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(54) **REINFORCED FOAM ARTICLES**

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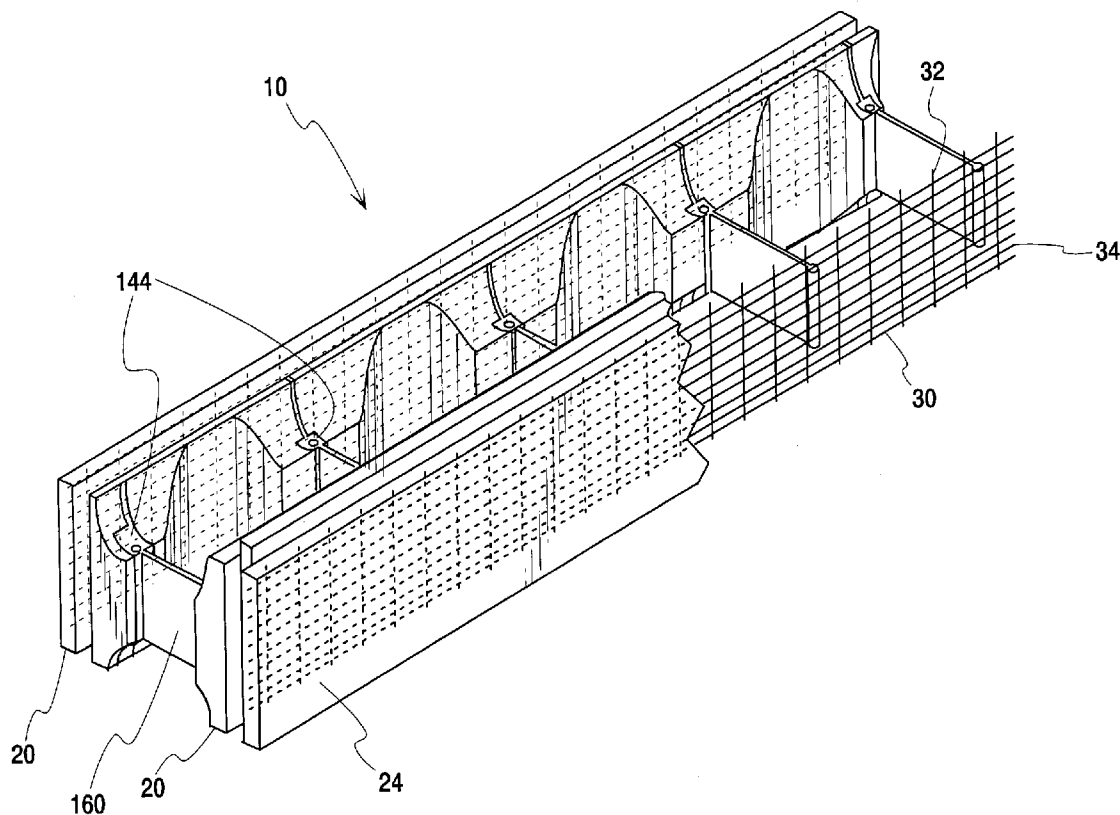
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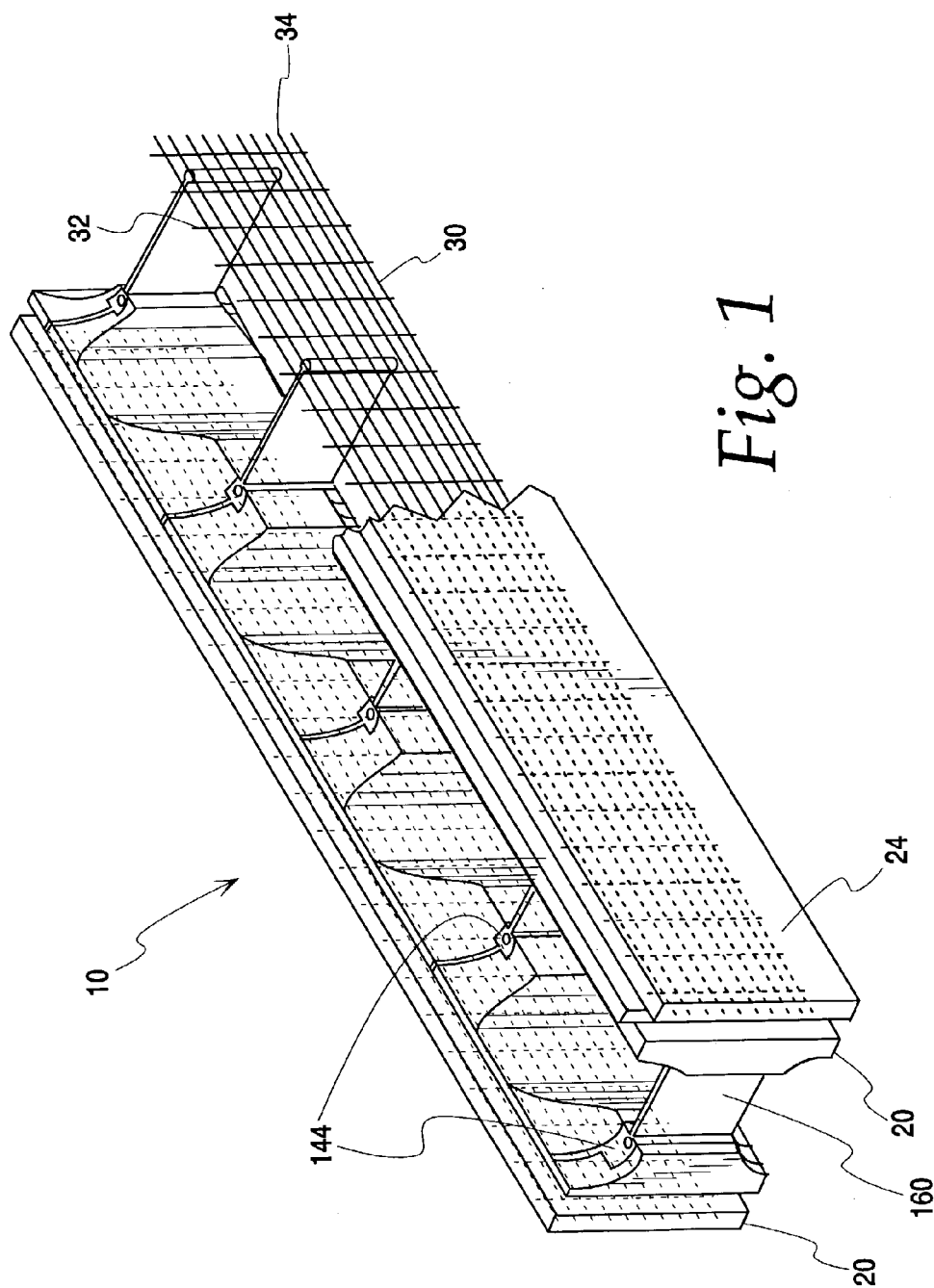
(57) **ABSTRACT**

Reinforcement is provided for foam articles made from dry flowable expanding beads. The reinforcement includes a net work of elements, preferably woven or roving type. The net work is positioned within the foam matrix at a location remote from an applied force so as to impart increased bursting strength to the foam matrix.

