

PATENT SPECIFICATION

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C1H	120	620	717	718	724	730	731	732
	735	737	738	742	747	748	752	753
	757	771	774	782	785	788	794	795
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(54) METHOD OF ENHANCING THE COMPRESSIVE STRENGTH OF HYDRAULIC CEMENT COMPOSITIONS

(71) We, W. R. GRACE & CO., a Corporation organised and existing under the laws of the State of Connecticut, United States of America, of 62 Whittemore Avenue, Cambridge, Massachusetts 02140, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to hydraulic cement compositions.

Among the various materials added to hydraulic cement compositions such as Portland cement concretes are those which have been found able to affect the interaction between the water and the cement particles in the composition. For instance chemical additives have been used for some time which act to render the wet hydraulic mix more "plastic" at a given proportion of water to cement in the hydraulic mix, or conversely to allow less water to be used in the mix to obtain a given plasticity. These materials are referred to as "dispersing" agents or "water reducing" agents.

The ability of a chemical additive to reduce the amount of mix water required to obtain a given plasticity, or "slump" as it is referred to in the art, has led to the valuable utility of the material as a compressive strength-enhancing additive for hydraulic cements. It is well established that, other factors being equal, a reduction in the amount of the water employed relative to the cement in the mix (the w/c ratio) will lead to an increase in the extended compressive strength of the hydrated cement compositions measured after 28 days from the preparation of the cement mixture. A variety of chemical materials have been employed as strength-enhancing, water-reducing agents while producing no side effects deleterious to strength, although many of the materials also act to retard the setting time of the hydraulic cement mixture. These materials therefore are normally used in conjunction with a set accelerator such as calcium chloride or a formate salt.

A chemical agent which has the ability to reduce surface tension in water (a surface active agent) might be expected to increase the plasticity of wet hydraulic cement mixes by entraining air in the wet mix and indeed the art has long recognised this utility. The increased air entrained during mixing is normally retained in the final hydrated product, and thus such surface active materials have been used as air-entraining agents for the hydrated cement product to render it more durable and resistant to freeze-thaw cycles. The amounts of air entrained are however deleterious to the compressive strength of the final set product and can even be dangerous if the material is "overdosed" during the concrete preparation.

We have now found, according to the present invention that, of the very large number of synthetic surface active agents, there are some which are particularly effective by themselves as very low addition rate additives to increase the extended compressive strength of hydrated hydraulic cement compositions such as Portland cement concrete.

According to the present invention there is provided a process for the production of a hydraulic cement composition such that the hydrated cement has improved compressive strength which comprises introducing into the composition from 0.001 to 0.1 percent by

weight based on the weight of the cement of a synthetic surface active agent having the following characteristics: (a) a cloud point not in excess of 80°C; and (b) a "mechanically-induced agitated foam height" of less than 30 millimetres, said surface-active agent being a non-ionic block copolymer of one or more alkylene diamines and an alkylene oxide, a non-ionic acetylenic glycol or a reaction product thereof with an alkylene oxide, a non-ionic polyethylene glycol ester, a non-ionic polyoxyethylene ether of oleyl alcohol, an anionic phosphate ester of an ethoxylated alkyl phenol or a non-ionic block copolymer prepared by sequential addition of ethylene oxide, then propylene oxide to ethylene glycol or a non-ionic block copolymer prepared by sequential addition of propylene oxide, then ethylene oxide to propylene glycol, other than a last said non-ionic block copolymer in which the polyoxyethylene content is from 30 to 90 percent by weight and the polyoxypropylene portion has a molecular weight from 870 to 2330.

The presence of these specific surface active agents significantly enhances the extended or overall (28 day) compressive strength of the hydrated cement product. These surface-active agents do not entrain air in the hydrated cement in amounts deleterious to compressive strength and thus are effective by themselves as strength-enhancing agents. One very desirable practical advantage offered by the use of these surfactants is that due to their low foamability and low water solubility, the danger of entraining unwanted high air contents in the cement product through an accidental overdose of the additive is considerably diminished.

It will be appreciated that Japanese Patent Application No. 13466/1962 discloses the use of certain polypropylene glycol-ethylene oxide block polymers as "a mixing agent" in cement. These block polymers are effectively polymers of the "Pluronic" type prepared by the sequential addition of propylene oxide then ethylene oxide to propylene glycol, the polyoxyethylene content being from 30 to 90 percent by weight the polyoxypropylene portion having a molecular weight of 870 to 2330.

The "cloud point" of the surfactants is a term conventionally employed in the surfactant art; it is used to indicate the sudden onset of turbidity of surfactant solution on raising the temperature (see, for example, "NON-IONIC SURFACTANTS", Schick, Vol I P 571 (1967)). As used herein, the term indicates the temperature in degrees centigrade at which a sudden onset of turbidity is observed in a 1% (by weight) solution of the surfactant in water.

Surface activity and low water solubility are not the only important criteria in determining the usefulness of a given material as a low addition rate, strength-enhancing additive to hydraulic cement. We have found that they must also be low foam-producing and possess a mechanically-induced, agitated foam height of less than 30 mm.

This foam height is determined by measuring the height of foam produced as the result of mechanical agitation at room temperature of a 0.10% by weight of the surfactant dissolved or dispersed in distilled water, or a mixture containing 95% by weight distilled water and 5% by weight spectroscopic isopropyl alcohol (e.g. Fisher Scientific Co. Catalogue No. A-419, Certified A.C.S. Spectranalised 2-Propanol) using a particular test procedure in which the surfactant solution or dispersion is placed in a container of specified dimensions and the container turned upside down and back again to its original upright position once a second.

This test procedure is best described in detail having reference to the accompanying drawings wherein:

Figure 1 is a perspective view of the mechanical apparatus for controlled agitation of the surfactant sample, and

Figure 2 is a perspective view of the measured container used in the apparatus, in which the surfactant sample is deposited and ensuing foam height measured.

Referring now to Figure 1, container 10 has mounted therein an electric speed reducer motor 11 (typically one seventy-fifth horsepower, 1800 rpm, 115 VAC (volts, alternating current) suitably wired through a capacitor 12 and linked to a gear reducer 13 (30/1 ratio output, 8.2 inch-pounds [0.092 mKg] torque at 60 rpm). Both the motor and the gear reducer actually used are products of the Bodine Electric Co., Chicago, Illinois. The speed reducer 13 is connected to a crank arm 14 which in turn is pivotally attached to rack 16 through a ballend 15. The rotational motion of crank arm 14 is thus converted to a reciprocating, somewhat longitudinal, motion of rack 16 through this arrangement. Rack 16 cooperates with pinion gear 17, which is secured to shaft 22. Support frame 19 rigidly anchors a pair of typically 3/4 inch (19 mm) journal bearings 18 to container 10. Shaft 22 is secured at one end to a housing 23 for the sample container, and then journaled through the first bearing 18, a support 21 for rack 16, pinion gear 17, and at its opposite end through the second bearing 18. Slide 20 is free to pivot about shaft 22. Through this arrangement, the reciprocating motion of slide 20 is converted to an oscillatory motion of housing 23.

Housing 23 has a set screw 24 threaded through its upper end. The set screw is welded to a metal plate having a rubber pad 25 adhered to its surface. Rotation of screw 24 in turn

raises or lowers the padded metal plate within the housing. Housing 23 has another rubber pad 30 at the bottom thereof.

Referring to Figure 2 container 26 has four leak proof glass sides and glass bottom 27. Ground glass top 28 is removable. A measure 29 graduated in millimetres is taped to the outside of the container. The glass container is as described in ASTM C115-73, Section 2.2.4. It is rectangular as shown, having inside dimensions of 2 inches by 1 1/2 inches by 8 inches in height.

In operation the surfactant sample to be tested is placed in container 26. Top 28 is then positioned in a fluid-tight manner, e.g. by first wetting the edge of container 26 contacting the ground glass top 28. The sealed container is then placed in housing 23 and the set screw 24 tightened to hold the glass container. Activation of motor 11 turns crank arm 14, which in turn causes rack 16 to move within slide 20. Movement of the rack causes pinion gear 17 to rotate one way, then another, which in turn oscillates housing 23 holding container 26. The device is constructed such that housing 23 inverts 180 degrees about a horizontal axis through the centre of the container 26, turning the container upside down and back again to its original upright position once each second of time. The ruler is affixed such that the zero point of the ruler is exactly at the height of 100 millilitres of the liquid placed therein (measured at the meniscus of the liquid). 100 Millilitres of the solution is pipetted into the container, and the container secured in the housing 23. The container is agitated for five minutes. After one minute has elapsed following cessation of the agitation, the height of the foam produced is measured. An "Individual Value" is recorded which is an average of the height across the entire surface of the foam produced. The sample is discarded and the entire procedure may be repeated one or more times, the final recorded value in the case of multiple readings being an "Average Foam Height", the actual numerical average of the "Individual Values".

For the synthetic surfactant below to satisfy the foam height requirements, a value of less than 30 millimetres must be obtained from both the test with distilled water and with the water-alcohol mixture. If the surfactant exhibits a foam height in excess of 30 millimetres in either case it is likely to entrain strength-damaging amounts of air in cement compositions.

While surface active agents satisfying the requirements may be ionic or non-ionic synthetic non-ionic surface active agents are generally preferred; they exhibit no ionic charge in aqueous solution. Hydrophilic character is often due to the presence of ether linkage or hydroxy groups in the molecule. Many commercially available products are available and it is these which have been tested.

Synthetic non-ionic surface-active agents satisfying the specified cloud point and foam height requirements may belong to such classes as:

(a) alkyl aryl polyether alcohols such as the condensation products of alkylphenols, e.g. octylphenol and nonylphenol with alkylene oxides, e.g. ethylene oxide, specific examples include condensation products of octylphenol and nonylphenol having a particular degree of ethoxylation and offered commercially, for example, under the tradenames "Triton", "ICEPAL CO" (Registered Trade Marks) and "Surfonic N".

(b) block copolymers of alkylene glycols or alkylene diamines and one or more alkylene oxides, such as those prepared by the sequential addition of propylene oxide and then ethylene oxide to a propylene glycol nucleus, or by the sequential addition of ethylene oxide and then propylene oxide to an ethylene glycol base or to the diamine base; specific examples include certain block copolymers of propylene glycol, propylene oxide and ethylene oxide offered commercially under the Registered Trade Marks "Pluronic", and "Pluronic R"; and "Tetronic".

(c) acetylenic glycols and reaction products thereof with alkylene oxides such as ethylene oxide; specific examples include certain tertiary acetylenic glycols offered commercially under the tradenames "Surfynol 104" and certain condensation products thereof prepared by reacting them with ethylene oxide and offered commercially under the tradenames "Surfynol 440" and "Surfynol 465".

Numerous specific examples of suitable materials are to be found in the Examples below. As stated above the additives are effective as extended (28 day) compressive strength enhancing agents in only very small amounts. Significant strength enhancement after 28 days of the hydraulic cement compositions can be obtained using 0.001 to 0.1%, preferably 0.001 to 0.05% by weight of the cement.

