COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT

HENRY WARD
COMMISSIONER OF HIGHWAYS

ADDRESS REPLY TO
DEPARTMENT OF HIGHWAYS
MATERIALS RESEARCH LABORATORY
132 GRAHAM AVENUE
LEXINGTON 29, KENTUCKY

February 22, 1962

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MEMO TO: A. O. Neiser
Assistant State Highway Engineer

There has been some considerable discussion recently concerning the finishing of structural concrete for the riding surfaces of bridge decks. The two main problems have been roughly-finished, poor-riding surfaces and premature deterioration of the concrete in the deck. These two items may be closely allied in that they can both result from over-manipulation and over-working of the concrete. It is believed that over-working can lower the entrained-air content to the critical point, which in turn, results in poor durability characteristics.

In an effort to improve the riding surface and the quality of the concrete in a bridge deck, a vibratory screed was used by R. R. Dawson Bridge Company on an overpass structure over I-64 in Shelby County in 1959. It was found then that some considerable reduction in hand work and finishing time could be realized through the use of vibrating screeds operating from pipe rails temporarily mounted in the deck.

Retarders have long been used on large-volume, monolithic pours, particularly when there was a supply problem. These are recognized aids when high temperature, low humidity and drying winds affect the initial set of concrete.

As a method for further improving the surface finish of bridge decks, the Bridge Construction Engineer, by letter of March 3, 1960, requested the Research Division to participate in an experimental project. The basic objective was to evaluate any benefits to bridge decks accrued through the use of retarders in the concrete mix. Of primary interest, and an item for long-range study, was the effect on the durability of the concretes in the control and test sections.

The attached report, "An Evaluation of Four Retarding Admixtures in Structural Concrete," by Milton Evans, Jr., Head, Concrete Section, and Ralph R. Waddle, Formerly Assistant Bridge Construction Engineer, describes the placement of concrete on three bridge decks. Strength tests on the materials placed are reported along with laboratory freeze-thaw durability tests.

One of the types of retarders was found to cause some finishing problems throughout rather extensive field trials. The laboratory freeze-thaw durability tests indicated that durable mixes could be obtained with each of the four retarders if sufficient air was entrained. I believe that we should keep a close surveilance on the field test installation and determine particularly if durability has been affected by extending the time during which the concrete was plastic. We plan to make regular annual inspections and to report any significant changes in the structural concrete.

Respectfully submitted,

W. B. Drake

W. B. Drake
Director of Research

WBD:dl
Enc.
cc: Research Committee Members
Bureau of Public Roads (3)

Commonwealth of Kentucky
Department of Highways

AN EVALUATION OF FOUR RETARDING ADMIXTURES IN STRUCTURAL CONCRETE

Jefferson County I-65-6(6)134
Shelby County RS-106-266-2

by

Milton Evans, Jr.
Research Engineer Associate

and

Ralph R. Waddle
Assistant Bridge Construction Engineer

Highway Materials Research Laboratory
Lexington, Kentucky
February, 1962

INTRODUCTION

Early in 1960, the Construction Division was becoming quite concerned with the growing problem of obtaining satisfactorily smooth reinforced concrete bridge decks. Increasing areas of new decks were not measuring up to requirements when checked with a straight-edge, and rough-riding surfaces were resulting even after corrective grinding. It appeared that, on large pours, perhaps more time for placing and finishing was needed; this was so particularly on hot, windy days when ambient conditions would cause the concrete to set more rapidly. A proposed method of providing more working time was to use retarding admixtures to slow the setting time of the concrete.

The Construction, Materials and Research Divisions, with the approval of the Bureau of Public Roads, embarked on a program to evaluate the usefulness of certain retarders. It was also recognized that many retarding admixtures are purported to contribute advantages other than retardation. Through their dispersing action and hence more efficient dispersal of water, less water is generally required to obtain the specified workability. This, of course, lowers the water-cement ratio in a given mix, and more strength is developed by the cement present. The other advantages usually realized by the reduction of the water-cement ratio in a concrete mix, such as reduced shrinkage, higher density, etc., would also be expected. Often the water-reducing admixtures, whether of a retarding nature or not, are promoted on the grounds that a quantity of cement can be deducted from a given mix without any detrimental effects upon the properties of the resultant concrete. These additional benefits claimed were not primary considerations in the evaluation undertaken -- that is, except as they might adversely affect the final results. However, some additional observations can be made about these characteristics of the admixtures used.

PROJECTS

After some preliminary work in the laboratory which indicated that there were no obvious disadvantages involved in the use of retarding admixtures in concrete for the purpose in mind, it was decided that a field trial should be made. The deck of the Broadway Bridge on the North-South Expressway in Louisville was selected as the primary structure for the evaluation, and the full co-operation of Struck Construction Company, contractor on project, was extended. In addition, part of the deck of the Jacobs Street Bridge, another Struck Construction Company project, which is located just south of the Broadway Bridge on the North-South Expressway, was included. Also, some additional work was permitted on the deck of the Guist Creek Bridge, an R. R. Dawson Construction Company project, on the Benson Road in Shelby County. Additional laboratory investigations were needed, particularly to check the effect of retarders on the durability of concrete. On all three of the projects selected, and in all the laboratory work as well, the same types of constituents were used. It was determined that approximately one and one-half hours additional working time would be desirable, and so the admixture designs were made accordingly. Inasmuch as the retardation time for a specific dosage was known to vary with existing temperatures, the quantity of admixture was varied accordingly on the job.

