NISTIR 5633

Testing of Selected Self-Leveling Compounds for Floors

Chiara F. Ferraris

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Building and Fire Research Laboratory
National Institute of Standards and Technology
Gaithersburg MD 20899

U.S. Departement of Commerce
Ronald H. Brown, *Secretary*
Technology Administration
Mary L. Good, *Under Secretary for Technology*
National Institute of Standards and Technology
Arati Prabhakar, *Director*

Abstract

During the past year, a severe odor developed in some floors of a large office building. The odor has been attributed to interactions among a self-leveling compound, carpet adhesive, and the carpet. The owner of the building, the General Services Administration (GSA), wanted to ascertain if the odor could be eliminate by removing the existing self-leveling compound and replacing it with a compound of a different composition. The National Institute of Standards and Technology (NIST) was asked to evaluate the properties of selected self-leveling compounds being considered for use in the building. Lightweight concrete was also to be tested for possible use as a substrate for the self-leveling compounds.

This report gives the results obtained on the self-leveling compounds alone or in combination with normal weight concrete or lightweight concrete. It also gives the test results obtained on lightweight concrete alone. An overall ranking of the compounds was not attempted, because the rank would depend on the wight given to each property by the user in each application of the compound. Specifications for some of the properties tested were developed by GSA.

It was not the aim of this study to measure or observe any odor generated by the self-leveling compounds alone or in conjunction with the concrete substrate or any other material.

Keywords: Bond to concrete; building technology; lightweight concrete; mechanical properties; self-leveling compounds; shrinkage; water interaction.

Table of Contents

List of Tables and Figures

1. Introduction

After construction, some floors of a large office building in Maryland had a sag of up to 100 mm (4 in). This situation was overcome by using a self-leveling compound, eventually covered by carpeting, attached with an adhesive. After about a year usage, an odor about which some occupants complained had developed in some floors of the building. The odor has been attributed to interactions among a self-leveling compound, carpet adhesive, and the carpet [12]. The owner of the building, General Services Administration (GSA), wanted to ascertain if the odor could be eliminated by removing the existing self-leveling compound and replacing it with a compound of a different composition.

The National Institute of Standards and Technology (NIST) was asked to evaluate the properties of selected self-leveling compounds for use at the Silver Spring Metro Center I building. Lightweight concrete was also to be tested for possible use as a substrate for the self-leveling compounds. It is not the aim of this study to measure or observe any odor generated by the self-leveling compounds alone or in conjunction with the concrete substrate or any other material.

This report gives the test results obtained on the self-leveling compounds alone or in combination with normal weight or lightweight concrete. It also gives the results obtained on lightweight concrete alone. Based on these results and on tests of odor generated (provided by another agency) GSA was able to select the best compound for their application.

2. The Self-Leveling Compounds Selected

In consultation with GSA, five self-leveling compounds were chosen to be tested. The selected compounds are identified, in this report, as A,B,C,D and E. The mixture proportions of the various compounds are shown in Table 1. It should be noted that for two products, Compounds C and D, the water content must be field adjusted after measurement of the flow. These are the manufacturers' recommendations to avoid surface problems such as bleeding or dusting. The manufacturers of Compounds A and B recommended that pea gravel be added when thick overlays were to be placed. Table 1 gives the proportions of pea gravel to be used, if any. In most cases, both 50 mm (2 in) and 100 mm (4 in) thick overlays required the use of gravel. For Compound E, gravel is needed only if the overlay is thicker than 50 mm (2 in).

Each manufacturer provided a primer (an aqueous solution) to be painted on the substrate, prior placing the self-leveling compound. The primers were not tested independently of the products, as their function was to contribute to the bonding of their specific overlay to the substrate.

Table 1: Recommended Mixture Proportions for Self-Leveling Compounds

Product	Water/ Dry Product (by mass)	Pea Gravel/ Dry Product (by mass)	Comments
Compound A	0.26	1.0	
Compound B	0.23	0.5	
Compound C	0.17 to 0.25	none	Very sensitive to water content (dusty surface if too much water)
Compound D	0.14 to 0.15	none	Very sensitive to water content (bleeding, weak surface film if too much water)
Compound E	0.167	0.2 (only for 100 mm (4 in) overlay)	

3. Lightweight concrete proportions

The lightweight concrete specifications were developed by GSA (see Appendix A). All the specimen were prepared at the ready-mixed concrete supplier's facility. Appendix B gives the data sheet from the supplier containing the concrete mixture proportions and measurements on the fresh concrete.

4. Properties Tested

NIST was requested to measure the following properties on the self-leveling compounds:

- Flow of fresh self-leveling compound
- Setting time
- Shrinkage
- Compressive strength
- Reaction to water and limewater: full immersion and capillary absorption
- Water evaporation through one surface
- Bond to normal-weight concrete and lightweight concrete
- Impact resistance of a feather-edged layer on normal-weight concrete and lightweight concrete.

A thick slab 100 mm (4 in) was also cast to observe any change in appearance.

The following properties were measured on the lightweight concrete:

- Slump
- Setting time (of the cement used)

- Shrinkage
- Compressive strength

To measure the above properties, ASTM standards were used when available. Where no ASTM test was available, special tests were developed. The following section describes the tests.

4.1 Self-leveling compounds

4.1.1 Flow of self-leveling compounds

A non-standard mini-slump test was used. This test is widely used for cement paste flow measurements and gives reproducible results.

The mini-slump test uses a cone with a 20 mm (0.8 in) top radius and a 40 mm (1.6 in) bottom radius and a height of 60 mm (2.4 in). The cone is placed on a glass plate and filled with the material to be tested. The cone is lifted gently and the diameter of the material spread is measured immediately to the nearest millimeter.

4.1.2. Setting time of self-leveling compounds

The setting time was measured with the Vicat needle apparatus, described in ASTM C 187. The method for testing was as described in ASTM C 191, but with some minor modifications:

- the specimen was kept on the laboratory bench at all times (not at 100% humidity).
- the interval of time between measurements was shorter than in ASTM C 191.

The reason for these modifications is that the setting times of the self-leveling compounds are far shorter than those for portland cement pastes.

4.1.3 Shrinkage of self-leveling compounds

Shrinkage was measured by recording length changes of bars (25x25x280 mm or (1x1x11 in)) made from the compounds. A comparator (resolution 0.002 mm (0.0001 in)) was used and the bars were monitored for 28 days. The bars were demolded after 24 hours and the measurements started immediately. During the first 24 hours, the specimen were kept covered in their molds. Then the bars were stored at room temperature and room relative humidity, i.e., 20 ^{0}C-25 ^{0}C and 30%-40% RH.

4.1.4 Compressive strength of self-leveling compounds

Compressive strength was measured using 50 mm (2 in) cubes as described in ASTM C 109, but with some modifications. The mixes were neat self-leveling compounds without added sand. The cubes were cured in the laboratory rather than in water, because this is closer to the curing condition expected in the field. During the first 24 hours the specimen were kept covered by aplastic sheet in their molds and then they were demolded.

4.1.5 Behavior in water and limewater of the self-leveling compounds

Three 50-mm (2 in) cubes of each material were tested for their behavior in water and limewater. One cube was submerged in distilled water and another in limewater. Both cubes were weighed (surface dry) before immersion and at regular intervals during immersion. The amount of water absorbed was calculated. Any changes in the appearance of the specimens were also recorded.

A third cube was placed with only one face in contact with distilled water (see Figure 1). The mass of the specimen as well as any changes in the appearance (such as efflorescence) were recorded regularly. All measurements were started after 7 days of air curing.