The additives are particularly valuable for increasing the extended compressive strength of Portland cement compositions, especially Portland cement concrete. The term "Portland cements" as employed herein include those products prepared by heating a mixture of limestone and clay or shale, or other calcareous and argillaceous materials to a fused state. The fused product, which is called clinker, is interground with a few percent, normally about 4 to 6 percent, of a retarder such as gypsum. The term "hydraulic cement" as used herein includes those inorganic cements which, when mixed with water, set and harden as a

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result of chemical reactions between the water and the compounds present in the cement. Organic "glues" and pastes, are not included within this definition.

The term "concrete" as used herein includes a mixture of such hydraulic cements and inert aggregates. Typical aggregates include conventional "coarse" aggregates such as gravel, granite, limestone and quartz sieve as well as those materials conventionally referred to as "fine" aggregates such as sand and fly ash. Conventional hydraulic cement concretes, e.g. Portland cement concretes, employ major amounts, i.e. over 50%, usually up to about 75% by volume of such aggregates in the set product.

The surface-active agents used in the present invention are especially suited for use in concretes intended for structural uses where high compressive strengths are particularly sought. These concrete compositions generally employ water to cement weight ratios of less than 1, usually from 0.4 to 0.6, and when hardened have compressive strength values typically in excess of 2000 psi (about 140 Kg/cm²) after 28 days.

The compositions of the invention can include conventional additional optional additives apart from materials which deleteriously affect the extended strengths such as strength-diminishing amounts of petroleum or other hydrocarbon oils and air-entraining agents.

In practice, commercial admixtures for Portland cement compositions such as concrete are often designed to affect more than one property of the cement composition and thus often contain more than one ingredient, designed for example to alter the rate of hydration and the plasticity of the wet mix, the rate of hydration and the compressive strength.

Thus the surfactant additives may be combined with e.g. compounds known to accelerate the set of hydraulic cement compositions. Representative of such set-accelerating materials are calcium chloride or other soluble chloride salt and non-chloride type accelerators such as formate salts, e.g. calcium formate and amine formates. In such a combination admixture the set accelerator generally comprises the major proportion, i.e. greater than 50% by weight of the total additive compositions.

For additional compressive enhancement, the compositions can further include, in an amount, for instance, of from 1 to 25% of the total additive, conventional materials employed for this purpose. Representative of such materials are water-soluble, water-reducing carbohydrates such as monosaccharides, for example glucose and fructose; disaccharides, for example lactose and sucrose; trisaccharides, for example raffinose; polysaccharides, for example starch and cellulose, as well as derivatives thereof such as pre-gelatinized starch, dextrin, corn syrup and carboxymethylcellulose; polyhydroxy polycarboxylic compounds such as tartaric acid and mucic acid; lignosulphonic acid and salts thereof such as calcium, magnesium, ammonium and sodium lignosulphonate; water-soluble salts of boric acid, such as the alkali metal salts thereof; and water-soluble silicone compounds; as well as mixtures thereof. The aforementioned water-reducing agents may also have some retarding effect on the rate of hydration which normally is offset by the presence of the set accelerator component.

Since the surfactants used in the present invention have low water-solubility as indicated by low cloud points, it is preferred to include a small amount of a solubility-enhancing surfactant such as "Triton X-100" (a non-ionic material prepared by condensing octylphenol with ethylene oxide, the material containing 66-68% oxyethylene units), to assist in solubilizing the surfactant additive. Such solubilizing action is most helpful in preventing the normally low-solubility strength-increasing surfactant additive from separating out as a visible separate phase, for instance as ambient temperatures surrounding the product increase.

To facilitate the production of "set-acceleration" which is proportional to the rate of addition of the additive composition to the cement it is desirable to incorporate an amine, preferably an alkanolamine. Thus the present invention also provides a set-accelerating additive for a hydraulic cement composition which comprises, by weight, a major amount of a set-accelerating agent for hydraulic cement and a minor amount of a synthetic surface-active agent possessing the characteristics (a) and (b) defined above and of an amine. The amine should generally be water-soluble and contains up to, say, 20 carbon atoms. Suitable amines include primary, secondary and tertiary mono- and polyamines such as aliphatic, including cycloaliphatic, mono- and polyamines, for example isopropylamine, n-propylamine, diisopropylamine, n-butylamine, di-n-butylamine, tri-n-butylamine, triethylamine, cyclohexylamine, ethylene diamine, diethylene triamine, triethylene tetramine and tetraethylene pentamine; heterocyclic mono- and polyamines, for example morpholine, N-methylmorpholine, 4-(2-aminoethoxy) ethylmorpholine, 2-(4-morpholinylethoxy) ethanol, bis-2-(4-morpholinyl) ethyl ether, piperazine, N-aminoethylpiperazine, N-hydroxy-ethylpiperazine, pyridazine, pyrrole, pyrrolidine, pyridine, piperidine, pyrimidine and pyridazine. Also suitable are alkanolamines such as triethanolamine. Mixtures of the foregoing amines, such as residue products resulting from the commercial production of pure or essentially pure amines are especially desirable due to

the relatively low cost of such products. The amount of amine employed in the additive composition generally ranges from 1 to 6 percent by weight of the additive composition (solids basis). The amount of surfactant in such a composition is generally from 0.15 to 3 percent, preferably 0.50 to 1 percent.

In the following Examples which further illustrate the invention, Portland cements from various manufacturers were employed to make hydratable compositions. The cements all met ASTM standards for Portland cements. Where employed, the concrete compositions were prepared according to ASTM C494 test procedures unless noted otherwise. Determinations of the amount of air entrained in the hydrated samples produced were made according to ASTM test procedure No. C231. Also, the "slump" of the wet mixes produced in the experiments was determined according to ASTM test procedure No. C143. The compressive strength of the mixes was determined by preparing test specimens and curing in accordance with ASTM procedure No. C192. The compressive strengths of the specimens were measured after 1, 7 and 28 days in accordance with ASTM C39.

In the Tables the symbols used have the following meanings:

P	= Product designation
MW	= Typical molecular weight of Poly(oxypropylene)
%H	= % Poly(oxyethylene) Hydrophilic Unit in molecule
B	= Blank
W/C	= Water/cement weight rate
S	= Slump
%A	= % Air
C.S.	= Compressive Strength
D	= Day
C.P(C°)	= Cloud Point in degrees Centigrade
S.T.	= Surface tension
F.H.	= Mechanically-induced, Agitated foam height
No.	= Number of tests
Av. F.H.	= Average Foam Height
A	= Amine
n.a.	= not available
I.S.	= Initial Set given in hours:minutes
(e)	= estimated
Insol.	= Insoluble
APPROX.	= APPROXIMATE

Example 1

This Examples illustrates the effect of small amounts of various commercially produced synthetic non-ionic polyol surfactants sold commercially by the WYANDOTTE CHEMICALS CORP. under the trademark "Pluronic", upon the air content and compressive strength of Portland cement concretes; the cloud point, foam height and surface tension was also measured using the specified procedures. For comparison, a "blank" containing no additive was identically prepared and tested. Measurements were first made with respect to the "blank" composition. The compositions containing the surfactant additives are then prepared and sufficient water added to the mix to give a "slump" as close as possible to that exhibited by the blank, plus or minus about 1/2 inch (1.25 cm). The amount of water actually used is recorded for calculation of the W/C ratio, and subsequently air content and compressive strengths at 1, 7 and 28 days are measured. The foam height values were obtained using the specified water-alcohol mixture.

The "Pluronic" polyols employed herein have been fully described in the literature; they are 100% active, non-ionic block copolymers made by controlled addition of propylene oxide to the two hydroxyl groups of a propylene glycol nucleus. The resulting hydrophobe can be tailored to any desired length, with a molecular weight from 800 to several thousands. The addition of ethylene oxide to this hydrophobe "sandwiches" it between hydrophilic poly(oxyethylene) groups of controlled length constituting from 10 to 80% of the final molecule. The nomenclature of the "Pluronic" materials employed herein is that of the manufacturer.

The "Pluronic R" surfactants are also non-ionic block copolymers, but the copolymer structure is reversed; they are prepared by the sequential addition of ethylene oxide and then propylene oxide to an ethylene glycol base. Specific details concerning the chemical

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nature of the "Pluronic" material are given in Table I. In these and all other Tables, the manufacturer and the ASTM type of the cement used is given. The percentage addition rate for the additive shown in the Tables is that as calculated based on the weight of the cement solids (solids on solids). The results shown in Tables I to X show that these materials cause relatively large amounts of incremental air to be entrained in the hydrated cement compositions and have no, or a negative effect on compressive strength development.

The following cement batches were used

Table	Cement Batch
II	Canada 1
III	Atlantic I
IV	"
V	E
	E'
	E''
VI	Canada 1
VII	Universal Atlas Indiana 1
VIII	Atlantic I
	G-H
	I
	J-K
	L
	M
	N
	O
	P
IX	Ideal 1
	Atlantic I
	Canada 1
X	Universal Atlas Indiana 1
	U-W
	X
	Y
	Canada 1

All of the "Pluronic" polyols listed in Table XI are "surface active" and are able to reduce the surface tension of water. None of the listed materials exhibited a surface tension as a 0.01% aqueous solution at 25°C above about 55 dynes per centimetre. The "Pluronic" types "P-103"; "P-104"; "P-105"; "F-108"; "P-123" and "F-127" all were excessively soluble, exhibiting a cloud point in excess of about 80°C. These also exhibited high foaming ability. The polyol "P-84" had a solubility near the 80°C limit, but was too high a foam producer. The "Pluronic" types "L-62"; "L-92"; and "L-72" exhibited cloud points in the range of about 20 to 35°C, and mechanically-induced, agitated foam heights in the range of about 10 to 20 millimetres in the water-alcohol mixture; these also gave optimum compressive strength increase most consistently. The preferred "Pluronic" type block copolymer additives, are those wherein (A) the typical molecular weight of the poly(oxypropylene) hydrophobe is from 950 to 1750 and the % poly(oxyethylene) in the total molecule is from 10 to 50; or (B) wherein such molecular weight is from 1750 to 2750 and such % poly(oxyethylene) is from 10 to 30; or (C) wherein such molecular weight is from 2750 to 4000 and such % poly(oxyethylene) is from 10 to 20. [All percentages are by weight unless otherwise stated.] Mixtures of such copolymers selected from such groups (A), (B), and (C) can also obviously be employed herein. The preferred such "Pluronic" type additives appear to be those wherein the typical molecular weight of poly(oxyethylene) hydrophobe ranges from 1450 to 3000, and further wherein the % poly(oxyethylene) in the total molecule ranges between 15 and 35.

All of the "Pluronic R" type polyol block copolymers tested are useful as additive components. However, the use of "Pluronic 25R8" as a strength-enhancer is extremely doubtful, as further tests with this material do not confirm the results of the experiment shown in Table V, as air was then entrained with this material. This is to be expected as it is on the cloud point borderline. The "Pluronic R" types used in our invention include materials wherein the typical molecular weight of the poly(oxypropylene) hydrophobe was about 2500 and % poly(oxyethylene) units was in the range of 10 to 80, and materials wherein the such typical molecular weight was about 3100 and such % poly(oxyethylene) was 10-40.

