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International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

Rheology of Self-Compacting Concrete Nanocomposites

Hitesh Kumar Patil, Arun Kumar Dwivedi

Abstract: ***In the current research work the fresh properties (filling and passing ability, and resistance to segregation of self-compacted concrete (SCC) are investigated with the nanocomposite particles. Under the scope of the research work, the rheological parameters of the fresh self-compacting concrete (SCC) fused with nano sized Blasting Grit (nBG) (average particle size 500 nm) and rod like Zinc Ash (nZA) (average particle size 300 nm) are analyzed. In the scope of the work nZA and nBG are fused in Pozzolana Portland Cement (PPC) and Fine Aggregate (FA) respectively, for 0%, 0.25%, 0.5% and 0.75% by weight of material. The rheological behavior of SCC like filling ability, passing ability and segregation resistance are studied for the modification in SCC. The result shows significance of the material and test method used in this experiment. The output of the experiment shows that the rate of fusing of nZA and nBG in ingredients of the concrete contributes in rheological and mechanical properties of SCC. For the validation of the experimental results the statistical models also prepared, the regression model, ANOVA model and Correlation model gives the importance of the ingredients used along with selected test for the work. The current research is useful for developing zinc ash and blasting grit as a building material. The outcomes of the experiments are more important in a fresh stage of the SCC which was developed as a sustainable way with the good flowing ability.***

Index Terms: ***ANOVA, Blasting grit, Correlation, Nano Particle, Rheology, Regression, Zinc Ash.***

I. INTRODUCTION

Concrete is second largest material after water, which is consumed by human beings. The main ingredient of concrete is cement which required energy and raw material for its production across the world. As of now, the worldwide utilization of cement is roughly 3.3 billion tons every year and is expanding at nearly 1% every year [1]. Self-Compacting Concrete (SCC) was introduced in JAPAN in 1988, in SCC there is no need of compaction by any means with enhancement in mechanical and durability properties of concrete [2]. The building business is swinging progressively to the utilization of SCC with the end goal to enhance numerous parts of building development as SCC offers a few points of interest in specialized, monetary,

Revised Manuscript Received on 30 July 2019.
***** Correspondence Author

Hitesh Kumar Patil*, Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon-425001, India.

Arun Kumar Dwivedi, School of Engineering and Technology, Sandip University, Nasik-422002, India.

furthermore, ecological terms. New SCC flow into place and around obstacles under its very own weight to fill the formwork totally and self-reduced with no isolation and blocking. SCC blends for the most part have a substantially higher substance of fine fillers.

As an outcome of the exploratory works and based on information accessible in specialized writing, self-compacting concrete must to give a higher characteristic durability and a lower tendency to break[3,4].In current improvement the rubble powder and coarse aggregate [5,6], Magnetic water and filler materials like fly ash [7,8], Curing agents [8], Palm oil clinker [9], red mud with fly ash [10], copper dioxide [11] is used as additives of SCC. There is a relationship between ingredients of mix design, green and harden properties of SCC [12]. Hardness and elastic modulus were increased and porosity decreases due to the addition of SiO_2, TiO_2 and Al_2O_3 [13,14]. Without affecting the strength of SCC palm oil fuel ash increases the acid and sulphate resistance, reduces dry shrinkage and water absorption [15]. The crushed marble stone enhances the green and harden stage properties of SCC [16]. The varies types of mineral admixtures increases properties of SCC in all respect [17].

Zinc is 985 places among 1662 hazards materials, Zinc Ash (ZA) is the generated as waste material approximately more than 80% of zinc ash were collected during the galvanizing process [18,19]. Steel grit available in angular shape and rough in nature, it's used for surface improvement technology for metal in the paint industry by pressure blasting action. Its particle ranges between 50mm to 100 nm [20]. The main objective of this work is to investigate the rheological properties of fresh SCC with nZA and nBG. This area of research needs more exploration and this study may important for future construction and help to find the possibility of nZA and nBG as ingredients of SCC in order to develop sustainable SCC.

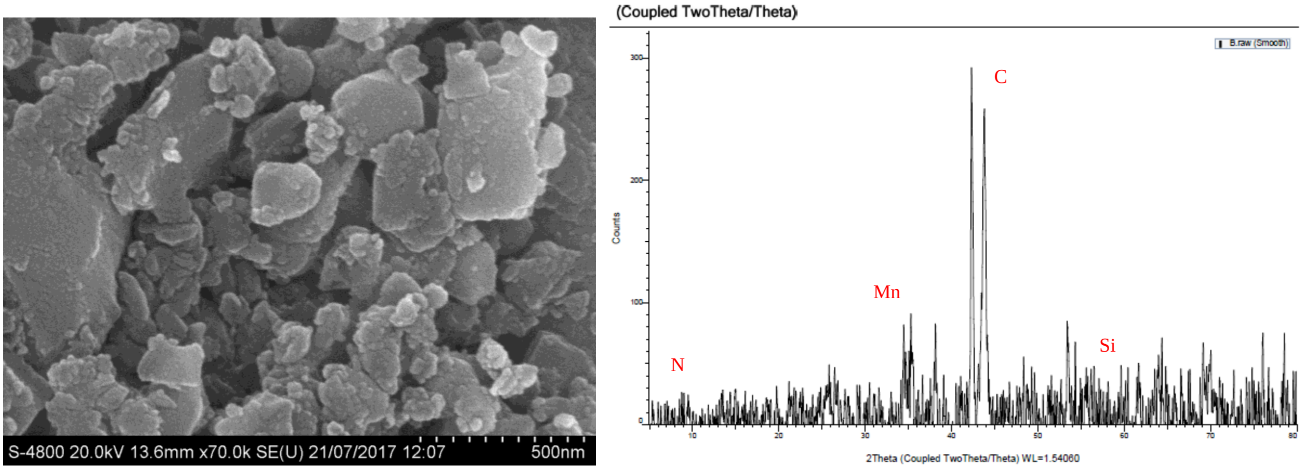
II. MATERIALS AND METHODS

Portland Pozzolana Cement (PPC) Ambuja made confirming to BIS [21], basalt rock as crush aggregates with 10 mm maximum size of aggregate [22] and Tapi river sand of zone II confirming to BIS [22] is used for the production of the SCC.The locally available waste materials from the paint industry in Nasik, (MS), India i.e. nZA and nBG are used as additives in cement and fine aggregate respectively. Chemical Composition of mild steel nBG shown in Scanning Electron Microscope (SEM) and X Ray Diffraction (XRD) image in Table 1 and Figure 1 (a).

