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**Michenko et al.**

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[54] **METHOD AND SYSTEM FOR MIXING UNLIKE INGREDIENTS**

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[52] **U.S. Cl.** ........................ **259/148**, 259/2, 259/72, 259/162, 259/DIG. 41, 259/DIG. 42
[51] **Int. Cl.** ........................... **B28c 5/18**, B01f 11/02
[58] **Field of Search** .............. 259/DIG. 15, DIG. 41, 259/DIG. 42, DIG. 43, DIG. 44, 2, 11, 12, 28, 29, 54, 72, 148, 153, 161, 162, 174; 310/17, 26; 68/3 SS

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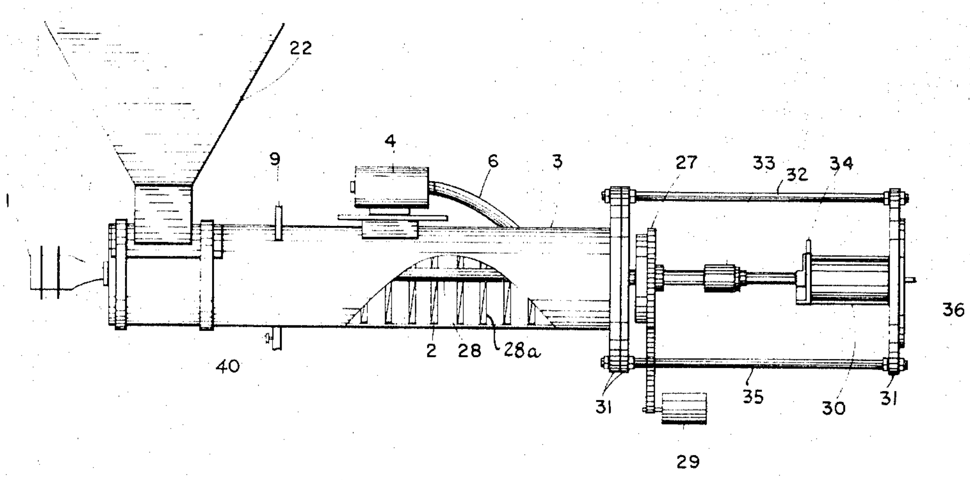
[57] **ABSTRACT**

A batching or mixing apparatus and process for combining in an unhomogenous mix the several ingredients through the simultaneous application of high and low frequency excitation. The high frequency excitation includes a sonic resonant electromechanical transducer impact coupled to a rotating auger shaft. The auger is of a specific design to permit the maximum application of the high frequency excitation to the mixture. A specific embodiment is disclosed for the continuous mixing and combining the ingredients for concrete having an improved compressive and bonding strength and a finished surface for sealing against penetration of liquids.

