This invention relates to fibrous structural material and method of making the same. It relates especially to structural material fabricated by bonding together unspun fibers into integral coherent sheet material.

It is a purpose of this invention to provide structural material made from unspun fibers that has very high strength for its weight and thickness. Thus, according to preferred embodiments of this invention a structural web or sheet can be made from cotton fibers, for example, that has greater tensile strength for a given gauge than non-ferrous metals, such as aluminum and magnesium metals, and has much greater strength, e.g. twice as much strength for a given weight as such non-ferrous metals.

Features of this invention relate to the method, to the apparatus and to the product. From the point of view of the method it is one of the features of this invention that unspun fibers which have been brought into such disposition in web material that they are predominantly in one direction are bonded together while the fibers of the web material are under tension, thereby setting the fibers not only as disposed predominantly in one direction but also in a condition of tensioned straightness. Other features of this invention relate to the steps utilized in connection with the bonding step including the steps whereby the fibers are straightened and oriented predominantly in one direction by tensioning and drawing so that when the fibers are bonded together the fibrous striated web material will have been conditioned in a manner especially suited for the bonding step. Other features of this invention relate to the manufacture of unspun fibrous web material during the conditioning steps and bonding step and in directing the web material from the conditioning step to the bonding step.

Certain apparatus features of this invention relate to the means employed for drawing and bonding under tension in web form unspun fibers and for handling the web material between the drawing and bonding steps.

The product of this invention is a unique web or sheet material that is of great value for a number of commercial purposes as a structural material. The product of this invention in its elemental form is a thin coherent striated web of bonded unspun fibers which is useful here and is also useful as a ply sheet in the formation of composite sheet material e.g. comprising a plurality of thicknesses or layers of the elemental web material. A feature of the product is the disposition and straightness of the fibers in the elemental web whereby high strength to weight of fiber and web thickness is secured. The web material also has high resistance to stretch in the direction of longitudinal disposition of the fibers in the elemental web material and composite fibrous sheet material can be made having special directional strength characteristics suitable for different purposes.

It is a feature of this invention that the fibers in the unspun fibrous web material are disposed so as to take full advantage of the strength of the fibers. According to this invention a multiplicity of the unspun fibers are straightened out so as to be disposed substantially at their maximum length when tensioned lengthwise and are likewise bonded together for the most part in one direction or nearly so in a sheet or web that is very uniform in its fiber density and thickness even in sheets of relatively large lateral dimensions. The method and the apparatus are instrumental in achieving the uniformity of the striated web material, for while the fibers may be originally in the form of slivers or the like, fibers are caused to be distributed very uniformly as by repeated lapping and drafting operations until the fibers occur in a dense striated web of substantially uniform fiber density and thickness throughout. The fibers are bonded in this dense and uniform fibrous web or sheet so that the bonding effect is very uniform throughout the lateral extent and thickness of the web material. Furthermore, any wrinkling tendency incident to drafting is compensated for by a spreading step to insure uniformity of the striated web material when the bonding material is applied to the web. In this manner a structural material that not only has high strength, but also has very uniform strength characteristics throughout, is afforded that renders the material suitable for numerous structural applications wherein a strong and light structural material is desired to be made uniformly throughout to close specifications.

In order to afford a better understanding of the practice of this invention, it will be described for purposes of exemplification in connection with the fabrication of unspun cotton fibers into thin coherent web material of high strength and density, reference being made to the accompanying drawings, wherein

Fig. 1 is a diagrammatic representation of a plant layout of machinery for making the unspun web material according to this invention,

Fig. 2 is a diagrammatic side elevational repre-
sentation of apparatus for carrying out a drafting and bonding operation,

Fig. 3 is a plan view of the drafting and spreading apparatus.

Fig. 4 is a side elevation view partly section of the apparatus of Fig. 3 and of means for applying the bonding material.

Fig. 5 is a perspective view of one of the spreader bars used in connection with the apparatus shown in Fig. 4.

Fig. 6 is a top view of an elemental web of unspun fibrous material made according to this invention.

Fig. 7 is a top view of a portion of the web material of Fig. 6 on a very greatly enlarged scale.

Fig. 8 is a transverse cross-sectional view of a portion of the web on a very greatly enlarged scale on the line 8—8 of Fig. 6.

Fig. 9 is a longitudinal sectional view of the web material on a very greatly enlarged scale on the line 9—9 of Fig. 6.

Fig. 10 is a plan view on a reduced scale of a composite sheet material that embodies this invention.

Fig. 11 is a side elevational view of a modified form of apparatus for spreading under tension a drawn web.

Fig. 12 is a cross section of the spreading apparatus on the line 12—12 of Fig. 11.

Fig. 13 is a cross section of the spreading apparatus on the line 13—13 of Fig. 11.

Fig. 14 is a cross section of the spreading apparatus on the line 14—14 of Fig. 11.

Fig. 15 is a modified form of drafting means that may be used in the practice of this invention, and

Fig. 16 is a further modified form of drafting means that may be used according to this invention shown in association with part of a spreading means.

For the purpose of affording a specific example of the practice of this invention in the manufacture of a highly desirable product, cotton fiber may for example be used which fiber contains about 70% of fiber that is about an inch or more in length although other grades of cotton may be used. Before the bonding step the unspun fibers are acted upon so as to distribute them uniformly in a sheet or web so as to be arranged predominantly in one direction and straightened. This treatment can be accomplished using different kinds of apparatus, the type of apparatus varying depending largely upon the type of fiber being handled. For cotton fibers that for the most part are about one inch in length the treatment is preferably accomplished by repeated drafting and drafting operations whereby the fibers are drawn predominantly in one direction and are straightened and at the same time are averaged so as to result in a web material having a high degree of uniformity.

A convenient arrangement of apparatus for producing a web comprising unspun cotton fibers of the character mentioned is shown in Figs. 1 to 5. The fiber stock e.g., fiber that has been cleaned and made into a picker lap may first be passed through a conventional carding machine which is indicated generally by the reference character 20 in Fig. 1 and which may comprise such conventional parts as a "picker-in" 21, a cylinder 22 and a doffer 23. The sheet material from the carding machine is condensed into a sliver 24 that is received by any suitable means such as a can 25. The sliver thus produced may for example contain approximately 50 grains per running yard of the cotton fiber. The fiber is next subjected to a drawing operation in some suitable device which may for example be a sliver lapping machine which is indicated generally by the reference character 26. In this machine about 20 of the slivers 24 for example may be taken from cans 25 and passed while arranged side by side between a series of drafting rolls 27. A series of three pairs of rolls may be used with the nip of adjacent pairs of rolls spaced from each other by a distance that is slightly greater than the length of the fibers. Each pair of rolls is operated at a speed that is different from the immediately preceding pair of rolls so that the fibers in the slivers 24 are drawn sufficiently to straighten them somewhat and arrange them so that at least partially the fibers become disposed longitudinally of the fibrous material passing through the drafting rolls. For example the last drafting roll may rotate so that the peripheral speed is twice the peripheral speed of the first pair of drafting rolls in the series and so that the fibrous mass will be drawn approximately 2 to 1. If 20 slivers each containing about 50 grains per running yard are run into the sliver lapping machine the fibrous web material that is discharged from the drafting rolls will contain about 500 grains per running yard. The web 28 which is discharged from the drafting rolls is approximately 10 inches in width and may be passed between calender rolls 29 and rolled up into a roll 30. The roll 29 can be removed from the lapping machine and taken to the ribbon lapping machine which is indicated generally by the reference character 30 and which subjects the fibers to a further drafting operation.