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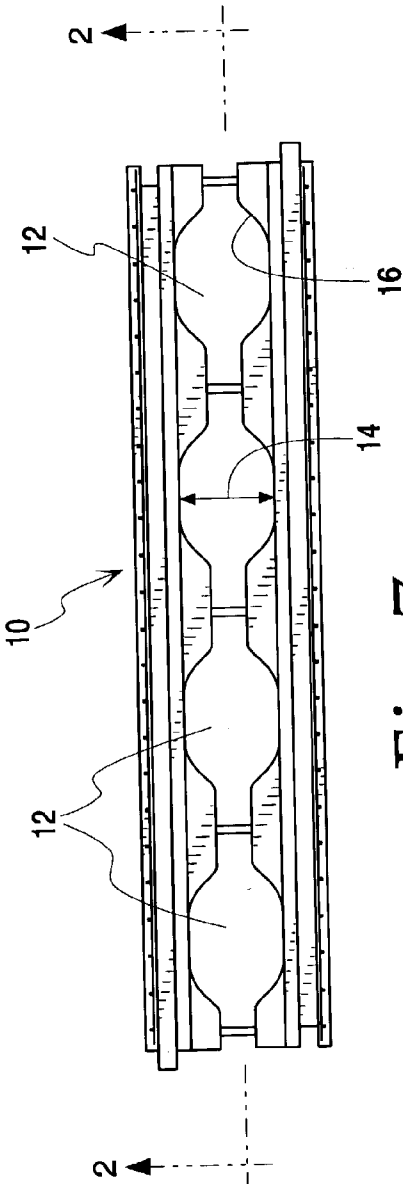


Fig. 7

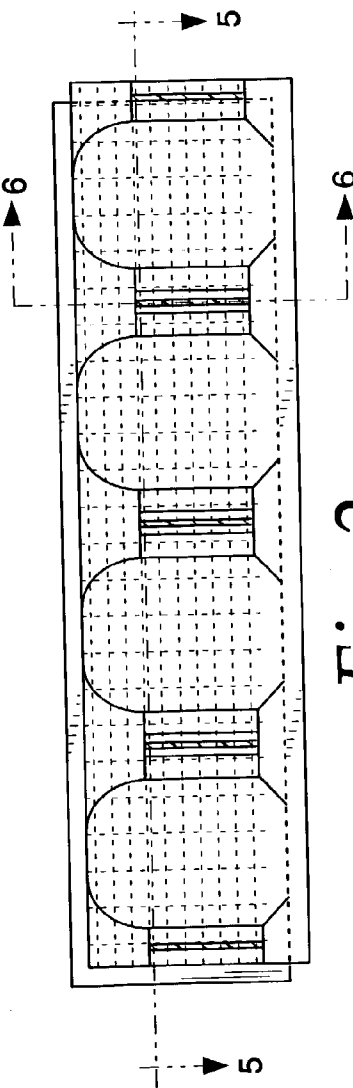


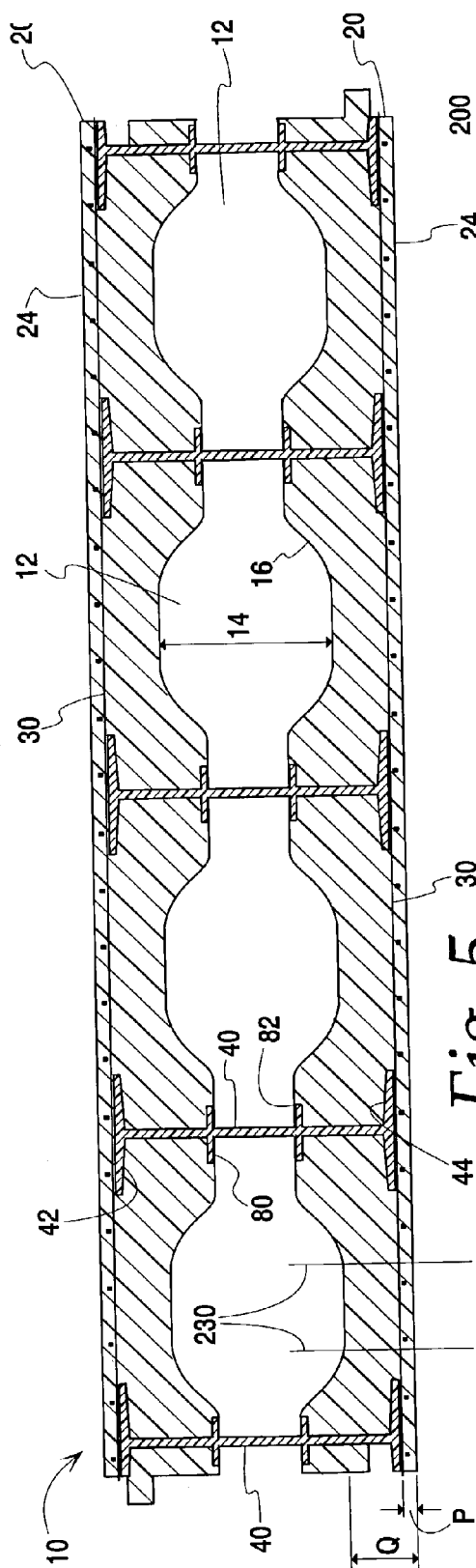
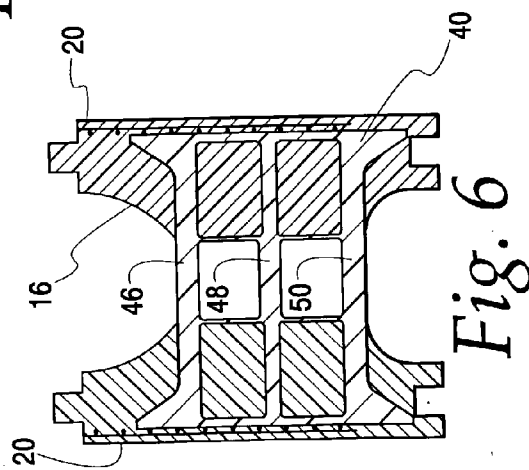
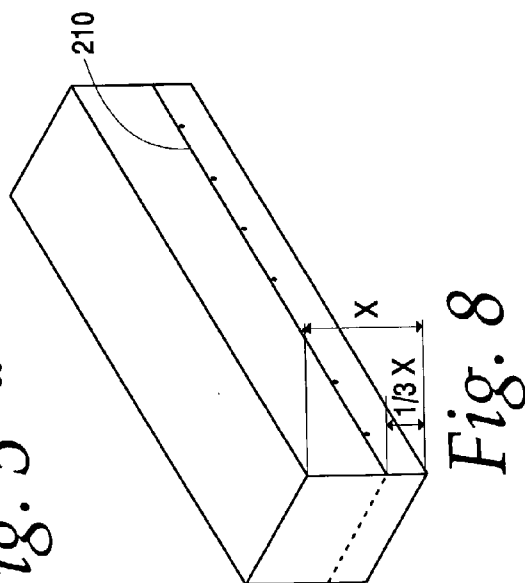
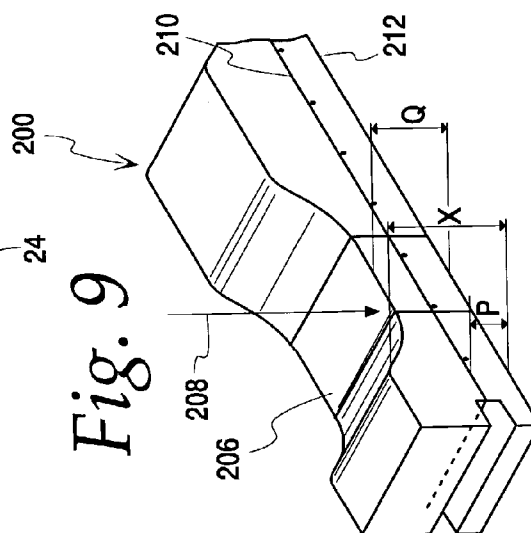
Fig. 2