RETARDING AGENTS

Two major classes of retarders are manufactured and marketed today, and both classes were employed in this project. The first and most widely used type, lignosulfonic acids and their derivatives, was employed in three forms; the second type, hydroxylated carboxylic acids and their derivatives, was entered in one form. This distribution of forms about matches the availability and consumption of these two classes. A further and important distinction between these materials is that the lignosulfonates prohibit bleeding, and the adipic acids tend to promote it. Also, the lignosulfonates are mild air-entraining agents, and the adipic acids are not.

The four materials used were provided by their individual manufacturers along with technical assistance from each.

The materials selected and their descriptive specifications were as follows:

1. Pozzolith HP 18 (Brown Powder), The Master Builders Company. This material is a calcium lignosulfonate, in a powder form, from which all fermentable wood sugars have been removed. It retards the initial set of concrete and is a mild air-entraining agent. It must be pre-mixed with water before it is added to the concrete mix. The normal dosage is 0.25 lb. per bag of cement, and this will give an average retardation of 1 to 1-1/2 hours when temperatures are in the 70°-90° range. Dosages can be varied to a low range of 0.20 lbs. per bag of cement to reduce retardation or can be increased to 0.35 lbs. per bag of cement to increase retardation of setting time. Within these ranges, it is most effective as a water-reducing admixture. When used with Type I cement such as is specified under Kentucky Highway Specifications, it is necessary to add an air-entraining agent to give the air content desired; but normally a reduced amount is required.

2. Protex PDA (Brown Powder), Autolene Lubricants Company. This material is a calcium lignosulfonate in a power form which retards the initial set of concrete and is a mild air-entraining agent. It must be pre-mixed with water before it is added to the concrete mix. The normal dosage is 0.25 lbs. per bag of cement, and this will give an average retardation of 1 to 1-1/2 hours when temperatures are in the 70°-90° range. Dosages can be varied to a low range of 0.20 per bag of cement to reduce retardation or can be increased to 0.35 lbs. per bag of cement to increase retardation of setting time. Within these ranges, it is most effective as a water-reducing admixture. When used with Type I cement such as is specified under Kentucky Highway Specifications, it is necessary to add an air-entraining agent to give the air content desired, but normally a reduced amount is required.

3. Daratard (Brown Liquid), Dewey & Almy Chemical Company. This material is a metallic salt of a lignin sulfonic acid in a liquid form which retards the initial set of concrete and is a mild air-entraining agent. It is ready to add to the concrete mixture as received. The normal dosage is 10 fluid ounces per bag of cement, and this will give an average retardation of approximately 1 to 1-1/2 hours at a temperature of approximately 90°. Dosages can be varied to a low range of 7 fluid ounces per bag of cement to reduce retardation or can be increased to 13 fluid ounces per bag of cement to increase retardation of setting time. Within these ranges, it is most effective as a water-reducing admixture. Used with Type I cement such as is specified under Kentucky Highway Specifications, it is necessary to add an air-entraining agent to give the air content desired, but normally a reduced amount is required.

4. Plastiment (Green Liquid), Sika Chemical Corporation. This material is a derivative of adipic acid in a liquid form which retards the initial set of concrete but does not entrain air. It is ready to add to the concrete mixture as received. The normal dosage is 3 fluid ounces per bag of cement, and this will give an average retardation of 1 to 1-1/2 hours when temperatures are in the 65°-85° range. Dosages can be varied to a low range of 2 fluid ounces per bag of cement to reduce retardation or can be increased to 4 fluid ounces per bag of cement to increase retardation of setting time. When used with Type I cement, such as is specified under Kentucky Highway Specifications, it is necessary to add the usual amount of an air-entraining agent to give the air content desired.