In the ribbon lapping machine the web material 28 from each of four of the rolls 20 that are carried by the ribbon lapping machine is passed between drafting rolls 31. These drafting rolls may be similar to the drafting rolls 27 except that in this case the speed of the rolls is adjusted so that the drafting will be about 4 to 1. Thus if each of the webs 28 contains about 500 grains of cotton per running yard that enters the drafting rolls 31 the web discharged from each of the sets of drafting rolls will weigh about 125 grams per running yard. In the ribbon lapping machine four pairs of rolls in each set of drafting rolls may for example be used. The webs discharged from the drafting rolls 31 are passed through bookfolds 32 which cause the four webs to become superposed and the superposed webs are passed between calender rolls 33 to form a composite web 34 which, according to the present example, would contain about 500 grains of cotton per running yard and would be 10 inches in width. The web 33 is then made up into the roll 34.

By the foregoing operations the fibrous sliver material from the carding machine has been drawn to an extent of about 8 to 1 and the web 33 discharged from the ribbon lapping machine corresponds to an average of 80 slivers. The web material taken from the ribbon lapping machine is therefore very uniform in fiber structure and has also been treated so that the fibers have been arranged for the most part in one direction and then straightened so that the fibers instead of being in the form of bends and crimps are fairly well straightened. Inasmuch, however, as there is no binder applied to the web the fibers tend to have a considerable amount of curl to assume their natural curved and crimped state.

The foregoing operations are largely of a preparatory nature adapted to condition the unspun...
fibrous material for the subsequent operations. In order to complete the manufacture of the structural material the web material 33 from roll 34 is fed into another drafting frame which is indicated generally by the profile character 35. This drafting frame may be of the general type referred to above and may comprise five pairs of drafting rolls 36, the nips of which are spaced apart by a distance slightly greater than the maximum fiber length of the fibers being handled. The speed of the drafting rolls is increased as the web material passes between them so as to further draw out the fibers in such a way as to straighten them and arrange them in one direction. The drafting may be carried on so that in the drafting frame 35 the web material 33 is drafted about 4 to 1. If the web going into the drafting frame weighs about 500 grams per running yard the web that is discharged from the drafting frame 35 will contain about 125 grams of fiber per running yard of the web material which is about 10 inches wide as it leaves the drafting frame 35.

The drafting rolls 36 (and the drafting rolls 27 and 31) may be provided with suitable means for adjusting them both laterally and vertically so as to secure desired action. Moreover, the rolls may be further covered with special materials such as leather, impregnated fabric, cork or the like to augment the drawing action.

As the striated web material is discharged from the drafting frame 35 it is not permitted to relax but while maintaining at least some degree of tension therem is passed between the applicator rolls 37. These rolls may apply material adapted to bond the fibers of the sheet together which material may be a temporary bonding material or a permanent bonding material. The bonding material may be carried in troughs 38 which supply the bonding material by feed rolls 39 (driven by any suitable means not shown) that uniformly deposit the bonding material on the rolls 37. The rolls 37 may for example be covered with some material such as a fabric which carries the desired amount of the binder material and applies it to the web material 33 as it passes between rolls 37. If desired and depending somewhat on the type of binder material applied, doctor blades 101 may be associated with the rolls 37 to control the amount of binder material carried to the bite between the rolls.

Between the drafting frame 35 and the applicator rolls 37 are means for spreading somewhat the sheet material that is discharged from the drafting frame 35. The sheet material as discharged from the drafting frame 35 before a bonding material is applied to the fabric. For example the sheet material may be spread laterally from a width of about 10 inches as it is discharged from the drafting frame to a width of about 14 to 18 inches as it passes between the applicator rolls 37. To accomplish this spreading action any suitable device may be used.

One device for laterally spreading the web material that is discharged from the drafting rolls 36 which has been found to be effective and the action of which is readily controllable is shown in Figs. 3, 4 and 5. By any suitable supporting means such as support members 40 and 41 rolls 42, 43, 44, 45 and 46 are carried in suitable bearings. The rolls are driven from a power driven sprocket wheel 47 by means of a sprocket chain 48 that passes over sprocket wheels 49, 50, 51, 52 and 53 which are carried for rotation with rolls 42, 43, 44, 45 and 46 respectively. The peripheral speed of roll 42 is caused to be slightly greater than the speed at which the fibrous web material is discharged from the set of drafting rolls 36. The peripheral speeds of rolls 42, 43, 44, 45 and 46 are successively somewhat increased so that the web material 33 is continuously subjected to tension. This may be done either by making the sprocket wheels 49, 50, 51, 52 and 53 successively in somewhat smaller or by utilizing rolls which successively have increased diameters. Placed between the rolls 42, 43, 44, 45 and 46 are spreader bars 54, 55, 56 and 57 which are secured to rotatably mounted bars 58, 59, 60 and 61 so that by rotating the bars the bowed portion 62 of the bars can have its position in the path of the web material between rolls 42, 43, 44, 45 and 46 adjusted as desired so as to avoid all contact with the web material or so as to exercise maximum spreading action on the web material. By any suitable means not shown the spreader bars 54, 55, 56 and 57 may be locked in the desired position. In Fig. 5 one of the spreader bars, i. e. bar 56, is shown. This bar has approximately a semicircular bowed portion 62. The bars 54 and 55 are curved somewhat more sharply outward from the sides than toward the center, this being the case particularly with bar 54. It has been found desirable to commence the spreading action at the sides and gradually extend the spreading action to the center of the web 33 in passing successively over the spreader bars 54, 55, 56 and 57. In making adjustments the spreader bars can be made of material which has sufficient flexibility to permit them to be curved to the shape that affords the desired results.

The spreading action takes place by moving the web material under bar 62 over the bowed portion 62 of the spreader bars thereby tending to spread the web laterally. The primary tension is exerted by the roll 46 which has associated therewith a press roll 63 that imposes its weight upon the sheet 33 passing between it and the roll 46 so that the drag on the sheet 33 will be more positive. The spreading apparatus disposes the web material so that it is presented more evenly to the applicator rolls 37 and tends to remove any longitudinally extending ripples that may be in the web material as discharged from the drafting rolls 35. Preferably the spreading is merely sufficient to remove the ripples and cause the web to lie flat without substantially pulling the fibers laterally away from each other. The drafting and spreading operation can be carried out at any suitable speed. In ordinary practice the web material is preferably passed from the drafting rolls to the applicator rolls at a speed of about 70 to 120 feet per minute. The web material may be moved out of the other drafting operations at approximately a similar speed. It is also possible to carry on a substantially spreading action without employing the spreader bars inasmuch as the web material tends to spread laterally when passed over a plurality of rolleras. The spreader bars serve to accelerate this spreading action, however.