Fig. 3



Fig. 4



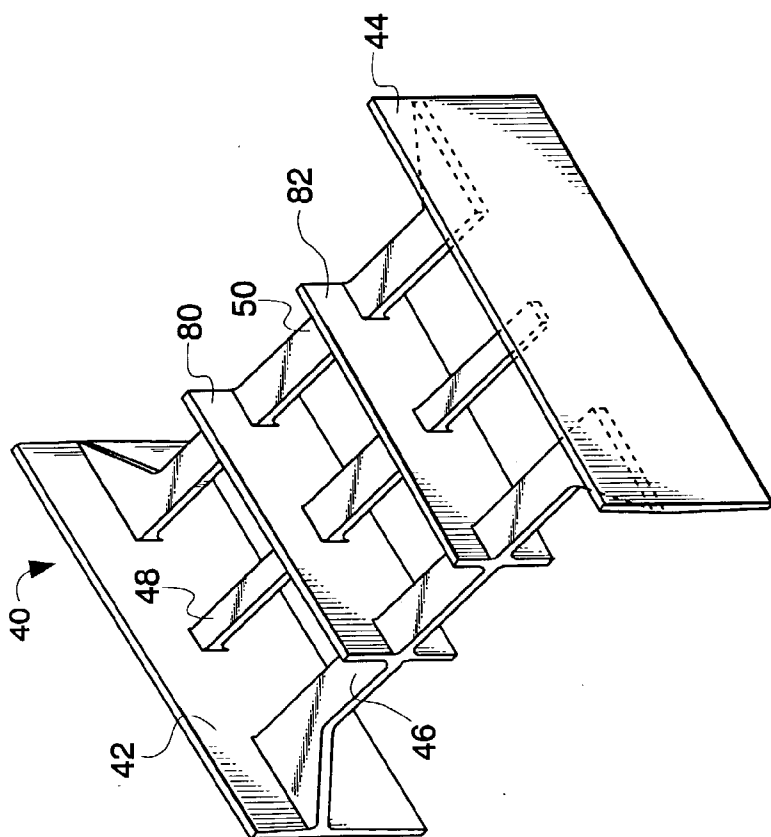


Fig. 10

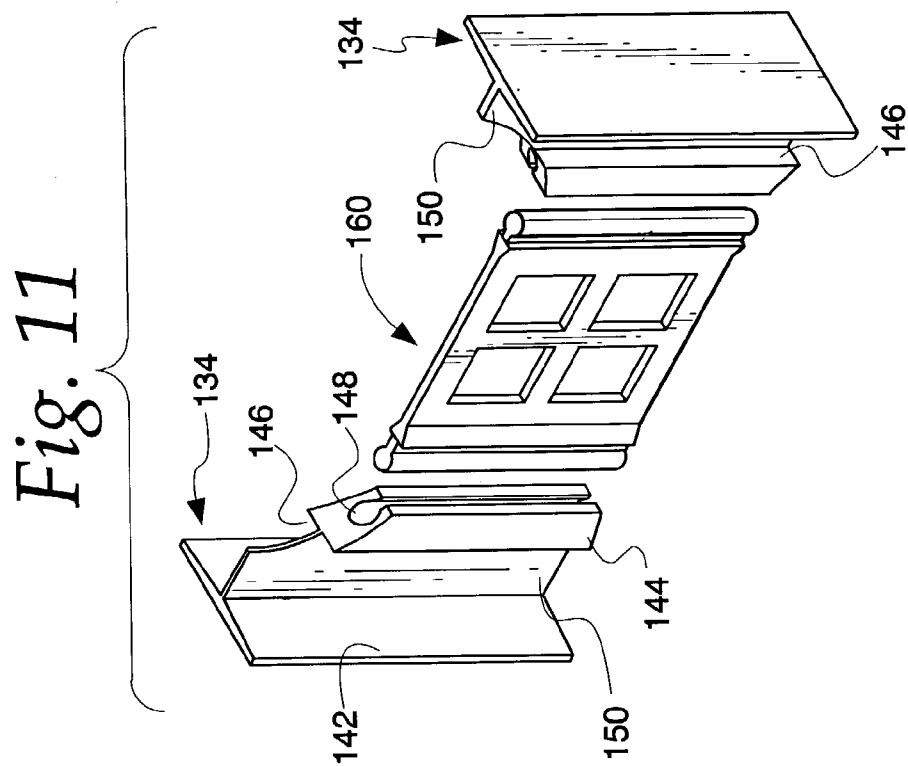


Fig. 11

REINFORCED FOAM ARTICLES

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention pertains to reinforced foam articles and in particular to articles made with dry expandable flowable foam beads.

