The Optimization of the quantity of the concrete for compressive strength by using Taguchi method

DISSERTATION II

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Signature of student
Tenzin Tenpa

ABSTRACT

In this paper the Taguchi method is used for formulating the Orthogonal array and the Signal to noise ratio (S/N). The conventional use of obtaining the optimum result by many test could lead to extra expenditure for the material, time and the energy. This method is found to be effective in previous research paper. The test which is conducted in this research paper is compressive test. Fresh concrete test such as workability and slump flow test are to be conduct. Finally the value obtain from the software Qualitek-4 is compared with actual experiment values to get the optimum result in less variable trial mixes.

DECLARATION

I, Tenzin Tenpa (11305024), hereby declare that this thesis report entitled "The Optimization of the quantity of the concrete for compressive strength by using Taguchi method" submitted in the partial fulfilment of the requirements for the award of degree of master of civil engineering, In the school of civil engineering, Lovely Professional University, Phagwara is my own work. The matter in this report has not been submitted to any other university or institute.

Date: **Tenzin Tenpa**

Place:

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CHAPTER 1

INTRODUCTION

The concrete usually consists of three basic components. Cement, coarse aggregates and fine aggregates. Water is added to the mixture to achieve paste form for homogenous mixture. And some selected additives are added for specific type of concrete such as light weight concrete, high strength concrete and self compacting concrete for different types of structures. Basic component cement act as binder which holds the whole mixture homogenously. But it is found that around 5% of the global carbon dioxide and 5% global energy is consuming in production of the cement. Which acts as major contribution in green house gas emission. Also the cement and other basic component are not sustainable and expensive.

Fine aggregates and cement(binder) can be Partial replaced with some materials which are either in waste form or byproduct. Which are also found that these can significantly improve in workability and segregation at initial stage, Compressive strength and flexural strength at hardened stage. Some material as additives can be Fly ash, Silica fume, EVA (Ethyl vinyl acetate) a plastic waste. In order to save the the quantity of the materials and approach in obtaining an economical construction. In normal test of partial replacement with different additives will take minimum 20 plus trial by varying the percentage of the content. Which will certainly consume more time for testing and more material will be used. For the mega structures more testing will be required and hence more testing would be needed.

In order to reduce the number of the trial experiment there is a technique called “Robust design”. It is a system of design tools which helps is reducing or simplify the variables in product or process, providing guiding performance at the same time in obtaining optimal setting or design according to Dr. Geinichi Taguchi. It also provides some extreme result which cannot be easily found by the conventional method in obtaining the optimal or suitable result.

1.1 Tools used for robust design

They are many tools which can be used for robust design but some of the most efficient method are

1) Taguchi method
2) Design of experiment
3) Multiple regression analysis

Taguchi method is based on performing evaluation and experiment to test the reaction of response variables under the set of control parameters that aims to attained the sets of optimum result for the given problems. This method uses orthogonal arrays to simplify the list of the control parameter and levels. The orthogonal array is in fact the list of the required number of experiment. For example, for orthogonal array $L_9\,(3^4)$ their will be maximum number of rows will be 9 and maximum factors is 4 with 3 levels.

The S/N signal to noise ratios is the objective functions in optimization in getting desired output. Which helps is analysis of the data and predictions for most optimal result. The Taguchi's method uses three result for the S/N ratios:

1) Smaller is better: When minimizing the response, the objective of experiment such as getting the lowest cost optimization of a budget construction project.
2) Bigger is better: When maximizing the response is the objective of experiment such as getting maximum mix design grade for the compressive strength.
3) Nominal is better: When neither small or larger value is the objective third equation is used for optimum result.

In these three cases they are different numerical expressions given by Taguchi's method which are:

- Smaller is better $\frac{S}{N} = -10 \log 10(\frac{1}{n} \sum_{k=1}^{n} y\, i^2$
- Bigger is better $\frac{S}{N} = -10 \log 10(\frac{1}{n} \sum_{k=1}^{n} \frac{1}{yi^2})$
- Nominal is better $\frac{S}{N} = -10 \log 10(\frac{1}{n} \sum_{k=1}^{n} (yi - yo)^2$

1.2 Taguchi method into existence

The Taguchi method was first introduce by an engineer called Genichi Taguchi, who develop the Taguchi method in early 1960s. He studied in India (Indian statistical institute in Calcutta) under the Dr. C R Rao and applied the method in japan in 1960s. Later in 1980s share his idea in US and AT&T. His work was basically on the DOE (Design of experiment) in the main concept was to reduce the variability response and increase the robustness of the product.
The main contribution of the Genichi Taguchi is the following

- Quality Engineering Philosophy –Targets and loss function
- Methodology – System, Parameter, Tolerance design steps
- Experiment Design – Use of the Orthogonal array
- Analysis – Use of the Signal to noise ratios (S/N)

Among which in my field will be using only the Experiment design (Orthogonal array) and the signal to noise ratios. Problem with the previous method found use by considering only one factor in the experiment. When factor is change one at time there is no problem but if two factor are changing simultaneously then the result of the product in experiment could be destructive. And therefore by varying only one factor may not result good performance of if experiment is conduct with one factor.

1.3 Orthogonal Array

Orthogonal array is matrix that control number of trials and experiment which will determine the conclusion of various experiment. The orthogonal array is much simpler compared to the factorial design experiment. The steps in the orthogonal array have made much simpler to calculate. The basic orthogonal array will as have illustrated in Table 1.

Orthongonal arrats	No. of row	Maximum No. of factors	Maximum value of No. of row at the standards 2	3	4	5
L_4	4	3	3	-	-	-
L_8	8	7	7	-	-	-
L_9	9	4	-	4	-	-
L_{12}	12	11	11	-	-	-
L_{16}	16	15	15	-	-	-
L'_{16}	16	5	-	-	5	-
L_{18}	18	8	1	7	-	-
L_{25}	25	6	-	-	-	6
L_{27}	27	13	-	13	-	-
L_{32}	32	31	31	-	-	-
L'_{32}	32	10	1	-	9	-
L_{36}	36	23	11	12	-	-
L'_{36}	36	16	3	13	-	-
L_{50}	50	12	1	-	-	11
L_{54}	54	26	1	25	-	-
L_{64}	64	63	63	-	-	-
L'_{64}	64	21	-	-	21	-
L_{81}	81	40	-	40	-	-

Table 1: Standard orthogonal array

For example:

For producing concrete cube many factors are need to be considered i.e. Workability, water cement ratio, temperature, compatibility and many more. Let us take them as A, B, C and D. They could be dependencies AB, BC, AC and A B C three level of interaction. It is not easy to find whether the among the factor variation of the value is effecting each other or not. Which result in poor result. After creating different combination of the different factor.

