AN EXPERIMENTAL RESEARCH ON SAND CONCRETE IN MEKONG DELTA

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Abstract: *This paper presents an experimental research on mechanical properties of sand concrete for possible use in the Mekong Delta. The research has been carried out at the University of Transport and Communications, Hanoi, Vietnam. By applying experimental method, several typical scenarios with different proportions of water, cement, sand, fillers, and additives have been examined to determine the following mechanical properties of the sand concrete: compressive strength, flexural strength, splitting strength, elastic modulus. The obtained results showed that the sand concrete can be usable for different construction projects in the Mekong Delta.*

I. INTRODUCTION

Many countries have, for many recently years, been establishing policies aimed to utilise as much as possible the use of local materials in building construction. Sand concrete is a family of cement concretes which can be used to overcome limitations about environmental or economic problems in the use of coarse aggregate. Especially, some certain regions it has the depletion of coarse aggregate deposits.

Back in 1869, concrete without coarse aggregate was used for buildings, the 52m high lighthouse of Port-Said (Egypt), which is still in used, was built with sand only [1]. In Russia in vast areas sand is the only building material to be used in concrete. Here, a lot of buildings have been constructed with sand concrete since fifties. The underground station in St.Petersburg was built with precast arches of sand concrete. In Germany first investigations to increase the sand content (more than 60 %) in a concrete mix design were made in 1971[2]. In France, since 1998 the national "SABLOCCRETE" project done with the cooperation of Russian, Algeria, Maroc is a big project sand concrete [1].

In the Mekong Delta in Vietnam, there is an abundance of sand but lack of coarse aggregates to produce traditional concrete. Therefore, the use of sand concrete to substitute for traditional concrete is considered since transport of coarse aggregates from other regions to the Mekong Delta is very costly.

Sand concrete is fine concrete consisting of a mixture of sand, cement, filler, and water. Besides these basic components, sand concrete typically includes one or more admixtures. When fine gravel is incorporated with sand and their ratio G/S remains below below 0.7 (with G= Gravel, S=Sand) the mix then can also be socalled as sand concrete. The sand concrete i s distinguished from a traditional concrete by using high proportion of sand; with a small proportion or without using fine gravel and the incorporation of filler. It is also distinguished from the mortar by its composition (mortar generally contains high cement content) and especially by its destination, as sand concrete are primarily intended for more traditional uses.

In order to apply this material into building purpose in Vietnam, several mechanical properties have been carried out. The result of this study will be characterized hereafter.

II. EXPERIMENTATION

2.1. Characterization of the used materials

2.1.1. Sand

Fine sand (FS) extracted from Vinh Long province near of Ho Chi Minh city and featuring by a maximum particle diameter of proximately 2.36mm. The proportion of grains (smaller than 0.075mm) is 2%; organic impurities are lighter than standard colour.

Coarse sand (CS), from Tri An lake (region around Ho chi Minh city), presents continuous particle size distribution ranging from 0.075 to 4.75mm. However the fraction smaller than 0.30mm remains very small; the proportion of grains smaller than 0.075mm is 1.3%; organic impurities are lighter than standard colour.

Fine sand and coarse sand were mixed with a ratio FS/CS equals to 1.7 by mass. The particle size distributions of the various sands used are shown in Fig 1. Table 1 lists the set of physical characteristics for three types of sand. The modulus of fineness of mixed sand equals to 2.75, and packing density is 60.5%.

Table 1. *Physical properties of the various used sands*

Sand	Bulk density (kg/m^3)	Specific density (kg/m^3)	Fineness modulus	Packing density (%)	Sand equivalent
FS	1399	2500	1.74	56	84
CS	1510	2560	3.30	59	87
FCS	1534	2536	2.75	60.5	86

