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16. Abstract

The most important result of this investigation is the development of the addition of urea-formaldehyde combinations in the form of a monomer system to the mixing water of portland cement mortars and concretes. Although the addition of this system to concretes produced only negligible strength increases, experimental data indicated that several combinations of the same system with mortars produced compressive strength increases of 1500 to 2500 psi.

It is not clear at this time why the urea-formaldehyde monomer system is effective in mortars and ineffective in concretes. Further investigation is needed to improve the effectiveness of this monomer system in concretes, too. The application of such a monomer system is also advantageous from economical standpoint because this is the least expensive form of the urea-formaldehyde combinations, and because the technology of such monomer systems in mortars and concretes is simple. Besides, despite the present ineffectiveness of the urea-formaldehyde monomer system in concretes, it still seems a significant breakthrough that the admixing of an unpolymerized urea-formaldehyde system increases considerably the strength of portland cement mortars.

Several other directions were also investigated, such as the optimization of the basic urea-formaldehyde prepolymers, acidic urea-formaldehyde prepolymers, and several other chemical systems and commercially available polymers. Some of these systems did produce strength increases but these were not high enough.

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FINAL REPORT

Polymer Pavement Concrete for Arizona - Study II

HPR 1-12 (154)

Prepared by: Dr. Sandor Popovics

PREFACE

This document is the report on Study II of a project entitled "Polymer Pavement Concrete for Arizona." The project identified as No. HPR 1-12 (154) by the Arizona Department of Transportation, was sponsored by the Arizona Department of Transportation in cooperation with the Federal Highway Administration through contractual agreement with Northern Arizona University in Flagstaff, Arizona. The project started on May 1, 1974, and ended on March 22, 1976.

The project made use of staff and facilities of the College of Engineering and Technology, Northern Arizona University. The principal investigator was Dr. Sandor Popovics. Dr. Jack S. Swenson worked as consultant on the project for approximately six months, while Mr. John C. Germ worked approximately 9 months as a research assistant.

Several companies contributed materials for the project, including the Phoenix Cement Company, Clarkdale, Arizona. The contribution of these companies is certainly appreciated. The help of the Bureau of Reclamation, especially the cooperation of Mr. Carl Selander and Mr. W. C. Cowan is also acknowledged with thanks.

ABSTRACT

of the Project

"Polymer Pavement Concrete - Study II" HPR 1-12 (154)

The most important result of this investigation is the development of the addition of urea-formaldehyde combinations in the form of a monomer system to the mixing water of portland cement mortars and concretes. Although the addition of this system to concretes produced only negligible strength increases, data in Table VI show that several combinations of the same system with mortars produced compressive strengths close to 7000 psi or even higher at the age of 28 days. Also, quite a few mortar series provided compressive strengths close to 9000 psi at the age of 90 days. These represent a 1500 to 2500 psi strength increase produced by this monomer system.

It is not clear at this time why the urea-formaldehyde monomer system is effective in mortars and ineffective in concretes. Further investigation is needed to answer this question and, hopefully, improve the effectiveness of this monomer system in concretes, too. The significance of this further research lies in the fact that the application of such a monomer system is also advantageous from economical standpoint because this is the least expensive form of the urea-formaldehyde combinations, and because the technology of such monomer systems in mortars and concretes is simple. Besides, despite the present ineffectiveness of the urea-formaldehyde monomer system in concretes, it still seems a significant breakthrough that the admixing of an unpolymerized urea-formaldehyde system increases considerably the strength of portland cement mortars.

In addition to this effort several other directions were also investigated. Firstly, the project had as its aim the optimization of the basic urea-formaldehyde prepolymers that were found promising in Study I. Unfortunately, these efforts were unsuccessful despite the fact the most of the possible variables (Urea-formaldehyde ratio, pH, catalyst, concentration, temperature, degree of polymerization, etc.) were investigated. The reason for this failure is not clear. Secondly acidic urea-formaldehyde prepolymers were investigated that were produced either with heating or without elevated temperature. Thirdly, several other chemical systems and commercially available polymers were also tried out. Some of these systems did produce considerable strength increases but these were still less then the ones mentioned above in connection with the addition of urea-formaldehyde monomer systems.

The investigation of the underlying mechanisms concerning the effects of polymers or monomer systems on the strength development of modified mortars or concrete was not intended in this project.

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Polymer - Pavement Concrete for Arizona -- Study II

Introduction

A successful polymerization improves the overall quality of concrete so much that their use should result in pavements and structures of superior quality, that is, which require less materials, less maintenance and are more lasting. The potential benefits are especially attractive in the northern part of Arizona where good, durable aggregates are scarce.

The Arizona Department of Transportation initiated a preliminary investigation on polymer pavement concretes in the College of Engineering, Northern Arizona University, in November, 1972. Since the present research is the continuation, that is the second phase, of that investigation, it may be mentioned that the problems to be solved by this investigation encompassed the improvement of the overall quality of portland cement concrete by chemical polymerization techniques that are field-implementable for pavement and other field concretes. It is important to note that according to the technical literature the polymerization methods which have been reported as successful, require either extensive radiation treatment or heat treatment, therefore, they are not practicable for concrete pavements and other field applications. Since much more concrete is used in highway engineering in pavements than for any other purpose, it seems worthwhile to continue the laboratory investigation for finding combinations of chemically activated polymer and portland cement concrete that are readily usable for pavement and other field applications.

The general objective of the present research is the confirmation and optimization of the results of our preliminary investigation. The optimum is defined in this phase as the polymer cement concrete that provides the maximum strength. The investigation of other technically important properties, such as durability, shrinkage, creep, wear resistance, etc., as well as the properties of fresh concrete (consistency, setting and stiffening, air-entrainment properties, bleeding, etc.) is planned in future projects based on the results of this proposed study.

The specific objectives of the present Study II were:

(1) to confirm the favorable results obtained in our preliminary research with a urea-formaldehyde system in mortar and subsequently to find the optimum composition of these systems;

(2) to find the optimum application of the urea-formaldehyde system for portland cement concrete;

(3) to try out several other monomer systems in mortars in the form of aqueous solutions; and

(4) to try out several commercially available monomer systems and pre-polymer systems in mortars from the urea-formaldehyde group and from other groups.

Highlights of our previous activities on the subject are as follows:

(a) A brief summary of the history and success of polymer concrete were presented in our 1972 report.

(b) It was also pointed out there that the polymerization methods found to be successful (polymer-impregnated concrete) are unsuitable for field applications, for instance for pavement, while the simpler methods (polymer-cement concrete) had not been investigated well enough

despite their practical significance.

(c) Our preliminary investigation started on the background stated above in November, 1972. The objectives of this work were:

(1) to try out a few methods through a limited laboratory investigation that seem suitable for producting polymer-cement concretes for pavements; and

(2) to determine the strengths of such mortars and concretes.

This limited investigation was conducted in three directions listed below.

(1) experiments with monomer systems that were reported or advertised as successful in polymer-cement concrete;

(2) development on new monomer systems that may be used advantageously in polymer-cement concretes; and

(3) experiments with polymer-coated aggregates.

This preliminary investigation provided in the following conclusions:

(1) the advertised benefits of commercial polymers in concrete are usually overstated;

(2) the advantages reported in publications or independent research reports cannot, as a rule, be reached economically because large quantities of monomer systems or polymers have to be used;

(3) the use of a certain type of urea-formaldehyde pre-polymer provided higher strength increases in portland cement mortar than any other tested polymer, pre-polymer or monomer system we know of; and

(4) the application of polymer-coated aggregate appears to improve the concrete strength but the strength increase is slight.

The performed laboratory work described in the present report can

be divided into the following parts:

Portland cement mortars modified with basic urea-formaldehyde pre-polymers.

Portland cement mortars modified with acidic urea-formaldehyde pre-polymers.

Portland cement mortars modified with unheated urea-formaldehyde pre-polymers.

Systematic experiments with portland cement mortars modified with various urea-formaldehyde pre-polymers.

Portland cement mortars modified with unpolymerized urea-formaldehyde systems.

Various experiments with modified portland cement mortars.

Portland cement concretes modified with urea-formaldehyde systems.

Measurements with nuclear gauge, x-ray and electron microscope (not included in the approved work plan).

It was not the purpose of this project to investigate the underlying mechanisms concerning the effects of polymers or monomer systems on the strength development of modified mortars or concretes.

Materials and Test Methods

Commercially available not air-entrained "Phoenix" Type II portland cement produced by the Phoenix Cement Company, Clarkdale, Arizona, was used in all of our experiments, unless it is indicated otherwise. It was homogenized and stored in sealed barrels to maintain the same quality throughout the testing.

The sand used in the mortar experiments was the standard C 109

Ottawa sand.

The gravel and sand used in the concrete tests were commercially available materials from the Camp Verde, Arizona, area. The light-weight aggregates were obtained from the Flagstaff, Arizona, area.

The coarse aggregate and concrete sand were separated into fractions by sieving; then the fractions were reblended in predetermined proportions. The combined grading for the concrete experiments is as follows:

Fraction Size	Quantity
Pan - Sieve #16	25% by weight
Sieve #16 - Sieve #4	20" " "
Sieve #4 - 3/8" Sieve	20" " "
3/8" Sieve - 1/2" Sieve	10" " "
1/2" sieve-3/4" sieve	15" " "
3/4" sieve-1" sieve	10" " "
Total	100% by weight

Various chemicals (urea, formaldehyde, silane, etc.) were used. Their detailed descriptions were given in the Final Report for the first phase (Study I) of this project.

Generally accepted test methods were used for the experiments. When ASTM methods were available, they were used and are referred to in this report by the ASTM Designation number.

In order to increase the reliability of the test results, many tests were repeated.

The experiments will be discussed and analyzed in the following parts

of this report. It should be noted that only compressive strengths of the tested mortars are reported here despite the fact that in numerous cases the tensile strengths were also tested. Since, however, the tensile strengths ran parallel with the compressive strengths in each and every case, the tensile strength results are not presented in this report for the sake of brevity. The air content of the plain Ottawa-sand mortars was relatively constant, within 1 and 2.5%.

Experiments with Portland Cement Mortars Modified with Basic Urea-Formaldehyde Pre-Polymers

In this group of experiments repeated attempts were made to reproduce the best strength results obtained by similar pre-polymers in the past first phase of the project. These first experiments and results were presented in Part III of the Final Report for Study I which part was prepared essentially by Dr. L. L. Turai, Consultant to the Project. Also, an optimum formulation was recommended by him in a subsequent document dated April 30, 1974.

Accordingly, pre-polymers of the urea-formaldehyde type having the composition and degree of polymerization recommended in the Final Report of Study I were prepared in the laboratory; that is, urea, formaldehyde in the form of formalin, and water were mixed in the recommended quantities, the pH of the system was raised above 7 to the recommended level, and then the solution was kept at elevated temperature until a slight haze appeared indicati the beginning of intensive polymerization. Then these pre-polymer solutions and dispersions were added to standard Ottawa sand mortars of 1:2.75 mix pro-

portions, by weight, replacing a portion of the amount of water used in the control specimens. Two-inch cubes were made with these mortars, cured in fog room and tested for compressive strength at various ages in the standard manner. (ASTM C 109.) The flow of the mortars was also determined by the standard method described in ASTM C 109 and C 230.

The characteristics of all the used urea-formaldehyde-water systems are shown in Table I. The basic systems are, of course, those that have a pH value greater than 7. The characteristics of the mortars, including the composition, flow, density, and compressive strength, are shown in Table II. The strength results of the control specimens, that is, strengths of comparable specimens but without any urea or formaldehyde, are also presented in Table II.

It can be seen that these basic urea-formaldehyde systems have not produced strength increases when incorporated into the fresh cement mortar despite the fact that the previously recommended procedure for the preparation of the pre-polymer system was scrupulously followed. On the contrary, in the majority of the cases they reduced the compressive strength considerable: cubes with polymers have given compressive strengths in the range of 1800 psi at the age of 7 days and compared to the control strength of approximately 4000 psi. In other words, we have not been successful to reproduce the significant strength increase reported by Dr. Turai by using his formulation despite the considerable effort (more that 100 mixtures tested) that was invested into this branch of the investigation.

At the present time we have no exact explanation for these failures or for the promising and not so promising results outlined above. In general, the urea-formaldehyde system is very complex and subject to many variables in its preparation as well as the many variables inherent

in the cement system. Nevertheless, it is our conclusion that further efforts to pursue formulations based upon Dr. Turai's recommendations would probably be fruitless.

