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OPTIMIZTION OF MIX DESIGN OF CONCRETE BY USING TAGUCHI METHOD

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ABSTRACT

The main objective of this paper is to demonstrate basics of Taguchi method of experimental design in Civilengineeringfor mixdesignofconcrete.Thisisamanagementtechniquewhichisusefulfor gettingoptimum value with given parameters. Applying knowledge of mathematics in engineering projects can help us to do projectseconomicalandefficiently.TaguchiMethodisaformerlyknownstatisticalqualitycontrolmethodwhich can be applied to various engineering fields such as electronical, mechanical, civil etc. In the present paper Taguchi method have used for the better mix design of M25 concrete in the view of compressive strength which is subjected to partial replacements. In this project qualitek4(QT4) software has used for automatic design of Taguchimethod which isavailableinmarket.For doingexperimentsomereplacementsforcementbysilicafume and fine aggregate by quarry dust have done. L_8 array has been used for designing mix by taking 6 parameters and 2levels.

Keywords - Taguchi method, statistical quality control, QT4, silica fume, quarry dust.

Ⅰ. INTRODUCTION

Taguchi method was coined by Dr. Genichi Taguchi in 1950. He is a Japanese engineer and statistician. It is a statistical quality control method which is better than conventional method in both ways of economy and time. It is a partial factorial method of experimental design that requires only a fewer trials than the traditional full factorial method. It works mainly based on signal to noise (S/N) ratio. Noise factors are viewed as the cause of variability in performance. It uses mathematical arrays for representing various trial mixes. In present paper L_8array has been considered i.e. 8 trial mixes.

Concrete is the main construction material in so many civil engineering projects from ancient times.
Fromlastfewdecadesitisdemandingthatconcreteshouldbeefficientandeconomical.Theconcretecompressive strength is mainly depending on proportion of its components. Compressive strength can be altered by adding admixtures up to certain extent in an economical manner. During cement production large CO_2evolves into atmosphere.River sandisusingasfineaggregatebutitstransportation costishigh.So,somealternatesofcement and sand have to provide at least up to some content to reduce pollution. Silica fume of 12% & 16% have been used for replacement of cement and quarry dust of 20% & 30% for replacement of fine aggregate in two levels respectively. W/C ratio and remaining parameters have used in two levels. Silica fume is mainly using from few years for early strength of concrete. After doing 28 and 56 days compressive strength tests, nearly 50% of compressive strength has been increased compared to optimum value of allmixes.

Ⅱ. WORKING OF TAGUCHI METHOD

In Taguchi method parameters and levels are main. Based on these parameters and levels the arrays

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will be selected design will be carried out. It gives arrays as the experimental trials. Each of them explained as follows:

A. Array

- It is a mathematical form which forms based on parameters and levels and represented by L_8, L_9, L_{16} etc. L represents array whereas the number in suffix represents size ofarray

2-level arrays- L_4, L_8, L_{12}, L_{16}, L_{32} 3-level arrays- L_9, L_{18}, L_{27}
4- level arrays- L_{16}, L_{320}

B. Parameters

- These are the factors which takes active part in experiment and they can controlled by designer.

These are again divided as internal and externalparameters.
Internal parameters- parameters that takes action part directly inside experiment i.e. cement, aggregates etc.
External parameters- parameters that acts from outside of experiment i.e. temperature, humidity etc.

C. Levels

- These are the number of ways, how parameters are using inexperiment.

D. S/N ratio

- signal to noise ratio is the main principle in this design we use. Signal is the main object of experiment for which we are doing. Noise is the main factor that causes the variability in final value. i.e. aging, wear, creep etc.

E. Principles

- Taguchi uses mainly 3 principles for controlling of final value in experiment and each one having different S/N ratio formula. They are asfollows:
- **Maximum is better-** Consider this when the goal is to maximize theresponse.

$$S/N = -10*\log\left(\left(\frac{1}{n}\right)\sum\left(\frac{1}{\overline{Y_0}^2 Y_i}\right)\right)$$

- **Nominal is better-** Consider this when the goal is to maintain the response between twointervals.

$$S/N = -10*\log\left(\left(\frac{1}{n}\right)\sum\left(Y_i - Y_0^2\right)\right)$$

- **Minimum is better-** Consider this when the goal is to minimize theresponse.

$$S/N = -10*\log\left(\left(\frac{1}{n}\right)\sum\left(Y_i^2\right)\right)$$

Where
Y_i= response of i^{th} experiment.
$Y_{0=}$ mean response of all experiments.
After considering the case we need give parameters and respected levels. The parameters will react with each one and will give optimum value. If a, b, c, d are parameters then the reactions between them will carried out asfollows:
a is variable- remaining parameters stays constant and a will react with every parameter.
b is variable- remaining parameters stays constant and b will react with every parameter.
Thisprocess willtakeplaceuntileveryparameterreactswith allparametersonce.Thevalueswillobtain based on each parameter response with other parameter. So, the basic thing is it considers all parameters as constant except one and it will react with other constantparameters.

Ⅲ. MATERIALS

The materials are those which are required for concrete and some replacements. The materials and their properties are described as follows:

A. Cement

- Cementisusingasmainbinderinconcrete.OPC53gradecementhas beenusedwithspecificgravityof 3.15 g/cc with following chemical composition in table: -1

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. Table 1: cement composition

Composite material	Quantity in cement
CaO	58.7%
SiO_2	24.6%
Al_2O_3	7%
MgO	3.4%
Fe_2O_3	2.4%
SO_3	1.9%
Free CaO	1%
Total Alkalis	0.75%

B. Coarseaggregate

● Coarse aggregate is strong and occupies more volume in concrete and gives strength. Crushed aggregate has been used from a stone crusher near to Narasaraopet. The specific gravity of coarse aggregates is 2.72 and uniformlygraded.

