TAGUCHI METHOD STATISTICAL STUDY OF THE OUTCOMES BETWEEN THE CONTROL VARIABLES IN MINITAB SOFTWARE

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Abstract: Increasing emphasis is being placed on infrastructure development in India as a result of which, the construction activity has increased by leaps and bounds. The production of cement has also grown to fulfil the constructional needs, which has effect in rapid diminution of earthy resources and created environmental problems due to release of Greenhouse gases. Therefore, to lessen the usage of cement, there is a need for supplementary cementitious materials. From this consideration fly ash, GGBS etc are being used as supplementary cementitious materials. The usage of calcined clay, as metakaolin (MK) in concrete has gotten impressive consideration as of late. On this, a survey has been coordinated to examine the show of metakaolin as substantial replacement material in concrete. Steel slag is a result of steel making processes of steel industry. It's likewise perhaps of the biggest modern waste which are being created overall in a tremendous amount. With the country facing huge shortage of earthy or river sand and even manufactured sand due to restrictions on quarrying, alternative fine aggregate like slag sand have become attractive in recent years. In the present study, concrete mixes incorporating Metakaolin and steel slag aggregate as partial replacement of cement and sand, respectively were investigated. Of the various experimental design techniques, the Taguchi method of experimental optimization has become very popular and is widely used. In the present study, Taguchi method of experimental design involving L16 orthogonal array was adopted. The control factors selected were water cementitious ratio (w/cm) (0.36 to 0.42), Metakaolin to cementitious ratio (M/cm) (10% to 25%), Steel slag to fine aggregate ratio (SS/FA) (10% to 40%) and 4 levels for each control factor was considered. The fresh and hardened properties of concrete were investigated at 7 and 28days. The test results were compared with the normal concrete mix and the test results indicate that the optimum replacement level of cement by metakaolin is up to 10%, which increases the compressive strength of concrete at 28days. The steel slag sand shows negligible contribution to compressive strength and split tensile strength of the concrete upto 30% beyond which it increases the split tensile strength.

Index Terms – **Cement, M-Sand, Fine Aggregate, Taguchi Method, Metakaolin.**

I. INTRODUCTION

Around 25 billion tonnes of cement are thought to be produced annually around the world. This corresponds to approximately 1.8 billion truck stacks annually, or about 6.3 million truck stacks daily, or more than 3.8 tonnes for one person worldwide annually. Humans consume no material with the exception of water in such colossal amounts. There are many cement delivering nations on the planet yet among that multitude of nations, China is the biggest maker. Cement production in India is the second-highest in the world. It should come as no surprise that India's concrete sector is a crucial part of its economy, directly or indirectly employing more than 1,000,000 people. Since it was freed in 1982, the Indian concrete sector has attracted enormous investments from both domestic and foreign companies. The government's push for large framework projects is expected to increase cement demand in India, resulting in a need for 45 million tonnes of concrete over the next three to four years.

By 2025, India is expected to use 550 to 600 million tonnes of cement annually (MTPA). The housing sector is the biggest cement interest driver, representing over 67% of total utilization in India. The other major consumers of concrete are the foundation industry, which accounts for 13% of purchases, company development, which accounts for 11%, and modern improvement, which accounts for 9%. Concrete businesses must build 56 million tonnes of capacity over the next three years in order to meet the increased demand. By the end of the next year, the concrete extent in India may have increased by 8% from the current level of 366 Metric Ton to 395 Metric Ton. It might spread out further to 421 Metric Ton toward the completion of 2025.

The cement business influences an Earth-wide temperature boost in two significant methods. The production of cement uses lots of carbon-based energy, primarily in the form of combustible gas or powdered coal, whose main byproduct is carbon dioxide.

a. Possible alternatives

The utilization of additional cementing ingredients and enhanced cement manufacturing technology are two environmentally friendly strategies that should be taken into consideration in order to address the problems of sustainable growth facing the cement industry. Researchers and scientists throughout the world are constantly looking for ways to create alternative binders that are environmentally friendly and support sustainable management due to the continuously rising demand for and consumption of cement as well as the backdrop of waste management. Currently, researchers are figuring out how to use agricultural or industrial waste as a supply of raw materials for the manufacturing sector. In comparison to other industrial and agricultural waste products, fly ash is regarded as the most feasible cementitious material due to its chemical composition, particle size, and availability. Amongst the agricultural by product, Metakaolin, which is abundantly available in the country, is a promising alternative cementitious material.

b. Metakaolin

By calcining kaolin clay at a moderate temperature, supplementary cementitious material (SCM) called metakaolin (MK) is created (650 to 800 C). The metakaolin undergoes further reactions to generate crystalline compounds at higher temperatures (>900 C), with the end products being free silica and mullite. It has a functional structure made of silica and alumina that will produce CH in response. Materials accessibility and sturdiness improvement have been the recommended guidelines for the use of earth-based pozzaloans in mortar and concrete. It is also possible to have an increase in strength, particularly in the early stages of relieving, depending on the calcining temperature and type of earth. The filler impact and accelerated cement hydration combined to boost early strength. The pozzalonic response between MK and the CH brought on by concrete's hydration enhances these effects in this way.

In Portland cement concrete, MK interacts with calcium hydroxide in cement paste at room temperature to produce calcium silicate hydrates (C-S-H), gehlinite hydrate (C2ASH8), and C4AH13, which are primarily (tetracalcium aluminate hydrate). The cementatious matrix's strength and impermeability are increased due to the production of secondary C-S-H, which simultaneously reduces total porosity and improves the pore structure. It has been shown that MK speeds up the rate of heat evolution while cement is curing. This has been linked to MK's strong reactivity with CH as well as its acceleration of Portland cement hydration. In order to evaluate the rates of reaction between MK and cement and MK and theCH formed during first hydration, quantification of the heat of hydration in MK/Portland cement systems can be utilised. Additionally, knowledge of the effects of MK use on strength development can be improved with the help of this kind of information.

c. Shortage of Other Ingredients of Concrete

Concrete is a composite material made out of coarse granular material the total or filler implanted in a hard network of material (the concrete or folio) that occupies the space among the total particles and pastes them together. After examining the impact and available options for concrete, the remaining fixings materials, such as fine total (sand) and coarse total, provide another problem for the production of cement.