Those factor which gives the same result even after the changes in factor could be eliminated to focus more on which gives better result. Since in each factor they could be changes, taking A as A1 and A2, similarly for other factor also. After the result are achieved. For every experiment the defective percentage is found to get the ranges and find the average of every factor. The result is then illustrated in the graph form to find the optimal value that will give the maximum yield.

Process Variable →	A	B	C	D	E	F	G	FRACTION OF TILES FOUND DEFECTIVE
Expt #1	A1	B1	C1	D1	E1	F1	G1	16/100
2	A1	B1	C1	D2	E2	F2	G2	17/100
3	A1	B2	C2	D1	E1	F2	G2	12/100
4	A1	B2	C2	D2	E2	F1	G1	6/100
5	A2	B1	C2	D1	E2	F1	G2	6/100
6	A2	B1	C2	D2	E1	F2	G1	68/100
7	A2	B2	C1	D1	E2	F2	G1	42/100
8	A2	B2	C1	D2	E1	F1	G2	26/100

Table 2: The orthogonal array (8trials)

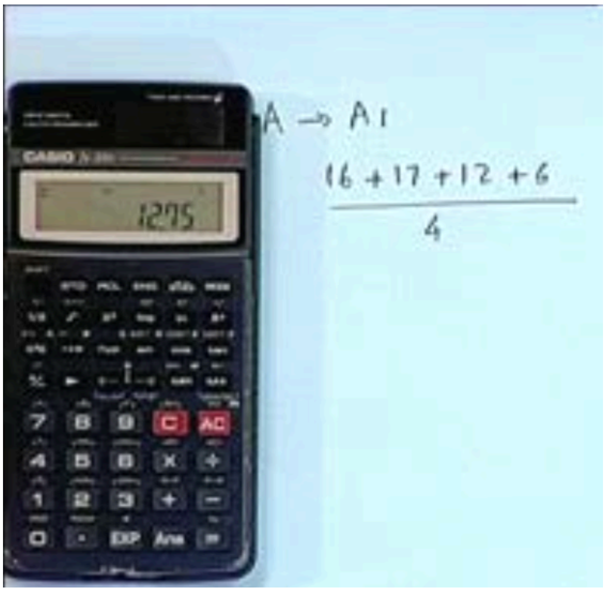

Figure 1: Average of the A1 defective %

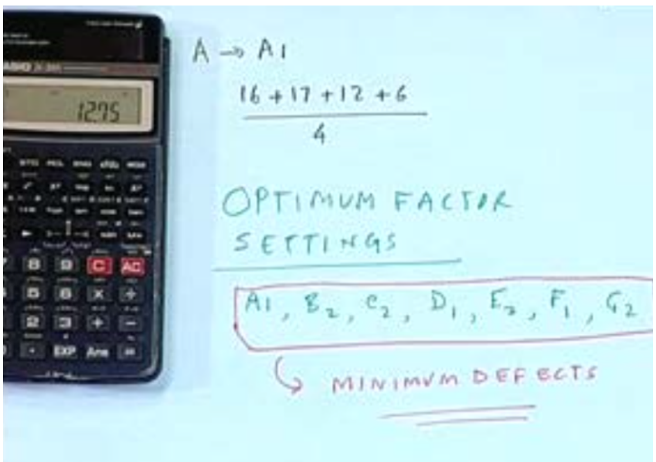

Figure 2: Finding the optimal solution

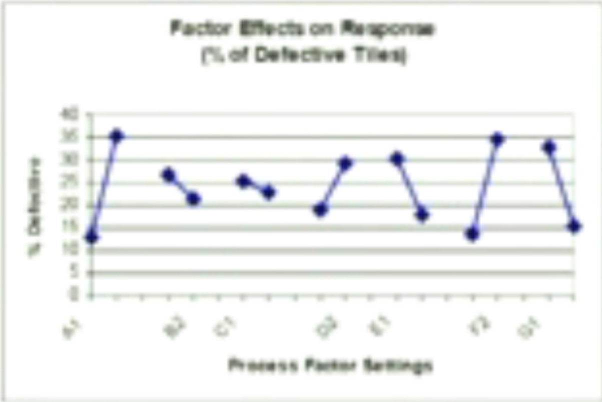

Figure 3: Graph representing the ranges of variation

1.4 Signal to noise ratios (S/N)

The signal to noise ratios is a term which is mainly used in the field of electronic and sound engineering. But with this concept the desired value can be achieved when the specific type of solution is expected. i.e. "smaller is better", "larger is better" and "nominal is better". The solution will vary while choosing the optimum value for each of the objectives. For objectives such as reducing the noise or cost of the particular problem minimum is better. While problems in which objectives is to find the optimum compression, flexural and torsional strength the "larger is better" will be followed.

1.5 Application of the Taguchi method

For this, the example of the determining the factor or parameter that effects during process of formation of surface defects in chemical vapor deposition(CVD) is taken. And it also has find the optimum setting for above parameter to give minimum defects.

Factor	Level 1	Level 2	Level 3
TEMPERATURE	T_0-25	T_0	T_0+25
PRESSURE	P_0-200	P_0	P_0+200
SETTING TIME	t_0	t_0+8	t_0+16
CLEANING METHOD	NONE	CM_2	CM_3

Table 3: The parameters (Factors)

Step 1: Choose a suitable design matrix and perform the test

For given four parameters the L_9 is the suitable design matrix. After running every combination formed in the design matrix and the observation is made. The formula used is neither the "smaller is better" or "larger is better". The nominal is better is choose for the given problem. Therefore, Ci value will be [square of mean /variance] in the formula.

i.e.

$$\eta_i = -10 \log_{10} C_i$$

The summary of the result made from this formula by using the above values of altered factor is called the signal to noise ratios.

Experiment no.	1 TEMPERATURE (A)	2 PRESSURE (B)	3 SETTING TIME (C)	4 CLEANING METHOD (D)	Observation
1	1	1	1	1	η=-20
2	1	2	2	2	η=-10
3	1	3	3	3	η=-30
4	2	1	2	3	η=-25
5	2	2	3	1	η=-45
6	2	3	1	2	η=-65
7	3	1	3	2	η=-45
8	3	2	1	3	η=-65
9	3	3	2	1	η=-70

Table 4: L_9 experiment matrix table

Step 2: Calculation of factor effects

The calculation of the effect is the actual deviation from the desired or ideal overall mean. The value of the mean can be found with the formula:

$$m = \frac{1}{9}\sum_{i=1}^{9}\eta_i = \frac{1}{9}(\eta_1 + \eta_2 + \ldots + \eta_9) = -41.67 \text{ dB}$$

The value of each factor A1, A2, A3 and similar for factor B, C and D can be found using the formula:

$$A_1 = m_{A1} - m = \frac{1}{3}(\eta_1 + \eta_2 + \eta_3) - m$$

Each value of the mean value is found from the S/N ratio given in Table 4. Is further calculated and shown in the Table 5.