**16 Claims, 5 Drawing Figures**



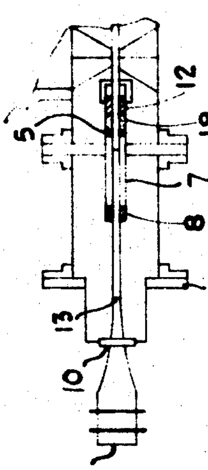



FIG. 1A

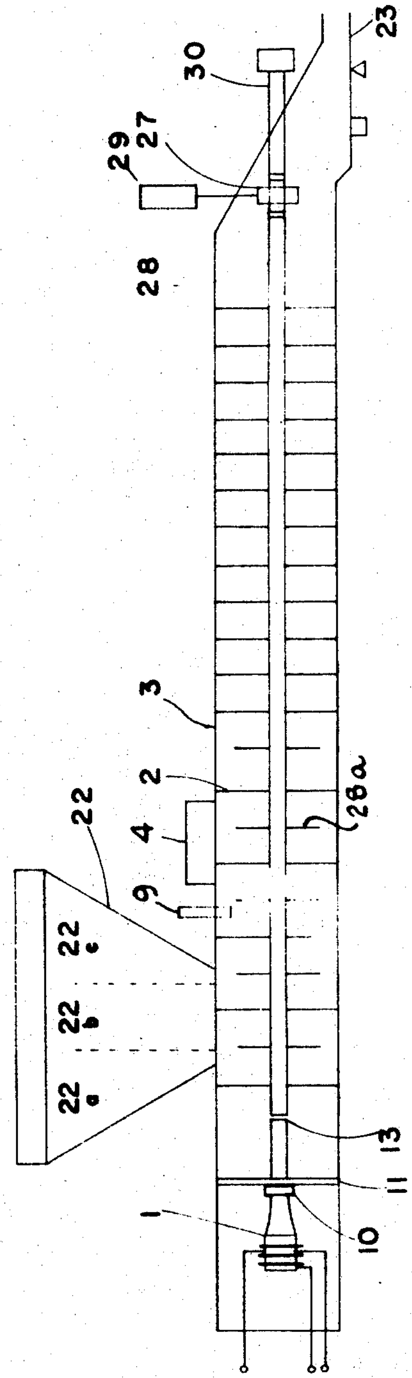



FIG. 1

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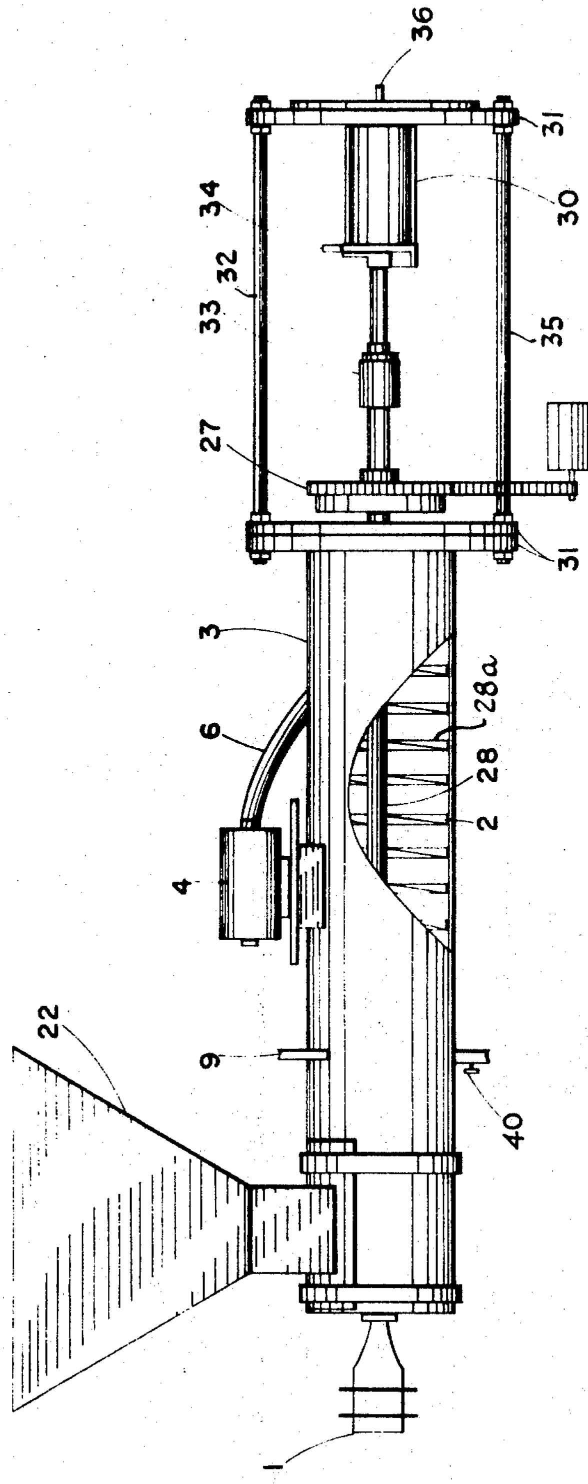


FIG. 2

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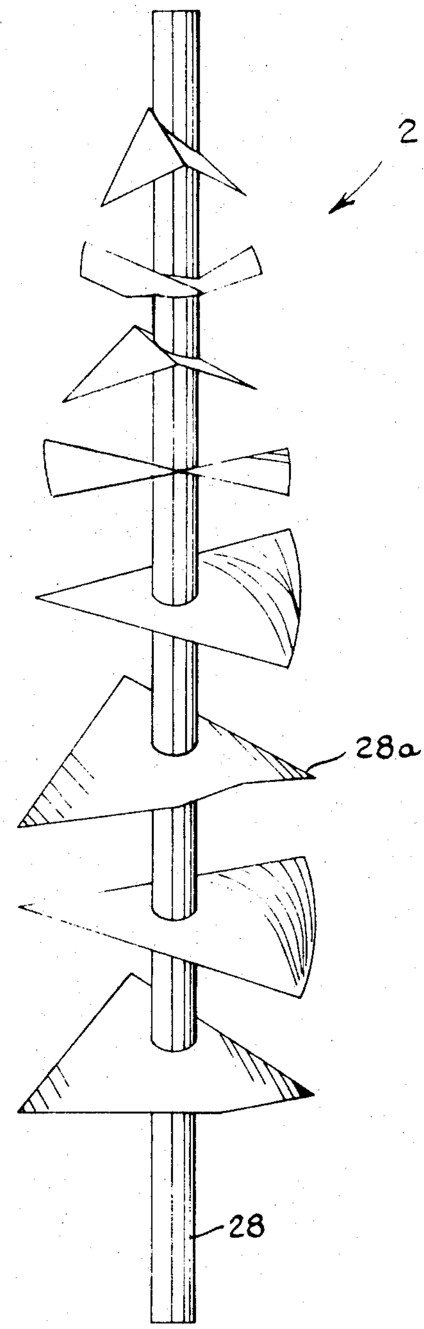


