Cement Plaster Proportioning Suitable for Sands from Different Sources in Batangas Province

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ABSTRACT

Crack development on plaster specimens of sands from Calaca, Lobo and Laurel was investigated to evaluate the suitability of different cement-sand-water proportioning mixes. Specific gravity, fineness modulus and percent water absorption were measured for each sand specimen. Both qualitative and quantitative laboratory and field tests were conducted on specimens proportioned as per ACI and ASTM C-926 requirements. Specimens for laboratory and field tests were made for each workable proportion for each sand source. The lengths and widths of observed cracks were measured in the laboratory specimens subjected to various temperatures and in field specimens at various durations after installation. Results point to cement-sand-water proportioning is the primary factor that determines the cracking behaviour of cement plaster; and to the 1: 4: 1 ½ , 1: 2 ¼ : 1 and 1: 3: 1 ½ as the best proportioning for sand from Calaca, Laurel and Lobo, respectively.

Introduction

Plastering is an age-old construction process which involves covering uneven surfaces usually with concrete. It is a basic step used in the local construction industry. During the plastic state of the plaster paste, it is relatively soft making it suitable as finishing material especially since it allows for curved shapes in a structure. It is a non-load bearing part of a structure yet it provides for increased durability by providing protective covering to the would-be-rather open concrete surfaces.

Cement plaster is the most commonly used plastering material in the local construction industry. It is a mixture of Portland cement and sand with required water to make a plastic mass. Portland cement plaster has also been called stucco. Generally stucco refers to the proprietary finish coat while both interior and exterior plasters are referred to as Portland cement plaster. Since the mixture contains Portland cement and water, its strength is dictated by the water-cement ratio: as the proportion of cement is increased, the strength and hardness of the plaster is increased at the expense of workability and ease of application. Conversely, increasing the proportion of water in the paste for greater workability may result to shrinkage cracks in the applied plaster. However, it is still common in small-scale construction projects to let workability dictate the proportioning of the aggregates in a concrete mix, without due consideration to its effect on cracking.

Considering the evident effects of aggregate proportioning in the resulting properties of a cement plaster, it is the purpose of this study to propose an initial proportioning mix based on the physical properties of the component sands as determined by testing process according to ASTM standards.

Statement of the Problem

The main focus of the study is to determine the cement plaster proportioning suitable for sands from different sources in Batangas Province. This aims to answer the following questions:

1. What are the physical properties of the selected sands in terms of:
    a. specific gravity
    b. Fineness Modulus
    c. percent absorption
2. What is the workability of the resulting plaster during field testing and laboratory testing in the following cement-sand-water proportions:
    a. 1 part cement: 2 ¼ parts sand,
    b. 1 part cement: 3 parts sand, and
    c. 1 part cement: 4 parts sand, in 4/5, 17/20, 1 and 1 ½ parts water, respectively?
3. What are the characteristics of the developed cracks in the resulting plaster applied in the field and in the molded plaster specimens subjected to laboratory testing?
4. What is the best cement-sand-water proportion suitable for plastering for each of the selected sand source in Batangas Province?

Theoretical Background

Concrete and Cement Plaster

Concrete is a mixture of water, cement and fine and coarse aggregates, constituents with increasing particle sizes. Portland cement acts as the binder of the aggregates by virtue of its reaction to water. Gravel made by crushing rocks or boulders is the norm for coarse aggregates because of the capability to choose the resulting crushed particle sizes as well as the greater bonding characteristic of the surfaces of the crushed over that of natural stones. River sand is the most widely-used fine aggregates primarily due to its abundance. Concrete without coarse aggregates is referred to as plaster.

It is not surprising that the properties of concrete will be largely affected by the properties of its individual components. The specific gravity of the aggregates is indicative of the strength of the resulting concrete. With quality aggregates, the critical factor turns to the binder – the cement paste – the strength of which is primarily a function of the water-cement ratio. In conjunction with these, the particle size distribution of the constituent-aggregates can either be an enabler or a mitigating factor in the achievement of the strength of the concrete. In a well-graded mix - having proportionate particle size distribution - there are enough finer aggregates to fill the voids between the coarser aggregates, resulting in tightly-packed aggregates held together by the binder. When there is relatively more coarse aggregates in proportion to fine aggregates, there will not be enough fines to fill the voids between the coarse aggregates which will result to a weaker concrete.