Factor	Level 1	Level 2	Level 3
A. Temperature	-20	-45	-60
B. Pressure	-30	-40	-55
C. Setting time	-50	-35	-40
D. Cleaning method	-45	-40	-40

Table 5: Result of the Average at each level

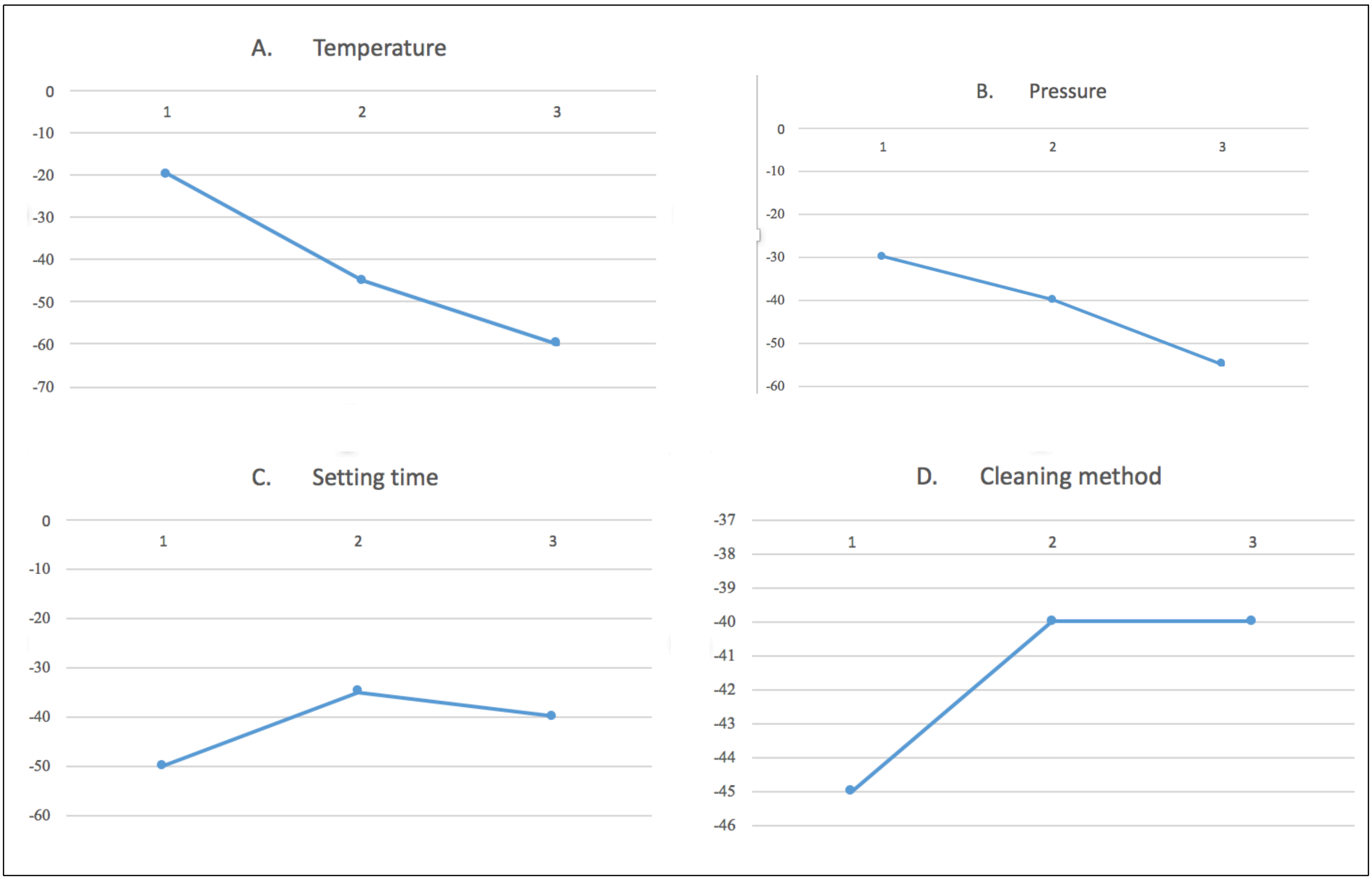

Figure 4: Plot diagram of the factor variations

Step 3: Selecting the optimal factor value

The goal of the given problem is to minimize the surface defect count found on the silicon wafers to produce better product. Hence from the Table 5 and Figure 4 it can be conclude that the factor A1, B1, C2 and D2 or D3 will give the optimal solution in minimizing the defects on the surface. Therefore, two combinations can be made A1B1C2D2 and A1B1C2D3 are possible solution.

CHAPTER 2

PROBLEM BACKGROUND

They are many research which is conducted on the optimization of the concrete with different replacement of the supplementary cement material (SCMs) but the very purpose of the optimization is to reduce the cost of the design mixes. In large scale construction thousands of design test will be conducted. Therefore, their will use the same trial procedure but with Taguchi method it helps is many ways such as cost efficient, energy consumption and making the whole procedure much simpler compare to the factorial design mixes by reducing the number of trail mixes.

CHAPTER 3

LITERATURE REVIEW

3.1 Design of geopolymer concrete with GGBFS at ambient curing condition using Taguchi method

The main purpose of using the granulated ground blast furnace slag (GGBFS) in the creating geopolymer concrete is to contribution towards green concrete. The main problem with the normal concrete which includes the Ordinary Portland Cement (OPC) whose production contributes in the emission of major green house gases and other harmful gas. In comparison of material used the GGBFS use the large amount of industrial waste such as Silica fume, fly ash and slag which reduce the carbon footprint. The test is carried out due to the general agreement is not there on the influence of different parameter on the its properties.

The experiment is design with the help of well-known Taguchi method, in this paper the optimal result is to maximize the compressive strength of ambient curing condition. The Taguchi experiment is performed with Qualitek-4 software. The parameter which influence the geopolymer in achieving the high strength i.e. binder contents, Al/Bi ratio, SS/SH ratio and SH concentration are considered.

In which following composition is taken for the design matrix:

Parameters	Proportion 1	Proportion 2	Proportion 3
Binder content (kg/m^3)	400	450	500
Al/Binder	0.35	0.45	0.55
SS/SH	1.5	2.0	2.5
SH (M)	10	12	14

Table 6: Proportion and parameters

L_9 orthogonal array is obtained in which there is 9 trial mix which is shown in the table 7. The table include the orthogonal array of three level from TM1 to TM9.