[0003] 2. Description of the Related Art

[0004] Ongoing efforts have been made to develop three-dimensional foam members for use in structural, i.e., load-bearing, applications. In the aircraft industry, for example, laminate structures have been proposed which include foam matrices formed from a so-called wet foaming process in which a liquid resin is flowed in place along with an expanding gas component or other blowing agent which reduces the density of the liquid resin to a desired level. The blowing agent may be incorporated in the liquid resin composition or may be introduced as the liquid resin composition is injected into the mold. The blowing agent may be liberated from solid or liquid components added to the liquid resin composition during mixing, or may comprise a gas, such as nitrogen or carbon dioxide, which is injected directly into the liquid resin composition.

[0005] One advantage of wet foaming processes is that the resin, being provided in a liquid form, has a prolonged wetting time in a liquid phase, and internal reinforcing components disposed within the core of the foamed articles are subjected to the expanding liquid resin over an extended time. This promotes intimate contact between the resin and the surfaces of the internal reinforcing members. During this time, the liquid resin conforms or flows around the outer surfaces of exposed internal reinforcing members. In addition to such conformance aspects, the liquid resin is allowed to form chemical attachments with surface features of the internal reinforcing members.

[0006] Often, the internal reinforcing members are treated with a sizing or other external coatings which enhance the chemical bond with the foaming liquid resin. As the prolonged wetting phase draws to an end, chemical interaction between the expanded resin and the outer surfaces of the internal reinforcing members is substantially completed achieving most, if not all of the resulting pull out strength present within the core of the resulting foamed article.

[0007] One example of a wet foaming process is given in U.S. Pat. No. 4,073,840 where discrete reinforcing fiber filaments are homogeneously dispersed in a liquid foamable resin composition prior to foaming of the composition, to form a fiber slurry. The fibers are typically provided in a bundle form and upon mixing in the foamable resin, the fiber bundles are separated and are wetted with the resin to form a wet foamable resin composition which is then fed into a mold apparatus where the foamable resin composition is allowed to foam to achieve its final density. Thermoset resin compositions such as foamable polyurethane resin compositions are preferred. As may be required for a particular process, catalysts, surfactants, foam stabilizers and curing agents are added to the foamable resin composition during mixing, prior to injection in the mold.

[0008] Despite advances in the art of producing foamed articles, further refinements are sought to allow the use of

different foaming processes to produce foam articles having a self-supporting reinforced core, whose reinforcing properties are continuous throughout the body of the foamed article.

SUMMARY OF THE INVENTION

[0009] A wide variety of structural foamed articles are produced today using so-called "dry" bead processes. Examples of such articles are found in commonly assigned U.S. Pat. Nos. 5,701,710 and 5,809,728. The self-supporting concrete form modules provided by these patents have met with widespread commercial acceptance. The modules incorporate internal, plastic tie structures having bearing surfaces embedded within the opposed walls of the resulting concrete form modules. While the concrete form modules produced according to these patents may employ liquid resin compositions, it has been found commercially advantageous to form such modules commercially available using dry expandable flowable foam beads.

[0010] Typically, the dry beads are blown into a mold cavity. Initially, the dry beads are freely movable to form a free-flowing packing arrangement within the mold cavity. The dry beads are then heated while under packing pressure and are allowed to expand within the mold cavity to achieve a desired density target value. During the heating and expansion phase, the outer surfaces of the dry beads are very briefly liquified to allow chemical bonding with adjacent beads so as to form a familiar three-dimensional unitary foam matrix. The wetting time of the dry beads is very brief compared to that of liquid resin compositions which are expanded using flowing agents. The wetting times of dry beads are typically on the order of 0.1-1% of the wetting times of liquid resin compositions. As a result, if significant pull out strength is to be attained with reinforcing members disposed within the foam matrix, attachments must be initiated and completed very quickly, as the expanding beads are wrapped about or otherwise conform to the outer surfaces of the internal reinforcing members.

[0011] According to one aspect of the present invention, substantial attachment forces between the dry, expandable, flowable beads are achieved using conventional molding processes which do not require extended wetting times. In many instances, it would be difficult, if not impossible, to substantially extend the very brief wetting phase of the dry expandable flowable foam beads if manufacturing advantages of conventional dry foam molding techniques are to be maintained.

[0012] In other aspects of the present invention, foamed articles having improved burst strength and other high performance qualities are produced using dry, expandable, flowable foam beads which form little, or no chemical attachment to internal reinforcing members. Improved internal support is provided by internal reinforcing members without appreciable pull out strength between the outer surfaces of the internal reinforcing members and the foam matrix within which the internal reinforcing members are embedded. For example, when foamed articles, such as concrete forms, are manufactured according to the present invention, two or three-dimensional arrays of internal reinforcing members greatly increase the burst strength of the form modules when subjected to hydrostatic loadings of wet poured concrete.

[0013] While the present invention has found immediate acceptance in the field of self-supporting concrete form modules, virtually any useful structural foamed article will benefit from the present invention to achieve reinforcement without substantial additional costs to provide molded structural articles of commercial significance. Because existing dry bead foaming processes can be carried out according to principles of the present invention without substantial modification, reinforcement of existing foamed articles can be enjoyed without requiring the manufacturer to incur prolonged development times, and improved reinforced foamed articles can be quickly brought to the marketplace.

[0014] It is an object of the present invention to provide foamed articles utilizing dry expandable flowable foam beads.

[0015] Another object of the present invention is to provide substantial internal reinforcement for such foamed articles.

[0016] A further object of the present invention is to provide molding techniques for such foamed articles which can be quickly carried out using inexpensive techniques.

[0017] A further object of the present invention is to provide foamed articles having improved internal reinforcement without requiring substantial pull out strength to be formed between internal reinforcing members and the foam matrix formed by dry expandable flowable foam beads.

[0018] A further object of the present invention is to provide foamed articles of the above type utilizing an internal reinforcing member in the form of an openwork such as mesh, screen or other interconnecting two-dimensional form. Pierced or perforated sheets can also be employed.

[0019] These and other objects according to principles of the present invention are provided in a freestanding form module for receiving flowable materials to make a wall which includes the form module, the flowable materials exerting a force in a selected direction, the form module comprising at least two spaced-apart form members having opposed interior form surfaces, each form member including a wall portion and a rib portion extending from the wall portion toward another one of said form members. At least one monolithic molded plastic tie member having opposed ends with a web member between the ends extending along a web axis, a bearing member at each end of the tie member, extending generally transverse to the web axis and embedded in the wall portion of a respective form member with the form member formed around so as to captively enclose the bearing member and each end of the tie member having a stabilizing member extending generally transverse to the web axis, spaced from the bearing member and embedded in the rib portion of a respective form member adjacent the interior form surface thereof with the form member formed around so as to captively enclose the stabilizing member. The improvement in said form members comprises a reinforced foamed article including a three-dimensional foam matrix core of expanded dry flowable foam beads; an internal reinforcing openwork reinforcing member disposed in the foam matrix and attached to the expanded beads of the foam matrix; a sizing between at least some of the foam beads and the openwork reinforcing member; and a majority of said openwork reinforcing member oriented in said foam matrix in a direction generally perpendicular to said preselected direction.