Cement-based materials gain strength by hydration, a primarily chemical reaction between water and cement brought about by the physical contact between them thereby binding the aggregates among them. Adequate strength of cement plaster depends upon complete hydration. Sufficient strength within the plaster wall is also needed to adequately withstand the stresses that may initiate adverse effects in the form of cracking or the development of one or more fissures in the plaster due to the movements in the surrounding structure. Therefore, there must be an adequate moisture contact within a plaster wall for the first few days of application, when the greatest development of strength and resistance to stress forms within the membrane, according to Geary's (2009) Drying Shrinkage.

The properties of fresh plaster have important requirements in the fresh and hardened states. In the fresh state, a plaster must be workable, cohesive and has good water retention. In the hardened state, the plaster must be strong enough to hold paint and withstand local impact and abrasion, free of unsightly cracking, well-bonded to the subtrate and have an acceptable surface texture. It is well-recognized in the field of materials engineering that these properties are largely dependent upon the properties of the materials that comprise them, such as sand in this case.

The presence of silt and clay in the sand reduces the strength of the plaster and holds dampness, while organic impurities make the sand useless for construction work. Particle sizes, the shape and texture of the particles and their surface areas are all important factors in the strength and durability of the concrete or plaster mixture. By virtue of its proportion, sand comprise the greatest component of a plaster and hence controls much of the plaster properties, such as shrinkage, porosity, strength, adhesiveness, etc. according to Russell (2011) in Cement Rendering and Building Plastering.

The specific gravity of the constituent aggregates can be specified for concrete mixes but since this is the property of a material, simply indicating the particular source of the aggregates can be enough to denote the needed concrete strength when coupled with the appropriate proportioning. It is not uncommon for workers to refer to a particular concrete strength through its corresponding aggregate proportioning. Proportioning is expressed in terms of parts by weight of the aggregates. For example, 1:2:4 refers to a concrete mix with 1 part cement, 2 parts sand and 4 parts gravel (coarse aggregates) by weight. With precise-control equipments, concrete strength in its corresponding aggregate proportioning can be easily specified and made in batching plants. The concrete mix is simply delivered to the construction site in transit mixers. In relatively smaller scale construction projects however, it is usual practice to proportion the plaster mix and concrete mix on site in parts by volume because this offers a more practical way of proportioning, usually in batches comprising of one bag of cement whether through manual mixing using shovels or by the use of a concrete mixer (which vary in size from one-bagger to three-bagger). Water is commonly added by 'oido' or as dictated by the desired workability.

Hydration and Shrinkage in Concrete

When cement is mixed with water to form a soft paste, it gradually stiffens until it becomes solid in a process called setting and hardening. The water in the paste dissolves material at the surfaces of the cement grains and forms a gel which gradually increases in volume and stiffness. This hydration process continues to proceed deeper into the cement grains at decreasing speed with continued stiffening and hardening of the mass (Nilson, 1997, p. 31). According to Building Research Institute (P) Ltd. (2008), under practical conditions within the period of concrete mixing and casting, the cement combines with only 23% of water, so additional water is required for workability. However, this water will eventually evaporate during drying of concrete, the effect of which includes development of cracks.

The additional amount of water must be present to provide mobility for the water in the cement paste during the hydration process so that it can reach the cement particles and to provide the necessary workability of the concrete mix (Nilson, 1997, p. 31). In wet plaster mortar mixture, about 1/5 of the water is absorbed in the reaction. Thus, it is obvious that concrete mixes will normally have more water than what is needed for hydration process. Excessive water leads to increased bleeding though it makes the plaster mix easier to apply.

The diverse requirements of mixability, stability, transportability, placeability, mobility, compactability and finishability of fresh concrete are collectively referred to as workability. The workability of fresh concrete varies depending upon the situation: a concrete workable for pouring into large sections may not be equally workable for pouring into heavily reinforced thin sections. (Gambhir, 2006, p.5) For this study, the concrete mixture is referred to as workable when it can be mixed with ease without the aggregates being separated.