Portland Cement Mortars Modified with Acidic Urea-Formaldehyde Prepolymers

Partly because of the above-discussed ineffectiveness of the basic urea-formaldehyde prepolymers in portland cement mortars, and partly to see the possibilities with other systems, in this group of experiments again urea-formaldehyde-water systems were used but without adjusting the naturally low pH systems. Their use in the Ottawa sand mortars was similar to the procedure described above in connection with the basic pre-polymer systems.

The characteristics of these urea-formaldehyde-water systems having pH lower than 7 are again shown in Table I. The characteristics of the mortars made with these acidic polymers are summarized in Table III.

It can be seen, mainly from the Hazing Time column of Table IA, that the acidic urea-formaldehyde system polymerizes much faster than the comparable basic system. Also, the stability of the "ready" acidic prepolymer system is shorter. The strengths of mortars made with acidic systems are much higher than the strengths obtained with the basic systems and in certain cases, such as U6, the strengths with polymer were significantly higher than the control strengths. It should be noted, however, that we have tried several times to reproduce the U 6 formulation to obtain the high compressive strength again but to date the strengths of the repeated experiments were lower than the peak strengths mentioned above, although they still belong to the best results we have obtained with polymer-cement mortar combinations. (See,

for instance, mixtures U 208, 210, 211, and 249.) A related pertinent point is that a part of the high strengths of the U 6 specimens is due to the low liquid-cement ratio and the reproducibility of the strength results of such dry mixtures is necessarily quite poor.

It can be seen that in the first 100 or so mixtures the urea-formaldehyde prepolymers were added to the portland cement mortars in the quantity of 15 to 20% of the weight of the cement used. An analysis of the comparable strength results showed, however, that it may be advantageous to reduce this quantity not only from the stand point of economy but also from the stand point of mortar strength. This discovery was somewhat of a surprise because all the available publications recommend the addition of epoxy or latex or other polymers in the quantity of about 20%. Nevertheless, repeated experiments, such as the unheated U 136, 137 and 138 (Table IV), or U 149 through 153 (Tables II and IV), proved that it is not worthwhile to use the urea-formaldehyde prepolymers in quantities greater than 5% of the weight of the cement. Therefore, in further mixtures mostly such small quantities of prepolymers or monomer systems were used.

Incidentally, it appears from the density and flow values of the control and the modified mortars in Tables II through V that neither the basic nor the acidic prepolymers of urea-formaldehyde have sizeable influence on the properties of the fresh portland cement mortars, including the flow.

Portland Cement Mortars Modified with Unheated Urea-Formaldehyde Prepolymers

In this group of experiments urea-formaldehyde systems were used

with waiting time but without any heating. The practical advantage of this approach is the simpler and cheaper technology of preparation of the chemical system as compared to the prepolymers prepared with heating.

The characteristics of these urea-formaldehyde systems are again shown in Table I. The characteristics of the mortars are shown in Table IV.

It can be seen that this type of urea-formaldehyde system produces, by and large, the same strengths as the heated basic systems or the heated acidic systems despite the simpler technology. The highest strengths were obtained with mixtures U 60, 240, 245, and 250. These strengths correspond to an approximately 500 psi increase in the compressive strength up to the age of 28 days and to an approximately 1000 psi increase at the age of 90 days produced by the unheated urea-formaldehyde prepolymers which increases are not too significant. The great strength increase at the age of 90 days is surprising but well documented.

Systematic Experiments with Portland Cement Mortars Modified with Various Urea-Formaldehyde Prepolymers

As the best results presented in Tables II, III and IV show, approximately the same flows and strengths can be obtained under favorable conditions with modified portland cement mortars regardless whether the modifying system is a basic or an acidic prepolymer of urea-formaldehyde and regardless whether the prepolymerization was achieved at room temperature or by heating. This was contrary to the expectations, therefore, a group of experiments was designed to provide information concerning the effects of several variables related to the prepolymer

system on the consistency and compressive strength of standard Ottawa sand mortars. The tested variables were: Urea-formaldehyde ratio (from 1:0.7 to 1:3 mole ratio) as well as the pH of the prepolymer system (basic of acidic); the type of formalin (buffered, unbuffered); and the presence or absence of preheating the urea-formaldehyde system. The characteristics of these prepolymer systems are listed in Table IA. The characteristics of the mortars are shown in Table V.

These results support the above mentioned finding, namely that changes in the urea-formaldehyde ratio and/or in the pH of the prepolymer system produce surprisingly little changes, by and large, in the flow or strength of the mortars. The properties of the mortars with 2% polymer modification are practically the same as those with 4% modification. Buffering the formalin does not seem to produce significant changes either. Speeding up the polymerization process by heat treatment of the urea-formaldehyde system seems also unimportant from the standpoint of mortar consistency and strength. This seems to mean that the selection of a urea-formaldehyde prepolymer for the modification of a portland cement mortar should be based on the simplicity of the technology rather than on the composition of the prepolymer.

Portland Cement Mortars Modified with Monomer Systems of Urea-Formaldehyde

In this group of experiments urea, formaldehyde, and water were combined and used immediately after combination as a mixing liquid for standard Ottawa sand mortars. In other words, the system was incorporated into the mortar before any sizeable polymerization could take place. The characteristics of the monomer systems are listed again in Table I. The

characteristics of the mortars made with these monomer systems are presented in Table VI.

This system provides the highest increases in the compressive strengths of the mortar when the urea was added in the quantity of 2% of the weight of cement and the formaldehyde in the same quantity. Strength increases up to 2500 psi at the age 28 days have been measured. The 90-day strengths are also quite high. There are two additional advantages of this type of urea-formaldehyde system: (1) this is cheaper and simpler to use than any of the other tested urea-formaldehyde systems; and (2) the lack of wet curing of the mortar after 7 days seems to improve the strength.

More specifically, even our very first experiments with U - F monomer systems (U 177) gave good strength increases at the age of 14 days and later. Repeated experiments provided equally good or even better results. One can mention here series U 180Y, 191, 191s, 201, 270, 322, 331, 341, 350, 351, 352, and many others.

In order to optimize the composition of the urea-formaldehyde monomer system for mortar strength, a wide variety of compositions were tried out under different conditions. The results of one such series are shown in Figures 1 through 4 where the compressive strengths of the modified portland cement mortars at various ages are plotted as a function of urea and formaldehyde contents. These figures, and the other pertinent results, do not show any definite regularity or optimum concerning the composition of the tested urea-formaldehyde monomer systems. There are, however, several other conclusions that can be drawn from the obtained experimental data in Table VI. For instance,

(1) the addition of the monomer system in larger quantities is harm-

ful (U 356 through 359);

(2) the urea-formaldehyde monomer system is compatible at least with some of the common water-reducing admixtures (U 351 and 352), and with small amounts of sugar (U 316). Larger amounts of sugar are detrimental;

(3) portland cement mortars modified with a U - F monomer system do not seem sensitive to insufficient wet curing. Compare, for instance, the strengths of U 180Y (wet curing until testing continuously) to those of U 180Y D (dry curing after 7 days), or U 234 to U 234 D.

(4) urea-formaldehyde monomer systems seem compatible with air-entrainment (U 388), other types of portland cement (U 387), and fly ash;

(5) the effectiveness of the urea-formaldehyde monomer system is not influenced by the type and brand of the formaline (U 365 through 369, U 373 through 377, U 380, and U 382 through 384).

Portland Cement Mortars Modified with Miscellaneous Prepolymer Systems

Several modifications of the urea-formaldehyde systems as well as chemicals other than urea or formaldehyde were also tried out. The characteristics of these systems are listed again in Table I while the characteristics of the mortars modified with these chemicals are listed in Table VII and VIII.

In one group of experiments substitutes were investigated for the urea in the urea-formaldehyde system. Phenol (U 154, 157, 158), melamine (U 160, 161), propinaldehyde (U 247, 248), and resoucinol (U 289, 293, 294, and 295) were tested with formaldehyde in portland cement mortars in the usual manner. It can be seen that all these systems provided strengths lower than the good urea-formaldehyde systems.

On the other hand, the strengths of the cubes in the U 334 through 338 series in Table VII show that considerable strength increases can be

achieved by the addition of a few percent of calcium chloride to the mortar. This is, of course, not a new discovery. What is hoped for, although not documented, here, however, is that the presence of the urea-formaldehyde system will inhibit the corrosive effect of this chemical in which case the strength increasing property of the calcium chloride can be utilized within much wider limits than at present.

Good mortar strengths were also obtained in another series of experiments where the effect of the formaldehyde, without urea, was investigated. (U 318, 319, 320, 325, etc.) Despite the favorable results, this line of research was not continued partly because these tests were made at the very end of the investigation, and partly because the utilization of formaldehyde does not fall strictly within the framework of the present project.

It can also be seen from Table VII that portland cement mortars modified with the other chemicals (silane, furfuryl alcohol, triethanolamine, etc.) did not give as high strengths as the good systems of urea-formaldehyde.

Table VIII contains the characteristics of portland cement mortars that were modified with commercially available products. Most of these results are mediocre. The highest strength increases were obtained with the application of Melment L-10 so called "super-plastifier" (U 313, 314, and 315). However, even these do not surpass the best results obtained in our experiments with urea-formaldehyde combinations.

Supplementary Experiments with Modified Portland Cement Mortars

Two additional mortar experiments can be mentioned here. In one series the compatibility of the urea-formaldehyde monomer system was test-

ed with fly ash. Two kinds of fly ash were used, namely, Cholla fly ash and Four Corner fly ash, both as a substitute and as an addition to portland cement in the mortar. The simulataneous use of water-reducing admixtures was also tried out.

The characteristics of these mortars are presented in Table IX. It appears that not only is the urea-formaldehyde system compatible with fly-ash and/or water-reducing admixtures but also the early strengths of such modified portland cement-fly ash mortars are quite good.

In another test series the degree of reproducibility of the results was tested that were obtained with Ottawa-sand mortars modified with a urea-formaldehyde monomer system. Only this combination was tested statistically because it provided the highest strengths. Both the within-batch and the between-batch variations were checked for cube weights and compressive strengths at the age of 14 days. The between-batch variation of the standard mortar flow was also established for three mixtures. Individual and average test results as well as other details are presented in Table X.

It appears from this limited investigation that the reproducibility of the modified mortars is about the same as the reproducibility of the standard Ottawa-sand portland cement mortars.

Experiments with Concrete

Since those Ottawa-sand portland cement mortars gave the best results that were modified with the monomer form of the urea-formaldehyde combination, non-air-entrained concrete and microconcrete experiments were performed with this chemical system. The urea was added to the fresh concrete in the quantity of 2% of the weight of the cement and the formaldehyde in

the same quantity.

The combined grading of the concrete aggregate is given at the beginning of this report. The aggregate-cement ratio was 6.6 by absolute volume which is 5.48 by weight for a normal weight aggregate. This corresponds approximately to 600 lb/cu yd (320 kg/m^3) cement content. A parallel test series was also performed with another kind of mixture that was called microconcrete to distinguish it from the Ottawa-sand mortar. The aggregate for the microconcrete consisted of 60% material passing Sieve #16 and 40% of the #16 - #4 fraction, by weight. Here the aggregate-cement ratio was 3 by weight which corresponds to 930 lb/cu yd (470 kg/m^3) cement content. In one concrete test series coated coarse aggregate was used. The particles were washed and dried and then covered by hand with a thin layer of pre-mixed epoxy. After the hardening of this epoxy layer, the concrete was made with the coated aggregate in the usual manner. Some of the concrete mixtures were repeated with lightweight aggregate keeping the aggregate-cement ratio by absolute volume the same. All these fresh mixtures displayed good workability. The average air content of these non-air-entrained fresh concretes was 1.2% (0.5 - 2.2%).

Each of these concrete combinations was tested for consistency by using the slump test according to ASTM C 143, for compressive strength by using 4" by 8" cylinders according to ASTM C 192 and C 39, and for flexural strength by using 4" by 4" by 14" beams according to ASTM C 192 and C 78 with third-point loading. The strengths were determined at the ages of 7, 14 and 28 days, and in several cases at the age of 90 days. Altogether 18 concrete mixtures were tested out of which the typical results are presented in Table XI.

It can be seen from the presented data in this table that the same urea-formaldehyde monomer system that produced repeatedly so significant strength increases in Ottawa-sand mortars, was ineffective when it was added to concrete. More specifically, the concretes modified with 4% urea-formaldehyde monomer system gave approximately the same strengths as the comparable control concretes, regardless whether the aggregate was normal weight (P1 and P8), or lightweight (LP 1), or the coarse aggregate was coated (C 14), or whether it was a microconcrete (MP 1).