C. Fineaggregate

● Fine aggregate occupies second place in volume of concrete after coarse aggregate. Fine aggregate has been used from a seller near Narasaraopet. Specific gravity of sand is nearly2.43.

D. Silicafume

● Silica fume, also known as micro silica. It is an amorphous polymorph of silicon dioxide, silica. It is an ultrafine powder. It is a byproduct of silicon and ferrosilicon alloy production. It has particles of diameter nearly 150 nm. It helps in increasing durability of concrete and it will reduce voids in concrete by filling it. It acts as a good binder and filler in concrete with a specific gravity of 2.2. It has been collected from Ashwin ceramics,Chennai.

E. Quarrydust

● Quarry dust is small rock particles obtained as residue by extracting large boulders for coarse aggregate or large stones. It is in grey color and having specific gravity of 2.62. It is sieved through 4.75 mm sieve and 75 µm sieve to separate particles of size greater and lesser than allowable size of fine aggregate. It has collected from a stone quarry near toNarasaraopet.

IV. MIX DESIGN

The design has done based on water content in two levels. Quantities of each parameter in each level are shown in table-2.

Table 2: mix design

S. No.	Parameter	Level-1	Level-2
1.	Silica fume	12%	16%
2.	Quarry dust	30%	20%
3.	W/C ratio	0.4	0.45
4.	Fine aggregate	513 kg/m^3	556 kg/m^3
5.	Coarse aggregate	1160 kg/m^3	1190 kg/m^3
6.	Cement content	465 kg/m^3	414 kg/m^3

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V. SOFTWARE ANALYSIS

The parameters with respected levels have been entered into software. The array of various trial mixes and no. of parameters are explained as follows:

- no. of internal parameters are 6 and no externalparameters.
- no. of levels are 2 and array isL_8.
- after entering results used S/Nanalysis.

Table 3: array

0	1	2	3	4	5	6
1	1	1	1	1	1	1
2	1	1	2	2	2	2
3	1	2	1	1	2	2
4	1	2	2	2	1	1
5	2	1	1	2	1	2
6	2	1	2	1	2	1
7	2	2	1	2	2	1
8	2	2	2	1	1	2

The columns in array shows parameter and rows shows mix design.

VI. RESULTS

The cubes have made with standard dimension of 150x150x150 mm and tested for compressive strength at 28 and 56 days. The curing is normal water curing and at room temperature. The values of each mix are shown in table-4.

Mix design trial no.	Strength at 28 days in MPa	Strength at 56 days in MPa
1	30.23	34.36
2	20.7	22.8
3	18.96	21.3
4	15.35	17.25
5	26.2	28.95
6	49.26	54.14
7	39.83	46.87
8	30.2	35.145

Table 4: results

From these results the average value for 56 days is 29.551 whereas optimum value is 36.185. The mix design for highest compressive strength of concrete with replacement is at 16% of silica fume and 30% of quarry dust.

Graphs

The graphs have been drawn by software automatically for 56 days strength, between average compressive strength of all mixes and each parameter as below.

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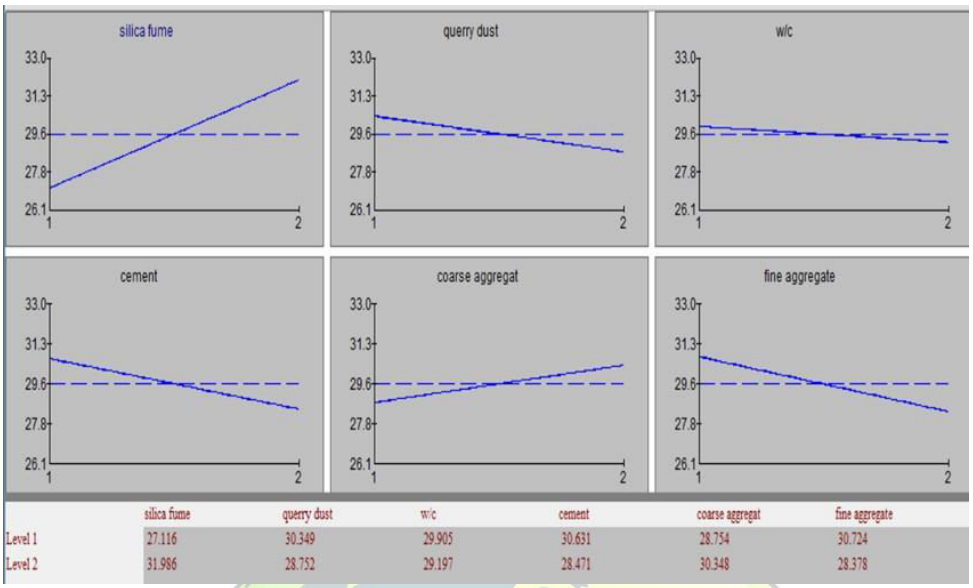

	silica fume	querry dust	w/c	cement	coarse aggregat	fine aggregate
Level 1	27.116	30.349	29.905	30.631	28.754	30.724
Level 2	31.986	28.752	29.197	28.471	30.348	28.378

VII. CONCLUSION

Taguchi method is a best management technique, which is more helpful in time and money saving. It is gaining more popularity due to its advantages. Silica fume and quarry dust are extracted materials which can be used as admixtures in concrete to increase desirable properties up to some extent which is economical.

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