FIG. 3

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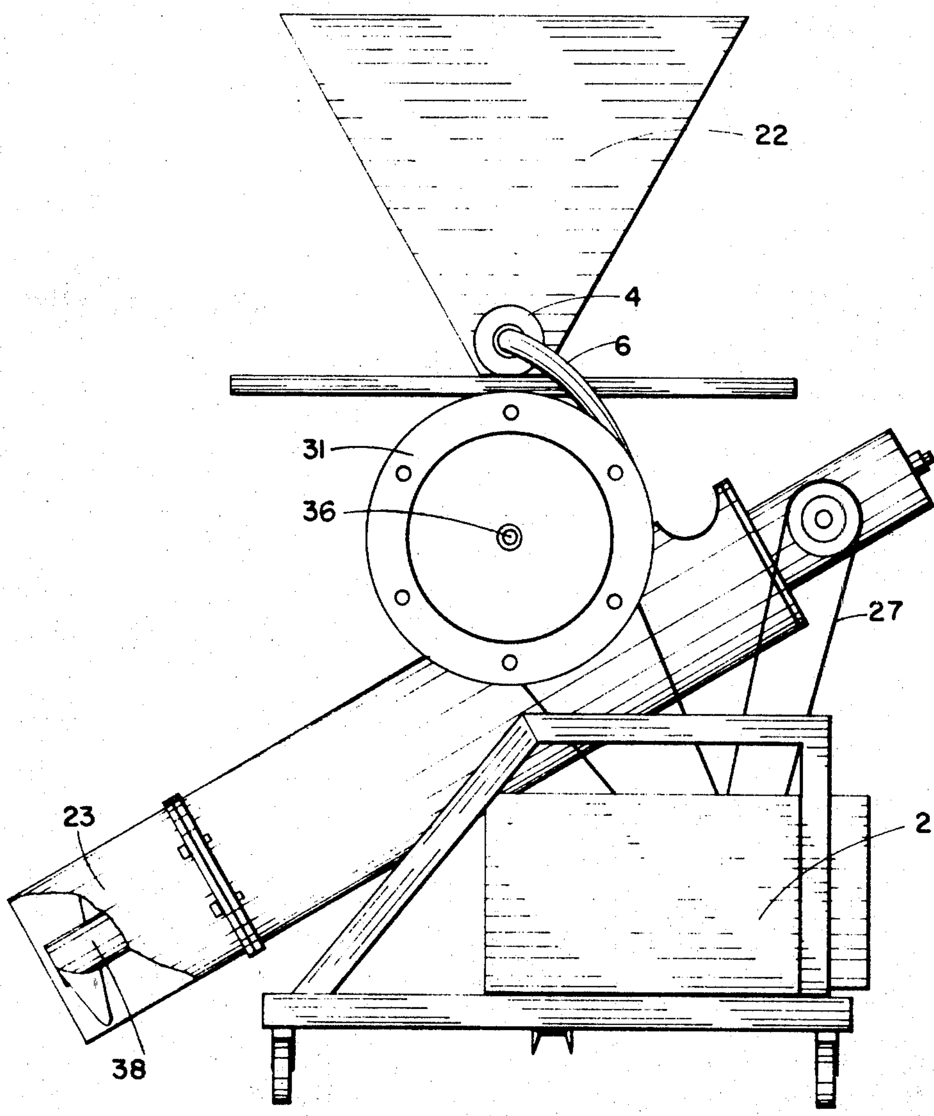