Experiment series	Binder content (kg/m^3)	Al/Binder	SS/SH	SH (M)
TM1	400	0.35	1.5	10
TM2	400	0.45	2	12
TM3	400	0.55	2.5	14
TM4	450	0.35	2	14
TM5	450	0.45	2.5	10
TM6	450	0.55	1.5	12
TM7	500	0.35	2.5	12
TM8	500	0.45	1.5	14
TM9	500	0.55	2	10

Table 7: The trial mix of L_9 orthogonal array

In conclusion:

The compressive strength is found after casting of concrete for validation of the Taguchi method. The conclusion is made when factor dependencies is inspected and combination of proportion is made. In which highest compressive strength is shown by the TM4 and lowest strength TM9 with 32.61 MPa and 34.40MPa at 7 and 28 days respectively. The other values are shown in the Table 8. From factorial diagram that binder content at 450 kg/m^3, Al/Bi at 0.35, SS/SH at 2.5 and SH concentration at 14M yields maximum compressive strength. Further to improve the setting time the Silica fume, Metakaolin and fly ash is added.

Trial mix	Compressive strength (MPa)	
	7 days	28 days
TM1	40.89	46.75
TM2	38.47	38.98
TM3	36.94	42.55
TM4	56.05	61.15
TM5	41.40	42.24
TM6	35.03	37.32
TM7	52.23	59.50
TM8	40.13	42.93
TM9	32.61	34.40

Table 8: The result of compression strength

3.2 Influence of various parameters on strength and absorption properties of fly ash based geopolymer concrete designed by Taguchi method

This paper focus on the parameter effecting the compressive strength and water absorption of concrete based on geopolymer concrete design with help of the Taguchi method. One of the main advantages of the geopolymer over the normal concrete is that it could obtain high strength at early stage due to the NASH and CASH geopolymer binder. But the comparison of the result between the 3days and 28days is less significant develop in strength. In this research paper the factor which are considered are OPC content (%), Molarity of NaOH (M) and the curing temperature (^{0}C). For the determination of the optimum design Taguchi method is used in which L_{16} orthogonal array is carried. Total of 16 combination of trial mixes is carried. 150x150x150 mm cube and 100x200 mm of cuboidal mold were cast for the water absorption and compression test. Under load of 2000kN compression testing machine (CTM) and 7 days of water absorption result is obtained as shown in Table 9.

Trial Mixture	Combination	Factors			Compressive strength (MPa)	Water absorption (%)
		OPC content (%)	Molarity of NaOH (M)	Curing temperature (°C)		
T1	A1B1C1	5	5	60	48.36	3.97
T2	A1B2C2	5	10	70	54.79	3.67
T3	A1B3C3	5	15	80	56.37	3.35
T4	A1B4C4	5	20	90	55.69	3.47
T5	A2B1C2	10	5	70	54.31	3.59
T6	A2B2C1	10	10	60	55.24	3.50
T7	A2B3C4	10	15	90	59.57	3.24
T8	A2B4C3	10	20	80	57.94	3.22
T9	A3B1C3	15	5	80	57.06	3.37
T10	A3B2C4	15	10	90	60.24	3.17
T11	A3B3C1	15	15	60	55.76	3.41
T12	A3B4C2	15	20	70	59.53	3.25
T13	A4B1C4	20	5	90	57.69	3.24
T14	A4B2C3	20	10	80	63.67	3.04
T15	A4B3C2	20	15	70	64.39	3.09
T16	A4B4C1	20	20	60	56.02	3.38

Table 9: Trial mixes of the L_{16} orthogonal array and result of compressive strength and water absorption

Mathematical model was constructed on basis of the obtained result and with use of (ANOVA) analysis of variance, which main purpose was to find the impact of the considered parameter. The ANOVA analyse both for water absorption and compressive strength at confidence 95%. The replacement of OPC with Fly ash was found out to be most significant parameter with highest of 42.58%, where as the other parameter such as molarity of NaOH and temperature for curing has less significant as per the ANOVA.

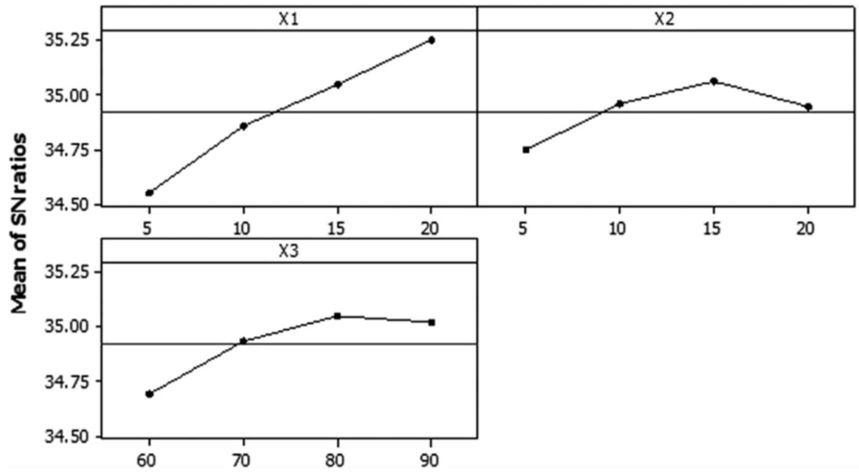

Figure 5: S/N for the Compressive strength

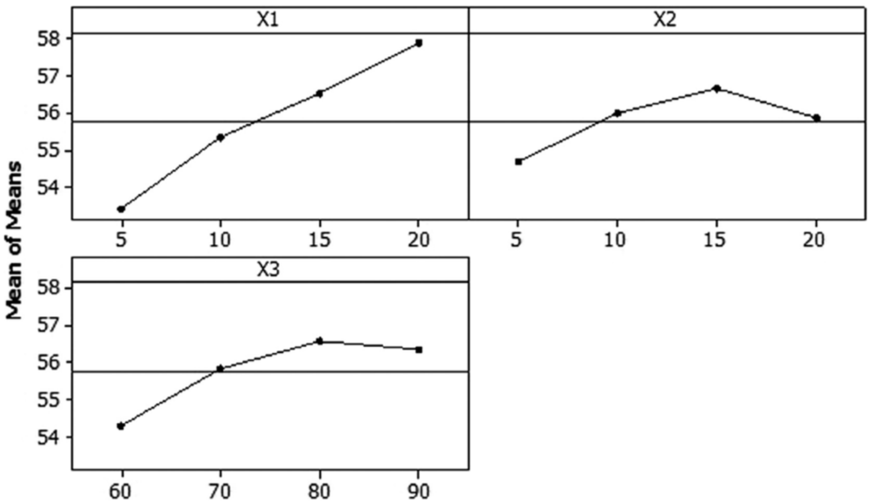

Figure 6: S/N for the water absorption

From the above S/N ratio plot shown in Figure 5 and 6. It can be concluded that the data behaving different at different phase of factor. But among all the possible combination the combination that yields the maximum compression strength and least water absorption are T15 and T14 respectively i.e. A4B3C2 and A4B2C3.