Another aspect to be considered other than workability of plaster is shrinkage. Water added for workability but that which is in excess of that needed for hydration will have to be released from the concrete. This happens during the drying process. The excess water works its way out of the concrete to the surface where it evaporates. As a result, the concrete shrinks and cracks. Shrinkage is the process of the reduction in dimensions that occurs as plaster dries while hardening. This continues for many years but probably about 90% of it occurs during the first year. The amount of moisture (water) that is lost varies with the distance from the surface. Furthermore, members with small cross sections shrink more proportionately than do those with large ones (McCormac, 2006, p.14).

In typical concrete, drying shrinkage amounts to about 63 mils over 10 ft (Schwartz, 2007). The amount of shrinkage is heavily dependent on the type of exposure the plaster gets. For example, if the plaster is subjected to a considerable amount of wind during curing, its shrinkage will be greater. In a related fashion, a humid atmosphere means less shrinkage, whereas a dry one means more. It should also be realized that it is desirable to use low absorptive aggregates. When absorptive aggregates are used, the result maybe 1 ½ or even two times the shrinkage with other aggregates (McCormac, 2006, p.14).

Cracking in Concrete

Concrete also contracts with decreasing temperature, with effects similar to those of shrinkage; temperature contraction that can lead to objectionable cracking, particularly when superimposed on shrinkage (Nilson, 1997, p. 51-52). Cyr (2012) said in Visual Inspection of Concrete that the cause of cracking can be related to the following: properties of the constituent materials; design mix; surrounding environment in which concrete is installed; mixing, placement, finishing and curing practices; the type of use; and maintenance practices.

Cracks that appear before the concrete has hardened are called plastic cracks. Plastic cracks are typically due to poor mix design, placement practices or curing methods, and may also be caused by settlement, construction movement, and excessively high rates of evaporation. Cracks that appear after concrete has hardened can have a variety of causes. Of concern for this study are the plastic and drying shrinkage. Plastic shrinkage forms a diagonal pattern caused by excessive early evaporation. Cyr (2012) also said that drying shrinkage forms a transverse or random pattern, which is primarily caused by excessive water in the mix.

Cracks should therefore be normally expected in concrete. It is the objectionable cracks that should be avoided or prevented as they are aesthetically unsightly. Cracks in structural concrete are detrimental to the strength of a structure and must be dealt with accordingly. However, cement plaster is not considered as structural concrete in the sense that it is does not directly carry loads though it serves as protective cover to load-bearing components of a structure. As such, this study is focused on evaluating the cracks in cement plaster specimens in relation to their aggregate proportioning to determine which proportioning will result to the least amount, and dimensions, of cracks in the specimens. Findings of the study can be used as the basis for proportioning the initial batch in construction sites that use trial batches to determine the proper proportioning of the concrete aggregates.

Methodology

Sands from various locations in Batangas Province were identified as sourced by construction supply stores. The sand used by most of the stores surveyed by random sampling was selected. These were sands from Calaca, Lobo and Laurel.

The physical properties of these selected sands were determined in the Batangas State University - Civil Engineering Department Laboratory. These properties include: specific gravity, Fineness Modulus and percent water absorption. The laboratory tests of the specimens were conducted at the Department of Public Works and Highways Batangas 4th District Engineering Office.

The sand-cement ratios used in this study were based on ASTM C-926 while the water-cement ratios were based on the ACI method of mixture design. Before mixing the aggregates, the sands were first soaked in water for 24 hours, then air-dried for 4 hours to attain similar degree of saturation or water content.

A total of one hundred eight (108) specimens were molded for the shrinkage tests from mixes proportioned as described in the Statement of the Problem using 300mmx300mmx15mm aluminum molds

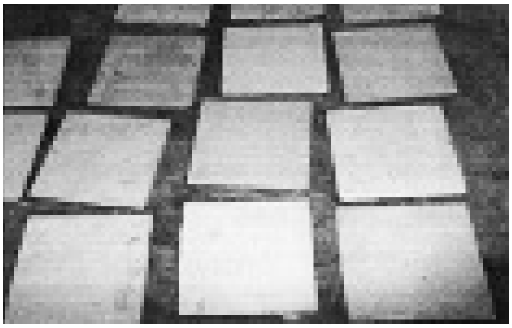


Figure 1. *Laboratory test plaster specimens.*

(Figure 1). Three test specimens per proportion per source were subjected to elevated temperatures using a pre-heated laboratory oven. The specimens were first subjected to a temperature of 50°C for 90 minutes. Then, they were exposed to a temperature of 80°C for the same duration. Measurements of the lengths of the developed cracks as well as their widths were then taken. Afterwards, the specimens were subjected to accelerated oven temperature of 100°C until cracks occurred, which were also measured. A straight-edge rule was used in measuring the lengths of the cracks while a tam crack comparator was used to measure the widths of the cracks.

