Nov. 13, 1945. J. A. DAVIS 2,388,679

METHOD OF FORMING EARTH BUILDING BLOCKS

Filed Nov. 3, 1941 4 Sheets-Sheet 1

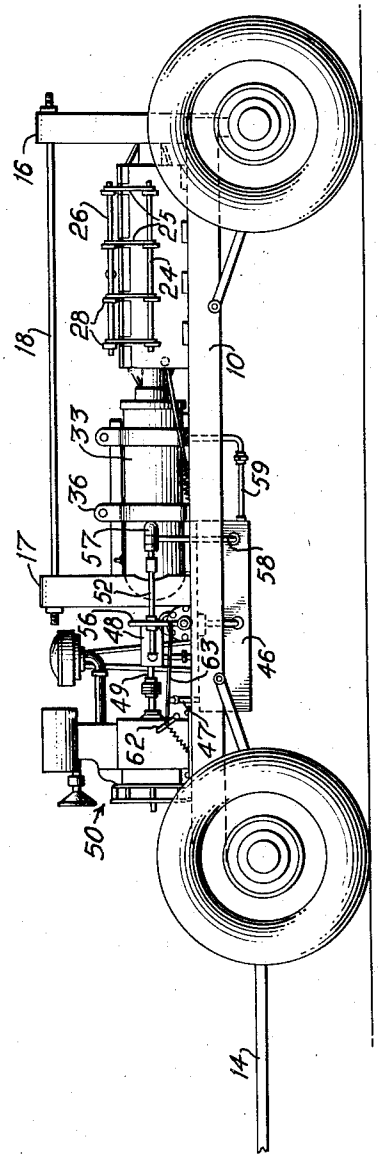


Fig. 1.

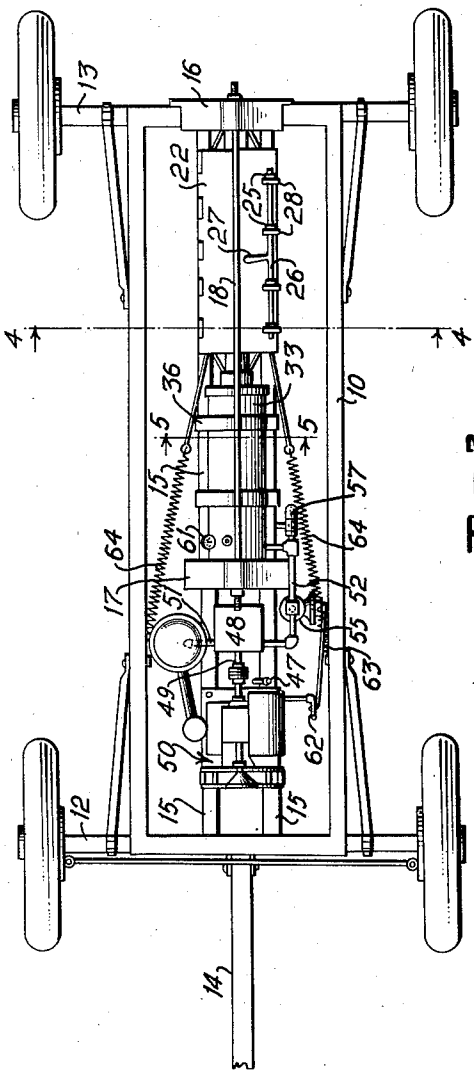


Fig. 2.