If it is necessary to choose the optimum value for both the water absorption and compressive strength it would be T15 - A4B3C2 as it is giving the maximum compressive strength and water absorption is lower, then the average value.

3.3 Investigating mix proportions of high strength self compacting concrete by using Taguchi method

The High strength self compacting concrete is special combination of the concrete the meets both the uniformity and strength that meets the requirements of handling the workability of concrete with little or no vibration at the same time it should not show segregation or bleeding. For typical high strength concrete the compressive strength should be more than 60Mpa at 28days of curing and low water –binder ratio of 0.40.

In this experiment the high strength self compacting concrete is taken for structure which possibly needs both of their feature. But to achieve such state they are many factor that influence. Factors that can possibly effect the achieving the state taken into consideration are

1. Water to cementitious materials ratio (W/C): (30 33 37)
2. Water content (W): (160 165 170)
3. Fine aggregate to Total aggregate percent (s/a): (39 43 48)
4. Fly ash content (FA): (15 30 45)
5. Air entraining agent content (AE): (0.006 0.007 0.008)
6. Super plasticizer content (SP): (8 10 12)

The orthogonal array of the L_{18} is used since more factor have to consider. Total of 18 mix trail is made with different parameter combinations as shown in Table 10.

Trial no.	W (l)	s/a (%)	FA (%)	AE (kg/m³)	SP (kg/m³	W/C (%)
1	160	39	15	0.06	8	30
2	165	43	30	0.07	10	30
3	170	48	45	0.08	12	30
4	160	39	30	0.07	12	33
5	165	43	45	0.08	8	33
6	170	48	15	0.06	10	33
7	160	43	15	0.08	10	37
8	165	48	30	0.06	12	37
9	170	39	45	0.07	8	37
10	160	48	45	0.07	10	30
11	165	39	15	0.08	12	30
12	170	43	30	0.06	8	30
13	160	43	45	0.06	12	33
14	165	48	15	0.07	8	33
15	170	39	30	0.08	12	33
16	160	48	30	0.08	8	37
17	165	39	45	0.06	10	37
18	170	43	15	0.07	12	37

Table 10: L_{18} orthogonal trial mixes

For materials and test, preparations of materials need in the self compacting concrete and high strength both are include. Some test is conducted for both the fresh concrete slump flow diameter, V funnel flow time, air content, concrete temperature with bleeding and segregation check at during slump flow test. The hardened concrete test consists water permeability, splitting tensile and compressive strength are tested.

In this paper the researcher has work on maximization of the compressive strength and splitting tensile strength which is “larger is better”. Minimize the air content, water permeability and water absorption which is “smaller is better in terms of signal to noise ratio. The variation of the factor on both the fresh concrete property and hardened concrete property is shown in the Figure 7 and 8.

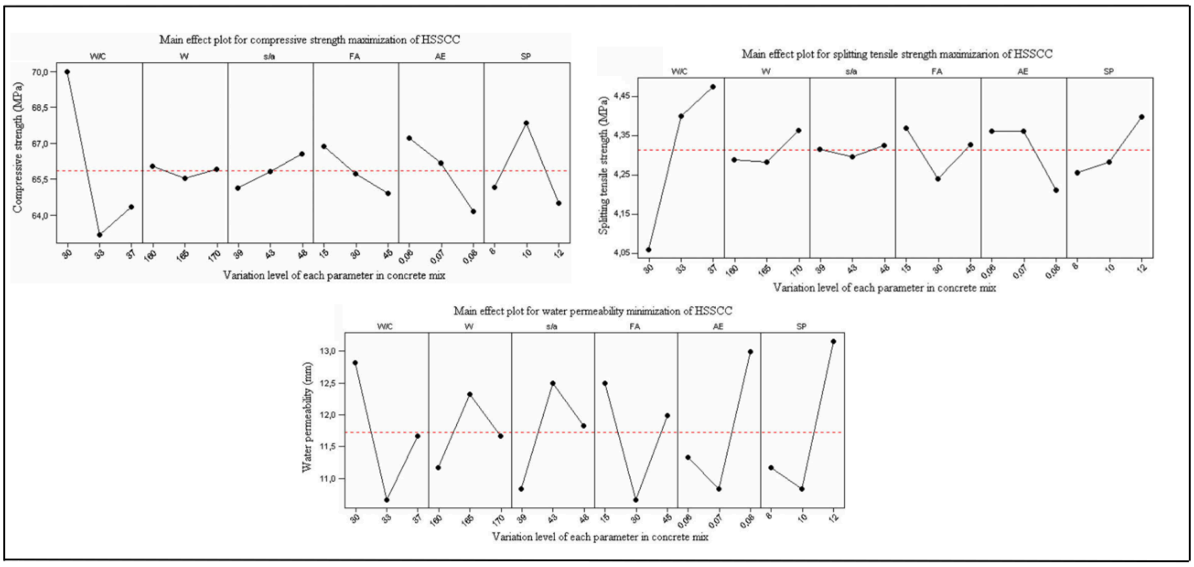

Figure 7: The variation of the hardened concrete properties

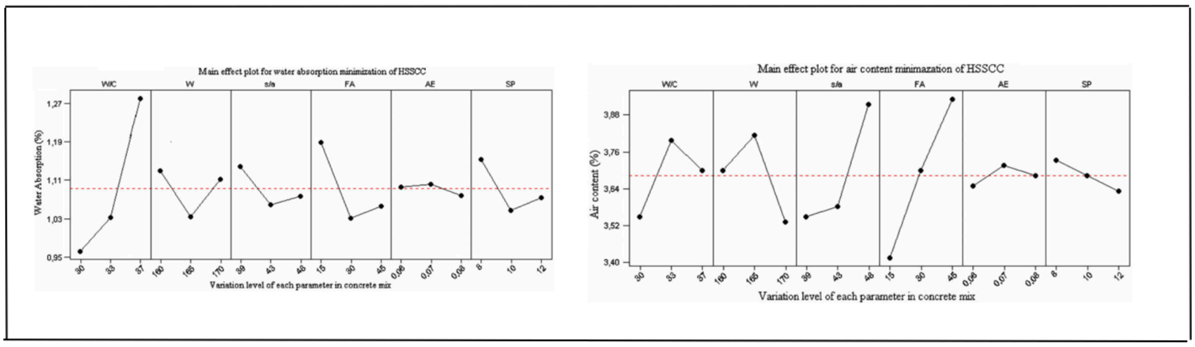

Figure 8: The variation of the fresh concrete properties

From the figure 7 and 8 make it easier to show the variation and in finding the optimal solution for both the properties is found. The values for factor at hardened stage and fresh stages are as following Table 11.