FIG. 4

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# METHOD AND SYSTEM FOR MIXING UNLIKE INGREDIENTS

## CROSS REFERENCES

There is disclosed in U.S. Pat. No. 3,396,285, for "Electromechanical Transducer," by Hildegard M. Minchenko, and assigned to The Ohio State University, a transducer capable of delivering extremely high power, i.e., measurable in horsepower (or kilowatts) at an acoustical frequency range. The principle underlying the high-power output is in the structural arrangement of the components immediately associated with the piezoelectric driving elements. In theory and practice, the piezoelectric elements are under radial and axial pressure that assure that they do not operate in tension even under intense sonic action. Significantly, the structural design of this transducer, that permits the extraordinary power output from the driving elements, resides in the novel method of clamping the piezoelectric elements both radially and longitudinally (axially). In this way the acoustic stresses in the piezoelectric elements are always compressive, never tensile, even under maximum voltage excitation.

The transducer disclosed in the aforementioned patent in intended, and therefore utilized, to deliver a steady-state vibratory power output signal. That is, the piezoelectric assembly is a component of a resonant structure that will produce a mechanical vibratory output at the frequency of the driving electrical signal — and vice versa.

There is further disclosed in U.S. Pat. No. 3,475,628, for "Sonic Transducer Apparatus," by Robert C. McMaster, et al., and assigned to The Ohio State University, the means for efficiently coupling a high power, high Q electromechanical transducer to drive a tool effectively, i.e., to drive the tool in a work environment. The significant feature of the invention is that the tool does not form a part of the resonant structure.

## BACKGROUND OF THE INVENTION

Concrete is a building and structural material created by mixing cement, a mineral aggregate, and water in a suitable proportion so that a plastic and workable mass results which can be molded into any desired shape. Concrete is one of the most important materials of construction and it ranks second only to steel in its wide and varied industrial applications.

Cement is the most important ingredient of concrete because it binds the particles of aggregate together into a strong cohesive mass. Cement is also the most expensive ingredient; hence it is desirable to use as little cement as possible for economic reasons. While any type of hydraulic cement can be used, Portland cement is employed mostly because of its uniformity, strength, reliability, and low price.

Mineral aggregate used for concrete is classed as fine and coarse aggregate. Both fine and coarse aggregate should be clean, free from clay, loam, and organic impurities and possess strong particles of suitable size and shape for the job. Maximum strength and water tightness of concrete for a given proportion of cement can be attained only with a well-graded aggregate. A well graded aggregate contains large particles with a sufficient amount of smaller particles to fill voids between the larger particles.

The function of water in a concrete mix is to hydrate the cement compounds and to lubricate the particles of the aggregate and cement so as to make the concrete mix workable. Normally, the amount of water necessary for hydration is about 20% by weight of the cement used. As this amount of water produces a very dry mixture which is extremely difficult to place into position, extra water is added to make the mixture workable. When the concrete dries, the excess water evaporates, leaving voids.

There are two common sources of voids in concrete: entrapped air bubbles and the excess water. Since air bubbles are more easily eliminated from wet than from dry mixes, there is an optimum water content at which the volume of the entrapped air plus the volume of water filling the voids will be at a minimum for any given method of compacting or placement. The most dense and strongest concrete is obtained by using the minimum amount of water consistent with the necessary degree of workability.

The consistency is usually regarded as the state of fluidity of the mix and as such determines its flow properties. This may vary from wet, to medium, to stiff, as the water content of the mix is increased. The workability is a more complex property than consistency, since it involves not only the properties of the mix but also all other factors that may be encountered in placing the mix in a particular position and in obtaining the required degree of consolidation. The most universally adapted test to determine the consistency of concrete mixes is the slump cone test. In this test the consistency is recorded in terms of inches of subsidence of the cone specimen which is made up of the tested concrete mix under strictly standardized conditions.

Practically all concrete mixing is done in specially designed concrete mixers. Only occasionally for very small jobs is mixing done by hand. After placing, the concrete is puddled and spaded to remove air bubbles and to aid in subsequent compacting of the concrete mix. Dry mixes tend to give a honeycombing surface, whereas wet mixes, although easy to place, tend to segregate, giving coarse aggregate at the bottom of the pour and a thin layer of cement, fine sand, and water at the top. This latter is known as the "laitance layer," and it is porous and has a chalky appearance. The presence of the laitance layer lowers considerably the resistance of concrete to moisture, weathering, abrasion, and erosion and prevents the effective bond of succeeding pours of concrete with that already placed.

