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NATIONAL BUREAU OF STANDARDS REPORT

10 858

OVERLAYS FOR CONTAMINATED CONCRETE FLOORS

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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ABSTRACT

Concrete floors contaminated with grease, oils, and fats of animal, vegetable, or mineral origin can be economically resurfaced by using methods developed by the Building Research Division of the National Bureau of Standards. These methods were developed for military kitchens but have other applications.

Monolithic surfacings based on polyester and epoxy resins can be applied successfully to grease contaminated concrete floors by a combination of barrier coatings and mechanical fastenings. Abrasive sheet vinyl can be secured to contaminated concrete by means of a special barrier system. Barrier coatings found to be successful were neoprene sealer and asphalt cut-back. Abrasive sheet vinyl can be applied successfully to contaminated concrete floors over a leveling coat, in turn applied over successive coats of neoprene sealer and acrylic latex. This leveling coat is a sand mix based on acrylic latex modified portland cement.

NBS Report

OVERLAYS FOR CONTAMINATED CONCRETE FLOORS

by Winthrop C. Wolfe

1. INTRODUCTION

This report is a summary and conclusion of a study by the Building Research Division which has been carried out during the past twenty years. The study was required by the continued use of World War II temporary buildings resulting from military necessity. In this study the Division has been evaluating and experimenting with flooring for these temporary buildings. This report is concerned primarily with the problem of flooring for mess hall kitchens. However, results, conclusions, and recommendations in this report are relevant to similar problems in other locations.

In 1952 the Building Research Division began to evaluate flooring in World War II mess hall kitchens and other locations and made some recommendations [1]* Many of these temporary buildings were closed in 1946 and reactivated in 1949. Company-type mess halls and barracks during World War II were similar wooden buildings with wooden flooring and subfloor throughout. The wooden floors were not satisfactory because of damage resulting from the frequent wet mopping required to keep them in a sanitary condition and the problem was aggravated in kitchens for reasons to be explained later. Some time between 1946 and 1952, most of the wooden floors in the company-type kitchens were covered with concrete, 1-1/2 to 2-1/2 inches thick, reinforced or anchored by various methods. The larger consolidated-type kitchens were floored originally with concrete slabs, four or more inches thick, over wood or on a fill.

*Numbers in brackets indicate references at the end of this report.

In some of the company-type kitchens the wooden flooring was removed and replaced by a fill over which a concrete slab was poured. The life of the concrete slabs proved to be about 5 to 8 years, after which the areas adjacent to ranges, sinks, and drains were eroded severely and the aggregate exposed.

A special study was made of flooring in mess hall kitchens and problems in these kitchens were summarized in a report [2] issued in 1964:

> "Floors in kitchens, the adjoining dishwashing rooms, and preparation rooms for raw foods are subjected to extremely severe conditions. The floors are exposed to grease; cooking oils; fatty, vegetable, and fruit acids; frequent scrubbing and cleaning, sometimes with strong alkaline detergents; and around stoves to temperatures as high as 275°F. (135°C.). In many areas the floors are almost continuously wet from spillages around dishwashing machines, sinks, live steam pipes, and from the dumping of hot food liquids directly on the floor adjacent to, but usually many feet from, the floor drain. Mechanical damage is also encountered from shuffling of feet at work tables and serving lines, dragging or impact of the edge of fully loaded garbage cans, and the agitation of stiff-bristled scrubbing brushes. It requires an exceptional floor to withstand such a combination of exposures".

Asphalt tile of the grease-resistant type was laid over some of the concrete slabs in kitchens but provided only about six months service. It was found that the tile was damaged readily by impact and contact with hot cooking utensils and required a smooth, rigid subfloor. The most satisfactory floor found in the 1953 survey was quarry tile with acid-resistant mortar joints laid over a structural concrete slab, which was reported to give about 15 years excellent service. However, quarry tile floors were reported as being very slippery when wet.