d. Fine Aggregate (FA)

Overall utilization of sand likens to approximately 40 billion tons every year and,

representing an expected 30 billion tons of this, development has by a long shot the greatest sand impression. The Applications of sand incorporate land recovery, structures and street dikes, however maybe most fundamentally sand is additionally a fundamental part of concrete. Making up around 35% of the volume of cement, sand makes up for shortfalls and grants solidarity to make it a produce a really strong and item dependable structure material. With the extending worldwide populace fuelling the requirement for lodging and foundation, regular sand is being separated at a disturbing rate. A decrease in accessible assets has made the extension of mining seaside regions and digging of the ocean bottom. This huge scope extraction is thus affecting marine and stream biodiversity, causing beach front and inland disintegration, expanding the possibility flooding, and bringing down the water table in certain region, compounding the gamble of dry spell.

e. Coarse aggregate

Open excavation, commonly referred to as quarrying, is the common method used to obtain natural coarse aggregates from massive rock formations. Issue related due to the lack of good and quality of CA(coarse aggregate) kept up the construction industries into a situation in accumulation an alternative to get over this condition. Since non-renewable aggregates from quarrying activities are currently employed in the construction industry, the problem is getting worse. The demand for coarse aggregates has risen at an alarming rate due to recent rapid development.

f. Steel Slag Sand

Steel slag, a byproduct of the steel-making process, is created in steel-making furnaces when the molten steel is separated from impurities. The slag is a complex mixture of silicates and oxides that forms as a molten liquid melt and solidifies after cooling. Blast furnace slag aggregate and electric arc furnace oxidizing slag aggregate are the two forms of concrete aggregate that are produced utilizing iron and steel slag as a raw material. Aggregates in both of these two categories come in both coarse and fine varieties. When molten slag is withdrawn from a blast furnace or electric arc furnace and slowly cooled, it solidifies mechanically, creating coarse aggregate. When molten slag is taken from the furnace and quickly cooled with water, air, or another method, fine aggregate a mechanically stabilized aggregate is produced.

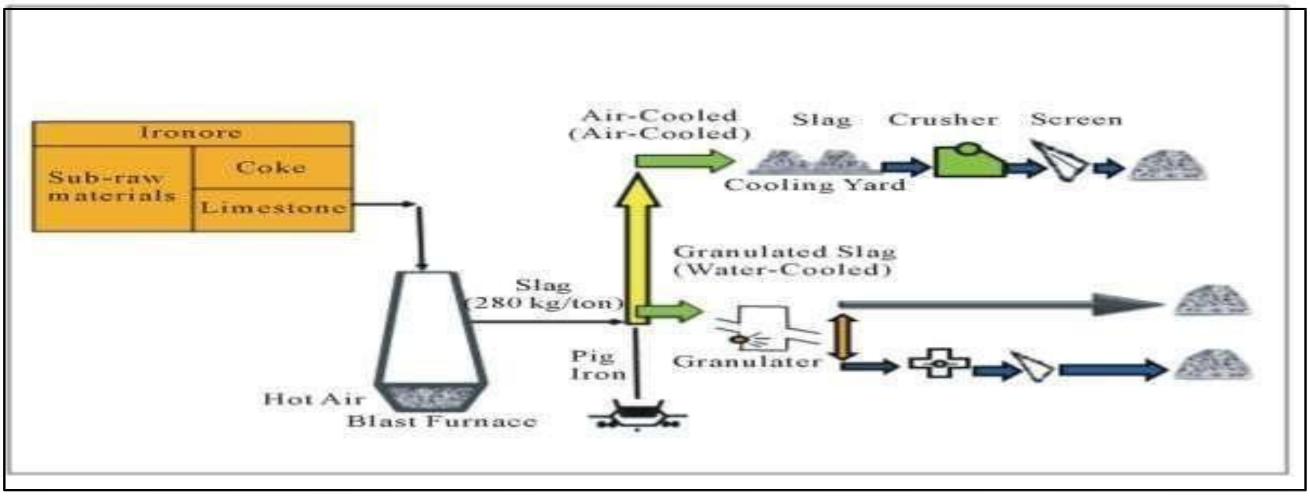

Fig 1:Slag aggregates production flow diagram

g. Role and application of slag sand as an additive for fine aggregate

The use of steel slag sand in concrete has a number of advantages, including-Functionality and admixtures of the substantial increments and water request decreases. Better protection from HCl and H2SO4.Works on the physico-mechanical qualities. Protecting effectiveness of substantial increments. Strengthening due to reduced sediment content and remarkably sensitive silica. Low maintenance costs are a benefit of high toughness. Extends the completion of smooth surfaces and boarding. In comparison to stream sand and M-sand, slag sand's density is noticeably lower.

II. Related work

Anita N Borade and B Kondraivendhan (2017); The goal of the current work is to investigate how Portland slag cement (PSC) and metakaolin (MK) affect the cement's ability to erode. Because of this, 15% MK by weight and quick concrete was used in place of traditional Portland concrete (OPC). Both the half-cell anticipated estimation and compressive strength standard considerable instances were available. For the experiments indicated above, the instances were presented with varying water to fastener ratios (w/b, for instance, 0.45, 0.5, and 0.55), and presented with a sodium chloride (NaCl) arrangement of 0%, 3%, 5%, and 7.5%. The examples were tested at a wide range of age points, including 7, 28, 56, 90, and 180 days. In this study, the effects of MK, w/b ratio, age, and NaCl openness on concrete were displayed, along with the correlation of the results of both MK and PSC concrete. Additionally, it was shown that concrete with MK exhibits more advanced performance as compared to concrete with PSC. Due to MK's faster rate of hydration, concrete with MK exhibits strong early-age compressive strength. On account of cement with MK instances, a more advanced execution is shown for both the compressive strength test and the half-cell potential test. In terms of consumption blockage, the substantial with MK clearly performs better than the substantial with PSC.