Optimal mix proportions	W/C (%)	W (l)	s/a (%)	FA (%)	AE (kg/ m^3)	SP (kg/ m^3)
Ultrasonic pulse Velocity	37	160	39	45	0.07	10
Water permeability	33	160	39	30	0.07	10
Air content	30	170	39	15	0.06	12
Water absorption	30	165	43	30	0.08	10
Splitting tensile Strength	37	170	48	15	0.06	12
Compressive strength	30	160	48	15	0.06	10

Table 11: The optimal mix proportions

The conclusion is made that the result obtain are satisfied. The Taguchi method used is appropriate for the hardened and fresh concrete properties. With the help of the Taguchi method it made the experiment very simple and cost effective otherwise more than 18 mix trials have to experiment to reach such robustness with using factorial design method. At the end ANOVA commercial software is used to to calculate the contribution of each of the parameter and found that the W/C ratios is most effective parameter among all. In which greater the contribution percentage shows greater effectiveness in the result of the desired product.

3.4 Application of Taguchi method for optimization of concrete strengthened with polymer after high temperature

The research has two main test i.e. compressive strength and the ultrasonic pulse velocity test. The ultrasonic pulse velocity test is experiment which also test the strength like compressive strength but this test is practice in-situ which consists of monitoring device that is send some ultrasonic pulse through the concrete block which is non destructive test. The concrete is subjected to polymerization. Activator methyl methacrylate and benzoyl peroxide is used fastened the impregnation process to improve in porosity.

The L_{32} orthogonal array is made with parameter i.e. heating degree (^{0}C), Silica fume (%) and polymerization type. The Taguchi method is used and found that non-significant variables at earliest stage. Experiment have been design to give the optimum working conditions for the factor which is considered.

Table 12 shows the design experiment in which the level for each parameter is given from which the L_{32} orthogonal array is created. Further the in this paper they focus on constructing the flow chart in which the process of choosing the suitable parameter and levels is mention. The flow chart consists of condition which checks whether the parameter is cost effective, good enough, studies the interaction, dependencies, determination of the controllable variables and uncontrollable variables.

Variable	Level 1	Level 2	Level 3	Level 4
Heating degree, H (°C)	20	200	400	600
Silica fume, S (%)	0	5	10	20
The polymerization type, P (kg/m^3)	The polymerization was made.	The polymerization was not made.	–	–

Table 12: The orthogonal plan for the mix design

The conclusion made after the compressive strength and the ultrasonic pulse test is made on concrete block. Concluding from graph plot shown in Figure 9 and 10 for both the experiment test at varying temperature and silica fume content. That for the compressive strength the silica fume content percentage by weight of 10 at 200 ^{0}C gives the optimum result which is same for the ultrasonic pulse velocity.