The first type of monolithic surfacing used was based on magnesium oxychloride but this type of floor was unsatisfactory in kitchens because the excessive amounts of water caused deterioration in less than one year. Other monolithic surfacings and quarry tile with thermosetting resin based bed and joints were used in the 1964 study [2]. The surfacings were compositions of two types. One type of composition was based on synthetic polymer latex and hydraulic cement. Polymers used in the formulations included butadiene-styrene, polyvinyl chloride, and polyvinylidene chloride. Hydraulic cements were either portland cement or high alumina cement. The other type of surfacing composition was based on thermosetting synthetic resin and epoxy was the only generic type of resin used. Most of the monolithic surfacings failed in less than a year and one formulation based on epoxy resin lasted for about three years. Quarry tile with furane resin based joints performed satisfactorily for nine years.

Further studies reported in 1968 defined the problem and its complexity [3]. With adequate surface preparation and competent installation, monolithic surfacings will perform satisfactorily. On the basis of the reported observations, it would appear that formulations based on polyester resins are more suitable for mess hall kitchens than those based on epoxy resins. However, there is not always a clear distinction between generic types of resin binders and surface preparation and installation are not always under control. What is needed are experiments and observations in which all factors are known and controlled to the greatest extent practicable. Even more important is to develop a reliable method for resurfacing damaged floors in mess hall kitchens. As pointed out in the 1968 article [3], replacement of the concrete floor might be more economical but resurfacing is preferable from a military standpoint. It is important not to interrupt training schedules or other activities in military buildings. Resurfacing damaged floors has a wider application than rehabilitation of temporary military structures. Activities in a building often change and it may be necessary, for example, to convert a garage or warehouse into office space. Removal of the slab or suspended floor might involve prohibitive expense of demolition, construction, and rental of alternate facilities.

2. SUMMARY OF 1970 PROGRESS REPORT

A progress report on this flooring study was included in a report on the general subject of flooring in government buildings [4]. On pages 65-6 of this report a distinction was made between field observations and field tests. By field observations is meant observations of flooring installations done commercially and not under the control of the investigator. Field tests are experimental installations or tests on installations performed by the investigator or under his supervision. Materials, workmanship, surface preparation, type and condition of the subfloor, ground moisture, temperature, humidity, and other pertinent factors are known and recorded. Additional field observations were made on mess hall kitchen floors but no field tests, as it seemed advisable to perform laboratory tests before experimenting with actual installations.

One of the possible causes of failures in monolithic surfacings is heat or temperature differential under and around ranges or stoves, ovens, and hot water heaters. Temperature readings were taken under a number of ranges, hot water heaters, and ovens in Army kitchens and temperatures ranged from 75° to 145°F. This is not nearly as high as the 275°F temperature mentioned in the 1964 report [2] but continued exposure to temperatures of 130°F or 145°F might have an effect on some resin toppings. The fact that these temperatures did not reach previous maxima may be attributed to improved cooking and heating equipment. Some of the early equipment may have been coal-fired. The question of maximum temperature or temperature differential likely to be encountered is related to the development of specifications for resinous flooring, the subject of a recent report [5].

Inadequate surface preparation is probably one of the chief causes of failures of monolithic surfacings in kitchens. As mentioned on pages 69 and 84-86 of the 1970 report, failures have often been attributed to the presence of grease on the concrete substrate. Removal of grease causes greater difficulty and expense in surface preparation to receive surfacings. Experiments described in the 1970 report, pages 85-86, showed that grease may penetrate concrete floors in kitchens to a depth of 1/4 inch. The depth of penetration was determined by coring or drilling, exposing the corings or holes to an aqueous solution of 1 percent Congo Red dye, and rinsing with water. Uncontaminated concrete was dyed red and greasy concrete remained gray. Experiments on cement mortar panels, described in the 1970 report, page 86, showed that customary treatments were unsuccessful in removing even surface contamination. Even if grease and oil is removed from the surface, it may "wick-up" or diffuse into surfacings and destroy or weaken the bond. In the experiments reported in 1970, cement mortar panels were impregnated with lard and then washed with hot detergent solution, 10 percent sodium hydroxide solution, trichloroethylene, and combinations of these treatments.