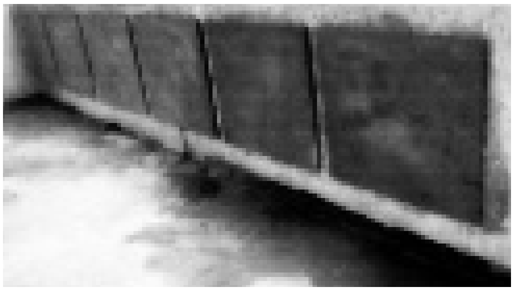


Figure 2. *Field test plaster specimens.*

The field testing was done by plastering a wall at the 3rd floor of the then unfinished Batangas State University College of Arts and Sciences Bldg. some of which are shown in Figure 2. The wall was pre-wetted before applying the plaster. The workable plaster mixtures were then applied directly to the wall surface with a thickness of 10mm.

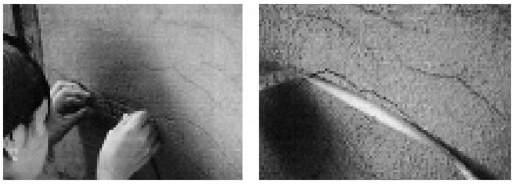


Figure 3. *Measuring the cracks on the specimens*

The installed plaster specimens were wetted for curing purposes thrice a day for 28 days. The characteristics of the developed cracks were observed at various durations after the installation: after 3 hours, after a day, after 7 days, after 14 days, after 28 days and after 90 days. The tam crack comparator was also used to measure the fine cracks. This was done as accurately as possible. For longer cracks, the use of steel tape was deemed appropriate. Measurements were taken following the path of the cracks.

Results and Discussion

Table 1 shows the different material properties relevant to the study for the selected sands. Variations in the specific gravity and water absorption properties can be expected to affect the amount of water needed in a mix. Indicative of the relative degree of fineness of a specimen, Fineness Modulus will dictate the needed proper amount of cement in a mix.

Table 1

Physical properties of the selected sands.

Source	Specific Gravity	Fineness Modulus	% Water Absorption
Calaca	3.333	2.700	4.51
Laurel	1.900*	3.662	3.45*
Lobo	2.340*	3.168	4.17*

** - values based from Antonio (2004)*

Table 1 shows how sands from one province can have very different properties. The specific gravity of Calaca sand is much greater than that of Laurel sand. The variations in the fineness modulus are also notable, as well as those for water absorption.

Workability property test results are shown in Table 2. Workability tolerance was greater in the laboratory test specimens as they were placed in, and hence supported by, molds. On the other hand, plaster specimens for the field tests had to adhere to the test wall, requiring greater workability compared to the laboratory test specimens. Specimens that can be mixed and placed as needed are called workable (W) while those wherein the aggregates did not attain homogeneity or practically segregated are referred to as non-workable (NW).

Table 2

Workability of cement plaster specimens.

Source	Proportions			Workability	
	Cement	Sand	Water	Field Test	Laboratory Test
Calaca	1	2 ¼	4/5	NW	NW
			17/20	NW	NW
			1	NW	W
			1 ½	W	W
	1	3	4/5	NW	NW
			17/20	NW	NW
			1	NW	W
			1 ½	W	W
	1	4	4/5	NW	NW
			17/20	NW	NW
			1	NW	NW
			1 ½	W	W
Laurel	1	2 ¼	4/5	NW	NW
			17/20	NW	W
			1	W	W
			1 ½	NW	NW
	1	3	4/5	NW	NW
			17/20	NW	NW
			1	NW	NW
			1 ½	W	W
	1	4	4/5	NW	NW
			17/20	NW	NW
			1	NW	NW
			1 ½	NW	W
Lobo	1	2 ¼	4/5	NW	W
			17/20	W	W
			1	W	W
			1 ½	NW	NW
	1	4	4/5	NW	NW
			17/20	NW	NW
			1	W	W
			1 ½	W	W
	1	4	4/5	NW	NW
			17/20	NW	NW
			1	NW	NW
			1 ½	W	W

Table 3.