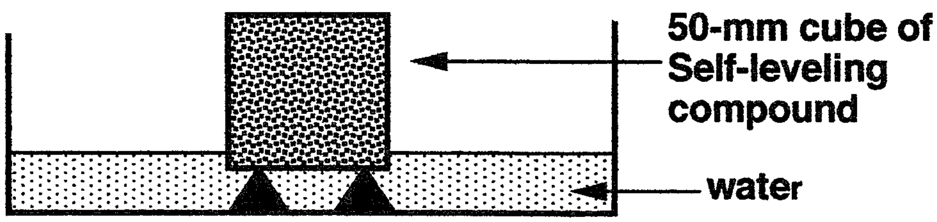


Figure 1: Capillary absorption set-up

4.1.6 Water evaporation from one surface of self-leveling compounds

The self-leveling compound must be dry before any carpeting can be applied. The following test was designed to estimate the amount of time needed to reach this condition.

Small cylinders (50 mm x 100 mm, or 2 x 4 in) were cast and kept in the molds for 24 hours. Immediately after demolding the bottom and the sides were wrapped with tape. The masses of the cylinders were recorded regularly until a constant mass was reached. Figure 2 shows the specimens.

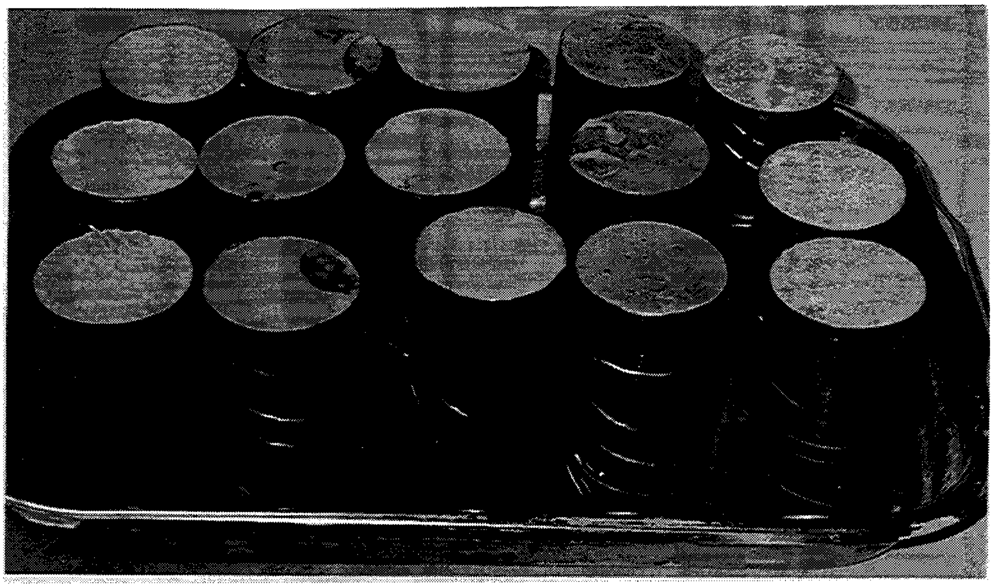


Figure 2: Specimens for water evaporation

4.1.7 Bond of self-leveling compounds to concrete

Two different tests were used depending on the type of concrete substrate used. For normal-weight concrete, a 50 mm (2 in) thick layer of the self-leveling compound to be tested was cast on top of a commercially available precast concrete slab. The slab dimensions were 460x460x50 mm (18x18x2 in). In each case, the surface of the concrete slab was brushed clean and primed according to the manufacturer's instructions. After 7, 14 and 28 days of air curing, a 64 mm (2.5 in) diameter core was drilled part way (a couple of millimeters) into the slab (see Figure 3). A metal cap was glued using a two part epoxy on the top of the core. The core was then pulled off using an hydraulic operated dynamometer. The tensile force needed to pull off the core was recorded. A description of the mode of fracture was also recorded.

For lightweight concrete, a direct shear test was used. Lightweight concrete cylinders (76x152 mm (3x6 in)) were cured in limewater at 20 °C-25 °C for 7 days and oven dried at 50 °C for 2 days. The cylinders were turned bottom side up, and a 50-mm (2 in) thick layer of the self-leveling compound to be tested was cast on top. The reason for turning the cylinders over was to use a smooth surface. The bottom surfaces were very smooth because the cylinders were cast in disposable plastic molds. The surface of the concrete was brushed clean and primed according to the manufacturer's instructions. After 7, 14 and 28 days of air curing of the self-leveling compound in the plastic molds, the interface strength was measured. The device used, shown in figure 4, applies a shear force on the bond between the concrete and the self-leveling.

ASTM C 882 test method, the commonly used bond test, was not used in this study, because special specimens would have had to be prepared and cured. Time constraints prevented us from preparing concrete specimens as described in the standard.