The reason is not clear why the urea-formaldehyde monomer system is so efficient in portland cement mortars while it is ineffecient in portland cement concrete. One can surmise that the reason can be the difference

(a) in the cement contents; or

(b) in the water-cement ratios; or

(c) in the bond between the cement paste and aggregate

of the portland cement mortar and the concrete. In any case, it is likely that only further research can find the reason and find a way to make the urea-formaldehyde system efficient in concrete, too.

In the meantime, it may still be possible to utilize the strength-increasing effect of the urea-formaldehyde monomer system in mortars for certain technical purposes.

Moisture and Density Determinations with a Nuclear Gauge

The reason for this experiment with the Nuclear Gauge was to determine: (a) if the gauge can be used on laboratory concrete beams of 6" X 6" X 21" size and (b) how the gauge would work for measuring moisture when a polymer is used in the concrete. This experiment was included in the originally approved work plan.

The equipment used was a Campbell Portaprobe, Nuclear Moisture Density Gauge. This gauge is produced by Campbell Pacific Nuclear Corporation, Model Number B (R) Mark II.

The measurements were performed as follows: The gauge was placed on the specimen and a series of 10 backscatter readings were taken for density. Then another series of 10 backscatter readings were taken for moisture. The density readings were averaged and then divided by the standard count, which was 1343.2; this then gives a ratio which can be found on the Backscatter Calibration Curve and converted to a density in terms of lb/cu ft. The moisture readings are done in the same manner, except the standard count is 347.5 and there is only one moisture calibration curve since all moisture measurements are backscatter. Moisture is also given in lb/cu ft.

The test results are presented in Table XII. The compositions and other technically important characteristics of the tested concretes are presented in Table XI.

The gauge seems to measure density accurately on the 6" X 6" X 21" beams. This is so probably because the broad side of the geiger tube is across the beam, therefore, making a good target for the reflected "rays"

from the samples. The moisture measurements seem to be low and the reason for this is probably that the moisture tubes are located in the opposite direction to the density tubes: they run along the edge of the specimen, therefore, they do not make good targets for the reflected rays. The moisture measurements do show a declining value with age which should be true because the specimens were taken out of the curing room at the age of 2 days. They were left out, therefore, the free moisture could evaporate causing the moisture content to drop. Looking at P3 and P4 specimens, the moisture content was higher for P3 because the water-cement ratio was higher for this specimen. The compositions of these specimens are the same as the compositions of specimens P1 and P8 respectively.

In brief, the gauge will work fine for density measurements but for moisture measurements it will give only a relative moisture when the specimen is narrower than about one ft. Therefore, for the moisture content of such narrow specimens a correction factor should be used the approximate value of which is the width of the specimen in feet. A more accurate correction factor can be determined experimentally from the ratio of the values measured on a narrow and on a standard specimen which were made of the same material and have the same moisture content. Such measurements were not performed in this project.

Since the gauge readings provide only relative values for moisture when beams of 6" X 6" cross section are used, our results do not answer the second question, namely, whether the gauge would work adequately when a polymer is used in the concrete.

X-ray Analysis of Urea-Formaldehyde Portland Cement Combinations

The primary purpose of this analysis was to see the feasibility of gaining information on inorganic cement-water matrix to polymer association. This experiment was not included in the originally approved work plan.

The analysis of samples was done by scanning of the refracted x-ray emission around a fixed target. A single x-ray source material and frequency was used. Typical diffraction spectra are shown in Figures 5, 6 and 7.

Although the scans do not seem to have perfectly stabilized base lines, they seem to show adequate experimental quality for a preliminary evaluation, as follows:

(1) In polymer and polymer-cement spectra, the number of lines appear greater below $20 = 50^{o}$ than in the cement-only spectra. In the cement-only spectra the number of lines are spread out over the entire 10° to 90° more uniformly.

(2) The total number of lines in the polymer and polymer-cement spectra is less than the total number of lines in the cement-only spectra.

(3) In all samples (smooth surface vs. powdered) the intensity of the lines in the powdered spectra is decreased with respect to the intensity of the lines in the smooth surface spectra. This would indicate a decrease in structure as a result of crushing the sample. This assumption, however, was not tested experimentally.

(4) All spectra (polymer, cement, and polymer-cement) contain a peak

complex at approximately 74° (a d-spacing of about 1.28 A.). A d-space is the interplanar distance between atoms of a crystal lattice.

(5) Conclusion #1 indicates that the d-spacings for the polymer systems are larger than the d-spacings for the cement-only systems. This is important from the standpoint of prohibiting a tight and closed polymer structure. The polymer does not appear to be filling in the cement latice "holes".

In brief, x-ray diffraction analysis seems feasible for the investigation of the composition and structure of portland cement pastes modified with urea-formaldehyde systems, although such analysis requires a considerable experience.

Examinations with Scanning Electron Microscope

The purpose of this limited work was again to see whether scanning electron microscope can be applied usefully for an investigation concerning the role of urea-formaldehyde systems in portland cement pastes. This experiment was not included in the originally approved work plan.

The equipment used was an ANR scanning electron microscope Model 1000. This unit includes a pre-aligned three lens electron optical column; goniometer X, Y, Z, rotation; tilt stage; high resolution record scope and camera; high resolution display scope; continuous (zoom) magnification from 5X to 300,000X; 30 kV adjustable power supply; analog scan system; and contrast and brightness exposure meters for automatic photography.

The examinations were performed as follows: a small piece, approximately 1g of well-hydrated Ottawa-sand portland cement mortar was selected in a random manner. This piece was dried in vacuum and covered with a

thin gold film. Then it was put into the testing chamber of the microscope, and observed visually in various spots through the high resolution display scope. Those spots that showed the best pictures were photographed through the high resolution record scope with a polaroid camera.

In our limited work, pictures were taken of a control portland cement mortar specimen, and pictures of a comparable mortar specimen but which was modified with the addition of 4% urea-formaldehyde monomer system. The magnification was 5000X and the power supply 20 kV. Two photos of the control specimen are shown in Figure 8 and two photos of the modified specimen in Figure 9.

These photos seem to indicate that the internal structure of the hydrated portland cement - water system (control) contains more fine fibres than the hydrated portland cement - water - urea - formaldehyde system. In other words, the scanning electron microscope appears to be a suitable instrument for the fundamental investigation concerning the role of urea-formaldehyde in portland cement pastes. However, any more definite or more specific statement would require a much wider investigation producing hundreds of micro-photographs.

Conclusions

1. The principal conclusion of the work presented in this report is that urea-formaldehyde monomer systems failed to produce strength increases when they were applied in portland cement concrete. This was an unpleasant surprise since

2. the addition of urea-formaldehyde combinations in the form of a monomer system to the mixing water of portland cement mortars increases the strength of the mortar significantly. As the data of Table VI show, several such combinations (U 180Y D, 201, 219 D, 322, 331, 341, 350, 351, 352, and many others) produced compressive strengths of Ottawa-sand mortars over 7000 psi (492 kg/cm^2) at the age of 28 days. Also, quite a few series provided compressive strengths close ot 9000 psi (632 kg/cm^2) at the age of 90 days. These represent a 1500 to 2500 psi (150 to 175 kg/cm^2) strength increases produced by this monomer system. The reason for the dicrepancy between the behavior of concrete and that of mortar is not clear yet.

3. The urea-formaldehyde monomer system is one of the cheapest chemicals. The technology of their application is very simple. Thus, the use of this chemical system is advantageous from an economical standpoint, too.

4. The success of the above-mentioned urea-formaldehyde system in portland cement mortars is a novelty since all the available technical publications and reports have presented negative results on polymer-cement mortars with post-mix polymerization.

5. Sizeable strength increases were also obtained in portland cement mortars with the application of formaldehyde. (Table VII: U 318,

319, 320, 325, etc.)

6. Sizeable strength increases were also obtained with the addition of calcium chloride (Table VII: U 334 through 338). It is hoped that the presence of the urea-formaldehyde system inhibits the corrosive effect of calcium chloride. However, the verification of this assumption is left for future research.

7. The tested other chemical systems (urea-formaldehyde prepolymers, commercially available polymers and prepolymers, etc.) did not produce as high strength increases as the ones mentioned above.

8. Further research on the utilization of the above-mentioned successful chemical systems in portland cement concrete is clearly indicated.

