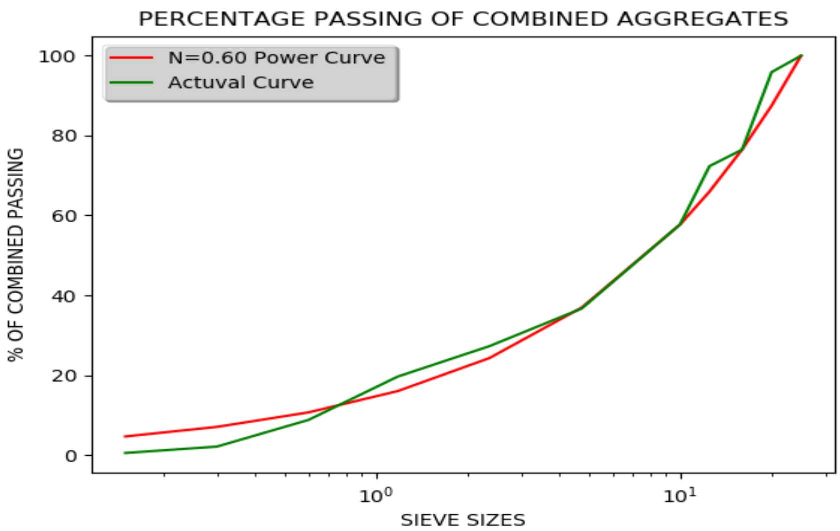

Fig: 6 Percentage passing of combined aggregates for 0.60 power curve

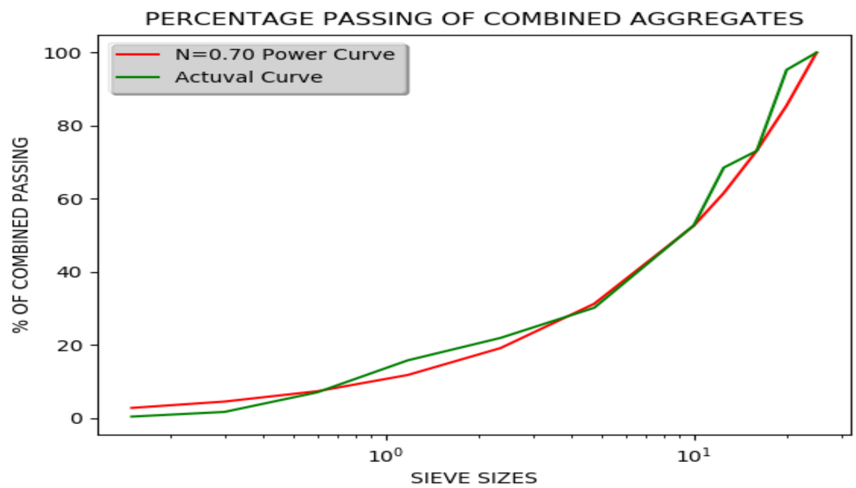

Fig: 7 Percentage passing of combined aggregates for 0.70 power curve

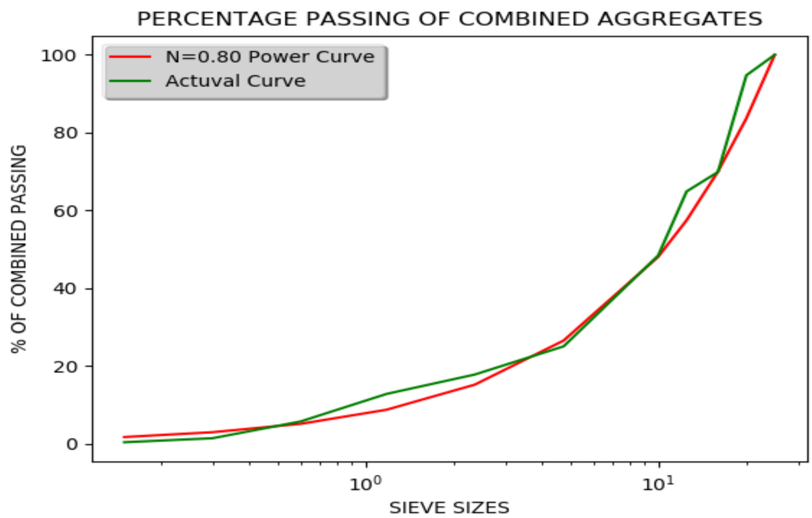

Fig: 8 Percentage passing of combined aggregates for 0.80 power curve