It has rough surface crystals and less specific surface area than nZA. The average range of size of used nBG is up to 500 nm. nZA is waste product from paint industry. The chemical composition of nZA is tabulated in Table 1 with SEM and XRD image details in Figure 1(b).

It has rod like shape with average particle size up to 300 nm.

(a)



(b)

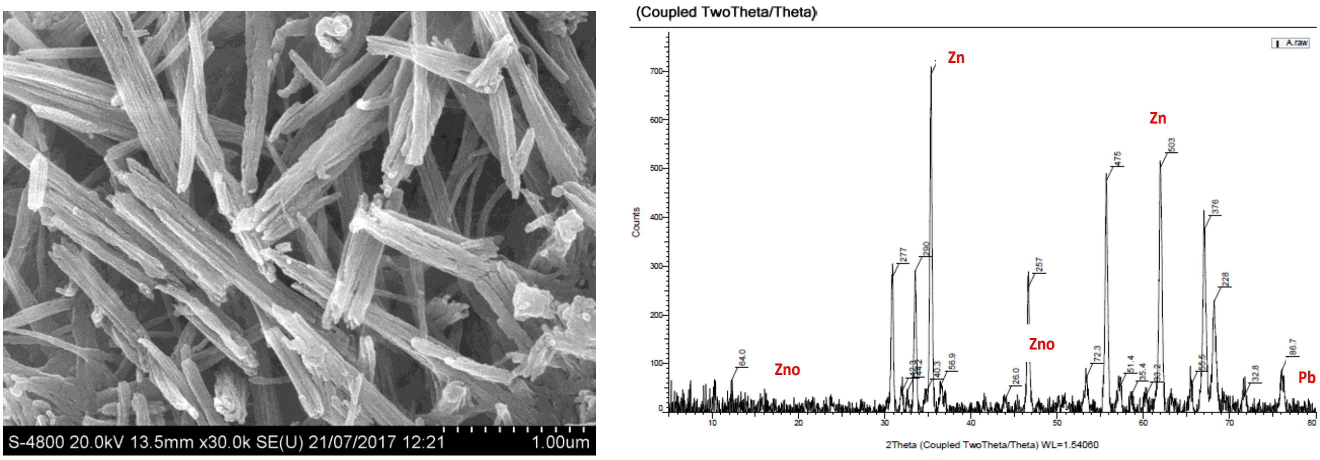


Figure 1. SEM and XRD images of (a) nano-Blasting Grit (nBG) and (b) nano-Zinc Ash (nZA)

Table 1. Chemical Composition of Blasting Grit and Zinc Ash

(1) Blasting Grit (BG)	**C**	**Mn**	**Si**	**N**					**Specific Gravity**
	0.95	0.8	0.18	0.19					**3.6**
(2) Zinc Ash (ZA)	**Zn**	**Fe**	**Pb**	**Al**	**Cu**	**Cd**	**Mg**	**Cl**	**3.56**
	61.2	0.65	0.23	1.64	0.069	0.0001	0.019	24.85	

Table 2. Concrete Mix Design details

(a) Comparison of the Concrete Mix Design Methods				
Materials	**Nan Su**[23]	**IS10262: 2009**[24]	**Combined Method Nan Su and IS Method**	**% Saving in material**
Cement (C) kg/m^3	320.0	466.2	452.7	**3**
water (W) kg/m^3	125.7	186.5	181.1	**3**
Fine Aggregate (FA) kg/m^3	814.2	1016.0	946.9	**7**
Coarse Aggregate (CA) kg/m^3	788.2	747.1	920.9	**0**

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Super Plasticizer (SP) kg/m^3	3.8	5.6	5.4	**3**
Concrete mix proportions as per above method is 1: 2.09: 2.03				

(b) Mix proportions of Nano SCC

Designation	Cement (C) kg	Zinc Ash (ZA) kg	Fine Aggregate (FA) kg	Blasting Grit (BG) Kg	Coarse Aggregate (CA) kg	Super Plasticizer (SP) kg	W/C
N00	452.7	0	946.9	0	920.9	2	0.4
N01	452.7	0	946.9	0	920.9	5	0.4
N02	452.7	0	946.9	0	920.9	7	0.4
N03	452.7	0	946.9	0	920.9	9	0.4
N04	452.7	1.1	946.9	2.4	920.9	2	0.4
N05	452.7	1.1	946.9	2.4	920.9	5	0.4
N06	452.7	1.1	946.9	2.4	920.9	7	0.4
N07	452.7	1.1	946.9	2.4	920.9	9	0.4
N08	452.7	2.3	946.9	4.7	920.9	2	0.4
N09	452.7	2.3	946.9	4.7	920.9	5	0.4
N10	452.7	2.3	946.9	4.7	920.9	7	0.4
N11	452.7	2.3	946.9	4.7	920.9	9	0.4
N12	452.7	3.4	946.9	7.1	920.9	2	0.4
N13	452.7	3.4	946.9	7.1	920.9	5	0.4
N14	452.7	3.4	946.9	7.1	920.9	7	0.4
N15	452.7	3.4	946.9	7.1	920.9	9	0.4

The algorithm adopted for the statistical analysis shown as follows in Table 3 (a), it clears the methodology of the work. In this algorithm there are 2 models are included, in first model the various experimental tests for testing of fresh properties of SCC are inputs and in second model material of the SCC like BG, SP and Water are inputs, the filling and passing ability and, resistance to segregation are outputs of both models.

