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Proposal of Flowable Fill Designs for improvement of excavation and filling works of trenches in sanitation systems

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Abstract. Population grow in recent years requires an extension of the current pipeline sanitary system. For this purpose, granular excavation and landfill works are associated with pedestrian traffic congestion. Therefore, it is necessary to develop an innovative and sustainable alternative to reduce the problems generated during the execution of the conventional process. This research proposes the use of flowable fill due to the multiple advantages offered by this material. On the one hand, it is economical for medium to large trench fill volumes, considering savings in labor (it is done with a small number of workers), in equipment (does not require the rental or purchase of compaction equipment) and in time (the pouring is done by directly pumping the mixture, from the mixing machines to the excavation). On the other hand, being self-compacting and self-leveling decreases the width of the trenches, reducing excavation and filling volumes; which, in turn, incur money savings. Also, this material guarantees work safety, since people are not required inside the excavation and fill in poorly accessible areas without any problem. Dosages were established for ten flowable fill mixtures with cement contents of 50, 60, 70, 80 and 90 kg of cement and a range of admixture from 1.75 to 2.00%; The results indicated that decreasing the fine aggregate - coarse aggregate ratio, the compressive strength of the mixtures increases and the slumps of the mixtures decreases, and the compressive strength increases directly proportional to the cement content.

1. Introduction

Conventional excavation and trench filling works for maintenance or installation of new pipes are a necessity to provide basic services for the population. Although conventional filling looks like a simple procedure, it demands a thorough control of the filling material, the condition of trench walls and the compaction process; to achieve the same soil conditions in their original state, and thus, avoid short and medium term slumps. Slumps that occur on soils under transit roads incur in cost overruns and traffic problems for vehicular and pedestrian traffic; due to excavation, filling and paving reworks [1].

Also, excavation works develop negative environmental impacts, since it is recurrent to leave the trenches open and expose them for a prolonged period. [1].

The flowable filling emerges as an alternative to avoid multiple problems which appears in excavation works and trench fillings, since it serves as a resistant and durable filling material for sanitation systems [2-5]. More importantly, it can be designed with an early strength able to support traffic loads within the first hours, after its pouring; and due to its self-compacting and self-leveling properties, ensures the alignment of the pipes over the time and avoids slumps possibilities [4,5,6].

2. Materials and Method

2.1 Materials

Lima Ordinary Portland Cement Type I was used; natural fine aggregate and 3/4” natural coarse aggregate from the “Jicamarca” quarry, with fineness modulus 2.93 and 6.73, respectively; superplasticizer (SP) and air entrainment (AE) admixture with a density of 1130 kg/m^3.

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2.2 Method
The parameters considered for the realization of the mixing designs were cement content, superplasticizer and air entrainment admixture, the fine aggregate-coarse aggregate ratio, and the water-cement ratio as shown in Table 1.

Table 1. Parameters

Parameters	
Cement Content (kg)	50 - 90
SP - AE admixture (%)	1.75 - 2.00
F.A./C.A. ratio	2.33 - 4.00
W/C ratio	2.44 - 4.70

The properties of compressive strength, flowability, density and air content were evaluated according to technical specifications of the ACI 229R Committee as indicated in Table 2.

Table 2. Technical Specifications

Technical Specifications	
Flowability (in.)	8 - 12
Air Content (%)	8 - 15
Density (kg/m^3)	1800-2200
Compressive Strength (kg/cm^2)	5 - 14

Ten flowable fill mix designs were proposed show in Table 3. The water content varied in a range of 220 to 235 kg / m^3 and the superplasticizer and air entrainment admixture dosage in a range of 1.75 to 2.00% to obtain flow values ranging from 8 to 12 inches, a range necessary to ensure a fluid and self-leveling consistency of the mixture. From the point of view of practical construction, the most important property of the flowable fill is the capacity it has for self-compacting and self-leveling, and which can be conveniently used in trenches and narrow places where the use of labor and machines becomes complicated.