Continuing the foregoing example of this invention the bonding together of the spun fibers in the web material by means of a caselin binder material will be described. The web material is caused to pass from the roll 46 between the applicator rolls 37. The peripheral speed of which is somewhat greater than the peripheral speed
of roll 48 so that the tension on the web material 33 will be maintained. The rolls 37 can be conveniently driven as by causing the chain 48 driven by sprocket wheel 47 to pass over sprocket wheel 164 that rotates with one of the rolls 37. While casein solution might be applied by rolls 37 I have found that it is preferable in obtaining a uniform application of casein as a binder to first apply a temporary binder, which may be merely water. Accordingly water 34 is placed in troughs 35 and is carried over the surface of rolls 36 and 37 to the web 32, preferably enough water being carried to form small beads 36 at the bite of the rolls 37. If desired doctor blades 101 may be associated with the rolls 37 or other equivalent means may be used to control the amount of binder, temporary or otherwise, applied to the web material. The water temporarily bonds the fibers together by surface tension effect of the water on the fibers tends to set the fibers in the condition of tensioned straightness that they are in upon reaching the applicator rolls. In this operation therefore the fibers of the fibrous web are bonded while the web is in the condition that they occupy when the web is under tension. As above mentioned the fibers have been oriented so that for the most part they are in one direction, particularly the longer fibers and are loosely associated so that they can be drawn out and straightened without rupturing the fibers or the web. These fibers are drawn out to maximum tensioned straightness and while still thus drawn out are bonded together.

The application of the temporary binder is followed by the application of a permanent binder while the bonding effect of the temporary binder persists. The permanent binder may be applied by another pair of applicator rolls 66 which have a peripheral speed substantially that of rolls 37 and to which the binder material in troughs 68 may be supplied by feed rolls 67. The supply of bonding material can, if desired, be controlled by doctor blades 102 or by other equivalent means. For convenience in handling the web material after leaving the applicator rolls 37 the material may drop to traveling conveyor 69, over rolls 70, 71 and 72 and thence to the applicator rolls 66. While the tension on the web 33 may be momentarily reduced by this handling of the web material the temporary binder (e. g. water) maintains the fibers in the web in substantially the same condition that they were in when they passed between the applicator rolls 37. Preferably, the rolls 70, 71 and 72 are power driven so as to lift the web material from the weight and again subject it to tension, and these rolls are preferably driven at successively increased speeds and at a rate such that the peripheral speed is slightly greater than the peripheral speed of rolls 37 so as to augment the tensioning effect in the direction of the fibers. Moreover, the rolls 66 are driven at a rate such that the peripheral speed is slightly greater than the peripheral speed of roll 72 so that the web is carried into these rolls under slight tension. The peripheral speed of the rolls may be so constituted as to be about 5% greater than the peripheral speed of rolls 37 for example. Similarly the rolls contacting the web material subsequent to rolls 66 are preferably driven at successively slightly increased peripheral speeds (e. g. a small fraction of one percent increase) until the binder is set in a setting step, e. g. in chamber 74, or during drying, e. g. in chamber 78.

75. In this way the web material is prevented from wrinkling during its travel through the apparatus and any tendency of the fibers to relax, before the bonding material has set, to a non-straightened condition is minimized with the result that the fibers in the web, after the bonding material has set, will still be substantially as straight as when they were introduced into the bonding step. The conveyors 69 and 73 may be of any desired length so that the time interval during which the web material rests thereon may be controlled as desired. Alternatively the conveyor may be drawn by any suitable means not shown so as to travel more slowly than the speed at which the web material is deposited thereon so as to permit the web material thereon and thereby increase the period of time during which the web is carried thereby.

It remains to dry the bonded web material and if desired subject it to further treatment. To this end the web material may fall from the applicator rolls 66 to a carrier 73 and thence to a treatment chamber or zone 74. From the treatment chamber the fabric can pass to a drying chamber or zone 75 in which it may pass over a plurality of heated drying rolls 76 until the moisture in the web has been reduced to about 10%. The treatment chamber 74 may be omitted if desired. The treatment chamber is shown, however, in order to illustrate that the bonded web may be treated in any way that may be desired. For example formaldehyde gas or tannic acid solution may be applied to the bonded web to insolubilize the casein. After the bonded web material has been dried it can be made up into a roll 78 and is available for any purpose. In addition to drying the web on drying rolls it may be dried in festoons or on a carrier that is passed through a drying chamber in any other suitable way.

Web material that has been made as above described is shown in Figs. 6, 7, 8 and 9. In Fig. 6 a fragment of the material is shown and illustrates the predominant straightness and unidirectional characteristics of the fibers. If the fibrous material is examined under magnification it appears somewhat as shown in Fig. 7, namely the fibers have one predominant direction. This is especially true with regard to the longer fibers 78 inasmuch as some of the shorter fibers 80 which usually occur in cotton fibers as commonly used may be disposed with some irregularity as indicated. This is due to the fact that it is the longer fibers that are acted upon most vigorously in the drafting operations and which are drawn to tensioned straightness when the web is in the condition under tension in the direction of the fibers. The abrupt shorting of miskellaneously disposed short fibers does not, however, impair the great strength of the web material in the predominant fiber direction and acts as a filler that to a slight degree augments the strength of the web material in a lateral direction. Figs. 8 and 9 indicate the disposition of
the fibers in a dense coherent mass with the long fibers essentially unidirectional. The indication of the fibers in Figs. 6, 7, 8 and 5 is diagrammatic, no attempt being made to show relative proportions or fiber count. Moreover, the showing of the web material in Figs. 1, 3 and 5 is diagrammatic to show the striated character of the web material, the fibers actually being in intimate but loose association in a substantially continuous web more than 1 fiber diameter in thickness. No attempt is made to indicate in Figs. 8 to 10 the presence of the binder inasmuch as the binder in the fabric will be present in different ways depending primarily upon the amount of the binder. If the binder constitutes about 25% or less of the material by dry weight, the binder is distributed for the most part on the surface of the fibers and acts to bond the surface of the individual fibers to the surface of adjoining fibers. Inasmuch as the fibers are straightened and are essentially unidirectional the binder in the amount used is most effective in bonding the fibers together. The fibers instead of being bonded together at only a few points of contact as is the case with randomly disposed fibers, are woven into an intimate contact and each straightened fiber becomes bonded over most of the surface thereof with adjoining substantially parallel fibers that are likewise straight. If larger amounts of binder are employed the fabric becomes more compact and eliminated by the binder component while still retaining the inherent advantages of the fiber base for the material.

Due to the conditioning steps wherein a large number of slivers are lapped and drawn the web material is very uniform in thickness and fiber density and binder distribution affording uniform high strength throughout.

In the example above given the cotton fiber contained over about 70% of fiber that is one inch or more in length. Of course, other grades of cotton fiber may be used. In order to achieve the advantages of the invention in marked degree, however, over about 50% of the cotton fiber stock should be ¾ of an inch in length, and preferably over 60% to 70% of the cotton fiber should be over ¾ inch in length. Fiber material which contains fibers about ¾ inch in length is regarded as "long" fiber. The percentages of fiber given above and elsewhere herein and in the claims are percentages by weight.