Table 3 (a) Algorithm (b) Experimental results for the models

(a) Algorithm Used

For Model 1

Inputs	**Outputs**
Slump Flow (SF) (mm) T50 Slump Flow (T50S) (Sec) V funnel (To) (VT0) (Sec) V funnel (T5) (VT5) (Sec) Orimet Flow (OF) (Sec) U Box (UB) (mm) J Ring (JR) (mm) L Box (LB) (ratio) Fill Box (FB) (%)	1) Filling Ability 2) Passing Ability 3) Segregation Resistance **Equations for**, Filling Ability, Passing Ability and Segregation Resistance = Constant + A*SF +B*T50S+C*VT0+D*VT5+E*OF+F*UB+G*JR+H*LB+I*FB Where A, B, C, D, E, F, G.H, and I are coefficients of regression

For Model 2

Inputs	**Outputs**
BG (KG) SP (Kg) Water (W) (L)	1) Filling Ability 2) Passing Ability 3) Segregation Resistance

Equations for,
Filling Ability, Passing Ability and Segregation Resistance = Constant + A*BG +B*SP+C*W
Where A, B, C, D, E, F, G.H, and I are coefficient of regression

(b) Experimental results of Fresh Properties of nano SCC

Designation	Slump Flow (mm)	T50 Slump Flow (Sec)	V funnel (To) (Sec)	V funnel (T5) (Sec)	Orimet (Sec)	U Box (mm)	J Ring (mm)	L Box (Ratio)	Fill Box (%)	Filling Ability (%)	Passing Ability (%)	Segregation Resistance (%)
Limit as per Eurocode [22]	650-800 mm	2 - 5 sec	8 - 12 sec	0 to +3	0 - 5 sec	0 to 30 mm	0 -10 mm	0.8 to 1	90 to 100 %			
N00	649.56	6.5	13.6	16.1	6.65	32.65	12.6	0.76	90.45	75.00 %	58.33%	100.00%
N01	670	4	10.98	12.98	4.36	22.55	5.66	0.83	92.56	79.95 %	56.63%	86.60%
N02	672.65	3.5	10.4	11.9	3.5	20.5	4.5	0.93	94.5	73.28 %	48.28%	66.60%
N03	680	2.5	9.5	10.7	3	18.6	3.6	0.95	95.4	50.00 %	55.00%	60.00%
N04	651	4.5	11.96	13.16	4.6	29.56	9.55	0.8	90	71.63 %	48.30%	93.30%
N05	652.63	3.38	8.97	10.17	3.45	22.17	7.16	0.8	90.23	48.33 %	41.63%	53.30%
N06	656.54	3.31	8.79	9.99	3.38	21.73	7.02	0.81	90.77	54.95 %	49.95%	46.60%
N07	654.61	2.48	7.21	8.41	2.7	17.38	5.62	0.8	90.5	18.30 %	24.98%	13.30%
N08	652.5	4.25	11.71	12.91	4.35	29.31	9.3	0.91	90.15	64.98 %	54.95%	80.00%
N09	654.78	3.19	8.78	9.98	3.26	21.98	6.98	0.91	90.38	39.98 %	48.30%	40.00%
N10	658.71	3.12	8.61	9.81	3.2	21.54	6.84	0.92	90.92	43.30 %	56.65%	33.30%
N11	656.06	2.34	7.06	8.26	2.56	17.23	5.47	0.92	90.65	16.63 %	33.30%	6.60%
N12	653.06	4.4	11.46	12.66	4.1	29.06	9.05	0.94	90.3	66.63 %	63.33%	73.30%
N13	655.35	3.3	8.6	9.8	3.08	21.8	6.79	0.94	90.53	38.28 %	56.63%	26.60%
N14	659.28	3.23	8.42	9.62	3.01	21.36	6.65	0.95	91.07	41.65 %	61.65%	20.00%
N15	656.36	2.43	6.91	8.11	2.41	17.09	5.32	0.95	90.8	16.65 %	41.63%	0.00%

Mix Proportions:
SCC modified with nZA and nBG, is configured by utilizing combination of Nan Su Method [23] and IS 10262: (2009) [24]. The concrete mix design program is made in MS excel for nano SCC, the combination of above methods results in significant saving in the martials, as shown in Table 2 (a). The mix proportions of nano SCC for different blends are given in Table 2 (b).

Testing methods:
In this research work SCC properties like filling ability, passing capacity and resistance to segregation and its results are considered by utilizing J ring, Fill box, L box, U box, V funnel (T0), Orimet, Slump flow, T50 Slump and V funnel (T5) test given in Table 3 (b), confirming as per European guidelines [25]. The addition of nZA and nBG enhances the rheological properties of SCC within the limits laid in code. The study is divided into two phases, in the first phase rheological parameter (filling ability, passing ability and segregation resistance) analyzed for the various test given in Table 3 (b), to validation of the experimental results of the test, the analysis the regression [26], ANOVA [26] and correlation analysis [27] were selected due to its suitability, given in Table 4 (a). In second phase of the work the same rheological parameters were studied for the material used for the making of SCC, the details are given in Table 4 (b).

Table 4. Summary of Mathematical Models

(a) Analysis for test Used

Regression Model For →		Filling Ability	Passing Ability	Segregation Resistance
(Intercept)		-4.591	-11.4	9.18
Slump Flow (SF) (mm)		0.037	0.011	-0.03
T50 Slump Flow (T50S) (Sec)		0.603	0.194	-0.055
V funnel (To) (VT0) (Sec)		1.084	-0.396	0.012
V funnel (T5) (VT5) (Sec)		-0.944	-0.16	-0.506
Orimet Flow (OF) (Sec)		0.251	0.498	1.193
U Box (UB) (mm)		-0.127	0.221	0.26
J Ring (JR) (mm)		-0.058	-0.28	-0.565
L Box (LB) (ratio)		0.271	0.535	-0.22
Fill Box (FB) (%)		-0.215	0.045	0.118
Model Summary	R	0.99	0.996	0.998
	R^2	0.981	0.993	0.996
	Adjusted R^2	0.952	0.982	0.991
	RMSE	0.046	0.014	0.03

Equation 1
Filling Ability =
-0.591+0.037*SF+0.603*T50S+1.084*VT0 -0.944*VT5+0.251*OF-0.127*UB-0.058*JR +0.271*LB-0.215*FB

Equation 2
Passing Ability =
-11.4+0.011*SF+0.194*T50S-0.396*VT0-0.16*VT5+0.4981*OF+0.221*UB-0.28*JR +0.535*LB+0.045*FB

Equation 3
Segregation Resistance =
9.18-0.03*SF-0.055*T50S+0.012*VT0-0.506*VT5 +1.193*OF+0.26*UB-0.565*JR-0.22*LB+0-118*FB