TABLE I

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP1	30g urea 50ml formalin 40ml H_2O	---	Heated to 90° in 16 min. Mixed with mortar 2 hrs. after.	
PP2	30g urea 50ml formalin 40ml H_2O	4.0	Heated to 66° in 28 min. Mixed with mortar 2.5 hrs. after.	
PP3	30g urea 50ml formalin 40ml H_2O	4.0	Heated to 34° in 15 min. Mixed with mortar 3 hrs. after.	
PP4	30g urea 50ml formalin 40ml H_2O	4.0	Heated to 50° in 36 min. Mixed with mortar 2.5 hrs. after.	
PP5	36g urea 60ml formalin 48ml H_2O	4.0	Heated to 42° in 15 min. Mixed with mortar 2 hrs. after.	
PP6	36g urea 60ml formalin 48ml H_2O	4.0	Heated to 45° in 15 min. Mixed with mortar 3 hrs. after.	
PP9	33g urea 55ml formalin 44ml H_2O	---	Kept at room temp. 1 hr.	
PP10	49.5g urea 82.5ml formalin 66ml H_2O	9.3	Heated to 41.8°. Quenched, then mixed with mortar.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP10A	45.9g urea 82.5ml formalin 66ml H_2O	3.9	Heated to 35° in 43 min. Quenched. Mixed with mortar 30 min. after.	
PP11	49.5g urea 82.5ml formalin 66ml H_2O	7.2	Heated to 93° in 77 min. Maintained for 28 min. Mixed with mortar 18 hrs. after.	
PP12	49.5g urea 82.5ml formalin 66ml H_2O	6.2	Heated to 70°. Kept at elevated temp. 3 days then mixed.	No haze when mixed with mortar.
PP13	49.5g urea 82.5ml formalin 66ml H_2O	6.2	Heated to 70°. Kept at elevated temp. 3 days then mixed.	No haze when mixed with mortar.
PP14	49.5g urea 82.5ml formalin 66ml H_2O	5.6	Heated to 81° in 13 min. Maintained for 8 min. Chilled to 27°. Mixed with mortar 3 hrs. after.	
PP15	49.5g urea 82.5ml formalin 66ml H_2O	5.7	Heated to 90° in 14 min. Maintained for 7 min. Chilled to 27°. Mixed with mortar 3.5 hrs. after.	
PP16	49.5g urea 82.5ml formalin 66ml H_2O	4.1	Heated to 90° in 11 min. Maintained for 10 min. Quenched. Mixed with mortar 30 min. after.	
PP16A	49.5g urea 82.5ml formalin 66ml H_2O	8.0	Heated to 82° in 52 min. Maintained for 29 min. Quenched, then mixed with mortar.	
PP17	49.5g urea 82.5ml formalin 66ml H_2O	8.0	Heated to 75° in 38 min. Maintained for 43 min. Quenched. Mixed with mortar 30 min. after.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP18	49.5g urea 82.5ml formalin 66ml H_2O	8.0	Heated to 93° in 30 min. Maintained for 3 min. Quenched, then mixed with mortar.	
PP19	49.5g urea 82.5ml formalin 66ml H_2O	9.0	Heated to 90° in 10 min. Maintained for 24 min. Quenched, chilled, then mixed with mortar.	
PP20	49.5g urea 82.5ml formalin 66ml H_2O	9.6	Heated to 90° in 13 min. Maintained for 18 min. Quenched. Mixed with mortar 20 min. after.	
PP21	49.5g urea 82.5ml formalin 66ml H_2O	11.1	Heated to 90° in 6 min. Maintained for 19 min. Quenched, then mixed with mortar.	
PP22	49.5g urea 82.7ml formalin 66ml H_2O	11.9	Heated to 80° in 15 min. Maintained for 17 min. Heated to 86° in 5 min. Chilled. Mixed with mortar 15 min. after.	
PP23	49.5g urea 82.5ml formalin 66ml H_2O	8.2	Temp. raised to 80°. Maintained for 20 min. Quenched, then mixed with mortar.	
PP24	49.5g urea 82.5ml formalin 66ml H_2O	9.0	Heated to 80° in 17 min. Maintained for 15 min, then mixed with mortar.	
PP26	36g urea 60ml formalin 60ml H_2O	4.1	Heated to 40° in 12 min. Quenched. Mixed with mortar 15 min. after.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP27	36g urea 60ml formalin 100ml H_2O	4.4	Heated to 47° in 14 min. Lowered to 20°, then quenched. Mixed with mortar 15 min. after.	
PP28	30g urea 60ml formalin 78ml H_2O	10	Heated to 79° in 44 min. Maintained for 73 min. Mixed with mortar 15 min. after.	
PP29	49.5g urea 66ml formalin 78ml H_2O	10	Heated to 86° in 1 hr. 36 min. Lowered to 80° then quenched. Mixed with mortar 1 hr. after.	
PP30	36g urea 60ml formalin 48ml H_2O	4.1	Heated to 42°. Maintained at 33° for 13 min. Mixed with mortar 2 hrs. after.	
PP31	36g urea 60ml formalin 48ml H_2O	4.2	Heated to 54° in 12 min. Maintained at 34° for 13 min. Mixed with mortar 3 hrs after.	
PP32	36g urea 60ml formalin 48ml H_2O	4.1	Heated to 59°. Quenched. Mixed with mortar 2.5 hrs after.	
PP34	36g urea 60ml formalin 48ml H_2O	4.4	Heated to 41°. Quenched. Mixed with mortar 2 hrs. after.	
PP35	36g urea 60ml formalin 48ml H_2O	4.3	Heated to 42° in 16 min. Quenched. Mixed with mortar 1 hr. after.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP18	49.5g urea 82.5ml formalin 66ml H_2O	8.0	Heated to 93° in 30 min. Maintained for 3 min. Quenched, then mixed with mortar.	
PP19	49.5g urea 82.5ml formalin 66ml H_2O	9.0	Heated to 90° in 10 min. Maintained for 24 min. Quenched, chilled, then mixed with mortar.	
PP20	49.5g urea 82.5ml formalin 66ml H_2O	9.6	Heated to 90° in 13 min. Maintained for 18 min. Quenched. Mixed with mortar 20 min. after.	
PP21	49.5g urea 82.5ml formalin 66ml H_2O	11.1	Heated to 90° in 6 min. Maintained for 19 min. Quenched, then mixed with mortar.	
PP22	49.5g urea 82.7ml formalin 66ml H_2O	11.9	Heated to 80° in 15 min. Maintained for 17 min. Heated to 86° in 5 min. Chilled. Mixed with mortar 15 min. after.	
PP23	49.5g urea 82.5ml formalin 66ml H_2O	8.2	Temp. raised to 80°. Maintained for 20 min. Quenched, then mixed with mortar.	
PP24	49.5g urea 82.5ml formalin 66ml H_2O	9.0	Heated to 80° in 17 min. Maintained for 15 min, then mixed with mortar.	
PP26	36g urea 60ml formalin 60ml H_2O	4.1	Heated to 40° in 12 min. Quenched. Mixed with mortar 15 min. after.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP27	36g urea 60ml formalin 100ml H_2O	4.4	Heated to 47° in 14 min. Lowered to 20°, then quenched. Mixed with mortar 15 min. after.	
PP28	30g urea 60ml formalin 78ml H_2O	10	Heated to 79° in 44 min. Maintained for 73 min. Mixed with mortar 15 min. after.	
PP29	49.5g urea 66ml formalin 78ml H_2O	10	Heated to 86° in 1 hr. 36 min. Lowered to 80° then quenched. Mixed with mortar 1 hr. after.	
PP30	36g urea 60ml formalin 48ml H_2O	4.1	Heated to 42°. Maintained at 33° for 13 min. Mixed with mortar 2 hrs. after.	
PP31	36g urea 60ml formalin 48ml H_2O	4.2	Heated to 54° in 12 min. Maintained at 34° for 13 min. Mixed with mortar 3 hrs after.	
PP32	36g urea 60ml formalin 48ml H_2O	4.1	Heated to 59°. Quenched. Mixed with mortar 2.5 hrs after.	
PP34	36g urea 60ml formalin 48ml H_2O	4.4	Heated to 41°. Quenched. Mixed with mortar 2 hrs. after.	
PP35	36g urea 60ml formalin 48ml H_2O	4.3	Heated to 42° in 16 min. Quenched. Mixed with mortar 1 hr. after.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP36	50g urea 100ml formalin	7.3	Heated to 93° in 5 min. Maintained for 1 hr. 40 min. Mixed with mortar 15 min after.	
PP40	50g urea 100ml formalin	7.7	Heated to 93° in 31 min. Maintained for 2 hrs. Mixed with mortar 30 min after.	
PP41	50g urea 100ml formalin	9.8	Heated to 93° in 31 min. Maintained for 1.5 hrs. Mixed with mortar 30 min. after.	
PP42	50g urea 100ml formalin	9.8	Heated to 93° in 1.5 hrs. Maintained for 38 min. Mixed with mortar 30 min. after.	
PP43	36g urea 60ml formalin	---	Kept at room temp. for 4.5 hrs. then mixed with mortar.	Buffered formalin
PP44	36g urea 60ml formalin	---	Kept at room temp. for 4.5 hrs. then mixed with mortar.	Buffered formalin
PP46	50g urea 100ml formalin	9.7	Heated to 93° in 32 min. Maintained for 1 hr. 50 minutes. Mixed with mortar 1.5 hrs. after.	
PP47	50g urea 100ml formalin	7.8	Heated to 93° in 17 min. Maintained 50 min. Mixed with mortar 30 min. after.	
PP52	36g urea 60ml formalin 48ml H_2O	---	Mixed at room temp. Kept at 27° for 50 min., then mixed with mortar.	
PP53	36g urea 60ml formalin 48ml H_2O	---	Same as 52 except mixed 1 hr. 10 min. later.	
PP54	50g urea 100ml formalin	7.3	Heated to 92° in 35 min. Maintained for 64 min. then, mixed with mortar.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP55	100g urea 200ml formalin	7.8	Heated to 92° in 20 min. Maintained for 1.5 hrs. then mixed with mortar.	
PP56	100g urea 200ml formalin	7.8	Heated to 92° in 6 min. Temperature maintained for 55 min. Quenched to 26°. Mixed with mortar 15 min. after 15ml extra formalin added to last 3 cubes.	
PP57	36g urea 60ml formalin 48ml H_2O	4.3*	Kept at 27° for 55 min. then mixed with mortar.	
PP58	36g urea 60ml formalin 48ml H_2O	4.3*	Kept at 27° for 55 min. then mixed with mortar.	Cloudier than 57.
PP59	100g urea 200ml formalin	7.7	Heated to 93° in 6 min. Maintained for 1 hr. 24 min. Quenched to 32°. Mixed with mortar 30 min. after.	
PP60	36g urea 30ml formalin 48ml H_2O	4.5*	Kept at room temperature for 1 hr. 20 min. then mixed with mortar.	
PP61	36g urea 30ml formalin 48ml H_2O	4.5*	Kept at room temperature for 1 hr 20 min. then mixed with mortar.	Cloudier than 60.
PP62	36g urea 30ml formalin 48ml H_2O	4.5*	Kept at room temperature for 1 hr. 20 min. then mixed with mortar. 30ml formalin was added to the mortar after regular mixing.	
PP63	36g urea 30ml formalin 48ml H_2O	4.5*	Kept at room temperature for 1 hr. 20 min. then mixed with mortar. 30ml formalin was added to the mortar after regular mixing.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP64	30g urea 50ml formalin 40ml H_2O	7.2	Heated to 93° in 7 min. Maintained for 61 min. Mixed with mortar 30 min. after. 15ml extra formalin added to last 3 cubes.	
PP65	36 urea 60ml formalin 48ml H_2O	4.3*	Mixed at room temperature and kept in ice bath.	
PP66	36g urea 60ml formalin 48ml H_2O	4.3*	Urea + H_2O mixed, diluted to 182ml, then mixed with mortar, after which the 60ml formalin was mixed to the mortar.	Delayed formalin
PP67	36g urea 30ml formalin 48ml H_2O	4.3*	Urea + H_2O mixed, diluted to 212ml, then mixed with mortar. After which the 30ml formalin was mixed to the mortar.	Delayed formalin.
PP71	100g urea 200ml formalin	6.9	Heated from 8° to 93° in 2 hrs. 27 min. Cooled with ice. Mixed with mortar 5 hours after.	
PP72	36g urea 60ml formalin 48ml H_2O	3.9	Kept at 5° for 5 hrs. 55 min. then mixed with mortar.	
PP73	36g urea 60ml formalin 48ml H_2O	4.1	Kept at 5° for 6 hrs. 10 min. Mixed with mortar after that.	
PP74	36g urea 60ml formalin 48ml H_2O	7.5	Heated to 93° in 20 min. Maintained for 65 min. Mixed with mortar 30 min. after.	
PP75	36g urea 30ml formalin 48ml H_2O	4.3	Kept at room temperature for 1 hr. 45 min. then mixed with mortar.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP76	36g urea 60ml formalin 48ml H_2O	4.3	Kept at room temperature 1 hr 20 min. then mixed with mortar.	
PP77	100g urea 200ml formalin	7.5	Room temperature mix.	No cubes were made.
PP78	50g urea 100ml formalin	7.0	pH adjusted before adding urea. Heated to 41°. In 1 hr. cooled. Mixed with mortar 20 min. after.	
PP79	100g urea 200ml formalin	7.5	Room temperature mix.	No cubes made.
PP80	100g urea 200ml formalin	4.5	Heated to 60° in 50 min. then diluted. Mixed with mortar 5 min. after.	
PP81	100g urea 200ml formalin	4.5	Heated to 65° in 50 min, then diluted. Mixed with mortar 15 min. after.	
PP82	100g urea 200ml formalin	4.5	Heated to 90° in 50 min, then diluted. Mixed with mortar 20 min. after.	
PP83	100g urea 200ml formalin	7.5	Kept at room temperature for 5 hours then diluted. Mixed with mortar 30 min. after.	
PP84	100g urea 200ml formalin	7.5	Kept at room temperature for 5 hours then diluted. 20ml extra formalin added to polymer before mixing with mortar 30 min. later.	
PP85	100g urea 200ml formalin	7.5	Kept at room temperature for 5 hours then diluted. Mixed with mortar 30 min. after dilution, after which 30ml extra formalin mixed to mortar.	
PP86	50g urea 100ml formalin	4.5	Heated to 95° in 9 min., diluted, then mixed with mortar.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP87	50g urea 100ml formalin	8.5	Heated to 90° in 13 min. Diluted after 2 hrs. then mixed with mortar.	
PP88	50g urea 100ml formalin	6.5	Heated for 2 hours, diluted, then mixed with mortar	No haze.
PP89	36g urea 30ml formalin 48ml H_2O	4.5	Kept at room temperature for 2 hrs. 5 min. then mixed with mortar.	
PP92	50g urea 100ml formalin	7.5	Heated to 90° in 1 hr and 34 min. then diluted. Mixed into mortar 30 min. after.	
PP93	60g urea 81ml formalin	7.5	Heated to 92° in 60 min. then quenched and diluted. Mixed with mortar 30 min. after.	
PP94	36g urea 30ml formalin 18ml H_2O	4.4	Kept at room temp for 1 hr. 42 min. Mortar mixed using 138ml H_2O, then 105 ml of polymer added belatedly to mortar.	Delayed polymer.
PP95	50g urea 100ml formalin	7.5	Heated to 91° in 3 hrs. 11 min. then diluted. Mixed with mortar 30 min. after.	
PP97	36g urea 30ml formalin 48ml H_2O	4.4	Kept at room temperature for 2 hrs., then mixed with mortar, after which extra 30ml formalin mixed with mortar.	
PP98	36g urea 30ml formalin 48ml H_2O	4.3	Kept at room temperature for 2 hrs. 15 min. then mixed with mortar after which extra 30ml formalin mixed to mortar.	
PP99	36g urea 60ml formalin 48ml H_2O	5.4	Kept at room temperature for 5 hrs. 20 min., then mixed with mortar.	No haze

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP100	36g urea 60ml formalin 48ml H_2O	5.7	Room temperature mix.	No cubes were made.
PP101	36g urea 70ml formalin 48ml H_2O	4.0	Kept at room temperature for 30 min., then mixed with mortar.	
PP102	50g urea 100ml formalin	7.5	Heated to 92° in 1 hr. 35 min., diluted, then mixed with mortar. 15ml extra formalin added to last 3 cubes.	
PP104	50g urea 100ml formalin	7.5	Heated to 92° in 36 min. Maintained for 2 hrs., diluted, then mixed with mortar.	
PP106	36g urea 60ml formalin	--	Mortar mixed with unheated 60ml formalin + 105ml H_2O. Delayed addition of 77ml urea solution (36g urea + 50ml H_2O).	Delayed urea.
PP107	36g urea 60ml formalin	---	Mortar mixed with 170ml H_2O. Delayed addition of 36g urea + 60ml formalin.	Delayed polymer.
PP108	50g urea 100ml formalin	7.5	Heated to 92° in 2 hrs. 48 min. Distilled for 15 min., diluted, then mixed with mortar.	
PP109	50g urea 100ml formalin	--	Heated to 92° in 2 hrs. 13 min. Quenched and diluted, then mixed with mortar.	20ml diluted acetic acid added before mixing with mortar.
PP110	50g urea 100ml formalin	7.5*	Heated to 92° in 2 hrs. 22 min. Distilled and diluted, then mixed with mortar.	Extra 15ml formalin added to last 3 cubes.
PP112	36g urea 60ml formalin 48ml H_2O	7.5	Kept at room temperature for 42 hrs. then mixed with mortar.	Buffered formalin.