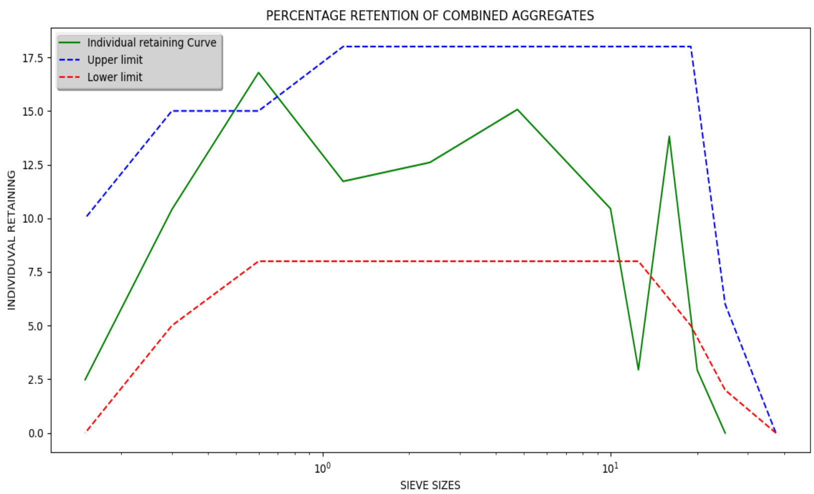

Fig: 9 Percentage retention of combined aggregates for 0.40 power curve

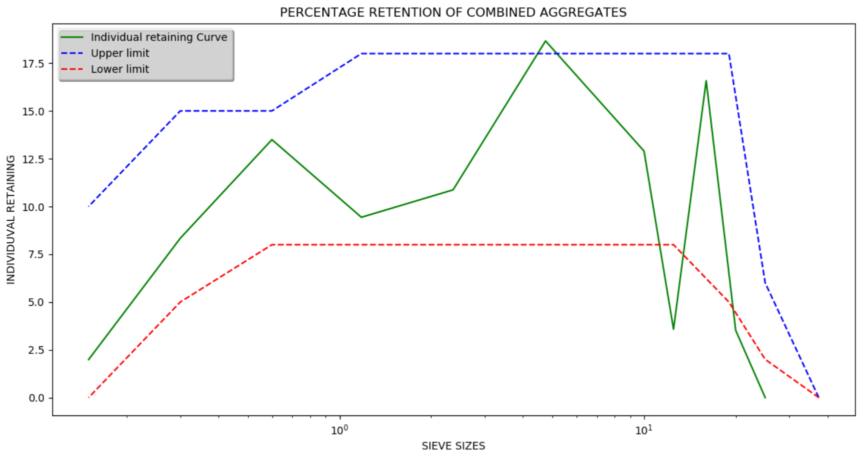

Fig: 10 Percentage retention of combined aggregates for 0.50 power curve

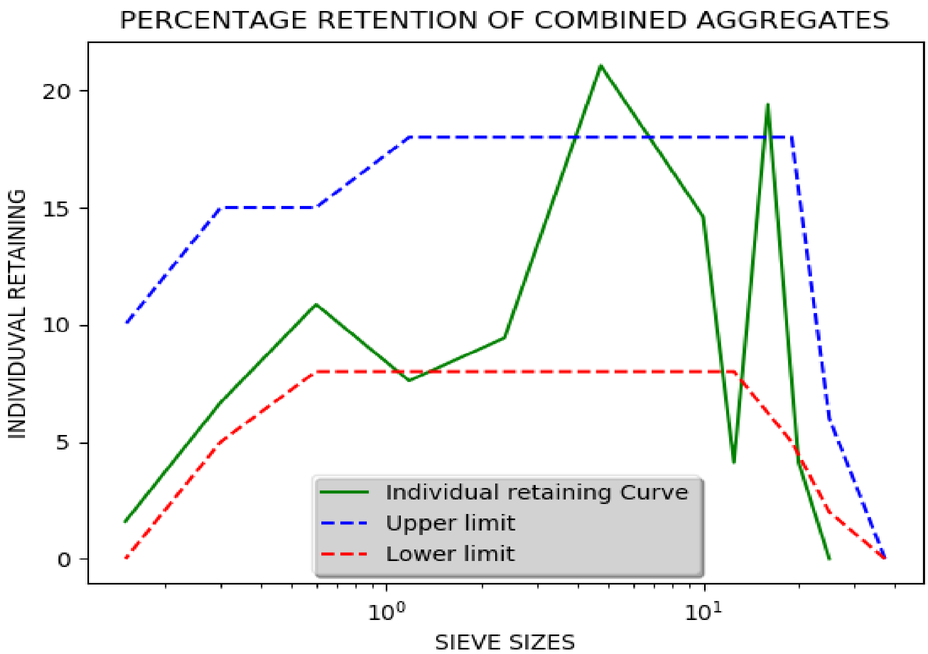

