Materials Today: Proceedings xxx (xxxx) xxx

Contents lists available at ScienceDirect

Materials Today: Proceedings

journal homepage: www.elsevier.com/locate/matpr

An analysis of acetic and sulphuric acids reaction in concrete elements with taguchi optimization method

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ARTICLE INFO

Article history:
Received 9 March 2020
Received in revised form 25 May 2020
Accepted 6 June 2020
Available online xxxx

Keywords:
Taguchi
Optimization
Fibre
L9 OA
Fly ash
M−sand

ABSTRACT

In this contemporary world, an increase in the demand for construction materials leads to major fluctuations and durability is considered as awfully indispensable in the properties of the concrete. This manuscript focus on concrete durability properties assimilates with L9 Taguchi optimization array to distinguish the profound optimal combination in the selected orthogonal array (OA). The parameters utilized in this work such as fly ash-sand, water-cement ratio and sisal fibre with various mixing proposing which inculcates the Taguchi orthogonal array. Experimental outcomes on chemical behaviour properties such as Acetic acid attack and sulphuric acid attack are presented. The experimental outcome shows the behaviour of concrete elements in contact with acetic and sulphuric acids. The experimental data, fabricated test images and graphical representations are displayed with the S/N ratio. The optimum test results are distinguished with better combinations.

1. Introduction

The construction industry is booming at each consequent year with major fiscal incline. The civil engineering expertise working continues to diminish the overall project cost and expanse [1]. Plethora of precaution confiscated to balance the pragmatic issues and to maintain the quality aspects [2]. The construction style The use of modern materials and construction techniques were incorporated in the concrete industry. The cost of binders and others aggregates are exorbitant in recent decades which makes construction even harder.[90] To overcome or tackle these issues new innovative and novel ideology should be imposed to face the upcoming near challenges. In this manuscript we deals with optimization methods [8] in specific Taguchi L9 orthogonal array [11]. It's awfully pivotal to prudent the optimum combination from the selected orthogonal arrays. The selection of orthogonal arrays (OA) is based on the number of levels and parameters or factors. In this manuscript we deal with four factors (parameters) and three levels. [56]From the above chosen condition from Taguchi optimization, an L9 orthogonal array (OA) is adopted. The selected factors such as Fly ash, M−sand, Water-cement (W/C) ratio and fibre (Sisal). There will be total of nine combination mix for L9 OA. Figs. 1-4.

2. Parameters

2.1. Fly-ash

It is one of the imperative binding materials (Pozzolanic materials) in the concrete world [14–20]. In this research it was partially mixed with constant cement material with plethora of combinations (nine combinations) [21–26]. The quality of fly ash was analysed and it's well suited for mixing various combinations in the concrete.

2.2. M−sand

In these recent years the usage of manufacture sand is inevitable [27–32]. The properties different between manufacture sand and ordinary river sand had been indentify and analysed. Since last decade plethora of research has been done in the effective usage of M−sand in the contemporary construction field [34–36,37]. In this

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https://doi.org/10.1016/j.matpr.2020.06.099
2214-7853/

Fig. 1. Extraction of sisal fibre.

Fig. 2. Fibre exacted from cactus plant.

Fig. 3. Cube casting for experiments.

project different percentage of M−sand is partially mixed with various combinations in L9 Taguchi orthogonal arrays [33].

2.3. Sisal fibre

In present-time the role of fibres in the strength of concrete is enormous [38–41]. The fibres are broadly classified in to natural and artificial fibres. In this project we centralize on one of the natural fibre called sisal. The sisal fibre is extracted from a desert plant called cactus [42]. The application of sisal fibre is traditionally used for rope and twine, and has many other uses, including paper, cloth, footwear, hats, bags, carpets, and dartboards [43–45]. In this project we are incorporating sisal fibre in concrete with various propositions.

Fig. 4. Casted cubes for testing.

2.4. Taguchi orthogonal array

The Taguchi optimization method is also called as fisher's factorial concept [3–8,10]. This method or concept was initially used for agricultural purpose. This optimization can be defined as the method to identifying the conditions or combinations that will give the maximum or minimum values in the L9 orthogonal array.(refer table 1).

2.5. Parameters and levels

The parameters and levels are assimilating to each other's [9,12]. In the optimization techniques the levels are conformed only based on the number of parameters or factors. The parameters are fly ash, M−sand, sisal fibre and W/C ratio [13]. The each percentage of parameters levels are encountered based on previous experimental experience and reliable literature reviews (Refer table 2).