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP113	36g urea 15ml formalin 85ml H_2O	5.0	Kept at room temperature for 4 hrs. 25 min., then mixed with mortar.	Low formalin.
PP114	50g urea 100ml formalin	7.5	Heated to 80° in 15 min. Maintained for 38 min., quenched and diluted, then 10ml H_3PO4 added. Mixed with mortar after.	Extra 15ml water added to last 3 cubes. Sample crosslinked with H_3PO4. Mix too dry.
PP115	15g urea 60ml formalin 48ml H_2O	5.0	Kept at room temperature for 1 hr. 20 min. then mixed with mortar.	Extreme low urea.
PP116	50g urea 100ml formalin	7.5*	Heated to 80° 12 min. Maintained for 20 min., diluted, then 10ml H_3PO4 added. Mixed with mortar after.	Sample crosslinked with H_3PO4.
PP117	50g urea 100ml formalin	7.5*	Heated to 80° in 15 min. Maintained for 22 min., diluted then 15ml H_3PO4 added. Mixed with mortar after.	-- " --
PP118	50g urea 100ml formalin	7.5	Heated to 90° in 32 min. Maintained for 35 min. then distilled and diluted. Mixed with mortar 30 min. after.	15ml extra formalin added to last 3 cubes.
PP119	50g urea 100ml formalin	7.5*	Heated to 90° in 5 min. Maintained for 65 min. then distilled and diluted. Mixed with mortar 30 min. after.	15ml extra formalin added to last 3 cubes.
PP120	50g urea 100ml formalin	7.5*	Heated to 90° in 10 min. Maintained for 65 min. then distilled, filtered, and diluted. Mixed with mortar 30 min. after.	-- " -- Some overheating occurred.
PP121	50g urea 169ml formalin	7.5	Heated to 90° in 15 min. Maintained for 1 hr. 45 min then distilled and diluted. Mixed with mortar 10 min after.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP122	1g aniline hydrochloride 130ml formalin 112ml H_2O	---	Mortar mixed with 112ml H_2O, then the formalin and catalyst were mixed to the mortar.	Sat'd formalin, aniline used as a catalyst.
PP123	50g urea 100ml formalin	7.5	Heated to 90° in 5 min. Maintained for 5 min., cooled and diluted. Mixed with mortar 20 min. after.	
PP124	36g urea 24ml formalin 48ml H_2O	7.7	Kept at room temperature for 28 hrs. diluted, then mixed with mortar. Delayed addition of 10ml formalin to complete batch.	Buffered formalin. 10ml extra formalin added to last 3 cubes.
PP125	50g urea 100ml formalin	7.5	Heated to 90° in 18min. Maintained for 2 hrs then distilled and diluted. Mixed with mortar 30 min. after.	
PP126	200g urea 400ml formalin	7.5	Heated 2.5 hrs., filtered next day, and kept at room temperature for 5 days; then diluted and mixed with mortar.	
PP127	50g urea 100ml formalin	7.5	Heated to 90° in 10 min. Maintained for 2 hrs., then distilled and diluted. Mixed with mortar 15 min. after.	
PP128	50g urea 100ml formalin	8.5	Heated to 90° in 7 min. Maintained for 70 min. then diluted. Mixed with mortar 20 min. after.	
PP129	36g urea 90ml formalin 48ml H_2O	7.8	Kept at room temperature for 4 hrs. 20 min., then diluted. Mixed with mortar 5 min. after.	Buffered formalin. 10ml extra formalin added to last 3 cubes.
PP129A	36g urea 100ml formalin 48ml H_2O	8.1	Kept at room temperature for 3 hrs. 25 min., then mixed with mortar.	Buffered formalin. 10ml extra formalin added to last 3 cubes.

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP130	50g urea 138ml formalin	4.1	Kept at room temperature for 1 hr. 40 min. then mixed with mortar.	
PP131	50g urea 203ml formalin	3.9	Kept at room temperature for 2 hrs. 5 min. then mixed with mortar.	
PP132	50g urea 100ml formalin	7.5	Heated to 90° in 10min. Maintained for 1 hr. then diluted. Combined with NH_4I. Mixed with mortar after.	
PP133	50g urea 100ml formalin	4.5*	Heated to 90° in 4 min. then diluted. Mixed with mortar after.	112ml 1M NaCl acetate soln. added.
PP134	50g urea 100ml formalin	7.5*	Heated 1.5 hrs. to 90°, then distilled and 50ml diluted. Mixed with mortar 5 min. after.	1/2 final volume used in mortar.
PP135	50g urea 100ml formalin	7.5	Heated to 90° in 11 min. Maintained for 1 hr. 19 minutes then distilled and 20ml diluted. Mixed with mortar 5 min. after.	20ml used in mortar
PP135A	50g urea 100ml formalin	7.5*	Same preparation as PP135 except 10ml was diluted. Mixed with mortar 30 min. after.	10ml used in mortar.
PP136	16.9g urea 29ml formalin 22.5ml H_2O	4.3	Kept at room temperature for 1 hr. 35 min. then mixed with mortar.	5% polymer
PP137	6.8g urea 11.35ml formalin 9ml H_2O	4.3	Kept at room temperature for 1 hr. 35 min., then mixed with mortar.	2% polymer
PP138	3.5g urea 5.7ml formalin 4.5ml H_2O	4.6	Kept at room temperature for 2 hrs. 15 min., then mixed with mortar.	1% polymer; extra 5 ml H_2O added to dissolve urea.

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP139	36g urea 50ml formalin 48ml H_2O	6.1	Heated 27 min. to 45°C then diluted. Mixed with mortar 3 hrs. after.	3 cubes made with dry batch. 11ml H_2O added to last 3 cubes. Approx. enough for medium wet.
PP145	90g urea 150ml formalin	4.5*	Heated to 45° in 15 min., then mixed with mortar (not diluted.)	No haze.
PP146	50g urea 100ml formalin	---	Heated for 15 min. to 90° then heat removed. Cooled for 60 min. then diluted and mixed with mortar.	5ml H_3PO_4 added after PP and mortar were mixed.
PP147	50g urea 122ml formalin	3.6	Kept at room temperature for 55 min. then mixed with with mortar.	1:1.8 mol ratio.
PP148	50g urea 170ml formalin	3.6	Kept at room temperature for 1 hr. 36 min. then mixed with mortar.	1:2.5 mol ratio.
PP149	50g urea 100ml formalin	7.5	Heated to 90° in 10 min. Maintained for 1.5 hrs., 1/2 batch diluted, then mixed with mortar.	8% polymer content.
PP150	50g urea 100ml formalin	7.5	Same as PP149 only 2% of PP used in mortar.	2% -- " --
PP150A	50g urea 100ml formalin	7.5	Same as PP149 only 1% of PP used in mortar.	1% -- " --
PP151	16.9g urea 29ml formalin 22.5ml H_2O	4.2	Kept at room temperature for 2 hrs. 5 min. then mixed with mortar.	5% -- " --
PP152	6.8g urea 11.35ml formalin 9ml H_2O	4.3	Kept at room temperature for 1 hr. 55 min. then mixed with mortar.	2% -- " --

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP153	3.4g urea 5.7ml formalin 45ml H_2O	4.3	Kept at room temperature for 2 hr. 30 min., then mixed with mortar.	1% polymer content.
PP154	51g phenol 36g formalin (15ml formalin) [a]	2.0	Heated to 90° in 45 min. Chilled to 70° and diluted, then mixed with mortar.	15ml formalin [a] added to mortar with the sand.
PP155	50g urea 100ml formalin	2.0	Heated 3 min. to 45°, then diluted, then mixed with mortar.	10-12 drops HCl added to adjust pH.
PP156	50g urea 100ml formalin	7.5	Refluxed 2 hrs. then diluted, catalyst added, then mixed with mortar.	20ml $ClCH_2CONa$ added as a catalyst.
PP157	94g phenol 125g formalin 4.7g $Ba(OH)_2$	6.5	Heated 2 hrs. at 60-65° then diluted and mixed with mortar.	15ml formalin added with the sand.
PP158	51g phenol 36ml formalin	6.5	Heated at 40-48° for 90 min., cooled and diluted, then mixed with mortar.	pH adjusted from acidic to basic with HCl. 15ml formalin added with sand.
PP159	50g urea 100ml formalin 125ml H_2O 20dr. H_3PO_4	3.0	Urea + H_2O heated to 40°C then acid + formalin added. Heated 1 min. until haze, then mixed with mortar.	
PP160	63g melamine 150ml formalin	4.0	Heated to 83° in 12 min. Maintained for 48 min. Cooled to 40° and filtered. After 1 hr setting, diluted with 60ml formalin and .75ml HCl for adjusting pH. Mixed with mortar 1 hr. 15 min. after.	
PP161	63g melamine 122ml formalin	4.0	Refluxed at 85° for 40 min., then 50 ml formalin and 5 ml HCl added for adjusting pH. Mixed with mortar after dilution.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP162	125g Am. Cyanimid Resin #52	2.0	Mixed with 1 ml HCl. Diluted to 242ml and mixed with mortar 5 min. after.	No cloudiness.
PP163	125g Am. Cyanimid Resin #39	2.0	Mixed with 5.5ml HCl. Diluted 2 hrs. later and mixed with mortar immediately after.	
PP164	50g urea 100ml formalin	7.8	Kept at 80° for 45 min. then diluted and mixed with mortar.	Modified with 2g resorcinol.
PP165	125g Am. Cyanimid Resin #39 5g urea	1.0	Blended with 6ml HCl. Stored 24 hrs. then diluted and mixed with mortar.	
PP167	60g urea 81ml formalin	5.5*	Heated to 73° in 25 min. then diluted and mixed with mortar.	No formaldehyde odor.
PP168	60g urea 81ml formalin	5.5*	Heated to 57° in 15 min. then diluted and mixed with mortar.	
PP169	60g urea 81ml formalin	5.5*	Heated to 73° in 25 min. then diluted and mixed with mortar.	
PP170	36g urea 60ml formalin	2.0	Kept at room temperature for 10 min., then diluted and mixed with mortar. Phosphoric acid added to adjust pH.	
PP171	60g urea 121ml formalin	7.5	Brought to reflux in 10 min. and heated for 1 hr. 11ml diluted and mixed with mortar 30 min. after.	No haze.
PP172	60g urea 242ml formalin	7.5	Heated to 90° in 10 min. Maintained for 1 hr. 11ml diluted and mixed with mortar 20 min. after.	
PP173	60g urea 165ml formalin	7.5	Heated to 90° in 15 min. Cooled 1 hr. then 11ml diluted. Mixed with mortar 1 hr. 20 min. after.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP174	60g urea 330ml formalin	7.5	11ml diluted. Mixed with mortar 23 hrs. after.	
PP175	36g urea 60ml formalin 48ml H_2O	4.0	Heated 15 min. to 43° then diluted. Mixed with mortar 15 min. after.	
PP176	50g urea 330ml formalin	7.5	Heated 10 min. to 90°. Maintained 1 hr. then diluted. Mixed with mortar 30 min. after.	1/4 mole ratio strong formalin smell.
PP177	11g urea 30ml formalin 205ml H_2O	5.5*	Room temperature polymer. Mixed with mortar directly after preparation.	
PP178	11g urea 30ml formalin 205ml H_2O	1.8	Room temperature polymer. Mixed with mortar immediately after preparation. 3 drops phosphoric acid to formalin.	
PP179	11g urea 30ml formalin 50ml H_2O	5.5*	Kept at room temperature for 20 min., diluted, then mixed with mortar.	8ml extra formalin added to last 3 cubes.
PP180	5.5g urea 15ml formalin	5.5*	Room temperature polymer. Diluted and mixed with mortar immediately after preparation.	5ml extra formalin added to last 3 cubes.
PP180Y	5.5g urea 15g formalin	---	Urea was dissolved in 25ml H_2O, the formalin was added, then polymer was diluted and mixed with mortar.	See PP180.
PP181	5.5g urea 15ml formalin	3.5	Room temperature polymer. Mixed with mortar immediately after preparation. Phosphoric acid added to water.	
PP183	120g urea 162ml formalin	7.5	Heated to 80° in 15 min. Maintained 1 hr. Mixed with mortar immediately after.	1/1 mole ratio.