Surendra B.V. Rajendra T (2016); This paper presents the aftereffects of an exploratory review completed to track down the impact of fly ash and metakaolin by halfway substitution of concrete of M-40 grade concrete, as far as further developed execution on compressive, and split rigidity. The controlled substantial example of M- 40 grade was arranged utilizing OPC 43 grade concrete. Different examples were ready by supplanting concrete with 15% fly debris and metakaolin at 5%, 10%, 15% and 20%. The different qualities were contrasted with controlled examples driving with an end that there is an expansion in Compressive Strength equal to 48.88%, and split tensile equal to 54%. Addition of Metakaolin and flyash has brought about improved primary strength and extreme strength of cement. The halfway substitution of concrete outcomes in decrease in the discharge of green gases. The simple accessibility of metakaolin and flyash and their lesser expense influences in less expensive economy.

Kailash BhimrajKumawat, Akshay More, Vikrant Netke, Aakash Ashok Rikhe (2016); Metakaolin (MK) is a pozzolanic material, which works on the solidness and strength of cement. In this review the test programs were done with 2%, 3% and 4% of fiber content by volume of cement with substitution of concrete by Metakaolin at 5% and 7.5% by weight of concrete. The point of work is to streamline the level of fiber content and to limit the concrete utilization by supplanting it by Metakaolin. It likewise gives way to powerful removal of modern waste to stay away from worldwide issue and safeguard climate. The primary target of this work was to decide the impact of replacement of concrete with Metakaolin on mechanical property of SIFCON mortar. For that reason compressive strength, flexural strength and Split pressure strength of SIFCON example were tried following 7 and 28 days of relieving, yielding positive outcomes. In this review, we found that 2% fiber substitution by volume of cement and Metakaolin at7.5% by weight of concrete yields best and efficient outcomes.

a. Steel Slag Aggregate

Isham Qasrawi [9], investigated by involving steel slag as a replacement of fine aggregate supplanting sand in the blends by supplanting it with proportions of 0%, 15%, 30%, 50% and 100%. The outcomes show that the compressive strength is improved when steel slag is utilized around 30%.The ideal outcomes are acquired for swap proportions of 30-50% for tensile and 15-30% for compressive strength.

Gaurav Singha [8], investigated chance of utilizing Granulated blast furnace slag (GBFS) as substitution of regular sand in concrete. The variety in compressive strength of cement with GBFS content alongside cost examination is finished to recommend the most advanced level of GBFS to be utilized in vario us conditions has been considered. The outcomes show that the ideal substitution of GBFS to the extent that strength and economy factor considered is 40% to 50%.

Subathra Devia and Gnanavel [13], studied the effects on fractionally substituting steel slag for the total of the coarse and fine particles (SS), on the different strength and solidness properties of cement, by utilizing the blend plan of M20 grade. Compressive strength, rigidity, flexural strength and solidness tests like corrosive opposition, utilizing Hcl, H2SO4, and Fast chloride infiltration, has been tentatively examined. The outcomes demonstrate that the fractional substitution of fine and coarse totals by steel slag works on the compression, malleable and also flexural strength. It is considered to be very rare for solid structures to suffer mass loss after being submerged in acids. The level of chloride particle vulnerability is evaluated in light of the cutoff points, given in ASTM.

Juan et. al [10], studied the utilization of slag aggregate in mortar and cement. A few blends of concrete were planned to break down their solidarity and properties. The outcomes show that this substantial can be created and utilized in many applications in structural designing and development. Review and tests were performed on the solidness of these concrete shows a satisfactory way of behaving against forceful conditions.

b. Taguchi Method of Optimization

Erdinc Arici [15], examined experimentally and statistically the impact of marble dust and glass fibre on the mechanical and physical characteristics of cement mortars exposed to high temperatures. The mixes containing marble dust (0%, 20%, 40% and 50% by volume) and glass fiber (0 kg/m3, 0.25 kg/m3, 0.50 kg/m3, 0.75 kg/m3) were prepared. The compressive strength and porosity value of the cement mortars were determined after being exposed to high temperatures (400, 600 and 800oC). In order to reduce the numbers of experiments, an L16 Taguchi orthogonal array was adopted to the study.

Reza Mohebi [19], studied the scraped area obstruction of Alkali- Activated Slag (AAS) concrete was explored by ASTM C1138. Four influencing factors including restoring temperature, alkaline solution for slag weight proportion, centralization of sodium hydroxide arrangement and sodium hydroxide to sodium silicate weight proportion were considered to accomplish the most extreme compressive strength and scraped spot obstruction of AAS substantial utilizing the Taguchi plan of investigation technique. The outcomes showed that the CO2 impression of AAS concrete was roughly 51% not exactly that of Ordinary Portland Concrete (OPC) concrete and hence the eco mechanical execution of AAS concrete was unrivaled.

Erdogan Ozbay et. al [20], examined high strength self-compacting concrete (HSSCC) blend extent boundaries were examined using Taguchi's analysis plan approach for perfect plan. The water/cementitious material proportion, water content, fine total to add up to total percent, fly ash content, air entraining specialist content, and superplasticizer content are the six factors used to plan blends in an L18 symmetrical cluster as a result. The Taguchi exploratory plan approach is used to investigate the experiment findings. The best blend levels are still being determined for the reduction of air content, water porousness, and water assimilation (absorption) values while increasing ultrasonic velocity (UPV), compressive strength, parting or splitting rigidity.

Ibrahim Turkmena et. al [21], assessed the harm brought about by compound assault on high strength substantial blends ready with silica rage (SF) and impact heater slag (BFS). The Taguchi technique has been utilized to decide the ideal circumstances expected to get the actual properties that will respect the strongest substantial blends. Significant cases were alleviated in lime-soaked water at 232oC for up to 14 days. Mineral admixture, water-to- binder ratio proportion, relieving system, and restoration time were the test variables used for this investigation. The investigation's findings showed that the combinations made up of 10% SF and 5% BFS were the strongest. This mixture was relieved in limewater for 120 days at a water-fastener (W/B) concentration of 0.30.