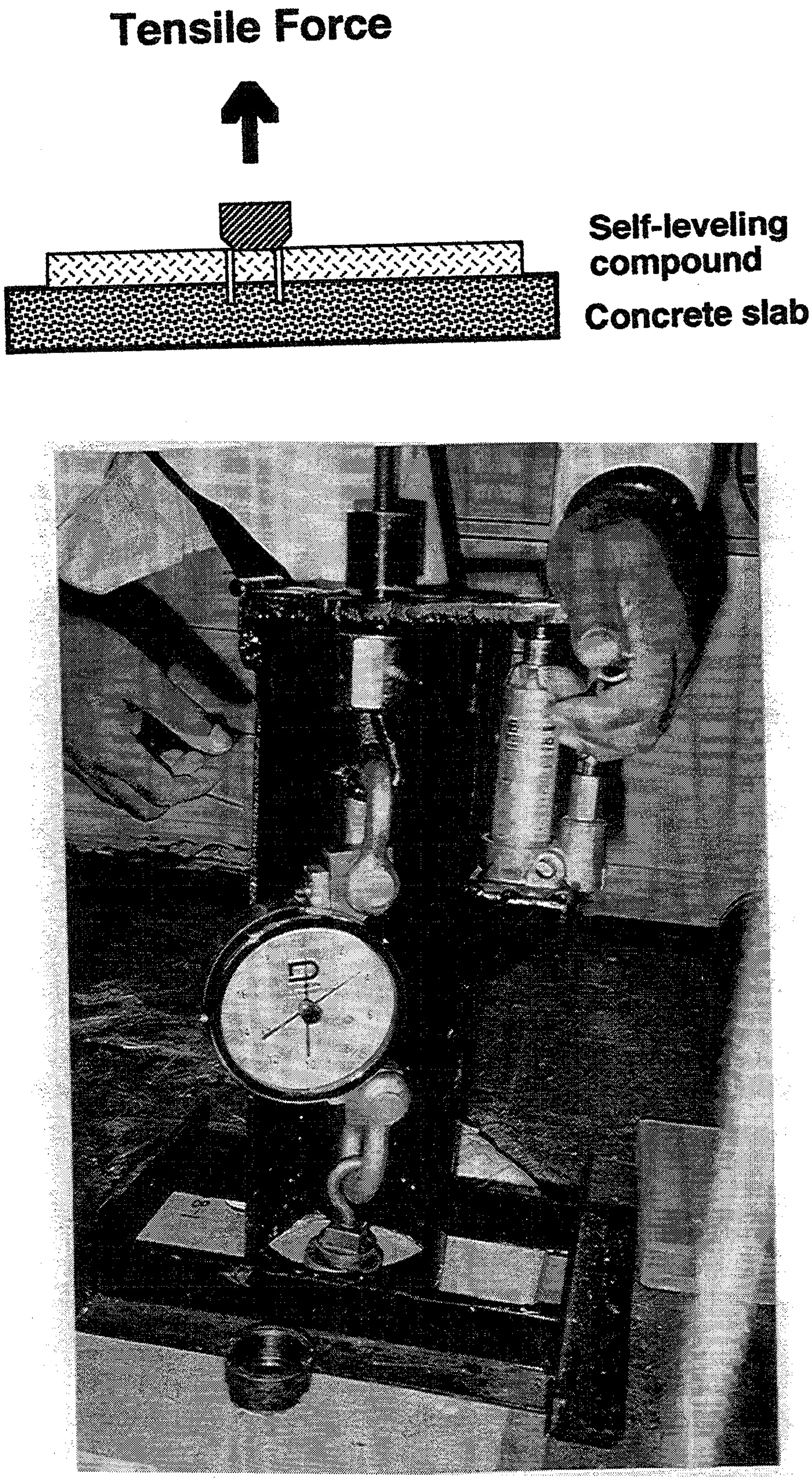


Figure 3: Tensile Bond Test

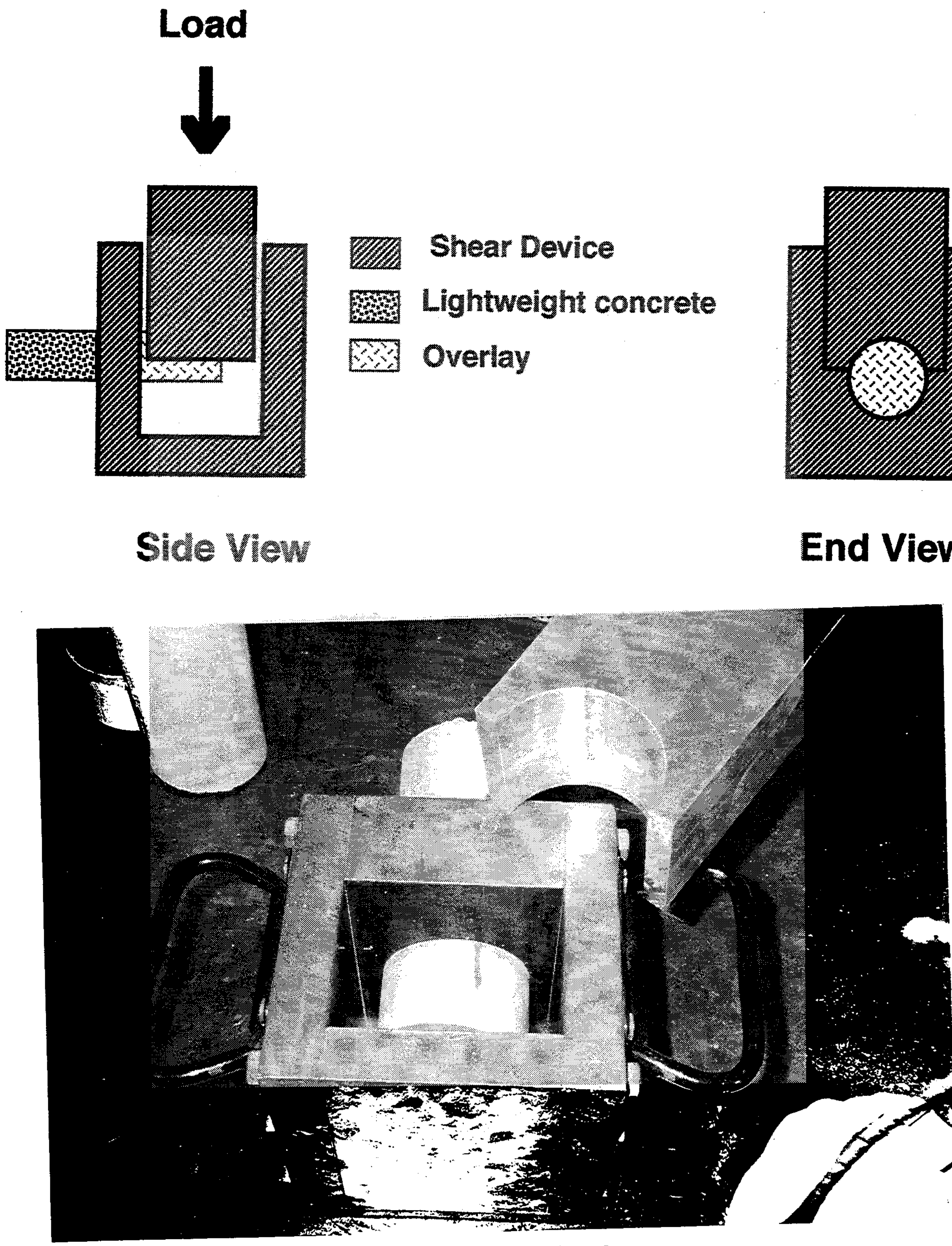


Figure 4: Direct shear bond test

4.1.8 Impact resistance on a feather-edged layer

A thin layer of the self-leveling compound was applied to a normal-weight concrete or to a lightweight concrete slab. To control the thickness of the layer, a special draw-down device (shown in Fig. 5) was used. The self-leveling compound was placed in front of the device and dragged to the length desired.

After a given curing time, two different steel balls (see Table 2) were dropped (not on the same spot) from a height of 1.2 m (4 feet). The characteristics of the steel balls are given in Table 2. The radius of the indentation created by each ball was recorded along with any other observation, i.e, cracks, dust, etc..

Table 2: Size of Balls Used in Impact Test on Feather-Edge Layer

	Diameter [mm]	Mass [g]
Ball 1	38	225
Ball 2	46	403

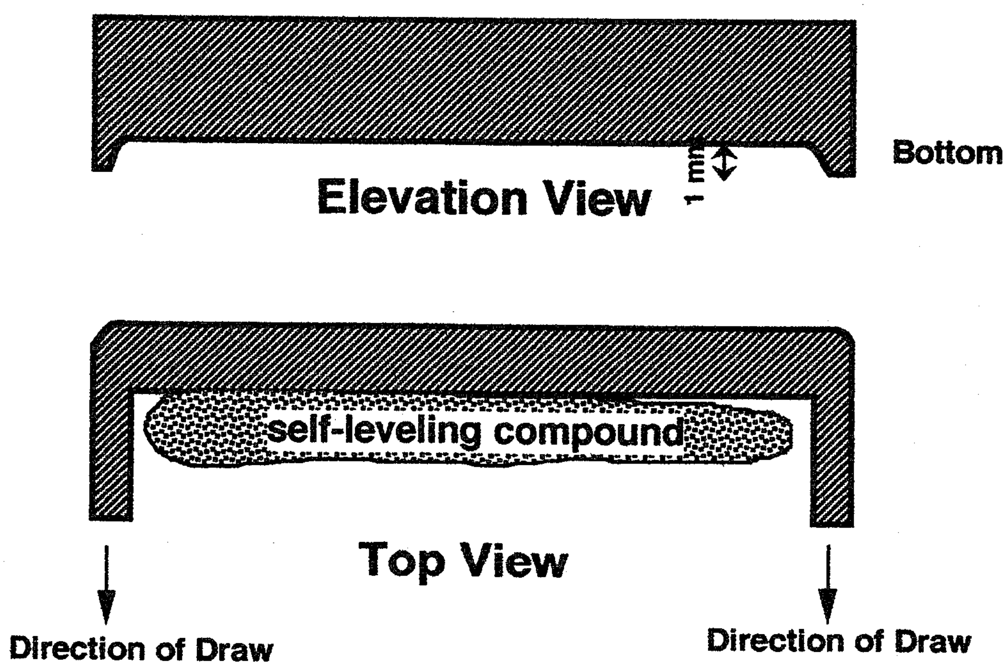


Figure 5: Draw-down blade for applying a feather-edge Layer

4.2. Properties tested on lightweight concrete

4.2.1 Flow and setting time of lightweight concrete

The standard slump test (ASTM C 143) was used to measure the slump. The setting time of the cement was measured with the Vicat needle apparatus, described in ASTM C 187. The method for testing is described in ASTM C 191.