After deposition the concrete mix is compacted by vibrating to produce a dense concrete free of voids. The most common method of compacting is now by vibration. This permits the use of relatively stiff mixes of lower sand content and lower water/cement ratio, thereby making a stronger concrete for a given cement content.

Other than the utilization of vibrators for compacting concrete, the batching process has not advanced or progressed — at least to the date of the "cement mixer." The prior art devices have not been advanced to improve the air bubble problem nor more significantly have not improved the homogeneity of the mixture.

It has been the accepted practice — and rightfully so to a limit — that the less water, the stronger the concrete. Other factors leading to improved compressive or bonding strength have been ignored. One of the major difficulties with concrete "breaking up" — as evidenced by a concrete highway — is the penetration of liquids into the concrete. Of specific significance is the freezing and thawing of water in the concrete. Again concrete with improvements leading toward a surface that is not penetratable by liquids has also been ignored.

As pointed out above, vibrators have been employed to enhance compacting of concrete after it has been poured into forms. Several prior art devices are used for this purpose. But even for their intended purpose they are insufficient in that the vibratory forces are not equally applied to the entire mix. Further, with the conventional rotating blade of a cement mixer the contact ratio of blade to ingredients is exceedingly small.

In the aforementioned sonic transducer patents, sonic energy is intermittently coupled to a workpiece. For reasons set forth in the aforementioned patents, it is a tremendous advance in the state of the art to couple high power sonic energy to a workpiece without the loss of power. It is to be noted, however, that the workpiece in U.S. Pat. No. 3,475,628, having sonic energy coupled thereto, is free of rotation. That is, heretofore, no method of means was known for coupling sonic energy to a rotating workpiece.

## SUMMARY OF THE INVENTION

The present invention is an advance in the state of the art in mixing of unlike ingredients. The process includes the combining of the ingredients, conveying the ingredients from one point to another, and causing the ingredients to be intimately mixed through the application of a low frequency excitation simultaneously with the application of high frequency excitation. The conveying process and apparatus is, in itself, an improved manner of effecting complete vibratory excitation to all of the combined ingredients into a homogeneous mixer. The conveyor includes a housing or vessel having a rotating feeder element centrally positioned therein. The low frequency excitation is coupled to the housing whereas the high frequency sonic energy is uniquely coupled to the rotating member.

## OBJECTS OF THE INVENTION

The principal object of the present invention is to provide an improved means and process for combining the unlike ingredients of a mixture.

Another object is to provide a means of mixing high density concrete.

Another object is to provide a concrete mix with improved over-all strength characteristics in tension and compression.

Another object is to provide a means for reducing entrapped air in a concrete mix.

Another object is to provide a means for increasing the homogeneity of a concrete mix.

Another object is to provide a means for evenly coating the aggregate of a concrete mix with bond (cement) particles.

Another object is to provide a means for improving the crystal distribution per square centimeter.

Another object is to provide effective means for coupling sonic energy to a rotating member.

Other objects and features of the present invention will become apparent from a reading of the following detailed description when read in conjunction with the drawings, in which:

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates schematically the apparatus for carrying out the process of the present invention;

FIG. 1*a* is an enlarged view of the transducer coupling;

FIG. 2 is a side view of an actual working embodiment, partly cut away of the present invention as adapted to a concrete mixing system;

FIG. 3 is a specific showing of the detailed construction of the auger of FIG. 1; and

FIG. 4 is an over-all pictorial end view of a preferred embodiment of the present invention.

## DESCRIPTION OF THE PROCESS

Referring only generally to the drawings, there is illustrated apparatus for carrying forth the principles of the present invention. Specifically, several ingredients of a mixture, such as fine and coarse aggregate, dry cement, and water are intermixed to produce the end product, i.e., concrete. Fundamentally the ingredients lumped together are vibrated simultaneously with high and low frequency vibrations.

The low frequency vibration penetrates deeply into the ingredients and hence enhances the mixture. The high frequency, due to the nature of the material, only penetrates slightly, but results in dense well sealed nonporous finish. The combination of high and low frequency vibrations accounts for an improved strength.