Dimensions of laboratory specimen cracks (mm of crack lengths, L and widths, W).

Temp.		Sample	Laurel Sand 1:3:1½	Laurel Sand 1:2¼:1	Laurel Sand 1:2¼:17/20	Calaca Sand 1:4:1½	Calaca Sand 1:3:1½	Calaca Sand 1:3:1	Calaca Sand 1:2¼:1½	Calaca Sand 1:2¼:1
Initial	L	1	-	-	-	290	150-200	-	190	40-220
		2	-	-	-	-	-	-	-	70-190
		3	215	-	-	-	-	-	-	18-400
	W	1	-	-	-	0.4	0.2	-	0.4	0.2-0.8
		2	-	-	-	-	-	-	-	0.2-0.8
		3	0.2	-	-	-	-	-	-	0.2
@ 50°C	L	1	-	-	-	290	150-200	-	190	40-220
		2	-	-	-	-	-	-	-	70-190
		3	215	-	-	-	-	-	-	18-400
	W	1	-	-	-	0.4	0.2	-	0.4	0.2-0.8
		2	-	-	-	-	-	-	-	0.2-0.8
		3	0.2	-	-	-	-	-	-	0.2
@ 80°C	L	1	-	-	150	290	150-310	-	190-270	50-220
		2	15-90	-	-	140	-	37-40	-	30-190
		3	240	-	-	-	-	-	-	18-400
	W	1	-	-	0.4	0.4	0.2	-	0.4-0.8	0.2-0.8
		2	0.2	-	-	0.4-0.8	-	0.2-0.4	-	0.2-1.1
		3	0.2-0.4	-	-	-	-	-	-	0.2-0.4
@100°C	L	1	45-310	-	250	80-290	150-310	40-70	190-270	30-230
		2	310	-	-	140	-	37-40	-	50-190
		3	310	-	-	-	-	-	190-270	18-400
	W	1	0.2-0.4	-	0.4	0.2-0.4	0.2	0.2-0.7	0.4-1.1	0.4-1.1
		2	0.4-1.1	-	-	0.4-0.8	-	0.2-0.4	-	0.2-1.5
		3	0.2-0.8	-	-	-	-	-	0.2-0.4	0.2-0.4
		Ave	0.27-0.43	-	0.133	0.2-0.4	0.067	0.13-0.37	0.2-0.5	0.267-3.0

Table 4.

Dimensions of Lobo sand laboratory specimen cracks (mm of crack lengths, L and widths, W).

Temp.		Sample	1:4:1½	1:3:1½	1:3:1	1:2¼:1	1:2¼: 17/20	1:2¼ : 4/5
Initial	L	1	-	-	-	-	-	135
		2	45-210	-	-	-	-	-
		3	-	29-110	-	-	-	-
	W	1	-	-	-	-	-	0.3
		2	0.2-0.4	-	-	-	-	-
		3	-	0.2-1.1	-	-	-	-
@ 50°C	L	1	-	-	-	-	-	135
		2	45-210	-	-	-	-	-
		3	-	29-110	-	-	-	-
	W	1	-	-	-	-	-	0.3
		2	0.2-0.4	-	-	-	-	-
		3	-	0.2-1.1	-	-	-	-
@ 80°C	L	1	-	50	-	-	-	135
		2	50-60	310	-	-	-	-
		3	-	125-340	-	-	-	-
	W	1	-	0.4	-	-	-	0.4
		2	0.2-0.8	0.4	-	-	-	-
		3	-	0.2-1.5	-	-	-	-
@100°C	L	1	30	140	-	-	-	135
		2	50-60	190-310	155	-	222	-
		3	-	130-330	-	-	-	-
	W	1	0.4-1.1	0.4	-	-	-	0.4
		2	0.2-0.8	0.4	0.2-0.4	-	0.2	-
		3	-	0.4-1.5	-	-	-	-
		Ave	0.20-0.63	0.13-0.76	0-.067-0.133	0	0.067	0.133

