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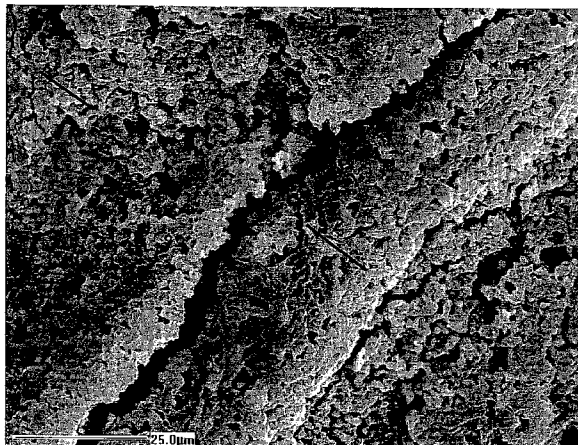
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(54) Title: A PROCESS FOR PRODUCING A FIBRE PLANT/LIME PRODUCT

Figure 7b)



(57) Abstract: A process for producing a fibre plant/lime product comprises a step of providing a fibre plant starting material having a water content of at least 50% (w/w), admixing the starting material with calcium oxide to form a reaction mixture, and allowing the calcium oxide react with embodied biological water in the starting material to form the fibre plant/lime product in which embodied biological free water in the fibre plant material has been converted to slaked lime. The fibre plant starting material is generally non-dessicated fibre plant material or ensiled fibre plant material. The ratio of fibre plant starting material to calcium oxide in the reaction mixture is between 10:20 and 10:1 (w/w). The fibre plant starting material is pulverised prior to reaction with the calcium oxide to produce particles having a mean length of between 1 and 100µm. The reaction mixture is processed to ensure intimate contact between the fibre plant starting material and the calcium oxide. Fibre plant/lime products, and secondary products including building and masonry, are also described.

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A PROCESS FOR PRODUCING A FIBRE PLANT/LIME PRODUCTTechnical Field

5 The invention relates to a process for producing a fibre plant/lime product. In particular, the invention relates to a process for producing a hemp/lime product. The invention also relates to fibre plant/lime products, especially hemp, lime products for use as building, insulation or masonry products.

10

Background to the Invention

There is an urgent need to find more appropriate building materials which are independent of fossil fuel sources, lock carbon into building material and reduce the requirement for fuel to maintain ambient dry warm conditions in buildings. Currently the building materials market is supplied by materials which have a high embodied energy, generate significant volumes of greenhouse gasses and are largely inappropriate for use in modern buildings. Indeed even synthetic insulating materials require high inputs of energy to manufacture and due to low moisture buffer values, cause internal condensation in buildings which has lead to a requirement in building regulations to ventilate and exhaust moisture to eliminate condensation and moulds.

There has therefore been a recent trend towards breathable building materials with good moisture buffering values such as sheep's wool insulation, timber and hemplime amongst others to improve the internal atmosphere and create warm/dry breathable buildings. However there is also a need to create supply chains

of such breathable materials at economic cost and on a locally available basis.

HempLime has shown great promise as one solution to the above
5 issues. There are however a number of major obstacle to rapid development of supply chains including: high risk of crop loss due to un-reliable weather patterns in autumnal temperate climates; high capital cost of processing plants using current methods of fibre and hemp processing; high storage and transport
10 costs; limit to localization due to the capital nature of processing; and inefficiencies in recovery of energy in lime cycle.

Lime has been used as a building material since ancient times
15 and is very well known in the building industry. Lime is used by species of the animal kingdom as the building material for skeletal and shell structures. Limestone is widely available around the world as sedimentary rocks but also in to form of shells in beaches, lakes, the oceans and so on. Quicklime is
20 produced by burning Calcium carbonate or lime stone in a Kiln to form Calcium Oxide CaO and CO_2 . Much of the energy used to burn lime is embodied in the quicklime as potential thermal energy. Slaking is the term commonly used to mean the addition of water or hydration of quicklime. When lime is slaked this energy is
25 vigorously released in the form of exothermic heat. This effect is well known in the lime and chemical processing industry. Hydrated Lime CaOH is another common building material. Quicklime CaO expands and becomes Hydrated lime in the presence of water. Hydrated lime has a lower bulk density than quicklime
30 and expands during the reaction process to occupy more space. Hydrated lime is common supplied as a dry powder with no adhesion properties and lime putty, where a surplus of water

over and above the hydration requirement's, has been added. Lime putty has excellent adhesion properties. Lime is also the main component of Portland cement in conjunction with mineral aggregates and water used to manufacture concrete and other building materials. However Hydrated lime reacts with CO₂ to become CaCO₃ or Calcium carbonate or Limestone. The addition of CO₂ or carbonation process is a gradual process over time and is responsible for the set of lime based building products particularly the High Calcium or fat limes. This material reacts with the air unlike Portland cement or Calcium alumina cements where the setting process is caused by internal chemical/mineral bonds giving a rapid set and where CO₂ released during calcination is not re-absorbed as is the case with High calcium and hydraulic limes. Hydraulic limes combine atmospheric set with a chemical set. It is well known amongst lime experts that high calcium or fat lime are slow to set due to the slow rate of CO₂ diffusion from the atmosphere into the lime matrix. However the fat limes or high calcium limes are recommended due to the breathability of the pure high calcium limes.

Recently Hemp has been used as an aggregate to manufacture building materials in conjunction with Lime to form HempLime or also sometimes referred to as Hemp Crete. Existing processes utilize dry hemp straw or dessicated hemp straw, as the feedstock for the production of these materials (see for example United States Patent Application No: 2004/0129182). These processes involve the collection and preparation of dry hemp aggregate, lime and water. With these existing processes, the embodied biological water in the hemp is lost in the field meaning that additional water must be supplied at the point of mixing. In many cases the embodied heat in the quicklime is also lost and a hydrated lime is used and in other cases quicklime is

used to dry the additional non cellular water to reduce drying time in the wall.

5 Statements of Invention

Broadly, the invention relates to a process for producing a fibre plant/lime product of the type comprising a composite of fibre plant material and slaked lime in which the slaked lime provides structural rigidity to the composite and assists in the binding of the components together. The process employs starting fibre plant material having a high percentage of water contained within the fibre plant material (embodied biological water). This may be, for example, freshly harvested fibre plant material, or fibre plant material which has been ensiled (microbiologically cultured or fermented) for a suitable period to time. The process involves admixing the starting fibre plant material and calcium oxide and allowing the embodied biological water in the fibre plant react with calcium oxide which results in some of the embodied biological water within the plant material (both within the cells and between the cells) being reacted, and replaced, with slaked lime. This provides a structural rigidity to the fibre plant material component of the fibre plant/lime product.

Accordingly, in a first aspect, the invention relates to a process for producing a fibre plant/lime product comprising a step of providing a fibre plant starting material having a water content of at least 50% (w/w), admixing the starting material with calcium oxide (or a source of calcium oxide) to form a reaction mixture, and allowing the calcium oxide react with embodied biological water in the starting material to form the

fibre plant/lime product in which embodied biological free water in the fibre plant material has been converted to slaked lime.

Typically, the process provides for the calcium oxide being intimately mixed with the fibre plant starting material such that the resultant slaked lime in the fibre plant is intimately mixed with the fibre plant material. Typically, the slaked lime intimately coats the fibres of the fibre plant material.

10 The process of the invention provides a number of advantages. First, the process obviates the need to pre-process the fibre plant material to remove water (dessication). This is an energy intensive process which removes water from the fibre plant material prior to reaction with the calcium oxide. It is either
15 carried out with drying machinery, with associated energy costs, or it is normally carried out in the field by leaving the harvested fibre plant material in the field and turning several times over a period of weeks to allow the material dry. This results in a fibre plant/lime product in a dessicated form which
20 usually needs to be stored prior to use. When it is eventually employed to produce a fibre plant/lime product, water needs to be re-added to the dessicated material to allow the mixing with calcium hydroxide and some times calcium oxide to proceed. Secondly, as indicated above, when dessicated fibre plant
25 material is employed to produce a fibre plant/lime product, water needs to be added to the process. The process of the invention obviates this requirement by employing the water embodied within the plant material as a water of reaction. Thirdly, the fibre plant/lime products of the process of the
30 present invention have improved properties compared to fibre plant/lime products generated using dessicated fibre plant material, including improved penetration of lime into the

vascular plant architecture, breathability, moisture buffering value (MBV), and setting times. In particular, the process of the invention provides for an intimate mixing of the calcium oxide within the reaction mixture which results in a fibre plant/lime product in which the resultant slaked lime is intimately mixed with the fibres of the product, typically coating the fibres. Furthermore, the process of the invention allows immediate use of harvested fibre plant material if required.

In a preferred embodiment of the invention, the fibre plant starting material is non-dessicated fibre plant material. This is taken to mean that the fibre plant material is not treated to dessicate the material by drying in the field or active drying using drying machinery or active drying processes.

In one embodiment of the invention, the fibre plant starting material is ensiled fibre plant material. Ensiling is a term known in the art, and refers to a process where the harvested fibre plant material is stored in a container which limits or prevents access of air to the stored material. It results in partial fermentation of the material during which the anaerobic conditions in the container favour the growth of anaerobic bacterial which utilise sugars and other substrates in the fibre material to produce fermentation by-products, including lactic acid and other organic acids. When ensiled hemp is employed in the process of the invention, these fermentation (generally including organic acid) by-products are neutralised to form organo-mineral salts such as calcium lactate, calcium lignin and cellulosic by-products which stabilise and help solidify the resultant fibre plant/lime product.

Typically, the ensiled fibre plant material is ensiled for a sufficient period of time to allow the production of fermentation products within the ensiled material. Generally, ensiling takes place for at least 40, 80, 160, 240, 320, 400 and 480 days. However, the ensiling period may be suitably reduced by modifying the process to accelerate fermentation by means of, for example, inoculating the material with a starter culture, addition of fermentation substrates, and modifying the temperature of the process.