Fig: 11 Percentage retention of combined aggregates for 0.60 power curve

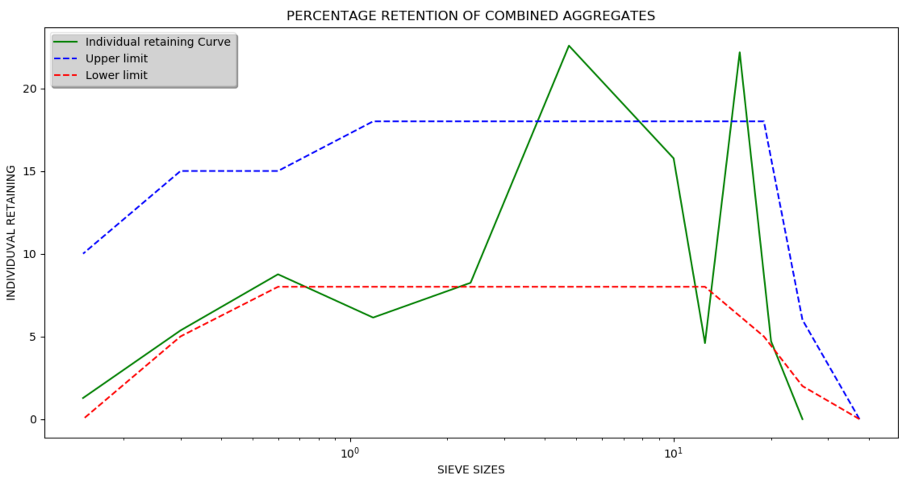

Fig: 12 Percentage retention of combined aggregates for 0.70 power curve

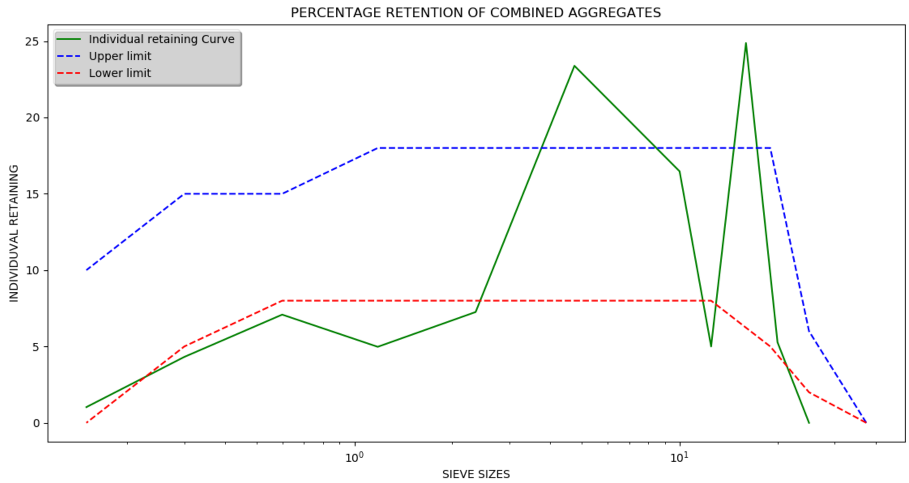

Fig: 13 Percentage retention of combined aggregates for 0.80 power curve