4.2.2 Shrinkage of lightweight concrete

The shrinkage measurement method was an adaptation of ASTM C 426. Lightweight concrete prisms were 50x50x304 mm (2x2x12 in). Two brass studs 250 mm (10 in) apart were embedded in the fresh lightweight concrete. The length changes were measured between the two studs. A comparator (resolution 0.002 mm or 0.0001 in) was used and the prisms were monitored for 28 days. During the first 24 h the specimens were kept covered in their molds. The prisms were demolded after 24 h and the measurements started immediately. The prisms were stored at room temperature and humidity, i.e., 20 ^{0}C-25 ^{0}C and 30%-40% RH.

4.2.3 Compressive strength of lightweight concrete

The compressive strength of the lightweight concrete was measured on cylinders 76 mm (3 in) in diameter and 152 mm (6 in) long. During the first 24 hours, the specimens were kept covered in their molds and then demolded. Subsequent curing was in limewater at 20 ^{0}C-25 ^{0}C. For measuring the compressive strength, the cylinders were capped either by a capping compound or by neoprene pads, as indicated in the results section.

5. Results and Discussion

5.1 Self-leveling compounds

5.1.1 Flow and setting time of self-leveling compounds

The flows of the self-leveling compounds are shown on Table 3, which are all considered adequate. All the products would be expected to be easy to place. The setting times varied depending on the product as shown in Table 3. All products set within a reasonable amount of time (1-2 h). However, the suitable setting time will depend on the amount of time needed to place the product, with the chosen mode of placement, e.g., drum mixed or pumped.

Table 3: Flow and setting time

Product Name	Water/ Dry Product (by mass)	Flow (Mini-slump) [mm]	Setting Time [min]
Compound A	0.260	138	70
Compound B	0.230	140	143
Compound C	0.233	96	54
Compound D	0.149	96	121
Compound E	0.167	158	43

5.1.2 Shrinkage of the self-leveling compounds

Figure 6 shows the shrinkage test results. Compounds A and E shrank significantly more than the others. Since there are no established performance requirements for shrinkage, it is possible that even the products with the greatest shrinkage would be acceptable. However, the likelihood of shrinkage cracking will increase with the amount of shrinkage.

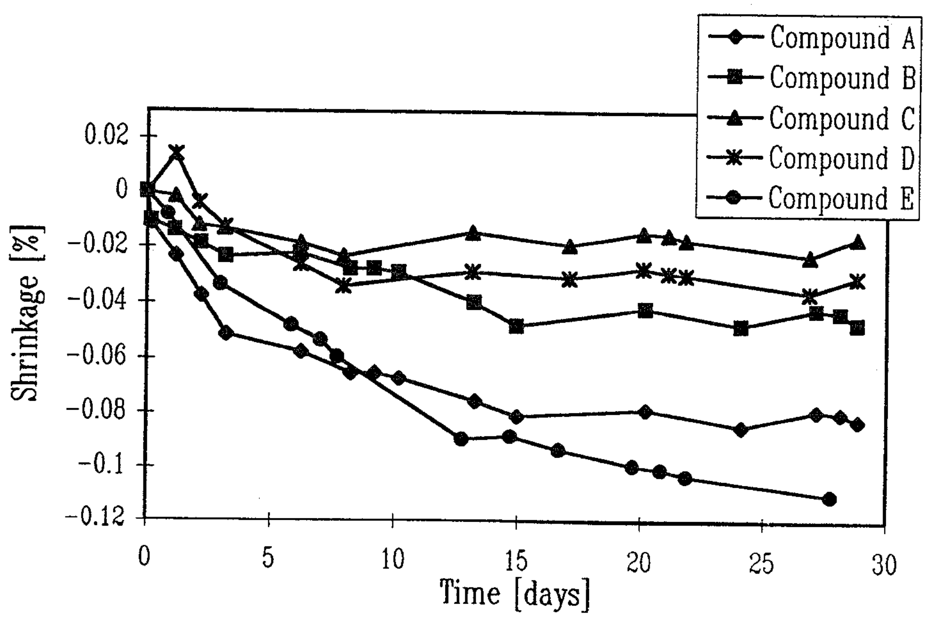


Figure 6: Shrinkage Versus Time.

5.1.3 Density of the self-leveling compounds

The densities of the cubes that were tested for compressive strength (see Table 4) were calculated from the masses of the cubes and their dimensions (using a caliper). The cubes were cured at room temperature in the laboratory air (not in limewater). The density decreased with time because the specimens were drying out.

The densities of all the products tested were within the range expected for an self-leveling compound, with Compounds E and D being slightly denser than the others.

Table 4: Density

Product Name	Density [g/cm^3] (lb/ft^3)			
	1 Day	7 Day	14 Day	28 Days
Compound A	1.91 (119)	1.82 (114)	1.79 (112)	1.74 (109)
Compound B	1.99 (124)	1.85 (116)	1.77 (111)	1.77 (111)
Compound C	2.02 (126)	1.82 (114)	1.82 (114)	1.84 (115)
Compound D	2.15 (134)	2.06 (127)	2.08 (130)	2.04 (127)
Compound E	2.13 (133)	2.04 (127)	2.09 (131)	2.03 (127)

Note: The densities are the average of measurements on three different cubes. The air dry mass of the cubes were used.
The standard deviation on these measurements is less than 0.08 g/cm^3 (5 lb/ft^3)

5.1.4 Compressive Strength of self-leveling compounds

The compressive strengths of all cubes (see Table 5) were above 21 MPa (3000 psi) at 14 days as requested by GSA. Therefore, all compounds were considered to be suitable in terms of compressive strength. It was observed that the cubes made with Compound D had a dusty surface, as shown in figure 7. It should be noted that Compound C was significantly weaker than the others.

Table 5: Compressive strength

Product Name	Compressive Strength in MPa (psi) [Standard deviation in MPa]			
	1 Day	7 Day	14 Day	28 Days
Compound A	20(2880) [0.4]	29(4180) [1.4]	33(4850) [0.6]	41(5960) [0.9]
Compound B	16 (2380) [0.3]	26(3770) [0.4]	28(4060) [0.1]	37 (5370) [0.6]
Compound C	9 (1320) [0.0]	17(2480) [0.5]	22(3220) [0.5]	22(3220) [2]
Compound D	16(2300) [1.3]	40(5760) [4]	47(6790) [3]	46(6670) [2]
Compound E	15(2250) [0.4]	38(5500) [2]	46(6740) [0.3]	50 (7292) [0.5]
Note: The compressive strengths are the averages of measurements on three cubes.				