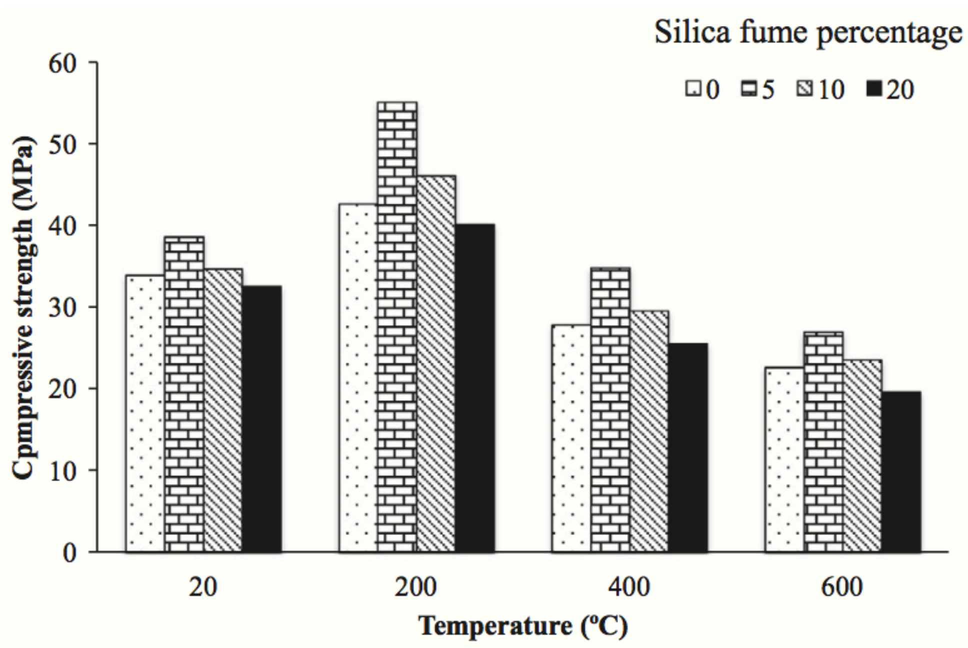

Figure 9: The variance of the compressive strength

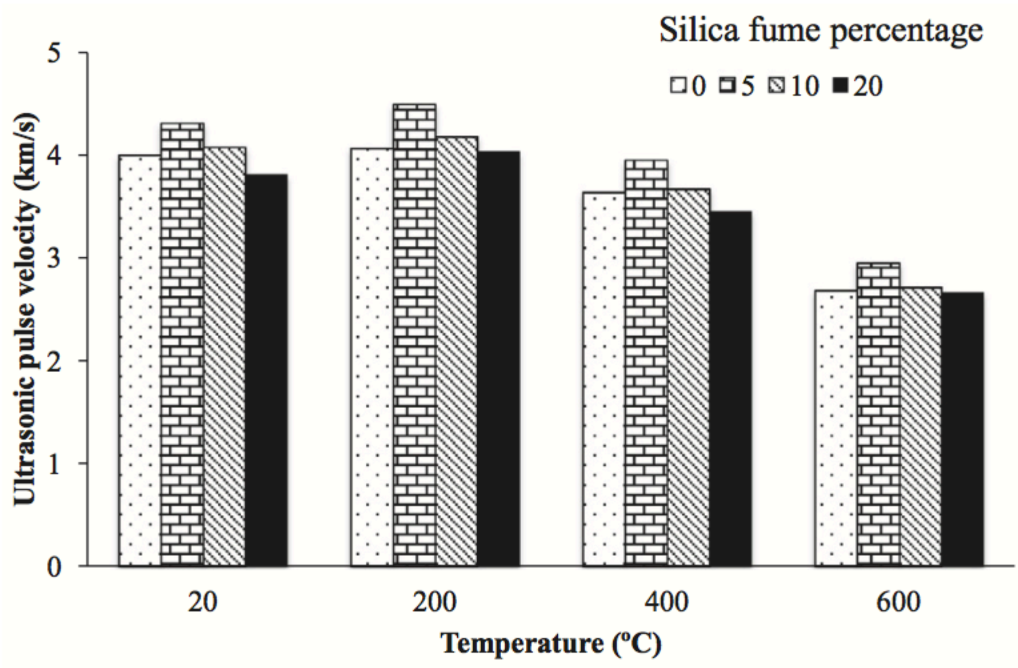

Figure 10: The variance of Ultrasonic pulse test

From previous research it is found that the ultrasonic pulse test having the value between 3.5-4.5km/s has been accepted as good condition. The result is used in ANOVA to find out the contribution of each of the parameter and S/N ratio graph is plot to relate the changes of the values in the test. From the ANOVA result concludes that the silica fume is showing about 85.35 % and 67% for the ultrasonic pulse test and compressive strength. The S/N ratio graph is shown in Figure 10 and 11 respectively.

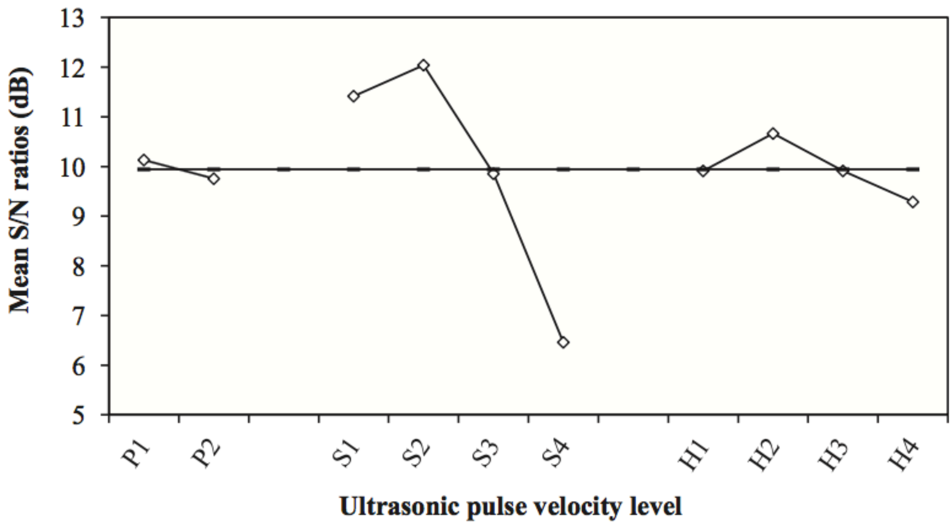

Figure 11: S/N graph for ultrasonic pulse test

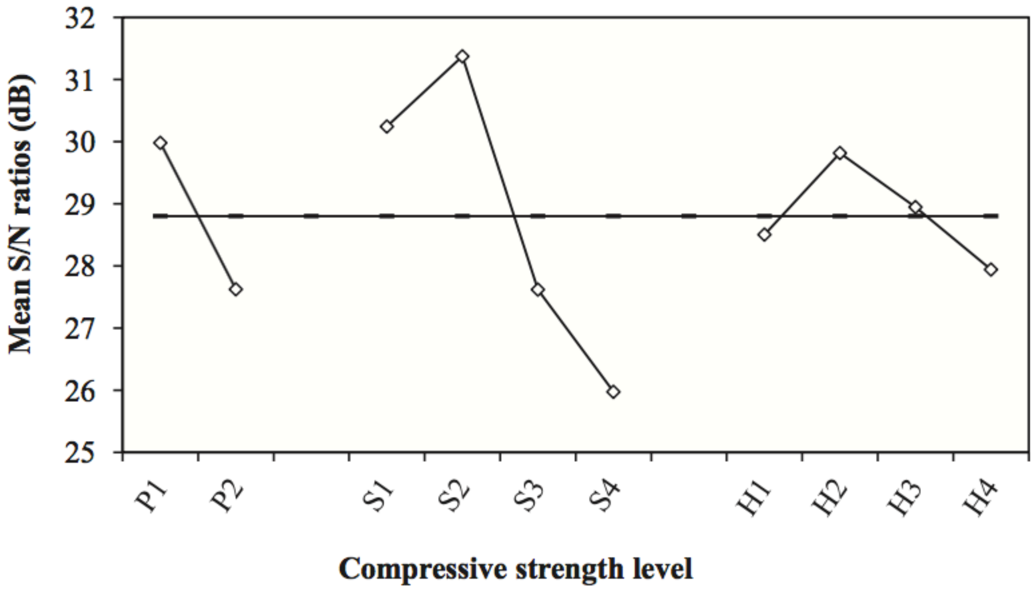

Figure 12: S/N ratio of the compressive strength test

As conclusion as expected the result predicted by the Taguchi method indicate that at silica fume 5% for both ultrasonic pulse test and compressive strength test with polymerization will give the optimum result. It was found that with increase in the temperature both the compressive and ultrasonic strength test tends to decrease. The contribution of each factor was found by the ANOVA.

3.5 Optimization of HSC Compressive Strength by Taguchi Method

In this research paper the objective is very simple which is to optimization of the high strength concrete. The L_9 orthogonal array is used for finding the optimum trial mixes. The factor which are considered are

1. Fine aggregate /total aggregate ratio
2. Silica fume replacement
3. Cementitious material
4. Water / cement ratio

Since it is L9 orthogonal array the three level is considered for every parameter considered in the experiment. The values of the factor changes at every level. Table 13 shows the list of all the factors and their level values.

	Factor	Level 1	Level 2	Level3
1	Fine agg/total agg	0.50	0.55	0.6
2	Silica fume replacement	5%	10%	15%
3	Cementitious material	500	550	600
4	Water /cemen material	0.22	0.25	0.28

Table 13: Factors and their Level

With the Orthogonal array plan the compressive test conducted on 9 experiment trail mixes and the values of each of the trail mixes is shown in the Table 14.

Trial num	F/total ag	SF	Cementitious mat	w/c	Average of samples Compressive strength (kg/cm^2) at 28-day age
1	0.5	5%	500	0.22	646
2	0.5	10%	550	0.25	674
3	0.5	15%	600	0.28	693
4	0.55	5%	550	0.28	628
Optimal result 5	0.55	10%	600	0.22	748
6	0.55	15%	500	0.25	662
7	0.6	5%	600	0.25	713
8	0.6	10%	500	0.28	638
9	0.6	15%	550	0.22	736

Table 14: L_9 orthogonal array

From the table 14 is was found that the trail number 5 is giving the optimal compressive strength at the at 28 day age with $748kg/m^2$. To verify the taguchi method the experiment was conducted. The S/N graph has plot to show the variation of the parameter shown in Figure 13.