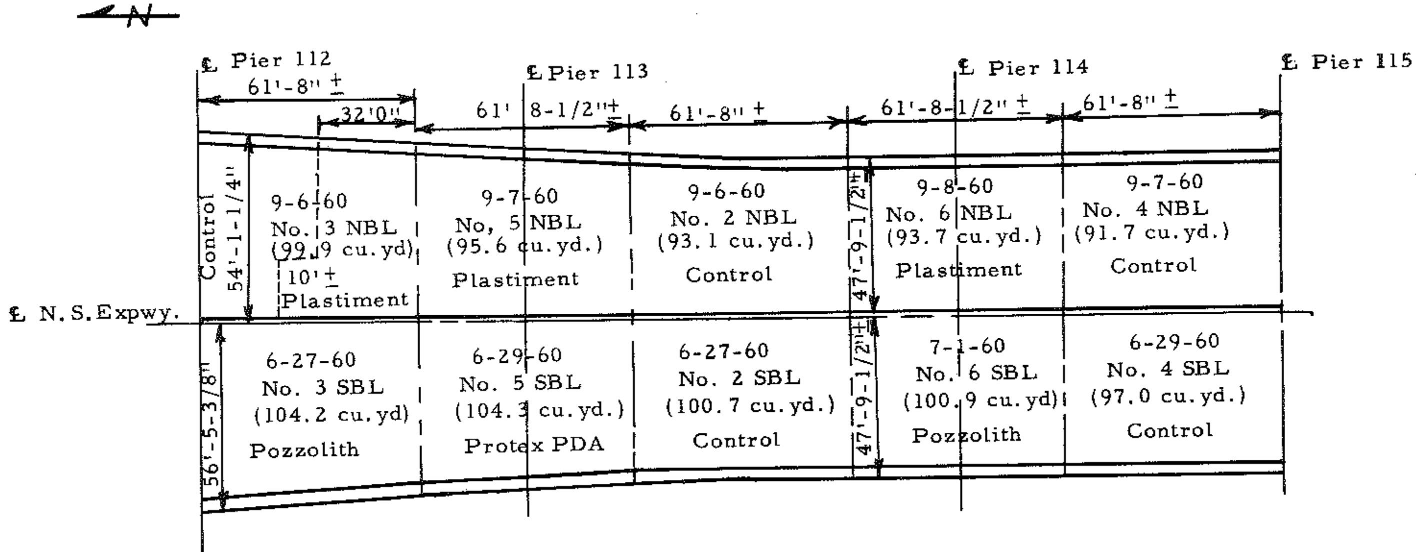
EVALUATION

In each case, a control section of air-entrained concrete was compared to a similar section of retarded, air-entrained concrete. The sections averaged approximately 100 cu. yds. of concrete each and were approximately 62 x 51 feet in area. The companion sections were placed, as nearly as possible, under the same conditions on the same day. Figure 1 is a layout of the sections on the Broadway Bridge. Figure 2 is a layout of the sections placed on the Jacobs Street Bridge, and Figure 3 shows the particulars of the Guist Creek Bridge section.

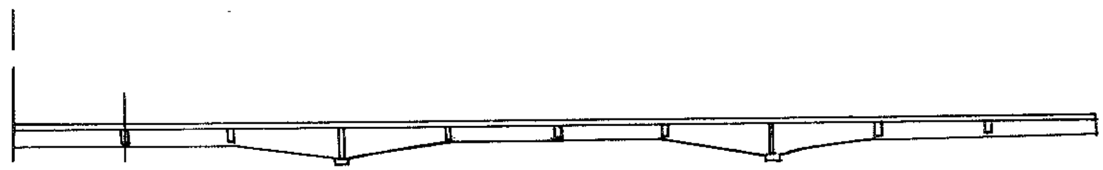
It must be noted that the concrete for all three projects was furnished by transit-mix trucks and was more inconsistent than was desired.

The finishability of the various mixes was observed, and the standard control tests for slump, air content, and compressive strength were made and recorded.

The pours were made on June 27 and 29, July 1 and 6, Aug. 17, and September 6, 7 and 8; and, the temperatures ranged from 76° to 95°F. Figures 4, 5, 6, 7 and 8 show the placing and finishing procedures employed.



ORDER & QUANTITIES OF BROADWAY SPAN CONCRETE POURS



POUR NO. 1

Fig. 1. Jefferson County, I 65-6(6)134, North-South Expressway, Bridge over Broadway.

