International Journal of Civil Engineering and Technology (IJCIET)
Volume 7, Issue 3, May–June 2016, pp. 192–199, Article ID: IJCIET_07_03_019
Available online at
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=7&IType=3
Journal Impact Factor (2016): 9.7820 (Calculated by GISI) www.jifactor.com
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

COST EFFECTIVENESS OF CONCRETE MIX DESIGN BASED ON VARIOUS CONSTITUENTS AND THEIR COMBINATIONS

Rahul Sheokand
Dept. of Civil Engineering, GNDEC Ludhiana, Punjab India

Karandeep Singh
Dept. of Civil Engineering, GNDEC Ludhiana, Punjab India

ABSTRACT

This study is an attempt to enable the people to achieve the lowest cost of Concrete Mix every time they design the mix before actual trails. For this research, a spreadsheet for concrete mix design has been created and shared openly on a blog. This spreadsheet can be used by the user himself for creating customized results. This work also shows the main aspects of spreadsheet and also illustrates the effect of variation in various components on the final cost of first selected design mix trail. It also illustrates that how one can find the most economical combination of various constituents available to achieve the desired strength. The effect of various options available in the market has also been analyzed and their result is shown to creating possible cost variation and potential savings that can be done.

Key words: Concrete Mix Design, Cost-Effectiveness, Economical Design Mix, Spreadsheet.

Cite this Article: Rahul Sheokand and Karandeep Singh, Cost Effectiveness of Concrete Mix Design Based on Various Constituents and Their Combinations, *International Journal of Civil Engineering and Technology*, 7(3), 2016, pp. 192–199.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=7&IType=3

1. INTRODUCTION

According to the 2011 Census, there were 1.77 million homeless people in India or 0.15% of the country's total population. There is a shortage of 18.78 million houses in the country [1]. High cost of construction is one the major reason behind this situation. Cost of construction of structure can be reduced by decreasing the cost of its individual components. Today most widely used material for construction in concrete

and most common of its constituents are cement, fine aggregate, coarse aggregates, admixtures and water [2]. Any strength of concrete can be achieved by multiple numbers ratios of various types of constituents. This study is an effort to enable the people to choose the most economical concrete mix of required strength for the first laboratory trails based on the current market rate of its constituents. Also a study is conducted to achieve a particular strength using various options of constituents available in market and finding the cheapest one and thus creating the most economical design mix for the first trail.

2. METHODOLOGY

A spreadsheet "Mix Design V2_0" has been created and uploaded to the website www.rsheokand.wordpress.com exact link being from where it can be download free of cost. This spreadsheet was created in such a way that it can be used for designing concrete mix as well as for finding the most economical constituents and thus reducing the overall price of concrete. The spreadsheet contains five sheets as shown in FIGURE 1 and their working is described below one by one.

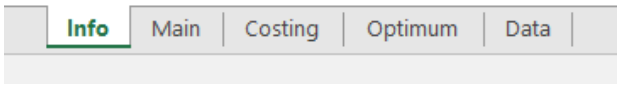


Figure 1 Sheets in Mix Design V2_0 spreadsheet

"Info" is the first sheet of spreadsheet that contains information about the author and ways one can contact him.

"Main" is the sheet in which user can enter the inputs values, all the cells where value can be entered are shown in orange background colour. Check zoning of fine aggregates and all the mix design procedure is also done here as shown in FIGURE 2. On the left hand side of Fig 2 there is Input area where user can enter various input values and there is "Zoning of the aggregates" section in middle where one can find the zone of fine aggregates based on values of sieve analysis even Zone of fine aggregates can be entered manually. "Rate" area of sheet is the area for entering values of rate of various constituents in various units which are available in drop down menu that comes when one clicks in unit of rate. "Result" section displays various mix constituents and the price along with net cost of concrete per m^3.