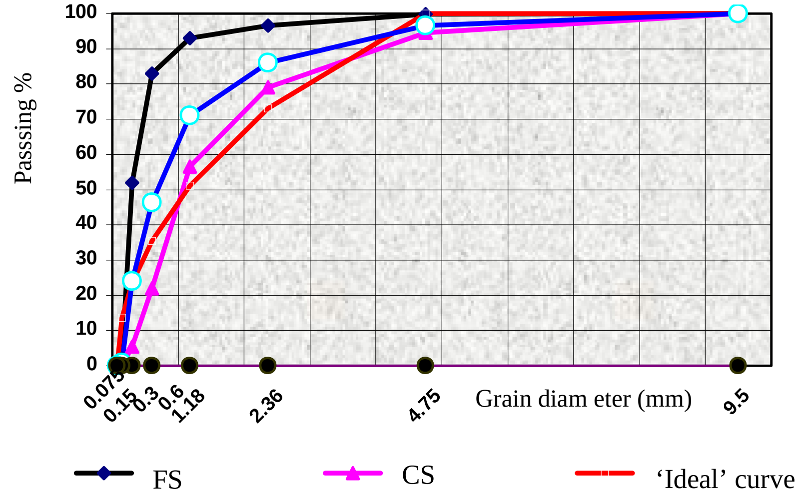

Figure 1. *Granular curve of the different sands*

2.1.2 Cement

The cement used is Nghi Son PCB40 cement (similar to CEM I); it chemical analysis and composition are given in Table 2. The physical characteristics are following: specific density 3100 kg/m^3 and Blaine specific surface area 3690 (cm^2/g).

Table 2. *Chemical analysis of the cement used*

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	free CaO
21.29	5.72	3.30	63.18	1.1	1.9	0.12	0.30	0.193

2.1.3 Fillers and admixture

The fillers used have been obtained by sifting (passing of 80 µm sieve), from Hoa An quarry (region around Ho Chi Minh City), and are mainly composed of limestone (98 mass % of $CaCO_3$). Its characteristics are following: specific mass 2740 kg/m^3 and Blaine specific surface area 3210 cm^2/g.

The admixture used is a super plasticizer (a typical Sika product), with a dry matter content of 1% of cement mass.

Drinking water is suitable for use in this concrete.

2.2. Preparation of sand concrete samples and testing

15 proportions of sand concrete mixes wich contains a mix of these two sands were used. They have three various factors includes: water/cement ratio, filler content, and age of sand

concrete. The factors effected on mechanical propert ies of sand concrete were investigated.

The specimens produced have been cured in air at 27±2 ^oC for 24 hours. Then, they were removed from the moulds and immesed in water until the day of testing.

Compressive strength, splitting strength, Young's modulus o f elasticity were determined on cylindrical specimens with 150mm diameter and 300mm height. Flexural strength was determined (using three-points method) for each mix on three 100x100x400 mm prismatic sample.

2.3. Experimental plan

In this experimental study, compressive strength (f_c), flexural strength (f_r), splitting strength (f_{sp}), and elastic modulus (E_c) vary from water/cement ratio (w/c), filler content (f), and age of sand concrete (t). The experimental design theory [11] is used to establish an opt imum experimental procedure [8, 11] and to elaborate empirical models considering both experimental parameters (Input: w/c, f, t) and results (Out put: f_c, f_r, f_{sp}, E_c). True values (w/c, f, and t) and normalize ones (x_1, x_2, x_3) in [-1, 0, 1] interval is given in Table 3, 4. This transformation enables to analyze in the same manner, both qualitative and quantifiable data [11]. In the following, all capital letters (C: Cement, W: Water, S: Sand, F: Filler, A: additives) refer to component weight per cubic m eter of mix. When using experimental design, priority semi - empirical models are built from mathematical expansion of the outputs as following:

$$y = a_0+a_1x_1+a_2x_2+a_3x_3+a_{12}x_1x_2+a_{12}x_1x_2+a_{23}x_2x_3+a_{11}x_1^2+a_{22}x_2^2+a_{33}x^3$$

These coefficients of the model are identified through regression analysis and all possible parameters are ordered such as to keep only the most influent. In this case, 15 mixes are required to establish the mathematical formulation.

Table 3. *Field of parameters*

True values	Field of parameters			Middle values	Interval	Normalize values
w/c	0.38	to	0.52	0.45	0.07	x_1
f	100	to	150	125	25	x_2
t	0.845	to	1.447	1.15	0.30	x_3

The experiments were designed based on the orthogonal array technique and ac cording to Standard NF P 18 - 500, proportion of sand concre te are given in table 4.