[0020] Other aspects of the present invention, and attendant advantages are provided in a method of producing a reinforced foamed article comprising the steps of providing dry expandable flowable foam beads; an openwork reinforcing member and a mold cavity. Placing the openwork reinforcing member in the mold cavity. Flowing the foam beads into the mold cavity and around the openwork reinforcing member. Heating the foam beads and the openwork reinforcing member within the mold cavity while allowing the foam beads to expand and fuse with one another to form a three-dimensional foam matrix with the openwork reinforcing member disposed therein.

[0021] Aspects of the present invention are described with regard to a particular example of a commercially significant concrete form module. The present invention is however not limited and can be employed with virtually any decorative or structural member made from dry expandable foamable beads. Further, the reinforcement matrix afforded by the present invention may be used with or without other reinforcing systems, such as the plastic ties of the preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] FIG. 1 is a perspective view of a concrete form module according to principles of the present invention;

[0023] FIG. 2 is a cross-sectional view taken along the line 2-2 of FIG. 7;

[0024] FIG. 3 is a first end view of the cross-section of FIG. 2;

[0025] FIG. 4 is a second end view of the cross-section of FIG. 2;

[0026] FIG. 5 is cross-sectional view taken along the line 5-5 of FIG. 2;

[0027] FIG. 6 is a cross-sectional view taken along the line 6-6 of FIG. 2;

[0028] FIG. 7 is a top plan view of the module of FIG. 1;

[0029] FIG. 8 is a schematic view of a test sample;

[0030] FIG. 9 is a schematic view of another test sample;

[0031] FIG. 10 is a perspective view of an internal tie member; and

[0032] FIG. 11 is an exploded perspective view of another tie member.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0033] As will be seen herein, the present invention may be employed to produce foam articles both decorative and structural of virtually any shape and size desired. The present invention has however found immediate commercial application in producing foam concrete forms of the type described in commonly assigned U.S. Pat. Nos. 5,701,710 and 5,809,728 the disclosures of which are incorporated as if fully set forth herein. Turning now to the drawings, FIG. 1 is a perspective view of a self-supporting foam module for use as a concrete form. Module 10 preferably includes alternating tongue and groove interlocking edges that allow multiple modules to be interlocked in a two-dimensional array to form a continuous wall. As can be seen in the top

plan view of **FIG. 7**, module **10** includes a serial succession of substantially cylindrical cavities or cells **12** which receive a flowable casting material, such as concrete, and which distribute the concrete throughout the module during a pour, when concrete is typically introduced into the top of a wall formed by multiple modules **10**.

[0034] During initial stages of the pour, the preferred casting material, i.e., concrete or the like cementitious product exhibits fluidic behavior, producing hydrostatic pressure that acts laterally, in a horizontal direction as indicated by arrows **14** in **FIGS. 5 and 7**, pressing against the inner surfaces **16** of opposed, discrete wall members **20**. Hydrostatic forces of the poured concrete act from within the modules **10** in a direction which causes internal bursting pressure, tending to force the walls **20** apart from one another. This direction of applied force extends along a Z-axis. Referring to **FIG. 1**, the outer surface **24** of wall **20** extends in a plane, along a vertical Y-axis and a horizontal X-axis. As shown in **FIG. 1**, an internal reinforcing mesh **30** has elements **32** extending in a Y-direction and elements **34** in an X-direction, forming an openwork arranged in the form of a rectilinear grid.

[0035] The internal bursting force caused by hydrostatic pressure of the poured concrete eventually dissipates as the concrete sets, becoming less fluid and eventually hardening into a solid form. It is generally preferred when pouring a wall that the concrete is poured at a relatively slow rate, allowing the bottommost portion of the concrete within the wall to begin to set, preventing a head pressure or internal bursting pressure acting over the full height of the wall. In practice, the rate of set of the poured concrete must be carefully monitored, taking into account the weight and temperature of the concrete mix, the rate of placement of the concrete use of admixtures in the concrete being poured and the effect of vibration or other methods of consolidating the poured concrete material.

[0036] The walls **20** of module **10** are preferably molded using foam material characterized as dry expandable flowable beads, as are known in the art, as distinguished from wet foaming systems in which a liquid resin is expanded by a blowing agent. The foam concrete form modules illustrated in the figure herein are preferably made of dry flowable expandable beads of styrene and polystyrene of sizes ranging between 0.40 mm and 1.10 mm, commercially available from Huntsman Chemical Corp. as Product No. 7454. Examples of other dry beads suitable for use with this embodiment of the present invention include: BASF Series BF or BFL (i.e., BF 422) available from BASF Corporation of Mount Olive, N.J.; Samsung Series SF (i.e., SF 301) available from Samsung Cheil Industries of Seoul, South Korea; and Nova M Grade (i.e., M77b or 35mb) available from Nova Chemicals Corporation of Pittsburgh, Pennsylvania. The module walls **20** have height and width dimensions (extending in the X and Y directions) of 12" and 48", respectively. Walls **20** have a thickness ranging between 2½" and 4" with minimum and maximum dimensions occurring in the pattern shown in **FIG. 5**. As can be seen in **FIGS. 5 and 6**, the internal wall surfaces **16** are irregular, i.e., non-planar, while the outer surfaces **24** of the walls have a generally flat, planar appearance as can be seen for example in **FIG. 1**. Referring to **FIGS. 5 and 6**, the opposed walls **20** are joined together at a fixed spacing by tie members **40** preferably made of a non-metallic molded plastic material such as an ABS compound commercially available from

DOW Chemical Company under the trade designation Magnum 9555. The plastic ties **40** are constructed according to commonly assigned U.S. Pat. No. 5,701,710. An individual tie **40** is shown in **FIG. 10** having major bearing plates **42**, **44** lying adjacent outer surfaces **24** of walls **20** and minor bearing plates **80**, **82** lying adjacent the inner surfaces **26** of walls **20**. Referring to **FIG. 6**, plastic ties **40** further include cross members **46**, **48** and **50** which extend between the major bearing plates.