ANOVA Analysis		Sum of Squares	df	Mean Square	F	p
For Filling Ability	Regression	0.652	9	0.072	33.99	< .001
	Residual	0.013	6	0.002		
	Total	0.664	15			
For Passing Ability	Regression	0.161	9	0.018	94.34	< .001
	Residual	0.001	6	1.893e -4		
	Total	0.162	15			
For Segregation Resistance	Regression	1.506	9	0.167	184.3	< .001
	Residual	0.005	6	9.077e -4		
	Total	1.511	15			

(b) Analysis for Materials Used

Regression Analysis For →		Filling Ability	Passing Ability	Segregation Resistance
(Intercept)		-69.167	-225.67	107.625
BG (KG)		-0.04	-0.025	-0.091
SP (Kg)		-0.059	1.25	-0.587
Water (W) (L)		0.387	0.003	-0.066
Model Summary	R	0.883	0.607	0.954
	R^2	0.779	0.368	0.91
	Adjusted R^2	0.724	0.21	0.887
	RMSE	0.111	0.092	0.107

Equation 4
Filling Ability = -69.167-0.04 *BG-0.059*SP+ 0.387*W

Equation 5
Passing Ability = -225.67-0.025*BG + 1.25*SP+ 0.003*W

Equation 6
Segregation Resistance =
107.625-0.091*BG-0.587*SP-0.066*W

ANOVA Analysis		Sum of Squares	df	Mean Square	F	p
Filling Ability	Regression	0.517	3	0.172	14.09	< .001
	Residual	0.147	12	0.012		
	Total	0.664	15			
Passing Ability	Regression	0.06	3	0.02	2.331	< .001
	Residual	0.102	12	0.009		
	Total	0.162	15			
Segregation Resistance	Regression	1.375	3	0.458	40.31	< .001
	Residual	0.136	12	0.011		
	Total	1.511	15			

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Table 5. Correlation analysis by test and material

Sr No	Test	Properties	Pearson's r		p	Sr No	Material	Properties	Pearson's r		P
1	Slump Flow (mm)	Filling Ability (%)	0.168		0.534	**1**	Cement (Kg)	Filling Ability (%)	0	a	
		Passing Ability (%)	0.148		0.583			Passing Ability (%)	0	a	
		Segregation Resistance (%)	0.054		0.842			Segregation Resistance (%)	0	a	
2	T50 Slump Flow (Sec)	Filling Ability (%)	0.766	***	< .001	**2**	ZA(Kg)	Filling Ability (%)	-0.52	*	0.043
		Passing Ability (%)	0.524	*	0.037			Passing Ability (%)	0.12		0.657
		Segregation Resistance (%)	0.817	***	< .001			Segregation Resistance (%)	-0.57	*	0.021
3	V funnel (To) (Sec)	Filling Ability (%)	0.909	***	< .001	**3**	FA(Kg)	Filling Ability (%)	0	e	
		Passing Ability (%)	0.583	*	0.018			Passing Ability (%)	0	e	
		Segregation Resistance (%)	0.961	***	< .001			Segregation Resistance (%)	0	e	
4	V funnel (T5)	Filling Ability (%)	0.898	***	< .001	**4**	BG (kg)	Filling Ability (%)	-0.52	*	0.043
		Passing Ability (%)	0.563	*	0.023			Passing Ability (%)	0.12		0.657
		Segregation Resistance (%)	0.948	***	< .001			Segregation Resistance (%)	-0.57	*	0.021
5	Orimet (Sec)	Filling Ability (%)	0.78	***	< .001	**5**	CA(Kg)	Filling Ability (%)	0	f	
		Passing Ability (%)	0.461		0.073			Passing Ability (%)	0	f	
		Segregation Resistance (%)	0.861	***	< .001			Segregation Resistance (%)	0	f	
6	U Box (mm)	Filling Ability (%)	0.736	**	0.001	**6**	SP(Kg)	Filling Ability (%)	-0.72	**	0.002
		Passing Ability (%)	0.559	*	0.024			Passing Ability (%)	-0.55	*	0.028
		Segregation Resistance (%)	0.812	***	< .001			Segregation Resistance (%)	-0.76	***	< .001
7	J Ring (mm)	Filling Ability (%)	0.46		0.073	**7**	Water (W) (L)	Filling Ability (%)	-0.27		0.304
		Passing Ability (%)	0.363		0.167			Passing Ability (%)	0.043		0.875
		Segregation Resistance (%)	0.569	*	0.021			Segregation Resistance (%)	-0.36		0.166
8	L Box (ratio)	Filling Ability (%)	-0.31		0.245						
		Passing Ability (%)	0.27		0.312						
		Segregation Resistance (%)	-0.43		0.097						
9	Fill Box (%)	Filling Ability (%)	0.229		0.393						
		Passing Ability (%)	0.141		0.603						
		Segregation Resistance (%)	0.139		0.607						
10	Filling Ability (%)	Passing Ability (%)	0.63	**	0.009						
11	Filling Ability (%)	Segregation Resistance (%)	0.948	***	< .001						
12	Passing Ability (%)	Segregation Resistance (%)	0.506	*	0.046						