For Calaca sand, it can be seen that only proportions with 1 ½ parts water by weight are workable although proportions having 1 part water but with lesser amount of sand in the laboratory test specimens are also workable. Laurel and Lobo sands showed greater sensitivity to the amount of sand. They both require more water as the amount of sand is increased. For Laurel sand, proportions 1: 2 ¼ : 1 and 1: 3 : 1 ½ are workable. For the Lobo sand, the proportions 1: 2 ¼ : 17/20, 1: 2 ¼ : 1, 1: 3 : 17/20, 1: 3 : 1 & 1: 4: 1 ½ are considered workable. Table 2 also shows that Laurel sand needs relatively more water than Lobo sand.

Considering the intended practical application of the study, further tests and analysis were devoted only to proportions that were found workable in both the field and laboratory tests. For laboratory testing, each of the fourteen workable proportions were mixed and placed in molds. Three specimens per proportion were prepared. These were placed inside an oven and subjected to elevated temperatures. Measured dimensions of the resulting cracks were summarized in Table 3 and Table 4. The length (L) and width (W) data shown in these tables do not necessarily refer to the same crack.

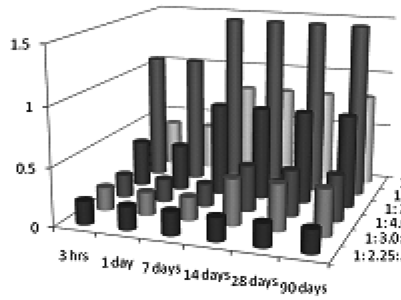
From both a structural and aesthetic points of view, the most desirable mix proportion would be that which results to no cracks or to the least amount of cracks. Based from the tabulated dimensions of cracks, the desirable proportioning for Laurel sand would be 1: 2 ¼ : 1. For Calaca sand, this would be 1: 3: 1 ½ while the desirable mix proportion for Lobo sand would be 1: 2 ¼ : 1.

Table 5 shows the crack dimensions of the cement plaster field specimens for the selected sands in various workable proportions. The cracks are tabulated in mm of minimum to maximum lengths and widths of the cracks observed in various durations after installation: 3 hours (3h); 1 day (1d); 7 days (7d); 14 days (14d); 28 days (28d); and 98 days (98d). The maximum crack width observed was 1.5mm and that of the crack length was 390mm. No change in cracks was observed after 28 days. In addition, warpage was observed on the plaster specimen for 1: 3: 1 ½ proportion for Calaca sand. Primarily considering the least widths of the cracks for each specimen, the following proportions are chosen as the recommended plaster proportioning: for Calaca sand, 1: 4: 1 ½; for Laurel sand, 1: 2 ¼: 1; and for Lobo sand, 1: 3: 1 ½.

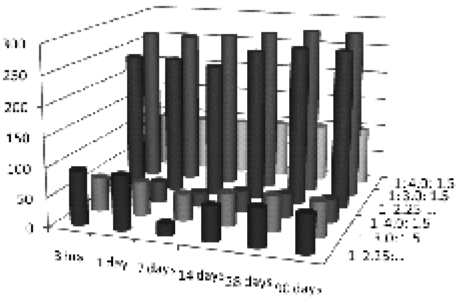
Table 5.

Dimensions of field specimen cracks (mm of crack lengths, L and widths, W).