[0037] Referring to **FIGS. 1 and 11**, modules **10** may also be constructed using multi-component tie members shown in **FIG. 11** included is a central component **160** located between a pair of outer components **134**. The central component **160** is slidably engaged with outer components **134** being received in grooves **148** formed in inner wall members **144**. Inner wall members **144** include linear bearing surfaces **146** which face toward an interconnecting webbing **150** and outer, major bearing plate portions **142**. Whether constructed in the unitary fashion as shown in **FIG. 10** or in an interlocking multi-component fashion as illustrated in **FIG. 11**, the plastic tie members of a module have bearing surfaces embedded within the foam matrix of the walls **20** so as to form a unified load-bearing system therewith. The plastic tie members reinforce the foam matrix walls **20** particularly with regard to internal bursting pressures extending in the Z-direction indicated by arrow **14** of **FIG. 5**.

[0038] In the dry bead technology of the present invention, the beads are dry and flowable when introduced into a mold. After a sufficient quantity of dry beads are packed into the internal cavity of a mold, the beads are heated in situ within the mold cavity. The beads respond to heating by softening and expanding within the mold cavity, exerting pressure on neighboring beads. The beads throughout the mold cavity undergo substantially simultaneous expansion upon introduction of heat. During the expansion, the outer surfaces of the beads are softened or liquified, with adjacent beads becoming fused together under pressure of the bead expansion. The so-called "wetting phase" of the dry beads, which coincides with their expansion phase, takes place over a relatively short time, on the order of 45 to 60 seconds which is for polystyrene beads of 0.40 to 1.10 inch diameter, compared to approximately 100-1000 seconds for liquid resin compositions.

[0039] As mentioned above, the present invention is directed to the use of dry expandable flowable beads, in conjunction with conventional molding methods and apparatus. As emphasized above, the critical interaction period (i.e., the wetting/expanding/fusing phase) for the dry expandable flowable beads is considerably shorter than the critical interaction period for other molding techniques, such as those employing liquid resin compositions. Due to the substantial differences between these two disciplines (dry expandable flowable beads and liquid resin compositions) the techniques and apparatus associated with liquid resin molding compositions are not applicable to the use of dry expandable flowable beads in a conventional molding application. It is understood that the critical interaction period for both disciplines involve both polymer surface melt interactions on the one hand and true chemical bonding and cross linking on the other hand. However, it is important to realize that these two factors are not equally important to the two disciplines. With the molding discipline employing dry

expandable flowable beads, polymer surface melt interactions which lead to good melt adhesion is the predominate factor promoted, while other factors such as true chemical bonding between the beads and other components of the mold composition are of far less importance. The successful molding compositions using dry expandable flowable beads focus on polymer surface melt interactions leading to good melt adhesion and this would not be compromised in an effort to promote true chemical bonding which is relatively unimportant to the success of the mold process. On the other hand, the molding of liquid resin compositions relies predominately on true chemical bonding, such as covalent bonding and cross linking. While polymer surface melt interactions may be present in the molding of liquid resin compositions, this factor is relatively unimportant and is not generally promoted at the risk of sacrificing the true chemical bonding which is of predominate importance for the molding of liquid resin compositions.

[0040] Despite the immediate commercial acceptance of concrete form modules constructed according to commonly assigned U.S. Pat. Nos. 5,701,710 and 5,809,728, further advances were sought with regard to strengthening the walls 20. In particular, reinforcement was desired to provide added resistance to the internal bursting pressure operating in the Z-direction indicated by arrow 14 in FIG. 5. As can be seen in FIG. 5, the plastic ties 40 provide a series of spaced apart reinforcements disposed between the cavities 12 which, due to their generally concave shape give rise to points of minimal wall thickness. It was desired to add reinforcement, particularly reinforcement against bursting pressures at the points of minimal wall thickness. As mentioned above, reinforcement is provided by openwork reinforcing members 30, lying in an X-Y direction, i.e., parallel to the outer flat surfaces 24 of walls 20 (see FIG. 1). The reinforcing members are seen on-edge in FIG. 5 positioned so as to lie adjacent to or more preferably against the outer surfaces of major bearing plates 44.

[0041] The openwork reinforcing members 30 most preferably comprise a rectilinear mesh having members 32 extending in the Y-direction and members 34 extending in the X-direction, as can be seen in FIG. 1. Examples of materials used for reinforcing member 30 include Total Wall HC/Type PM hard coat mesh available from Total Wall, Inc. of Madison, Wis.; Total Wall sm/type PB soft coat mesh available from Total Wall, Inc. of Madison, Wis.; GlasGrid 8501 mesh available from Saint-Gobain Technical Fabrics of Niagara Falls, N.Y.; and Styrotek Hard coat mesh available from Styrotek, Inc. of Delano, Calif.

[0042] Reinforcing members of the rectilinear mesh type are generally preferred due to their ready commercial availability. If desired, the rectilinear mesh could be aligned along a bias direction, i.e., at acute angles to the horizontal and vertical directions. Multiple openwork members could also be employed, whether side by side or overlying or not.

[0043] The reinforcing members could however be made of virtually any material including cloth, plastic or metal, and can also be made as a hybrid composition of cloth, metal or plastic materials, for example. The materials could, for example, be provided as fibers which are wound together in a roving fashion to form the elements 32, 34. The elements could be knotted together, welded or otherwise joined together to form an openwork. If desired, the members

forming the openwork need not be joined together with welding, or adhesives, or the like but may instead be interlaced as with metal screen fabric construction for example.

[0044] The opening size of the openwork may be of any dimension desired, but is preferably large enough to allow a substantially free flow of dry molding beads to pass through the reinforcing member as the mold cavity is filled with molding beads. The preferred openings of the openwork preferably vary between 0.4 mm and approximately 3 inches.

[0045] The elements making up the openwork may be of any cross-sectional size desired but are preferably sized in relation to the cross-sectional size of the dry expandable flowable foam beads with which they are to be enmeshed. It is preferred that the mesh elements defining the mesh openings range between $\frac{1}{4}$ bead diameters and 2-bead diameters. As mentioned, the dry foam beads are freely flowable when introduced into the mold cavity and only upon later application of heat are the beads, particularly the outer surfaces of the beads, softened during the wetting/expanding phase. During this phase, substantial inter-bead pressures and pressures of expansion are developed sufficient to cause individual beads to "wrap around" or otherwise conform to the outer surfaces of the openwork members.

[0046] If desired, the outer surfaces of the openwork members may be coated with an appropriate sizing as is known in the art to augment attaching forces between the foam beads and the openwork members.

[0047] Typically, an appropriate sizing will introduce surface structures on the openwork members which allow the foam beads an easier purchase or chemical bonding grasp. Upon an extreme bursting failure of module 10, the sizing may be thought of as promoting clogging of the openwork openings preventing a flow of beads and bead clusters to pass through the openwork in a direction toward the outer surfaces 24 of the wall members 20 (see FIG. 1).