In 1968 an estimate was obtained from a flooring contractor for surface preparation and installations of a trowel-on epoxy monolithic surfacing on company-type mess hall kitchens in Fort George G. Meade, Maryland. Surface preparation included scrubbing with degreasing chemicals, followed by scarifying with machines to expose clean, sound concrete. The following is a breakdown of the cost:

Estimate for Surface Preparation and Installation of Monolithic Surfacing

	Total Cost		Cost per sq. ft.	
	One kitchen 825 sq. ft.	Two kitchens 1650 sq. ft.	One kitchen 825 sq. ft.	Two kitchens 1650 sq. ft.
Surface preparation. . .	$444.00	$806.00	$0.54	$0.49
Installation labor . . .	1016.00	1586.00	1.23	0.96
Materials.	1548.00	2715.00	1.88	1.65
Supervision	1047.00	1124.00	1.27	0.68
Total.	$4055.00	6231.00	4.92	3.78

This cost estimate was considered excessive by the Post Engineer's Office at Fort Meade. The estimate was not included in the 1970 report but justifies the work described in this report.

Since the cost of surface preparation to receive monolithic surfacings is prohibitive, it was decided to experiment with more economical methods for surfacing concrete floors contaminated with oils and greases. Cement mortar test specimens were coated heavily with a mixture of lard, vegetable oil, and mineral oil and the surfaces washed with a hot detergent solution. Various coatings and sheet materials were tried as grease barriers. Some coatings and adhesives for sheet materials were found to be reasonably compatible with the greasy surfaces. A number of systems were tried in qualitative and quantitative bond tests but the most reliable procedure for resurfacing contaminated concrete appeared to be:

(1) Clean the greasy surface with hot detergent solution.

(2) Allow to dry overnight under ambient conditions.

(3) Apply by brush a solution of neoprene in organic solvent.

(4) Trowel on a sand mix based on an epoxy or polyester resin of a type used commercially for monolithic surfacings.

Asphalt cut back (solution of asphalt in hydrocarbon solvent) showed some promise as a grease barrier under a trowel-on epoxy surfacing but was not tried under a polyester surfacing.

3. REPORT OF WORK SINCE 1970 PROGRESS REPORT

3.1 Preparation of specimens

Cement mortar cubes and panels were prepared, following the directions on pages 90 and 97 of the 1970 report [4]. As in the previous report, the cubes were used for quantitative tests. The cement mortar panels, however, were used for qualitative observations. The cement mortar mix used was as follows:

Ingredient	Amount for 4 panels	Amount for 9 cubes or 3 molds
Tap water.	1,600 ml	600 ml
Type I portland cement	4,000 g	1,330 g
Standard graded Ottawa sand. .	5,100 g	1,700 g
Standard 20-30 Ottawa sand . .	5,100 g	1,700 g

Standard graded Ottawa sand is defined in Section 4, ASTM C109-64, Standard Method of Test for COMPRESSIVE STRENGTH OF HYDRAULIC CEMENT MORTARS (USING 2-IN. CUBE SPECIMENS), Standard 20-30 Ottawa sand is defined in Section 3, ASTM C190-70, Standard Method of Test for TENSILE STRENGTH OF HYDRAULIC CEMENT MORTARS.

The cement mortar cubes were 2-inch cubes, cast in molds described in U. S. Patent 2,061,137, Bowen and Company, Inc., Bethesda, Maryland. The molds were modified by drilling holes, 17/64 inch (0.6747×10^{-2}m) in diameter, in a position such that the three completed cubes from each mold would each have a 1/4 inch (0.6350×10^{-2}m) diameter steel pin through the center of two faces adjacent to the top or troweled surface under test. The pins were inserted through the drilled holes before casting the cement mortar cubes. The cubes were cast according to ASTM C109 except that a mixture of standard 20-30 and standard graded Ottawa sand was used in place of graded Ottawa sand. The top or troweled surface was treated with the grease mixture as described later and subsequently this surface was covered with the coating system under test.