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP184	120g urea 162ml formalin	7.5	Heated to 75° in 15 min. Maintained for 45 min. Mixed with mortar the following day. KOH added.	
PP186	50g urea 100ml formalin	8.5	Heated to 90° in 15 min. Maintained for 90 min. then mixed with mortar.	
PP186A	50g urea 100ml formalin	8.5*	Same batch as PP186 except mortar was made 3 days later with 4% polymer.	8ml extra formalin added to last 3 cubes.
PP187	50g urea 100ml	8.5	Same as PP186 but refluxed for 30 min. and filtered next day before mixing with mortar.	
PP189	11g urea 30ml formalin 50ml H_2O	5.5*	Kept at room temperature for 2 hrs. then diluted and mixed with mortar.	8ml formalin added to last 3 cubes.
PP191	11g urea 30ml formalin	---	Same as PP179 except that 11g urea dissolved in 30ml formalin and 10 min. later 2 drops phosphoric acid were added to it at room temperature. 5 min. later it was diluted to 220g and mortar was made.	8ml extra formalin added to last 3 cubes.
PP195	75g urea 138ml formalin	7.5	Heated to 90° in 40 min. Maintained 30 min. then diluted. Mixed mortar with 177ml H_2O + 15ml formalin and a delayed addition of 17ml of PP195 + 33ml H_2O.	Delayed polymer, 2.8% solids on cement.
PP198	185g urea 255ml formalin 485ml H_2O	7.5	KOH added. Required 20min. for 90° temperature at 95% rheostat setting then held at reflux with rheostat on 40-50. 45min. at 90° reflux.	1/1 mole ratio. 2% used in mortar.
PP200	50g urea 100ml formalin	2.5	Heated to 40°. 14 drops HCl in 2ml H_2O added and mixture was stirred. Hazed 20 sec. after adding acid. Diluted and mixed with mortar.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP201	11g urea 30ml formalin	5.5*	Same as PP177 except 133ml H_2O was added instead of 155ml. Total volume of liquid was 220ml.	Dry consistency.
PP202	50g urea 100ml formalin	3.0	Heated to 60°, cooled to 45°, then 2 drops HCl in 2 ml H_2O was mixed into the polymer. It was diluted and mixed with mortar.	
PP204	50g urea 100ml formalin	3.5	Heated to 45° in 15 min. Then acid added, diluted with water and mixed with mortar.	
PP205	50g urea 100ml formalin	4.0	Heated to 45° in 10 min. Then HCl added, diluted and mixed with mortar.	No haze.
PP206	50g urea 100ml formalin	4.5	Heated to 45° in 10 min. Then HCl added, diluted and mixed with mortar.	
PP208	50g urea 100ml formalin	3.0	Heated to 45° in 10 min. Then 15 drops HCl were added, the mixture was diluted and mixed with mortar.	Different formalin from PP208.
PP209	11g urea 30ml formalin	5.5*	Same as PP177 except .2g aniline hydrochloride was added with 10ml H_2O to the formalin. Then it was diluted and mixed with mortar.	
PP210	60g urea 30ml formalin	2.0	Heated to 40° in 5 min. Then HCl was added, mixture was diluted and mixed with mortar.	
PP211	60g urea 45ml formalin	2.5	Heated to 45° in 10 min. then acid added,diluted and mixed with mortar.	5% solids on cement.
PP212	60g urea 45g formalin 2g ethyleneglycol	2.0	Glycol was added and heated to 45° in 10 min. Acid added, diluted and mixed with mortar.	Ethylene glycol is a pre-polymer stabilizer.
PP213	2g ethylene glycol	2.0*	Ethylene glycol diluted and mixed with mortar.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP214	ethylene glycol	2.0*		5% ethylene glycol on the cement.
PP215	11g urea 30ml formalin	5.5*	Same as PP209 except there was a 5 min. waiting time after the 30ml formalin and the aniline hydrochloride were mixed. After that the urea was mixed in, diluted and mixed with mortar.	
PP217	27.5g ethylene glycol 214.5g H_2O 15 drops HCl	---	Polymer was made then mixed with mortar.	
PP218	11g urea 30ml formalin	5.5*	Same as PP177 except 266ml H_2O was used instead of 242ml.	Wet consistency.
PP219	11g urea 30ml formalin	5.5*	Same as PP177 except buffered formalin was used: $MgCO_3$ pretreated to pH 7-8.	
PP220	185g urea 255g formalin 485g H_2O	3.1	30g of 24 hr. old polymer was acidified, diluted and mixed with mortar just as precipitation started.	Similar to PP198.
PP221	185g urea 255g formalin 485g H_2O	3.1*	30g of 24 hr. old polymer was acidfied, diluted and added to mortar a few seconds before haze started.	Similar to PP198. Some cement paste setting noted.
PP222	185g urea 255g formalin 485g H_2O	3.1*	30g of 24 hr. old polymer was acidified and held 1 min. before dilution to first haze, then 1 min. after dilution to good haze level before cement addition.	Similar to PP198.
PP224	11g polyethylene glycol	---	2% polyethylene glycol on cement diluted and mixed with mortar.	
PP227	5.5g ethanol	---	1% ethanol diluted and mixed into mortar.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP228	80g urea 232g formalin 5.5g ethanol	7.5	1% ethanol and 2% polymer on cement diluted and mixed into mortar.	1/2 mole ratio.
PP229	80g urea 232g formalin 5.5g ethanol	2.5	1% ethanol, 2% polymer on cement and 10 drops HCl hazed in 15 sec, diluted and was mixed with mortar.	
PP231	60g urea 162g formalin	4.5	2% polymer on cement diluted and mixed into mortar 5 days after preparation.	
PP232	100g urea 290g formalin	7.5	4% polymer on cement diluted and mixed with mortar.	8ml formalin acidified with 2 dr. of conc. H_3PO4 was added to last 3 cubes.
PP233	100g urea 290g formalin	7.5*	4% of polymer was diluted. .2g aniline HCl was added in 10ml H_2O, and mixed with mortar.	
PP234	5.5g urea 30ml formalin	5.5*	Room temperature polymer. Diluted and mixed with mortar immediately after preparation.	
PP237	22g Am. Cyanimid Resin #52	2.0	Sample was treated with 36 drops HCl 24 hrs. before dilution. No hazing occured until it was diluted with tap water directly before mixing with mortar.	
PP238	60g urea 162g formalin 5g urea	4.5*	40g polymer + 5g urea were combined,diluted and mixed into mortar.	
PP239	60g urea 162g formalin 5g urea	4.5*	40g polymer + 5g urea + 18 drops HCl mixed together and then mixed into mortar.	Acidified PP was clear until tap water & urea added.
PP240	11g urea 30ml formalin	---	.2g aniline hydrochloride dissolved in 11.5g H_2O, and 30ml formalin in 110.3g H_2O were combined and added immediately to mortar.	See PP209.

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP241	11g urea 30ml formalin	---	Same as PP240 but .4g aniline hydrochloride was used in 10g H_2O.	
PP242	80g urea 232ml formalin	8.5	33g polymer combined with 1g para-toluene sulfonic acid. Kept at 105° until haze, then diluted and mixed immediately with mortar.	
PP243	45g urea 43g propinaldehyde 25g H_2O	8.5	1/1 mole ratio urea/propinaldehyde prepolymer. Made Made to pH 8.5 with KOH. Heated 90 min. at 85°. Refluxing started at 60-70°,	No cubes made.
PP244	30g urea 29g propinaldehyde 25g water		1/2 mole ratio urea/propinaldehyde prepolymer. 2NKOH added, heated at 85° for 120 min., diluted and mixed.	No cubes made.
PP245	80g urea 232g formalin 50g TiO_2	---	TiO_2 powder mixed dry then 68g of polymer was diluted and added. Polymer mixture was then mixed with mortar.	Mix xeemed dry but had good flow.
PP246	allylic alcohol	---	2% allylic alcohol mixed with mortar. Very strong disagreeable odor.	Much of the chemical was volabilized in mixing.
PP247	45g urea 43g propinaldehyde	8.5*	2% 1/1 mole ratio urea/propinaldehyde diluted and mixed with mortar.	Similar to PP243.
PP248	30g urea 29g propinaldehyde	8.5*	2% 1/2 mole ratio urea/propinaldehyde diluted and mixed with mortar.	Similar to PP244.
PP249	45g urea 183g formalin	3.0	2% of polymer + .4g phloroglucerol warmed gently then diluted and mixed with mortar.	Heavy haze in water.
PP250	11g urea 30g formalin .8g aniline hydrochloride	---	The aniline hydrochloride was dissolved in H_2O then the urea and formalin were added, and mixed with mortar.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP251	10g ethylene diamine 10g formalin	---	Chemicals were mixed,diluted, then combined with mortar immediately.	
PP253	80g urea 232g formalin	---	11g polymer was mixed into mortar.	
PP254	80g urea 232g formalin	---	11g polymer mixed into mortar with 50g MnO_2 used in place of 50g of sand.	See PP245.
PP255	60g urea 137g formalin 44g furfuryl alcohol.	8.0	Heated 2 hrs. at 90°. 40g H_2O removed by vacumme. 5 drops acetic acid, 44g furfuryl alcohol, .55g trethanolamine added and mixture was heated 30 min. more at 90°. 2% was on cement was mixed with mortar.	Calcium phosphate-ammonium bromide catalyst.
PP256	11g urea 15g formalin	5.5*	Similar to PP177 except 1% formaldehyde was used instead of 2%.	
PP257	5.5g urea 74ml formalin	5.5*	Same as PP177 except for the differences in urea and formalin.	
PP258	80g urea 232g formalin	3.4	33g polymer with 3 drops HCl allowed to stand 6 min to light haze then diluted and mixed with mortar.	
PP259	80g urea 232g formalin	3.6	33g polymer with 18 drops acetic acid allowed to stand 12 min. to light haze then diluted and mixed with mortar.	
PP260	80g urea 232g formalin	3.1	33g polymer with 2 drops H_3PO_4 allowed to stand 12 min. to haze then diluted and mixed with mortar.	
PP261	80g urea 232g formalin	2.1	33g polymer with 1 drop H_2SO_4 diluted, let stand 8 min. until haze, then mixed with mortar.	
PP262	27.5g urea 15ml formalin	---	Similar to PP177 except for the different polymer weights.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP263	16.5g urea 15ml formalin	---	Similar to PP177 except for the different polymer weights.	
PP264	22g urea 15ml formalin	---	Similar to PP177 except for the different polymer weights.	
PP265	22g urea 30ml formalin	---	Similar to PP177 except for the different polymer weights.	
PP266	11g urea 60ml formalin	---	Similar to PP177 except for the different polymer weights.	
PP267	22g urea	---	Dissolved in water and mixed with mortar.	
PP268	16.5g urea 45ml formalin	---	Similar to PP144 except for the different polymer weights.	
PP269	16.5g urea	---	Dissolved in water and mixed with mortar.	
PP270	5.5g urea 60ml formalin	---	Similar to PP177 except for the different polymer weights.	
PP271	2.7g urea 30ml formalin	---	Similar to PP177 except for the different polymer weights.	
PP272	5.5g urea 45ml formalin	---	Similar to PP177 except for the different polymer weights.	
PP273	glycerol formate	--	11g of a 70% solids water solution of glycerol formate prepared by reacting formalin with glycerol at 30°-40°. 2% total weight polymer on cement.	
PP274	30g urea 89.1g formalin	7.5	Polymer was refluxed 2 min. at 90° then allowed to cool with stirring to 30°, then 12g additional urea was dissolved in it.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP275	11g urea 45ml formalin	---	Similar to PP177 except for a different polymer weights.	See PP271.
PP276	16.5g urea 30ml formalin	---	Similar to PP177 except for the different polymer weights.	
PP281	5.5g urea 30ml formalin	---	Similar to PP177 except that the urea was dissolved in 50ml H_2O then mortar was made with 162ml H_2O + 15ml formalin. After 30 sec waiting time the 50ml urea solution was mixed with 15ml formalin and the mixture was added to the mortar.	Delayed chemicals.
PP282	11g urea 30ml formalin	---	Similar to PP177 except that mortar was made with 162ml H_2O and 30ml formalin. After 30 sec waiting time 11g urea dissolved in 50ml H_2O was mixed into the mortar.	Delayed urea.
PP283	11g urea 30ml formalin	---	Similar to PP282 except that mortar was made with 11g urea urea dissolved in 212ml H_2O. After 30 sec waiting time 30ml formalin were mixed into mortar.	Delayed formalin.
PP286	2.25g urea 30ml formalin	---	Similar to PP177 except for different polymer weights.	
PP288	75g urea 102ml formalin	8.0*	2% polymer on cement catalyzed with 2g resorcinol.	
PP289	27g resorcinol 81g formalin	---	Resorcinol/formaldehyde system made by heating 10 min. to boiling then cooling slowly. Diluted and mixed with mortar.	3% polymer on cement.
PP293	27g resorcinol 81g formalin	---	Resorcinol/formalin + 2g sodium phthalate.	3% polymer on cement.