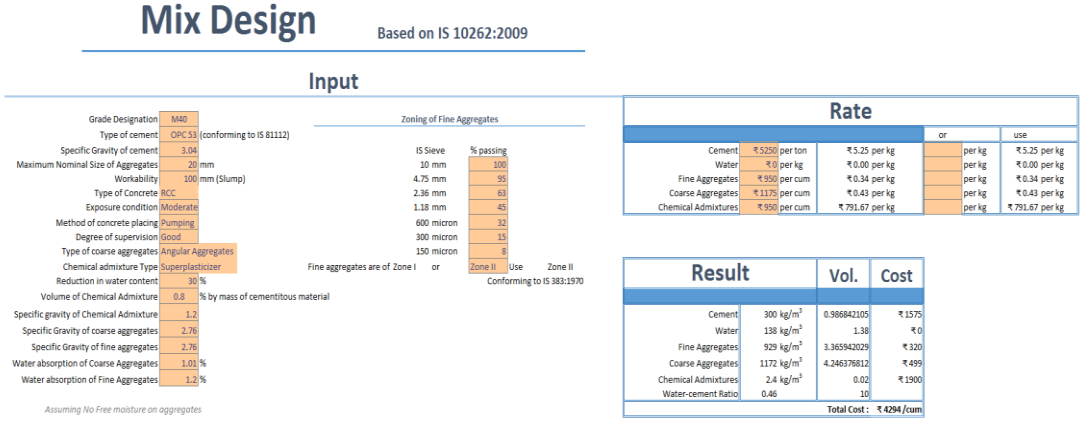


Figure 2 Main Sheet of Spreadsheet showing Input area, Zoning of fine aggregates, Result mix and cost calculation.

Area of "Main" Sheet below the area shown in FIGURE 2 is shown in FIGURE 3. Here different calculations such as calculating water cement ratio, calculating cement content, aggregates proportioning and mix calculations are shown. If the value of water content ratio exceeds the permissible value warning is shown with red background and similar is the case if cement contents falls below the minimum value calculated as per IS 456:2000. All the values calculated can be over ridden by entering a new value in cells with orange background. The value calculated by procedure mentioned in IS 10262:2009 shall be used if value is left blank.