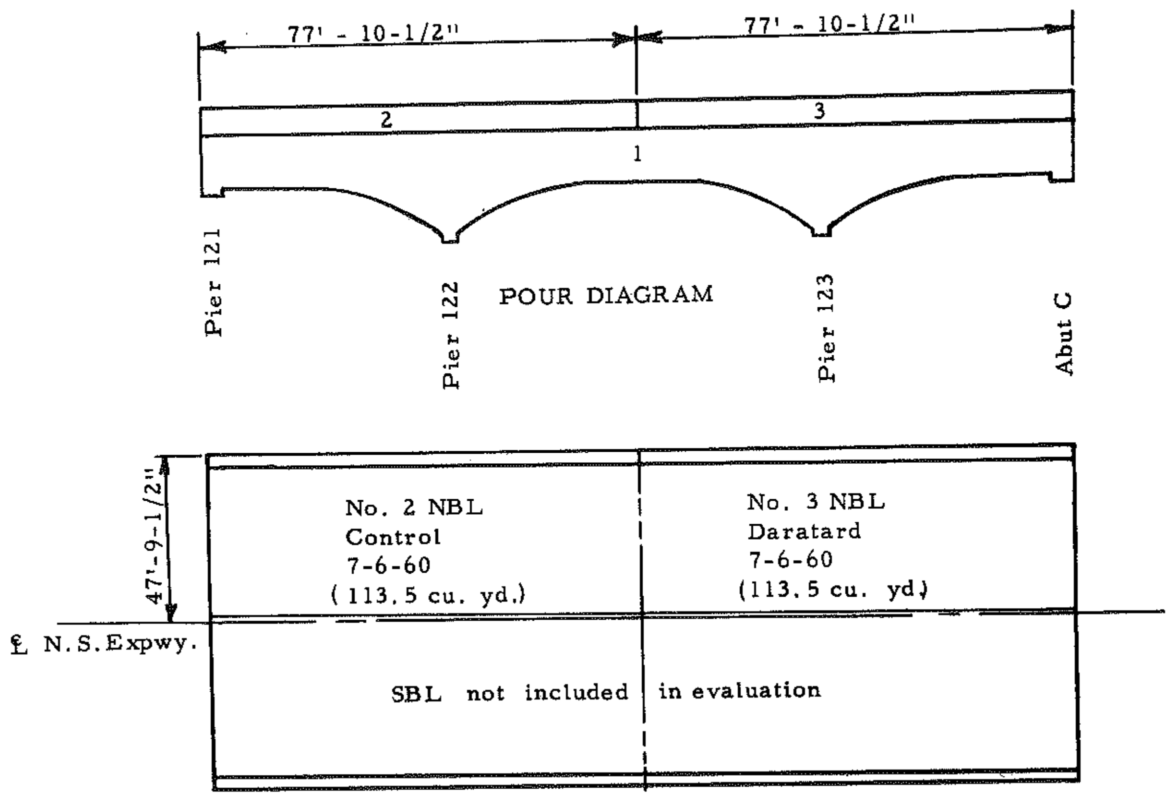


Fig. 2. Jefferson County, I 65-6(6)134, North-South Expressway, Bridge over Jacob Street, Northbound Lanes.

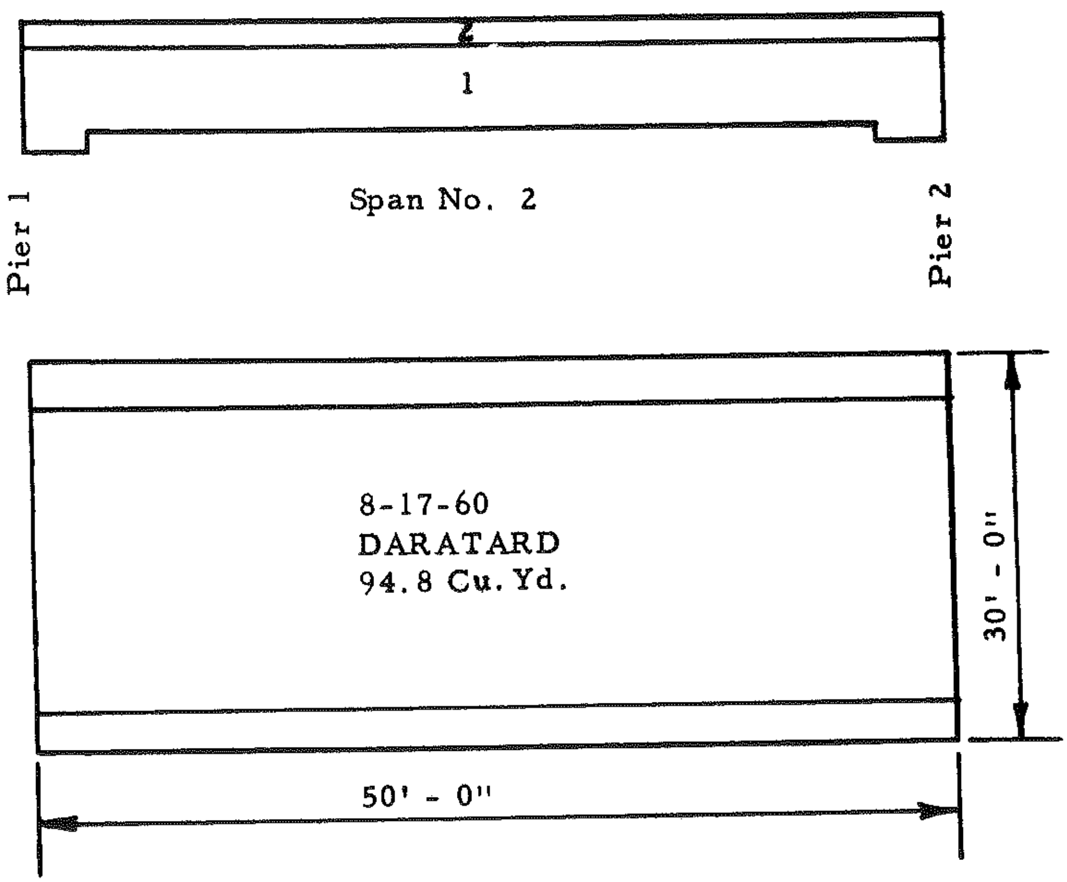


Fig. 3. Shelby County, RS 106-266-2, Benson Road, Bridge over Guist Creek.