The characteristics above mentioned of the structural web are those which result from manufacturing steps above described wherein ordinary cotton fibrous stock is used and wherein the stock is subjected to a drawing of about 32 to 1 in preparing it for the bonding step. In such case, as above mentioned, some of the shorter fibers remain somewhat indiscriminately disposed. It is possible, however, by subjecting the fibrous web material to repeated drafting and lapping operations prior to the bonding step to cause substantially all of the fibers to become straightened and straightened in one direction. For certain uses of the finished material this may be desirable but for most purposes it is not necessary to obtain such a high degree of fiber straightness and arrangement in one direction.

The occurrence of miscellaneous distributed fibers may likewise be eliminated by subjecting the cotton to a combing operation using any suitable type of combing machine designed for handling cotton fibers of which many are known, the shorter fibers being largely eliminated by the combing step so that the drafting operation may result in a material consisting essentially of long cotton fibers, e. g. ¾ inch or more, substantially all of which are straightened and are arranged in one direction prior to the bonding step. A material thus produced will be found to have maximum strength per unit weight of fibers in the direction of the fibers and will be dense and will require a minimum of bonding material.

A web material made as above described is suitable for many commercial purposes. In such a material at least about 70% of the fibers have substantially tensioned straightness, namely, the straightness that the fibers assume when stretched taut, and are arranged approximately in one direction, e. g. within about 15° of the mean direction of those fibers that are for the most part in one direction. In this type of fabric web about 80% of the fibers over ¾ of an inch in length are among those fibers which are arranged approximately in one direction and are substantially of tensioned straightness.

As aforesaid the extent to which the cotton fibers are drawn depends largely on the type of fabric that is to be produced. Thus for webs that when made up are to be quite light and are to exhibit great uniformity of texture and very high strength in the direction of the fibers the elemental web material may be subjected to the conditioning operation until about 90% of the fibers are disposed substantially in one direction and exhibit tensioned straightness as they are led to the bonding step.

On the other hand the drawing may be discontinued when only a small proportion of the fibers are disposed in one direction and exhibit tensioned straightness. This can be accomplished for example by taking the material discharged from the sliver lapping step which has been above described and in which the fibers are drawn about 2 to 1 to yield a web weighing about 500 grams per running yard, and then passing the material through the drawing frame 35 on which the fibrous sheet is drawn 4 to 1 and thence to the applicator rolls 37 so that the fibrous material will be drawn a total of 8 to 1. Such a fabric web is not as uniform as a fabric web which has been subjected to additional lapping and drawing steps before the fibrous material is bonded together. In any such web material it is preferable that the major proportion of the fibers that are arranged approximately in one direction and are straightened, include at least about 70% of the fibers that are over about ¾ of an inch or more in length.

A fibrous web which has only approximately 50% of the fibers disposed in one direction and straightened by tension nevertheless exhibits great strength. Such a web is especially useful in making relatively heavy sheet materials containing a plurality of the elemental webs, e. g. about 8 to 20, thereby minimizing any lack of uniformity in the elemental webs. Even with such heavy composite fabrics, however, it is desirable to draft the fibrous material prior to bonding until about 70% of the fibers is straightened by tension and are approximately in one direction. A fabric which contains about 800 grams of cotton fiber per square yard and which contains about 200 grams per square yard of casing binder, for example, has a tensile strength of about 50 pounds per inch in each direction when the individual webs are disposed with the pre-
The structural material of this invention either in the elemental web form or in the form of a composite sheet containing a plurality of elemental webs can be made so that the ratio of thickness in thousandths of an inch to weight of fiber in grains per square yard is about 1 to 200. While such materials are preferable, even those materials according to this invention wherein the ratio of thickness in thousandths of an inch to grains per square yard is only about 1 to 100 are very dense as compared with materials heretofore produced by any other means.

In the practice of this invention one can readily produce structural sheet or web material which has a tensile strength in the preponderant direction of the fibers of at least about 10,000 pounds per square inch and preferably at least about 20,000 pounds per square inch.

In the practice of this invention I have found that it is distinctly preferable, especially in connection with cotton fibers to bond the fibrous material in a manner such that the fibers are disposed in one direction and has been straightened by tension, while the fibers are disposed in thin elemental striated webs ranging from about 75 to about 250 grains per square yard in weight. In such case the action on the fibers in tensioning and bonding the composite sheet and the fibers become more uniformly bonded together.

In connection with cotton fibers it is desirable not to carry on the bonding step when the material being treated weighs more than about 400 grains per square yard inasmuch as while heavier webs may be brought to the bonding step somewhat inferior results are obtained.

Somewhat more generally the straited web material should be of sufficient thickness so that the fibers at least in major proportion will be contained in juxtaposition when oriented to tensioned straiteness and approximately in one direction, and should preferably be in thickness about 2 to about 8 times the diameter of the fiber that is used.

When it is desired to make heavier material this can be done by laminating or plying the elemental webs until a sheet of desired thickness and weight is produced. The fibers in the elemental webs are preferably bonded together before being assembled in a composite sheet and may be made up into a composite sheet by bonding together webs in which the fibers have previously been bonded together.

In Fig. 10 there is illustrated a composite sheet which includes elemental webs 81 and 82 in which the preponderant fiber direction extends longitudinally of the sheet. If desired the composite sheet can include a web 83 in which the fibers extend transversely so as to give transverse strength to the composite sheet as a whole. In such case the presence of the transverse sheet 83 tends to keep the fibers in webs 81 and 82 from spreading and thereby increasing the strength of the material in the fiber direction of the webs 81 and 82 so that the strength in this direction is somewhat greater than if the web 83 were not included. The number and fiber direction of the fibrous webs can be widely varied and it is an advantage of this invention that means are afforded whereby strength in the direction or directions of greatest strains can be attained with a minimum of fiber material.

The nature and amount of the bonding agent that is used can be varied widely depending upon the type of material to be produced. For most purposes binder to the extent of about 20%, to 50% by weight (dry) of the weight of the fibers is incorporated with the fibers especially when the binder is relatively inelastic or non-plastic at ordinary temperatures. Lesser amounts, e.g., about 10%, is sufficient for many purposes. On the other hand, 50% to 100% may be used if highly impregnated fibrous material is desired. The use of amounts of binder as high as about 100% may be desirable, e.g., in the production of waterproof material in which the binder is a natural or synthetic rubber material or a bituminous material.

The particular bonding material that is selected is largely optional. Among bonding materials applied in an aqueous medium there are, in addition to casein above mentioned, numer-
ous others such as glue, latex, asphalt emulsions and the like. When the bonding agent is applied in an aqueous medium and then dried, a water vapor to a temporary binder so that the permanent binder may be more uniformly deposited on and among the fibers. In such case two application steps, one involving the application of the temporary binder and the other the application of the permanent binder constitute preferred practice. If desired in the application of water as a temporary bonding step a wetting agent may be employed such as pine oil soap, and the like, in order to promote more uniform impregnation of the fabric with the permanent binder. Moreover, reactive materials such as coagulants may be incorporated in the first application, e.g. a coagulant such as alum, tannic acid, formaldehyde, etc., may be included to insolubilize or harden the permanent binder subsequently added.