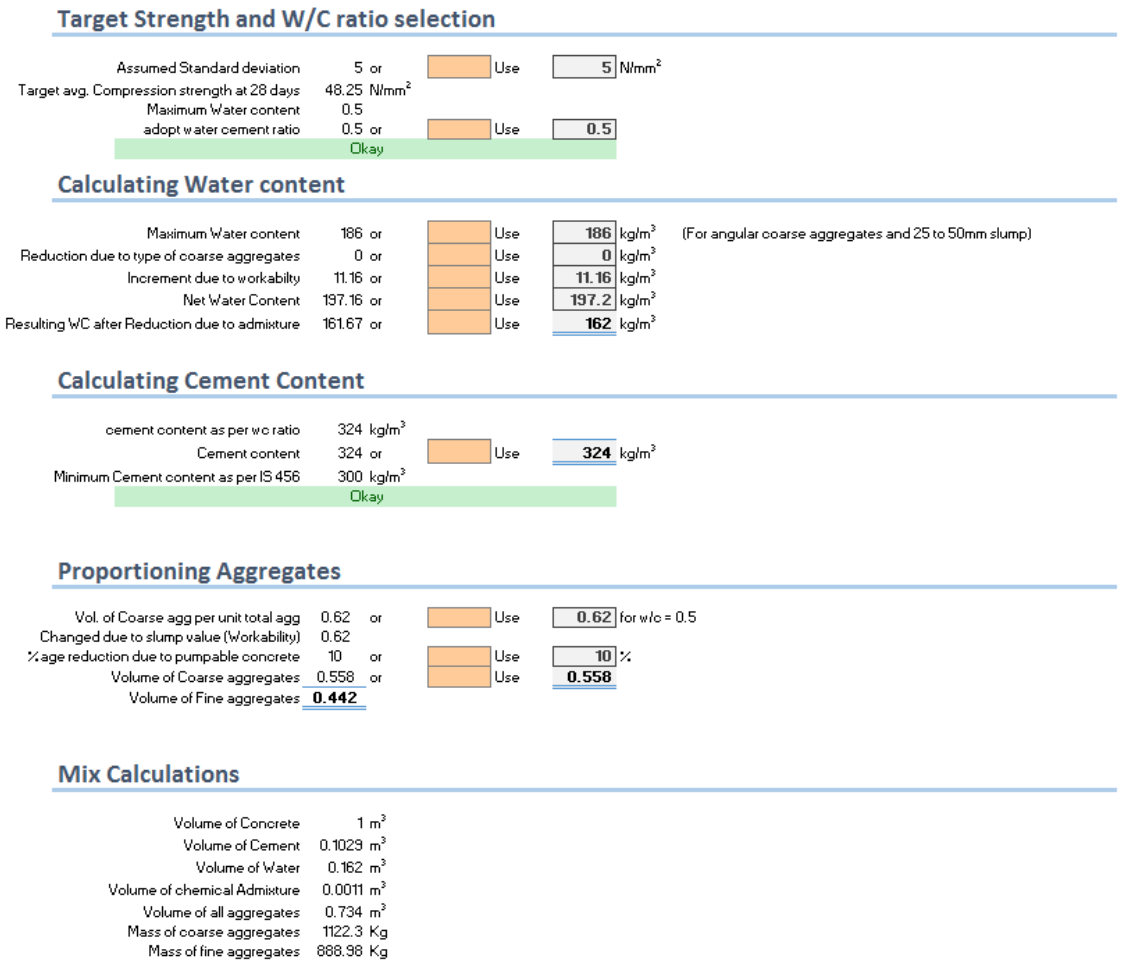


Figure 3 Area below input portion of "Main" sheet of Spreadsheet "Mix Design V2_0"

"Costing" sheet is shown in FIGURE 4 This sheet can be used for finding the most appropriate individual constituent of concrete. For ex. in Cost effectiveness of Admixture portion the value for five different types of admixture can be entered. Value currently entered are as per local market survey done on phone calls. As these may vary from region to region so user can enter all the available option. "Click on check Cost Effectiveness" button will put these value in "Main" sheet one by one and final price of concrete will be shown in corresponding cells. Rest of the parameters will be used as they are entered in main sheet. Similar goes the case with all other components.

Cost Effectiveness of Admixture

Name of Admixture	Ad1	Ad2	Ad3	Ad4	Ad5
Reduction in Water Content (in %)	20	30	25	35	18
Volume of Admixture (% cement)	0.6	0.8	0.6	3	0.4
Specifice gravity of Admixture	1.17	1.2	1.18	1.19	1.17
Price of Admixture	93	44	45	40	80
Units for Price	per kg	per kg	per kg	per kg	per kg
Cost of Concrete per cum	2627.6	2499.3	2464.6	2758.4	2590.6
Cost of Concrete per cum	2628	2499	2465	2758	2591

Check Cost Effectiveness

Minimum cost will be ₹ 2465 for Admixture Ad3 creating 10.62 % savings as compared to most expensive one

Cost Effectiveness of Fine Aggregates

Name of Aggregates	Fa1	Fa2	Fa3	Fa4	Fa5
Price of Aggregates	900	950	1200	1250	1275
Units for Price	per cum	per cum	per cum	per cum	per cum
Zone	Zone II	Zone I	Zone III	Zone II	Zone II
Specific Gravity of fine aggregates	2.71	2.76	2.75	2.74	2.74
Water absorption of Fine Aggregates	1	1.2	1.3	1.15	1.15
Cost of Concrete per cum	2574.5	2587.3	2671	2687.2	2695.3
Cost of Concrete per cum	2575	2587	2671	2687	2695

Check Cost Effectiveness

Minimum cost will be ₹ 2575 for Fine Aggregates Fa1 creating 4.45 % savings as compared to most expensive one

Cost Effectiveness of Coarse Aggregates

Name of Aggregates	Ca1	Ca2	Ca3	Ca4	Ca5
Price of Aggregates	1200	1175	1200	1250	1275
Units for Price	per cum	per cum	per cum	per cum	per cum
Maximum Nominal Size	20	20	20	20	20
Type of coarse aggregates	Angular A	Angular A	Angular A	Angular A	Angular A
Specific Gravity of Coarse aggregates	2.71	2.76	2.75	2.74	2.74
Water absorption of Coarse Aggregates	1	1.01	1.3	1.15	1.15
Cost of Concrete per cum	2705.2	2695.3	2705.5	2725.9	2736.1
Cost of Concrete per cum	2705	2695	2706	2726	2736