A batch of mix for four cement mortar panels was blended in a portable concrete mixer. Each mold was about half filled with the mix;

tamped with a mason's trowel; struck off with a large plasterer's trowel; and steel troweled to a smooth surface.

The cubes were cured under sheet polyethylene for one day; removed from the molds; and cured under water for six days, a total of seven days. The cubes were brushed with a solution of one part by volume concentrated hydrochloric acid to 5 parts water; rinsed thoroughly with tap water; and air dried for about two months. The panels were air dried without curing, as they were supposed to simulate poor concrete surfaces.

Half of the cement mortar cubes were treated with the grease mixture and the other half were "clean" cubes to be used as sandwich specimens for test to be described later in this report. The "greasy" cubes were brushed with a warm mixture of equal parts of lard, corn oil (vegetable oil), and mineral oil, heated and stirred together. This treatment was repeated twice, a total of three treatments, allowing the grease to soak in for several days after each treatment. Before treating further, the surfaces were cleaned with a hot detergent solution. The detergent used was Detergent, General Purpose, Federal Specification P-D-220A, Type 2, Class 1. One part of detergent was diluted with five parts of hot water; brushed on with a stiff brush; let stand for five minutes; scrubbed with a stiff brush; rinsed thoroughly with hot water. This cleaning treatment was repeated. The cement mortar panels were treated with the grease mixture and cleaned with detergent in the same manner.

Following treatment with grease and washing with detergent the cement mortar cubes and panels were covered with five different overlay systems. Materials used in these systems were as follows:

Neoprene sealer. Commercial product consisting of solution of neoprene in organic solvent, probably methyl ethyl ketone.

Asphalt cut-back primer. Commercial product used as primer for concrete surfaces to receive asphalt or vinyl asbestos tile.

Acrylic latex. Commercial product, presumably a water emulsion of a methacrylate resin.

Epoxy adhesive. Commercial adhesive for sheet vinyl floor covering, a one-step epoxy resin product.

Abrasive sheet vinyl. A commercial product, 0.100 inch thick, which comes in rolls 6 feet wide and consists of about 25 percent aluminum oxide abrasive in a matrix of vinyl composition which consists of about 70 percent vinyl resin and 30 percent plasticizer.

Polyester resin mix. The following batch was mixed in a portable concrete mixer:

1,500 g polyester resin
25 ml catalyst for same
4,000 g standard graded Ottawa sand
4,000 g standard 20-30 Ottawa sand

The polyester resin was one made for monolithic surfacings for concrete floors and the spectrogram by the National Bureau of Standards indicated that it resembled an unsaturated polyester - isophthalic acid polymer. The catalyst was stated on the label to be a 60 percent solution of methyl ethyl ketone peroxide in dimethyl phthalate.

Epoxy resin mix. The following batch was mixed in a portable concrete mixer:

500 g epoxy resin

500 g curing agent for same

4,000 g standard graded Ottawa sand

4,000 g standard 20-30 Ottawa sand

The epoxy resin was a general purpose type used in surface coating, laminating, casting, potting of electrical equipment, and in adhesives. It was stated by the manufacturer to be an unmodified epichlorohydrin - bisphenol-A type of resin with viscosity 100-160 poises by ASTM D445; average molecular weight approximately 380; equivalent weight (g. resin to esterify one mole of acid), 85; epoxide equivalent (g. resin containing one g equivalent of epoxy groups), 185-192 by ASTM D1652.

The curing agent was stated by the manufacturer to be a modified amine in solution in a special oil; viscosity 3.2 poises at 25°C; equivalent weight (g capable of reacting with a one g equivalent of epoxy groups), 180.

Leveling coat. Some of the commercial acrylic latex described above, 600 ml, was mixed with 1,300 g Type I portland cement and 3,400g standard 20-30 Ottawa sand in a portable concrete mixer. This mix hardens in about 15-20 minutes, but the setting time can be increased by diluting the latex with water.