Alireza Joshaghani et. al [23], examined the pervious concrete's mechanical and physical characteristics. To maximize the effectiveness of these qualities, Taguchi design of experiments was adopted. There were three levels for each of the three criteria (coarse aggregate size, water-to-cement ratio, and % of cement paste). The findings demonstrate that as the coarse aggregate's maximum size rises, permeability and porosity also rise. Additionally, the compressive strength is significantly reduced as a result. Strength and permeability have a trade-off that should be taken into account in order to satisfy the minimal standards for pervious concrete.

III. BACKGROUND

A significant amount of CO2, an ozone depleting material, enters the atmosphere as a result of the production of Portland concrete, a key component of cement (GHG); creation of 1 ton of Portland concrete produces around 1 ton of CO2 and additional GHGsto relieve this issue, a few elective materials have been recommended. In the current review, an endeavor has been made to research reasonability of purpose of Metakaolin as halfway swap for concrete in concrete. Metakaolin is a result from ceramic production industry which in any case makes ecological issue in removal. Regular stream sand is also in low supply, hence manufactured sand is also being used as an alternative. Anyway, limitation on quarrying of totals to produce sand has required post for elective totals. To lessen the use of Manufactured sand, a side-effect of steel producing industry for examples lag sand is utilized as an incomplete substitution material for fine total. Thus, a use of these materials in making a development material would be a possible answer for accomplish supportability in development industry.

Although there have been numerous studies on metakaolin, high strength concrete has not received much attention. The high strength concrete containing steel slag aggregate has also not been the subject of numerous investigations. The use of Metakaolin as a partial substitute for cement and steel slag aggregate as a partial substitute for fine aggregate in concrete to produce high strength concrete is the study's driving force.

This could aid in the conservation of natural resources, the efficient utilization of the expanding waste stream, and the reduction of energy consumption. As a result, an experimental investigation is conducted to determine whether Metakaolin and steel slag sand are suitable for use in the production of high strength concrete.

IV. PROPOSED METHODOLOGY

Concrete mix proportioning is the most popular method of selecting suitable concrete ingredients and determining their relative amounts with the goal of producing a substantial of the required strength and functionality as affordably as possible. The projected execution of concrete in two states, namely the plastic and solidified states, represents the proportioning of concrete's component parts. The plastic concrete cannot be set and compacted as intended if it is not workable. As a result, the quality of functionality becomes crucial significance. The quality and quantity of cement, water, and aggregates; clustering and blending; and other factors all affect a solidified substance's compressive strength, which is typically seen as a record of its various attributes.

a. Design of Experiments

Design of experiments (DOE) is a deliberate strategy to decide the connection between factors influencing a cycle, like substantial creation and the result of that interaction, like different properties of concrete. All in all, finding circumstances and logical results relationships is utilized. This data is expected to deal with the cycle inputs to streamline the result.

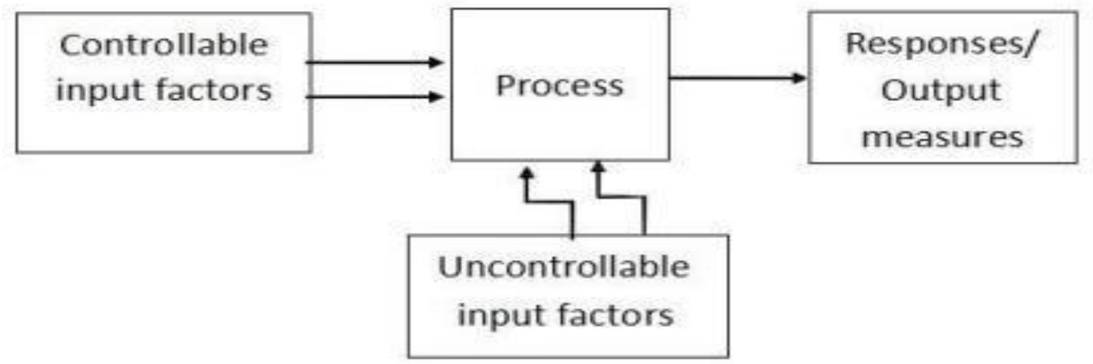

Fig 2: Operation of DOE

b. Experiment Design According To Taguchi

In view of "Symmetrical ARRAY or ORTHOGONAL ARRAY" testing, Taguchi of the Nippon Telegraph and Telephone Company in Japan has developed an approach that significantly reduces "fluctuation or variance" for the trial with "ideal or optimum settings" of control boundaries. "Orthogonal Arrays" (OA) provide a set of well counterbalanced (minimum) experiments and TAGUCHI'S SIGNAL-TO- NOISE RATIOS (S/N), which are log functions of wanted output, serve as objective functions for optimization, help in data analysis and reasoning of optimum outcome.

The plan and investigation of tests spins around the comprehension of the impacts of various factors on another variable. In numerical language, the goal is to lay out a circumstances & logical results connection between various free factors and a reliant variable of interest. The reliant variable, with regards to DOE, is known as the reaction, and the free factors are termed as control factors. Tests are attempted at various control factor values, known as levels. Each attempt of a trial includes a blend of the levels of the researched control factors. In tries different things with many variables, every mix of the levels of the elements is alluded to as a treatment. At the point when similar quantities of reaction perceptions are interpreted for every one of the treatments of an investigation, the plan of the examination is supposed to be adjusted. Rehashed perceptions at a granted treatment are called reproduces. The quantity of medicines of a still up in the air based on the quantity of element levels being explored in the examination.