Check Cost Effectiveness

Minimum cost will be ₹ 2695 for Coarse Aggregates Ca2 creating 1.5 % savings as compared to most expensive one

Cost Effectiveness of Cement

Name of Cement	C1	C2	C3	C4	C5
Price of Cement	4850	5250	5300	5275	5400
Units for Price	per ton	per ton	per ton	per ton	per ton
Type of cement	OPC 43	OPC 53	OPC 43	OPC 43	OPC 43
Specific Gravity of cement	3	3.04	3.01	3.16	3.15
Cost of Concrete per cum	2604.7	2736.1	2750.9	2749.3	2789.4
Cost of Concrete per cum	2605	2736	2751	2749	2789

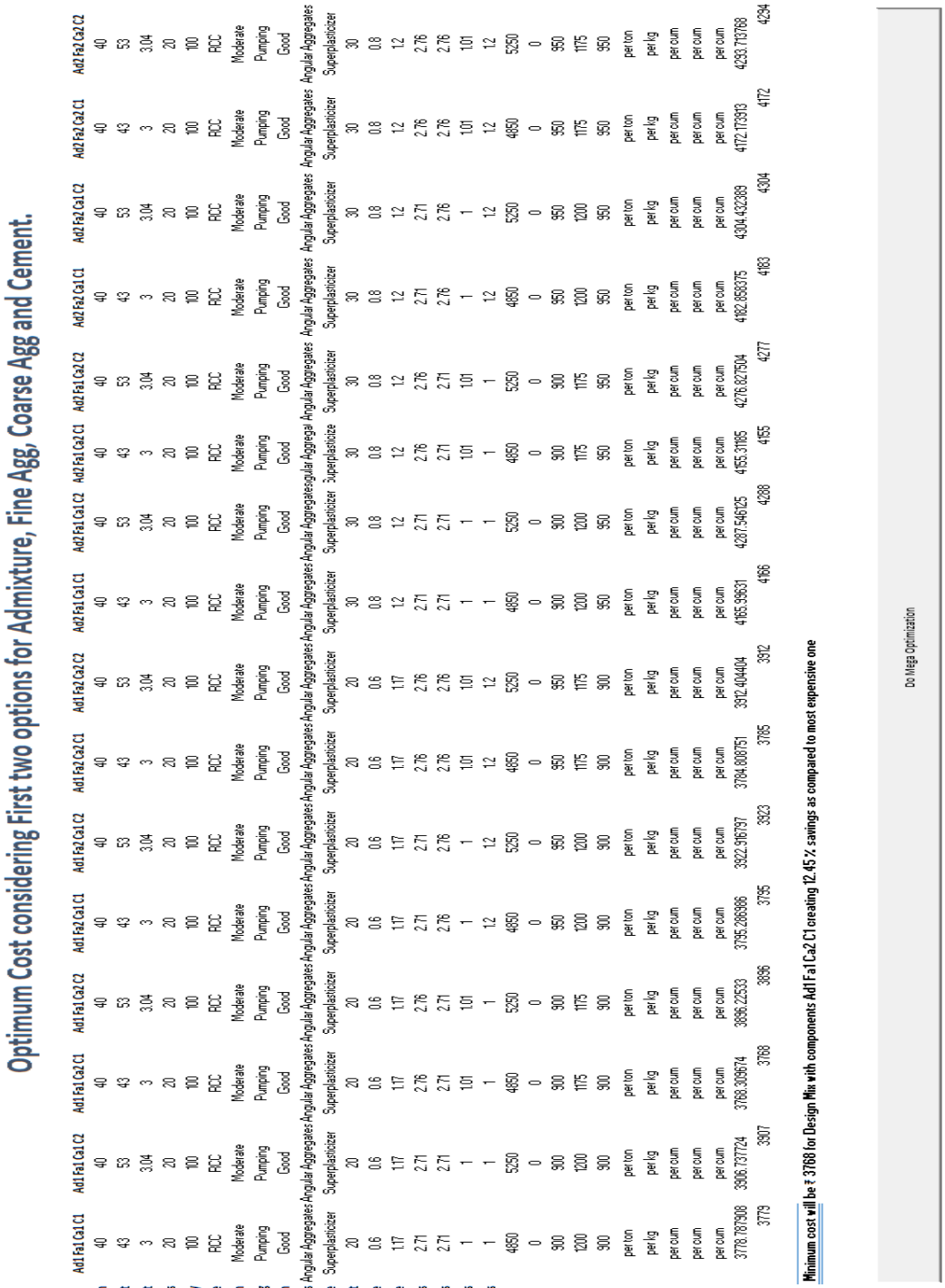
Check Cost Effectiveness

Minimum cost will be ₹ 2605 for Cement C1 creating 6.6 % savings as compared to most expensive one

Figure 4 "Costing" Sheet of Mix Design V2_0

"Optimum" is the most important sheet for this research work. This sheet is shown in FIGURE 5 it is rotated for better visiblity. This sheet creates 16 possible combinations of concrete based on first two types of compnents entered in "Costing" sheet. Two admixtures being "Ad1", "Ad2", fine aggregates "Fa1", "Fa2", coarse aggregates "Ca1","Ca2" and cements "C1" and "C2". On clicking on button "Do mega Optimization" all these 16 combinations are used for making concrete mix and

calculating cost. The result given in states the Price of each and thus the deisgner can use the most economical type of concrete for first trail.



Optimum Cost considering First two options for Admixture, Fine Agg, Coarse Agg and Cement.

	Ad1Fa1Ca1C1	Ad1Fa1Ca1C2	Ad1Fa1Ca2C1	Ad1Fa1Ca2C2	Ad1Fa2Ca1C1	Ad1Fa2Ca1C2	Ad1Fa2Ca2C1	Ad1Fa2Ca2C2	Ad2Fa1Ca1C1	Ad2Fa1Ca1C2	Ad2Fa1Ca2C1	Ad2Fa1Ca2C2	Ad2Fa2Ca1C1	Ad2Fa2Ca1C2	Ad2Fa2Ca2C1	Ad2Fa2Ca2C2
Grade Designation	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Type of cement	43	53	43	53	43	53	43	53	43	53	43	53	43	53	43	53
Specific Gravity of cement	3	3.04	3	3.04	3	3.04	3	3.04	3	3.04	3	3.04	3	3.04	3	3.04
Maximum Nominal Size of Aggregates	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Workability	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Type of Concrete	RCC	RCC	RCC	RCC	RCC	RCC	RCC	RCC	RCC	RCC	RCC	RCC	RCC	RCC	RCC	RCC
Exposure condition	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Method of concrete placing	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping
Degree of supervision	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