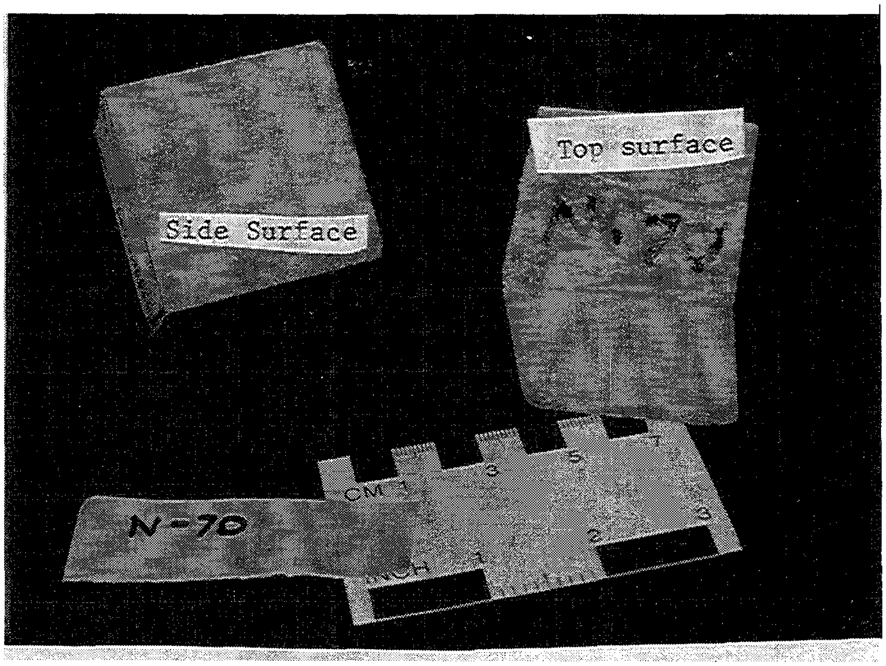


Figure 7: Compound D cube after drying in air for one week

5.1.5 Behavior in Water and Limewater of the self-leveling compounds

From each set of three cubes, one cube was used to measure the water absorption by capillary suction. Figure 8 shows the results obtained. Compound C absorbed significantly more water than the others.

Three specimens developed efflorescence during the capillary absorption (Compounds C, D and E). Figures 9-11 show the cubes after one week of water exposure. Observations after two weeks showed further build up of efflorescence on these specimens. The efflorescence on Compounds D and E was white, probably calcium carbonate[1], while the efflorescence on Compound C was yellow. Efflorescence might be a problem if the compound is not completely dry when the carpet is applied, or if it should get wet during service. The problem could be a lack of adhesion of the carpet to the self-leveling compound.

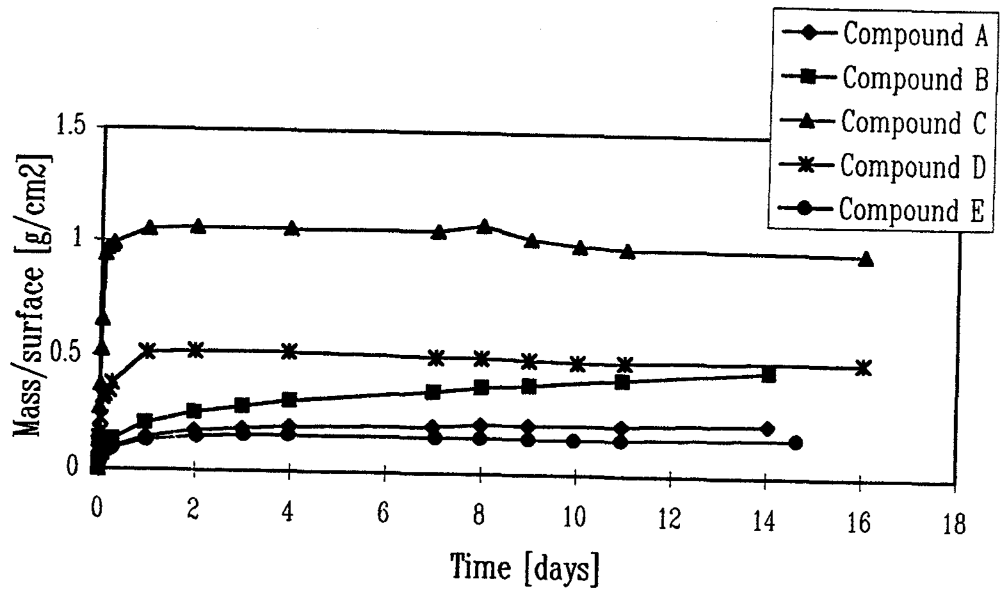


Figure 8: Water absorption by capillary suction

1) No chemical tests were performed to determine the chemical composition of the efflorescence