With continued general reference to the drawings, the high frequency vibrations are uniquely applied to the mixture. More specifically, the sonic vibration from an electromechanical transducer is imparted to the rotating auger feeding the ingredients from the hopper through the various stages of mix. In keeping with the teachings of the aforesaid U.S. Pat. No. 3,475,628, the sonic energy is coupled from the transducer to a rotating shaft without making the shaft a part of the resonant structure. That is, as done in the prior art devices, direct coupling of a resonant transducer to a workpiece results in the workpiece becoming a part of the resonant structure. In the present invention there is only intermittent contact between the transducer and the rotating shaft. It is also of basic significance that the coupling is between a linear motion transducer and a rotating shaft.

To increase the contact between the source of high frequency vibrations and the dense material, the area of contact is greatly enlarged over that normally utilized in concrete mixing. The area of contact of the high frequency vibrations is enlarged by a specially designed auger.

## DETAILED DESCRIPTION OF THE DRAWINGS

With specific reference to FIG. 1 there is shown schematically the apparatus of the present invention. The embodiment shown is for mixing fine and coarse aggregate with dry cement and water and to continuously extrude concrete. The apparatus comprises the extruder principally the mixing cylinder **3**, auger **2**, hopper **22**, a power source **29** connected to the shaft **28**, and a water inlet **9**. Mounted at the end of the auger shaft **28** is a gear/chain drive **27**. This gear/chain drive **27**, connected to a driving force **29** is used to turn the mixing auger **2**.

The operation of the concrete mixer to a point, with reference to the mechanical structure, is more or less straight forward. That is, the coarse and fine aggregate together with cement from the hopper are fed together into the mixing cylinder 3.

The hopper compartments 22*a*, 22*b*, 22*c*, are partitioned so as to permit the flow of the correct proportions of cement, gravel, and sand into the mixing cylinder 3. The "correct proportions " are determined by the type and strength of the concrete desired. Standard proportions are used.

As the concrete ingredients begin to feed into the mixing cylinder 3 from the hopper 22, the driving force 29 is actuated causing the gear/chain drive 27 to turn the mixing auger shaft 28 and hence auger fins 28*a*. The mixing auger fins 28*a* rotate and mix the concrete ingredients. As the mixing auger fins 28*a* rotate and mix, they cause the dry concrete ingredients to traverse a first stage of the mixing cylinder 3. Water introduced into the mixing cylinder 3 through the water orifice 9 is mixed with the dry concrete ingredients. The dry ingredients mixed with water are moved along the remainder of the length of the mixing cylinder 3 as the rotating auger shaft 28 and auger fins 28*a* further blend the concrete ingredients. The blended concrete is ejected from the end of the mixing cylinder 3 and into the trough 23.

The present invention, in addition to the general mechanical mixing components further incorporates the application of a combination of low and high frequency vibratory energy to the apparatus. Low frequency vibration introduced into the mixing cylinder 3 through source 4 at a point external to the cylinder penetrates through both the wet and concrete mixtures within the cylinder. This low frequency vibration facilitates the mixing process by bringing more of the concrete ingredients into contact with the auger fins 28*a*.

In operation the low frequency source 4 introduces vibratory-mechanical energy into the cylindrical mixing cylinder 3. Low frequency energy so introduced produces vibratory oscillations transverse to the longitudinal axis of the mixing cylinder 3. A pneumatic vibratory-mechanical energy source 4 producing vibrations at a rate of approximately 300 cycles per minute is used. However, other types of low frequency vibratory-mechanical energy sources may be used in lieu of or in conjunction with pneumatic devices.

To complete the operation of producing a much improved concrete mix in accordance with a preferred embodiment of the present invention, simultaneously with the application of a low frequency vibration to the mixing cylinder 3, there is applied a high frequency vibration to the auger shaft 28.

With specific reference to the schematic illustration there is illustrated the incorporation into the system a piezoelectric electromechanical transducer. The system of the present invention is made possible by the transducer of the aforementioned U.S. Pat. No. 3,396,285. It is this transducer that is capable of delivering sufficient power to properly mix such amounts of dense heavy material.

Also, as stated above, the sonic vibratory force from the piezoelectric transducer 1 is "applied" to the auger shaft 28. That is, the auger shaft 28 is not directly or physically interconnected with the end or tip of the sonic transducer. To the contrary, there is only intermittent coupling between the transducer and the auger shaft 28 in accordance with the fundamental principles of the aforementioned U.S. Pat. No. 3,475,628.