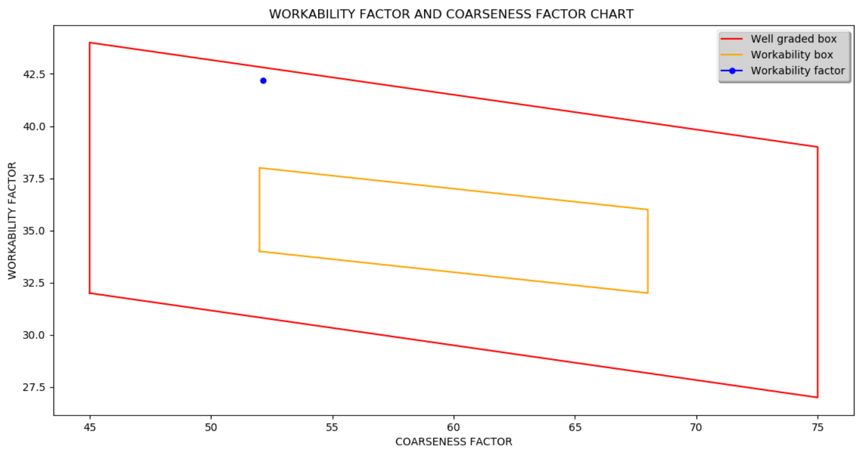

Fig: 14 Workability and Coarseness factor for 0.40 power curve

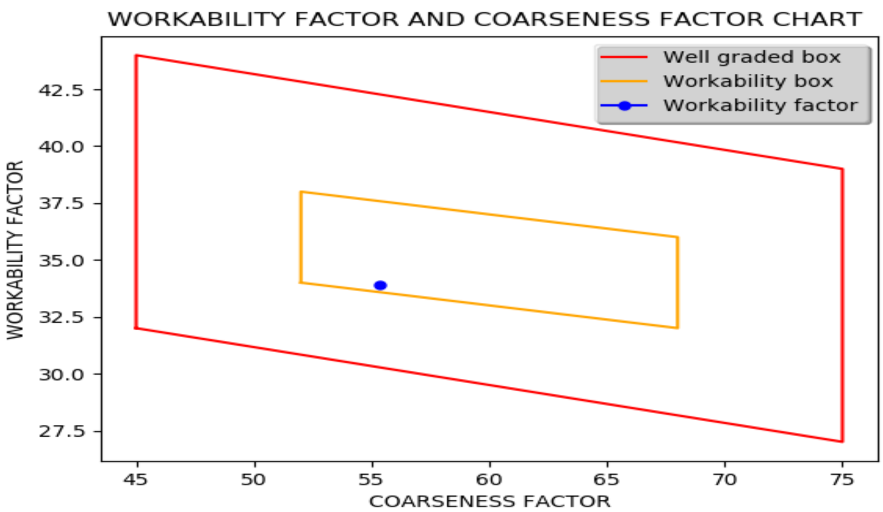

Fig: 15 Workability and Coarseness factor for 0.50 power curve

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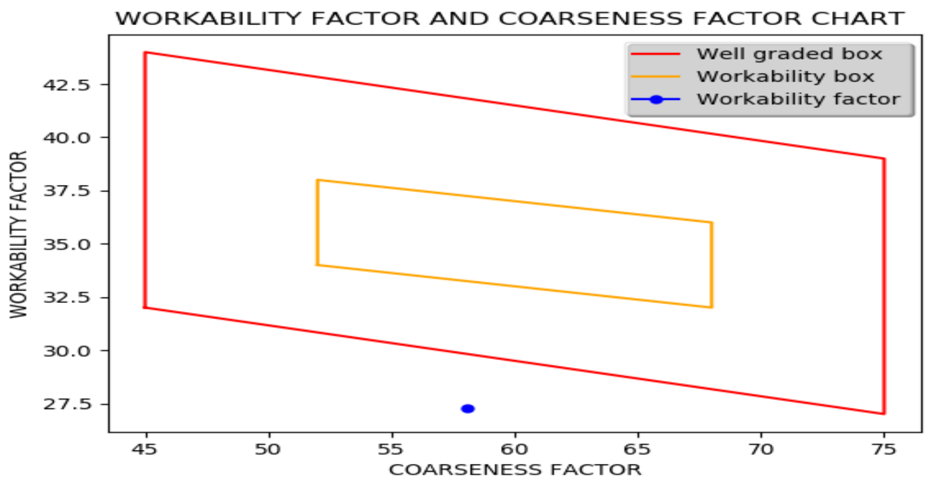