Example II

In this Example, the efficacy of certain synthetic surface active alkyl polyether alcohols, namely condensation products of octylphenol or nonylphenol with ethylene oxide offered under the commercial names "Triton X" (Rohm & Haas Co.), "Igepal Co" (General Aniline & Film Corp.), and "Surfonic N" (Jefferson Chemical Co., Inc.), is illustrated for Portland cement concretes.

The "Triton X" non-ionic materials can be prepared by condensing octylphenol with a varying number of moles of ethyleneoxide. The "Surfonic N" and "Igepal Co" surfactants are prepared by condensing nonylphenol with a varying number of moles of ethylene oxide. Hydrophilic character is given to the alkylphenol hydrophobic moiety by the incorporation of the poly(oxyethylene) units. The foam height values given in Table XII are those as tested in the above described alcohol-water mixture.

It can be seen from Tables XIII to XX that of the "Tritons" the higher ethoxylated "Triton X-100", "Triton X-114" and "Triton X-45" have to be excluded as they entrain considerable amounts of air. "Triton X-45" is a marginal performer; it has a tendency to entrain air in the higher concentrations. In Table XVI K for the second column of slump figures higher addition rates such as 0.025 and 0.05 show a severe loss of slump in the first five minutes after discharge from the mix; the incremental air is proportional to the addition rate. The effect of W/C on compressive strength is very critical at the higher addition rates such as 0.025%.

The following cement batches were used

Table	Cement Batch
XIII A	Atlantic I
B	Universal Atlas Indiana 1
C-D	Canada 1
E	Atlantic I
XIV F-H	"
XV H-I	"
XVI J	"
K	Canada 1
XVII A-C	"
D-F	Universal Atlas Indiana 1
XVIII G-K	Atlantic I
XIX L-M	"
XX A-C	"

Corresponding findings have been made with the "Surfonics" and "Igepals". Materials having a percent ethoxylation over about 50, namely "Surfonic N-60", "Surfonic N-95", "Igepal CO-530" and "Igepal CO-520" are unsatisfactory and can even be so deleterious to strength as to be dangerous, for example should the material be "overdosed" by the concrete preparer.

Table XII shows that all these materials exhibit excessive foam heights. As expected "Triton X-45" is marginal in this respect. The remainder ("Triton X-35"; "X-15"; "Surfonic N-10"; "N-20"; "N-40"; and "Igepal CO-430") are either insoluble, or have a "cloud point" near zero and have foam heights below the permitted maximum. The preferred alkyl aryl polyether alcohol condensates are "Triton X-35", "Surfonic N-40" and "Igepal CO-430" which contain 35 to 50 percent poly(oxyethylene) in the molecule.

Example III

In this Example, the use of certain synthetic surface active acetylinic glycols and ethoxylated products thereof in Portland cement concrete compositions are presented, namely those offered commercially under the name "Surfynol" by Airco Chemicals and Plastics. "Surfynol 104" is a non-ionic surface active agent composed of 2,4,7,9-tetramethyl-5-decyn-4,7-diol; it is a tertiary acetylinic glycol. "Surfynol 440" is a non-ionic surface active agent, and is prepared by reacting "Surfynol 104" with alkylene oxide, i.e. ethylene oxide in a mole ratio of 3.5 moles of ethylene oxide per mole of the tetramethyl decyndiol (see Table XXI for details of characteristics). "Surfynol 465" is also a non-ionic surface active agent prepared by reacting "Surfynol 104" with ethylene oxide, the mole ratio being 10 moles of ethylene oxide per mole of the tetramethyl decyndiol. The concrete test results performed are given in Table XXII. In this Table the cement batches were as follows:

A Atlantic I
B Canada 1
C Universal Atlas Indiana 1
D Ideal 1

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All of the "Surfynol" products tested in Table XXII were effective as low addition rate, compressive strength enhancing additives; each lowered the surface tension of water, were either "insoluble" or had a solubility below the 80°C approximate limit, and were low foamers (in water-alcohol mixture).

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Example IV (Comparative)

In this Example, the efficacy of a proprietary commercial synthetic non-ionic surfactant "Plurafac RA-20" (Registered Trade Mark) offered commercially by the Wyandotte Chemicals Corp. as a low addition rate, compressive strength-enhancing agent is illustrated. The "Plurafac" products are described as 100% active, non-ionic biodegradable surfactants of straight chain, primary aliphatic, oxyethylated alcohols. Details of "Plurafac RA-20" as well as the results obtained are presented in Table XXIII; the tests were performed on Atlantic I cement batch A.

The results show that as the amount of this surfactant is increased, very high strength-damaging incremental air is entrained and the foam height is too high.

In a similar experiment testing the effect of "Plurafac RA-40" as a compressive strength-enhancer for Portland cement concrete, this material was found to entrain strength-damaging high amounts of air at an addition rate of 0.05%. "Plurafac RA-40" is similar to "Plurafac RA-20", except that it has a cloud point of 25°C and has a lower degree of ethoxylation than "RA-20" which indicates a lower water solubility. Agitated foam height tests of "Plurafac RA-40" in the water-alcohol mixture indicate a test value of less than 30 millimetres. However, when tested using water alone, it exhibited a foam height average test value of 38.

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Example V

This Example illustrates the usefulness of small amounts of synthetic block copolymer non-ionic surfactants offered commercially under the name "Tetronic" by the Wyandotte Chemicals Corporation. These materials are block copolymers prepared in a manner similar to the "Pluronic" block copolymers of Example 1, except that ethylene diamine is used as the base to which ethylene oxide and propylene oxide are added sequentially. As in the case of the "Pluronics", the products vary depending upon the amount of poly(oxypropylene) hydrophobe and the % poly(oxyethylene) hydrophilic units present in the molecule. Typically the molecular weight of the poly(oxypropylene) portion is from 2500 to 4500 and the % poly(oxyethylene) units is from 10 to 20. The "Tetronic" block copolymers employed herein are listed in Table XXIV, and the physical and chemical properties thereof in Table XXV. Tablets XXVI and XXVII represent the test results in concrete; in Table XXVI A and B were both Canada 1 Cement Batches while in Table XXVII C and D were both Atlantic I Cement Batches.

These experiments show that Tetronic 1102 and 1502 entrain large amounts of incremental air as the addition rate was increased to 0.05%.

The high figure obtained for the blank in Table XXVI B must be questionable.

Example VI

In this Example, representative results are given of only preliminary evaluations of other commercially available synthetic surfactants.

The results using non-ionic, surface active polyethylene glycol esters offered commercially under the name "ARMAK KESSCO PEG" by Armour Industrial Chemical Co. are given in Table XXVIII using an Atlantic I Cement Batch. The materials shown are polyoxyethylene esters of oleic acid. The number following the "PEG" in the Table indicates the molecular weight of the polyoxyethylene glycol portion of the molecule.

Other commercially available surface active products include (a) "BRIJ 92" (Registered Trade Mark of Atlas Chemical Industries, Inc.) a non-ionic polyoxyethylene ether of oleyl alcohol which when added at 0.02% exhibited increase in compressive strength of the concrete; "BRIJ 30" (Atlas Chemical Industries, Inc.) a non-ionic polyoxyethylene ether of lauryl alcohol which at the 0.02% addition level tended to entrain a high amount of incremental air which discouraged further testing, and "BRIJ 72" (Atlas Chemical Industries, Inc.) a non-ionic polyoxyethylene ether of stearyl alcohol which when added at the 0.02% level exhibited the same tendencies as "BRIJ 30"; (b) "SPAN 30" (Registered Trade Mark of Atlas Chemical Industries, Inc.) a non-ionic fatty acid partial ester of

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sorbitol anhydride (sorbitan monooleate) which when added at a level of 0.02% caused high incremental air entrainment and low compressive strength; (c) "TWEEN 81" (Registered Trade Mark of Atlas Chemical Industries, Inc.) a non-ionic polyoxyethylene derivative of a fatty acid partial ester of sorbitol anhydride (polyoxyethylene 5 sorbitan monooleate), which, at a 0.02% addition level entrained a moderate amount of incremental air and exhibited a slightly lower compressive strength than the blank; (d) "TRITON H-66" (Rohm & Haas Co.) an anionic phosphate ester of an ethoxylated alkylphenol, potassium salt, which at a low addition level entrained a high amount of incremental air and exhibited low compressive strength; and (e) "TRITON H-55" (Rohm & Haas Co.) an anionic phosphate ester of an ethoxylated alkylphenol, potassium salt, which at a low addition level entrained no incremental air and exhibited a compressive strength increase.

Example VII

The following is a detailed Example of a set-accelerating, strength-enhancing additive composition employing a preferred strength-enhancing surfactant of the invention, "Pluronic L-92".

	% by Weight
Calcium chloride	84.8
"Pluronic L-92"	1.94
"Triton X-100"	0.83
"Corn Syrup"	12.43
	100.00

A typical addition rate of this additive composition to structural Portland cement concretes lies generally in the range of from 0.10 to 2%, preferably 0.3 to 1% by weight of additive solids based upon cement solids.

Example VIII

The composition described in Example VII is generally acceptable as a set-accelerating, strength-enhancing additive for Portland cement concrete, particularly concrete intended to be placed at low ambient temperatures, e.g. 60°F and below, under which low temperature conditions acceleration of the setting time is especially desired. However, such composition has the disadvantage that the setting time of the concrete was not shortened at addition rates higher than those recommended, that is the degree of shortening of setting time is not proportional to the rate of addition of the additive composition. In this Example, an additive composition is given which, unlike the additive composition of Example VII, gives a "set-acceleration" which is proportional to the rate of addition of the composition to the cement composition. Thus an important advantage is obtained with the composition of this Example in that a reliable predetermined degree of set-acceleration can be obtained by selecting the addition level in advance.

The following is a detailed Example of a set-accelerating, strength-enhancing composition according to the invention employing a preferred strength-enhancing surfactant of the invention, "Pluronic L-92". The composition is an aqueous blend containing the following proportions of solid materials:

	Solids % by weight
Calcium chloride	94.60
"Pluronic L-92"	1.00
"Triton X-100"	0.40
"Amine"	4.00
	100.00

A typical addition rate of this additive composition to structural Portland cement concretes lies generally in the range of from 0.10 to 2%, preferably 0.3 to 1% by weight of additive solids based upon cement solids. The amine used in the above composition was a mixture of alkanolamines and higher boiling homologues obtained as a coproduct in a continuous commercial process of producing amines.

- In an experiment, the components of the additive composition detailed above in Example VIII were tested singly and in various combinations as additive to Portland cement concretes. Water to cement ratio, slump, % air and compressive strength were all determined as in previous tests, except that the concrete was prepared at 60°F (15.5°C) and cured at 50°F (10°C) for three days. The rest of the curing period was at 73° (23°C) plus or minus 3°F (1.6°C) in a fog room. The concrete cement content was 517 pounds/cu.yard (307Kg/cu.m). The test simulates "low temperature" conditions. Setting time was determined according to ASTM C-403. The results shown in Table XXIX (using Ideal 1 cement) evidence the excellent set acceleration and optimum 3, 7 and 28 day compressive strength enhancement obtained using the combination additive composition of the invention. The results of similar experiments are shown in Table XXX (using Atlantic cement); compressive strength gain and set-acceleration comparable to higher amounts of calcium chloride are noted.
- In Table XXXI (using Atlantic I cement), the effect of varying the amine concentration in the composition of the invention is shown. In Table XXXII (using Atlantic I cement), the effect of varying the amount of "Pluronic L-92" is shown, as is a comparison between a composition of the invention containing a smaller amount of calcium chloride and an ASTM TYPE A C494 water reducing admixture (designated ASTM) containing additionally, 1 percent of calcium chloride.
- In Tables XXXIII to XXXV using Ideal 1, Atlantic I and Ideal 1 cement respectively, the effect of varying the addition rate of the composition of the invention is shown.