Type of coarse aggregates	Angular Aggregates	Angular Aggregates	Angular Aggregates	Angular Aggregates	Angular Aggregates	Angular Aggregates	Angular Aggregates	Angular Aggregates	Angular Aggregates	Angular Aggregates	Angular Aggregates	Angular Aggregates	Angular Aggregates	Angular Aggregates	Angular Aggregates	Angular Aggregates
Chemical admixture Type	Superplasticizer	Superplasticizer	Superplasticizer	Superplasticizer	Superplasticizer	Superplasticizer	Superplasticizer	Superplasticizer	Superplasticizer	Superplasticizer	Superplasticizer	Superplasticizer	Superplasticizer	Superplasticizer	Superplasticizer	Superplasticizer
Reduction in water content	20	20	20	20	20	20	20	20	30	30	30	30	30	30	30	30
Volume of Chemical Admixture	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Specific gravity of Chemical Admixture	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Specific Gravity of coarse aggregates	2.71	2.71	2.76	2.76	2.71	2.71	2.76	2.76	2.71	2.71	2.76	2.76	2.71	2.71	2.76	2.76
Specific Gravity of fine aggregates	2.71	2.71	2.71	2.71	2.76	2.76	2.76	2.76	2.71	2.71	2.71	2.71	2.76	2.76	2.76	2.76
Water absorption of Coarse Aggregates	1	1	1.01	1.01	1	1	1.01	1.01	1	1	1.01	1.01	1	1	1.01	1.01
Water absorption of Fine Aggregates	1	1	1	1	1.2	1.2	1.2	1.2	1	1	1	1	1.2	1.2	1.2	1.2
Price of Cement	4650	5250	4650	5250	4650	5250	4650	5250	4650	5250	4650	5250	4650	5250	4650	5250
Price of Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Price of Fine Aggregates	900	900	900	900	950	950	950	950	900	900	900	900	950	950	950	950
Price of Coarse Aggregates	1200	1200	1175	1175	1200	1200	1175	1175	1200	1200	1175	1175	1200	1200	1175	1175
Price of Chemical Admixtures	900	900	900	900	900	900	900	900	950	950	950	950	950	950	950	950
Unit of Price of Cement	per ton	per ton	per ton	per ton	per ton	per ton	per ton	per ton	per ton	per ton	per ton	per ton	per ton	per ton	per ton	per ton
Unit of Price of Water	per kg	per kg	per kg	per kg	per kg	per kg	per kg	per kg	per kg	per kg	per kg	per kg	per kg	per kg	per kg	per kg
Unit of Price of fine Aggregates	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum
Unit of Price of Coarse Aggregates	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum
Unit of Price Admixture	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum	per cum
	3778.787908	3906.7377724	3768.3096674	3896.225533	3795.2883986	3922.3167197	3784.880751	3912.4044404	4165.93631	4287.546125	4155.31165	4276.827504	4182.8583375	4304.432369	4172.173913	4293.793788
	3779	3907	3768	3896	3795	3923	3785	3912	4166	4288	4155	4277	4183	4304	4172	4294