The following overlay systems were applied to the cement mortar cubes and panels, previously treated with grease and washed with detergent:

System I. Two coats of neoprene sealer were brushed on, allowing a day between coats and before applying the surfacing. The polyester resin mix, described previously, was troweled on with a mason's trowel and troweled as smooth and level as possible. A sandwich was made with each cube by pressing a "clean" cube into the mix.

System II. Two coats of asphalt cut-back primer were brushed on, allowing a day between coats and before applying the surfacing. The polyester resin mix was applied and sandwiches made with the cubes as in System I.

System III. Two coats of neoprene sealer and a surfacing of the epoxy resin mix were applied as in System I.

System V. Two coats of neoprene sealer and one coat of acrylic latex were applied, allowing a day between coats and before applying the leveling coat. The leveling coat, described above, was troweled on as were the resin surfacings in Systems I-IV. The next day the coat was hard and appeared dry and abrasive vinyl was applied, using the epoxy adhesive and a notched trowel with notches 1/16-inch deep, 1/16 inch wide, and 3/32 inch apart (1 inch = 2.54×10^{-2}m).

Each overlay system described above was used on three panels and ten cubes. Sandwiches were made with each treated cube and a "clean" cube. In Systems I-IV, the resin mix was used to cement the "clean" cube. In System V the epoxy adhesive was used to cement the "clean" or untreated cube. Sandwich specimens of this type were described in a previous article by the author [6]. However, "clean" or untreated cement mortar cubes were used in the present work instead of wooden cubes.

3.2 Results of quantitative bond tests on cement mortar cubes

Specimens for tests consisted of cube sandwiches as described previously and these specimens were secured to a tensile testing instrument with special yokes as described in the previous article [6]. A crosshead speed of 0.2 cm/min. was selected for all tensile tests. The maximum load at time of failure of the specimen was recorded in each case and the results are shown in Table 1. Each value recorded is the average of ten tests except for System I, in which only nine tests were recorded and also except for those systems marked with an asterisk. In System I, one of the specimens failed before a recording was obtained.

Table 1. Adhesion of Overlay Systems to Greasy Cement Mortar Cubes

System	Maximum load at failure			Tensile Bond Strength Average Maximum Stress	
	Kgf	N	lbf	N/m^2	psi
I	148	1447	326	561×10^3	81
II	108	1061	239	411×10^3	60
III	264	2590	582	1004×10^3	146
IV	97	1030	232	399×10^3	58
V	28	275	62	106×10^3	16
I*	158	1545	348	599×10^3	87
III*	272	2667	600	1034×10^3	150
IV*	103	1014	228	393×10^3	57

*Results counting actual bond failures and excluding failures of the cubes. In some cases, a cement mortar cube failed by breaking in half at the steel pin. Results counting actual bond failures included 5 tests of System I, 9 of System III, and 8 of System IV.

Table 2. Identification of Overlay Systems Reported in Table 1

System	Barrier Coating	Overlay
I	Neoprene sealer	Polyester resin mix
II	Asphalt cut-back primer	Polyester resin mix
III	Neoprene sealer	Epoxy resin mix
IV	Asphalt cut-back primer	Epoxy resin mix
V	Neoprene sealer - acrylic latex - leveling coat of portland cement mix modified with acrylic latex	Abrasive sheet vinyl

Apparently the results of tests on Systems I, III, and IV were not changed appreciably by excluding tests in which the cubes failed before bond failure occured.

A bond strength requirement for epoxy resin terrazzo appears in the NTMA Specifications of the National Terrazzo and Mosaic Association, Inc., 716 Church Street, Alexandria, Virginia 22314. The criterion is a minimum tensile strength with 100 percent concrete failure of 300 psi. For details, see page 9 of NBS Report 10 655 [5] and reference cited [7].