When the binder is added in an aqueous medium subsequent treatment of the web is largely confined to drying, although before, during, or after drying the web may be subjected to further treatment, e.g. in a treating chamber such as that described in the aforementioned patent.

Other bonding materials such as bitumens, cellulose esters, cellulose ethers, synthetic resins, and materials of the like, may be applied when dissolved in an appropriate solvent or blended with such solvents such as naphtha, acetone, etc., is used subsequent evaporation of the solvent in a suitable solvent recovery system, is preferable. When a volatile non-aqueous solvent is employed the temporary bonding step may be omitted. In this case the binder solution can be applied by applicator rolls, for example. However, it is frequently desirable especially when the binder material is relatively tacky as applied, to first incorporate a small amount of a temporary binder, e.g. about 1 to 5% of starch, silicate of soda, methyl cellulose or the like and thereafter apply the permanent binder as a separate step.

Binder materials which are thermoplastic may likewise be employed by applying them in a heat liquefied condition or by applying them in a finely divided state, and then heating the finished web material to render the thermoplastic material sticky and bond the fibers together. Thus, bitumens such as asphalts, pitches, tars, etc., cellulose esters and cellulose ethers such as cellulose acetate, cellulose nitrate, ethyl cellulose, benzyl cellulose, etc., a wide variety of synthetic and natural resins such as urea-furfural resins, vinyl resins, etc., may be employed. The binder material may be a reversible thermoplastic such as asphalt which after application may be softened by reheating or may be thermosetting such as phenol-formaldehyde resins of the “Bakelite” type. After the fibers have been cobonded by the thermoplastic binder in a tacky or sticky condition it is usually sufficient merely to permit the web material to cool until the binder is substantially non-tacky.

The flexibility or pliability of the structural web or sheet material will depend largely upon the character and amount of binder that is used. Thus a web or sheet containing about 50% of the weight of the fiber of a relatively rigid binder such as synthetic resin binder of the phenol-formaldehyde type will be quite stiff especially when a plurality of the individual ply sheets are made up into a composite sheet of considerable thickness. Binders of the cellulose ester or other type afford structural sheet materials of intermediate stiffness. Structural sheet material comprising relatively soft binders such as low softening point bituminous materials, rubber and the like can be made which are very pliable.

While reference has been made to the employment of a bonding material which remains on the surfaces of the fibers it is also possible to treat the fibers with a material that attacks them sufficiently so that the surface becomes sticky and bonded and then removing the material but leaving the fibers bonded together. Thus, in the case of cotton fibers the fibrous web may be treated with sulphuric acid, zinc chloride or the like, e.g. by the applicator rolls. The added material that attacks the fiber may thereafter be neutralized or washed away by suitable means, the extent of the action being dependent upon the time interval during which the material in active condition remains in contact with the fibers prior to neutralizing it or washing it away. Any such material, since it results in bonding the fibers together, is regarded herein as a bonding material.

Where a plurality of the elemental webs are combined to form a composite sheet this can be done in several ways. For example, the web material after having been bonded while the web is under tension can be laminated while the bonding material is adhesive so that the webs will adhere together. Alternatively, the composite sheet material as a result of evaporation of solvent, cooling and the like may be permitted to harden and thereafter the web material may be bonded together. If the bonding material can be reactivated, e.g. by heating a reversible thermoplastic material or by peptizing a solvent activatable adhesive, the adhesive may be reactivated by the heating or the solvent peptization so that the webs may be bonded together. Of course, in any event additional adhesive or other bonding material the same as or different from the bonding material on the fiber in the elemental webs may be employed. If the fibrous material is sufficiently porous after having been bonded under tension, a bonding material may be applied after the webs have been laminated so that it may penetrate sufficiently through the composite sheet to bond the laminations together. Another desirable way to bond the elemental webs together is to dispose finely divided thermoplastic material such as asphalt, cellulose esters or others, resins or the like between superposed webs and then subject the composite sheet to heat as by passing it between or over rolls heated sufficient to render the thermoplastic material tacky and bond the webs together.

Whether the sheet material is in the form of an elemental web or a composite sheet it is preferable as aforesaid to employ, only about 10 to 50% of the weight of the fiber of binder that remains incorporated with the sheet material. The fibers that are arranged approximately in one direction and are of substantially tensioned straightness will have any tensile load in the direction of the fibers distributed among them, and excess of binder tends to detract from the strength of the material per unit weight rather than otherwise since the fiber is usually stronger than the binder material. The amount of binder that is appropriate for cementing the fibers together to prevent relative slippage of the fibers is all that is required and since the fibers are in
a dense compact arrangement the amount of binder required is relatively small. It is to be understood that the foregoing operation whereby the improvements of the invention may be attained merely constitute an illustrative example of the practice of this invention and that the drawing or drafting can be performed in other ways and that the spreading of the fibers, web, if the spreading step is performed, can be carried out by other means. Thus, in Fig. 11 there is shown an alternative device that may be employed for spreading the fibrous web between the drafting and the application of the bonding material. In this modification the web material in passing from the drafting rolls 36 to the rolls 37 passes over a saddle-backed part 103 which is downwardly curved and is bowed outwardly, e. g. as indicated in the cross-sectional views shown in Figs. 12, 13 and 14. The peripheral speed of the rolls 37 is slightly greater than the peripheral speed of the last of the drafting rolls 36 so that the web material 33 is maintained under tension in passing over the part 103 which because of the curvature thereof causes the web 33 to spread, e. g. from about 10 inches as discharged from the drafting rolls to about 14 to 18 inches when the web 33 reaches the applicator rolls. It is apparent that equivalent means may likewise be employed.

In carrying on the spreading step the extent of the spreading will depend somewhat on the material being handled. It is usually desirable to spread the web material prior to the bonding step by about 25% to 75% of its original width. Especially with heavier fibers which tend to be more uniformly distributed as discharged from the drawing apparatus less spreading, e. g. about 10% to 25% of its original width is usually sufficient prior to the bonding step.

The bonding material can also be applied in other ways, for example, as illustrated in Fig. 11. As shown, the bonding material is sprayed onto the web 33 before it goes between the rolls 37 from nozzles 100. This method of application of bonding material is especially suitable when a relatively small amount of bonding material is to be applied. It is also possible to seize the conditioned web material drawn to tensioned straightness and thereafter apply the bonding material, e. g. through a foraminous restraining member. Alternatively a thermoplastic binder such as asphalt may be blown into the web 33 in powdered form from the nozzles 100 and the rolls 37 may be heated to soften the asphalt and bond the fibers in the web material together. Various other ways of applying binder are also possible although for most purposes the ways above described have been found to be preferable.

The type of drafting apparatus that is used may be varied. The type of apparatus that is used should be that which is best suited for handling the particular fiber to be made into a web. For drawing and lapping cotton fiber some apparatus such as that described above for purposes of exemplification is usually most desirable. The use of drafting frame equipment containing a plurality of adjacent rolls that have successively increased peripheral speeds is very effective in straightening the fibers and arranging them in one direction. The extent of the drafting in each drafting frame and the sequences of lapping may be varied widely although the fibers should not be arranged too thickly in order to obtain a good drawing action.