TABLE I

"Pluronic"	M.W.	%H
L31	950	10
L35	950	50
L42	1200	20
L43	1200	30
L44	1200	40
L61	1750	10
L62	1750	20
L63	1750	30
L72	2050	20
L81	2250	10
P84	2250	40
L92	2750	20
L101	3250	10
P103	3250	30
P104	3250	40
P105	3250	50
F108	3250	80
L121	4000	10
L122	4000	20
P123	4000	30
F127	4000	70
25R1	2500	10
31R1	3100	10
25R2	2500	20
31R2	3100	20
25R4	2500	40
31R4	3100	40
25R8	2500	80

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TABLE II

A	PLURONIC (0.02%)	W/C	S (inches)	% A	C.S.			
					1 D (PSI)	7 D (PSI)	28 D (PSI)	28 D (kg/cm ²)
B		0.59	3 3/4	1.9	1023	3175	4130	290.3
L-81		0.58	3 3/4	2.2	1230	3537	4524	318.0
L-92		0.56	3	2.6	1321	3684	4627	325.3
L-62		0.56	3 1/4	2.5	1484	3959	4799	337.4
L-63		0.55	3	2.8	1428	3684	4695	330.1
P-103		0.48	4	7.2	1421	3418	4190	294.6
B								
B		0.60	4 3/4	2.0	1098	3247	4468	314.1
P-105		0.48	5	8.8	1046	2646	3410	239.7

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TABLE III

A	PLURONIC (0.05%)	W/C	S (inches)	% A	C.S.			
					1 D (PSI)	7 D (PSI)	28 D (PSI)	28 D (kg/cm ²)
B		0.60	4 1/2	1.4	1098	2909	3907	274.7
L-81		0.57	4 1/4	1.9	1261	3207	4504	316.6
L-92		0.51	3 3/4	4.0	1572	3645	4803	337.7
L-62		0.55	4	2.7	1361	3426	4397	309.1
L-63		0.55	4 1/4	2.9	1337	3346	4592	322.8
L-44		0.55	4	3.6	1293	3318	4345	305.5
L-35		0.55	4 1/4	4.0	1234	3116	4218	296.5
P-103		0.46	6	12.7	875	2053	2566	180.4
F-127		0.45	5 1/4	13.8	764	1600	2033	142.9
F-108		0.46	5 1/4	13.0	772	1986	2324	163.4

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TABLE IV

PLURONIC (0.05%)	W/C	S (inches)	% A	C.S.			
				1 D (PSI)	7 D (PSI)	28 D (PSI)	28 D (kg/cm ²)
B	0.60	4 1/2	1.4	1297	2753	4146	291.5
L-62	0.57	4 1/2	2.5	1329	3131	4309	302.9
L-63	0.57	4 1/2	2.8	1289	3048	4381	308.0
L-44	0.56	5	3.4	1421	3227	4361	306.6
P-84	0.46	5 1/4	10.1	1373	2646	3696	259.8
L-35	0.56	4 1/2	3.1	1397	3203	4261	299.5
P-104	0.44	6 1/4	14.7	557	1202	1556	109.4
P-103	0.44	4 1/4	9.6	1393	2785	3493	245.6
P-123	0.48	4 3/4	9.0	1313	2646	3322	233.5

TABLE V

E	PLURONIC R W/C	S (inches)	cm	% A	1 D		7 D		28 D	
					(PSI)	(kg/cm ²)	(PSI)	(kg/cm ²)	(PSI)	(kg/cm ²)
B	0.61	3 3/4	9.5	1.6	1011	71.1	2976	209.2	4425	311.1
0.05% 31 R1	0.57	3 1/2	8.9	2.5	1114	78.3	3697	259.9	4818	338.7
0.05% 31 R2	0.57	4	10.2	2.7	1051	73.9	3478	244.5	4683	329.2
0.05% 25 R1	0.57	4	10.2	2.6	1067	75.0	3486	245.1	4783	336.2
0.05% 25 R2	0.57	3 1/2	8.9	2.5	1166	82.0	3796	266.8	4990	350.8
0.05% 25 R8	0.57	3 1/2	8.9	2.8	1043	73.3	3549	249.5	4846	340.7
0.05% 31 R4	0.56	3	7.6	2.9	1126	79.2	3462	243.4	4970	349.4
0.05% 31 R4	0.57	4 1/2	11.4	3.3	1015	71.4	3418	240.3	4747	333.7
0.05% 25 R4	0.57	4 1/4	10.8	3.2	999	70.2	3438	241.7	4679	328.9

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E'	PLURONIC R W/C	S (inches)	% A	1 D. (PSI)	1 D. (kg/cm ²)	7 D. (PSI)	7 D. (kg/cm ²)	28 D. (PSI)	28 D. (kg/cm ²)
B	0.60	4 3/4	1.6	1130	79.4	2264	159.2	4329	304.3
B	0.59	3 3/4	1.9	859	60.4	1934	136.0	3497	245.8
0.01% 25 R1	0.57	3 3/4	2.2	1289	90.6	2519	177.1	4616	324.5
0.01% 25 R2	0.57	3 3/4	2.3	1381	97.1	2586	181.8	4616	324.5
E''									
B	0.60	4	1.4	784	55.1	3358	236.1	5181	364.2
0.01% 35 R1	0.58	3 1/2	2.3	879	61.8	3633	255.4	5368	377.4
0.01% 35 R2	0.58	3 3/4	2.1	875	61.5	3848	270.5	5376	377.9
0.01% 31 R4	0.57	3	2.4	1011	71.1	3935	276.6	5805	408.1

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TABLE VI

PLURONIC L92	W/C	S (inches)	% A	1 D (PSI)	1 D (kg/cm ²)	7 D (PSI)	7 D (kg/cm ²)	28 D (PSI)	28 D (kg/cm ²)
B	0.60	4 3/4	1.4	1162	81.7	2745	193.0	4150	291.7
0.001%	0.58	4 1/4	2.2	1186	83.4	3000	210.9	4281	301.0
0.005%	0.56	4 1/4	2.6	1452	102.1	3410	239.7	4584	322.3
0.010%	0.56	3 1/2	2.6	1444	101.5	3394	238.6	4639	326.1
0.010%	0.56	5 1/4	2.7	1170	82.3	3076	216.2	4301	302.4
0.025%	0.54	4 1/4	3.2	1249	87.8	3199	224.9	4675	328.7
0.050%	0.52	5	5.5	1448	101.8	3159	222.1	4126	290.1
0.100%	0.49	6 1/4	8.9	1281	90.1	2773	194.9	3768	264.9

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TABLE VII

G	PLURONIC	W/C	S (inches)	(cm)	% A	1 D (PSI)	(kg/cm ²)	7 D (PSI)	(kg/cm ²)	28 D (PSI)	(kg/cm ²)
B	0.60	3 1/2	8.9	1.8	1154	81.1	3183	223.8	4389	308.5	
	0.02% L-121	0.58	4 1/4	10.8	1257	88.4	3557	250.1	4652	327.0	
	0.04% L-121	0.58	3	7.6	1277	89.8	3772	265.2	4735	332.9	
	0.02% L-101	0.58	4	10.2	1297	91.2	3597	252.9	4540	319.2	
	0.04% L-101	0.58	3	7.6	1289	90.6	3529	248.1	4719	331.7	
	0.02% L-81	0.57	3 1/2	8.9	1110	78.0	3454	242.8	4532	318.6	
	0.04% L-81	0.58	3 3/4	9.5	1226	86.2	3700	260.1	4687	329.5	
	0.02% L-61	0.57	3 1/4	8.3	1134	79.7	3482	244.8	4472	314.4	
0.04% L-61	0.57	4 1/4	10.8	1353	95.1	3617	254.3	4974	349.7		
H											
B	0.60	4	10.2	1.6	1158	81.4	3243	228.0	4544	319.4	
	0.01% L-122	0.57	3 1/2	8.9	1337	94.0	3549	249.5	4651	327.0	
	0.02% L-122	0.57	5	12.7	1297	91.2	3493	245.6	4548	319.7	
	0.04% L-122	0.57	4 1/2	11.4	1421	99.9	3688	259.3	4743	333.4	
	0.01% L-92	0.57	4 3/4	12.1	1309	92.0	3577	251.5	4787	336.5	
	0.02% L-92	0.55	4 1/2	8.9	1417	99.6	3800	267.1	4918	345.7	
	0.04% L-92	0.51	4	10.2	1345	94.6	3490	245.3	4417	310.5	

TABLE VIII

I	PLURONIC	W/C	S (inches)	% A	C.S.			
					1 D (PSI)	7 D (kg/cm ²) (PSI)	28 D (kg/cm ²) (PSI)	28 D (kg/cm ²)
J	B	0.59	4 1/2	1.4	1122	78.9 3275	230.2 5073	356.6
	0.04% L92	0.56	4 1/4	1.8	1273	89.5 3553	249.8 5595	393.3
	0.04% L92	0.57	3 3/4	1.9	1202	84.5 3760	264.3 5734	403.1
	0.08% L92	0.56	3 1/2	2.0	1241	87.2 3649	256.5 5730	402.8
K	B	0.60	4 1/2	1.3	1170	82.3 3227	226.9 4795	337.1
	0.05% L92	0.57	3 3/4	2.2	1281	90.1 3601	253.2 5344	375.7
	B	0.60	4	1.3	1114	78.3 3418	240.3 4942	347.4
	0.001% L92	0.58	4 1/2	1.8	1289	90.6 3728	262.1 5005	351.9
L	0.005% L92	0.56	3 1/2	2.1	1472	103.5 3716	261.2 5181	364.2
	0.010% L92	0.57	4 1/2	1.9	1345	94.6 3720	261.5 5097	358.3
	0.050% L92	0.56	4 3/4	2.2	1389	97.6 4039	283.9 5387	378.7
	0.100% L92	0.55	3 3/4	2.1	1421	99.9 4162	292.6 5527	388.5
B	0.59		4 1/4	2.3	908	63.8 2905	204.2 3907	274.7
	0.10% L92	0.52	5	5.8	1146	80.6 3092	217.4 3935	276.6