[0048] The openwork preferred in the present invention may be relied upon to prevent the outward travel of beads and bead clusters during a bursting event caused by excessive internal pressures within the cavities 12 extending in the direction of arrow 14 of FIG. 5. In certain instances, depending primarily upon the mesh opening and the adhesion strength of bead clusters, the openwork may provide sufficient burst resistance without employing a sizing to augment bead adhesion to the openwork members. If inter-bead adhesion strength is sufficiently adequate, it is unlikely during a burst failure mode that bead clusters formed by internal breakage of walls 20 would be small enough to pass through the openwork openings of conventional openwork materials. Accordingly, the openwork may be viewed as providing adequate retention or burst strength capability even in the absence of a sizing or other performance coating applied to the openwork members. It will be realized by those skilled in the art that openwork members constructed as a roving, that is as a twisted interlocking set of fibers or filaments will provide continuous inter-filament interstices which provide a form of mechanical "sizing" or enhancement for bead attachment.

[0049] Several different types of openwork have been given above. In addition to these, the openwork may be

formed as a pierced sheet or as the combination of a structure netting overlain by a flexible sheet of plastic or other material, similar to the construction of commonly available snow fence. Virtually any type of openwork construction may be employed in carrying out the present invention.

[0050] As mentioned, it is preferred that the openwork be provided in a generally planar form oriented in an X-Y or vertical plane direction. This arises from the structural application of the illustrated embodiments in which concrete in a liquified phase is poured into mold structures in such a way as to exhibit a lateral or Z-axis burst force. It is generally desirable that the reinforcement provided by the present invention extend in directions generally parallel to the direction of tension of the molded articles and perpendicular to the direction of the force to be resisted.

[0051] If desired, the reinforcement or openwork of the present invention can be applied in variant directions having a small component in the Z-direction. For example, the openwork can be applied as a flexible fabric having undulating portions which extend out of, i.e., away from a vertical plane. While such angular variances can be tolerated in carrying out the present invention, excessive angular deviations of the reinforcing material will likely result in a substantial reduction in the bursting strength of walls **20**. The application of a particularly aggressive sizing agent may be employed to mitigate strength reduction.

[0052] Preferably, openwork employed in carrying out the present invention to form an internal integrated reinforcing matrix have several important characteristics or properties which provide optimal reinforcing enhancement to a (usually unreinforced) matrix of dry flowable expandable beads which are molded in a commercially advantageous known manner. The present invention contemplates the use of dry flowable expandable beads of virtually any composition and size in commercial use today. Examples of bead materials include styrene, polystyrene, propylene, and polypropylene having bead sizes ranging between 0.1 mm and 2 mm. The present invention has found immediate commercial application in the field of concrete form modules made of dry flowable expandable beads of styrene and polystyrene of sizes ranging between 0.1 mm and 1.6 mm.

[0053] Typically, the dry flowable expandable beads contemplated by the present invention undergo molding by injection into a mold cavity with subsequent loading of the mold/cavity with a substantial quantity of beads, and subsequent exposure of the beads to an external heat source which causes the outer surfaces of the beads to become wetted while the beads expand to achieve a desired target foam density. This critical period in the formation of the molded structure is referred to herein as the wetting/expansion phase in which the previously dry flowable beads are expanded and joined together to achieve an integral solidified mass of selected (final) foam density. According to one aspect of the present invention, the openwork is disposed in the interior of the mold cavity at the time the dry flowable expandable beads are injected in the mold cavity, and at the onset of the wetting/expanding phase of the molding operation.

[0054] It has been found important that certain identifying characteristics of the openwork is needed to achieve a desired strength enhancement compared to similar molded

articles comprised of unreinforced dry flowable expandable beads. These desirable characteristics are believed helpful in obtaining a desired engagement between the outer surfaces of the openwork and the outer surfaces of the beads as they undergo the wetting/expanding phase of the molding operation. These characteristics will, to some extent, depend upon the bead material and bead size chosen for the particular molded article.

[0055] Identifying characteristics of the reinforced molded article include: compatible chemical compositions of dry beads and openwork; that the dry beads are of the flowable expandable type so as to be free flowing to achieve desired packing or density throughout the mold cavity; a cross-sectional size of the openwork and the ratio of the cross-sectional size of the openwork to the length of the openwork elements forming the openwork openings; optionally sizing or the like surface treatment on the openwork to promote enhanced attachment to the expanding beads; folding or other compressed multiple layers of the openwork is generally not preferred; a proportion of openwork to foam beads of approximately 1% by mass; and an orientation of at least 5% of the openwork within the foam core in a direction parallel to the direction of tension and perpendicular to the direction of stress imparted to the molded article.

[0056] As mentioned above, particularly in relation to **FIG. 5**, the openwork reinforcement of the present invention is employed in a commercially significant load bearing structure which employs a spaced apart series of plastic tie members **40**. Due to the configuration of cavities **12** within module **10** it was found desirable to provide added reinforcements adjacent the cavities, i.e., between the tie members **40**. If desired, the openwork reinforcement of the present invention could be employed at virtually any point within the foam matrix of walls **20**. For example, the openwork could be employed at points between the major and minor bearing plates **44**, **82** of tie members **40**.

[0057] As indicated above, the openwork of the present invention is employed in the form of a flexible fabric. In order to take the fullest advantage of the reinforcement strength of the fabric used in the preferred concrete form embodiment it was found expedient to attach the openwork reinforcement to the major bearing plates **44** of the plastic ties **40**. In the preferred embodiment, a pressure sensitive adhesive was employed to attach the openwork to the exposed outer surfaces of the major bearing plates and to allow the adhesive opportunity to fully cure before subjecting the openwork to the molding pressures of the expanding foam matrix. With the foam matrix fully cured, internal bursting forces applied from within cavities **12** will be transmitted by the openwork reinforcement to the major bearing plates of the tie members. It has been found that, even absent the adhesive joinder of the openwork to the major bearing plates, the openwork, held in place by the foam matrix, is adequate to retain heretofore impossible bursting strength. In the worst failure modes, the openwork was found to adequately retain the fluid concrete poured within cavities **12**, albeit with an attending bulging dislocation of foam matrix at the outer surface **24** of walls **20**.

[0058] Examples of the present invention have been set forth with regard to a particular type of a commercially significant structure, that of a concrete form module. The present invention is however not so limited and can be

employed with virtually any decorative or structural member made from dry expandable foamable beads, including molded packaging materials. Further, the openwork reinforcement afforded by the present invention may be used with or without other internal reinforcing systems, such as the plastic ties of the preferred embodiment.