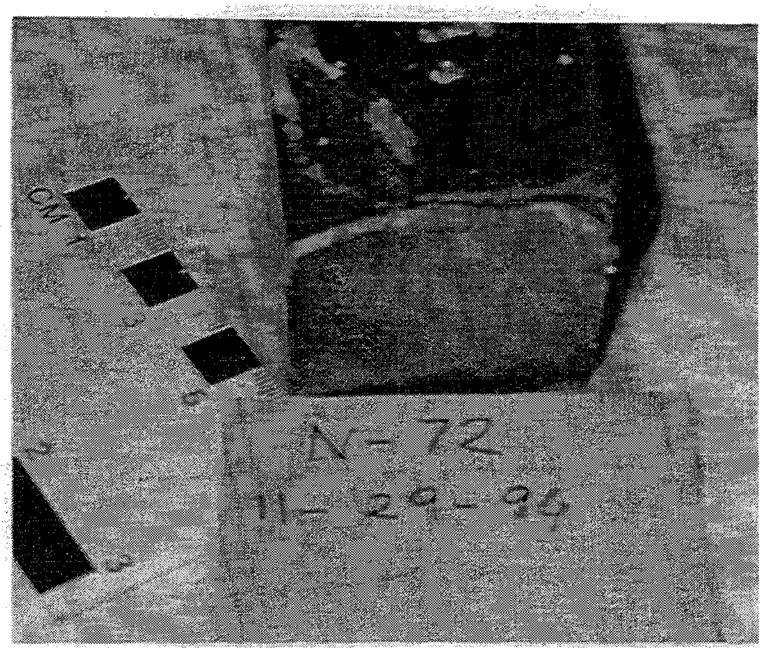


Figure 9: Efflorescence on a Compound C cube subjected to capillary absorption

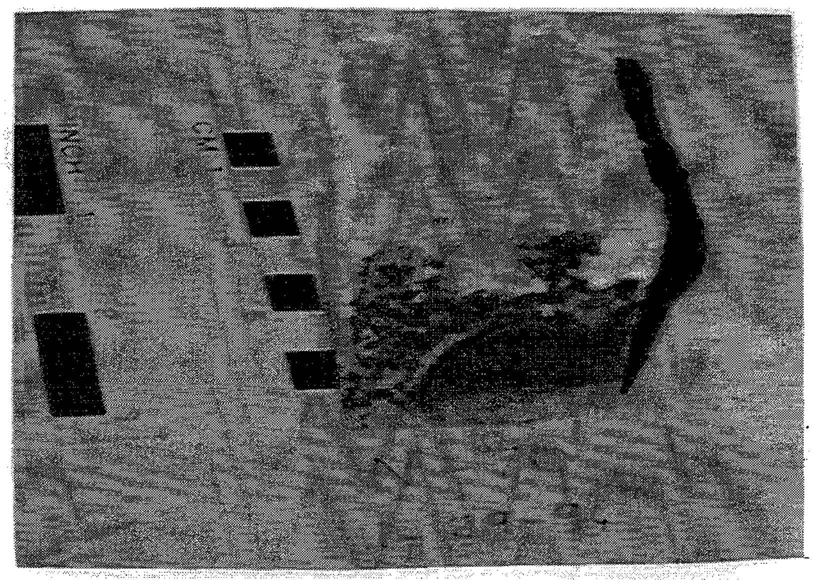


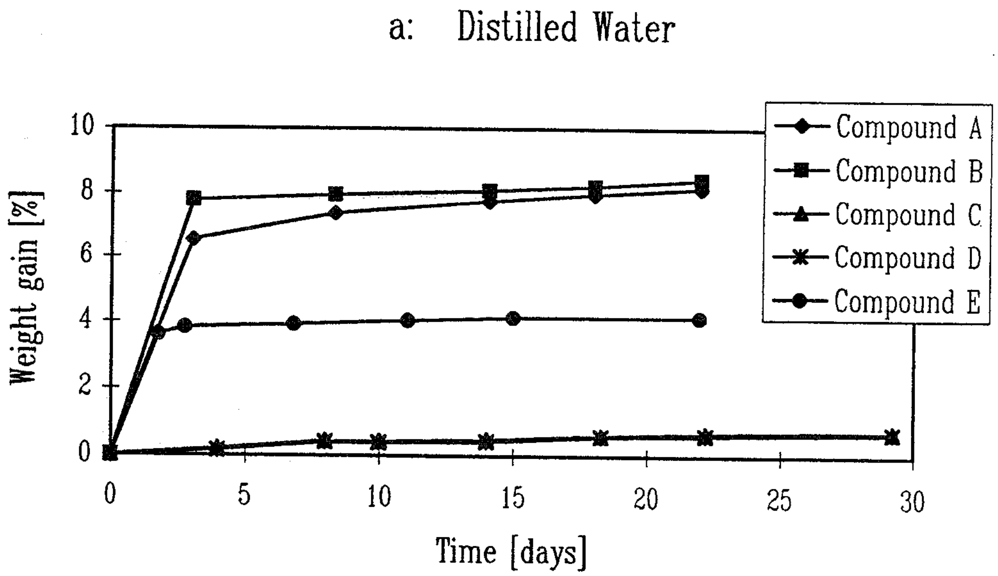
Figure 10: Efflorescence on a Compound D cube subjected to capillary absorption

Figure 11: Efflorescence on a Compound E Cube Subjected to Capillary Absorption

The second and third cubes were fully immersed, one in water and one in limewater. Figure 12 shows the results. The compounds fell into three groups:

1). Compounds A and B, which absorbed up between 6 and 8% of water by mass
2). Compound E which absorbed about 4% of water by mass.
3). Compounds D and C which absorbed less than 1% by mass.

However, none of the specimens showed any sign of deterioration, such as change of shape, leaching or disintegration. This is a severe test because it is unlikely that the product would be totally immersed in water for such a long time (over 21 days).



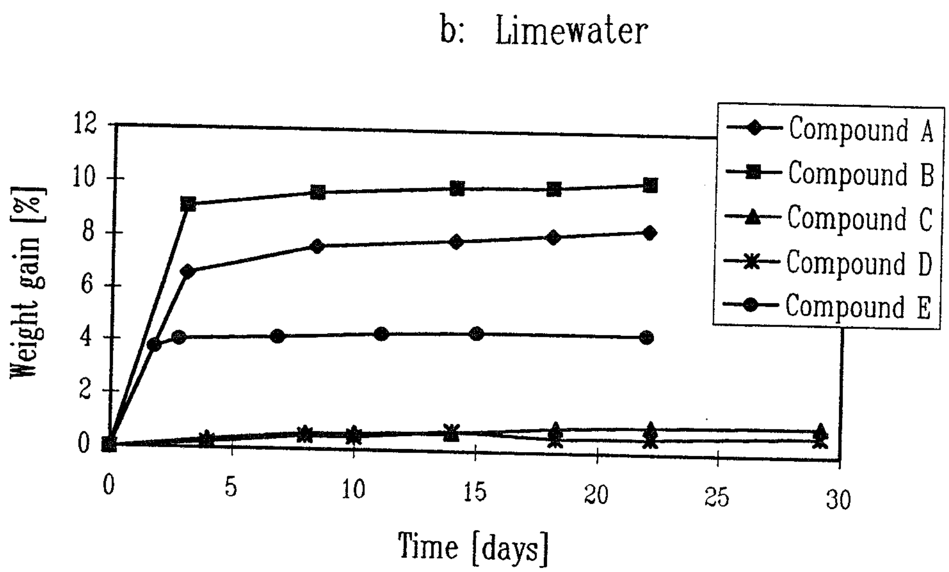


Figure 12: Water uptake during full immersion in a) distilled water or b) limewater.

5.1.6 Water evaporation from one surface of self-leveling compounds

The specimens were stored in the laboratory and weighed regularly. Figure 13 gives the results obtained. Each curve is the average of three specimens. It should be noticed that Compound C has a water loss about twice as large as the others.

At the time of this report, not all the specimens had reached equilibrium. Table 6 gives the expected time at which constant mass is expected to be reached.

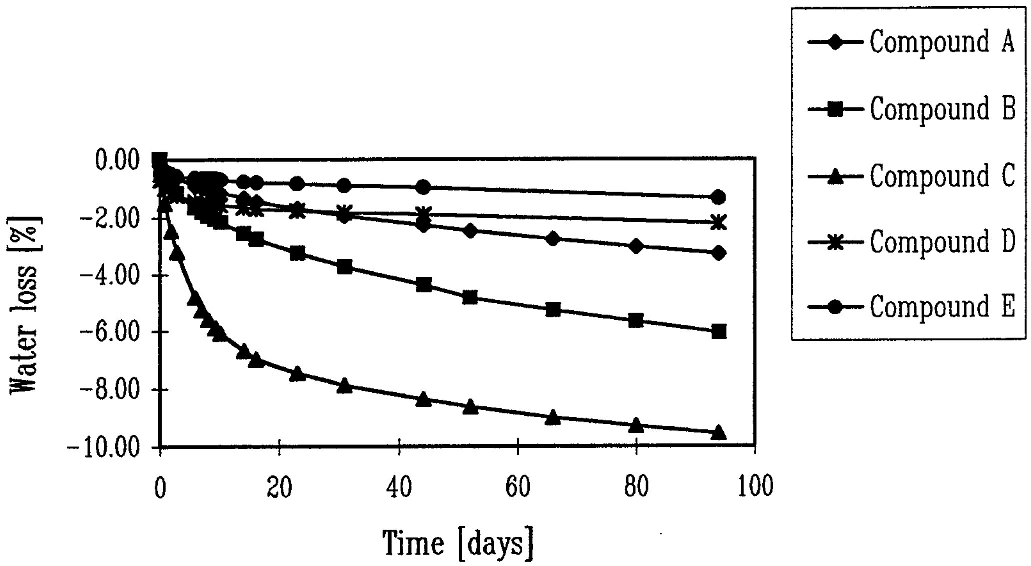


Figure 13: Water Evaporation from one Surface

Table 6: Time to reach constant dry mass

Product Name	Time to constant mass [days]
Compound A	> 95
Compound B	> 95
Compound C	> 95
Compound D	5-6
Compound E	7-8

5.1.7 Bond to concrete

The variability of the measured tensile-bond strength on normal-weight concrete was high, but some trends could be observed. The results given in Table 7 are the two measurements on each slab at the given age. Table 8 gives the region where the fracture occurred. The overlay usually debonded at the overlay/concrete interface.

Two observations were made during the preparation of the specimens for this test.

1) The Compound C overlay had a dusty surface.
2) A thin layer of material peeled off the slab with compound D as shown on Figure 14.

In both cases, the manufacturer claimed that too much water had been added. At their suggestion, new specimens were made, under their supervision, with a less water. The new specimens had better surfaces but Compound D was dusty to the touch. The new specimens were the ones tested for the bond strength test. Several cores broke while trying to drill into Compound C. This is the only product that displayed such behavior.