The "TAGUCHI TECHNIQUE" entails using a rigorous test plan to reduce the collection in a cycle. Delivering a high-quality product at a low cost to the producer is the technique's ultimate purpose. In order to examine what different restrictions mean for the mean and change of an execution brand for cooperative work that indicates how effectively the cycle is working, Taguchi developed a system for organizing assessments. To identify the constraints affecting the connection and the levels at which they should be altered, Taguchi's exploratory proposal uses even displays. Like the factorial arrangement, the TAGUCHI TECHNIQUE tests groupings of mixtures rather than all possible combinations. This takes into account the gathering of substantial data to determine which elements have the most influence on product quality with a minimal amount of experimentation, saving time and resources. The Taguchi technique works best when there are approximately 3 and 50 variables, minimal to no correspondences between elements, and two or three elements that contribute on the most fundamental level.

c. Taguchi's approach

Genichi Taguchi created the Taguchi method in the 1950s as a statistical methodology for process improvement. The approach of parameter design developed by Taguchi offers the design engineer a systematic & efficient technique for determining nearby optimum design parameters aimed at performance and cost. The major concept of Taguchi that must be discussed is the ‘‘noise factors”. Noise factors are viewed as the cause of variability in performance, including why products fail. The signal–to-noise ratio (S/N) is used in evaluating the quality of the product. The S/N processes the level of performance and the effect of noise factors on performance and is an evaluation of the stability of performance of an output characteristic. A Taguchi experimental design, for illustration, will have sixteen treatment combinations in total (L16 Orthogonal array) if three factors each take four levels.

d. The Taguchi Technique Flow Chart

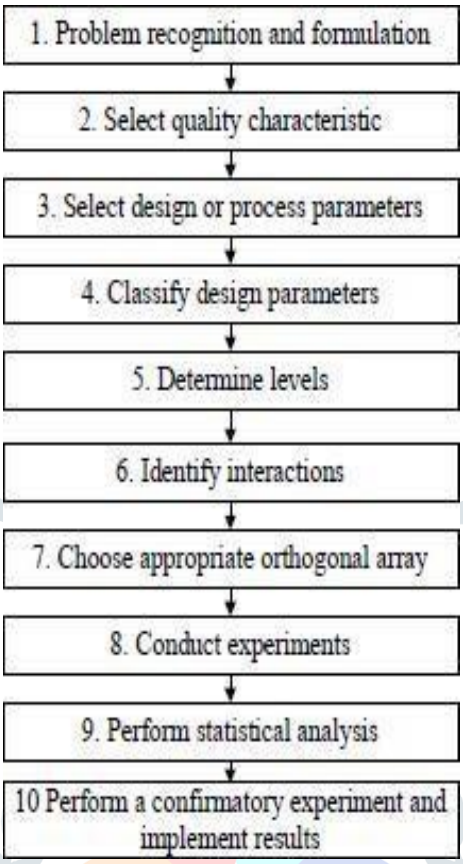

Fig 3:Taguchi Method of Optimization Flow Chart

e. Principle Of Taguchi's Technique

It is by and large progressively perceived that the top notch of an item or administration and the related consumer loyalty are the key for big business endurance. Likewise perceived is the way that pre-creation tests, expecting to be appropriately planned and broke down, can contribute essentially towards quality enhancements of an item. A customary (yet extremely famous) strategy for working on the nature of an item is the technique for changing each consider turn during pre-creation trial and error.

In this technique, the architect notices the consequence of a trial subsequent to changing the setting of just a single variable (boundary). This technique has the significant disservices of being expensive and untrustworthy. The Japanese were quick to understand the capability of another strategy utilizing measurable plan of investigations Statistical Design Of Experiments (SDE). SDE, rather than the one element technique, advocates the changing of many factors all the while in an efficient manner (guaranteeing a free investigation of the item factors). In one or the other strategy, whenever factors have been enough described, steps are taken to control the creation cycle so that reasons for low quality in an item are limited.

Five major points of the Taguchi quality philosophy are: In competitive market climate, constant quality upgrades and cost drops are essential for business endurance. A significant assessment of a thing's nature fabricated item is the complete public misfortune brought about by that item. Modification the pre-creation trial technique from shifting each calculate turn to differing many factors all the while (SDE), with the intention of incorporating quality into the thing and the cycle.The client's misfortune because of low quality is around corresponding to the square of the deviation of the exhibition trademark from its objective or ostensible worth. Taguchi changes the goals of the analyses and the meaning of value from "accomplishing conformance to determinations" to "accomplishing the objective and limiting the changeability.

V. RESULTS AND DISCUSSIONS

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a. Application of the Taguchi Method

Table 1:Factors And Levels Adopted

FACTORS	LEVELS			
W/cm	0.36	0.38	0.40	0.42
M/cm	0.10	0.15	0.20	0.25
SA/FA	0.10	0.20	0.30	0.40

Where,

W/cm = Water to Cementitious Ratio, M/cm = Metakaolin to Cementitious Ratio,SA/FA = Steel Slag Aggregates to Fine Aggregate.

b. Selection of Orthogonal Array

Taguchi's set of tables known as orthogonal arrays are used to establish the conditions for the fewest number of experiments. According to the quantity (Numbers) and intensity (Levels) of the factors, an orthogonal array is chosen.There are three factors in this study, each with four levels. Based on the quantity of elements chosen and their levels, the following L16 orthogonal array has been chosen, as shown below.