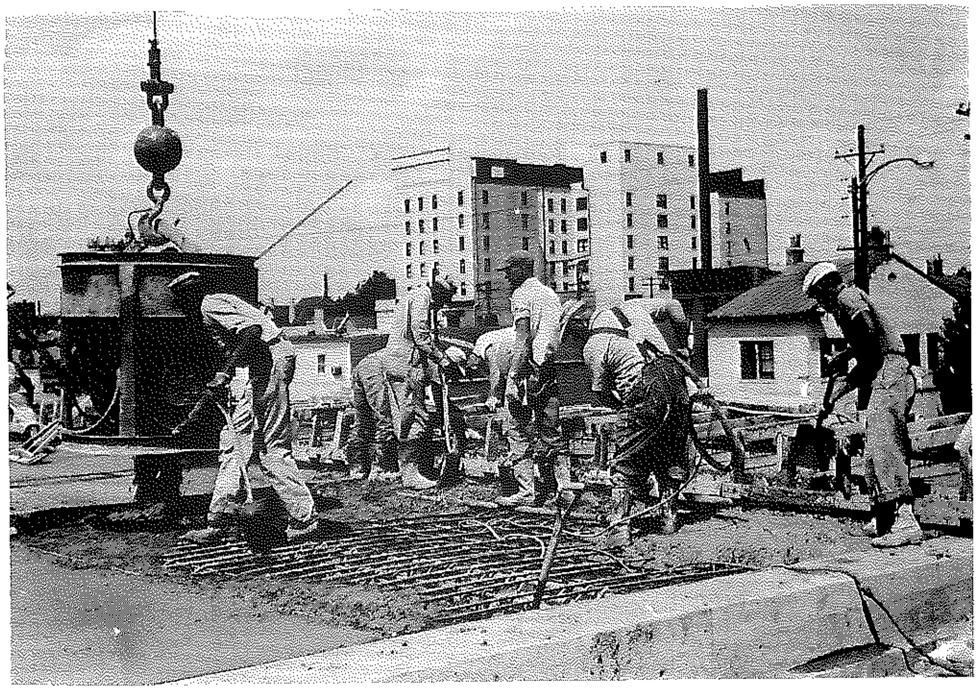


Fig. 4. Placing Procedures.

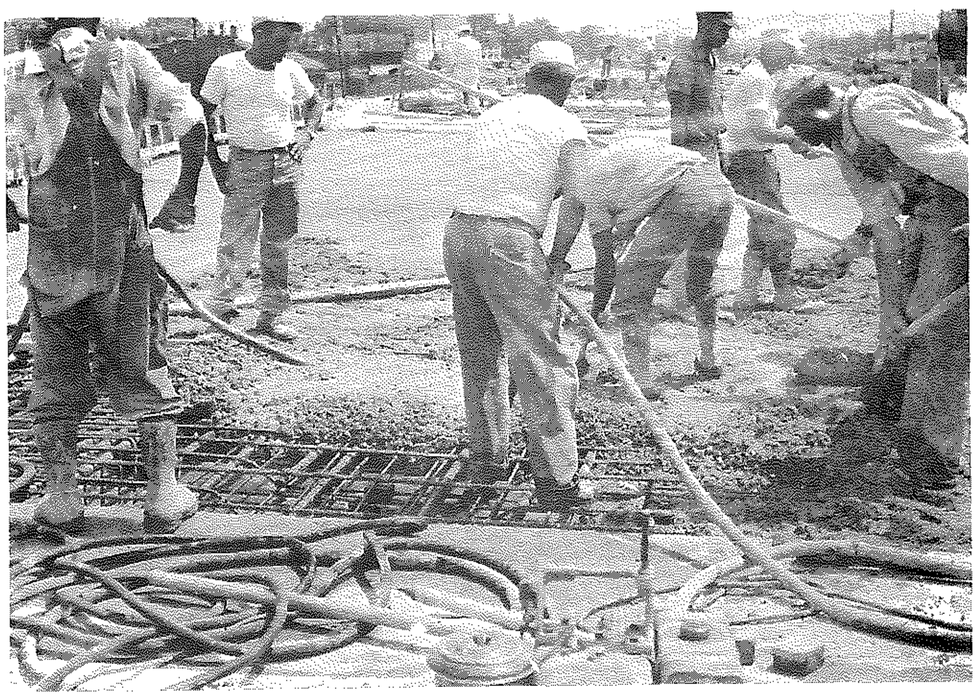


Fig. 5. Placing Procedures.

Fig. 6. Striking-off Procedures.