Table 7: Bond to concrete: tensile strength

Product Name	Load/surface area in MPa (psi) for the two measurements #1/#2		
	7 Days	14 Days	28 Days
Compound A	0.28/0.56 (47/81)	0.32/0.62 (41/90)	0.48 (69)
Compound B	0.29/0.28 (43/41)	0.48/0.28 (69/41)	0.11/0.03 (16/4)
Compound C	0.25/0.24 (37/35)	0.42/0.37 (61/53)	0.76/0.81 (110/118)
Compound D	0.11/0.27 (16/39)	0.28/0.27 (41/39)	0.07/0.42 (10/61)
Compound E	0.07/0.08 (10/12)	0.17/0.00 (24/0)	0.03/0.08 (4/12)

Table 8: Bond to concrete: region of debonding

Product Name	Region of debonding for two observations #1/#2		
	7 Days	14 Days	28 Days
Compound A	B/O	B/B	O/ND
Compound B	B/O	B/B	B/B
Compound C	B/B	B/B	B/B
Compound D	B/O	O/B	B/B
Compound E	B/B	B/B	B/B

Notes:
B = Debonded at the interface between concrete and overlay
O = Failed in the overlay
ND = Not determined

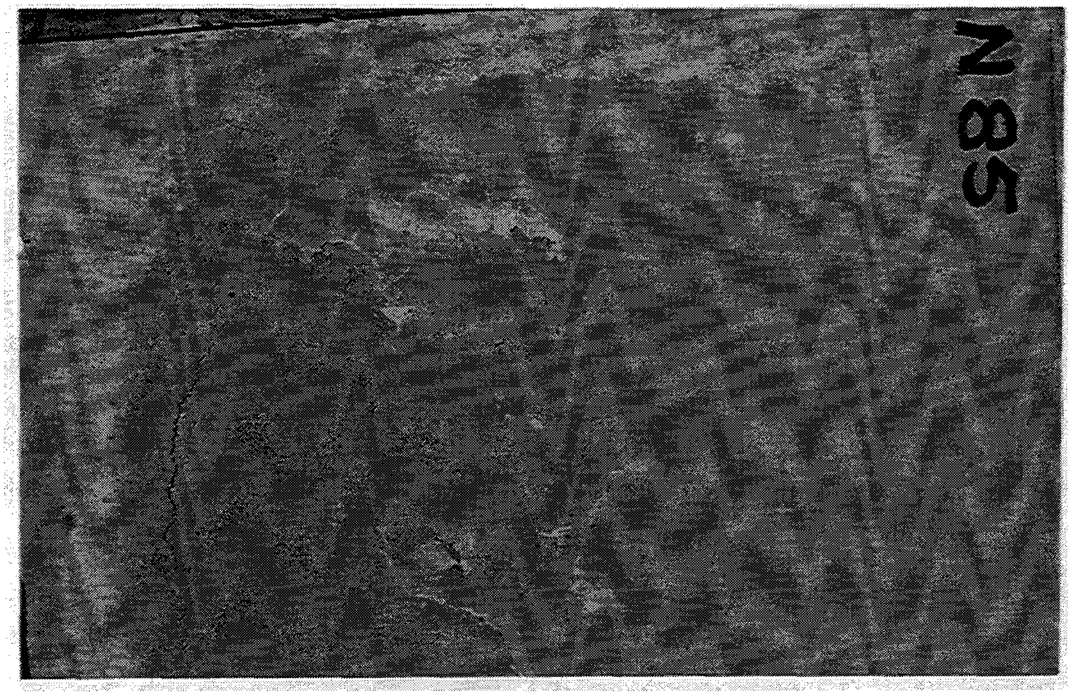


Figure 14 : Surface of Compound D for the first overlay cast. A thin film peeling off from the surface is clearly visible.

The results given in Table 9 are the two measurements on each cylinder, at the given age, for bonding to lightweight concrete. All the specimens sheared off at the bond interface. A large difference in bond strength can be observed between two groups of products:
1) Compounds E and A, and
2) Compounds B, C and D

Table 9: Bond to lightweight concrete: tensile strength

Product Name	Load/surface area in MPa (psi) for the two measurements #1/#2		
	7 Days	14 Days	28 Days
Compound A	4.3/3.7 (630/540)	3.4/3.7 (490/540)	4.5/4.4 (660/640)
Compound B	0.9/1.0 (130/150)	1.1/1.9 (170/280)	2.2/2.6 (310/380)
Compound C	1.0/1.2 (140/180)	0.6/0.5 (90/70)	2.0/1.5 (290/220)
Compound D	1.1/1.1 (160/170)	1.4/1.4 (210/200)	2.3/1.5 (330/350)
Compound E	2.2/1.8 (320/260)	3.6/3.2 (520/460)	3.6/3.0 (520/430)

5.1.8 Impact resistance of feather-edged layer

A thin layer of all compounds was easy to apply on normal-weight concrete, primed or unprimed, as well as on primed lightweight concrete. None of the compounds showed any deterioration or cracking during drying. Table 10 gives the measured indentations for a thin layer on normal-weight concrete, and Table 11 gives the indentation for a thin layer on lightweight concrete. None of the impacts led to extensive cracking. The damage was always local. For Compound C, on the primed normal-weight concrete surface, cracks and dust production made it impossible to measure the indentation diameter. It should be noted that the two Compound C trials (on primed and unprimed concrete) were not from the same batch. Since Compound C surface appearance and quality are strongly dependent on the water content, it could be that the cracked surface was due to an incorrect water dosage.

Table 10: Results of impact on feather-edge layer on normal-weight concrete

Product Name	Indentation Diameter [mm]			
	Unprimed surface		Primed Surface	
	Ball # 1	Ball # 2	Ball # 1	Ball # 2
Compound A	7	9	7	10
Compound B	8	10	8	11
Compound C	7	11	cracks	cracks
Compound D	10	14	12	16
Compound E	7	9	6	10
Notes: Only one drop per ball was done				

Table 11: Results of impact on feather-edge layer on primed lightweight concrete

Product Name	Indentation Diameter [mm]	
	Ball #1	Ball #2
Compound A	9	11
Compound B	8	9
Compound C	7	11
Compound D	dusty	13
Compound E	9	11
Notes: Only one drop per ball was done		

5.2 Results on Lightweight concrete

5.2.1 Flow and setting time of lightweight concrete

The slump of the lightweight concrete was, after adjustment of the admixture dosage, 184 mm (7.25 in). Its air content measured by the volumetric method described in ASTM C 173 was 6.5%. The initial setting time (Vicat needle) of the cement paste was 182 min (3h 02min) and the final setting time was 377 min (6h 17min).

5.2.2 Density of lightweight concrete

The density was measured on the cylinders that were tested for compressive strength (see Table 12). The diameter and the length of the each cylinder was measured to determine its volume. Since the cylinders were cured under limewater, they were saturated when they were weighted.

Table 12: Density

Density in kg/m^3 (lb/ft^3)			
2 Days	7 Days	14 Days	28 Days
1870 (117)	1880 (117)	1960 (122)	1930 (120)
Note: The densities are the averages of measurements on two cylinders			

Density was also measured using a dried cylinder. A cylinder, cured for 28 days in limewater, was air dried at 20°C -25°C and 30%-40% relative humidity for 7 days. The calculated air-dry density then was 1830 kg/m^3 (113 lb/ft^3) which is within the tolerance permitted by the GSA specification (appendix A).

5.2.3 Compressive strength of lightweight concrete

The compressive strengths of the lightweight concrete (see Table 13) were above 27 MPa (4000 psi) at 14 days. Since the GSA specification calls for 27 MPa (4000 psi) at 28 days, the concrete would be suitable in term of strength.

Table 13: Compressive strength of lightweight concrete

Compressive Strength in MPa (psi)			
2 Day	7 Day	14 Day	28 Days
16 (2280)	22 (3226)	38 (5550)	42 (6070)
capping compound	capping compound	Neoprene pads	Neoprene pads
Note: The compressive strengths are the average of two cylinders.			