In a preferred embodiment of the invention, the ratio of fibre plant starting material to calcium oxide in the reaction mixture is from 10:50 and 4:1, preferably from 10:50 and 10:5, ideally from 1:4 and 2:1, all provided as w/w.

In one embodiment of the invention, in addition to high calcium lime as sole components of the additional components are added prior to, during and/or after the reaction such as silica powder/slurries, clay powders/slurries, lime slurries, Portland cement, calcium alumina cement, aluminium powders, silicon powder, polymer resins or any binder of an organic or inorganic nature.

Typically, the fibre plant starting material is pulverised prior to reaction with the calcium oxide to produce particles typically having a mean length of between 1 and 100mm, ideally between 5 and 50mm. In this regard, mean length means the average length or size of the particles taken across a widest diameter of the particles. When the particles have an elongated shape, this will generally be their length. Pulverisation may also provide a pulverised product in which the size or length of

the particles are variable within a given range, for example most of the particles may have a size of between .1 and 100mm.

5 In one embodiment of the invention, the reaction mixture is processed to ensure intimate contact between the fibre plant starting material and the calcium oxide. This may be achieved, for example, by partially pressing or compacting the reaction mix during the reaction. Generally, the starting fibre plant material and the calcium oxide are added to a reaction vessel
10 and mixed by means of a single or twin auger or turned during the reaction period so as to allow a sufficient amount of contact between the calcium oxide and the fibre plant material. Trials indicate that this is achieved, for example, by means of any suitable bulk mixer having a screw or auger or paddle type
15 mixer, operating continuously or discontinuously. For example, the fibre plant and calcium oxide may be added to the mixer, mixed initially for a period of at least 4 minutes, and then allowed to sit for a period 4 minutes to allow the calcium oxide react with the moisture in the fibre plant. After a suitable
20 period of time, for example, ten minutes, the materials may be mixed again for a further minute before being allowed to sit for a further reaction period. This is repeated until the desired moisture content in the fibre plant material is achieved.

25 In the process of the invention, biological water in the fibre plant reacts with the calcium oxide (often provided in the form of quick lime) in an exothermic reaction to form calcium hydroxide (commonly known as slaked or hydrated lime) and heat.

30 $\text{CaO} + \text{H}_2\text{O} \text{ (biological)} \leftrightarrow \text{Ca(OH)}_2 + \text{complex by-products} + 488 \text{ BTU/lb of CaO}$

From a drying point of view, this has the two-fold effect of removing water from the reaction mixture chemically through the formation of calcium hydrate, and the removal of water by means of evaporation as a result of the heat generated in the reaction vessel and final placement position.

The amount of calcium oxide required in the process depends on a number of variables, including the moisture content of the starting fibre plant material, the desired moisture content of the finished fibre plant material, the type of fibre plant being processed, and also the thermal conductivity of the reaction vessel in which the process of the invention is being carried out. Thus, as it hydrates, approximately 3.1kg of calcium oxide combines with approximately 1kg of water to produce calcium hydroxide. Thus, if you start with 1 tonne of fibre plant having a moisture content of 70%, approximately 700kg of the fibre plant will be water. If you require that the moisture content be reduced to 19%, this would entail that 245kg of water is reacted. In ideal reaction conditions, about 790kg of calcium oxide would be required to react the 110kg of moisture. This would mean that the fibre plant: calcium oxide ratio would be 100:79 (w/w). However, in practice there are benefits to maintaining a level of moisture within the mixture as moisture provides an important mechanism for adhesion between particles therefore in practice a moisture content of not less than 30% is desirable for immediate on site use as a building material. Research at the Institute for Post harvest technology demonstrated the surprising result that very low concentrations of CaO will generate stables. In one embodiment of the invention lower moisture contents are acceptable where only a feedstock for further processes is required.

In one embodiment of the invention, the process involves the steps of determining the moisture content of the starting fibre plant material, deciding the desired moisture content of the finished fibre plant/lime product, calculating the amount of water to be removed from the fibre plant to arrive at the desired moisture content, subsequently calculating the amount of the calcium oxide required to remove that amount of water under ideal reaction conditions, and employing excess calcium oxide in the reaction.

The calcium oxide may be provided in a substantially pure form. However, it may also be provided in the form of lime, quicklime, or burnt lime having a high proportion of calcium oxide. In a preferred embodiment of the invention the calcium oxide is provided in the form of high calcium quicklime. In one embodiment of the invention fresh calcium oxide having a temperature greater than 98 degrees centigrade is used directly from the kiln thereby further improving thermal and energetic efficiencies.

In one embodiment of the invention, the fibre plant/lime product is used as an insulating material, for example, thermal insulation materials and sound insulating materials. These properties are due to the low density of the product provided by the fibre plant/lime product.

In one embodiment of the invention, the fibre plant/lime product is post-treated to form a secondary product. Typically, post treatment includes the step of adding further water and/or further components to the fibre plant/lime product. Water may be added as a liquid, or in the form of a paste or slurry in which water is admixed with other secondary components. The further

components may comprise structural elements, such as mineral components, and binding elements such as organic polymers and non-organic binders. In one embodiment, the binding element is a lime-containing product such as, for example, lime putty.

5 Typically, the structural element is a mineral component such as a mineral powder. Examples of further components include: silica powder/slurries; clay powders/slurries; lime slurries; Portland cement; calcium alumina cement; aluminium powders; silicon powder; polymer resins or any binder of an organic or inorganic

10 nature.

In one embodiment of the invention, the fibre plant/lime product is milled prior to post-treatment. This may take place when, for example, the fibre plant/lime product is fully or partially

15 solidified after the reaction with the lime is completed, and the solid mass needs to be broken up for further processing. The process of breaking up the solid or semi-solid mass is not restricted to milling, and the skilled person will know a number of other methods of breaking up the product into a more

20 particulate form.

In one embodiment, the fibre plant/lime product is optionally milled and then mixed with water to provide a wet-mix fibre plant/lime paste. This paste may be used as a building material,

25 and may be prepared at a building site for use as a poured concrete-like product, or for use as mortar or plaster. It may also be packaged in a water and air tight packaging for storage and further use as, for example, a building material. In one embodiment, the water is provided in the form of suspension

30 comprising water and a building component such as lime (i.e. lime putty). Suitably, the further components are added to form the paste such as a structural component as described above.

In one embodiment of the invention, the fibre plant/lime product or the secondary product is post-treated to form a masonry product, wherein the treatment is selected from the group consisting of: casting; compression; drying; heating; autoclaving CO² injection. Suitably, prior to treatment of the fibre plant/lime product, a further component is added to the fibre plant/lime product selected from the group consisting of: water; mineral products including clays, gypsum, water glass pozzalanas, rock dust; lime products including hydraulic limes, portland cement, calcium alumina cement, and organic compounds such as bitumen, and any organic polymer.

Ideally, the fibre plant starting material has a water content of at least 55% (w/w), preferably at least 60% (w/w), more preferably at least 65% (w/w), and ideally at least 70% (w/w). Typically, the reaction time is sufficient to decrease to water content of the fibre plant material to 10%, 20% or 30% (w/w).

Generally, at least 75% of the water content of the fibre plant starting material is embodied biological water. Suitably, at least 80% of the water content of the fibre plant starting material is embodied biological water. Preferably, at least 85% of the water content of the fibre plant starting material is embodied biological water. More preferably, at least 90% of the water content of the fibre plant starting material is embodied biological water. Ideally, at least 95% of the water content of the fibre plant starting material is embodied biological water

Typically, at least 50% (w/w) of the slaked lime contained within the fibre plant/lime product is embodied within the fibre plant component of the fibre plant/lime product. Preferably, at

least 60% or 70% (w/w) of the slaked lime contained within the fibre plant/lime product is embodied within the fibre plant component of the fibre plant/lime product. Ideally, at least 75% (w/w) of the slaked lime contained within the fibre plant/lime product is embodied within the fibre plant component of the fibre plant/lime product.

In one embodiment, the process of the invention is a process for (partially) drying fibre plant material.

The starting fibre plant material is selected from the group shown in Appendix 2. In a preferred embodiment, the fibre plant material is selected from the group consisting of: hemp; jute; manila hemp; kenaf; miscanthus; sisal; papyrus; flax; nettle; cardoon; and combinations thereof. One suitable combination is hemp and nettle. Other suitable combinations will be apparent to the skilled person.

In a particularly preferred embodiment of the invention, the starting fibre plant material is hemp.

The invention also relates to a fibre plant/lime product obtainable by a process of the invention, or a secondary product obtainable by the process of the invention, and to the use of such a fibre plant/lime product or secondary product as a masonry, insulation or building product. Typically, the masonry, insulation or building product is selected from the group consisting of: building products; building aggregates; fibre plant-crete products (i.e. hempcrete); fibre plant-based floor screed products; fibre plant/lime block (i.e. hemp/lime block); fibre plant/lime plaster (i.e. hemp/lime plaster); insulation material; and fibre plant/lime (i.e. hemp/lime) renderings.

The invention also relates to a wet-mix fibre plant/lime paste obtainable by the process of the invention.

- 5 The invention also relates to a masonry product obtainable by the process of the invention.

The invention also relates to a fibre plant/lime composite product of the type formed in a process in which fibre plant
10 material is admixed with calcium oxide resulting in the formation of slaked lime which binds the composite and which upon drying reacts with CO₂ to form a calcium carbonate, wherein the plant fibres of the fibre plant material are intimately coated with crystals of slaked lime. The term "intimately
15 coated" should be understood as meaning that a significant proportion of the surface of the fibres of the fibre plant material is coated with slaked lime crystals as shown in the attached figures. In the fibre plant/lime product of the invention, the fibre plant material is typically converted to a
20 light weight insulating solid organic masonry product which can be described as a fibrous plant material, and which has been hardened by deposition or conversion into calcium carbonate. The material could be described as masonry, stone like. The material can be the main or partial component of a family of building
25 products including but not limited to plasters, mortars, insulation plasters mortars, grout, tile adhesives, caulking material extruded putties, bricks, blocks, wall infill, floor infill, roof insulation, mass hempcrete, roof tile, continuous roofing system, cement system re-enforcement.