Table 3. Flowable fill Designs Chart

Summary Table of Flowable fill Designs to Prepare in Laboratory										
Mixture	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
Portland Cement Type I (kg)	50	50	60	60	70	70	80	80	90	90
Water (kg)	235	220	235	220	235	220	235	220	235	220
Fine Aggregate (%)	80	70	80	70	80	70	80	70	80	70
Coarse Aggregate (%)	20	30	20	30	20	30	20	30	20	30
SP - AE admixture (%)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.75	1.75
Theorical Air (%)	10	10	10	10	10	10	10	10	10	10
F.A./C.A. ratio	4.00	2.33	4.00	2.33	4.00	2.33	4.00	2.33	4.00	2.33
W/C ratio	4.70	4.40	3.92	3.67	3.36	3.14	2.94	2.75	2.61	2.44

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3. Results and Analysis

3.1. Flowability and Fine Aggregate – Coarse Aggregate Ratio

The flow values obtained at 0, 30, 60, 90 and 120 minutes for the mixtures made based on the fine aggregate - coarse aggregate ratios = 4.00 and 2.33, are shown in Figures 1 and 2, respectively.

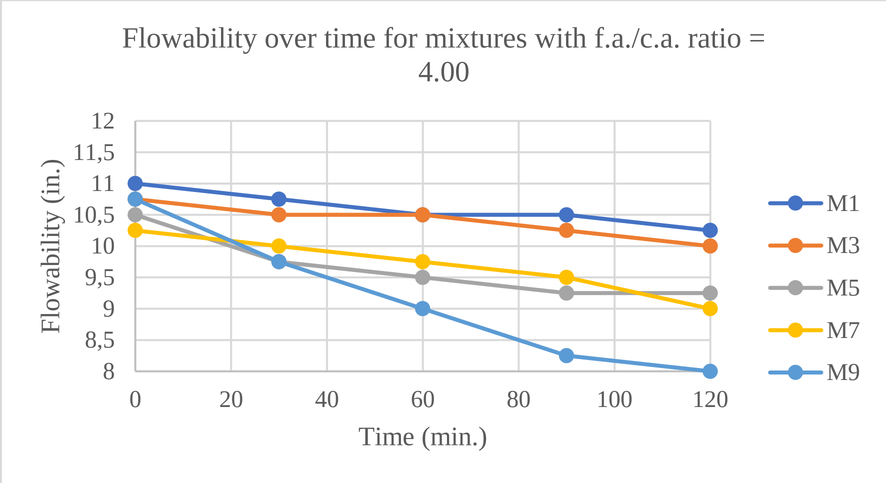

Figure 1. Flowability over time for mixtures in f.a./c.a. ratio=4.00

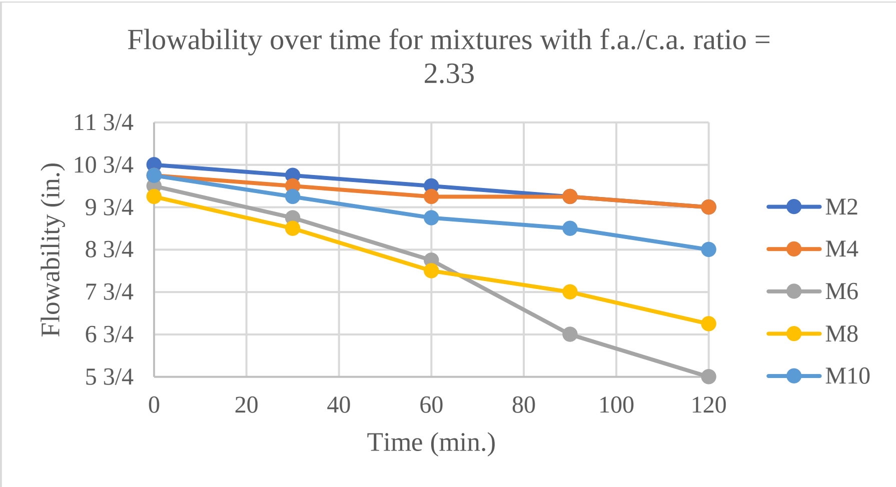

Figure 2. Flowability over time for mixtures with f.a./c.a. ratio = 2.33

The flow values obtained at 0, 30, 60, 90 and 120 minutes for the mixtures in relation to f.a./c.a.=4.00 varied from 11" to 8". and for mixtures in relation to f.a./c.a.=2.33 between 10 3/4" to 5 3/4".

All the mixtures with a f.a./c.a ratio = 4.00, met the flowability range established by ACI 229R committee (8" – 12"), ensuring the workability for the transport and pouring. However, in mixtures with a f.a./c.a. ratio = 2.33, reduced flowability values were observed. The lowest values were obtained for mixtures with low cement content and a f.a./c.a. ratio = 4.00, this prove that a high percentage of fine aggregate and a low cement content in the dosage increases the flowability of the flowable fill mixture.