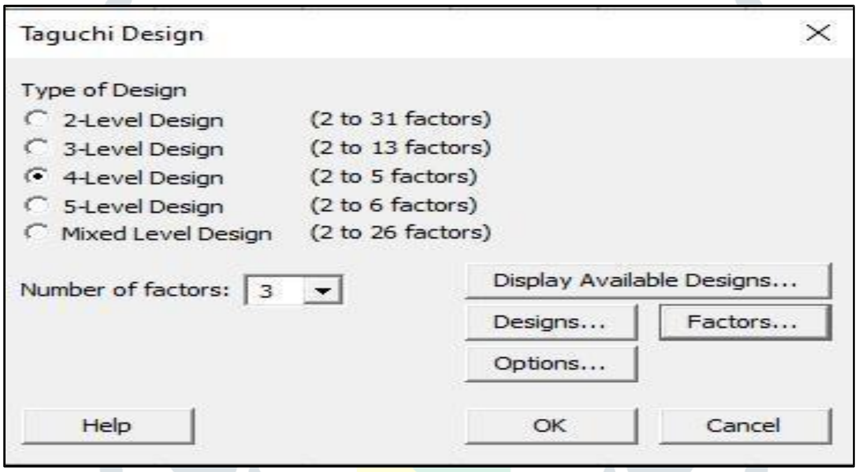

Figure 4: Selection of level and Factors in MiniTab

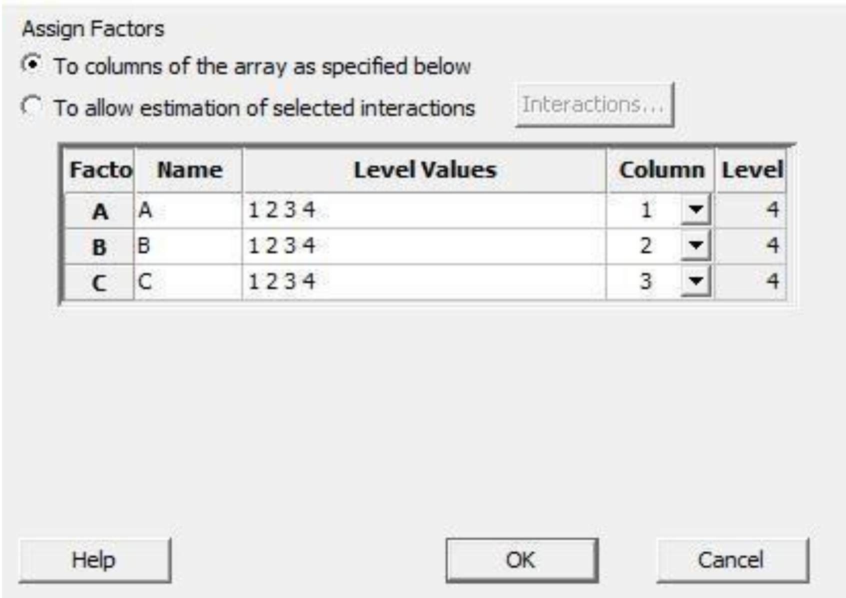

Figure 5: Assigning Factors Name and Values

↓	C1 FActor 1	C2 Factor 2	C3 Factor 3
1	1	1	1
2	1	2	2
3	1	3	3
4	1	4	4
5	2	1	2
6	2	2	1
7	2	3	4
8	2	4	3
9	3	1	3
10	3	2	4
11	3	3	1
12	3	4	2
13	4	1	4
14	4	2	3
15	4	3	2
16	4	4	1

Figure 6: THE ORTHOGONAL ARRAY OF TAGUCHI

According to the orthogonal array above from MiniTab, the factors' structures and levels.

Table 2: Defining Ratios for An Orthogonal Array (L16)

No. of Ratio	W/cm	M/cm	SA/FA
1	0.36	0.1	0.1
2	0.36	0.15	0.2
3	0.36	0.2	0.3
4	0.36	0.25	0.4
5	0.38	0.1	0.1
6	0.38	0.15	0.2
7	0.38	0.2	0.3
8	0.38	0.25	0.4
9	0.4	0.1	0.1
10	0.4	0.15	0.2
11	0.4	0.2	0.3
12	0.4	0.25	0.4
13	0.42	0.1	0.1
14	0.42	0.15	0.2
15	0.42	0.2	0.3
16	0.42	0.25	0.4

c. Proportioning of Mix Design

Proporting of mix design configuration is finished according to Indian standard code IS: 10262:2019 in MS-EXCEL Mix Design Spreadsheet was developed. The bit-by-bit strategy of blend configuration is made in Annexure-I.

Table 3: Mix proportions

WATER / CEMENT RATIO	0.36	0.38	0.40	0.42	
CEMENT CONTENT	425	403	383	365	KG/CU.M
WATER CONTENT	196	197	197	198	KG/CU.M

COARSE AGGREGATE	1077	1081	1084	1087	KG/CU.M
FINE AGGREGATE	617	628	639	650	KG/CU.M
CHEMICAL ADMIXTURE	4.25	4.03	3.83	3.65	KG/CU.M

Table 4: Mix proportions

C	FA	CA	AD	W/C
1	1.452	2.535	0.01	0.36
1	1.559	2.683	0.01	0.38
1	1.669	2.831	0.01	0.40
1	1.781	2.979	0.01	0.42

Table 5: Design of the Initial Concrete Mix For All The Experiments

Total Cementitious content (Kg/m3)	Cement (Kg/m3)	METAKAOLIN (Kg/m3)	Steel Slag (Kg/m3)	FA(M Sand) (Kg/m3)	CA (Kg/m3)	Total Volume (liters)
425	382.5	42.5	555.3	61.7	1077	2119
425	361.25	63.75	493.6	123.4	1077	2119
425	340	85	431.9	185.1	1077	2119
425	318.75	106.25	370.2	246.8	1077	2119
403	362.7	40.3	502.4	125.6	1081	2112
403	342.55	60.45	565.2	62.8	1081	2112
403	322.4	80.6	376.8	251.2	1081	2112
403	302.25	100.75	439.6	188.4	1081	2112
383	344.7	38.3	447.3	191.7	1084	2106
383	325.55	57.45	383.4	255.6	1084	2106
383	306.4	76.6	575.1	63.9	1084	2106
383	287.25	95.75	511.2	127.8	1084	2106
365	328.5	36.5	390	260	1087	2102
365	310.25	54.75	455	195	1087	2102
365	292	73	520	130	1087	2102
365	273.75	91.25	585	65	1087	2102

d. MATERIAL CHARACTERIZATIONS

It is notable that the fixings attributes have a major impact on the strength of the cement. The following materials were used in the current examination: Cement used (43 Grade Ordinary Portland Cement),Metakaolin, M-sand, Steel Slag Aggregate sand, Water, Super plasticizer.

i. Experiments Conducted on Cement

For the current review OPC of grade 43 Zuari concrete was utilized. The concrete is tried by IS determination (IS: 12269-1987) to decide its different properties. The general amount of concrete expected for the examination was obtained in a solitary part and put away in the proper way. According to Indian standard calculations, the specific gravity, normal consistency, initial and final setting times, and compressive strength of cement were determined. The findings are shown in the table beneath.

ii. Physical and chemical properties of cement

Table 6: Chemical Properties

Chemical Composition	SiO_2	Al_2O_3	Fe_2O_3	Ca O	Mg O	SO_3	K_2O	LOI
OPC	18.4	5.6	3.00	66.8	1.4	2.8	0.5	2