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP294	11g resorcinol 30ml formalin	---	Resorcinol/formalin mixed, heated 10 min. to 90° then cooled; 1g sodium paratoluene sulfonic acid added, diluted and mixed with mortar.	2% polymer on cement.
PP295	27g resorcinol 81g formalin	---	Made like PP294, catalyzed by later addition of .6 mole formaldehyde to the mixed mortar.	Delayed formalin.
PP296	50g urea 100ml formalin	---	Polymer treated with MnO_2 and allowed it to stand 2 weeks before diluting, and mixing it with mortar.	Didn't appear to be crosslinked. 3% polymer.
PP297	G.E. SC-50 Sodium methyl siliconate	---	1% G.E. SC-50 sodium methyl siliconate on cement diluted and mixed with mortar.	
PP298	Acetaldehyde	---	1% acetaldehyde on cement diluted and mixed with mortar.	
PP299	Propinaldehyde	---	1% propinaldehyde on cement diluted and mixed with mortar. The aldehyde was temporarily dispersed by shaking up just before addition.	
PP300	Formic Acid	---	1% formic acid on cement diluted and mixed with mortar.	
PP301	Formaldehyde	---	1% formaldehyde (as formalin) diluted and in medium wet mixed with mortar.	
PP302	100g furfuryl alcohol 1g conc H_3PO_4	5.5	Mixture was heated 1 hr. at 100°C. It was neutralized after cooking with about 4ml 20% NaOH to pH 5-6. This mixture was hot vacuumed for 1.5 hrs. at 30°-50° to remove H_2O.	No cubes made.
PP303	150g furfuryl alcohol 75g formalin 12ml 20% H_3PO_4	5.0	Mixture was refluxed at 90°-100° for 1 hr. It was then cooled to 70° and neutralized with about 4ml 20% NaOH to pH5.	No cubes made.

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP304	Urea Acetaldehyde	7.5	Mixture was refluxed 90 min. at 90°. pH was brought 7.5 with 2n KOH.	No cubes made.
PP305	11g urea 30ml formalin 205ml H_2O	---	Another repitition of U177.	27 cubes made for statistical evaluation.
PP306	6ml methyl alcohol 236g H_2O	---	1% methyl alcohol mixed with mortar.	
PP307	6ml ethyl alcohol 236g H_2O	---	Same as PP306 except that 6ml of ethyl alcohol was used.	
PP308	150g furfuryl alcohol 25g formalin 12g 20% H_3PO4	---	Unheated mixture catalyzed with ptoluene sulfonic acid. 1% catalyst added in a few ml of H_2O. 20% by weight binder in aggregate mix of 600G 0-16 mesh, 600g 4-16 mesh, 700g 4-3/8". Mixture hand mixed and tamped in cube molds pre-coated with parafin wax/oil.	No cubes made.
PP309	100g furfuryl a. 1g conc H_3PO4	5.5	Polymer with .2g ptoluene sulfonic acid catalyst diluted and mixed with mortar.	3% furfuryl alcohol on cement.
PP310	150g furfuryl alcohol 25g formalin 12g 2% $ZnOl_2$	---	Like PP308 except the catalyst was 2% zinc chloride added to the water.	No cubes made.
PP311	150g furfuryl alcohol 75g formalin	5.0	Chemicals with 1% $ZnCl_2$ catalyst diluted and mixed with mortar.	3% chemicals on cement.

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP312	Hyline/tretrahydro-furan hexamethylene diamine	---	2% Hyline/tretrahydrofuran (preboiled) in medium wet mortar batch. Made with 1% aqueous hexamethylene diamine instead of H_2O. The mortar was made with water and the isocyamate prepolymer was added to it after mixing.	
PP313	22g Melment L-10	---	40% liquid/cement made with 22g H_2O replaced by 22g Melment L-10 (American Hoechst).	Dry consistency. "Melment" is a 20% solids basic formaldehyde/ melamine polymer solution sold for addition to concrete.
PP314	33g Melment L-10	---	187g H_2O and 33g Melment L-10 mixed with mortar.	
PP315	44g Melment L-10	---	176g H_2O and 44g Melment L-10 mixed with mortar.	
PP316	11g urea 30ml formalin .55g sugar	5.5*	Same as PP177 except that .55g sugar was added to the diluting water.	
PP317	11g urea 30ml formalin 205ml H_2O	5.5*	Remake of PP177 using new cement.	
PP318	16.5g formalin	---	Diluted and mixed with mortar.	1% formaldehyde on cement.
PP319	16.5g formalin 1.1g formic acid	---	Polymer mixed, diluted and mixed with mortar.	
PP320	16.5g formalin 1.7g methyl alcohol	---	Polymer mixed,diluted and mixed with mortar.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP321	11g urea 30g formalin	4.5	2% urea and 2% formaldehyde in medium wet batch. Mixed and diluted immediately like PP177 but stock formalin was used with pH adjusted to 4.5 with formic acid.	
PP322	11g urea 30g formalin	4.0	SAme as PP321 except formalin pH was adjusted to 4.0.	
PP323	11g urea 30 formalin	3.5	Same as PP321 except formalin pH was adjusted to 3.5.	
PP324	11g urea 30g formalin	3.0	Same as PP321 except formalin pH was adjusted to 3.	
PP325	30g formalin 0.55g sugar 236ml H_2O	---	Sugar dissolved in H_2O. Just before mixing mortar formaldehyde is added to the solution.	
PP326	11g urea 5.5g orzan 30ml formalin	---	Urea in 30ml H_2O and orzan in 20ml H_2O were combined and the formalin was added. Then entire mixture was diluted and mixed with mortar.	
PP327	5.5g urea 15ml formalin	---	Polymer was mixed and added to mortar immediately.	
PP328	22g urea 60ml formalin	---	Polymer was mixed and added to mortar immediately.	
PP329	11g urea 30ml formalin	3.5	Formalin pH adjusted with concentrated H_2SO4. Polymer was then mixed and added to mortar.	
PP330	11g urea 30ml formalin	3.5*	Like PP329 but with concentrated H_3PO4.	
PP331	11g urea 30ml formalin	3.5*	Like PP329 but with concentrated H_3PO4.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP332	11g urea 30ml formalin	3.5	Like PP329 but with concentrated acetic acid.	
PP333	11g urea 15g $CaCl_2$	5.5*	Like PP177 but with $CaCl_2$ solution instead of formalin	No cubes made.
PP334	16.5g $CaCl_2$	---	$CaCl_2$ dissolved in 242ml H_2O and mixed with mortar.	
PP335	11g $CaCl_2$	---	$CaCl_2$ dissolved in 242ml with H_2O and mixed with mortar.	
PP336	.55g sugar 11g urea 11g $CaCl_2$	---	Polymer was mixed,diluted and mixed with mortar.	
PP337	11g urea 11g $CaCl_2$	---	Like PP336 but without sugar.	
PP338	16.5g $CaCl_2$ 1.1g sugar	---	Same as PP334 except sugar was added to liquid.	
PP339	25g urea 72.5ml formalin	7.5	Kept at room temperature for 24 hrs., then diluted and mixed with mortar.	
PP340	11g urea 42ml formalin	5.5*	Like PP177 but with late addition of formalin. 12ml additional formalin added after "remixing" interval. 9 cub batch.	
PP341	11g urea 30ml formalin	5.5*	Like PP177. 9 cube batch.	
PP342	10% sulfuric acid ethylene glycol	---	1% of the polymer mixture was made up 3 hrs. earlier and stored at room temperature.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP343	5.5g crown zetterbach orzan 5	---	1% of liquid in medium wet mix.	No cubes made.
PP344	Cloud Hill K-36	---	1% Cloud Hill K-36 in medium wet batch.	
PP345	11g urea 30ml formalin $MgCO_3$	5.5*	9 cube batch like PP177 made with $MgCO_3$ pre-treated formalin.	
PP346	11g urea 42ml formalin $MgCO_3$	5.5*	9 cube batch like PP177 but with 12ml $MgCO_3$.	
PP347	1% liquin	---	Total liquid 190ml. Tended to "Walk" out of mixture.	Broke in molds.
PP348	1% G.E. SC-50	---	Polymer mixed in medium wet mortar batch.	
PP349	1% triethanolamine		Polymer mixed in medium wet mortar batch.	
PP350	11g urea 42ml formalin	5.5*	Like PP177. Repeat of PP340.	
PP351	11g urea 30ml formalin 5.5ml 300-R	5.5*	Like PP177 except that 5.5g fx-32 plastifier was added to mortar.	
PP352	11g urea 30ml formalin 1.5ml 300-R	5.5*	Like PP177 except that 1.5ml of 300-R plastifier was added to mortar. Total liquid = 220ml.	
PP354	1296g CH_2O urea	6.0	CH_2O raised to 800 then urea was added. pH raised to 6 with KOH. Cubes made with 2% polymer based on cement weight.	

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
PP355	16.5g $CaCl_2$	---	Repeat of PP334.	
PP356	37g urea 100ml formalin	---	5% urea mixed with 5% formalin and diluted to 325ml (9 cube batch).	
PP357	5 5g urea 150ml formalin	---	Like PP356 except mixed 7.5% urea with 7.5% formalin (9 cube batch).	
PP358	37 g urea 100ml formalin	---	10% concentration of both urea and formalin. 9 cubes.	
PP359	37 g urea 100ml formalin	---	12.5% concentration of urea and formalin.	
PP360	11g urea 30ml formalin methanol	5.5*	Same as PP177 but using the DuPont sample of formalin with 7% methanol content.	
PP361	15ml DuPont formalin	---	15ml DuPont formalin (7% methanol) diluted to 242ml mixed into mortar.	
PP362	11g urea 30ml formalin	5.5*	Same as PP 177 but using the DuPont sample of formalin with 11% methanol content.	
PP363	11g urea 30ml formalin	5.5*	Same as PP177 but using DuPont sample 44% LM.	
PP364	11g urea 30ml formalin	5.5*	Same as PP177 but using Dupont sample 37% LM.	

* Esximate

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
pp 375	11g urea 30ml formalin	5.5*	Same as pp 177 but formalin was Hercules 37M10-12	
pp 376	11g urea 30ml formalin	5.5*	Same as pp 177 but formalin was Hercules 37U.	
pp 377	11g urea 30ml formalin	5.5*	Same as pp 177 but formalin was Hercules 44U.	
pp 379	11g urea 30ml formalin 1.1g WRDA	5.5*	220.1ml total. Same as pp 177 only with water reducing agent addition.	
pp 380	11g urea 21ml formalin	5.5*	Same as pp 177 but formalin was from Grace 52.26% formaldehyde.	
pp 381	11g urea 30ml formalin	5.5*	Repeat of pp 177	
pp 382	11g urea 30ml formalin	5.5*	Same as pp 177 only formalin was Borden 37% stabilized.	
pp 383	11g urea 30ml formalin	5.5*	Same as pp 177 only formalin was Borden 37% unstabilized.	
pp 384	11g urea 30ml formalin	5.5*	Same as pp 177 only formalin was Borden 37/7%.	