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TABLE VIII

M	PLURONIC	W/C	S (inches)	S (cm)	% A	C.S.				
						1 D (PSI)	1 D (kg/cm ²)	7 D (PSI)	7 D (kg/cm ²)	28 D (kg/cm ²)
B		0.57	4 1/4	10.8	1.5	1214	85.3	3744	263.2	377.4
0.005% L92		0.55	4 1/2	11.4	2.3	1202	84.5	3923	275.8	390.0
0.010% L92		0.54	3 3/4	9.5	2.3	1174	82.5	4074	286.4	395.8
0.050% L92		0.55	4 1/4	10.8	2.1	1162	81.7	4007	281.7	402.0
0.10% L92		0.55	4 1/4	10.8	2.0	1162	81.7	4230	297.4	408.4
N										
B		0.58	4 1/4	10.8	1.3	1863	130.7	3398	238.9	353.3
0.005% L92		0.56	3 1/2	8.9	2.3	991	69.7	3947	277.5	382.9
0.010% L92		0.55	3 1/2	8.9	2.2	1027	72.2	3772	265.2	379.8
0.050% L92		0.55	3 1/4	8.3	2.3	991	69.7	3780	265.7	379.3
0.100% L92		0.55	4	10.2	2.1	1018	72.9	3573	251.2	361.7

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TABLE VIII

O	PLURONIC	W/C	S (inches)	% A	1 D (PSI)	7 D (PSI)	28 D (PSI)	C.S.	28 D (kg/cm ²)
B		0.60	4 1/4	1.2	1074	3052	4480	214.6	314.9
	0.005% L92	0.56	4	2.1	1301	3490	5196	245.3	365.3
	0.010% L92	0.56	4 1/4	2.3	1373	3525	5145	247.8	361.7
	0.050% L92	0.55	4	2.4	1381	3669	5204	257.9	365.8
P									
B		0.57	4	1.6	1086	3279	5033	230.5	353.8
	0.0025% L92	0.55	4	2.0	1261	3971	5447	279.2	382.9
	0.005% L92	0.54	3 1/2	2.2	1265	4043	5686	284.2	399.7
	0.010% L92	0.55	4 1/4	2.5	1321	3939	5797	276.9	407.5

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TABLE IX

O	PLURONIC	W/C	S (inches)	% A	C.S.			
					1 D (PSI)	7 D (kg/cm ²) (PSI)	28 D (kg/cm ²) (PSI)	28 D (kg/cm ²)
B	0.61		3 3/4	1.5	840	3068	215.7	4699
	0.02% L31		3	2.8	1035	3454	242.8	5372
	0.02% L62		2 1/2	2.9	1050	3537	248.7	5244
B	0.59		3 1/2	1.9	1170	3326	233.8	4337
	0.02% L72		3 1/4	2.3	1428	3812	268.0	4799
	0.02% L92		3	3.4	1432	3915	275.2	4727
	0.02% L43		2 1/2	2.6	1281	3577	251.5	4504
S	0.61		4 1/4	1.4	1110	3271	230.0	4409
	0.01% L92		4 1/2	2.2	1245	3796	266.9	4986
	0.01% L42		3 1/2	2.1	1281	3486	245.1	4747
	0.01% L62		4	2.0	1329	3609	253.7	4651
	0.01% L72		4 1/2	2.0	1192	3458	243.1	4528
	0.01% L122		4 1/2	2.2	1285	3812	268.0	4440
	0.005% L122		4	1.9	1230	3438	241.7	4532

TABLE IX (continued)

O PLURONIC	W/C	S (inches)	% A	1 D			7 D			28 D		
				(PSI)	(kg/cm ²)	(PSI)	(PSI)	(kg/cm ²)	(PSI)	(PSI)	(kg/cm ²)	
				C.S.								

TABLE X

U	PLURONIC	W/C	S (inches)	% A	1 D (PSI)	1 D (kg/cm ²)	7 D (PSI)	7 D (kg/cm ²)	28 D (PSI)	28 D (kg/cm ²)
B		0.60	3 3/4	1.5	871	61.2	3748	263.5	5324	374.3
0.02% L62		0.56	3 1/4	2.9	887	62.4	3740	262.9	5328	374.6
0.02% L62		0.57	5	3.0	987	69.4	3999	281.1	5571	391.6
0.02% L72		0.57	3 1/2	2.4	931	65.4	4074	286.4	5563	391.1
0.02% L92		0.56	4	2.7	859	60.4	3680	258.7	5742	403.7
V										
B		0.60	4	1.4	744	52.3	3474	244.2	5356	376.5
0.02% L62		0.57	2 3/4	2.7	883	62.1	3983	280.0	5837	410.3
0.02% L72		0.57	3 3/4	2.8	816	57.4	3864	271.6	5471	384.6
W										
B		0.60	3 3/4	1.4	788	55.4	3545	249.2	5097	358.3
0.02% L62		0.57	3 3/4	3.0	919	64.6	3784	266.0	5527	388.5
0.02% L72		0.57	4 1/2	2.5	883	62.1	3724	261.8	5571	391.6
0.02% L92		0.57	3 3/4	2.9	891	62.6	3716	261.2	5423	381.2

TABLE X (continued)

U	PLURONIC	W/C	S (inches)	% A	1 D (PSI)	1 D (kg/cm ²)	7 D (PSI)	7 D (kg/cm ²)	28 D (PSI)	28 D (kg/cm ²)
X	B	0.60	4	1.4	1074	75.5	3529	248.1	4902	344.6
	0.02% L62	0.56	3	2.6	1237	87.0	4003	281.4	4998	351.4
	0.02% L72	0.57	3 3/4	2.4	1090	76.6	3704	260.4	4964	349.0
	0.02% L92	0.57	4 1/4	2.8	1039	73.0	3796	266.9	5073	356.6
Y	B	0.60	4 1/4	1.6	1015	71.4	3123	219.5	4361	306.6
	0.02% L62	0.58	4 1/4	2.7	1166	82.0	3561	250.3	4739	333.2
	0.02% L72	0.57	3 1/2	2.4	1281	90.1	3700	260.1	4830	339.5
	0.02% L72	0.58	3 3/4	2.7	1158	81.4	3374	237.2	4568	321.1
	0.02% L92	0.57	4 1/2	3.3	1150	80.8	3677	258.5	4476	314.7
	0.01% L92	0.57	5 1/4	2.4	1054	74.1	3167	222.6	3987	280.3
	0.005% L92	0.58	4 3/4	2.0	1054	74.1	3235	227.4	4285	301.2
	0.02% L42	0.58	4 3/4	2.5	1226	86.2	3700	260.1	4345	298.4

TABLE XI

5	PLURONIC	C.P. (°C)	S.T. (Dynes/cm)	No.	F. H. Av. F.H. (mm)	5
10	P-104	81	33.5	2	62	10
	P-105	91	40.8	2	83	
	F-108	>100	45.5	2	124	
	P-123	90	34.3	2	57	
	F-127	>100	41.8	2	>150	
	P-103	86	37.6	2	47	
15	P-84	74	44.9	2	32	15
	L-63	34	45.9	2	24	
	L-122	19	33.7	2	27	
	L-42	37	49.5	4	8	
	25 R4	40	42.6	3	10	
20	25 R8	80	50.8	4	9	20
	31 R4	31	44.4	2	18	
	L-43	42	50.3	2	7	
	L-72	25	42.9	2	11	
	L-62	32	45.3	2	16	
25	L-92	26	37.8	2	15	25
	L-61	24	48.5	2	6	
	L-101	15	34.9	2	5	
	25 R1	28	41.0	2	10	
	31 R1	25	36.6	2	6	
30	L-81	20	43.7	2	4	30
	L-121	14	32.5	2	6	
	31 R2	30	41.2	2	11	
	L-35	77	53.0	2	5	
	L-44	65	48.3	2	8	
35	L-31	37	50.4	2	8	35
	25 R2	33	40.1	2	9	

TABLE XII

40	P	%H	C.P.(°C)	S.T. (Dynes/cm)	No.	F. H. Av. F.H. (mm)	40
45	Triton X-100	66.68	65	31	2	>150	45
	Triton X-114	60-63	25	30	2	129	
	Triton X-45	51	>0	29	2	31	
	Triton X-35	39	>0	29	2	2	
50	Triton X-15	18	>0	Insol	1	0	50
	Surfonic N-95	64-67	54.2	30.5	2	>150	
	Surfonic N-60	54	Insol	28.9	2	62	
	Surfonic N-40	44	Insol	28 (Approx.)	2	5	
	Surfonic N-20	29	Insol	Insol	1	0	
55	Surfonic N-10	17	Insol	Insol	1	0	55
	Igepal CO-530	54	Insol	28 (Approx.)	2	45	
	Igepal CO-520	50	Insol	30	2	37	
	Igepal CO-430	44	Insol	Insol	2	14	

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TABLE XIII

A.	P	W/C	S (inches)	% A	C. S.			
					1 D (PSI)	7 D (PSI)	28 D (PSI)	28 D (kg/cm ²)
0.002% Triton X-35	B	0.59	4	1.3	1440	3864	5586	392.7
	B	0.57	3 3/4	2.1	1798	4488	6028	423.8
	B	0.58	4 1/4	1.1	1062	3366	5113	359.4
0.002% Triton X-35	B	0.55	4 1/4	2.1	1281	3856	5650	397.2
	C	0.59	4 1/4	1.5	1158	3291	4369	307.1
0.002% Triton X-35	B	0.57	4	2.2	1154	3402	4480	314.9
	D	0.55	4 1/2	1.4	1444	3398	4389	308.5
0.002% Triton X-35	B	0.56	4	1.9	1214	3064	4114	289.2
	B	0.56	4	1.9	1214	3064	4114	289.2

TABLE XIII (continued)

A	P	W/C	S (inches)	% A	1 D		7 D		28 D	
					(PSI)	(kg/cm ²)	(PSI)	(kg/cm ²)	(PSI)	(kg/cm ²)
	0.004% Triton X-35	0.56	4	2.0	1532	107.7	3816	268.3	4795	337.1
	0.010% Triton X-35	0.54	4 1/4	2.0	1456	102.4	3478	244.5	4528	318.3
E										
B		0.61	4	1.4	955	67.1	3016	212.0	4651	327.0
0.006% Triton X-15		0.58	3 3/4	2.2	891	62.6	3565	250.6	5045	354.7
0.006% Triton X-35		0.58	3 3/4	2.1	1011	71.1	3856	271.1	5196	365.3
0.006% Triton X-45		0.57	3 1/2	2.2	1046	73.5	3700	260.1	5300	372.6
0.006% Triton X-114		0.56	3 1/2	2.7	1023	71.9	3497	245.8	5173	363.7
0.006% Triton X-100		0.58	4 1/2	3.0	959	67.4	3497	245.8	4922	346.0
0.006% Triton X-100		0.57	3 1/2	2.5	951	66.8	3609	253.7	5244	368.7

W/C (water/cement) S (inches) % A 1 D (PSI) (kg/cm²) 7 D (PSI) (kg/cm²) 28 D (PSI) (kg/cm²)