30

Brief Description of the Figures

The invention will be more clearly understood from the following description thereof, given by way of example only, with
5 reference to the accompanying electron micrograph pictures (provided courtesy of Dr Adel El-Turki, Bristol University) in which:

Figs 1 to 3 are electron micrographs of a hemp/lime product
10 according to the invention formed using ensiled hemp and calcium oxide in 2:1 ratio (w/w) without any added water and in which Figs 1 and 2 show the fibres of the hemp intimately coated with slaked lime crystals, and Fig. 3 shows the interface (4) between
15 a slaked lime crystal and the surface of a hemp fibre where bonding has taken place.

Figs 4 to 7 are electron micrographs of a secondary product
(paste) of the invention formed using the hemp lime product of
Figs 1 to 3 which is mixed in a ration of 5:50:45 (w/w)
20 (hemp/lime product 5%, lime putty 50%, and mineral powder 45%). The figures show the intimate contact between the slaked lime crystals (3) and the hemp fibres (2), and the intimate mixture between the fibres (2), the slaked lime crystals (3) and the mineral components of the mineral powder (1). Fig. 7b clearly
25 shows the slaked lime crystals coating intimately the hemp fibre.

Detailed Description of the Invention

30 The invention will be more clearly understood from the following description, given by way of example only.

Example 1

Freshly harvested hemp was weighed and was determined to have a dry matter content of 30% and moisture content of 70%. The hemp was chopped to approximately 10-20mm lengths. Quicklime was added at a proportion of 1 hemp:1 quicklime by weight in an open vessel. A weight was placed on the mixture to improve contact. The mixture was left to react and an exothermic process was observed after one half hour. After the mixture had cooled a sample was removed and weighed. The sample weighed 172 grams. The sample was then oven dried at 200°C for 30 minutes to remove substantially all of the moisture content. After drying the sample weighed 130 grams. Thus, 42g of water remained after the quicklime treatment which is the equivalent of 24% moisture content. Thus, the process of the invention reduced the moisture content of the hemp from 70% to 24% in a short period of time.

Example 2

A bail of plastic wrapped 4ft x 4ft ensiled hemp was stored outside for one month and delivered to site for processing. The bail was opened at 6pm and a wet straw mass with strong lactic acid odour and extensive microbial colonies were observed. This raw ensiled straw was removed and reduced and pulverised to approximately 6mm particle length and layered with powdered quicklime in a 2:1 quicklime/hemp ratio (w/w). This mixture was placed in a vessel with a lid that was in turn placed in an insulated box and a heavy weight applied to maintain intimate contact between the hemp and the powdered quicklime. This reaction mixture was left for two hours after which the mass of hemp had become quite solid and an expansion of the mass had taken place. This mixture was lightly milled to break up the mass and this was mixed with water in a ratio of 30% water to

provide a (secondary product) paste. After addition of water no further heat evolution was observed, indicating the all of the quicklime had been converted to slaked lime. A portion of this mixture was applied to a dry rendered block work wall with a plasterers trowel and a closed surface was achieved. This was three hours after the hemp was removed from the bail. It was noted that the applied plaster did not exhibit the same rank odours of the original hemp silage, indicative that pasteurization and neutralization of long chain organic fatty acids had occurred. Gradual hardening was evident within minutes and good adhesion was also self-evident.

The lack of exothermal reaction when additional water was added confirms that the water used in the reaction of 'quick lime' to 'slaked lime' could only have originated from hemp material only. This simple test also demonstrates that expensive process of field drying and the Capital expensive process of decortication, currently used in the hemp industry are redundant steps in the generation of hemp/lime based building materials.

Example 3

Non-desiccated nettle was mixed with 2 parts hemp dry matter with 1 part lime (w/w) through a twin augur extruder. A spontaneous exothermic reaction of 98 degrees centigrade was observed. The mixture has a moisture content of 30% after the process had completed. The material was immediately pressed into a form and continued to evaporate moisture as steam from the hot mass surface. The material became a solid mass and dried completely over a period of 5 weeks. The material has a bulk density of .53tons/m³ which indicates it as an ideal insulating building material.

Example 4.

100kg of freshly swathed hemp was placed into a chopper box and chopped into lengths of .01 to 01.m in length. The moisture content of chopped hemp was measured as 70% (w/w). The chopped
5 hemp was then placed in a large mixer and 100kg high calcium quicklime added. The contents were then mixed for two minutes to disperse the quicklime throughout the hemp, before being left to react for one hour. The contents were then mixed for a further two minutes before being left for two hours to react. The final
10 product hemp was found to have a moisture content of 19%.

Example 5

A bail of wrapped 4ft x 4ft ensiled jute was stored outside for one month and delivered to site for processing. The bail was
15 opened a wet straw mass with strong lactic acid odour and extensive microbial colonies were observed. This raw ensiled jute was removed and reduced and pulverised to approximately 6mm particle length and layered with powdered quicklime in a 2:1 jute/quicklime ratio (w/w). This mixture was placed in a vessel
20 with a lid that was in turn placed in an insulated box and a heavy weight applied to maintain intimate contact between the straw and the powdered quicklime. This reaction mixture was left for two hours after which the mass of jute had become quite solid and an expansion of the mass had taken place. This
25 mixture was lightly milled to break up the mass and this was mixed with water in a ratio of 30% water to form a (secondary product) paste. After addition of water no further heat evolution was observed, indicating the all of the quicklime had been converted to slaked lime. A portion of this mixture was
30 applied to a dry rendered blockwork wall with a plasterers trowel and a closed surface was achieved. This was three hours after the jute was removed from the bail. It was noted that the

applied plaster did not exhibit the same rank odours of the original jute silage, indicative that pasteurization had occurred. Gradual hardening was evident within minutes and good adhesion was also self-evident.

5

The lack of exotherm when additional water was added confirms that the water used in the reaction of 'quick lime' to 'slaked lime' originated from jute material only.

10 Referring to the Figures, the intimate coating of slaked lime crystals on the hemp fibres in the product is clearly shown, especially in Figure 7(b) where the hemp fibre is completely covered in slaked lime crystals. This is achieved in part due to the fact that no water is added to the initial reaction which
15 means that the calcium oxide is forced to react with the embodied biological water in the plant material itself, and this ensures that resultant slaked lime will be intimately and homogenously formed throughout the product and will coat the fibres of the hemp component of the product.

20

With convention hemp farming techniques, field losses for farmers are heavy, reducing profit for farmers. It is envisaged that storage will be a major obstacle as production expands over
25 the coming years. While farmers see hemp as a new and exciting break-crop, crop saving over 6 weeks of September and October, with field losses of up to 40%, delays in sowing subsequent crops, are all barriers to general farming acceptance and profitability.

30

Industrial hemp processing is currently exclusively based on the reduction of the dried crop through de-cortication systems based

on hammer mills and/or roller breakers and subsequent separation of fibre hurd/shive and dust. Systems are supplied by companies such as Tamafa, Van Domelle and LaRoche with a price tag of £3-5 Million for a 10,000ton/annum line involving up to 70 pieces of separate equipment. Hemp decortication is a capital intensive process and the hemp must be dry or serious production blockages and delays will occur. It should be pointed out that regarding the production of hemp/lime materials, water is added at the end of the process, thus water is removed in the field only to be re-added again by the processor

Farming aspects

In this process, the supply chain begins with ensiled fibre plant material. The fibre plant crop is cut and chopped, blown into a forage wagon by a suitable forager such as a Class Jaguar 850 6mm precision chop and blown into a forage trailer and removed immediately from the field to be ensiled in existing silage pits. Lactic acid bacteria quickly convert the material to stable fibre plant silage for storage until required for further processing. This step has a number of advantages:

- The farmer losses none of his crop and 98% of the crop should end up on the weigh bridge
- The farmer can immediately plough his field for a winter cereal such as wheat or green crop such as grass.
- The farmer has no turning operation to dry the crop. Some farmers have had to turn the crop up to 6 times in 07 and during each turning operation field losses occur
- The risk of total loss during an extremely wet autumn is completely eliminated

- The farmer does not have to build additional storage to store the fibre plant crop
- Beef farmers are currently seeking alternative farm enterprises, as the beef sector is not profitable. Beef farmers can switch to fibre plant farming at little capital cost.

Processing Aspects

The following are all the advantages for the processor

- The reduction/rendering of the crop to a small particle size has occurred in one simple operation in the field. Green fibre plant is much easier to cut than desiccated fibre plant. This has now been achieved
- An existing work force of silage contractors and silage equipment can be directed towards the harvest the fibre plant crop simultaneously over broad geographical areas. With the dry line decortication system very expensive custom made equipment must first of all be sourced and this acts as a barrier to farmer entry as no harvesting service is readily available
- only simple blending machinery to combine the materials is required
- the process actually generates energy and the overall energy requirements are largely reduced
- the footprint of the factory space is reduced and in one expression of this process no factory is necessary at all

as materials can be processed directly from field to final wall placement.

- production can be expanded very quickly to satisfy demand
- the price can be reduced to the end user as the capital investment is an order magnitude less than de-cortication/desiccated fibre costs
- farmer contracts are easily achieved as the farmer will now make a good return
- bioregional expansion is more achievable as factory space, energy cost and transport costs are all reduced

As a comparison, a hemp/lime product formed according to the process of the invention (non-dessicated hemp/lime) was compared with a conventional dessicated hemp/lime product and other lime-based building products in terms of product breathability and Moisture Buffering Value MBV. The results of this comparison are summarized in Table 1 below.