__Table 4.__ Parameters their values

N°	Normalize values			True values		
	x_1	x_2	x_3	w/c	f	t
1	1	1	1	0.52	150	28
2	1	1	-1	0.52	150	7
3	1	-1	1	0.52	100	28
4	-1	1	1	0.38	150	28
5	1	-1	-1	0.52	100	7
6	-1	1	-1	0.38	150	7
7	-1	-1	1	0.38	100	28
8	-1	-1	-1	0.38	100	7
9	1.732	0	0	0.57	125	14
10	0	1.732	0	0.45	168	14
11	0	0	1.732	0.45	125	56
12	-1.732	0	0	0.33	125	14
13	0	-1.732	0	0.45	82	14
14	0	0	-1.732	0.45	125	4
15	0	0	0	0.45	125	14

__Table 5.__ Sand concrete mix proportion for e xperiment

N°	Ratio (w/c)	Filler content (f)	Age (t)	Compositions (per 1m^3)					
				Cement C (kg/)	Water W (l)	Sand S (kg)	Filler F (kg)	Additive A (l)	Total (kg)
1	0.52	150	28	413	215	1,507	150	4.55	2,290
2	0.52	150	7	404	210	1,507	150	4.44	2,275
3	0.52	100	28	413	215	1,532	100	4.13	2,264
4	0.38	150	28	513	195	1,444	150	5.64	2,308
5	0.52	100	7	404	210	1,532	100	4.04	2,250
6	0.38	150	7	513	195	1,444	150	5.64	2,308

7	0.38	100	28	513	195	1,510	100	5.13	2,323
8	0.38	100	7	513	195	1,510	100	5.13	2,323
9	0.57	125	14	350	200	1,515	125	3.50	2,193
10	0.45	168	14	467	210	1,469	168	5.13	2,319
11	0.45	125	56	456	205	1,503	125	4.56	2,293
12	0.33	125	14	563	185	1,476	125	6.47	2,356
13	0.45	82	14	433	195	1,528	82	4.33	2,242
14	0.45	125	4	444	200	1,503	125	4.44	2,277
15	0.45	125	14	456	205	1,503	125	4.56	2,293

Each sand concrete proportion made in the laboratory has chosen from the experimental plans. Concrete-mixer has revolving-paddle and 180 dm^3 in volume and the rate of rotation is 37 revolutions per minute. Mixing time is from 4 to 6 minutes. Making and curing concrete test specimens, experimenting according to ASTM are given in Table 6. The results of the experiment are given in Table 7.

Table 6. *Measurement according to*

N^o	Testing	Standard
1	Making and curing	ASTM C192/C 192M-02
2	Slump of fresh concrete	ASTM C143/ C143M-00
3	Compressive strength	ASTM C39/C39-01
4	Flexural strength	ASTM C78-02
5	Splitting strength	ASTM C496-96
6	Young's static modulus	ASTM C469-02

Table 7. *The results of experiment*

N^o	x_1	x_2	x_3	S (cm)	f_c (MPa)	f_r (MPa)	f_{sp} (MPa)	E_c (MPa)	f_c/f_r	f_c/f_{sp}	f_r/f_{sp}
1	0.52	150	28	8.5	35.17	4.29	3.39	28,750	8.20	10.38	1.27
2	0.52	150	7	7.9	29.90	3.97	2.20	23,321	7.53	13.58	1.80
3	0.52	100	28	8.6	37.91	4.33	3.58	28,376	8.76	10.58	1.21
4	0.38	150	28	4.5	47.83	5.01	4.62	35,303	9.55	10.35	1.08
5	0.52	100	7	7.3	24.38	3.61	2.32	20,861	6.75	10.52	1.56