Now assigning the proposed parameters values in the Taguchi L9 orthogonal array. According to L9 OA with four factors (parameters) and three levels, there are nine experimental to be done (Refer table 3 and 4).

In the Taguchi orthogonal array there are different levels like L1, L2,L3,L4 etc., all those levels are chosen merely based on number of factors or parameters, here in our project we imposing four factors (W/C, M−sand, Fly ash and sisal fibres) hence chosen orthogonal array is L9. Refer table 3.

Table 1
Standard orthogonal array $(L_9)3^{4.}$

Experimental No.	Factor A	Factor B	Factor C	Factor D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	**2**	**1**	**2**	**3**
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Please cite this article as: K. V. Sabarish and T. S. Parvati, An analysis of acetic and sulphuric acids reaction in concrete elements with taguchi optimization method, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.06.099

Table 2
Parameters and levels.

Factors		Level 1	Level 2	Level 3
Water/ binder ratio	A	0.40	0.45	0.5
Fly ash (%)	B	20	25	30
M Sand (%)	C	30	35	40
Sisal Fiber (%)	D	1	1.5	2

Table 3
levels 3 OA.

LEVEL 3 NO OF FACTOR	ORTHOGONAL ARRAY
2–4	**L9**
5–7	L27

Table 4
Taguchi optimization experimental design (L9).

Experimental No	AWater binder/ ratio	BFly ash (%)	CM sand (%)	DSisal fiber (%)
1	0.40	20	30	1
2	0.40	25	35	1.5
3	0.40	30	40	2
4	**0.45**	**20**	**35**	**2**
5	0.45	25	40	1
6	0.45	30	30	1.5
7	0.50	20	40	1.5
8	0.50	25	30	2
9	0.50	30	35	1

3. Results and discussions

3.1. Acetic acid attack

The acetic acid test is one of the most reliable tests for finding how the concrete members behaving in contact or how it's correlate with hostile chemical environments [45,46]. This procedure will interpret how acetic acid react with cubes (150*150*150) MM. The cubes are casted with various mix propositions which includes sisal fibre, M−sand, Fly ash and W/C ratio [47]. Initially the cubes are casted and cured in the mould for 24 h, after the period of 24 h; all cubes are demoulded and left in the curing tank for 7 days. After the span of 7 days all cubes are kept explore in the atmosphere for 48 h (2 days) for constant weight, subsequently, the specimens are weighed and immersed in 5% sulphuric acid (H2SO4) solution for 60-days. please refer Table 5 and 6.

The calculated pH value of the acidic media was at 0.3. The value of the pH was monitored and checked subsequently to maintain at 0.3. [49]The cubes are confiscated from the acid solution after the period of 60 days and were totally immaculate in the conventional water and kept in atmosphere for 2-day for calculating constant weight. Subsequently the cubes are weighed and loss in weight and hence the percentage loss of weight was calculated [48].

Table 5
Conventional Concrete: (150*150*150) MM.

SNO	SAMPLES	W1	W2
28th DAY	Sample 1	8.551	8.051
	Sample 2	8.590	8.100
60th DAY	Sample 1	8.538	8.024
	Sample 2	8.536	8.084

A = Water Binder/Ratio
B = Fly Ash (%)
C = M Sand (%)
D = Sisal Fiber (%)
W1 = Initial Weight Of Sample 1 (After 28th Day)
W2 = Initial Weight Of Sample 2 (After 28th Day)
W11 = Sample 1 After Acetic Acid Attack(After 28th Day)
W22 = Sample 2 After Acetic Acid Attack(After 28th Day)
A = Water Binder/Ratio
B = Fly Ash (%)
C = M Sand (%)
D = Sisal Fiber (%)
W1 = Initial Weight Of Sample 1 (After 60th Day)
W2 = Initial Weight Of Sample 2 (After 60th Day)
W11 = Sample 1 After Acetic Acid Attack(After 60th Day)
W22 = Sample 2 After Acetic Acid Attack(After 60th Day)
*All Units In kg

From the above chart all the value of 28th, 60th and conventional result of 60th day test results of nine combinations were plotted on chart 1. From the data's plotted it's obvious that C4 shows the minimum value which means minimum Acetic Acid Attack. Hence its proven that compared to all nine combinations (C1,C2,C3,C4,C5,C6,C7,C8,C9), the 4th combination C4 had least Acetic Acid Attack. This will enhance the durability of the concrete on chemical attacks. Please refer Table 7 and 8.