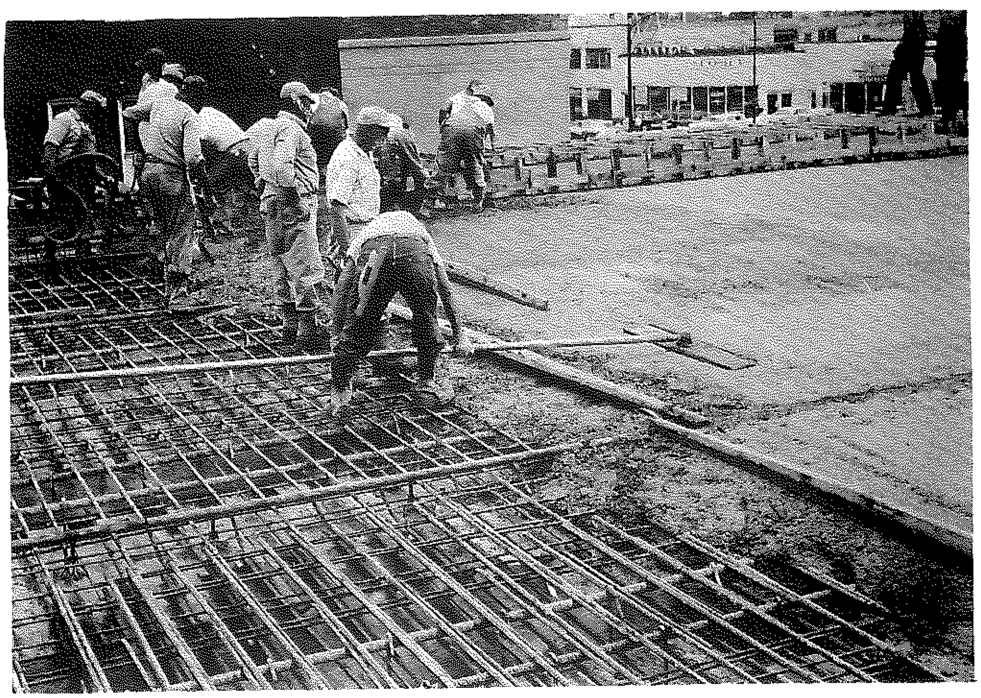


Fig. 7. Finishing Procedures.

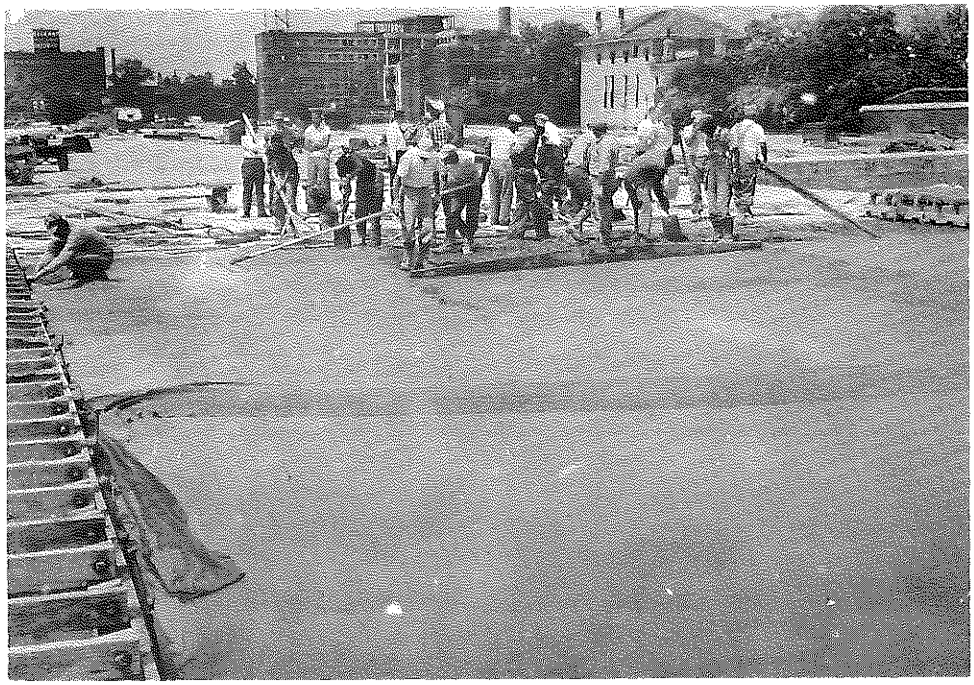


Fig. 8. Placing and Finishing Procedures.

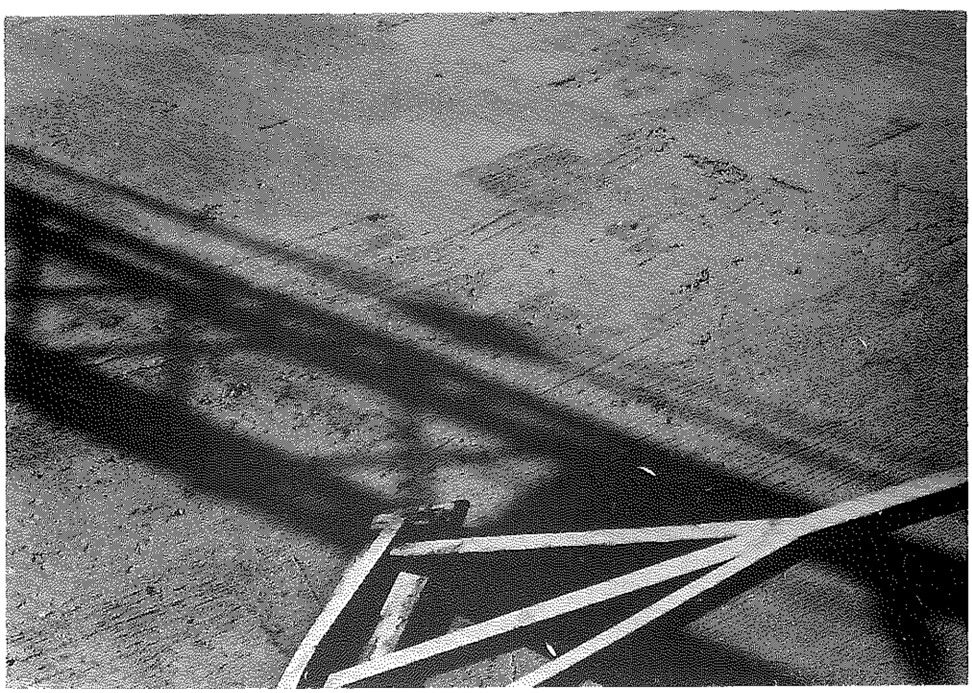


Fig. 9. Openings which could not be closed by floating in one of the ligno sulfonate sections.