With specific reference to FIG. 1*a* the high frequency piezoelectric electromechanical transducer 1 is secured at its node to the flange 10 adjacent to mixing cylinder 3 bulkhead support 11. The transducer 1 is positioned with the vibrating tip 13 of its energy concentrating horn adjacent to one end of the auger shaft 28. Nylon bearings 8 and 12 are fitted around the transducer tip and auger shaft 28, respectively. The nylon bearings are retained by the sleeve 7 and end cap 5. The sleeve 7 is secured to the shaft 28 and the bearing are retained in position by the spring 18.

As more clearly shown in FIG. 2, mounted to the opposite end of the auger shaft 28, but not connected to it, is an air piston 30, which provides a controlling force against the auger shaft 28. The piston 30 is secured to a flange plate 31 which is mounted to the mixing cylinder 3 by threaded rods 32 and 35. The air pressure, that is, the force, is regulated by the air line 32 connected to the air piston. The air piston 30 periodically and cyclically impacts the end of the auger shaft 28 causing it to laterally move. The movement is sufficient that the opposite end of the auger shaft 28 impacts with the tip 13 or end of the piezoelectric transducer 1.

It is to be noted, in operation, that the auger shaft 28 is rotating, whereas the tip of the transducer has no rotating movement but only a lateral movement. In this way then there is impact vibratory energy by a lateral force to a rotating shaft.

The movement of the auger shaft 28 along the axial direction of the longitudinal axis of the mixing cylinder 3 is constrained by the nylon bearings 8 and 12. The spring 18 causes the auger 2 to return to its original position and to again have its other shaft end placed in contact with the piston 30.

High frequency vibration introduced into the auger shaft 28 of auger 2 as it rotates does not penetrate deeply into the ingredients of the concrete. Rather, the high frequency vibration causes intense excitation of the concrete ingredients in the regions adjacent the auger fins 28*a* and shaft 28. This intense excitation thoroughly and evenly distributes the cement throughout the aggregate of the concrete mix. This thorough, even distribution enhances the strength and mechanical properties of the concrete mix.

With specific reference to FIG. 3 there is shown pictorially the detailed construction of the auger shaft 28 (of FIGS. 1 and 2). The auger shaft 28 has two primary functions; the first to mix the ingredients and to move the mixture from one end of the mixing cylinder 3 to the other. This, of course, is more or less conventional. The second function of the auger 2, in keeping with the teachings of the present invention, is to impart the high frequency vibrations to the ingredients being mixed.

As pointed out above, the high frequency vibration causes intense excitation of the concrete ingredients in the regions adjacent the shaft 28 and fins 28*a* of auger 2. This is an inherent factor since due to the density of the ingredients the high frequency excitation will not penetrate deeply. Accordingly, the second primary function of the auger 2 then can be redefined as providing an area of contact as great as possible between the fins 28*a* and the mixed ingredients.

The fins 28*a* of the auger 2 are not of the conventional design and configuration but are uniquely shaped to move the mixture at the same time as maximizing the application of the high frequency excitation to the mixture.

It is also to be noted that the fins **28***a* of the auger **2** are not uniform in construction nor are they evenly spaced along the shaft of the auger **2.** It must be appreciated that initially the ingredients are simply dumped together and there is really very little mixture. As the ingredients progress the mixture increases. The application of high frequency vibration then must also increase as the mixtures progress through the mixing cylinder **3.**

The final portion of the mixing cylinder **3** of FIG. **1** defines the compressive stage. It is seen in FIG. **3** that the concentration of fins **28***a* of auger **2** is greatest at this stage.

Referring again to FIG. **2,** there is shown pictorially and partly cut away, a side view, of the actual constructed embodiment of the machine for carrying out the principles of the present invention. In FIG. **2,** the mixing cylinder **3** is cut away to show the auger **2** and the attendant fins **28***a*. The end cap is removed to show the piston **30** pressure controls **32** and **34,** coupling **33** and the gear/chain drive **27** driven by motor **29.** Also shown is the low frequency vibrator **4** mounted on the outside of mixing cylinder **3** with its source of power **6.** Water inlet is shown at **9** with valve control **10.** The transducer **1** is mounted on the hopper **22** end.

In FIG. **4** the housing **23** for the extrusion stage is partly cut away to show the concrete mixer extruder **38.** The gear/chain drive **27** is shown together with its drive motor **29.** The air inlet **32** provides the control for the piston **30** mounted by the flange plates **31.** Also shown is the low frequency vibiator **4** with its power source **6** adjacent the hopper **22.**

Although certain and specific embodiments have been shown, it is to be understood that modifications may be made without departing from the true spirit and scope of the invention.