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Nov. 13, 1945. J. A. DAVIS 2,388,679

METHOD OF FORMING EARTH BUILDING BLOCKS

Filed Nov. 3, 1941 4 Sheets-Sheet 2

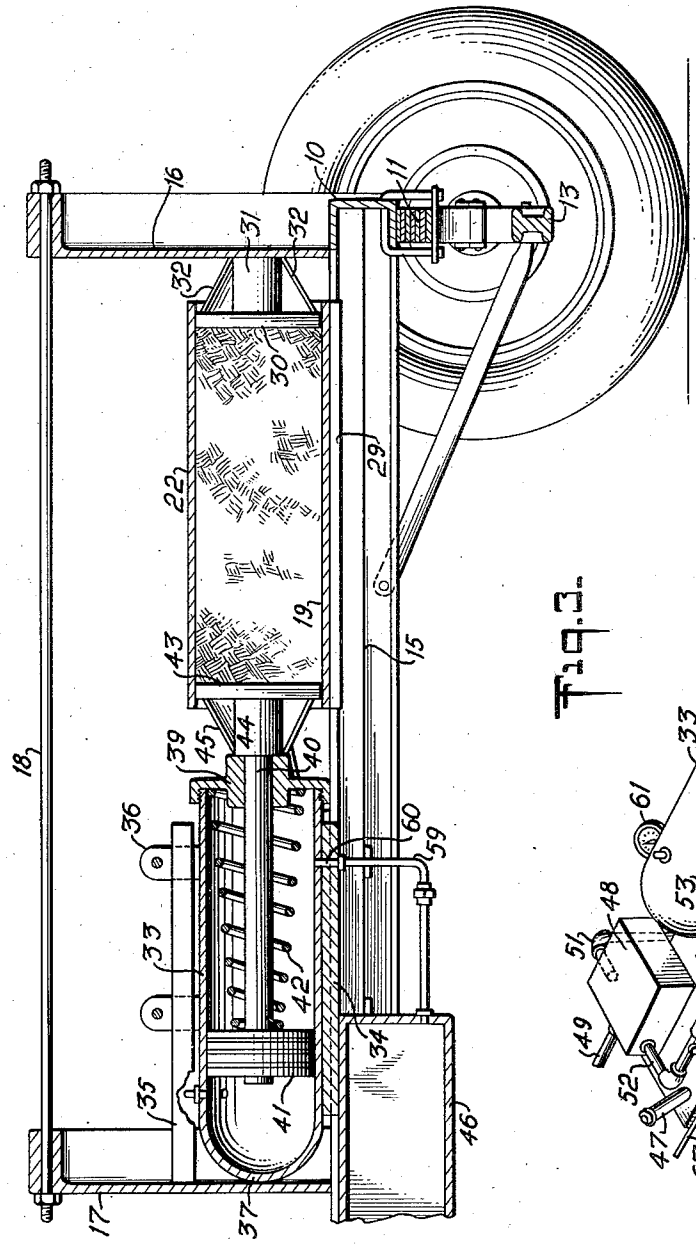


Fig. 3.

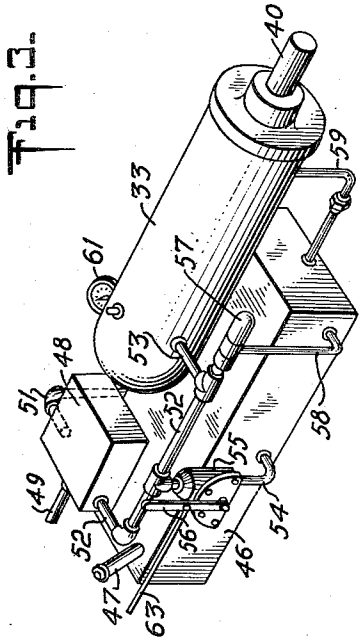


Fig. 2.

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Nov. 13, 1945. J. A. DAVIS 2,388,679