For drafting fibers that are longer than cotton fibers modified equipment is desirable such as that shown in Figs. 15 and 16 which may be a hill box or draw box or the like. There are a number of relatively long fiber materials e. g. bast fibers such as jute, sisal, hemp, ramie, flax, and coir, or natural silk. In making web material from such fibers the fibers are preferably caused to occur in lengths average 5 to 6 to 8 inches and the fibers in this form are carried and run into heavy sliver form. The slivers, e. g. two, may be run for example into the hill box shown in Fig. 15 comprising the sliver guide 81, the retaining rolls 82 and 83, the slip roll 84, the drawing roll 85 and press roll 86. The rolls 83 and 85 are spaced apart by a distance that is greater than the length of the fibers and between them are the movable fallers 87 on the pins of which the fibers are carried from the roll 83 to the roll 85. The fallers move at a speed that is somewhat greater than the peripheral speed of the roll 83. The drawing roll 85 may have a peripheral speed about 4 times that of roll 83 thereby drawing the fibers by about 4 to 1. Any suitable to be varied widely although the fibers should not move the fallers 87 so that at the end of their travel toward roll 85, return them and elevate them at the end of the return travel. It is usually desirable to subject the fibrous material to further drafting. In such case the web material discharged from rolls 83 and 85 may be made up into a roll 88 or if desired may be passed to sliver form. Apparatus for carrying on a second drafting operation is shown in Fig. 16 which includes the retaining rolls 98 and 91, the slip roll 92, the drawing roll 95 and the press roll 94. The roll of material 88 feeds into the rolls 90, 91 and 92 and is carried by the fallers 95 to rolls 93 and 94. The fallers travel at a speed somewhat greater than the peripheral speed of roll 93 and 94 has a peripheral speed about 3 times the peripheral speed of roll 93 thereby drawing the fibers about 8 to 1. If desired one or more webs, e. g. from roll 93 in addition to roll 98, may be fed into the device of Fig. 15 to show that the fibrous web will not become excessively attenuated in the drafting. Alternatively one or more slivers may be fed into the device of Fig. 16 as may be desired.

In the device of Fig. 16 the fallers 95 are carried in the form of a continuous belt about rolls 93 and 97. The action is essentially the same as the action of the fallers in the device of Fig. 15 and the devices of either Figs. 15 or 16 may be used although the device of Fig. 15 is somewhat preferable. The different mechanisms are shown primarily to illustrate the fact that the drafting mechanism may take many different forms. It is preferable however when the fiber is subjected to more than one drafting operation that the fiber is subjected to more than one drafting operation that the pins on the fallers used for any drafting after the first drafting be somewhat more numerous than the pins on the fallers used in the first drafting operation.

After the fibrous web material has passed from rolls 93, 94 it is taken over spreading means such as that shown in Figs. 2 to 5 or in Fig. 11 for example to means for applying bonding material while maintaining the web material under tension as it travels from the rolls 93, 94 to the means for applying the bonding material.

By way of example two very heavy slivers of
jute fiber weighing about 1200 grains per running yard may be run into the drafting apparatus of Fig. 15 wherein it is drawn about 4 to 1 to form web material about 11 inches wide weighing 600 grains per running yard. Four of these webs thus made (weighing in all about 2400 grains per running yard) are then run to the drafting apparatus shown in Fig. 16 wherein the fibrous web material is drawn about 8 to 1 to form a web material about 11 inches wide weighing about 300 grains per running yard. This latter material is then spread for about 15 inches in width before the bonding material is applied. The bonding material may be any of those described above and used in similar proportions. The bonding material may be applied by any of the means heretofore referred to or the equivalent thereof. For such very coarse fiber the web preferably weighs about 400 to 800 grains per square yard when the bonding material is applied.

The process can also be carried out in connection with fibers of intermediate length such as wool, in which the fibers coiled into strips 2 or 3 inches in length. In such case a draw box or gill box or the like may be used to straighten the fibers and arrange them in one direction but, of course, the spacing between the retainers and the drawing rolls will be less than when longer fibers such as wool, hemp, etc., are used.

Any operation or apparatus for drawing fibers, by some such action as drafting rolls, gill box, or draw box wherein fibers are seized and pulled out essentially in one direction thereby straightening them in one direction, is referred to as a drafting operation or apparatus and is to be distinguished from mere sheet-forming actions such as felting or the action of a carding machine.

In addition to fibers such as those above mentioned, other fibers may made up into web structural material e.g., synthetic fibers such as rayon, cellulose acetate and the like. Web structural material consisting wholly or partially of mineral fibers e.g., asbestos fibers may also be made according to this invention. In connecting mineral fibers such as asbestos fibers, a material for these to be incorporated shall of course be sodium silicate may be employed. Moreover, fibers which are unspinnable, e.g., kapok, milkweed fibers, manila, Spanish moss and the like, can be made up into structural material according to this invention.

Regardless of the character of the fiber that is employed it is desirable that the proportion of the fiber that is arranged approximately in one direction and brought to tensioned straightness correspond substantially with the proportions above mentioned in connection with cotton fibers for the reasons mentioned in connection with the foregoing description of web materials and composite sheet materials made from cotton fibers.

In the practice of this invention the web material is treated in various ways during the performance of the method. Thus, the web material can be treated with a dye or stain or pigment during the application of either the temporary or permanent binder or as a separate operation. Moreover, waterproofing or water-repellent material may be incorporated. If desired, a filler material such as finely divided clays (bentonite, kaolin, etc.), silica dust or the like may be incorporated in a similar way.

In the foregoing description a web material about 14 to 18 inches wide is described. It is, of course, possible to make the web material of other widths. This can be done by varying the lateral capacity of the equipment used, e.g., equipment such as described above. It is preferable that the web material during the drafting operation be at least 9 inches in width and that the drafted web material be at least about 12 inches in width when the fibers are integrally bonded.

For making wide web material it is also possible to mount a plurality of the units in parallel and operate them simultaneously at the same speed, the output of each unit being placed alongside the output of an adjacent one. Thus, a plurality of the drafting frames can be placed side by side and the web material discharged from each spread laterally until the marginal edges abut each other. The wide web can then be passed between a common pair of applicator rolls for applying the bonding material. If fibers from a carding machine or the like are used as a source of fibrous material it is not necessary to pass the carded sheet to a drafting form. Inasmuch as the carded material in sheet form may be subjected to repeated lapping and drafting operations to condition fibrous materials in the manner above referred to.

In order to obtain material having uniform density and thickness so as to achieve a product having uniform strength characteristics throughout, it is desirable to make at least two ribbon or sheet-like intermediate webs and then lap them and subject the composite web to drafting to attenuate the composite intermediate web and draw the fibers thereof to increased straightness and uniformity in a direction corresponding to that of the drafting. Preferably at least four such intermediate web or sheet-like bodies are made and lapped so as to obtain a drafted web that is very uniform.