	Calaca Sand			Laurel Sand		Lobo Sand				
	1:2¼:1½	1:3:1½	1:4:1½	1:2¼:1	1:3:1½	1:2¼: 17/20	1:2¼:1	1:3:1	1:3:1½	1:4:1½
3h L	92-237	58-266	36-95	43-67	37-254	76-216	60-89	29-94	10-33	15-84
3h W	0.2-0.4	0.2-1.1	0.2-0.4	0.2-0.4	0.2-1.1	0.2-0.4	0.2-0.8	0.2-0.8	0.2	0.2-0.4
1d L	92-237	58-266	36-95	43-67	37-254	76-216	60-89	29-94	10-33	15-84
1d W	0.2-0.4	0.2-1.1	0.2-0.4	0.2-0.4	0.2-1.1	0.2-0.4	0.2-0.8	0.2-0.8	0.2	0.2-0.4
7d L	20-230	46-272	26-95	34-78	37-254	69-226	36-220	10-112	10-33	15-94
7d W	0.2-0.8	0.2-1.5	0.2-0.8	0.2-0.8	0.2-1.1	0.2-0.8	0.2-0.8	0.2-1.1	0.2-0.4	0.2-0.4
14d L	59-260	56-279	37-98	23-254	10-268	41-266	40-257	11-175	26-38	22-98
14d W	0.2-0.8	0.4-1.5	0.4-0.8	0.3-0.8	0.2-1.5	0.2-0.8	0.2-1.1	0.2-1.1	0.2-0.4	0.4-0.8
28d L	65-270	60-287	40-100	25-270	11-270	45-280	45-390	12-190	30-40	25-100
28d W	0.2-0.8	0.4-1.5	0.4-0.8	0.3-0.8	0.2-1.5	0.2-0.8	0.2-1.1	0.2-1.1	0.2-0.4	0.4-0.8
90d L	65-270	60-287	40-100	25-270	11-270	45-280	45-390	12-190	30-40	25-100
90d W	0.2-0.8	0.4-1.5	0.4-0.8	0.3-0.8	0.2-1.5	0.2-0.8	0.2-1.1	0.2-1.1	0.2-0.4	0.4-0.8
Pattern	random	random	random	parallel	parallel	random	random	parallel	parallel	parallel
Location	upper right	upper right	center	center	upper left	center	center	sides	upper right	Center

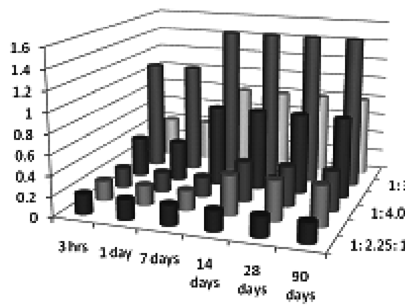


Width of cracks

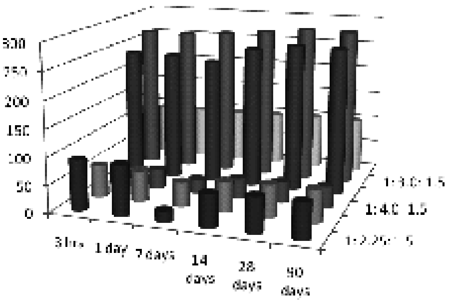


Length of cracks

Figure 4. *Dimensions of Cracks of Calaca Sand*



Width of cracks



Length of cracks

Figure 5. *Dimensions of Cracks for Laurel Sand.*

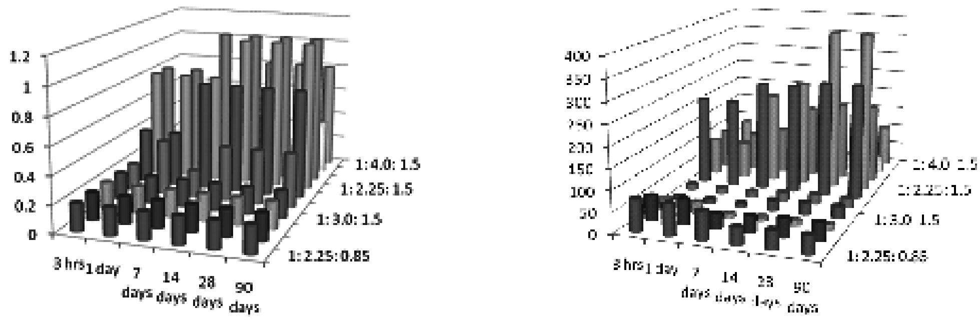
Figure 4 depicts the variations in the dimensions in graphical form of the cracks in Calaca Sand cement plaster specimens. The rows in the graphs show the variation in dimensions according to age of the specimens. The columns indicate the variations in the dimensions as a result of the differences in the mix proportions of the plaster specimens.