5.2.4 Shrinkage of lightweight concrete

Figure 15 shows the shrinkage test results. The scatter of the data is quite significant as shown by the discrepancy between the two curves. Only two prisms, out of the three available, were considered because some of the measurements of the third one were obviously incorrect (the shrinkage calculated was 10 times larger due to a misread initial value). As no criteria were assigned for the shrinkage of the concrete, the acceptability of this lightweight concrete on the basis of shrinkage cannot be determined. A higher shrinkage greatly increases the chance of cracking when restraint is present.

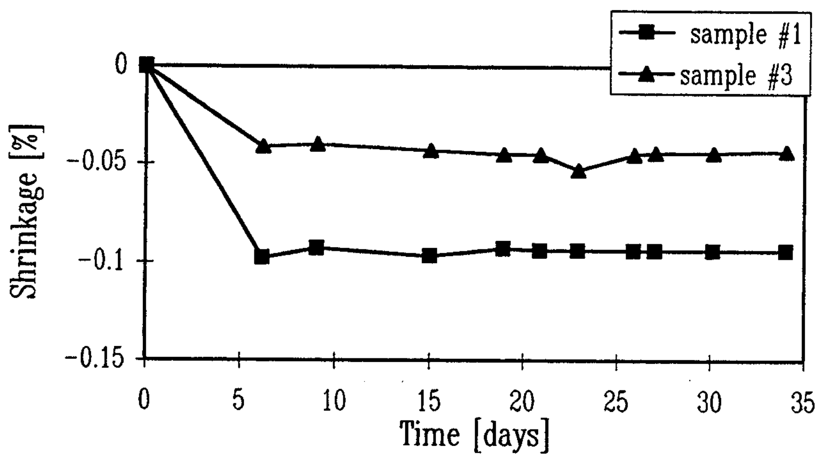


Figure 15: Shrinkage versus time of lightweight concrete.

6. Summary and Conclusion

To form a basis for selecting the most suitable self-leveling compound for the application planned, the following tests were performed on five self-leveling compounds: Flow, setting time, shrinkage, compressive strength, interaction with water and limewater, bond to normal weight concrete and light weight concrete. As lightweight concrete was a possible substrate, the following properties of lightweight concrete were tested: flow, setting time of the cement, shrinkage, compressive strength.

The compressive strength and densities were within the GSA specifications developed for the present application. For the other properties tested, no specifications were given by GSA. Each property should be examined keeping in mind the application. For instance, as the self-leveling compound will be used indoors, the interaction with water is not likely to be very important, i.e., it is unlikely that efflorescence will develop. The setting times must be carefully considered in the light of the method of application, i.e., if a pump is to be used, a longer setting time may be needed to avoid clogging the pump. However, if a batch-to-batch approach is used, a shorter setting time is acceptable. The shrinkage is small for all compounds but the materials shrinking the most have the potential to develop more cracking. The bonds to concrete, either normal weight or lightweight, are not critical although small, because the compounds are used on a horizontal surface that is not subjected to large tensile forces. The quantity of mixing water should be carefully controlled; too much could lead to a dusty and bleeding surface which might be unsuitable for carpeting without special cleaning.

The lightweight concrete met GSA's specifications. No special problem could be expected from its use.

In conclusion, there is no unique set of criteria for use in selecting a self-leveling compound. The data in this report should help make an appropriate selection when the application conditions are defined.

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APPENDIX A: Lightweight Concrete Specification by GSA

Lightweight Concrete

Specification:

1. Lightweight concrete is to be used on existing structural concrete floor slab as a levelling material where floor slab has deflected.

2. Lightweight concrete shall have a 28 day compressive ~~for~~ strength (f'c) of 4,000 psi.

3. Lightweight concrete shall be composed of:

   a. Portland Cement: ASTM C150, Type 1
      Use one brand of cement throughout project.

   b. Lightweight aggregates: ASTM C 330

   c. Water: Potable

   d. Air-Entraining Admixture: ASTM C 260, certified by manufacturer to be compatible with other required admixtures. Provide 4%-6% air-entrainment for 3/4 inch (19mm) maximum aggregate.

   e. Water-Reducing Admixture: ASTM C494, Type A

   f. Fly Ash: ASTM C618, Type F.
      Newsome ASTM C989, Grade 120

4. Water-Cement Ratio: 0.45

5. Slump Limit: Proportion and design mixes to result in concrete slump at the point of placement as follows:

   Slump shall be the minimum necessary for efficient mixing, placing and finishing. Maximum slump shall be 6 inches (150 mm) for pumped concrete ~~and 5 inches (125 mm) elsewhere~~.

6. Unit Weight: Calculated equilibrium unit weight of 110 pcf (1762 kg/cu. m.) plus or minus 3 pcf (48.1 kg/cu.m) as determined by ASTM C567.

7. Procedure for measuring mixing and placing and finishing lightweight concrete:
   ACI 304.5R

8. Mixing, handling, placing, finishing and curing:
   ACI 523.1R

9. Pumped concrete:
   ACI 304.2R

*10. Water in the correct amount to be added at the site to concrete mix prepared by the manufacturer to attain the specified w/c ratio and slump. Manufacturer shall indicate the amount of water to be added to the mix, before using the concrete for testing.

11. Maximum aggregate size: 3/4 in.

*For Information for testing purpose only

Appendix B: Report from the Contractor on Lightweight Concrete

Project________Super - Lightweight - GSA/NIST
Mix__________658 w/ 30% Newcem

Factor 0.093

Date *11/21/94*
Specimen *NIST 330*

Materials	Design Wts One Yard	SSD Wts (1.5)cuft	S.G.	Absolute Volume	% Moisture total	% Moisture Absorp	% Moisture Free	Free Moist (lbs)	Wts + Moisture
Fine Agg	1305	120.85	2.59	8.076	8.5	1.3	7.2	8.70	129.55
Coarse Agg	875	81.02	1.5	9.348	9.1	6	3.1	2.51	83.53
Coarse Agg		0.00							
Cement	461	42.69	3.15	2.345					
Newcem	197	18.24	2.93	1.077					
Water	38	29.31	1	5.073	29.3				
Air(per cwt)	0.65	11.71		1.08					
				18.92					
Admix #1(per cwt	3	54.05							
Admix #2(per cwt	8	~~144.13~~ 168.1							
Admix #3									
Special									

Starting Water *23.80*
Remaining Water *4.50*
Water Used *19.3*

Moisture in Agg
Fine Agg *8.70*
Coarse Agg *2.51*
11.21

Age	Compress Strength
1	
1	
1	
3	
3	
3	
7	
7	
7	
14	
14	
14	
28	
28	
28	
Average	
1	
3	
7	
14	
28	

Slump (*Initial / Final*) *3.5 / 7 1/4*
% Air *6.5 %*
Conc Temp *70*
Air Temp *73*
Net Weight *36.8-7.3*
Unit Weight *116.00*

Batch Weight________
W/C Ratio *.50*
Yield *28.2*
Water (lbs) *30.51 328*
Water (gal) *39.4*

Slump Initial 2"-3"
Slump final 6"-8"
Air Conten5.0%-6.0%

	Manufacturer	Location
Fine Aggregate	Silver Hill S & G	Clinton, MD
Coarse Aggregate #1	Solite 3/4"	Aquadale, NC
Coarse Aggregate #2		
Cement	ICC	Frederick, MD
Air Ent	Daravair	W. R. Grace
Admix #1	WRDA-~~19~~ *Hycol*	W. R. Grace
Admix #2	Daracem 100	W. R. Grace
Admix #3		
Special		