Table 7: Cement Test Results

<table>
<tr><th>Experiments</th><th>Result</th><th>According</th><th>Code Provision</th></tr>
<tr><td>Specific Gravity</td><td>3.15</td><td></td><td></td></tr>
<tr><td>Normal Consistency (%)</td><td>31</td><td>IS 4031 (Part IV)- 1988</td><td></td></tr>
<tr><td>Initial setting time(minutes)</td><td>100</td><td rowspan="4">IS 4031 (Part V)- 1988</td><td>30 Minutes maximum is recommended.</td></tr>
<tr><td>Final setting time(minutes)</td><td>255</td><td>Maximun allowable 600 Minutes</td></tr>
<tr><td>Soundness</td><td>3mm</td><td></td></tr>
<tr><td>Fineness of Cement</td><td>6%</td><td></td></tr>
</table>

iii. Tests on Metakaolin

Physical Properties

Table 8: Physical Composition of Metakaolin

Experiment	Result	As per
SPECIFIC GRAVITY	3.03	IS:- 1727 1998
FINENESS OF METAKAOLIN	3%	
STANDARD CONSISTENCY METAKAOLIN	50%	
SOUNDNESS OF METAKAOLIN	2mm	

iv. Test on FA(M-Sand)

Table 9: Results of the tests conducted on fine aggregate (M-sand)

Experiment	Result	According
Gradation	Zone – II	
Specific Gravity	2.2	IS 2386 (PART III)
Water Absorption (%)	3.39	
Fineness Modulus	3.39	IS 383 – 1970
Compact Bulk Density kg/m3 Loose Compact Bulk Density kg/m3	1.88 1.658	IS 2386 (PART III)

Table 10: Sieve Analysis Of M-sand

SL NO	SEIVE SIZE	MASS RETAINED	PERCENTAGE RETAINED	CUMULATIVE PERCENTAGE MASS RETAINED(x)	CUMULATIVE PERCENTAGE (100-x)
1	4.75	10	1	1	100
2	2.36	20	2	3	97
3	1.18	270	27	30	70
4	0.6	340	34	64	36
5	0.425	220	22	86	14
6	0.3	20	2	88	12
7	0.212	60	6	94	6
8	0.15	30	3	97	3
9	0.075	20	2	99	1
10	Pan	10	1	100	0