*Estimate

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
pp 365	11g urea 30ml formalin	5.5*	Same as pp 177 but formalin was Tennaco Methanol Free Stable.	
pp 366	11g urea 30ml formalin	5.5*	Same as pp 177 but formalin was 7% MEOH sample.	
pp 367	11g urea 30ml formalin	5.5*	Same as pp 177 but formalin was Tennaco 9-12% MEOH sample.	
pp 368	11g urea 30ml formalin	5.5*	Same as pp 177 but formalin was DuPont 7% methanol	
pp 369	14.8g urea 40ml formalin methanol	-------	Similar to pp 177 but DuPont 7% methanol was used.	9 cube batch
pp 370	11g urea 30ml formalin	5.5*	Repeat of pp 177.	
pp 371	11g urea 30ml formalin	5.5*	Repeat of pp 177.	
pp 372	11g urea 30ml formalin	5.5*	Repeat of pp 177.	
pp 373	2.75g urea 11ml formalin	-------	Urea was mixed with formalin then polymer was diluted and mixed with mortar.	

*Estimate

TABLE I (Cont.)

Characteristics of the Chemical Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
pp 385	27.5ml Borden Uf-71	-------	6 - cube batch using 27.5ml Borden's Uf-71 and 214.5 H_2O.	
pp 386	27.5ml Borden Uf-85	-------	Same as pp 385 only Borden's Uf-85 was used.	
pp 387	11g urea 30ml formalin	5.5*	Repeat of pp 177 using type III cement.	
pp 388	11g urea 30ml formalin Darex	5.5*	Repeat of pp 177 only 238.3ml polymer was used with the addition of 3.7ml Darex	

*Estimate

TABLE I (cont.)

Characteristics of the Urea-Formaldehyde Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
CD1	508.5g cement 917.1g pan #16 610.2g #16-#4 240.6ml H_2O	---	Control cubes made with aggregate. Cubes made in the usual way.	
CH-1	550g cement 1512.5g sand 242ml H_2O	---	Heat treated control cubes. 18 hrs. after preparation the cubes were removed from the molds and put into a room temp. water bath. Then the water temp. was raised by gas heating to 85° in 3 hrs. and 85° was maintained for 3 hrs. The cubes and water were then cooled to 42°. The first cubes were broken 3 hrs. after heat was removed.	
CP1	11g urea 30ml formalin	---	Polymer was mixed and put into cube mixture immediately.	Cubes made with: 508.5g cement 917.1g pan #16 610.2g #16-#4 210.6ml H_2O
CP2	11g urea 30ml formalin	---	Polymer was mixed and put into cube mixture immediately.	cubes made with: 508.5g cement 763.7g pan #16 763.7g pan #16-#4 240ml H_2O
CP3	11g urea 30ml formalin	---	Polymer mixed and put into cube mixture immediately.	Cubes made with: 508.5g cement 610.2g pan #16 917.1g #16-#4 240ml H_2O
F1	15ml formalin	---	1% formalin. Standard mortar.	
F2	42ml formalin	---	2.8% formalin. Standard mortar	
F3	15ml formalin	---	Mortar was mixed using 220ml H_2O. After regular mixing interval a solution of 15ml formalin + 7ml H_2O was added.	
F4	15ml buffered formalin	---	1% buffered formalin. Standard mortar mix.	

TABLE I (cont.)

Characteristics of the Urea-Formaldehyde Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
F5	10ml formalin	---	.67% formalin. Standard mortar mix.	
F6	27.5ml formalin	---	2 % formalin. Standard mortar mix.	
F7	27.5ml formalin	---	2% formalin in dry mix mortar batch.(220ml total)	
F8	15ml buffered formalin KOH	9.5	pH of formalin raised from 7.7 to 9.5 with a few drops of KOH. 1% formalin. Standard mortar mix.	
F9	15ml formalin 3drops H_3PO_4	2.7	pH of formalin lowered from 3 to 1.7 with 3 drops of H_3PO_4. 1% formalin. Standard Mortar mix.	
K1	8.3g K36	---	K36 Booster cubes. Standard mortar made with 8.3g K36 + 238ml H_2O.	
K2	8.3g K36	---	K36 Booster cubes. Standard mortar made with 8.3g K36 + 215ml H_2O for dry mix(220ml).	
S1	55g urea	---	55g urea put into standard mortar mix.	
S2	55g urea	---	Repeat of S1	
S3	55g urea	---	Made as usual except using 180ml H_2O to start, then urea + H_2O solution were added.	
S4	5.5g urea	---	1% urea in standard mortar mix.	
S5	27.5g urea	---	5% urea in standard mortar mix.	
S6	11g urea	---	2% urea in standard mortar mix.	
SI1	0.2g $CaCl_2$ 1.8ml formamide 11g sodium silicate	---	$CaCl_2$ was dissolved in H_2O and diluted to 230ml with H_2O. Then 1.8ml formamide was added followed by 11g sodium silicate Mortar made immediately.	

TABLE I (cont.)

Characteristics of the Urea-Formaldehyde Systems Used

Polymer No.	Composition of the System	pH	Method of Preparation	Remarks
SL1	1ml Silane A-186	---	Mortar was made using 221ml H_2O. After 1 min. Silane A-186 (mixed with 20ml H_2O) was added.	
SL2	1ml Silane A-187 defoamer	---	Same as SL1 except: a) Silane A-187 was used; and b) 2ml defoamer was added.	
SL3	1ml Silane A-1100	---	Same as SL1 except that Silane A-1100 was used.	
SL4	1ml Silane A-186	---	Same as SL1 except 1ml Silane A-186 was added to the mixing water. Then this liquid of 242ml was used to make mortar.	
SL5	3% Silane A-186	---	3% A-186 added as in SL1. Mix seemed frothy.	
T1	11ml triethanolamine	---	2% TEA was mixed with 2.33ml H_2O then mortar was made. Mortar stiffened quickly.	Cubes broke when removed from molds.
T2	5.5ml triethanolamine	---	Same as T1 except only 1% TEA was added to 236.5ml H_2O. No undue stiffening was noticed.	Cubes broke when removed from molds.
T3	5.5ml triethanolamine	---	Same as T2.	"
T4	3ml triethanolamine	---	Same as T2 except for the different amount of TEA.	"
T5	5.5ml triethanolamine	---	Same as T2 only molds were coated with wax.	"

TABLE IA

Characteristics of the Urea-Formaldehyde Systems Used

Odd numbered A series contain 2% polymer; even numbered series contain 5% polymer. w indicates mortars that were obtained from the mortars of the same Cube Nos. but without w, by mixing about 25% additional formaldehyde belatedly to them. Liquid - Cement ratio is 0.44 by weight.

Polymer No.	Composition of the System	Method of Preparation
A1, A1w A2, A2w	64g urea 138g formalin	Heated to 90° in 10 minutes, maintained 1hr.
A3, A3w A4, A4w	100g urea 136g formalin	Heated 10 min. to 90°, maintained for 1.5hr then diluted and mixed with mortar.
A5, A5w A6, A6w	75g urea 152g formalin	Heated 10 min to 90°, maintained 80 min. then diluted. Mixed with mortar 15 min after dilution.
A7, A7w A8, A8w	60g urea 162g formalin	Heated to 90° in 5 min, maintained 2 min. and diluted. Mixed with mortar 10 min. after dilution.
A9, A9w A10, A10w	64g urea 138g formalin	Heated to 90° in 5 min, maintained for 2 min. then diluted. Mixed with mortar about 30 min. after dilutuion.
A11, A11w A12, A12w	45g urea 183g formalin	1/3 mole ratio. $MgCO_3$ pretreated HCHO. Refluxed sample.
A13, A13w A14, A14w	75g urea 102g formalin	1/1 mole ratio. Refluxed.
A15, A15w A16, A16w	60g urea 162g formalin	Room temperature. Polymer. Maintained at 25° for 22.5 hrs. Diluted and mixed with mortar 23.5 hrs after preparation.
A17, A17w A18, A18w	60g urea 162g formalin	Hazed in 3 hrs at room temperature.
A19, A19w A20, A20w	90g urea 81g formalin	Heated 90 min. at 90°. Hazed in 20 min.

TABLE IA (Cont.)

Characteristics of the Urea-Formaldehyde Systems Used

Odd numbered A series contain 2% polymer; even numbered series contain 5% polymer. w indicates mortars that were obtained from the mortars of the same Cube Nos. but without w, by mixing about 25% additional formaldehyde belatedly to them. Liquid - Cement ratio is 0.44 by weight.

Polymer No.	Composition of the System	Method of Preparation
A21, A21w A22, A22w	90g urea 81g formalin	90° reflux for 1.5 hrs. Haze in 30 min. Diluted immediately and mixed with mortar 45 min. later.
A23, A23w A24, A24w	75g urea 102g formalin	Reflux 1.5 hrs. Haze developed in 50 min. heating time.
A25, A25w A26, A26w	64g urea 138g formalin	90° reflux for 1.5 hrs. $MgCO_3$ pretreated HCHO.
A27, A27w A28, A28w	60g urea 162g formalin	90° reflux - heated 12 min. to 90° then it hazed immediately (possibly due to new formalin).
A29, A29w A30, A30w	75g urea 102g formalin	$MgCO_3$ pretreated formalin. Very slight haze after 90 min. at 90°.
A31, A31w A32, A32w	45g urea 183g formalin	Room temperature polymer. Haze time was about 2 hrs. at 24° instead of expected 3 hrs.
A33, A33w A34, A34w	60g urea 162g formalin	$MgCO_3$ pretreated formalin. Cooked 90 min. at 90°. Hazed just before use.
A35, A35w A36, A36w	90g urea 81g formalin	Heated at 90° for 90 min. Hazed at about 30 min. instead of expected 70 min.
A37, A37w A38, A38w	75g urea 102g formalin	A 90 min. at 90° reflux. No haze when diluted.
A39, A39w A40, A40w	45g urea 183g formalin	1/3 mole ratio, pH adjusted with KOH, reflux 90 min. at 90°.

TABLE IA (Cont.)

Characteristics of the Urea-Formaldehyde Systems Used

Odd numbered A series contain 2% polymer; even numbered series contain 5% polymer. w indicates mortars that were obtained from the mortars of the same Cube Nos. but without w, by mixing about 25% additional formaldehyde belatedly to them. Liquid - Cement ratio is 0.44 by weight.

Polymer No.	Composition of the System	Method of Preparation
A41, A41w A42, A42w	45g urea 183g formalin	Heated to 90° - clouded almost at once and was diluted for mortar.
A43, A43w A44, A44w	90g urea 81g formalin	Urea was mixed with formalin at room temperature.
A45, A45w A46, A46w	75g urea 102g formalin	Acid batch. Hazed in 3 hrs.
A47, A47w A48, A48w	64g urea 138g formalin	Acid batch. Hazed 2.5 hrs. Mixed with mortar 4.5 hrs after preparation.
A49, A49w A50, A50w	75g urea 102g formalin	Acid batch. Hazed in 2.75 hrs.
A51, A51w A52, A52w	60g urea 162g formalin	1/2 mole ratio acid batch. Haze time about 3 hrs.
A53, A53w A54, A54w	90g urea 81g formalin	Unheated batch.
A55, A55w A56, A56w	78g urea 102g formalin	Unheated batch. Haze time 3.5 hrs with stirring.
A57, A57w A58, A58w	68g urea 138g formalin	1/1.5 mole ratio. pH adjusted with KOH. Unheated haze time 3.5 hrs. with stirring.
A59, A59w A60, A60w	45g urea 183g formalin	1/3 mole ratio. pH adjusted with KOH.

TABLE IA (Cont.)

Characteristics of the Urea-Formaldehyde Systems Used

Odd numbered A series contain 2% polymer; even numbered series contain 5% polymer. w indicates mortars that were obtained from the mortars of the same Cube Nos. but without w, by mixing about 25% additional formaldehyde belatedly to them. Liquid - Cement ratio is 0.44 by weight.

Polymer No.	Composition of the System	Method of Preparation
A61, A61w A62, A62w	45g urea 183g formalin	1/3 mole ratio. $MgCO_3$ pretreated formalin. Unheated batch.
A63, A63w A64, A64w	100g urea 136g formalin	1/1 mole ratio. $MgCO_3$ pretreated formalin. Unheated batch.
A65, A65w A66, A66w	90g urea 81g formalin	1/.7 mole ratio. $MgCO_3$ pretreated formalin. Haze time 4 hrs.
A67, A67w A68, A68w	60g urea 162g formalin	1/2 mole ratio. $MgCO_3$ pretreated formalin. 19 hrs. haze time.
A69, A69w A70, A70w	68g urea 138g formalin	1/1.5 mole ratio. $MgCO_3$ pretreated formalin. Haze time 14 hrs.