It is apparent from the foregoing that fibrous structural material having great strength for the weight of the fiber can be produced according to this invention in a very economical way. Fabric-like sheet material having the strength of woven fabrics can be made without going through the costly operations of spinning and weaving. Moreover, sheet material resembling sheet metal in strength in order to enhance its thickness and which is much stronger than non-ferrous metals, such as aluminum, for their weight. High strength can be obtained with a minimum of binder material and a material can be produced according to this invention that is very dense and of great strength for its thickness. The fibrous material is also so uniform in thickness, fiber density and binder distribution as to have throughout very uniform strength characteristics. A new structural material, therefore, is afforded having great commercial utility.

While this invention has been described in connection with certain specific embodiments thereof it is to be understood that this has been done merely for the purpose of illustrating the practice and affording a better understanding thereof. Accordingly, the scope of this invention is to be governed by the language of the following claims construed in the light of the foregoing description.

I claim:

1. A method of making a fabricated web of co-bonded unspun fibers which comprises subjecting unspun fibers to drafting until the fibers are preponderantly straightened and arranged in one direction longitudinally of an elongated
fibrous web, spreading said fibrous web laterally while being subjected to longitudinal tension, and bonding said fibers together while said web is under longitudinal tension.

2. A process of making a web of cobounded unspun fibers which comprises forming a plurality of elongated bodies of unspun fibers, subjecting said bodies to drafting to draw the fibers therein in the direction of the drafting and orient and straighten said fibers in the direction of the drafting to form a plurality of webs with the fibers so oriented and straightened therein, lapping a plurality of said webs to form a composite web containing a plurality of web laminations, subjecting the composite web to a drafting operation to attenuate the composite web and draw the fibers to increased straightness in a direction corresponding to the drafting while said fibers are in a dry and essentially unbonded condition, and thereafter cobonding the fibers together while in slatted attenuated web form to form a coherent integrally bonded web material, the fibers not being permitted to relax between the drafting step and the bonding step.

3. Apparatus for making a web of cobounded unspun fibers which comprises drafting means for straightening and arranging the fibers in a predominant direction longitudinally of an elongated web, means spaced from said drafting means for applying a bonding material to the web, means for maintaining said web under tension between said drafting means and said means for applying the bonding material to said web.

4. Apparatus for making a web of cobounded unspun fibers which comprises drafting means for straightening and arranging the fibers in a predominant fiber direction longitudinally of an elongated web, said drafting means including a plurality of adjacent pairs of rolls between which said fibers pass and means for driving said pairs of rolls at successively increased speeds to accelerate the movement of said web material and draw the web material longitudinally, applicator rolls for applying a bonding material to said fibers of said web, means for maintaining said drafting rolls while said web is under tension longitudinally, and means for rotating said applicator rolls so that the peripheral speed of said applicator rolls is at a somewhat greater speed than the peripheral speed of the last pair of said drafting rolls to maintain said web under tension longitudinally thereof when fed into the nip of said applicator rolls.

5. In apparatus for making unspun fibrous material, the combination with drafting means for straightening unspun fibers and arranging them in a predominant fiber direction, of tensioning means for subjecting said fibrous web material discharged from said drafting means to tension and means between said drafting means and said tensioning means for laterally spreading web material discharged from the drafting means.

6. Apparatus according to claim 5 wherein the spreading means comprises a plurality of rollers over which the web material is adapted to pass.

7. Apparatus according to claim 6 wherein the spreading means comprises a plurality of rollers over which the web material is adapted to pass and between said rollers for bowing out the center of the web material as it passes between said rollers to spread the web material laterally.

8. Apparatus according to claim 5 wherein the spreading means comprises an elongated centrally bowed part over which the fabric is adapted to pass and thereby become spread laterally.

9. Apparatus for making a web of cobounded unspun fibrous material which comprises drafting means for straightening said fibers and arranging them in a predominant fiber direction in an elongated slatted web, said drafting means including a plurality of adjacent pairs of rolls between which said fibers pass and means for driving said rolls at successively increased speeds to accelerate the movement of said web as it passes successively between said rolls and draw said web material longitudinally, means for spreading said web discharged from the last pair of drafting rolls laterally upon being discharged from said drafting means, applicator means for applying a bonding material to the web, and means for maintaining said web material continuously under tension during the travel thereof between said drafting means and said applicator means.

10. Apparatus for making a web of cobounded unspun fibers which comprises drafting means for producing an attenuated web in which the fibers have a predominant fiber direction, a pair of rolls, means for carrying said web of material under tension in said fiber direction sufficiently to straighten the fibers in said direction between said drafting means and said rolls and means for applying bonding material to said web received by said rolls after said web is discharged from said drafting means and while said fibers are in said condition of tensioned straightness.

11. A method of making structural sheet material which comprises forming a slatted web of loosely associated contiguous fibers about 50% of which are at least about 0.1 inch in length, in which at least 50% of the fibers at least 0.1 inch in length have a predominant fiber direction and are disposed within about 15° of said mean direction and in which the fibers are arranged in substantially uniform thickness and fiber density, subjecting said web material to pulling tension in said direction at a first zone while said web is restrained at a second zone so as to prevent movement of said web at said second zone at a rate that is as great as the rate at which said web is pulled at said first zone, said first zone being spaced from said second zone by a distance greater than the length of the fibers in said web, thereby causing said fibers disposed in said direction between said first and second zones to be dragged relatively to contiguous fibers and become tensioned and straightened while in an essentially slatted web form, and bonding said fibers of said web together before said pulling tension imposed on said web is relaxed and forming a coherent integrally bonded sheet material of substantially uniform fiber density and binder distribution throughout wherein said fibers brought to said condition of tensioned straightness as aforesaid are maintained in said condition by said binder after said pulling tension is relaxed.

12. A method of making structural sheet material comprising unspun cotton fibers, which comprises carding cotton fibers about 50% of which are at least 0.1 inch in length, then drafting the carded cotton fibers to draw the fibers...
at least 8 to 1 in the direction of the drafting and orient said fibers in the direction of the drafting and straighten said fibers longitudinally in an elongated sheetlike body, said fibers being drawn under tension in the final stage of said drafting into and between the nip of a pair of rolls which grip the sheetlike body therewith, drawing said sheetlike body from the nip of said pair of rolls under tension and with dragging of individual fibers disposed longitudinally thereof relative to contiguous fibers in frictional contact therewith, thereby maintaining said fibers in a condition of tensioned straightness and longitudinally of the sheetlike body during the travel of the fibers from the nip of said rolls, and, while so drawing said sheet-like body with said fibers in said condition of tensioned straightness, bonding the said fibers of said sheetlike body together by application of a binder thereto to form a coherent integrally bonded sheet material wherein said fibers are fixed in said condition of tensioned straightness by the said binder so applied thereto.

13. A method according to claim 12 wherein the cotton fibers after the carding step are subjected to drafting to draw and partially orient and straighten the fibers in the direction of the drafting and wherein a plurality of bodies of the so drawn and partially straightened fibers are lapped and then subjected to further drafting prior to the final step wherein the fibers in a sheetlike body are fixed by application of binder thereto while travelling in a condition of tensioned straightness longitudinally of the sheetlike body, the total drafting accomplished by the drafting steps subsequent to carding being at least 62 to 1.