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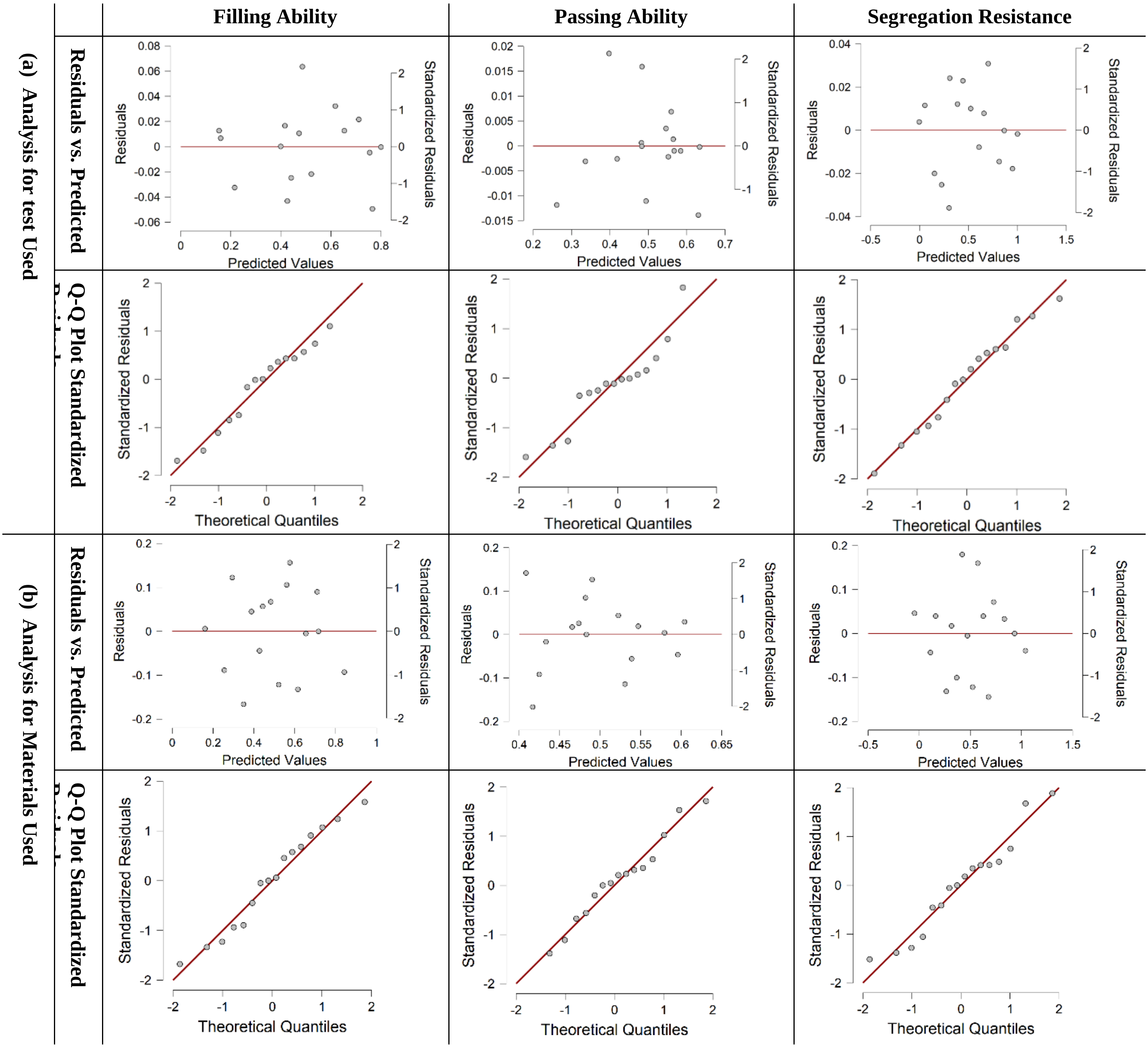