TABLE XIII

TABLE XIV

F.	P	W/C	S (inches)	% A	C.S.			
					1 D (PSI)	7 D (PSI)	28 D (PSI)	28 D (kg/cm ²)
B.	B	0.61	4	1.4	951	3283	230.8	4914
	0.010% Triton X-15	0.59	4	2.0	959	3446	242.3	4994
	0.010% Triton X-35	0.58	3 1/2	2.0	991	3462	243.4	5216
	0.010% Triton X-45	0.57	3 1/2	2.4	1134	3891	273.5	5419
	0.010% Triton X-114	0.56	3 3/4	3.3	1146	3748	263.5	5491
	0.010% Triton X-100	0.54	3 1/2	4.0	1094	3673	258.2	5017
G.	B	0.61	4 1/4	1.5	824	2964	208.4	4544
	0.02% Triton X-15	0.58	4 1/4	2.1	979	3501	246.1	5153
	0.02% Triton X-35	0.57	4	2.3	1074	3772	265.2	5427
	0.02% Triton X-45	0.55	4	3.6	1214	3875	272.4	5364
	0.02% Triton X-114	0.50	4	7.0	1043	3410	239.7	4588
	0.02% Triton X-100	0.49	4 1/2	8.0	935	3108	218.5	4086
H.	B	0.58	3 1/2	1.5	1432	4072	286.3	5295
	0.05% X-114	0.46	7 1/4	14.0	760	1990	139.9	2485

TABLE XV

H.	P Triton X-35	W/C	S (inches)(cm)	% A	C.S.			
					1 D (PSI)	7 D (PSI)	28 D (PSI)	(kg/cm ²)
B	0.61	4	10.2	1.6	911	3080	4608	323.9
0.001	0.58	4 1/4	10.8	2.4	1011	3529	5200	365.6
0.001%	0.57	3 1/2	8.9	2.0	923	3617	5085	357.5
0.002%	0.59	4	10.2	2.1	971	3299	4942	347.4
0.004%	0.58	4	10.2	2.1	979	3517	4994	351.1
0.008%	0.58	4 1/4	10.8	2.1	1023	3728	5272	370.6
0.016%	0.58	3 3/4	9.5	2.2	1074	3744	5447	382.9
0.032%	0.57	4 1/4	10.8	2.5	919	3649	5117	360.0
I.								
B	0.60	4 3/4	12.1	1.6	895	1906	4627	325.3
0.01%	0.58	4 3/4	12.1	2.1	975	2196	5033	353.8
0.05%	0.58	5	12.7	2.3	907	2101	4846	340.7
0.10%	0.58	5 1/4	13.3	2.2	931	2053	4695	330.1

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TABLE XVI

J ₂	P Triton X-45	W/C	S (inches)	% A	1 D			7 D			28 D		
					(PSI)	(kg/cm ²)	(PSI)	(kg/cm ²)	(PSI)	(kg/cm ²)	(PSI)	(kg/cm ²)	(PSI)
B	0.001%	0.61	3 3/4	1.6	848	59.6	3346	235.2	4791	336.8	4791	336.8	4791
	0.001%	0.58	3 3/4	2.6	995	69.9	3712	261.0	5276	370.9	5276	370.9	5276
	0.004%	0.58	3 1/4	2.2	1007	70.8	3370	236.9	5232	367.8	5232	367.8	5232
	0.004%	0.59	4 1/4	2.2	1062	74.7	3756	264.0	5431	381.8	5431	381.8	5431
	0.008%	0.57	3 1/2	2.4	995	69.9	3728	262.1	5296	372.3	5296	372.3	5296
	0.016%	0.56	4 1/2	3.7	1043	73.3	3720	261.5	4934	346.9	4934	346.9	4934
	0.016%	0.55	3 1/2	3.3	1058	74.4	3923	275.8	5300	372.6	5300	372.6	5300

C.S.

TABLE XVI

K.	P.	Triton X-45	W/C	S1		S2	% A	1 D		7 D		28 D	
				(inches)	(cm)	(inches)		(PSI)	(kg/cm ²)	(PSI)	(kg/cm ²)	(PSI)	(kg/cm ²)
		B	0.59	4	10.2		1.8	1031	72.5	2921	205.3	4385	308.3
		0.001%	0.58	5 1/4	13.3		1.9	1114	78.3	3231	227.1	4592	322.8
		0.001%	0.57	3 1/2	8.9		2.0	1210	85.1	3533	248.4	4870	342.4
		0.004%	0.58	3 1/4	8.3		2.0	1114	76.3	3430	241.1	4803	337.7
		0.008%	0.56	5 1/2	14.0		2.5	1202	84.5	3525	247.8	4834	339.8
		0.008%	0.55	4 1/2	11.4		2.5	1273	89.5	3617	254.3	5025	353.3
		0.025%	0.52	5 1/2	14.0	3 1/2	3.4	1305	91.7	3720	261.5	4950	348.0
		0.025%	0.53	4 1/2	11.4	3 1/2	3.9	1162	81.7	3271	230.0	4389	308.5
		0.05%	0.53	2 3/4	7.0	2 1/4	3.7	1110	78.0	2909	204.5	4122	289.8
		0.10%	0.51	4 1/4	10.8	3 3/4	6.9	987	69.4	2582	181.5	3621	254.6
		0.10%	0.53	5 1/2	14.0	5 1/2	7.5						

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TABLE XVII

A.	W/C	S (inches)	% A	C.S.			
				1 D (PSI)	3 D (PSI)	7 D (PSI)	28 D (PSI)
P. Igepal CO-430							
B	0.59	3 3/4	1.9	859	60.4	1934	136.0
B	0.60	4 3/4	1.6	1130	79.4	2264	159.2
0.005%	0.57	3 1/4	2.1	1353	95.1	2706	190.2
0.010%	0.57	3 1/4	2.3	1357	95.4	2678	188.3
B							
B	0.58	4 1/4	1.7	1249	87.8	3239	227.7
0.005%	0.57	4 3/4	2.1	1417	99.6	3541	248.9
0.010%	0.56	4 1/2	2.5	1508	106.0	3812	268.0
C.							
B	0.59	3 1/4	1.7	1233	86.7	3430	241.1
0.005%	0.57	3 1/2	2.2	1385	97.4	3565	250.6
0.010%	0.56	4	2.5	1361	95.7	3736	262.6

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TABLE XVII (continued)

A.	W/C	S (inches)(cm)	% A	1 D (PSI) (kg/cm ²)	7 D (PSI) (kg/cm ²)	28 D (PSI) (kg/cm ²)
B. Igepal CO-430						
D.						
B	0.60	4 1/2 11.4	1.4	796 60.0	3458 243.1	5188 364.7
0.0025%	0.57	3 1/2 8.9	2.0	955 57.1	3935 276.6	5610 394.4
0.005%	0.57	4 10.2	2.1	931 65.4	3899 274.1	5750 404.2
0.01%	0.57	4 10.2	2.7	979 68.8	3931 276.3	5459 383.8
E.						
B	0.61	3 3/4 9.5	1.3	852 59.9	3386 238.0	5328 374.6
0.0025%	0.58	3 1/2 8.9	1.2	991 69.7	3828 269.1	5761 405.0
0.005%	0.58	3 1/2 8.9	2.2	983 69.1	3903 274.4	5642 396.6
0.005%	0.59	4 1/2 11.4	2.2	947 66.6	3752 263.8	5483 385.5
F.						
B	0.60	3 3/4 9.5	1.4	788 55.4	3545 249.2	5097 358.3
0.005%	0.58	3 1/2 8.9	2.3	856 60.2	3645 256.2	5352 376.2

TABLE XVIII

G. P. Igepal CO-430	W/C	S (inches)(cm)	%A	D			
				1 (PSI)	7 (PSI)	28 (PSI)	28 (kg/cm ²)
B	0.60	4 10.2	1.5	963	3271	4647	326.7
0.002%	0.57	3 1/2 8.9	2.0	1198	3585	4938	347.1
0.004%	0.57	3 3/4 9.5	2.0	1301	3617	5208	366.1
0.008%	0.56	3 1/2 8.9	2.3	1460	4031	5256	395.5
H.							
B	0.60	4 1/4 10.8	1.4	1027	3529	4978	350.0
0.002%	0.60	4 1/4 10.8	2.2	1194	3891	5224	367.2
0.004%	0.58	3 3/4 9.5	2.1	1138	3891	5077	356.9
0.008%	0.58	5 12.7	2.4	1078	3780	5181	364.2
0.02%	0.55	3 3/4 9.5	3.4	1154	3696	5352	376.2
I.							
B	0.60	4 10.2	1.4	1074	3529	4902	344.6
0.008%	0.57	3 3/4 9.5	2.2	1234	3840	5077	356.9

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TABLE XVIII (continued)

G. P. Igepal CO-430	W/C	S (inches)(cm)	% A	C.S.			
				1 D (PSI) (kg/cm ²)	7 D (PSI) (kg/cm ²)	28 D (PSI) (kg/cm ²)	
J.							
B	0.60	5 12.7	1.4	863 60.7	3183 223.8	4623 325.0	
B	0.59	3 1/2 8.9	1.4	1086 76.3	3788 266.3	5248 368.9	
0.004%	0.58	3 1/2 8.9	2.1	1086 76.3	3629 255.1	5181 364.2	
0.008%	0.57	3 1/2 8.9	2.4	1118 78.6	3665 257.6	5177 363.9	
K.							
B	0.60	4 10.2	1.5	987 69.4	3338 234.7	4620 324.8	
0.008%	0.57	3 7.6	2.5	1198 84.2	3852 270.8	5125 360.3	
0.008%	0.58	3 3/4 9.5	2.3	1241 87.2	3792 266.6	4994 351.1	
0.02%	0.56	3 1/4 8.3	3.6	1206 84.8	3684 258.9	4850 341.0	
0.02%	0.57	3 3/4 9.5	3.5	1046 73.5	3573 251.2	4930 346.6	
0.04%	0.58	2 3/4 7.0	3.9	852 59.9	3119 219.3	4206 295.7	

TABLE XIX

L.	P. Igepal	W/C	S (inches)(cm)	% A	C.S.			
					1 D (PSI)	7 D (PSI)	28 D (PSI)	28 D (kg/cm ²)
B		0.60	3 1/2	8.9	999	70.2	3493	245.6
		0.55	3 1/2	8.9	1313	92.3	3927	276.1
	0.02% CO-430	0.53	3 1/2	8.9	1472	103.5	4222	296.8
	0.02% CO-520	0.52	4 1/4	10.8	1325	93.1	3856	271.1
M.		0.58	4	10.2	1176	82.7	3933	276.5
		0.52	4 3/4	12.1	1241	87.2	3482	244.8
	0.05% CO-520	0.50	5 1/4	13.3	1136	79.9	3234	227.4
	0.05% CO-530						3905	274.5

TABLE XX

A.	P. Surfonic	W/C	S (inches)(cm)	% A	C.S.		
					1 D (PSI) (kg/cm ²)	3 D (PSI) (kg/cm ²)	28 D (PSI) (kg/cm ²)
B.	B	0.61	4 1/4 10.8	1.5	896 63.0	1966 138.2	4548 319.7
	0.02% N-10	0.58	4 3/4 12.1	2.8	1031 72.5	2252 158.3	5117 359.7
	0.02% N-20	0.59	4 3/4 12.1	2.0	1150 80.8	2316 162.8	5324 374.3
	0.02% N-40	0.57	4 3/4 12.1	2.4	1086 76.3	2495 175.4	5407 380.1
	0.02% N-60	0.54	5 1/4 13.3	5.3	1257 88.4	2543 178.8	5316 373.7
	0.02% N-95	0.51	5 1/4 13.3	6.5	1062 74.7	2200 154.7	4556 320.3
B.	B	0.60	3 1/2 8.9	1.6	999 70.2	3493 245.6	4942 347.4
	0.02% N-40	0.56	3 7.6	2.6	979 68.8	3549 249.5	5041 354.4
	0.02% N-60	0.52	5 1/2 14.0	6.4	1174 82.5	3350 235.5	5352 376.2
	0.02% N-60	0.50	2 3/4 7.0	5.4	1313 92.3	3935 276.6	5065 356.1
C.	B	0.60	3 1/4 8.3	1.5	1074 75.5	3501 246.1	4699 330.3
	0.02% N-40	0.58	3 7.6	2.8	1225 86.1	3840 270.0	4950 348.0
	0.02% N-60	0.54	5 1/4 13.3	6.5	1289 90.6	3422 240.6	4484 315.2