3.2. Sulphuric Acid Attack Test

As prescribed in IS: 516–1959 the sulphate attack test procedure was followed in the manuscript [50–52]. The resistance of concrete to sulphate attacks was studied by determining the loss of weight or variation in weight of concrete cubes immersed in sulphate water having 5% of sodium sulphate (Na_2SO_4) and 5% of magnesium sulphate (MgSO4) by weight of water and those which are not immersed in sulphate water. The concrete cubes size of 150 mm size after the duration of 28 days of water curing and kept dried for 24 h were immersed in 5% Na2 SO4 and 5% MgSO4 added water for 60 days [53].The concentration of sulphate water was maintained throughout the period of length [54,55]. After the period of 60 days immersion, the concrete cubes (150*150*150) mm were removed from the sulphate waters and after wiping out the water and weighted. Please refer Table 8 and 9. This type of accelerated test of finding out the loss of weight for assessing sulphate resistance of concrete Mehta and Burrows (2001). chart 2 represents the loss in weight of concrete due to Sulphate respectively.

W1 = Initial Weight (After 28th Day And 60th Day)
W2 = After Sulphuric Acid Attack (After 28th Day And 60th Day)
A = Water Binder/Ratio
B = Fly Ash (%)
C = M Sand (%)
D = Sisal Fiber (%)
W1 = Initial Weight Of Sample 1 (After 28th Day)
W2 = Initial Weight Of Sample 2 (After 28th Day)
W11 = Sample 1 After Sulphuric Acid Attack(After 28th Day)
W22 = Sample 2 After Sulphuric Acid Attack(After 28th Day)
*All units in kg
A = Water Binder/Ratio
B = Fly Ash (%)
C = M Sand (%)
D = Sisal Fiber (%)
W1 = Initial Weight Of Sample 1(After 60th Day)
W2 = Initial Weight Of Sample 2(After 60th Day)
W11 = Sample 1 After Sulphuric Acid Attack(After 60th Day)
W22 = Sample 2 after Sulphuric Acid Attack (After 60th Day)
*All units in kg

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Table 6
Acetic Acid Attack Test: 28th Day Result (150*150*150) MM

Sno	Combination	W1	W2	W11	W22			
	A	B	C	D				
1	0.40	20	30	1	8.543	8.634	8.502	8.525
2	0.40	25	35	1.5	8.632	8.554	8.426	8.399
3	0.40	30	40	2	8.590	8.586	8.100	8.056
4	**0.45**	**20**	**35**	**2**	**8.538**	**8.522**	**7.978**	**8.022**
5	0.45	25	40	1	8.554	8.602	8.254	8.200
6	0.45	30	30	1.5	8.543	8.585	8.154	8.187
7	0.50	20	40	1.5	8.554	8.435	8.478	8.502
8	0.50	25	30	2	8.576	8.589	8.086	8.096
9	0.50	30	35	1	8.594	8.465	8.315	8.304

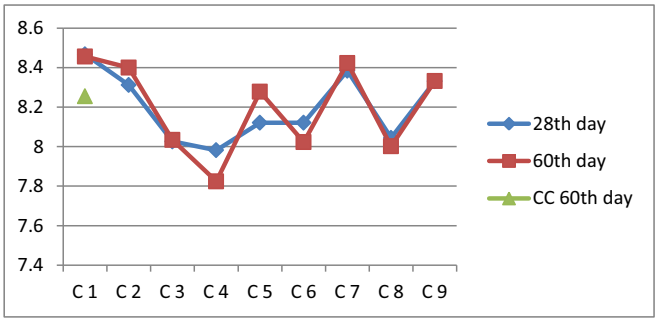

Chart 1. Data comparison for acetic acid attack (28th ,60th and Conventional).

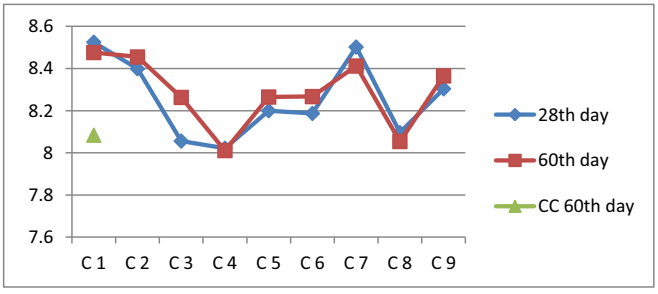

Chart 2. Data comparison for Sulphuric Acid Attack (28th ,60th and Conventional).