Figure 2. Summary of graphs for Regression Analysis

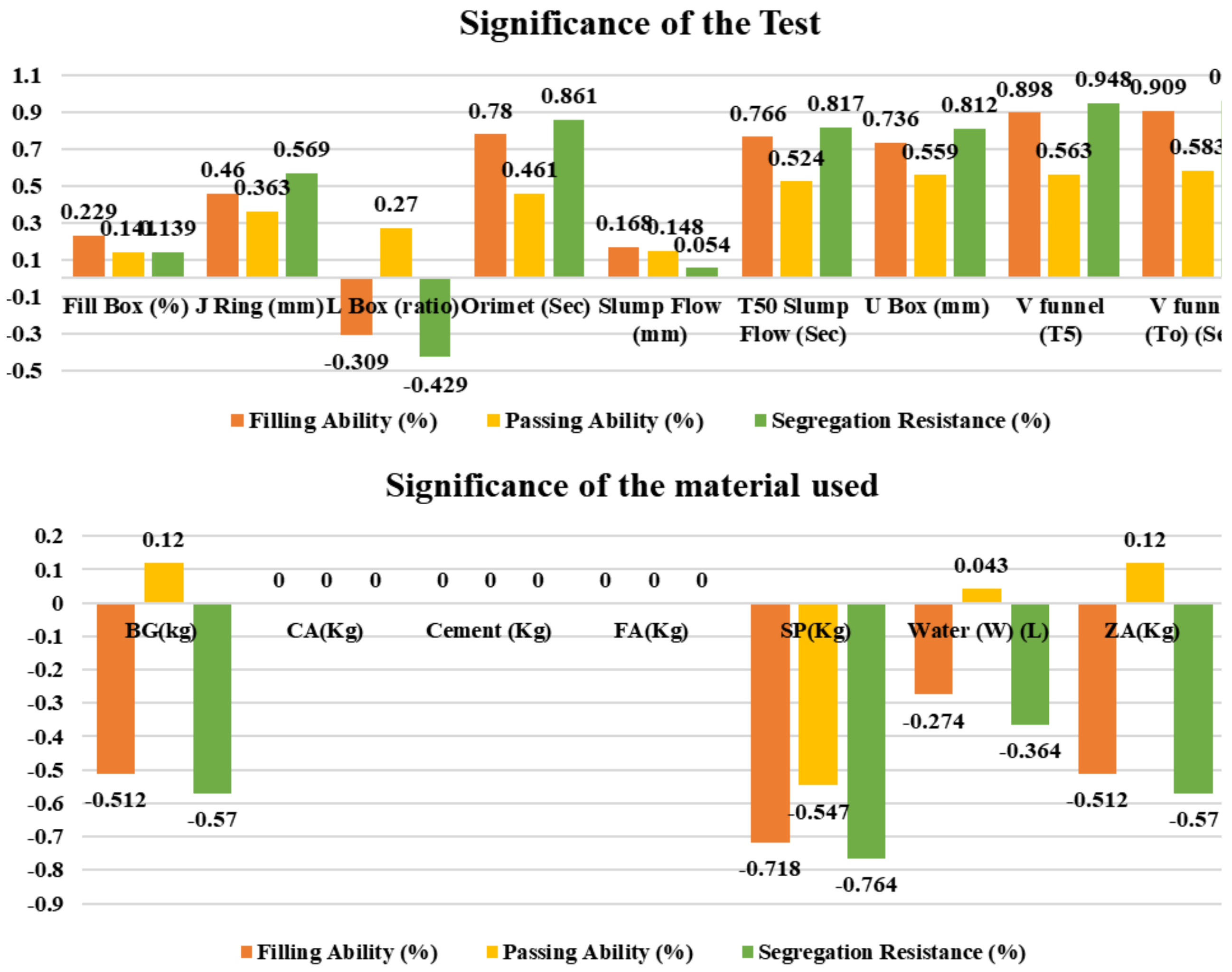
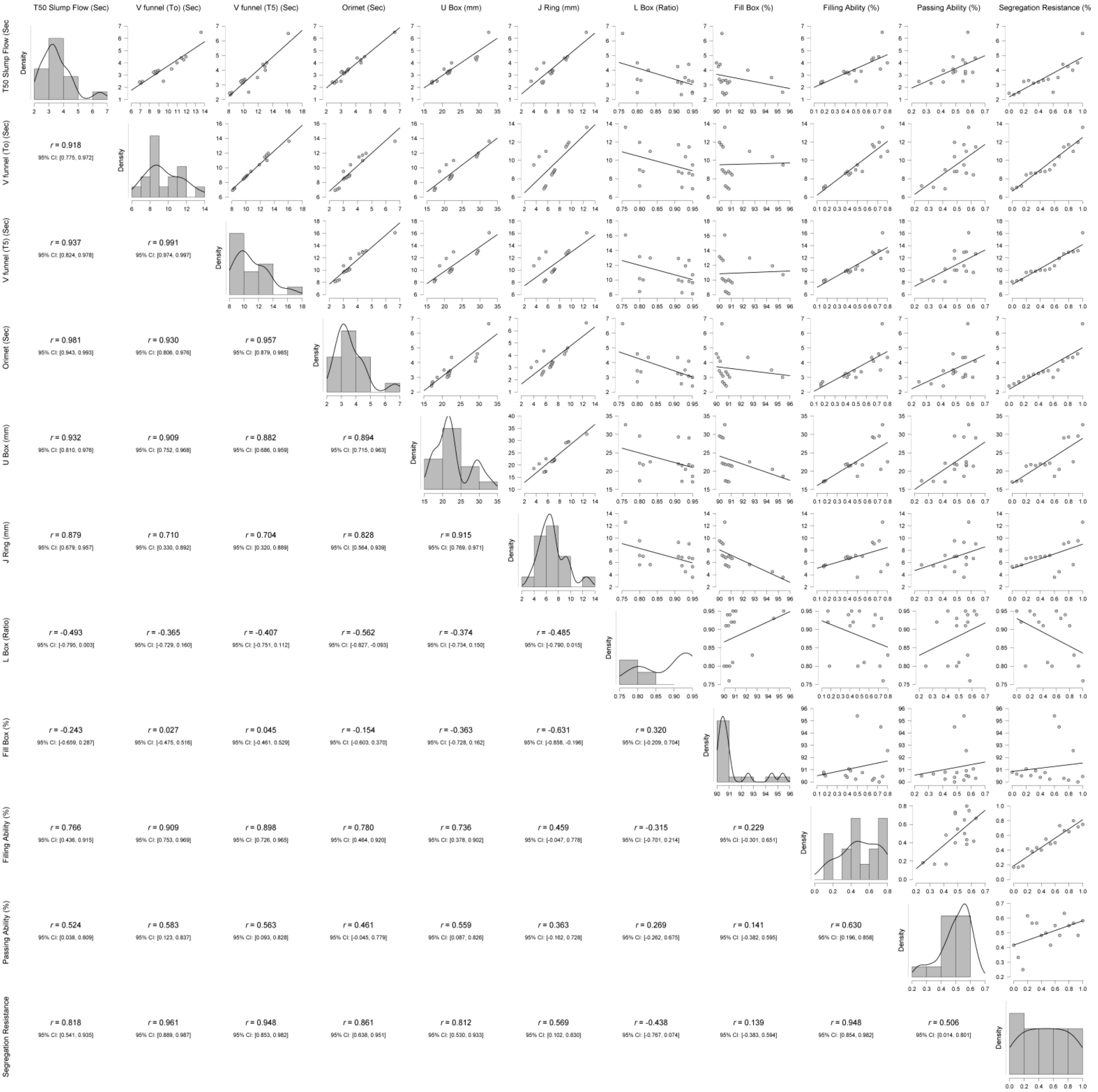


Figure 3. Summary of significance of the test and materials used

(a) Correlation Plot between various test used for calculation of filling ability, passing ability and resistance to segregation



(a)Correlation Plot between material used and filling ability, passing ability and resistance to segregation