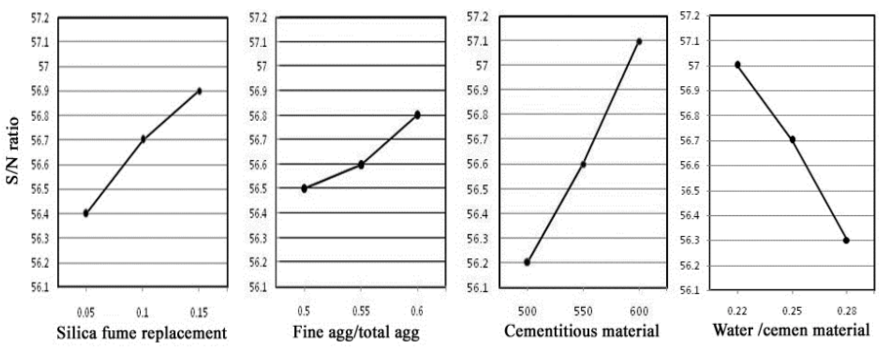

Figure 13: S/N graph plot for each parameter

In this research the optimum compression strength is achived at W/C=0.22, SF=15%, fine aggregate to total agregate ratio=0.6 and cemtitious material =600 kg/m^2. As conclusion the taguchi is very much efffective in using in field of cost saving, time consumption and energy by reducing the number of trail experiment.

CHAPTER 4

OBJECTIVES

1. To find a suitable Taguchi orthogonal array plan and design for the research paper.
2. To get the value for the Signal to noise ratio values for design orthogoanl array.
3. Verification of the obtain data by Taguchi method with actual experimentation.
4. To plot the graph of Signal to noise ratio .
5. To find the degree of contribution by using the ANOVA.

CHAPTER 5

RESEARCH METHODOLOGY

5.1 The orthogonal design and factor

The Taguchi method is constructed on basis of the selected parameter for the optimization of the concrete. The suitable number of parameter is yet to be find. The procedure of finding the number of factors and level can be found by using the flowchart given in the Figure 14.

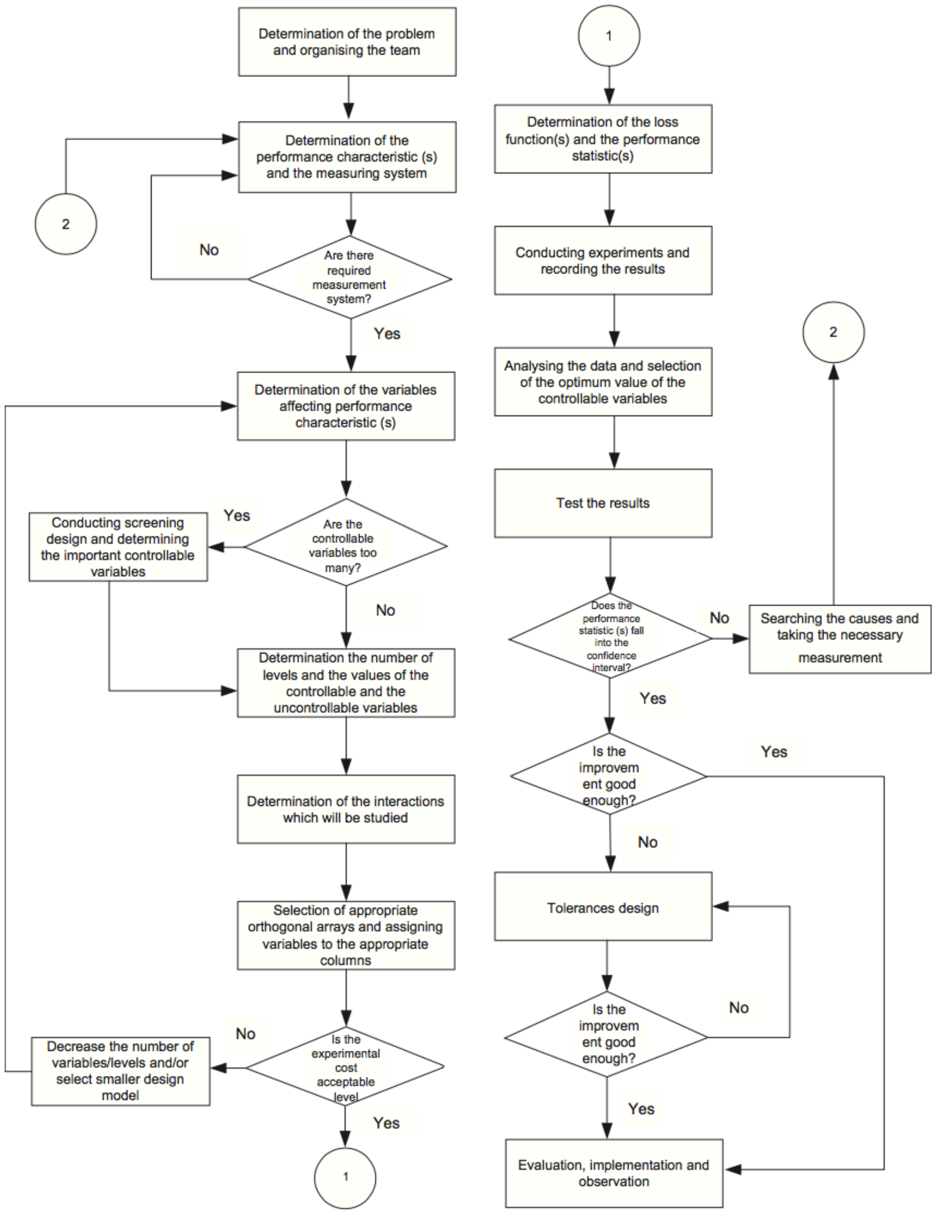

Figure 14: Flowchart of systematic approach to application

5.2 Orthogonal array

The orthogonal array will be most likely L_9 in which there will be four factor with three level each. But further research study is needed.

5.3 The software

The software which is going to be used for formulating the Taguchi method would be Qualitek-4. This software will be able to calculate the optimal result test for the compressive test. Further study is to be done for understanding the working of the software Qualitek-4.

CHAPTER 6

EXPECTED RESEARCH OUTCOMES

The expected result outcomes would be the verification of the Taguchi method design combination trial mixes of by conducting an actual compression test for the selected material. The research will also focus on the cost saving of optimization of concrete using the Taguchi method compare to the conventional method.

CHAPTER 7

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