TABLE XXI

P.	% H	C.P. (°C)	S.T. (Dynes/cm)	No.	F.H.	Av. F.H. (mm)
Surfynol 104	0	Insol	45.1	1		0
Surfynol 440	41	Insol	44.0	1		0
Surfynol 465	66	61	44.5	2		21

TABLE XXII

A.	P.	W/C	S (inches)	S (cm)	% A	C.S.			
						1 D (PSI)	7 D (PSI)	28 D (PSI)	28 D (kg/cm ²)
A.	"Surfynol"	0.60	3 1/4	8.3	2.3	1325	3939	5240	368.4
		0.57	3 1/4	8.3	2.3	1146	3549	4950	348.6
		0.56	3 1/4	8.3	2.3	963	3271	4647	326.7
		0.55	3 1/4	8.3	2.3	851	3037	4329	304.3
		0.54	3 1/4	8.3	2.3	794	2864	4029	285.8
B.	Blank	0.60	3 1/2	8.9	2.0	1210	3637	5173	363.7
		0.57	3 1/2	8.9	2.0	1040	3112	4397	311.2
		0.56	3 1/2	8.9	2.0	880	2640	3637	264.0
		0.55	3 1/2	8.9	2.0	794	2395	3395	239.5
		0.54	3 1/2	8.9	2.0	710	2160	3043	216.0
B.	0.01% 440	0.60	4	10.2	1.6	1130	2264	3043	304.3
		0.59	4	10.2	1.6	980	1934	2574	257.4
		0.57	4	10.2	1.6	859	1710	2264	226.4
		0.56	4	10.2	1.6	794	1592	2043	204.3
		0.55	4	10.2	1.6	710	1430	1810	181.0
B.	0.01% 465	0.60	4	10.2	1.6	1186	2395	3168	316.8
		0.59	4	10.2	1.6	1040	2160	2864	286.4
		0.57	4	10.2	1.6	880	1810	2395	239.5
		0.56	4	10.2	1.6	794	1684	2160	216.0
		0.55	4	10.2	1.6	710	1592	2043	204.3

TABLE XXII (continued)

TABLE XXII (continued)

A.	W/C	S (inches)	S (cm)	%A	C.S.			
					1 D (PSI)	7 D (PSI)	28 D (PSI)	28 D (kg/cm ²)
B "Surfynol"	0.60	4 1/2	11.4	1.4	796	3458	5188	364.7
	0.56	3 1/2	8.9	2.7	871	3947	5395	379.3
	0.55	3	7.6	2.9	859	3899	5248	368.9
D.	0.58	3 1/2	8.9	1.6	871	3382	4781	336.1
	0.56	3 3/4	9.5	2.9	921	3429	5091	357.9
	0.56	3 1/2	8.9	2.4	940	3284	5208	366.1
B 0.01% 465	0.57	4	10.2	2.3	948	3476	5082	357.3

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TABLE XXIII

	% H	C.P. (°C)	S.T. (Dynes/cm)	No.	F.H. Av. F.H. (mm)	C.S.		
						1 D (PSI)	7 D (PSI)	28 D (PSI)
Plurafac RA=20		45	32.9	2	87			
A.								
PLURAFAC								
RA-20								
W/C								
Blank	0.58	3 1/2	8.9	1.5	1432	100.7	4072	5295
0.01%	0.55	4	10.2	3.1	1292	90.8	4117	5309
0.025%	0.51	5	12.7	7.0	1358	95.5	3651	4496
0.05%	0.48	4 1/2	11.4	8.8	1381	97.1	3618	4337

TABLE XXIV

P. "Tetronic"	M.W.	% H
1502	6501-7000	20
1102	4501-5000	20
702	2501-3000	20
1501	6501-7000	10
1301	5501-6000	10
1101	4501-5000	10
901	3501-4000	10
701	2501-3000	10

TABLE XXV

P. "Tetronic"	C.P. (°C)	S.T. (Dynes/cm)	No.	Av. F.H. (mm)
1502	70	35 (e)	2	44
1102	31	36 (e)	2	29
702	27	41.1	3	5
1501	15	35.1	2	3
1301	16	34.7	3	9
1101	17	35.7	1	0
901	20	37.3	1	0
701	22	40.9	1	0

TABLE XXVI

A.		C.S.									
P. "Tetronic"		W/C		S		% A		1 D		7 D	
		(inches)	(cm)	(PSI)	(kg/cm ²)	(PSI)	(kg/cm ²)	(PSI)	(kg/cm ²)	(PSI)	(kg/cm ²)
B		0.60	4 1/2	11.4	1.5	1082	76.1	3250	228.5	4110	288.9
0.01% 901		0.58	5 1/4	13.3	2.1	1210	85.1	3438	241.7	4687	329.5
0.01% 1101		0.58	3 1/2	8.9	2.0	1261	88.6	3525	247.8	4154	292.0
0.01% 1301		0.58	3 1/2	8.9	2.0	1154	81.1	3342	234.9	4417	310.5
0.01% 1501		0.58	4 1/4	10.8	1.9	1122	78.9	3330	234.1	4369	307.1
0.01% 1102		0.57	5 3/4	14.6	3.1	1078	75.8	3414	240.0	4230	297.4
0.01% 1102		0.55	4 3/4	12.1	2.9	1142	80.3	3390	238.3	4405	309.7
0.01% 1502		0.58	4	10.2	1.9	1074	75.5	3430	241.1	4381	308.0
B.											
B		0.60	5	12.7	1.5	1214	85.3	3501	246.1	4803	337.7
0.02% 701		0.59	4	10.2	1.8	1146	80.6	3219	226.3	4440	312.1
0.02% 1101		0.59	4	10.2	1.6	1409	99.1	3414	240.0	4504	316.6
0.02% 1301		0.58	4 1/2	11.4	2.0	1234	86.8	3450	242.5	4616	324.5
0.02% 1501		0.59	4 1/2	11.4	1.7	1202	84.5	3458	243.1	4584	322.3
0.02% 702		0.57	3 1/3	8.5	2.2	1253	88.1	3513	247.0	4810	338.1
0.02% 1102		0.57	6 3/4	17.3	4.9	1110	78.0	3255	228.8	4238	298.0
0.02% 1502		0.58	3 3/4	9.5	1.9	1222	85.9	3583	251.9	4830	339.5

TABLE XXVII

C.			C.S.						
P. "Tetronic"	W/C	(inches)	S (cm)	% A	1 D (PSI)	1 D (kg/cm ²)	7 D (PSI)	7 D (kg/cm ²)	
B	0.59	4	10.2	1.6	986	69.3	3388	238.2	
0.05% 701	0.58	4 1/2	11.4	1.7	1097	77.1	3514	247.0	
0.05% 901	0.57	4 1/2	11.4	1.8	1210	85.1	3855	271.0	
0.05% 1101	0.57	3 3/4	9.5	1.7	1137	79.9	3611	253.9	
0.05% 1301	0.56	3 1/2	8.9	2.4	1168	82.1	3761	264.4	
0.05% 1501	0.57	3 3/4	9.5	1.7	1160	81.5	3725	261.9	
0.05% 702	0.57	3 3/4	9.5	2.2	1055	74.2	3389	238.2	
0.05% 1102	0.51	5	12.7	7.5	1099	77.3	3185	223.9	
0.05% 1502	0.52	3 3/4	9.5	5.8	1162	81.7	3266	229.6	
D.									
0.05% 702	0.56	3 1/2	8.9	2.4					
0.05% 1102	0.53	5 3/4	14.6	7.2					
0.05% 1502	0.53	3 3/4	9.5	6.0					

TABLE XXVIII

P.	W/C	S (inches)	S (cm)	% A	C.S.					
					1 D (PSI)	(kg/cm ²)	7 D (PSI)	(kg/cm ²)	28 D (PSI)	(kg/cm ²)
B	0.59	3 3/4	9.5	1.4	1154	81.1	3406	239.4	4926	346.3
0.001 PEG 200	0.57	3 3/4	9.5	1.7	1305	91.7	3752	263.8	5073	356.6
0.01 PEG 200	0.56	4	10.2	2.0	1313	92.3	3796	266.9	4814	338.4
0.001 PEG 400	0.57	4 1/4	10.8	2.2	1325	93.1	3708	260.7	5065	356.1
0.01 PEG 400	0.56	4 1/4	10.8	2.9	1206	84.8	3478	244.5	4655	327.7
0.001 PEG 600	0.57	3 3/4	9.5	1.9	1373	96.5	3907	274.7	5244	368.7
0.01 PEG 600	0.55	4	10.2	2.8	1245	87.5	3597	252.9	4759	334.6
0.05 PEG 400	0.58	2 1/2	6.4	2.7	1070	75.2	3115	219.0	4643	326.4

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TABLE XXIX

CaCl ₂	A	% s/s Pluronic L-92	Triton X-100	W/C	S (inches)	% A	3 D (PSI)	7 D (PSI)	28 D (PSI)	I.S.			
--	--	--	--	0.57	4 1/2	11.4	1148	80.7	2528	177.7	4228	297.2	10:30
0.473	--	--	--	0.57	4 3/4	12.1	1678	118.0	3535	248.5	4865	342.0	5:55
--	0.02	--	--	0.55	4 1/2	11.4	1568	110.2	3202	225.1	5010	352.2	6:40
0.473	--	0.005	--	0.54	4	10.2	2027	142.5	3980	279.8	5220	367.0	5:30
0.473	--	--	0.002	0.56	5	12.7	1800	126.5	3653	256.8	4779	336.0	5:35
0.473	0.02	--	--	0.56	4 1/2	11.4	1890	132.9	3732	262.4	5153	362.3	5:35
0.473	0.02	0.005	0.002	0.53	4 3/4	12.1	2090	146.9	4052	284.9	5426	381.4	5:30