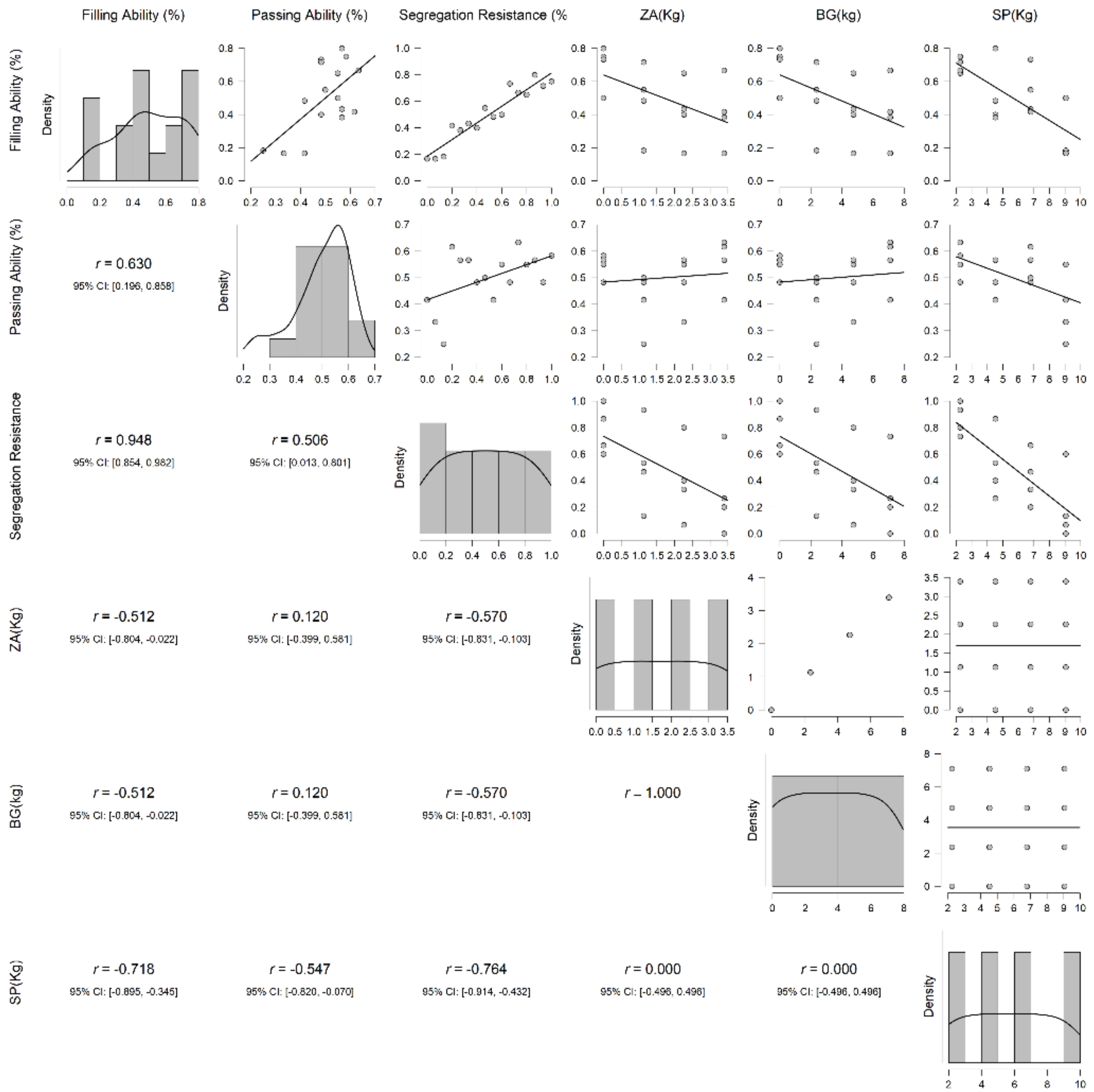
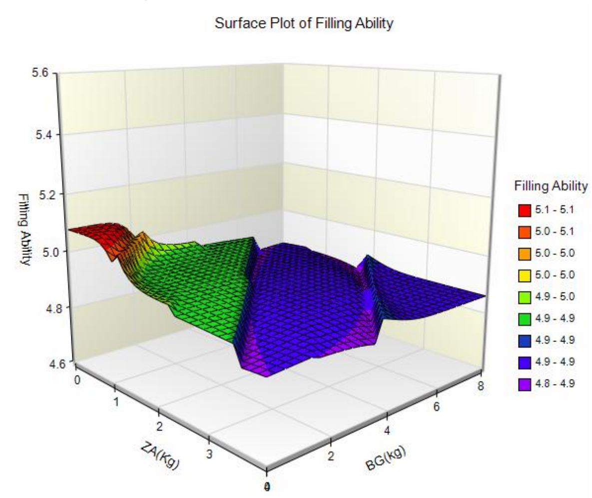
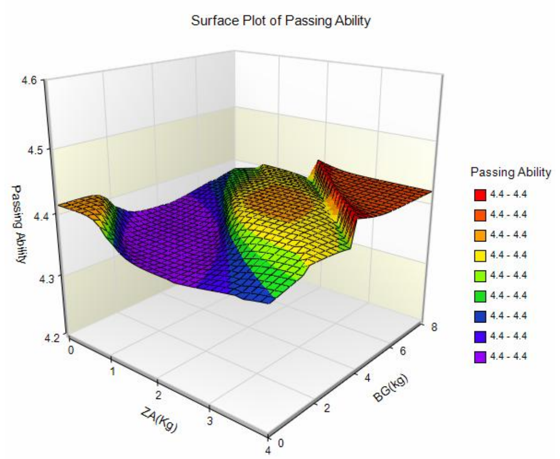


Figure 4. Correlation Plot (a) Various Tests (b) Material of SCC

(a) Filling Ability



(b) Passing Ability



(c) Segregation Resistance

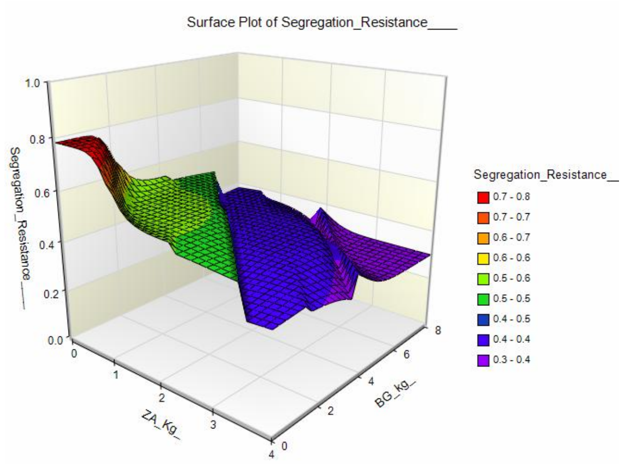


Figure 5. Surface and Contour plot of (a) Filling ability (b) Passing Ability and

Table 6. (a) Variations in workability and its possible causes (b) effect of variations of workability on properties of SCC

(a) Variations in workability and its possible causes

Sr No	Test	Limits[25]	Possible Causes			
1	Slump Flow	650-800mm	If Results < Limit	**Viscosity too High**	If Results > Limit	**Viscosity too Low**
2	T50 Slump Flow	2 - 5 sec		**Viscosity too Low**		**Viscosity too High**
3	V funnel (To)	8 - 12 sec		**Viscosity too Low**		**Viscosity too High**
4	V funnel (T5)	0 - +3 sec		**Viscosity too Low**		**Viscosity too High**
5	Orimet	0 - 5 sec		**Viscosity too High**		**Viscosity too High**
6	U Box	0 to 30mm		**False result**		**Viscosity too High**
7	J Ring	0 -10 mm		**Viscosity too High**		**Viscosity too Low**
8	L Box	0.8 to 1		**Viscosity too High**		**False result**
9	Fill Box	90 to 100 %		**Viscosity too High**		**False result**