Table 1

Portland cement	Hydraulic lime	Fat Lime	Desiccated hemplime	Non-desiccated hemp-lime
Non breathable Very low MBV	Compromised breathability Medium MBV	Breathable Medium MBV	High MBV	Rapid breathability Very High MBV
Fast Set	Medium set	Slow set	Slow set	Medium set

A further comparison of non-dessicated cultured (ensiled) hemp/lime (of the invention) and dessicated hemp/lime (prior art) was carried out and the results are summarized in Table 2 below.

5

Table 2

Desiccated Contaminated Hemp	Non-desiccated Cultured Hemp
• Danger of Total Crop Loss in Temperate Climates • Creation of degenerative microbial and fungal populations on hemp/fibre straw feedstock • Harvest involves field drying which takes time even in ideal conditions and involves multiple field operations • Heavy Field losses occur as crop is laid on field, turned and returned. Baler fails to pick-up crop and crops disintegrates due to mechanical damage.	• Danger of crop loss eliminated as harvesting is climate independent • Fermentation of beneficial microbial population to preserve and condition crop for processing Simple one pass harvesting operation achieved in one day • Field losses virtually eliminated as crop is cut and blown directly into transport wagon. Crop is not laid on ground or handled on ground. All leaf, seed flower and stem fractions are saved. • Contamination of crop eliminated

• Contamination of crop with soil stones and field debris likely • Multiple operations increase farm, machinery, diesel and labor costs • Mechanical cutting and reduction of crop impossible as reduced crop cannot then be picked up from ground • Bales demonstrate uneven moisture content and variations • Degeneration of biochemical/photochemical cellular and extracellular components • Up to 15% of saved crop becomes dust or store causing health risk to factory worker and necessitates significant investment in fire prevention • Requires large storage sheds to be of	• Single operation reduces farm, machinery, diesel and labor costs • Mechanical cutting and reduction of crop simplified and crop can be easily cut while cells are still turgid and green. • Preserved hemp/fibre has uniform moisture content • Preservation of biochemical/phytochemical cellular and extracellular components • No dust issues occur during production process , significantly reducing danger of fire, dust explosions and health and safety of personnel creating • No storage infrastructure required. Field storage possible or existing extant silage stores can be utilized
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commercial economic interest	- Existing harvesters owned/operated commercial contractors available for immediate use - Green crop can be sown immediately after harvested to improve agronomic economics - Increased dry matter yield to farmers and increased income - Increased utilizable yield to processor from given land base - Reduced capital cost of processing. Simple & economical
- Specialist harvesters and lack of commercial contractors act as impediment to commercialization of industry - Green crop sowing limited due to extended harvest period - Reduced dry mater yield to farmers resulting in reduced income - Reduced utilizable yield to processor from given land base - Typical €2-5million capital requirement for processing	

From the above it can be seen that there is no advantage in field drying and preserving hemp when compared with non-desiccated cultured hemp. The simple reason that no single commercial example of a non-desiccated cultured hemp processing

operation exists is due to the high energy cost of drying the non-desiccated hemp. The cost is so high that it excludes commercialization. The invention realizes the heretofore unused step of introducing quicklime as the sap desiccating step while
5 simultaneously providing the mineral component in the hemplime mix. The invention simplifies and economizes all harvesting, agronomic and processing aspects. The invention allows for rapid deployment of a carbon locking building materials by removing supply chain impediments such as profitability, availability of
10 harvesting equipment, availability of storage, availability of processing machinery infrastructure and localization of processing.

The invention is not limited to the embodiments hereinbefore
15 described which may be varied in construction, process and detail without departing from the spirit of the invention.

APPENDIX 1

Bio-Slake Trials Potzdam
Ratio by weight

5

CaO	Hemp	Temp. Peak (°C)	Time to to peak (min)	Total Moisture % (after reaction)	Final Dry Matter [%]	DM unprocessed hemp (before mix) [%]	percental reduction of moisture due to slaking [%]
1	0.25	70.1	41	18.39	81.6	27.7	53.9
1	0.50	59.7	37	37.4	62.6	27.7	34.9
1	1.00	43.4	46	47.5	52.5	27.7	24.8
1	1.50	34.6	52	55.89	44.1	27.7	16.4
1	2.00	32.3	37	59.43	40.6	27.7	12.9
1	4.00	28.1	43	65.36	34.6	27.7	6.9

CaO	Hemp	Temp. Peak (°C)	Time to to peak (min)	Total Moisture % (after reaction)	Final Dry Matter [%]	DM extruded hemp (before mix) [%]	percental reduction of moisture due to slaking [%]
1	0.25	79.3	31	12.1	87.9	30.67	57.2
1	0.50	69.5	26	29.28	70.7	30.67	40.1
1	1.00	41.3	45	44.69	55.3	30.67	24.6
1	1.50	34.6	48	51.6	48.4	30.67	17.7
1	2.00	28.5	52	55.37	44.6	30.67	14.0
1	4.00	27	53	61.87	38.1	30.67	7.5

CaO	Hemp	Temp. Peak (°C)	Time to to peak (min)	Total Moisture % (after reaction)	Final Dry Matter [%]	DM milled hemp (before mix) [%]	percental reduction of moisture due to slaking [%]
1	0.25	70.6	20	12.55	87.5	30.44	57.0
1	0.50	65.4	24	29.66	70.3	30.44	39.9
1	1.00	58.3	35	45.1	54.9	30.44	24.5
1	1.50	40.8	39	52.7	47.3	30.44	16.9
1	2.00	31.6	46	55.38	44.6	30.44	14.2
1	4.00	27.8	50	57.54	42.5	30.44	12.0

10

APPENDIX 2

<u>Abelmoschus esculentus</u>	Okra		
<u>Abelmoschus moschatus</u>	Musk Mallow		
<u>Abies balsamea</u>	Balsam Fir		
<u>Abutilon theophrasti</u>	China Jute		
<u>Acer glabrum</u>	Rock Maple		
<u>Acer macrophyllum</u>	Oregon Maple		
<u>Agathis robusta</u>	Queensland Kauri		
<u>Agave americana</u>	Agave		
<u>Agave parryi</u>	Century Plant		
<u>Agave utahensis discreta</u>	Century Plant		
<u>Agave utahensis eborispina</u>	Century Plant		
<u>Althaea cannabina</u>			
<u>Althaea officinalis</u>	Marsh Mallow		
<u>Ammophila arenaria</u>	Marram Grass		
<u>Ampelodesmos mauritanicus</u>			
<u>Aphananthe aspera</u>			
<u>Apocynum androsaemifolium</u>	Spreading Dogbane		
<u>Apocynum cannabinum</u>	Indian Hemp		
<u>Apocynum venetum</u>			
<u>Araujia sericifera</u>	Cruel Plant		
<u>Artemisia tridentata</u>	Sage Brush		
<u>Asclepias asperula</u>	Antelope Horns		
<u>Asclepias eriocarpa</u>	Woollypod Milkweed		
<u>Asclepias hallii</u>	Purple Silkweed		
<u>Asclepias incarnata</u>	Swamp Milkweed		

<u>Asclepias lanceolata</u>	Purple Silkweed		
<u>Asclepias ovalifolia</u>			
<u>Asclepias pumila</u>	Low Milkweed		
<u>Asclepias purpurascens</u>	Purple Milkweed		
<u>Asclepias quadrifolia</u>	Fourleaf Milkweed		
<u>Asclepias rubra</u>	Red Silkweed		
<u>Asclepias speciosa</u>	Showy Milkweed		
<u>Asclepias syriaca</u>	Common Milkweed		
<u>Asclepias tuberosa</u>	Pleurisy Root		
<u>Asclepias viridiflora</u>	Green Milkweed		
<u>Asimina triloba</u>	Papaw		
<u>Astelia grandis</u>			
<u>Astelia nervosa</u>			
<u>Avena abyssinica</u>	Abyssinian Oat		
<u>Avena barbata</u>	Slender Oat		
<u>Avena brevis</u>			
<u>Avena byzantina</u>	Red Oat		
<u>Avena fatua</u>	Wild Oats		
<u>Avena ludoviciana</u>	Oats		
<u>Avena nuda</u>	Naked Oat		
<u>Avena nudibrevis</u>			
<u>Avena orientalis</u>	Hungarian Oat		
<u>Avena sativa</u>	Oats		
<u>Avena sterilis</u>	Sterile Oats		
<u>Avena strigosa</u>	Bristle Oats		
<u>Avena wiestii</u>			
<u>Betula pendula</u>	Silver Birch		

<u>Betula pubescens</u>	White Birch		
<u>Boehmeria cylindrica</u>	False Nettle		
<u>Boehmeria glomerulifera</u>			
<u>Boehmeria longispica</u>			
<u>Boehmeria macrophylla</u>			
<u>Boehmeria nipononivea</u>	Ramie		
<u>Boehmeria nivea</u>	Ramie		
<u>Boehmeria spicata</u>			
<u>Boehmeria tricuspis</u>			
<u>Brachychiton populneus</u>	Kurrajong		
<u>Broussonetia kazinoki</u>	Kozo		
<u>Broussonetia papyrifera</u>	Paper Mulberry		
<u>Camelina sativa</u>	Gold Of Pleasure		
<u>Canna indica</u>	Indian Shot		
<u>Cannabis sativa</u>	Hemp		
<u>Caragana arborescens</u>	Siberian Pea Tree		
<u>Caragana boisii</u>			
<u>Caragana fruticosa</u>			
<u>Caragana jubata</u>	Shag-Spine		
<u>Chamaecyparis nootkatensis</u>	Nootka Cypress		
<u>Chamaerops humilis</u>	Dwarf Fan Palm		
<u>Chilopsis linearis</u>	Desert Willow		
<u>Chlorogalum pomeridianum</u>	Soap Lily		
<u>Cirsium brevistylum</u>	Indian Thistle		
<u>Clematis ligusticifolia</u>	White Clematis		
<u>Corchorus capsularis</u>	Jute		
<u>Corchorus olitorius</u>	Jew's Mallow		