METHOD OF FORMING EARTH BUILDING BLOCKS

Filed Nov. 3, 1941 4 Sheets-Sheet 3

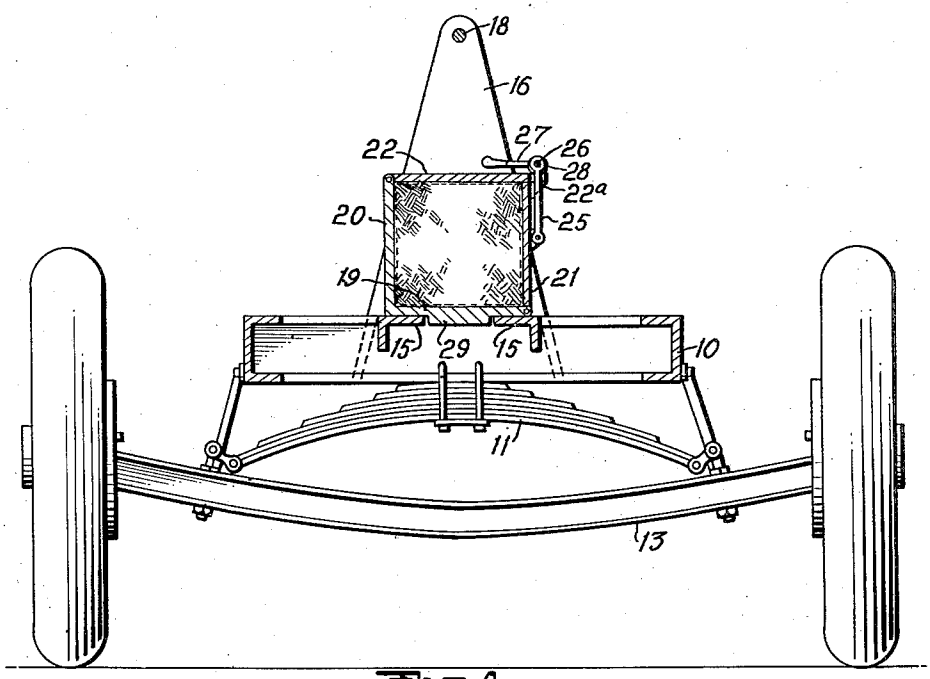


Fig. 4.

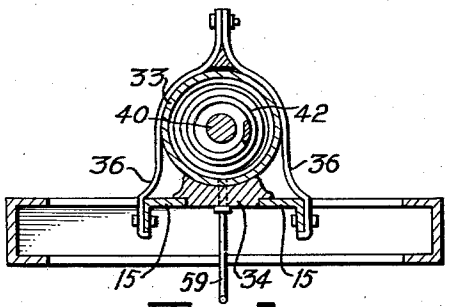


Fig. 5.

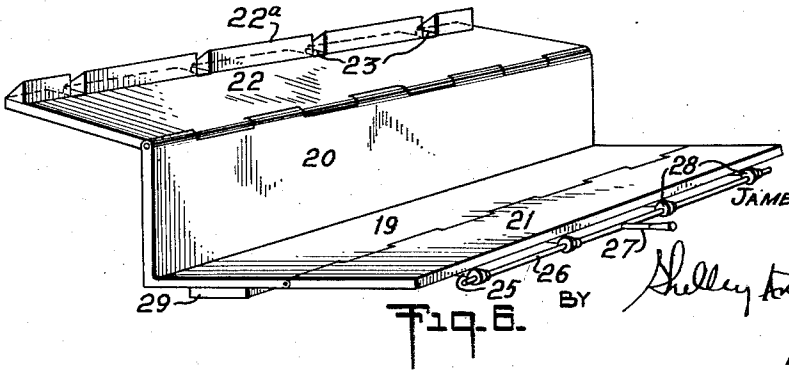


Fig. 6.

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Nov. 13, 1945. J. A. DAVIS 2,388,679

METHOD OF FORMING EARTH BUILDING BLOCKS

Filed Nov. 3, 1941 4 Sheets-Sheet 4

Fig. 8.

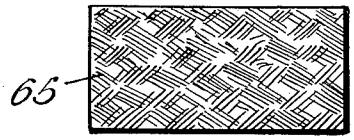


Fig. 9.

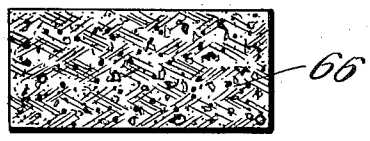


Fig. 10.