(b) Effect of variations of workability on rheological properties of SCC

Sr No	Possible Actions	Effect on		
		Filling Ability Passing	Passing Ability	Segregation Resistance
a	**If viscosity is too high**			
	Increase water content	**Increase ↑**	**Increase ↑**	Decrease ↓
	Increase paste volume	**Increase ↑**	**Increase ↑**	**Increase ↑**
	Increase superplasticizer	**Increase ↑**	**Increase ↑**	Decrease ↓
b	**If viscosity is too low**			
	Reduce water content	Decrease ↓	Decrease ↓	Increase ↑
	Reduce paste volume	Decrease ↓	Decrease ↓	Decrease ↓
	Reduce super plasticizer	Decrease ↓	Decrease ↓	**Increase ↑**
	Increase viscosity modifying agent	Decrease ↓	Decrease ↓	**Increase ↑**
	Use finer powder	**Increase ↑**	**Increase ↑**	**Increase ↑**
	Use finer sand	**Increase ↑**	**Increase ↑**	**Increase ↑**

III. RESULTS AND DISCUSSIONS

The fusion of ZA and BG in SCC causes the real changes in the rheological properties which are shown as given in Table 3 (b). The test results of SCC fused with ZA and BG were increase as compared to normal SCC. The results of the fluctuations for checking of SCC rheological properties are shown in Table 3 (b). Table 4 (a) gives the details of statistical analysis like regression and ANOVA analysis for the various test used in the work. After the regression analysis for test and methods the mathematical equations are form, Equation 1, Equation 2 and Equation 3 gives equation for the filling ability, passing ability and segregation resistance they are calculated as from the test used in the research work.

Similarly, Table 4 (b) shows the analysis of rheological parameters for material used in research. The filling ability, passing ability and segregation resistance were calculated by Equation 4, Equation 5 and Equation 6 respectively. In Figure 2 graph of Residuals vs. Predicted and Q-Q Plot Standardized Residuals of regression analysis was shown. It shows that the model was more significant for the calculation of the rheological properties of SCC. Table 5 shows the Pearson correlation of filing ability, passing ability and segregation resistance with various test used for accessing the rheological parameters of SCC along with the materials used for preparation of SCC. The main significance of this study was predicted on the base of probability (P) * $p < .05$, ** $p < .01$, *** $p < .001$. Figure 3 shows the significance of the various tests and significance of the material used for the research work and for the rheological parametric study. The correlation plot between various test used for finding rheological properties of SCC and material for making of SCC was shown in Figure 4, the plot gives the relation of the materials and the test used with the filling ability, passing ability and segregation resistance of the SCC. Figure 5 shows the relation of nBG and nZA with filling ability, passing ability and segregation resistance in the form of surface and contour plot. To compare the relation between the nZA and nBG with rheological properties the surface plot and contour plot is selected which gives better results for the prediction of the relation of filling ability, passing ability and segregation resistance with nZA and nBG. Table 6 (a) shows the possible causes for variation in workability of SCC for test used and for the material used in production of SCC. The effect of nZA and nBG on filling ability, passing ability and segregation resistance shown in Table (b).

IV. CONCLUSION.

The properties of SCC fused with nZA and nBG were inspected. This work comprises full research laboratory test important to develop numerical model by statistically. The cement, water content, coarse aggregate content and W/C take constant. The proportions of nZA, nBG and super plasticizer are varied. Filling ability, passing ability and segregation resistance were assessed by the model developed for various test and materials. The following conclusions were made from the study.

- The properties of the concrete were change as per percentage of addition of nZA and nBG. It was observed that the increase in results obtained up to 5% only but beyond it the results was decreases, due to increase in weight of concrete.
- The models are valid for 0 to 3.4 kg/m3 of nZA, 0 to 7.1 kg/m3 of nBG and 2 to 9 kg/m^3 of super plasticizer (SP).
- Multiple regression model for test shows that good value of R^2 (for filling ability = 0.98, passing ability = 0.99, segregation resistance= 0.99) which denotes the more significant results for filling ability, passing ability and segregation resistance of SCC. The regression model for materials gives the rheological properties differ than each other. Regression model for filling ability and segregation resistance gives the more significant value of R^2 (0.78 and 0.91 respectively) than regression model for passing ability (R^2 =0.37).
- ANOVA model for the test perform shows the significant value of F= 33.99, 94.34 and 184.3 for filling ability, passing ability and segregation resistance respectively. Model of ANOVA analysis for the materials of SCC gives the value of F= 14.09, 2.331 and 40.31 for filling ability, passing ability and segregation resistance respectively, it shows that the passing ability model for material is not so significant than the other models.
- Pearson correlation shows the more significant test and material used for the rheological properties of the SCC. Significance of the correlation shows as if $p < .05$, then shows less significance; if $p < .01$, then shows medium significance; if $p < .001$, then shows then more significance.
- P=0 due to Variance = 0 in so correlation of this is 0.
- Form surface and contour plot in Figure 5, it can be concluded that the passing ability is directly proportional to % of nZA and nBG and filling ability and segregation resistance inversely proportional to % of nZA and nBG.

The current research work is useful for developing zinc ash and blasting grit as a building material. The outcomes of the experiments are more important in a fresh stage of the SCC which was developed as a sustainable way with the good flowing ability.

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AUTHORS PROFILE

Mr. Hiteshkumar Patil, Research Scholar, North Maharashtra University, Jalgaon-4225001(MS) India
Email: hitusp@gmail.com,
8888559924(mob).
https://orcid.org/0000-0002-6850-2336

https://scholar.google.co.in/citations?user=nya2c74AAAAJ&hl=en&authuser=1
https://www.researchgate.net/profile/Hitesh_Patil/info

Prof (Dr). Arunkumar Dwivedi, Professor & Dean (Academics), Sandip University Trimbak Road Nashik-422213 (MS) India, 422213.
Email: arun.dwivedi@sandipuniversity.edu.in,
8669174904(mob).

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https://www.researchgate.net/profile/Arun_Kumar_Dwivedi2