The effects of the specimen age and of the mix proportioning can be clearly seen from the figure. The age of the specimens shows little variation. On the other hand, the mix proportioning shows contrasting differences. This shows that mix proportioning is the factor that largely affects the cracks of the Calaca sand plaster specimens.

Figure 5 likewise shows the variations in the dimensions in graphical form of the cracks in Laurel Sand cement plaster specimens. The rows in the graphs show the variation in dimensions according to the duration after installation of the specimens. The columns indicate the variations in the dimensions as a result of the differences in the mix proportions of the plaster specimens.

The effects of the specimen age and of the mix proportioning can be clearly seen from the figure. Similar to that for Calaca sand, the age of the specimens shows little variation in the dimensions of the cracks. On the other hand, the mix proportioning also shows contrasting differences. This shows that mix proportioning is the factor that largely affects the cracks of the plaster specimens from Laurel.

Figure 6 also shows the variations in the dimensions in graphical form of the cracks in Lobo Sand cement plaster specimens. The rows in the graphs show the variation in dimensions according to the



Width of cracks   Length of cracks

Figure 6. *Dimensions of Cracks for Lobo Sand.*

duration after installation of the specimens. The columns indicate the variations in the dimensions as a result of the differences in the mix proportions of the plaster specimens.

The effects of the specimen age and of the mix proportioning is clearly illustrated in the figure. Similar to that for Calaca and Laurel sands, the age of the specimens shows little variation in the dimensions of the cracks. Conversely, the mix proportioning also shows the contrasting differences. This shows that mix proportioning is the factor that largely affects the cracks of the plaster specimens for Lobo sand, although the age of the cement plaster specimen has a more pronounced effect in this sand compared to the other two sand sources. This aspect would also point to time-effect that needs to be considered by workers when using concrete mixes sourced from Lobo.

Considering the aforementioned test results, and giving more weight to the field test since it more closely represents actual site conditions, the researchers chose the best cement-sand-water proportion for the different sands under study. The 1: 3: 1 ½ proportion is best for Lobo sand in this respect, while the proportion 1: 4: 1 ½ is the best choice for Calaca sand and the 1: 2 ¼ : 1 proportion can be expected to give best results for the Laurel sand.

Aside from the comparative advantage of these proportionings over the other mixes using the same material, the acceptability of their cracks based on the Stucco Crack Width Evaluation Survey of Trade Associations were also evaluated. Plaster Council limits crack width to 59mils (1.5mm), American Concrete Institute sets this limit to 30mils (0.8mm) while both Portland Cement Association and Stucco Manufacturers Association set this ceiling at 60mils (1.5mm). Since the cracks developed in the specimens corresponding to the above-selected proportions for the different sand sources fall within the aforementioned limits, the expected cracks from the recommended proportionings are considered to be acceptable.

Conclusions

Sands from various sources differ in construction-relevant properties. Differences in the properties of the sand specimens require different aggregates-proportioning for acceptable plaster mixes. Furthermore, workability requires proportionate increase in the amount of water as the amount of sand is increased in the mix.

The age of the plaster show relatively little effect on cracking. The primary factor that determines the cracking behaviour of cement plaster is cement-sand-water proportioning.

The best cement-sand-water proportion for plaster using sands from Calaca, Laurel and Lobo are 1: 4: 1 ½ , 1: 2 ¼ : 1 and 1: 3: 1 ½ , by weight, respectively.

Considering the above results, the sand from Lobo appears to be the best for use as plaster among the three sources.

Recommendations

It is recommended that builders/contractors adopt a proportioning close to those described above when using the sand from the subject sources or use the same as a basis for their trial batches when determining the appropriate proportioning for the subject sand.

Further study on crack behaviour of plaster mixes using the proportioning used by local builders is likewise recommended considering that these vary widely because they are being done by trial and error and are usually dictated by the workability desired by workers at the site.

Study on crack behaviour of plaster mixes using sands from other sources is also recommended. Consolidation of results from these studies will pave the way for the creation of reference data which builders can use as reference for the basically trial and error method used by workers in trial batch process for determining the desirable mix proportioning for their plastering works.

Study on possible material that can mitigate cracking when mixed with the subject sands, or for use in plaster mixes, is likewise recommended. Use of such material can allow mixing workable concrete without much concern on cracking.

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