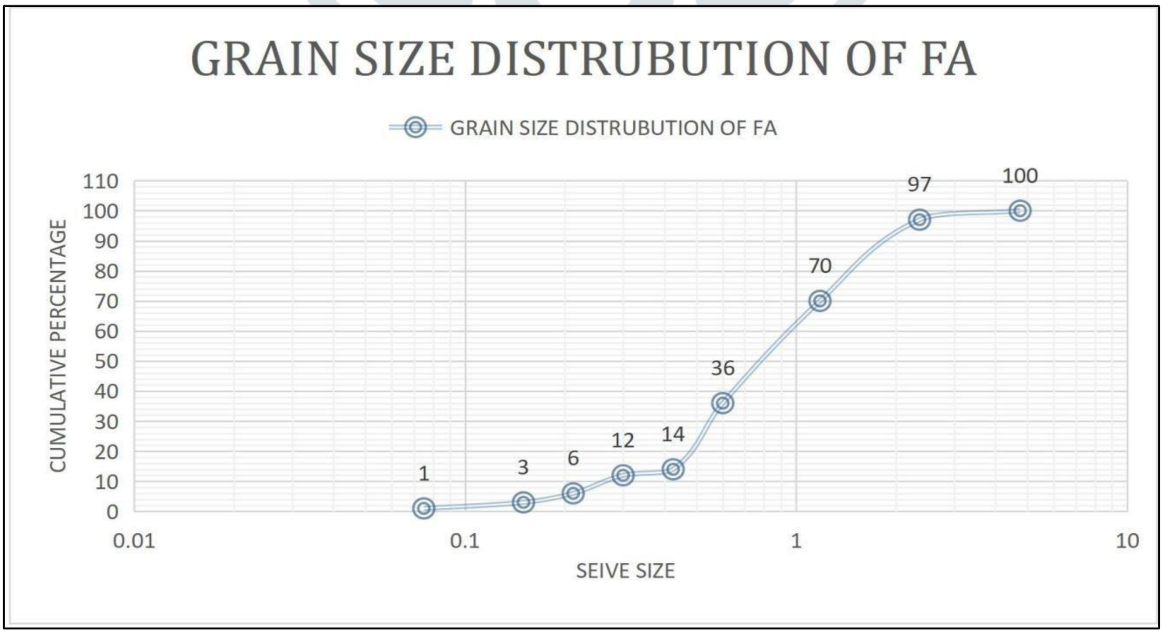

Fig 7: Grain Size Distribution Of FA

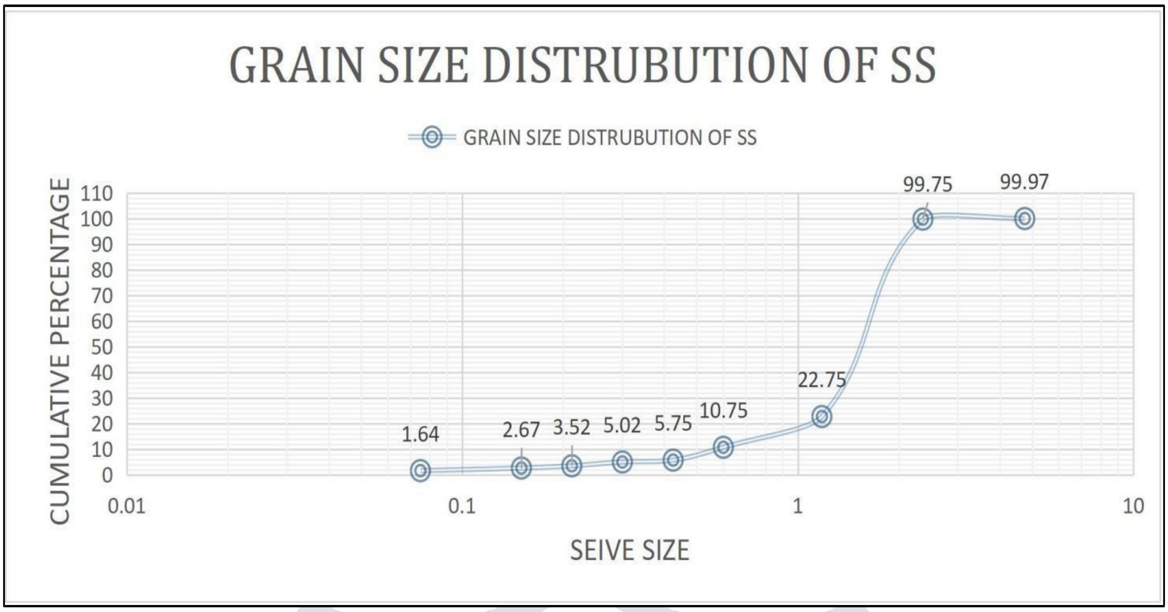

Fig 8: Grain size distribution of Steel Slag aggregate

e. Discussions

Steel Slag sand has a low water absorption rate, which improves workability; however, metakaolin does absorb some water. The dose of the super plasticizer is increased due to the non-spherical nature of steel slag sand and the fine texture of Metakaolin particles interfering with the workability of concrete. The volume of cementitious binder-containing particles increases and the workability declines as the water cementitious ratio falls.

Comparing the Results of Compression Strength

Table 7.2: Results of the compressive strength test at 7 and 28 days are compared

W/cm	M/cm	SA/FA	7 days Strength (N/mm^2)			28 days Strength (N/mm^2)		
			OPC	Mix	Increasein strength	OPC	Mix	Increase in strength
0.36	0.1	0.1	17.856	18.01	0.154	29.76	35.8	6.04
0.36	0.15	0.2		16.38	-1.476		34.96	5.2
0.36	0.2	0.3		14.56	-3.3		27.96	-1.8
0.36	0.25	0.4		12.18	-5.676		23.96	-5.8
0.38	0.1	0.2	15.948	17.91	1.962	26.58	34.66	8.08
0.38	0.15	0.1		15.14	-0.808		32.94	6.36
0.38	0.2	0.4		13.69	-2.26		24.94	-1.64
0.38	0.25	0.3		11.71	-4.238		22.67	-3.91
0.4	0.1	0.3	15.582	16.99	1.408	25.97	33.45	7.48
0.4	0.15	0.4		14.14	-1.442		30.84	4.87
0.4	0.2	0.1		12.69	-2.89		23.18	-2.79
0.4	0.25	0.2		11.43	-4.152		21.81	-4.16
0.42	0.1	0.4	14.928	15.84	0.912	24.88	32.04	7.16
0.42	0.15	0.3		13.14	-1.788		27.53	2.65
0.42	0.2	0.2		12.3	-2.63		22.18	-2.7
0.42	0.25	0.1		11.22	-3.708		19.77	-5.11

Determination of Contribution of Each Factors

Table 7.14: Evaluation of Each Factor's Contribution @ 28 Days

Correction Factor Evalution		
Total Results (N)		448.68
Correction Factor (T^2/N)		12582.11
For W/cm		
Evalution of Factor Sum of Squares = ($\sum An^2/NAn$ - CN)		
Sum of squares	Level 1	3762.6
	Level 2	3317.76
	Level 3	2985.53
	Level 4	2576.58
Factored sum of squares(total-CF)		60.35
Evalution of Mean Square = Factor sum of squares / Degree of freedom		
Mean Square		20.12
For M/cm		
Evalution of Factor Sum of Squares = ($\sum An^2/NAn$ - CN)		
Sum of squares	Level 1	4621.28
	Level 2	3986.66
	Level 3	2414.74
	Level 4	1944.81
Factored sum of squares(total-CF)		383.14
Evalution of Mean Square = Factor sum of squares / Degree of freedom		
Mean Square		127.71
For SA/FA		
Evalution of Factor Sum of Squares = ($\sum An^2/NAn$ - CN)		
Sum of squares	Level 1	3118.11
	Level 2	3226.24
	Level 3	3113.64
	Level 4	3124.81
Factored sum of squares(total-CF)		0.69
Evalution of Mean Square = Factor sum of squares / Degree of freedom		
Mean Square		0.23
Total of mean squares of all the factors		148.06
Percentage contribution	W/cm	13.59
	M/cm	86.26
	SA/cm	0.15

VI. CONCLUSION

Current automotive architectures have not been designed with security in mind. The increasing amount of connectivity inside and between vehicles and the Internet in recent years made such approaches necessary to ensure the safety of passengers. While gateways to external networks are often protected, internal networks are seldom separated in terms of security. Authentication, authorization and encryption are typically not used and often cannot be employed due to the restriction of the underlying communication systems. due to the typical bus structure of internal networks, an attacker has full access to all functions, once he penetrated the external gateway. The influence across components is especially high in a bus structure, as all messages could be sent and received by all communication participants.

Especially the influence on safety is important, as it can lead to loss of life in the worst case, e.g. when a vehicle is under attack. A security mechanism exceeding the real-time requirements of the vehicle, can lead to similar consequences. While much work has been performed on securing external interfaces and connections with firewalls and gateway systems, the internal vehicle networks have not received the required attention. Based on the above requirements, this paper proposes the design and implementation of message authentication framework, allowing to efficiently secure the internal communication. Message authentication corresponds to any content of the data payload created exclusively for ensuring the authenticity, security of the remaining information in the data payload. Calculation of the message authentication code normally depends on the Authentication Data, Secured Key, CMAC algorithm, and counter information, thus limiting the possibility of simulating a message by a hacker to the vehicle network.

The approaches to secure automotive architectures in this thesis can only form an initial step into the large area of automotive systems security. Further work is required to ensure the security of automotive architectures and their components. One of the major tasks, both in terms of time and effort, is the standardization of any proposed approach. Only through standardized approaches, it is possible to avoid custom, potentially insecure solutions and enable the clean integration of thoroughly tested approaches. Standardization further fosters widespread adoption of approaches. Thus, it forms the basis of future automotive security solutions.

This paper focuses on the security of the messages and networks in the architecture. Additional work is required in both analysis and design of ECUs. The approaches proposed in this thesis rely on the software on ECUs to be secure. This needs to be ensured with secure (key) storage, secure execution environments, secure boot, etc.

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