<u>Cordyline australis</u>	Cabbage Tree		
<u>Cordyline indivisa</u>	Cabbage Tree		
<u>Cornus sericea</u>	Red Osier Dogwood		
<u>Cortaderia selloana</u>	Pampas Grass		
<u>Corylus cornuta californica</u>	California Hazel		
<u>Cowania mexicana</u>	Cliffrose		
<u>Cudrania tricuspidata</u>	Silkworm Thorn		
<u>Cyperus tegetiformis</u>			
<u>Cytisus scoparius</u>	Broom		
<u>Daphne bholua</u>			
<u>Debregeasia hypoleuca</u>			
<u>Debregeasia longifolia</u>	Wild Rhea		
<u>Debregeasia wallichiana</u>			
<u>Desmodium elegans</u>			
<u>Dianella caerulea</u>	Blue Flax Lily		
<u>Dianella congesta</u>	Beach Flax Lily		
<u>Dianella laevis</u>	Flax Lily		
<u>Dianella revoluta</u>	Flax Lily		
<u>Dianella tasmanica</u>	Flax Lily		
<u>Dirca occidentalis</u>	Leather Wood		
<u>Dirca palustris</u>	Leather Wood		

<u>Elaeagnus commutata</u>	Silverberry		
<u>Ensete ventricosum</u>	Ethiopian Banana		
<u>Epilobium angustifolium</u>	Willow Herb		
<u>Eryngium pandanifolium</u>			
<u>Eucalyptus macrorhyncha</u>	Red Stringybark		

<u>Firmiana simplex</u>	Chinese Parasol Tree			
<u>Fitzroya cupressoides</u>	Alerce			
<u>Fremontodendron californicum</u>	Flannel Flower			
<u>Galeopsis tetrahit</u>	Common Hemp Nettle			
<u>Geitonoplesium cymosum</u>	Scrambling Lily			
<u>Genista tinctoria</u>	Dyer's Greenweed			
<u>Gerbera lanuginosa</u>				
<u>Girardinia diversifolia</u>	Himalayan Nettle			
<u>Glycyrrhiza glabra</u>	Liquorice			
<u>Grewia oppositifolia</u>				
<u>Gynatrix pulchella</u>	Hemp Bush			
<u>Helianthus annuus</u>	Sunflower			
<u>Hemiptelea davidii</u>				
<u>Hesperaloe funifera</u>				
<u>Hesperaloe nocturna</u>				
<u>Hibiscus cannabinus</u>	Kenaf			
<u>Hibiscus heterophyllus</u>	Native Rosella			
<u>Hibiscus mutabilis</u>	Cotton Rose			
<u>Hibiscus rosa-sinensis</u>	Chinese Hibiscus			
<u>Hibiscus sabdariffa</u>	Roselle			
<u>Hibiscus sinosyriacus</u>	Rose Of Sharon			
<u>Hibiscus syriacus</u>	Rose Of Sharon			
<u>Hoheria populnea</u>	Lacebark			
<u>Hordeum bulbosum</u>	Bulbous Barley			
<u>Hordeum deficiens</u>				
<u>Humulus lupulus</u>	Hop			
<u>Iris douglasiana</u>	Mountain Iris			

<u>Iris ensata</u>	Japanese Water Iris		
<u>Iris macrosiphon</u>	Bowltube Iris		
<u>Iris purdyi</u>	Purdy's Iris		
<u>Iris tenax</u>	Tough-Leaf Iris		
<u>Juniperus communis</u>	Juniper		
<u>Juniperus communis nana</u>	Juniper		
<u>Juniperus monosperma</u>	One-Seed Juniper		
<u>Juniperus occidentalis</u>	Western Juniper		
<u>Kosteletzkya pentacarpos</u>			
<u>Laportea bulbifera</u>			
<u>Laportea canadensis</u>	Canadian Wood Nettle		
<u>Laportea macrostachya</u>			
<u>Lardizabala bitermata</u>	Zabala Fruit		
<u>Larix laricina</u>	Tamarack		
<u>Lavatera cachemiriana</u>	Lavatera		
<u>Lavatera plebeia</u>	Lavatera		
<u>Lavatera thuringiaca</u>	Lavatera		
<u>Leymus arenarius</u>	Lyme Grass		
<u>Linum bienne</u>	Pale Flax		
<u>Linum crepitans</u>			
<u>Linum humile</u>			
<u>Linum marginale</u>	Native Flax		
<u>Linum monogynum</u>			
<u>Linum perenne</u>	Perennial Flax		
<u>Linum usitatissimum</u>	Flax		
<u>Lomandra longifolia</u>	Longleaf Mat-Rush		
<u>Lonicera ciliosa</u>	Orange Honeysuckle		

<u>Lupinus albus</u>	White Lupin			
<u>Lygeum spartum</u>	Albardine			
<u>Lyonsia straminea</u>				
<u>Malva alcea</u>				
<u>Malva excisa</u>				
<u>Malva meluca</u>				
<u>Malva mohileviensis</u>				
<u>Malva moschata</u>	Musk Mallow			
<u>Malva sylvestris</u>	Mallow			
<u>Marsdenia roylei</u>				
<u>Marsdenia tenacissima</u>	Rajmahal Hemp			
<u>Morus alba</u>	White Mulberry			
<u>Morus alba multicaulis</u>	White Mulberry			
<u>Morus australis</u>	Korean Mulberry			
<u>Morus bombycis</u>	Kuwa			
<u>Morus macroura</u>	Himalayan Mulberry			
<u>Morus mongolica</u>	Mongolian Mulberry			
<u>Morus nigra</u>	Black Mulberry			
<u>Morus rubra</u>	Red Mulberry			
<u>Musa basjoo</u>	Japanese Banana			
<u>Osmunda regalis</u>	Royal Fern			
<u>Pancratium maritimum</u>	Sea Daffodil			
<u>Phormium cookianum</u>	Wharariki			
<u>Phormium tenax</u>	New Zealand Flax			
<u>Phragmites australis</u>	Common Reed			
<u>Picea engelmannii</u>	Mountain Spruce			
<u>Picea rubens</u>	Red Spruce			

<u>Pimelea arenaria</u>				
<u>Pimelea axiflora</u>				
<u>Pimelea ligustrina</u>				
<u>Pimelea microcephala</u>	Mallee Riceflower			
<u>Pimelea pauciflora</u>	Poison Pimelea			
<u>Pinus sylvestris</u>	Scot's Pine			
<u>Plagianthus regius</u>				
<u>Plantago lanceolata</u>	Ribwort Plantain			
<u>Psoralea macrostachya</u>	Large Leather Root			
<u>Pteroceltis tatarinowii</u>				
<u>Pueraria montana lobata</u>	Kudzu Vine			
<u>Puya chilensis</u>				
<u>Ricinus communis</u>	Castor-Oil Plant			
<u>Robinia pseudoacacia</u>	Black Locust			

<u>Rubus fruticosus</u>	Blackberry			
<u>Rulingia dasyphylla</u>				
<u>Sabal etonia</u>	Scrub Palmetto			
<u>Sabal mexicana</u>	Mexican Palmetto			
<u>Sabal minor</u>	Bush Palmetto			
<u>Sabal palmetto</u>	Cabbage Palmetto			
<u>Salix bebbiana</u>	Beak Willow			
<u>Salix exigua</u>	Coyote Willow			
<u>Salix hookeriana</u>	Dune Willow			
<u>Salix lasiolepis</u>	Pacific Willow			
<u>Salix scouleriana</u>	Scouler's Willow			
<u>Salix sitchensis</u>	Sitka Willow			

<u>Sansevieria aethiopica</u>	Bowstring Hemp		
<u>Sesbania herbacea</u>	Colorado River Hemp		
<u>Sidalcea acuta</u>			
<u>Spartium junceum</u>	Spanish Broom		
<u>Sporobolus indicus</u>	Smut Grass		
<u>Stachys sylvatica</u>	Hedge Woundwort		
<u>Stellera chamaejasme</u>			
<u>Stipa splendens</u>	Chee Grass		
<u>Stipa tenacissima</u>	Esparto Grass		
<u>Taxodium distichum</u>	Swamp Cypress		
<u>Thuja occidentalis</u>	American Arbor-Vitae		
<u>Thuja plicata</u>	Western Red Cedar		
<u>Tilia americana</u>	American Basswood		
<u>Tilia amurensis</u>			
<u>Tilia caroliniana</u>	Carolina Basswood		
<u>Tilia chinensis</u>			
<u>Tilia cordata</u>	Small Leaved Lime		
<u>Tilia heterophylla</u>	White Basswood		
<u>Tilia japonica</u>	Japanese Lime		
<u>Tilia mongolica</u>	Mongolian Lime		
<u>Tilia oliveri</u>			
<u>Tilia platyphyllos</u>	Large Leaved Lime		
<u>Tilia tomentosa</u>	Silver Lime		
<u>Tilia tuan</u>			
<u>Tilia x europaea</u>	Common Lime		
<u>Trachycarpus fortunei</u>	Chusan Palm		
<u>Trachycarpus martianus</u>			