Minimum cost will be ₹ 3768 for Design Mix with components Ad1Fa1Ca2C1 creating 12.45 % savings as compared to most expensive one

Do Mega Optimization

Figure 5 "Optimum" sheet of Mix Design V2_0

"Data" sheet contains only the data from IS Code 456, 10262 and 383 that are used for designing the mix [6].

3. DISCUSSION AND FUTURE ASPECTS

Using the spreadsheet, Data of 5 different admixtures namely Ad1, Ad2, Ad3, Ad4 and Ad5 were processed and the result of cost of concrete is shown in TABLE 1.

Table 1 Cost Effectiveness of Admixtures

Admixture	Cost of Concrete per cubic meter (in ₹)
Ad1	2628
Ad2	2499
Ad3	2465
Ad4	2758
Ad5	2591

Hence one can save up to 10.62% on cost If Mix designer would have used the most expensive option to when using the best option selected using spreadsheet.

Similarly, TABLE 2, shows the variation of cost while using Fine aggregates "Fa1", "Fa2", "Fa3", "Fa4" and "Fa5". TABLE 3, shows the variation of cost while using Coarse aggregates "Ca1", "Ca2", "Ca3", "Ca4" and "Ca5" and TABLE 4 shows variation for cement "C1", "C2", "C3", "C4" and "C5".

Table 2 Cost Effectiveness of Fine Aggregates

Admixture	**Cost of Concrete per cubic meter (in ₹)**
Fa1	2575
Fa2	2587
Fa3	2671
Fa4	2687
Fa5	2695

Table 3 Cost Effectiveness of Coarse Aggregates

Admixture	**Cost of Concrete per cubic meter (in ₹)**
Ca1	2705
Ca2	2695
Ca3	2706
Ca4	2726
Ca5	2736

Table 4 Cost Effectiveness of Cement

Admixture	**Cost of Concrete per cubic meter (in ₹)**
C1	2605
C2	2736
C3	2751
C4	2749
C5	2789

Difference is cost observed for Fine Aggregates, Coarse Aggregates and Cement is 4.45%, 1.5% and 6.6 % respectively.

Considering admixtures Ad1, Ad2, Fine Aggregates Fa1, Fa2, Coarse aggregates Ca1, Ca2 and cement C1 and C2, 16 combinations are possible. Cost for each of the

following has been calculated using "Optimum" sheet and Results are shown in TABLE 5.