Table 7
Acetic Acid Attack Test: 60 th Day Result (150*150*150) MM

Sno	Combination	W1	W2	W11	W22			
	A	B	C	D				
1	0.40	20	30	1	8.534	8.556	8.456	8.476
2	0.40	25	35	1.5	8.643	8.565	8.356	8.455
3	0.40	30	40	2	8.465	8.571	8.148	8.263
4	**0.45**	**20**	**35**	**2**	**8.534**	**8.522**	**7.928**	**8.011**
5	0.45	25	40	1	8.555	8.454	8.267	8.265
6	0.45	30	30	1.5	8.434	8.643	8.243	8.267
7	0.50	20	40	1.5	8.443	8.565	8.387	8.412
8	0.50	25	30	2	8.615	8.876	8.100	8.054
9	0.50	30	35	1	8.674	8.564	8.315	8.365

*All units in kg

Table 8
Conventional Concrete: (150*150*150) MM

SNO	SAMPLES	W1	W2
28^{TH} DAY	Sample 1	8.563	8.003
	Sample 2	8.552	8.032
60^{TH} DAY	Sample 1	8.552	8.255
	Sample 2	8.489	8.134

Table 10
Sulphuric Acid Attack Test: 60th Day Result (150*150*150) MM

Sno	Combination	W1	W2	W11	W22			
	A	B	C	D				
1	0.40	20	30	1	8.613	8.611	8.421	8.467
2	0.40	25	35	1.5	8.543	8.551	8.345	8.312
3	0.40	30	40	2	8.552	8.536	8.062	8.026
4	**0.45**	**20**	**35**	**2**	**8.538**	**8.542**	**7.948**	**7.982**
5	0.45	25	40	1	8.542	8.521	8.133	8.121
6	0.45	30	30	1.5	8.566	8.554	8.113	8.121
7	0.50	20	40	1.5	8.551	8.531	8.375	8.384
8	0.50	25	30	2	8.539	8.544	8.009	8.044
9	0.50	30	35	1	8.542	8.487	8.321	8.331

From the above chart all the value of 28th, 60th and conventional result of 60th day test results of nine combinations were plotted on chart 2. From the data's plotted it's obvious that C4 shows the minimum value which means minimum Sulphuric Acid Attack. Hence its proven that compared to all nine combinations (C1,C2,C3,C4,C5,C6,C7,C8,C9), the 4th combination C4 had least Sulphuric Acid Attack. This will enhance the durability of the concrete on chemical attacks. Please refer Table 10.

Table 9
Sulphuric Acid Attack Test: 28th Day Result (150*150*150) MM

Sno	Combination							
	W1	W2	W11	W22				
	A	B	C	D				
1	0.40	20	30	1	8.532	8.546	8.441	8.456
2	0.40	25	35	1.5	8.667	8.685	8.367	8.400
3	0.40	30	40	2	8.552	8.545	8.043	8.034
4	**0.45**	**20**	**35**	**2**	**8.453**	**8.555**	**7.816**	**7.824**
5	0.45	25	40	1	8.467	8.565	8.234	8.278
6	0.45	30	30	1.5	8.543	8.556	8.103	8.023
7	0.50	20	40	1.5	8.578	8.657	8.432	8.423
8	0.50	25	30	2	8.581	8.657	7.987	8.002
9	0.50	30	35	1	8.569	8.554	8.345	8.332

*All units in kg

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4. Conclusion

The durability is one of the indispensable properties in the concrete field with chemical prospective is taken in the observation in the project, eventually it is concluded from the experimental outcomes that combination four (C4) is minimal exposures to the chemical attacks. Due to the positive reaction from the chemical reaction it is more appropriate or tangible to be satisfying the durability properties of the concrete elements. Doing so in optimization methods plethora of construction materials are limited in greater extends. In this manuscript the profound knowledge on concrete exploring in chemical encompass (acetic and sulphur acids) with most optimum combination. This identified combination can be further extended to structural experiments.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Please cite this article as: K. V. Sabarish and T. S. Parvati, An analysis of acetic and sulphuric acids reaction in concrete elements with taguchi optimization method, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.06.099

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Please cite this article as: K. V. Sabarish and T. S. Parvati, An analysis of acetic and sulphuric acids reaction in concrete elements with taguchi optimization method, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.06.099