14. A method according to claim 12 wherein the fibers when drawn into the bonding step are disposed in a sheetlike body weighing between 75 and 400 grams per square yard and are drawn by gripping the sheetlike body between the nip of a second pair of rolls which pull individual fibers and drag them relative to other fibers in frictional contact therewith so as to tension said fibers and dispose said fibers in tensioned straightness in the sheetlike body when the binder is applied to bond the fibers together into a coherent sheet material.

15. A method according to claim 12 wherein the fibrous sheetlike body is maintained under longitudinal tension after the binder is applied and during setting of the bonding material applied to the fibers.

16. A method of making a fabricated sheet of co-bonded unspun fibers which comprises arranging the fibers in an elongated body, and subjecting the fibers while in the elongated body form to drafting to draw the fibers at least 8 to 1 in the direction of drafting and orient the fibers in the direction of drafting in a sheetlike body wherein the fibers are straightened in said direction longitudinally of the sheet like body, said sheetlike body being drawn under tension in the final stage of drafting into and between the nip of a pair of rolls which grip the material of the sheetlike body therewith, drawing said sheetlike body of fibers from the nip of said pair of rolls under tension and with dragging of individual fibers disposed longitudinally of the sheetlike body relative to contiguous fibers in frictional contact therewith, thereby disposing and maintaining said fibers in said sheetlike body in a condition of tensioned straightness during the travel of the sheetlike body from the nip of said rolls, and, while so drawing said sheetlike body with said fibers in said condition of tensioned straightness, bonding the said fibers of said sheetlike body together to form a coherent integrally bonded sheet material wherein the fibers are fixed in co-bonded relation in said condition of tensioned straightness.

17. A method of making a fabricated sheet of co-bonded unspun fibers which comprises subjecting unspun fibers loosely associated in dry non-co-bonded condition to drafting in a sheetlike body wherein the fibers are positively straightened by gripping the fibers between drafting rolls and by drawing the sheetlike body by said rolls while the fibrous material of said sheetlike body is restrained at a distance greater than the length of the fibers from the nip of said rolls, thereby orienting said fibers in the direction of travel of said sheetlike body and straightening the fibers in said direction longitudinally of the sheetlike body, the drafting accomplishing a drawing of at least 8 to 1, then further drawing and attenuating said sheetlike body of fibers by gripping the sheetlike body between rolls which are rotated at a peripheral speed that draws the fibers in said non-co-bonded condition and as oriented by the drafting with dragging of individual fibers disposed longitudinally of the sheetlike body relative to contiguous fibers in frictional contact therewith, thereby maintaining the fibers in a condition of tensioned straightness during the travel of the sheetlike body to said last mentioned rolls, and, first applying a binder to bond said fibers together immediately adjacent said last-mentioned rolls and prior to discharge of said fibers from the nip of said last-mentioned rolls, thereby fixing said fibers in co-bonded relation in said condition of tensioned straightness in a coherent sheet.

18. A method according to claim 17 wherein the fibrous sheetlike body, after leaving the rolls last mentioned in claim 17 adjacent to which the binder is applied, is subjected to tension during the setting of the binder.

19. A method of making a sheet of co-bonded unspun cotton fibers which comprises forming a thin stranded sheetlike body of fibers which are arranged approximately in one direction and a major proportion of which are substantially straight, drawing said sheetlike body in the direction of said straightened fibers while said fibers are in non-co-bonded dry state with dragging of said fibers relative to other fibers in frictional contact therewith to maintain said fibers in straightened condition, and, while so drawing said sheetlike body, applying a first binder material thereto to fix said fibers in said straightened condition in said sheetlike body, and then applying further binder to said sheetlike body while said fibers are maintained in said straightened condition by said first binder material to additionally bond said fibers in straightened condition into a coherent and integrally bonded sheet material.

20. A method according to claim 19 wherein said first binder is water and said further binder material is a non-volatile adhesive substance and is applied in an aqueous medium to said web while the fibers in said web are still moist.

21. Structural sheet material comprising a web of unspun fibers at least about 50% of which are at least ¾ inch or more in length, said web being characterized by the fact that at least about 70% of the fibers of ¾ inch or more in length are dis-
posed approximately in one direction, are of substantially tensioned straightness, are substantially non-stretchable and are co-bonded together in longitudinally non-slippable relation by a substantially non-stretchable binder distributed substantially uniformly about and among said fibers.

22. Structural sheet material in the form of a rigid, hard, dense body, said structural material consisting primarily of unspun fiber and binder, at least 50% of the fiber component being fibers of 2/3 inch or more in length, and said structural material being characterized by the fact that at least 70% of the fibers over 2/3 inch in length are maintained in a condition of tensioned straightness by said binder and are disposed in approximately the same direction in each individual layer of one or more layers comprised in said structural material, and said structural material being further characterized by the fact that said binder for said fibers is a substantially non-stretchable binder that is distributed substantially uniformly about and among said fibers, and the fiber density in said structural material being such that the ratio of thickness in thousandths of an inch to weight of fiber in grains per square yard is 1 to at least 100.

23. Structural sheet material according to claim 22 wherein said fibers comprise cotton fibers and wherein said substantially non-stretchable binder constitutes about 10% to about 50% by dry weight of said structural material and wherein the fiber density is such that the ratio of thickness in thousandths of an inch to weight of fibers in grains per square yard is 1 to at least 200.

24. Structural sheet material in the form of a rigid, hard, dense body, said structural material being characterized by comprising a plurality of integrally bonded superposed webs of unspun fibers, at least 60% of the fibrous material of said web being substantially unstretchable fibers 2/3 inch or more in length and at least about 70% of the fibers of 2/3 inch or more in length being disposed approximately in one direction in each web and being of substantially tensioned straightness, and said fibers in each of said webs being co-bonded together by a substantially non-stretchable binder material distributed substantially uniformly about and among said fibers, the fiber density in said webs of said structural material being such that the ratio of thickness in thousandths of an inch to weight of fiber in grains per square yard is 1 to at least 200.

25. Structural sheet material according to claim 24 wherein the fibers in said webs are unspun cotton fibers distributed in substantially uniform thickness in each web so that the fiber in each web weighs about 70 to 400 grains per square yard and wherein said substantially non-stretchable binder material in each web constitutes from about 20% to about 50% by dry weight of the weight of the fibers.

26. Apparatus for making a web of co-bonded unspun fibers which comprises drafting means for producing an attenuated web in which the fibers have a preponderant fiber direction in the direction of the drafting, a pair of rolls arranged for passage of said web therebetween after discharge from said drafting means, means including said pair of rolls for drawing said web in said fiber direction to dispose the fibers in said web in a condition of tensioned straightness in said web after said web is discharged from said drafting means and when said web is fed between said rolls, and means immediately adjacent said pair of rolls for applying bonding material to said web passing between said rolls while said fibers in said web are in said condition of tensioned straightness.

27. Apparatus according to claim 26 which also includes means for subjecting said web after leaving said pair of rolls with said binder applied thereto to tension during the setting of the binder.

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