Table 5 Finding cost of most optimum mix design using "Optimum" sheet of Mix Design V2_0

Mix Design	Cost per m^3 (in ₹)	Mix Design	Cost per m^3 (in ₹)
Ad1Fa1Ca1C1	3779	Ad2Fa1Ca1C1	4166
Ad1Fa1Ca1C2	3907	Ad2Fa1Ca1C2	4288
Ad1Fa1Ca2C1	3768	Ad2Fa1Ca2C1	4155
Ad1Fa1Ca2C2	3896	Ad2Fa1Ca2C2	4277
Ad1Fa2Ca1C1	3795	Ad2Fa2Ca1C1	4183
Ad1Fa2Ca1C2	3923	Ad2Fa2Ca1C2	4304
Ad1Fa2Ca2C1	3785	Ad2Fa2Ca2C1	4172
Ad1Fa2Ca2C2	3912	Ad2Fa2Ca2C2	4294

Hence using the "optimum" sheet a saving of 12.25%.

All the portions of Spreadsheet are well differentiated and all the steps are shown making it capable for being used for education purpose and providing option for overriding the calculated values at almost every point, spreadsheet can be used in laboratories for mix designing.

4. CONCLUSION

Based on the above article and discussion about of use the Spreadsheet the conclusions drawn are as below:

1. Spreadsheet can check the cost effectiveness of the different components used in design mix.
2. On basis of cost effectiveness check as per market rates it can be stated that significant amount of cost saving can be done in mix design by using the spreadsheet.
3. Spreadsheet is easy to understand and to teach with and hence can be used for studying and learning various aspects of mix design and their relations

Limitation of the spreadsheet noted so far is that due to large size it takes about 1-2 secs depending on system configurations to do the optimization of cost effectiveness calculations.

Main application of spreadsheet is in ready mix design plants where requirements of concrete is high and keeps on varying based on clients and constituents. This can also be used in labs and consultancy firms where frequent recommendation for mix designs are required.

It can also be used for learners and teachers for teaching and illustrating the dependency of various properties on mix design.

Future development of the spreadsheet can also be done by adding more option and flexibilities like using flyash with cement, adding support for more types of admixtures. For comparison of more than two option for each component, Spreadsheet can be modified. For example, for finding optimum with 5 different option of each component 625 different options can be created for finding most economical mix of all.

REFERENCES

[1] Somesh Jha, 1.77 million people live without shelter, albeit the number decline over a decade, Business-Standard http://www.business-standard.com/article /economy-policy/1-77-million-people-live-without-shelter-albeit-the-number-decline-over-a-decade-113120600835_1.html

[2] R Sheokand, Types of Concrete. InfraIQhttp://infraiq.com/index.php /2016/05/18/types-of-concrete/

[3] R Sheokand, Spreadsheet for most economic Mix Design. https://rsheokand.wordpress.com/ https://rsheokand.wordpress.com/2016/06/02/spreadsheet-for-most-economic-mix-design/

[4] IS 456 (2000) - Plain and Reinforced Concrete - Code of Practice. Bureau of Indian Standards.

[5] IS 10262 (2009) - Concrete mix proportioning Guidelines. Bureau of Indian Standards.

[6] IS 383 (1970) (Reaffirmed 1997) – Specification for Coarse and Fine Aggregates from natural sources for concrete. Bureau of Indian Standards

[7] M. C. Nataraja, G. N. Chandan and T. J. Rajeeth, Concrete Mix Design Using Copper Slag as Fine Aggregate, International Journal of Civil Engineering and Technology, 5(9), 2014, pp. 90–99.

[8] I. Siva Kishore and Ch. Mallika Chowdary, A Study on Waste Utilization of Marble Dust In High Strength Concrete Mix, International Journal of Civil Engineering and Technology, 6(12), 2015, pp. 01–07.

[9] I. Siva Kishore And Ch. Mallika Chowdary, Influence of Steel Fibers as Admix In Normal Concrete Mix, International Journal of Civil Engineering and Technology, 7(1), 2016, pp. 93–103.