Fig. 10. A ligno sulfonate retarded section which was hard to finish because of stickiness.

In order to better weigh the advantage of longer workability sought in these tests, the average cost of each type of material per yard of concrete has been computed:

Pozzolith	37-1/2¢
Protex	48¢
Daratard	53¢
Plastiment	79¢

The primary purpose of this endeavor was to obtain more finishing time of bridge deck slabs without invoking any undesirable effects. The initial set was in each case retarded for at least one and one-half hours; and, in one or two instances, it was retarded somewhat longer. However, the retardation time was controlled sufficiently well to demonstrate that, for any given mix, a specified delay can be secured.

Unfortunately, in the case of the three ligno sulfonate retarded mixtures, a certain stickiness of the mix was observed which made finishing difficult. Although the mixes remained workable longer and were of the specified slump, they were not satisfactory in that it was not possible to pass a float over the surface without causing some pulling and opening of the surface. Figures 9 and 10 are typical of these surfaces just before covering with the curing material. Nevertheless, there is a possibility that this condition could be eliminated by a completely different concrete mix design in which the usual ratio of sand to coarse aggregate and/or the type of the concrete constituents might be varied. On the other hand, the adipic-acid mixture was plastic as long as desired and was satisfactorily workable. Apparently, this material fulfilled the requirements originally set out. However, it must be remembered that under adverse conditions, many admixtures have been known to worsen an already bad situation. Therefore, care must be exercised in the selection of materials and in fixing conditions to insure satisfactory results; and constant control must be provided in order to detect and correct any inconsistencies which arise.

The materials used in the bridge sections of this project are described in Table 1. Design factors and compression test results for the same sections are given in Table 2.

The strengths developed by the retarded concrete mixtures placed in the bridge decks on this project, shown in Table 2, have, in nearly every case, for the various curing periods, been equal to or greater than those for the control mixtures made similarly and under the same conditions therebeing only minor exceptions. These exceptions are perhaps indications of inconsistencies between batches delivered in transit-mix trucks or in making and handling

Table 1. Description of Materials used in Broadway & Jacobs Street Bridge

Material	Type	Source	Characteristics
Coarse Aggregate	Crushed Limestone	Lambert Bros. Okolona, Ky.	Ky. Spec. No. 6 Stone
Fine Aggregate	Ohio River Sand	Aggregate Serivce Inc., Utica, Ind.	Ky. Spec. Concrete Sand
Cement	Porland Type I	Louisville Cement Louisville, Ky.	Bulk
Water	Potable	Louisville Water Company	Suitable for Concrete
A/E Agent	Protex A/E	Autolene Lubricants Co.	Vinsol resin solution, liquid
Retarders	Pozzolith HP-18	Master Builders Co.,	Calcium lignosulfonate, powder
	Protex PDA	Autolene Lubricants Co.	Calcium lignosulfonate, powder
	Daratard	Dewey & Almy Chemical Co.	Calcium lignosulfonate solution, liquid
	Plastiment (Liquid)	Sika Chemical Corp.	Adipic Acid derivative, liquid

Note: These materials were stocked, proportioned, mixed in transit and delivered by the R. B. Tyler Co. from their plant at 1446 Levering Street, Louisville, Kentucky.

Table 2. Design Factors and Compression Test Results for Field Sections.

Retarder	Amount per Sack	W/C Gallon per Sack	C F Sack per Yard	Slump (in.)	% Air	Curing Period - Days - Strength, psi. 3	7	8	9	28	35	Date
Pozzolith	.25 lb.	5.66	1.5	3.0	5.0	4863	--	--	5376	6544	--	6-27
Plain	0	5.98	1.5	3.0	5.0	3714	--	--	4174	5131	--	--
Protex PDA	.25 lb.	5.98	1.5	3.5	4.5	--	3910	5049	--	5128	--	6-29
Plain	0	5.89	1.5	3.5	4.5	--	4369	3979	--	5111	--	--
Daratard	10fl.oz.	5.46	1.5	3.8	4.0	--	4703	--	--	6544	--	7-6
Plain	0	5.82	1.5	3.8	4.0	--	4141	--	--	4960	--	--
Plastiment	1.8fl.oz.	5.55	1.5	3.5	5.0	2997	--	--	3641	--	4592	9-6,7 & 8
Plain	0	5.77	1.5	3.5	4.5	2421	--	--	3213	--	4849	--

the specimens. The results of additional laboratory investigations which have been completed are given in Table 3. As with the results of tests performed on specimens made in the field, it can be seen that in essentially every case the strengths, both compressive and flexural, developed by the retarded concrete mixtures in the laboratory have been equal to or greater than those for the control mixtures made in the laboratory. As would be expected, these laboratory results are more consistent than those obtained with specimens made in the field.