<u>Typha domingensis</u>	Southern Cattail			
<u>Typha latifolia</u>	Reedmace			
<u>Typha orientalis</u>				
<u>Ulmus davidiana</u>	Japanese Elm			
<u>Ulmus glabra</u>	Wych Elm			
<u>Ulmus japonica</u>	Japanese Elm			
<u>Ulmus pumila</u>	Siberian Elm			
<u>Ulmus rubra</u>	Slippery Elm			
<u>Ulmus wallichiana</u>				
<u>Urtica angustifolia</u>				
<u>Urtica breweri</u>				
<u>Urtica californica</u>	Stinging Nettle			
<u>Urtica cannabina</u>				
<u>Urtica dioica</u>	Stinging Nettle			
<u>Urtica gracilis</u>	Stinging Nettle			
<u>Urtica holosericea</u>	Stinging Nettle			
<u>Urtica hyperborea</u>				
<u>Urtica incisa</u>	Scrub Nettle			
<u>Urtica laetivirens</u>				
<u>Urtica lyallii</u>	Stinging Nettle			
<u>Urtica parviflora</u>				
<u>Urtica pilulifera</u>	Roman Nettle			
<u>Urtica platyphylla</u>				
<u>Urtica procera</u>	Stinging Nettle			
<u>Urtica serra</u>				
<u>Urtica thunbergiana</u>				
<u>Urtica urens</u>	Annual Nettle			

<u>Veratrum viride</u>	Indian Poke			
<u>Viburnum dilatatum</u>	Linden Viburnum			
<u>Vicia faba equina</u>	Horsebean			
<u>Vicia faba major</u>	Broad Bean			
<u>Vicia faba minuta</u>	Tick Bean			
<u>Washingtonia filifera</u>	Desert Fan Palm			
<u>Wisteria floribunda</u>	Japanese Wisteria			
<u>Wisteria venusta</u>	Silky Wisteria			
<u>Xerophyllum tenax</u>	Indian Basket Grass			
<u>Yucca aloifolia</u>	Spanish Bayonet			
<u>Yucca angustissima</u>				
<u>Yucca baccata</u>	Spanish Bayonet			
<u>Yucca brevifolia</u>	Joshua Tree			
<u>Yucca constricta</u>	Buckley's Yucca			
<u>Yucca elata</u>	Soap Tree			
<u>Yucca filamentosa</u>	Spoonleaf Yucca			
<u>Yucca filifera</u>				
<u>Yucca glauca</u>	Soapweed			
<u>Yucca gloriosa</u>	Spanish Dagger			
<u>Yucca harrimaniae</u>	Spanish Bayonet			
<u>Yucca recurvifolia</u>				
<u>Yucca rupicola</u>	Twisted-Leaf Yucca			
<u>Yucca schidigera</u>	Mojave Yucca			
<u>Yucca smalliana</u>	Adam's Needle			
<u>Yucca whipplei</u>	Our Lord's Candle			
<u>Zelkova schneideriana</u>	Chinese Zelkova			

CLAIMS

1. A process for producing a fibre plant/lime product comprising a step of providing a fibre plant starting material having a water content of at least 50% (w/w), admixing the starting material with calcium oxide to form a reaction mixture, and allowing the calcium oxide react with embodied biological water in the starting material to form the fibre plant/lime product in which embodied biological free water in the fibre plant material has been converted to slaked lime.
2. A process as claimed in Claim 1 in which the fibre plant starting material is non-dessicated fibre plant material.
3. A process as claimed in any of Claims 1 to 2 in which the fibre plant starting material is ensiled fibre plant material.
4. A process as claimed in Claim 3 in which the ensiled fibre plant material has been ensiled for a sufficient period of time to allow the production of fermentation products within the ensiled material.
5. A process as claimed in Claim 4 in which the fibre plant material is ensiled for at least 7 days.
6. A process as claimed in any preceding Claim in which the ratio of fibre plant starting material to calcium oxide in the reaction mixture is between 10:20 and 10:1 (w/w).

7. A process as claimed in any preceding Claim in which the fibre plant starting material is pulverised prior to reaction with the calcium oxide to produce particles having a mean length of between 1 and 100mm.

5

8. A process as claimed in any preceding Claim in which the reaction mixture is processed to ensure intimate contact between the fibre plant starting material and the calcium oxide.

10

9. A process as claimed in any preceding Claim in which the fibre plant/lime product is milled prior to further treatment.

15 10. A process as claimed in any preceding Claim in which the fibre plant/lime product is optionally milled and then mixed with water to provide a wet-mix fibre plant/lime paste.

20 11. A process as claimed in any of Claim 1 to 10 in which the fibre plant/lime product is post-treated to form a masonry, insulating or building product, wherein the treatment is selected from the group consisting of: casting; compression; drying; and heating; autoclaving or
25 any combinations thereof.

12. A process as claimed in Claim 12 in which s part of the post-treatment of the fibre plant/lime product, a further component is added to the fibre plant/lime product
30 selected from the group consisting of: a structural component; and a binder component.

13. A process as claimed in Claim 12 in which the structural component is selected from the group consisting of: clays; gypsum; water glass pozzalanas; rock dust; and other mineral-containing products.

5

14. A process as claimed in Claim 12 or 13 in which the binder component is selected from the group consisting of: lime products including hydraulic limes, portland cement, and calcium alumina cement; and organic compounds such as bitumen, and any organic polymer.

10

15. A process as claimed in any preceding Claim in which the fibre plant starting material has a water content of at least 60% (w/w).

15

16. A process as claimed in any preceding Claim in which at least 75% of the water content of the fibre plant starting material is embodied biological water.

20

17. A process as claimed in Claim 16 in which at least 90% of the water content of the fibre plant starting material is embodied biological water.

25

18. A process as claimed in any preceding Claim in which at least 50% of the slaked lime contained within the fibre plant/lime product is formed from embodied biological water in the plant material.

30

19. A process as claimed in any preceding Claim in which at least 80% or 90% of the slaked lime contained within the fibre plant/lime product is formed from embodied biological water in the plant material.

20. A process as claimed in any preceding Claim which is a process for (partially) drying fibre plant material.

5 21. A process as claimed in any preceding Claim in which the starting fibre plant material is selected from the group consisting of: hemp; jute; manila hemp; kenaf; miscanthus; sisal; papyrus; flax; nettle; cardoon; and combinations thereof.

10 22. A process as claimed in Claim 21 in which the starting fibre plant material is hemp.

15 23. A fibre plant/lime product obtainable by the process of any of Claims 1 to 22.

24. A wet-mix fibre plant/lime paste obtainable by the process of any of Claims 10 to 22.

20 25. A masonry, building, or particle board, product obtainable by the method of any of Claims 11 to 22.

25 26. A fibre plant/lime product of Claim 23 for use as a masonry, insulating or building product.

30 27. Use as claimed in Claim 26 in which the building product is selected from the group consisting of: building aggregates; plasters; mortars; insulation plasters mortars; grout; tile adhesives; caulking material extruded putties; bricks; blocks; wall infill; floor infill; roof insulation; mass hempcrete; roof tile; continuous roofing system; and cement system re-enforcement.

28. A fibre plant/lime composite product of the type formed in a process in which fibre plant material is admixed with calcium oxide resulting in the formation of slaked lime which binds the composite and which upon drying reacts with CO_2 to form a calcium carbonate, wherein the slaked lime intimately coats the fibres of the fibre plant material.

29. A fibre plant/lime product as claimed in Claim 28 in which the slaked lime particles bind to a surface of the fibres.