Statistical analyses were not performed on the results in Table 1, as the purpose of the tests was not to make comparisons but to determine whether any of the systems would have an acceptable bond to the greasy concrete surface. Each of the resin systems I-IV had an appreciable bond to the greasy concrete surface but did not meet the NTMA requirement of 300 psi. System IV with abrasive vinyl has a greater bond to greasy concrete than that of asphalt tile, using asphalt cut-back or asphalt emulsion adhesive to untreated or "clean" cement mortar cubes [6].

3.3 Qualitative observations of cement mortar panels.

The overlays on the cement mortar panels appeared to bond well and there was no separation between any of the elements of the overlays nor between the overlays and the panels. The panels covered with resin systems I-IV, Tables 1 and 2, were broken up with a hammer and the pieces examined for bond failure. In the case of System I, polyester resin mix with neoprene barrier, the overlay remained bonded to the cement mortar. Most of the overlay was intact after breaking up panels treated with System IV, epoxy resin mix with asphalt barrier. The overlays broke loose from panels treated with Systems II and III. System II consisted of polyester resin mix with asphalt barrier and Systems III consisted of epoxy resin mix with neoprene barrier.

Panels covered with abrasive sheet vinyl, System V, were not broken up but the sheet vinyl was peeled off. This required the use of pliers and considerable effort.

Apparently the most reliable overlay systems are polyester resin mix with neoprene barrier and abrasive sheet vinyl with a barrier consisting of neoprene - acrylic - acrylic modified portland cement leveling coat. The compatibility of the epoxy resin mix with asphalt is not surprising in view of the oil-modified curing agent used in the epoxy mix and the fact that asphalt-modified and oil-modified epoxy resin compositions are widely used [4].

3.4 Mechanical bonding of overlays to contaminated concrete.

Bonding media and mechanical fastening have been used for many years for magnesium oxychloride flooring [8]. Since resin systems I-IV in Tables 1 and 2 have an appreciable bond to greasy cement mortar surfaces, it was decided to experiment with a combination of barrier coatings and mechanical fastening. In ANSI A88.1-1951 [8], rubber latex and resin compositions are prescribed as bonding media for magnesium oxychloride flooring. Mechanical fastening prescribed in ANSI A88.1-1951 include expanded metal, hexagonal mesh fencing, reinforcing mesh, and hardware cloth.

For testing, six reinforced concrete slabs were obtained from the Structures Section. These slabs were 16- by 18- by 6- inches thick. The top surface of the slabs were treated with grease mixture and washed with detergent as described previously in the report, in Section 3.1. Three of the blocks were then coated with neoprene sealer and three with asphalt cut-back primer as in Section 3.1. In applying overlays, expanded metal was first screwed to the blocks with machine screw type masonry anchors. Four anchors were used for each block about three inches from each corner. Resin mortar or portland cement mix was applied over the expanded metal to fill the spaces, then more mix was applied to cover the metal, and the surface was finally troweled smooth. Materials were the same as in Section 3.1 except that a cement mortar mix, described in Section 3.1 for preparation of test cubes and panels, was used in place of the acrylic modified portland cement. Overlays applied to the blocks are identified in Table 3.

Table 3. Overlays Used on Concrete Blocks

Block	Barrier Coating	Overlay
A	Neoprene sealer	Polyester resin mix
B	Asphalt cut-back primer	Polyester resin mix
C	Neoprene sealer	Epoxy resin mix

Block	Barrier Coating	Overlay
D	Asphalt primer	Epoxy resin mix
E	Neoprene sealer	Cement mortar mix
F	Asphalt cut-back primer	Cement mortar mix

Abrasive sheet vinyl, previously described, was laid over blocks E and F, using a commercial resin latex adhesive used for sheet vinyl floor coverings.

An attempt was made to perform pipe cap bond tests [4], [7] but in order to save time, a quick setting epoxy adhesive was used. After curing for four hours, the bond strength of the adhesive varied considerably but was never more than 68 psi ($469 \times 10^3 N/m^2$). This is insufficient to evaluate the resin overlays. The epoxy adhesive normally used requires heat or a curing time of at least 24 hours. This is too slow for a field test.