None of these results, either from the field or from the laboratory, indicate that any of the retarders produced concrete of insufficient strength. Equally significant are the results of the freeze-thaw durability tests made in the laboratory on the various retarder specimens, given in Table 3. All of the specimens containing 3.2 percent or more entrained air have proven to be very durable; the specimens containing 2.3 percent entrained air have proven to be fairly durable; and the specimens containing only 1.7 and 1.6 percent air have not proven to be satisfactory. This comparison of durability of these specimens is made on the basis of a durability factor; where 300 freeze-thaw cycles without a loss of properties is considered passing. It is apparent from this analysis that the factor which affects the durability of these specimens is not related to the kind of retarder or the use of a retarder, but is dependent upon a sufficient quantity

Table 3. Design Factors and Test Results for Laboratory Retarder

Description	Retarder Amt./yd.^{3} fl.oz.	Retarder Amt./yd.^{3} lbs.	W/C gal./sk.	Quantities per cu.yd. C.F. sks.	Quantities per cu.yd. Water gal.	Quantities per cu.yd. A/E Agt. oz.	Air %	Slump (in.)	Unit Wt. lbs. per ft.^{3}	Compr.Str. 28-Day psi.	Flex.Str. 28-Day psi.	Cycles -40% E	Durability Factor %
Control-Plain	-	-	5.34	5.98	31.93	0	1.7	3.0	151.2	5424	975	210	42
Control-A/E	-	-	5.01	5.99	30.01	3.1	4.5	2-3/4	147.2	5312	950	880	176
*Daratard-Plain	54	3.5	5.34	5.96	31.82	0	2.3	2-1/4	152.0	6502	1188	600	120
*Daratard-A/E	54	3.5	5.01	6.00	30.06	3.1	4.8	2-1/2	147.6	6278	1150	720	144
*Plastiment-Plain	18	1.2	5.34	5.96	31.83	0	1.6	3-1/2	152.0	6396	1038	360	72
*Plastiment-A/E	18	1.2	5.01	5.96	29.86	3.1	4.8	2-3/4	146.8	6549	1100	820	164
**Pozzolith-Plain	-	1.5	4.90	5.97	29.25	0	3.2	3.0	150.0	5934	1000	790	158
**Pozzolith-A/E	-	1.5	4.62	6.03	27.86	1.2	4.7	3-3/4	147.6	6355	1100	910	182
**Protex-PDA-Plain	-	1.5	4.62	5.87	27.12	0	4.6	3-3/4	147.2	6252	946	830	166

*These retarders are furnished in solution. They were weighed and added to the mixes as received.
**These retarders are furnished in powder form. The required amount was weighed and put into solution before it was added to the mixes.

Notes:
A. The constituents used in making these tests are of the same types as those which were used in the field evaluations. See Table 1.
B. No A/E specimens were made with Protex PDA because this admixture entrained the amount of air required for the A/E specimens without any air-entraining agent being added.
C. Strength and durability items are average factors representing 3 specimens in each category.

of entrained air. These tests do not indicate that the durability of any of the concretes has been impaired by the use of the retarding admixture employed.

In order to ascertain if the bridge decks placed with a retarding admixture during this evaluation were smoother than those placed without such an admixture, the conventional method of checking the surfaces with a straight-edge was employed. It was found that all of the sections, retarded and plain, were better than average, but no appreciable improvement in smoothness could be seen in the retarded sections -- this is not to say that the jobs were without defects because some grinding was necessary to bring the grades within acceptable tolerances.

While the foregoing results indicate perhaps that the use of retarding admixtures was of no benefit in regard to smoothness, it should be pointed out that the higher temperatures encountered for a given day's pouring would naturally occur later in the day, and it was at such times that the retarded concrete was obviously easier to handle. However, on this particular project, this was not a critical difference, because the placement crews were experienced, properly equipped, and of sufficient size to handle the job; the concrete was being supplied from nearby without delays; the whole operation was well organized; and the weather conditions were not too critical. But, it should not be overlooked that in a different situation and under more severe conditions the additional working time obtainable with some of the admixtures tested might very well have been of decided benefit in the handling of the concrete. In fact, in the summer of 1961, the contractor encountered considerable difficulty in handling and placing the concrete in the first slab of the New Albany-Louisville Bridge. He was granted permission to use a retarder in the placement of subsequent slabs during the remainder of the summer. Twenty-two slabs, containing approximately 135 cu. yds. of concrete each, were placed using a total of approximately 300 gallons of Plastiment.

The Plastiment was added to the concrete according to the temperatures expected during placement and finishing of each batch. Often the first batches for a pour contained no Plastiment; the next batches to be finished during the hotter part of the day were retarded according to the temperature; and the last batches were only slightly retarded or not retarded at all if the temperatures were expected to be low during the finishing process. The temperature above which a retarder was considered necessary appeared to be around 75°F. When Plastiment was used on this job, the setting time was extended and the handling properties of the concrete were noticeably improved.

Thus far our tests and experience have indicated that no harmful effects have developed in the concretes where the adipic-acid type retarder has been introduced. No harmful effects have been observed in the concretes where the lignosulfonic types of retarders have been used except for a perceptible stickiness of the plastic concrete, which makes it somewhat more difficult to finish. With both types of retarders, it appears that a 10 to 16 percent increase in flexural and compressive strengths can be expected.

These results indicate that further use of these materials, in situations where their particular properties would be advantageous, is warranted.