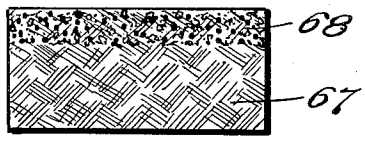


Fig. 11.

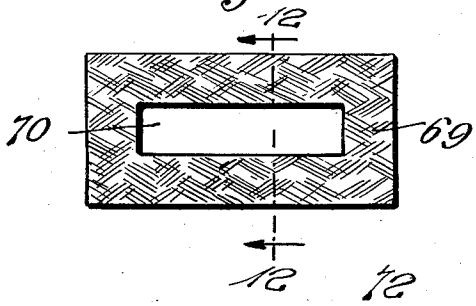


Fig. 12.

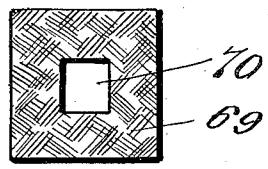


Fig. 13.

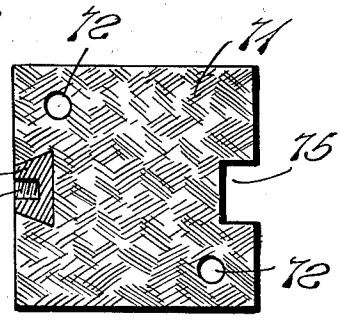


Fig. 15.

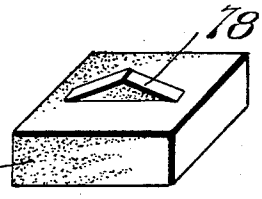
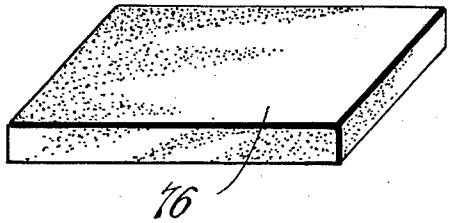


Fig. 14.



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Patented Nov. 13, 1945 2,388,679

UNITED STATES PATENT OFFICE

2,388,679

METHOD OF FORMING EARTH BUILDING BLOCKS

James A. Davis, Lawrence, Kans.

Application November 3, 1941, Serial No. 417,711

10 Claims. (Cl. 25—156)

This invention relates to method and apparatus for producing a new kind of material, and has particular reference to the fabrication of suitable building material from ordinary earth and like materials. This application continues and extends the inventions shown in my application Serial No. 199,721, now matured into U. S. Patent No. 2,265,771.

It is a purpose of the invention to provide a method for constructing building blocks and building material of all shapes, of highly compressed earth; the earth being of ordinary types commonly found.

It is further an object of the invention to provide building material in shape suitable for building construction, relatively impervious to moisture, and highly stable.

It is a further object of the invention to provide compressed building material, having a high tensile strength.

It has been the practice in making structures to be used for buildings and like purposes to utilize natural earth as found on the site of construction. Such earth has been made more or less permanent in its properties by the use of baking in the sun, as in adobe construction, or by moderate compression as in the rammed-earth construction. These methods have been known for many years, and although crude, have been utilized with moderate success. Both types of construction leave much to be desired. Both are susceptible to washing away by rain, particularly the adobe construction. The heat insulation is not high, and the strength is only moderate. Neither material, as utilized in final form, has any appreciable tensile strength. Cracks are therefore likely to form due to settling of the building, the inducing of tensile stresses thereby, and the inability of the material to resist such tensile stress. Both types of structure have the great disadvantage that they require much time to construct. The adobe construction requires the moulding and pre-baking in the sun which occupies considerable time since if sun-baking is resorted to, one must wait for favorable weather. The rammed-earth construction utilizing earth rammed by hand into forms requires the use of expensive forms, and the speed of construction is limited by the fact that there is room for only a few workers at any one time. The ramming process is slow and one must wait until it is completed before he can shift the forms for use on another part of the building. If one attempts to avoid this slowness by providing a great number of separate forms, the cost of the forms becomes prohibitively high, their transportation becomes expensive, and one is faced with the necessity of keeping all forms uniform so that a part of the building made with one form will fit a part made with another. Because of the awkwardness and slowness of the rammed-earth type of construction, attempts have been made to find a suitable substitute.