What is claimed is:

**1.** The process of intermixing several unlike ingredients, comprising: introducing said ingredients to a retainer defining a confined mixing area, applying a low frequency vibration to said ingredients, and simultaneously applying a high frequency vibration to said ingredients;

sequentially moving said ingredients in a series of mixing areas in said confined mixing area, and increasing said intermixing sequentially through said series of mixing areas; and

applying said high frequency vibration throughout said series of mixing areas.

**2.** The process of claim **1** wherein said continuous application of said high frequency vibration throughout said continuous series of mixing areas further comprises increasing the intimate contact between said high frequency vibration and said ingredients as said ingredients progress through said retainer.

**3.** The process of claim **1** wherein said step of applying said low frequency vibration to said mixture of ingredients is a constant application and wherein said step of applying said high frequency vibration to said mixture of ingredients is an intermittent application.

**4.** The prcess of claim **3** wherein said intermittent application of high frequency vibrations is at a frequency less than that of said high frequency.

**5.** A system for intermixing unlike ingredients comprising: retainer means and means for continuously introducing said ingredients thereto means for applying a low frequency vibration to said ingredients, and



means for simultaneously applying a high frequency vibration to said ingredients; means for continuously introducing said ingredients to said retainer, means positioned in said retainer for continually mixing said ingredients, and means associated with said retainer for extruding the mixture.

**6.** A system as set forth in claim **5** wherein said means for applying said high frequency vibration further includes applying said high frequency vibration throughout said series of mixing areas.

**7.** A system as set forth in claim **6** wherein said means for applying said high frequency vibration to said ingredients includes continuous means extending throughout said series of mixing areas, wherein said high frequency vibrations penetrate said ingredients in a continuous series of dense regions.

**8.** A system as set forth in claim **7** wherein said continuous means for applying said high frequency vibration to said ingredients further comprises an auger having a shaft, a plurality of fins permanently attached thereto, means for centrally positioning said auger in said retainer, and means for rotating said auger.

**9.** A system as set forth in claim **8** wherein said retainer is a cylinder and said auger is centrally positioned in said cylinder; means for positioning said ingredient introducing means adjacent an opening in one end of said cylinder and extruding means positioned adjacent the other end of said cylindrical retainer.

**10.** A system as set forth in claim **7** wherein said means for applying said high frequency vibration to said ingredients includes continuous mixing means extending through said series of mixing areas, means connected to said continuous mixing means for increasing the intimate contact between said high frequency vibration and said ingredients as said ingredients progress through said retainer.

**11.** A system as set forth in claim **5** wherein said means for applying said low frequency vibration to said mixture of ingredients is a constant application, and wherein said means for applying said high frequency vibration to said mixture of ingredients is an intermittent application.

**12.** A system for intermixing unlike ingredients comprising: cylindrical retainer means for said ingredients, means for introducing said ingredients to said retainer, means for applying a low frequency vibration to said ingredients, electromechanical transducer means for simultaneously applying a high frequency vibration to said ingredients; said transducer being a resonant structure with one end thereof an energy concentrator, said end of said transducer operating to vibrate back and forth with the maximum power capability of said transducer;

mixing means having an auger including a shaft and a plurality of fins permanently attached thereto; means for centrally positioning said auger in said retainer, and means for rotating said auger; means for positioning said maximum power output end of said transducer adjacent one end of said rotating auger shaft.

**13.** A system as set forth in claim **12** further comprising means for intermittently coupling said back and forth moving end of said maximum power output end of said transducer to said rotating shaft.

**14.** A system as set forth in claim **13** wherein said intermittent coupling means further comprises means for periodically impacting said rotating shaft with a sufficient force to cause said end of said rotating shaft to in turn contact said end of said transducer.

15. A system as set forth in claim 14 wherein said periodic impact means includes a hydraulic impact hammer having a frequency of impact substantially less than the frequency of said high frequency vibration.

16. A system for intermixing unlike ingredients comprising: a cylindrical retainer means for said ingredients, means for mixing said ingredients in said retainer, said mixing means including a shaft and fins, means for centrally positioning said shaft in said retainer, and means for rotating said shaft; means for applying a low frequency vibration to said ingredients, means for simultaneously applying a high frequency vibration to said ingredients, said last named means including said shaft and fins of said mixing means, and means for coupling said source of high frequency vibration to said rotating shaft; said fins positioned on said shaft aperiodically with the greatest number of said fins positioned on said shaft in an area advanced in said mixing cylinder.

* * * * *