6	0.38	150	7	8.8	37.21	4.46	3.20	29,202	8.34	11.65	1.40
7	0.38	100	28	5.5	55.42	5.32	4.63	34,255	10.42	11.96	1.15
8	0.38	100	7	12	37.54	4.37	3.59	28,647	8.59	10.46	1.22
9	0.57	125	14	8.5	28.60	3.55	2.87	22,184	8.06	9.95	1.24
10	0.45	168	14	8	42.28	4.07	3.04	32,270	10.39	13.93	1.34
11	0.45	125	56	9.4	44.02	4.36	4.04	36,423	10.10	10.89	1.08
12	0.33	125	14	3.5	48.33	5.39	3.83	35,803	8.97	12.62	1.41
13	0.45	82	14	4.5	37.24	3.65	2.87	32,557	10.20	12.97	1.27
14	0.45	125	4	5.5	29.26	3.81	2.52	23,840	7.68	11.61	1.51
15	0.45	125	14	3.5	39.57	4.12	3.02	32,239	9.60	13.09	1.36

2.4. Results and discussion

As the results in table 7, determination of regression model of mechanical properties is completed by the aid of a computer with Maple software. This way is a quite simple and very quickly to gives precise values of coefficients. After the regression models were determined. Equation are verified as following [8]:

+ To verify the suitable results of experiment in accordance with the Cochran law.

+ To estimate coefficients to fit with by statistical method (at a 95% confidence level) in accordance with the Student law.

+ To verify the optimal process quantities (factors) through the confirmation of experiments the Fisher law.

Solving and fitting regression models are following:

Fitted model of compressive strength:

+ With normalized values: $y_1 = 39.57 – 6.06\ x_1 + 5.21\ x_3$

+ With true values: $f_c = 58.69 – 86.53\ (w/c) + 17.29\ lg(t)$

Fitted model of flexural strength:

+ With normalized values: $y_2 = 4.12 – 0.44\ x_1 + 0.25\ x_3$

+ With true values: $f_r = 5.99 - 6.27\ (w/c) + 0.83\ lg(t)$

Fitted model of splitting strength:

+ With normalized values: $y_3 = 3.02 - 0.44\ x_1 + 0.54\ x_3$

+ With true values: $f_{sp} = 3.81 - 6.33\ (w/c) + 1.80\ lg(t)$

Relation between compressive strength and elastic modulus was established:

$$E_c = 1808.f_c^{0.767}$$

From the obtained results in Table 7 and regression models several discussions can be withdrawn:

In valid selective factors, types of sand concrete obtained compressive strength from 25MPa to 55MPa; flexural strength from 3.55 MPa to 5.93 MPa; splitting strength from 2.20 MPa to 4.6 MPa, and elastic modulus from 20861 MPa to 36423 MPa respectively. This results point out the rate of an increase in compressive strength as fast as the rate of an increase in flexural strength and splitting strength. The investigation of types of fracture shows: 69% cone type (a), 22% cone and split type (b), 4% shear type (d), and 4% columnar type [ASTM C39]. Almost specimens of sand concrete have the type of fracture similary to the type of fracture of traditional concrete. This manner availably says that "theories of mechanical properties of sand concrete similar to those of traditional concrete".

Regression models point out that the sensibility of w/c and t to the strength of sand concrete is more than the sensibility of f .

The ratios of f_c/f_r, f_c/f_{sp} of sand concrete and traditional concrete which have compressive strength from 15MPa to 55MPa are from 6.7 to 10.5, and from 9.9 to 13.9 in sand concrete; from 9 to 12, and from 10 to 15 in traditional concrete, respectively [10]. Therefore, the rate of an increase in flexural strength and splitting strength of sand concrete is more fast than the those of traditional concrete.

III. CONCLUTION

* The obtained results from this research, would hopefully be initial contributions to the use of sand concrete in the Mekong Delta region in Vietnam (especially, aiming at enhancing the reuse of local materials in some regions of Vietnam).

* An experimental work has been performed to study how water/cement ratio (w/c), filler (f) content, age of sand concrete (t) can modify some mechanical properties of sand concr ete.

* In this study, fitted models of experimental theory were simple equation to using to design the proportion of sand concrete.

* Theories of mechanical properties of traditional concrete can be used for sand concrete.

* Mixing time is a half as long as compared to traditional concrete, and vibrating time is shorter. As results, enery comsumption can be reduced.

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