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3.2. Strength – Cement Content

The resistance results obtained at 2, 7, 14 and 28 days for the mixtures made based on the cement content (50, 60, 70, 80 and 90 kg) in the dosage is shown in Figure 3.

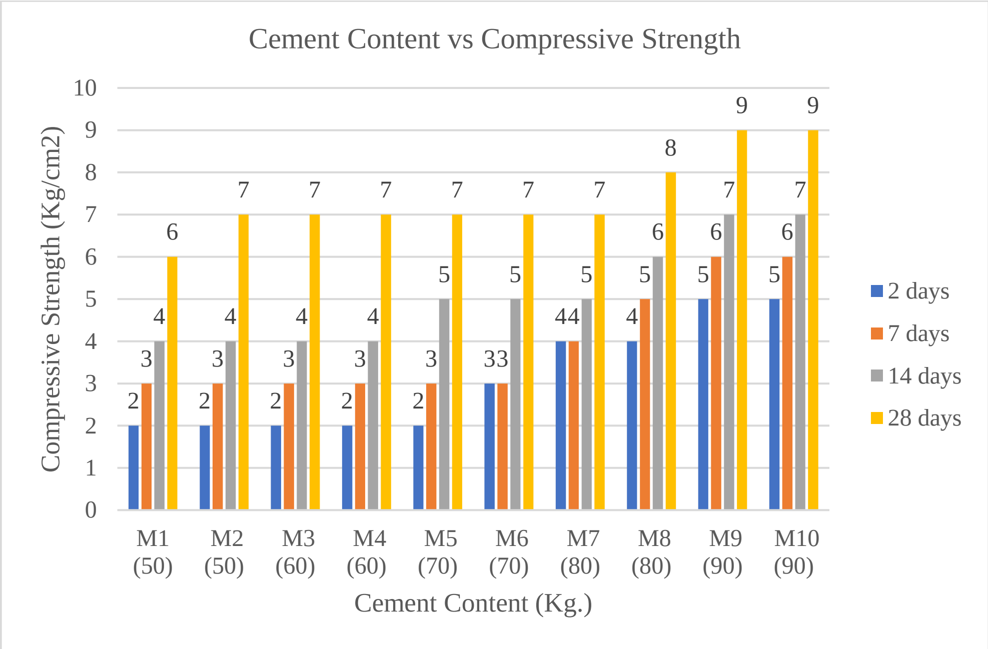

Figure 3. Cement Content vs Compressive Strength

The mixtures with 50 kg, 60 kg and 70 kg of cement content in their dosing developed a compressive strength of 2 to 7 kg / cm^2 in 28 days, mixtures with 80 kg of cement content in their dosing developed a resistance at compression of 4 to 8 kg / cm^2 in 28 days and mixtures with 90 kg of cement content in their dosage developed a compressive strength of 5 to 9 kg / cm^2 in 28 days.

The M6 and the mixtures with cement content in its dosage of 80 and 90 kg developed a resistance to compression at 2 days between 3 and 5 kg / cm^2, they reached the resistance of a natural soil that fluctuates between 3 and 7 kg / cm^2, which guarantees a rapid release of traffic after emptying the excavation.

All the mixtures developed a compressive strength at 28 days between 6 and 9 kg / cm^2, so it meets with the range established by the ACI 229R Committee (5 to 14 kg / cm^2), and ensures an easy removal of the material in case there is any change or failure in the sanitation system.

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Figure 4. Compressive Strength Test

Figure 5. Slump Test

4. Conclusions

- The compressive strength not confined at 28 days of the mixtures varied from 6 - 9 kg / cm^2, meeting with the range established by the ACI 229R Committee (5 to 14 kg / cm^2). Higher 28-day strength values were achieved for mixtures with cement content in their 90 kg dosage.
- The flowability values of the mixtures with f.a./c.a. ratio = 4.00 varied from 8 - 11", meeting the range of flowability established by the ACI 229R committee (8 - 12").
- The lowest flowability values were achieved for mixtures with low cement content and f.a./c.a. ratio = 4.00.
- The mixtures with cement content in their dosage of 80 and 90 kg developed, at 2 days, a compressive strength between 3 - 5 kg / cm^2, they reached the resistance of a natural soil.

5. References

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