TABLE XXX

CaCl ₂	% s/s Pluronic L-92	Triton X-100	A	W/C	S (inches)	% A	3 D (PSI)	C.S. 7 D (PSI)	28 D (PSI)	I.S.				
--	--	--	-	0.56	3 3/4	9.5	1.3	1571	110.4	3038	213.6	4690	329.7	8:40
0.4871	0.009	0.0039	-	0.52	3 1/2	8.9	3.7	2373	166.8	4324	304.0	5662	398.0	5:50
0.4771	0.009	0.0039	0.01	0.52	3	7.6	3.0	2681	188.5	4674	328.6	5992	421.2	5:10
0.7306	0.0135	0.0059	-	0.52	6 1/4	15.9	9.0	2056	144.5	3766	264.7	4721	331.9	--
0.7306	0.0135	0.0059	-	0.51	1 1/2	3.7	2.9	2904	204.2	5048	354.9	6333	445.2	4:25
1.0	--	--	-	0.56	3 1/4	8.3	1.9	2469	173.6	4294	301.9	5512	387.5	4:20
1.5	--	--	-	0.57	3 1/4	8.3	1.7	2508	176.3	4492	315.8	5436	382.2	3:25
--	--	--	-	0.57	4	10.2	1.5	1470	103.3	3019	212.2	4660	327.6	8:55
0.4871	0.009	0.0039	-	0.53	5	12.7	4.4	2200	154.7	4220	296.7	5363	377.0	5:50
0.4771	0.009	0.0039	0.01	0.53	4 3/4	12.1	4.2	2375	167.0	4351	305.9	5572	391.7	5:15
0.7306	0.0135	0.0059	-	0.52	6 3/4	17.3	8.3	2079	146.2	3995	280.8	4915	345.5	5:00
1.0	--	--	-	0.57	3 1/2	8.9	1.6	2246	157.9	4309	302.9	5533	389.0	4:15
1.5	--	--	-	0.58	4 1/2	11.4	1.5	2416	169.8	4500	316.4	5637	396.3	3:25

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TABLE XXXI

CaCl ₂	% s/s Pluronic L-92	Triton X-100	A	W/C	S (inches)	% A	3 D (PSI)	7 D (kg/cm ²) (PSI)	28 D (kg/cm ²) (PSI)	I.S.
1.0	0.002	0.002	0.01	0.57	4	10.2	1441	238.4	4755	9:00
0.483	0.005	0.002	0.01	0.55	4	10.2	2186	300.9	5522	5:45
0.473	0.005	0.002	0.02	0.54	4	10.2	2411	327.3	5925	5:30

TABLE XXXI

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TABLE XXXII

CaCl ₂	% s/s Pluronic L-92	Triton X-100	A	W/C	(inches)	S (cm)	% A	³ D (PSI)	(kg/cm ²)	C.S. (PSI)	⁷ D (kg/cm ²)	²⁸ D (PSI)	(kg/cm ²)	I.S.
0.480	0.007	0.003	0.01	0.54	3 3/4	10.2	1.6	1441	101.3	3391	238.4	4755	334.3	9:00
0.483	0.005	0.002	0.01	0.55	4	10.2	3.1	2186	153.7	4280	300.9	5522	388.2	5:45
0.473	0.005	0.002	0.02	0.54	4	10.2	3.2	2411	169.5	4656	327.3	5925	416.5	5:30
0.720	0.0105	0.0045	0.015	0.52	4 1/4	10.8	4.8	2576	181.1	4763	334.8	5981	420.5	4:45
1.0	+ASTM		0.54	3	7.6	-	-	2650	186.3	4865	342.0	6039	424.5	4:40

TABLE XXXIII

CaCl ₂	% s/s Pluronic L-92	Triton X-100	A	W/C	(inches)	S ₁₀₀ (cm)	% A	3 D (PSI)	(kg/cm ²)	C.S. (PSI)	7 D (kg/cm ²)	28 D (PSI)	I.S.
—	—	—	—	0.57	4	10.2	1.7	1190	83.7	2518	177.0	4389	9.35
0.473	0.005	0.002	0.02	0.54	4	10.2	3.2	2001	140.7	3610	253.8	5205	6.15
0.710	0.0075	0.003	0.03	0.53	4	10.2	3.9	2228	156.6	3992	280.6	5451	5.10
0.946	0.010	0.004	0.04	0.52	3 3/4	9.5	4.4	2494	175.3	4283	301.1	5849	4.15

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TABLE XXXIV

CaCl ₂	% s/s Pluronic L-92	Triton X-100	A	W/C	(inches)	S (cm)	% A	3 D (PSI)	7 D (PSI)	28 D (PSI)	I.S.
+	-	-	-	0.57	4	10.2	1.7	1704	3135	4659	10:05
0.3784	0.004	0.0016	0.016	0.55	4 1/4	10.8	2.7	2523	4148	5467	6:40
0.5676	0.006	0.0024	0.024	0.54	4	10.2	2.9	2698	4442	5724	6:25
0.7568	0.008	0.0032	0.032	0.53	4	10.2	3.4	3005	4503	5934	6:00

TABLE XXXV

CaCl ₂	% s/s Pluronic L-92	Triton X-100	A	W/C	(inches)	S (cm)	% A	3 D (PSI)	(kg/cm ²)	C.S. (PSI)	7 D (kg/cm ²)	28 D (PSI)	(kg/cm ²)
---	---	---	---	0.57	4 1/4	10.8	1.4	1104	77.6	2607	183.3	4477	314.7
0.0946	0.001	0.0004	0.004	0.55	4 1/4	10.8	2.1	1510	106.2	3150	221.4	4923	346.1
0.1892	0.002	0.0008	0.008	0.55	3 1/2	8.9	2.7	1690	118.8	3366	236.6	5114	359.5
0.2838	0.003	0.0012	0.012	0.55	3 1/2	8.9	2.8	1913	134.5	3541	248.9	5312	373.4

1990E XX/7A

**WHAT WE CLAIM IS:**

1. A process for the production of a hydraulic cement composition such that the hydrated cement has improved compressive strength which comprises introducing into the composition from 0.001 to 0.1 percent by weight based on the weight of the cement of a synthetic surface active agent which is a non-ionic block copolymer of one or more alkylene diamines and an alkylene oxide, a non-ionic acetylenic glycol or a reaction product thereof with an alkylene oxide, a non-ionic polyethylene glycol ester, a non-ionic polyoxyethylene ether of oleyl alcohol, an anionic phosphate ester of an ethoxylated alkyl phenol or a non-ionic block copolymer prepared by sequential addition of ethylene oxide, then propylene oxide to ethylene glycol or a non-ionic block copolymer prepared by sequential addition of propylene oxide, then ethylene oxide to propylene glycol, other than a last said non-ionic block copolymer in which the polyoxyethylene content is from 30 to 90 percent by weight and the polyoxypropylene portion has a molecular weight from 870 to 2330, said surface active agent having the following characteristics; (a) a cloud point (as hereinbefore defined) not in excess of 80°C; and (b) a "mechanically-induced agitated foam height" (as hereinbefore defined) of less than 30 millimetres.

2. A process according to claim 1 wherein said cement is Portland cement.

3. A process according to claim 1 or 2 wherein said cement is a structural concrete composition possessing a compressive strength, measured after 28 days of hydration, in excess of 2000 p.s.i. (140 kg/cm²).

4. A process according to any one of claims 1 to 3 wherein the surface active agent is present in an amount from 0.001 to 0.05 percent.

5. A process according to any one of the preceding claims wherein the surface active agent exhibits a surface tension as a 0.01% by weight aqueous solution at 25°C of less than 55 dynes per centimetre.

6. A process according to any one of the preceding claims wherein the surface active agent possesses a cloud point from 20° to 35°C and a foam height from 10 to 20 millimetres.

7. A process according to any one of the preceding claims wherein the surface active agent is non-ionic.

8. A process according to claim 7 wherein the surface active agent is prepared by adding propylene oxide followed by ethylene oxide to propylene glycol and further (a) the molecular weight of the resulting poly (oxypropylene) portion of the copolymer is from 1750 to 2750 and the resulting percent by weight poly (oxyethylene) is from 10 to 30; or (b) said molecular weight is from 2750 to 4000 and said percent poly (oxyethylene) is from 10 to 20.

9. A process according to any one of claims 1 to 7 wherein the surface active agent is a non-ionic acetylinic glycol or an alkoxyated product thereof.

10. A process according to claim 9 wherein the surface active agent is a tertiary acetylinic glycol.

11. A process according to claim 10 wherein the glycol is 2,4,7,9-tetramethyl-5-decyn-4,7 diol.

12. A process according to any one of claims 9 to 11 wherein the surface active agent is a reaction product of ethylene oxide and said acetylinic glycol.

13. A process according to claim 12 wherein the product contains 3.5 to 10 moles of ethylene oxide per mole of acetylinic glycol.

14. A process according to any one of claims 1 to 7 wherein the surface active agent is a block copolymer of ethylene diamine, ethylene oxide and propylene oxide.

15. A process according to claim 14 wherein the molecular weight of the poly (oxypropylene) portion of said copolymer ranges from 2500 to 4500 and the percent by weight poly (oxyethylene) units in the polymer molecule is from 10 to 20.

16. A process according to any one of the preceding claims wherein the cement composition contains a major amount by volume of aggregate.

17. A process according to any one of the preceding claims wherein the cement composition contains a set-accelerating agent.

18. A process according to claim 17 wherein the set-accelerating agent is calcium chloride.

19. A process according to any one of the preceding claims wherein the cement composition contains a water-soluble, water-reducing agent which is a carbohydrate; polyhydroxy polycarboxylic compound; lignosulphonic acid or a salt thereof; a boric acid salt; a silicone or a mixture thereof.

20. A process according to any one of the preceding claims wherein the cement composition contains an amine.

21. A process according to claim 20, wherein said amine is an alkanolamine or a mixture thereof.

22. A process according to any one of the preceding claims wherein water is added to

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give a water to cement weight ratio of from 0.4:1 to 0.6:1.

23. A process according to claim 1 substantially as described in any one of Examples I, III and V to VII.

24. A cement composition whenever prepared by a process as claimed in any one of the preceding claims.

25. A Portland cement structural concrete composition whenever prepared by a process as claimed in any one of claims 1 to 23.

26. A hydraulic cement composition which comprises a hydraulic cement and a synthetic surface active agent as defined in claim 1 and possessing the characteristics (a) and (b) specified in claim 1 in an amount from 0.001 to 0.1 percent by weight based on the weight of the cement.

27. A composition according to claim 26 which has one or more of the features of claims 2 to 4 and 16 to 21.

28. A set-accelerating additive for a hydraulic cement composition which comprises, by weight, a major amount of a set-accelerating agent for hydraulic cement and a minor amount of a synthetic surface active agent possessing the characteristics (a) and (b) specified in claim 1 and of an amine.

29. An additive according to claim 28 wherein the set-accelerating agent is calcium chloride.

30. An additive according to claim 28 or 29 which contains a water-soluble, water-reducing agent which is a carbohydrate, polyhydroxy polycarboxylic compound, lignosulphonic acid or a salt thereof, a boric acid salt, a silicone, or a mixture thereof.

31. An additive according to claim 30 wherein the water-reducing agent is present in an amount from 1 to 25 percent by weight based on the weight of the additive.

32. An additive according to any one of claims 28 to 31 which contains from 1 to 6 percent by weight of the amine and 0.15 to 3 percent by weight of the synthetic surface active agent.

33. An additive according to any one of claims 28 to 32 wherein the amine is an alkanolamine or a mixture thereof.

34. A composition or additive according to any one of claims 26 to 33 wherein the synthetic surface active agent is one defined in any one of claims 1 and 5 to 15.

35. A composition or additive according to claim 26 or 28 substantially as described in any one of Examples I, III and V to VIII.

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