All overlays appeared to have a satisfactory bond after about a month and were then subjected to an impact test. A steel ball weighing 10.7 lbs (4.85 kg) was dropped from a height of 18 inches (0.457m) on the four corners of each block. This represents a force of about 193 inch-pounds or about 16 ft-lbs (21.4 joules). The polyester and epoxy overlays were not affected. The abrasive vinyl was momentarily indented but recovered. There was no damage observed to the cement overlay when the sheet vinyl was pulled off, which required considerable force.

4. CONCLUSIONS AND RECOMMENDATIONS

From experiments reported here and in the previous report [4], it appears that polyester and epoxy surfacings can be applied successfully to grease contaminated concrete surfacings by a combination of barrier coatings and mechanical fastenings. Abrasive sheet vinyl can be secured to contaminated concrete by means of a special barrier system. The most successful barrier coating at the present state-of-the-art appears to be based on neoprene in organic solvent, such as methyl ethyl ketone. Asphalt cut-back primer, while not as effective, is also satisfactory. Abrasive sheet vinyl can be applied successfully over a leveling coat, in turn applied over successive coats of neoprene sealer and acrylic latex. The leveling coat is a mix of acrylic latex modified portland cement and sand. While standard 20-30 sand was used in the experiments reported here, 60-mesh sharp or angular sand is preferable for actual use. For the resin mixes, it is better to use a blend of angular sand, such as:

10 percent	-100 mesh
25 percent	-70 +100 mesh
35 percent	-30 +50 mesh
30 percent	-15 +30 mesh

Machine screw type masonry anchors were used in the experiments with the concrete blocks but this would be too slow and expensive for actual use. The best type of masonry anchors for fastening expanded metal to actual concrete floors are the power-actuated or hammer-drive type, which are available from manufacturers and suppliers of power tools and industrial equipment. Concrete nails may also be used and these are recommended in ANSI A88.1-1951 [8].

APPENDIX

Corrections to Table 2, NBS Report 10 357

The values for tensile bond strength in Table 2, page 94 of NBS

Report 10 357 [4] are in error. These values were calculated by dividing the figures for maximum load at failure by the area of the machined pipe cap. The pipe cap was used in the tests on the cement mortar panels, reported in Table 4, page 99, NBS Report 10 357 and the figures in Table 4 are correct. Values for tensile bond strength in Table 2 should have been calculated by dividing figures for maximum load by the area of the top surface of the cube, which is 4 in.^{2} or $25.8064 \times 10^{-4} m^2$. This error does not change the relative bond strengths of the overlay systems and does not invalidate the statistical analysis. Following is a corrected table, using rounded-off figures, in accordance with the degree of precision of the measurements. Values for standard deviation of the means are omitted. Values for F_{PROB} are unchanged. Tensile bond strengths in the original table were multiplied in the corrected table by the factor

$$1.539375 = \frac{6.1575}{4} = \frac{\text{Area of pipe cap surface in inches}}{\text{Area of cube surface in inches}}$$

NBS 10357, Table 2 (corrected). Adhesion of Overlay Systems to Clean and Greasy Cement Mortar Cubes

Data Group	System Table 1	Surface	No. of Tests	Tensile Bond Strength Average Maximum Stress		
				N	psi	F_{PROB}
1	A	Clean	10	336×10^3	49	
2	A	Greasy	10	201	29	
1,2	A	Clean, Greasy				0.008
3	B	Clean	10	356	52	
4	B	Greasy	10	251	36	
3,4	B	Clean, Greasy				0.018
5	C	Clean	10	466	68	
6	C	Greasy	10	408	59	
5,6	C	Clean, Greasy				0.232
7	D	Clean	10	854	124	
8	D	Greasy	10	778	113	
7,8	D	Clean, Greasy				0.406
9	E	Clean	5	1,271	184	
10	E	Greasy	5	1,112	161	
9,10	E	Clean, Greasy				0.333

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