Figure 1

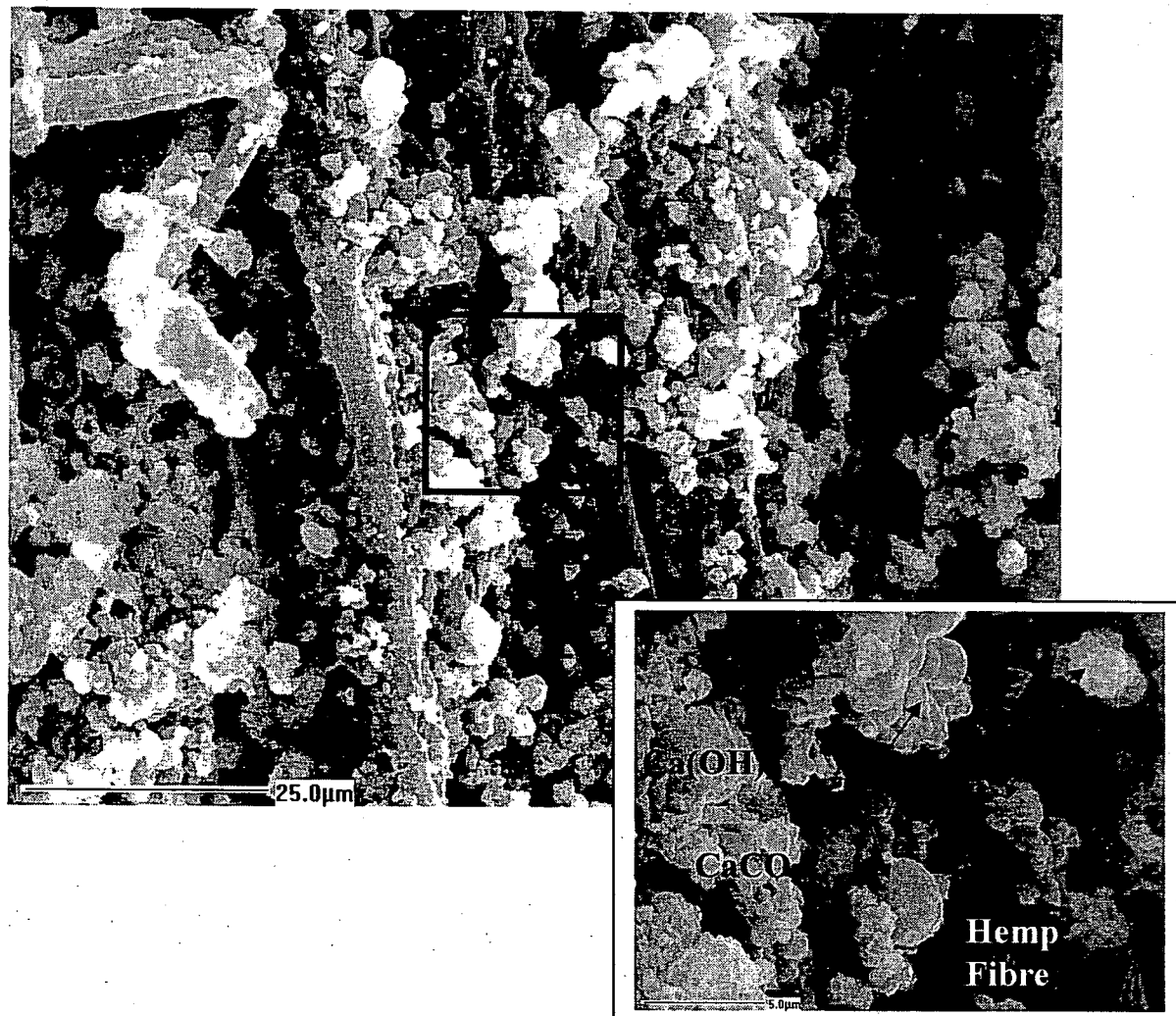


Figure 2

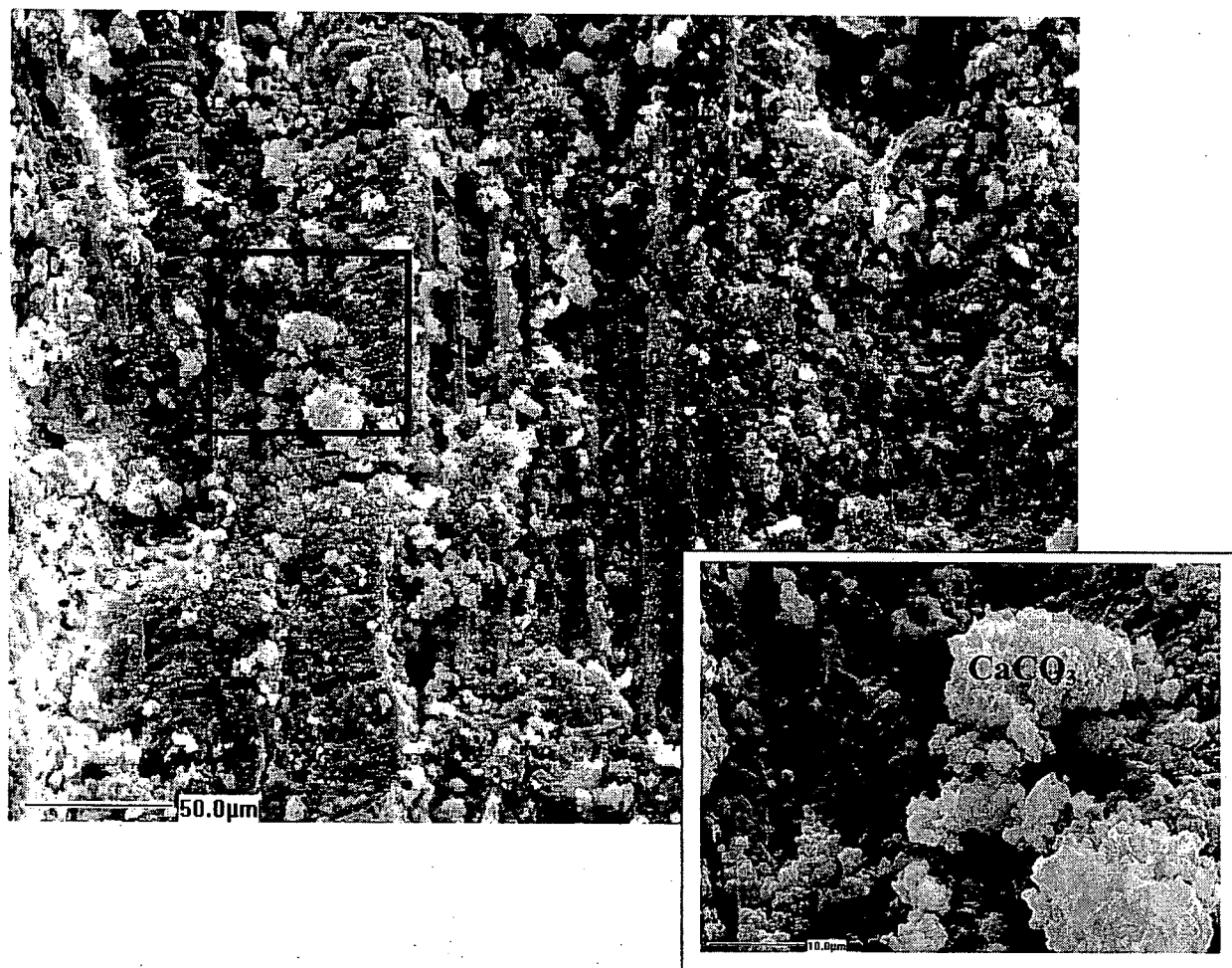


Figure 3

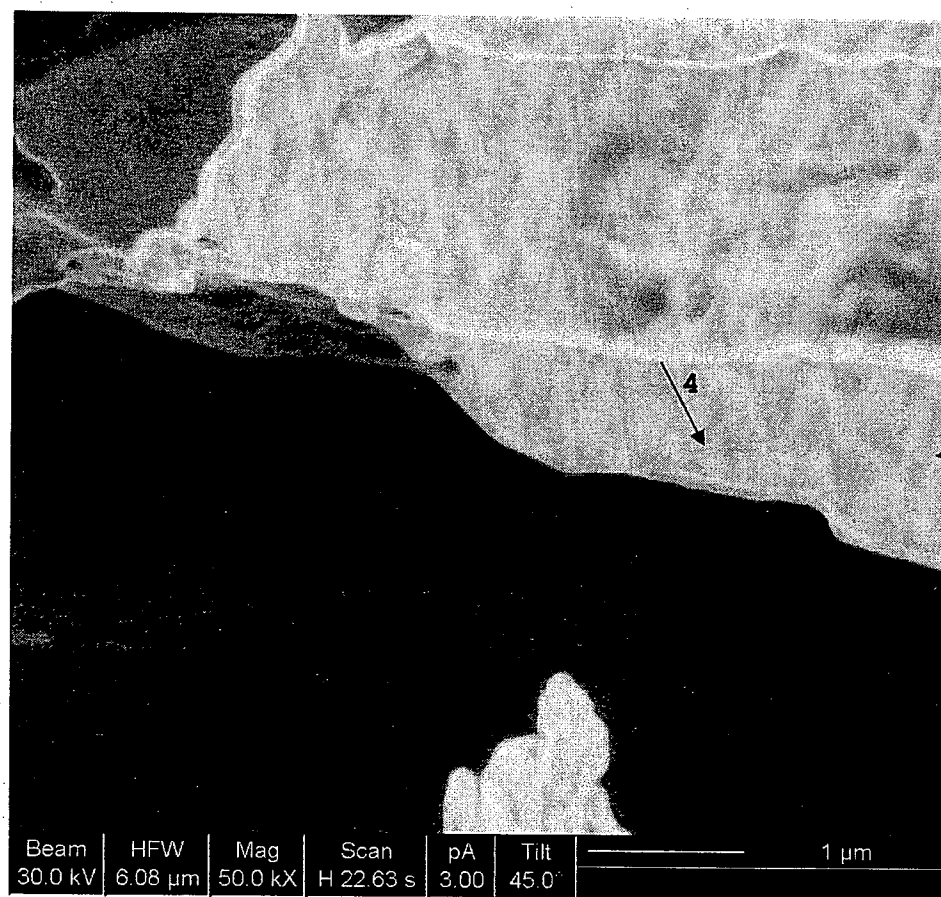


Figure 4a)

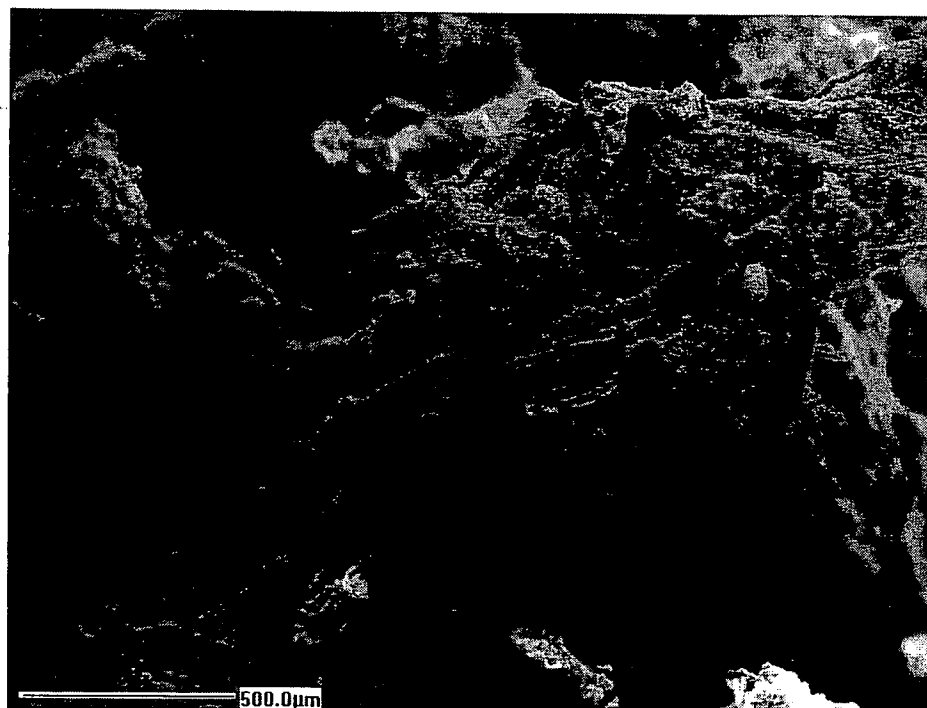


Figure 4b)