Fig: 16 Workability and Coarseness factor for 0.60 power curve

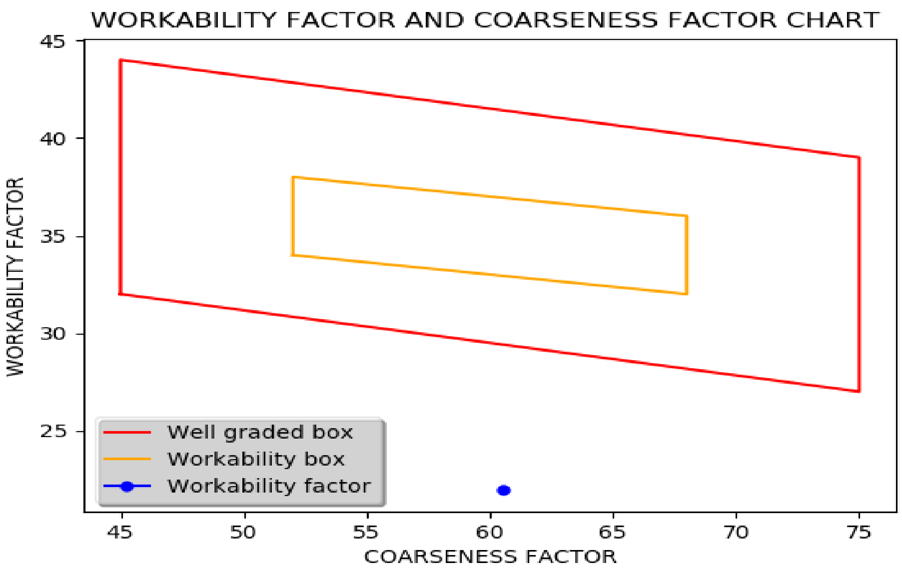

Fig: 17 Workability and Coarseness factor for 0.70 power curve

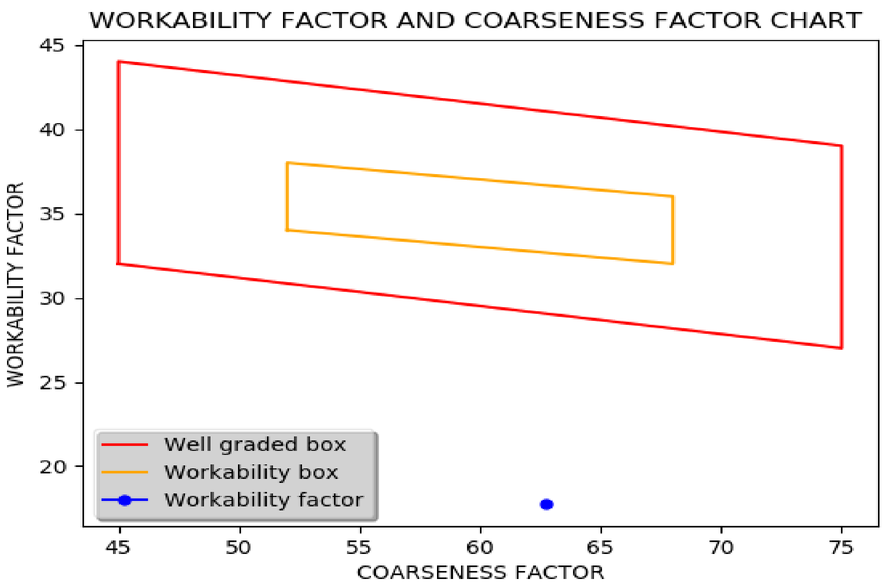

Fig: 18 Workability and Coarseness factor for 0.80 power curve

V. CONCLUSIONS

This project attempts to develop a computer based program for calculating the optimized aggregate gradation proportions of given sieve analysis values of different sizes of aggregates (up to four sizes including fine aggregate) used in optimized concrete mix preparation. The iteration method of analysis takes less time for calculating the optimized mix proportions compare to the manual calculations.

In this program development we are consider both pullers and siltstone coarseness factor charts of analysis for calculating the optimized aggregates gradations of different aggregates and also program gives minimum standard deviation value and fineness modulus values of all aggregates.

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