[0059] Referring to **FIGS. 8 and 9**, it is generally preferred that the openwork reinforcement be embedded within a foam matrix wall adjacent that surface of the wall located opposite the location of applied force. For example, in the illustrated embodiment, the applied force is that of an outwardly directed bursting force imparted by a force system (i.e., the hydrostatic forces of poured concrete) located within a foam matrix structure. Accordingly, it is generally preferred that the openwork reinforcement be located adjacent the outer wall of the foam matrix structure, remote from the application site of the force to be resisted.

[0060] Referring to **FIG. 9**, a generalized foam matrix structure is indicated at **200**. Reinforcement of a wall surface portion **206** was studied. The assumed direction of force to be resisted is indicated by arrow **208** and is applied to a wall portion having a total thickness Q .

[0061] The openwork reinforcement according to principles of the present invention is introduced at a distance P from the opposed surface **212** of structure **200**. Openwork reinforcement **210** is embedded within the foam matrix core of structure **200** either with or without benefit of chemical sizing or other mechanical structural features to promote adhesion of the foam beads to the members comprising the openwork. Outward bulging or dislocation of the openwork is resisted by the thickness portion of the foam matrix core indicated by the dimension P . It is generally preferred that the ratio P/Q range between 0.28 and 0.5. Smaller ratios would indicate a reduced foam matrix layer to support the openwork against outward bulging. As indicated above, while complete failure of the openwork is avoided, an outward bulging or distortion of the foam matrix may not be desirable from an appearance standpoint. The most preferred placement of openwork **210** at a position $P/Q=0.33$ is illustrated in **FIG. 8**.

[0062] As indicated above with reference to **FIG. 5**, for example, the openwork **24** is located closer to the outer surface **24** of the foam matrix than would otherwise be preferred. Studies were made of foam core samples taken between the cut lines **230** of **FIG. 5**. The openwork was determined to be located at a position P/Q ranging between 0.210 and 0.30. The reduced value of P/Q , i.e., the reduced foam matrix thickness between the openwork and the adjacent outer surface **24** of wall **20** is offset by cooperation between reinforcement of the present invention and the internal construction of module **10**. Of particular interest here is the relatively close spacing of the major bearing plates **44** of ties **40**. With appropriate adhesive securement between the openwork and the major bearing plates as indicated above the outward bulging of openwork **30** under applied force is sufficiently reduced so as to allow reduced P/Q values of approximately 0.21.

[0063] The drawings and the foregoing descriptions are not intended to represent the only forms of the invention in regard to the details of its construction and manner of operation. Changes in form and in the proportion of parts, as well as the substitution of equivalents, are contemplated as

circumstances may suggest or render expedient; and although specific terms have been employed, they are intended in a generic and descriptive sense only and not for the purposes of limitation, the scope of the invention being delineated by the following claims.

What is claimed is:

1. In a freestanding form module for receiving flowable materials to make a wall which includes the form module, the flowable materials exerting a force in a selected direction, the form module comprising at least two spaced-apart form members having opposed interior form surfaces, each form member including a wall portion and a rib portion extending from the wall portion toward another one of said form members; and at least one monolithic molded plastic tie member having opposed ends with a web member between the ends extending along a web axis, a bearing member at each end of the tie member, extending generally transverse to the web axis and embedded in the wall portion of a respective form member with the form member formed around so as to captively enclose the bearing member and each end of the tie member having a stabilizing member extending generally transverse to the web axis, spaced from the bearing member and embedded in the rib portion of a respective form member adjacent the interior form surface thereof with the form member formed around so as to captively enclose the stabilizing member;

the improvement in said form members comprising:

a reinforced foamed article including a three-dimensional foam matrix core of expanded dry flowable foam beads;

an internal reinforcing openwork reinforcing member disposed in the foam matrix and attached to the expanded beads of the foam matrix;

a sizing between at least some of the foam beads and the openwork reinforcing member; and

at least a majority of said openwork reinforcing member oriented in said foam matrix in a direction generally perpendicular to said preselected direction.

2. The improvement of claim 1 wherein at least 97% of said openwork reinforcing member is oriented in a direction generally perpendicular to said preselected direction.

3. The improvement of claim 1 wherein the foam beads are comprised of polystyrene and said openwork reinforcing member is comprised of fiberglass.

4. The improvement of claim 3 wherein 50% of the foam beads have a size dimension of 0.40 mm and 50% of the foam beads have a size dimension of 1.10 mm.

5. The improvement of claim 1 wherein the openwork reinforcing member is comprised of openwork members having openings ranging in size between 0.4 mm and approximately 3 inches.

6. A method of producing a reinforced foamed article comprising the steps of:

providing dry expandable flowable foam beads;

providing an openwork reinforcing member;

providing a mold cavity;

placing the openwork reinforcing member in the mold cavity;

flowing the foam beads into the mold cavity and around the openwork reinforcing member; and

heating the foam beads and the openwork reinforcing member within the mold cavity while allowing the foam beads to expand and fuse with one another to form a three-dimensional foam matrix with the openwork reinforcing member disposed therein.

7. The method of claim 6 further comprising the step of forming a chemical attachment between the openwork reinforcing member and the foam beads.

8. The method according to claim 7 further comprising the step of coating the openwork reinforcing member with a sizing material to enhance said chemical attachment.

9. The method according to claim 6 wherein the step of providing internal reinforcing fiber members comprises a step of providing internal reinforcing fiber members having an aspect ratio ranging between 0.001 and 0.00001.

10. The method according to claim 6 wherein the openwork reinforcing member comprises a fiberglass mesh.

11. The method according to claim 10 wherein said foam beads are comprised of one of said styrene and said polystyrene.

12. The method of claim 6 wherein the reinforced foam article is to be subjected to an applied force extending in a preselected direction, said method further comprising the step of providing a rigid bearing plate disposed in said foam matrix, said rigid bearing plate having a major surface facing in the preselected direction.

13. The method of claim 12 further comprising the step of attaching a portion of said openwork reinforcing member to said bearing plate.

14. The method of claim 12 further comprising the step of attaching a portion of said openwork reinforcing member to said bearing plate with a pressure sensitive adhesive.

15. The method of claim 6 wherein the reinforced foam article is to be subjected to an applied force extending in a preselected direction, said method further comprising the step of orienting at least a majority of said openwork reinforcing member in a direction generally perpendicular to said preselected direction.

16. The method of claim 15 wherein at least 97% of said openwork reinforcing member is oriented in a direction generally perpendicular to said preselected direction.

17. The method of claim 6 wherein the foam beads are comprised of polystyrene and said openwork reinforcing member is comprised of fiberglass.

18. The method of claim 17 wherein the foam beads have a size dimension of 0.40 mm to 1.10 mm.

19. The method of claim 17 wherein 50% of the foam beads have a size dimension of 0.40 mm and 50% of the foam beads have a size dimension of 1.10 mm.

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