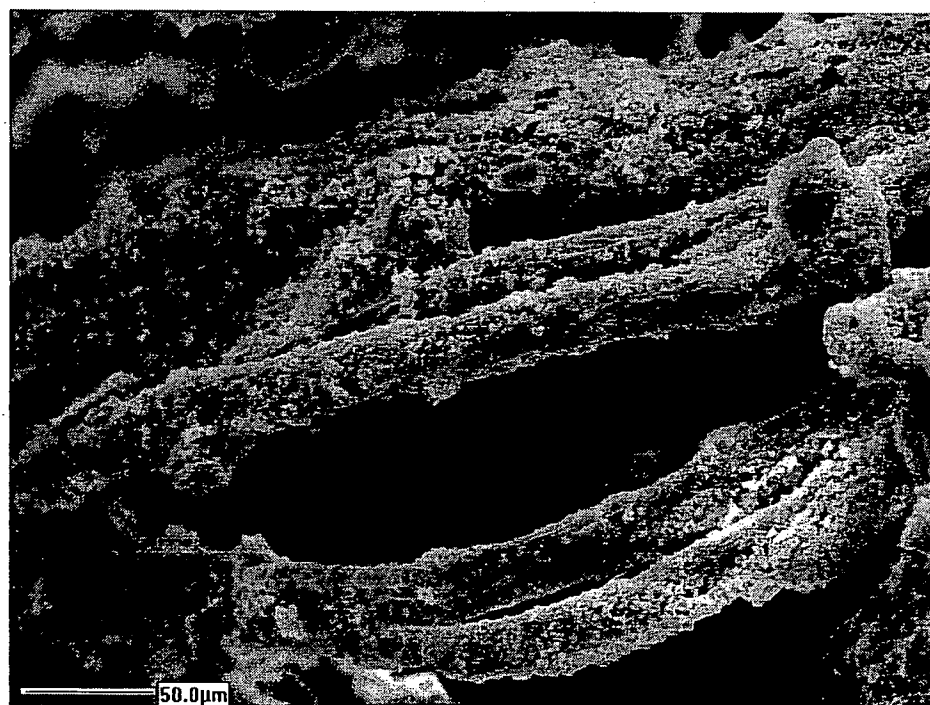


Figure 5

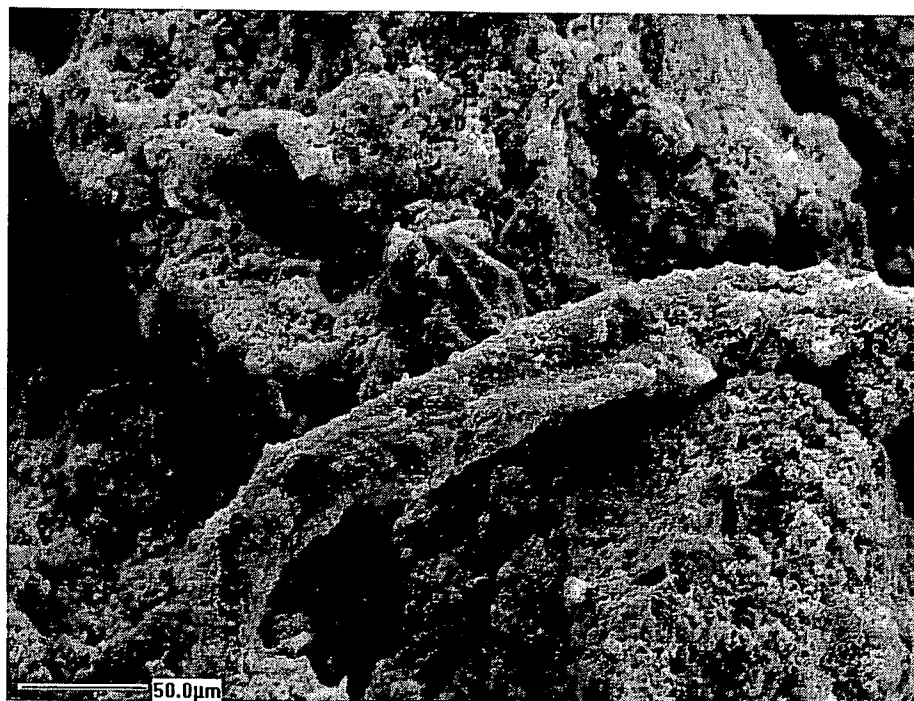


Figure 6

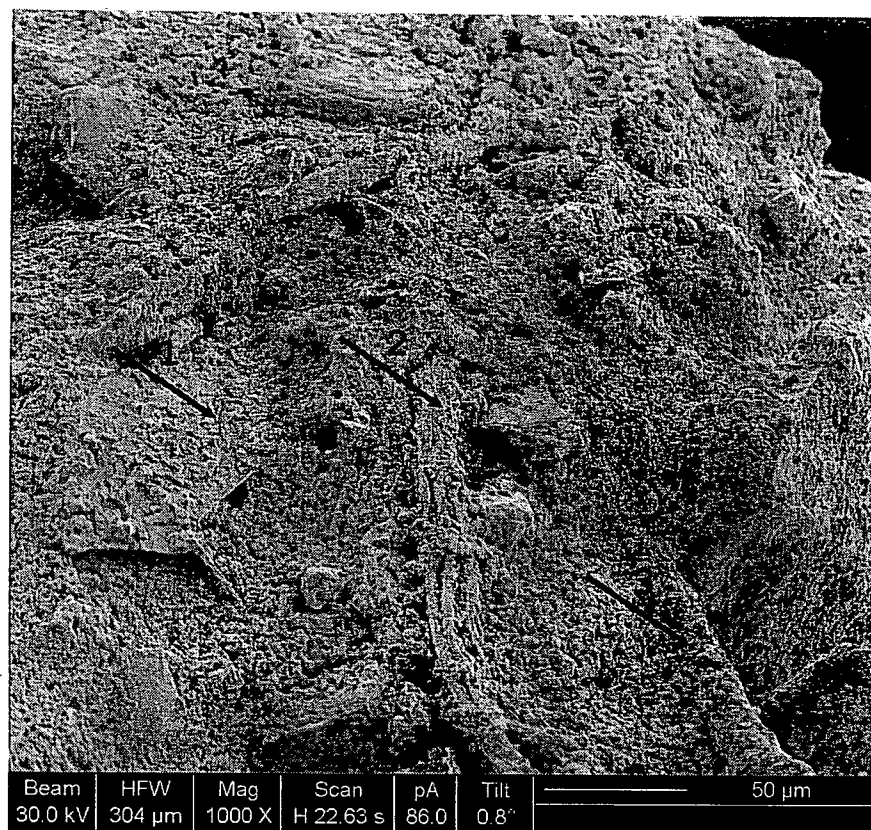


Figure 7a)

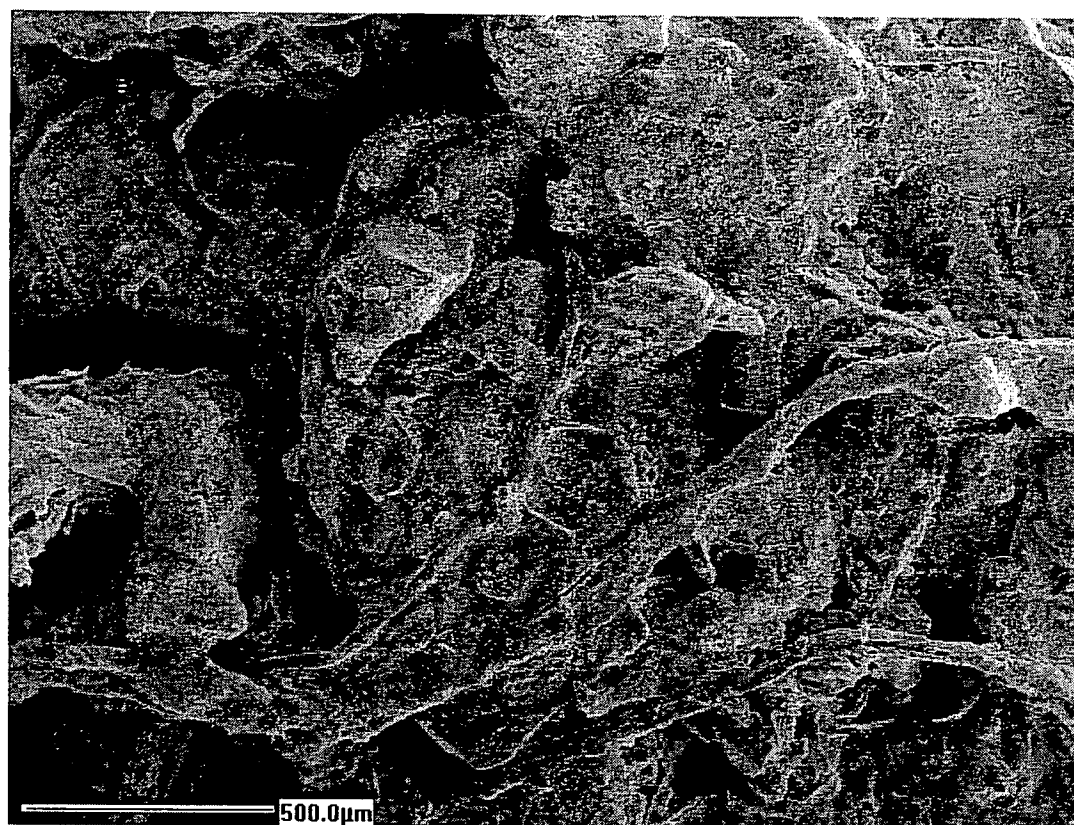


Figure 7b)