The present invention includes the construction of a block of compressed earth of exceptionally high compressive strength and exceptionally high tensile strength. It includes the provision of a machine which will compress the earth rapidly into suitable blocks, it then being possible to lay the blocks with great rapidity and to complete a structure within only a fraction of the time required for any equivalent alternative.

In the compressed earth construction as used previously, and particularly as utilized in rammed-earth structures, the compression was not sufficient to develop the full strength possible in compressed earth. I have found after a long series of experiments that when earth is subjected to unusually high pressures, such as a thousand pounds per square inch, it acquires a strength far in excess of that which would be expected on the basis of blocks made with less pressure. There appears to be a sudden and unexpected acquisition of strength upon the use of high pressures, and although this phenomenon is not yet thoroughly understood, it has been demonstrated adequately by experiment. A possible explanation is that the various particles comprising the earth mixture are forced into such intimate contact that molecular attraction exists, and the block becomes to all intents and purposes, a solid block of stone-like material.

The block resulting from the following of operations as described herein is one possessing new properties not heretofore known in the art. The block is different from that met with in the adobe or rammed-earth construction in its exceptional strength and imperviousness, and is different from molded blocks such as concrete blocks or baked blocks such as bricks in having an unusually high tensile strength. The block combines in a remarkable way a low cost of fabrication, simplicity in fabrication, and at the same time ideal properties for a building material. The high tensile strength in particular makes the block resistant to cracking due to settling or distortion of a building, and also makes buildings constructed therewith particularly resistant to earthquake. In the case of earthquakes, it is recognized that a great deal of damage is done by a compressional and

tensile wave which passes through the structures. It is the tensile component of this wave which often results in destruction. A building material able to resist tensile stress has admirable properties where such conditions are to be met. As pointed out previously, and as here again emphasized, blocks or structures made of poured concrete, although considered very strong for most purposes, do not possess the remarkable tensile strength possessed by these blocks. There is an acquisition of shear strength which accompanies the tensile strength and which also makes the block resistant to shear stresses of the type developed during earthquake and in settling of the structure.

To obtain the unusual results described above, it is found desirable to utilize compressive forces of at least 1,000 pounds per square inch in forming the block. The pressure may be reduced to as little as 500 pounds per square inch, with some sacrifice in the strength and other properties of the blocks. However, if the pressure is reduced below 500 pounds per square inch, it is noted that the compressed block will take on the character of ordinary rammed earth and will not possess the unusual properties mentioned above. There is some pressure in the vicinity of 500 pounds per square inch which is critical. Below this pressure, an ordinary mass of earth is obtained. Above this pressure, a block having unusual strength and other unusual properties as enumerated above, is obtained. Why this critical pressure should exist and why there should be so sharp a threshold is not thoroughly understood. This fact has been confirmed many times by experiment. An explanation will probably lie in the fact that when a pressure above a certain critical figure is utilized, the pressure is sufficient to distort the individual particles so that they adhere to adjoining particles over a relatively large area. Otherwise the particles would touch each other only at separated points giving limited areas of contact and a negligible adhesion due to the limited contact. Another possible explanation is that the water, which is a necessary part of the block, is squeezed into very thin individual films by the high pressure. This thin film has a very high tensile strength. If the pressure is not sufficient to develop these very thin films of water, the strength obtained will be insufficient. Pressures of 1,500 pounds per square inch have been used successfully in the production of a very satisfactory block.

The production of such a block requires the use of the proper proportions of ingredients, such ingredients being common and being clay, soil, sand, and water. The proper proportions are described below. Another remarkable property is that the addition of very small proportions of addition agents will increase the strength and stability far in excess of what might be expected. Thus as little as five to ten per cent of Portland cement, practically a negligible quantity, will result in the doubling of the strength of the block. This cannot be due to the Portland cement alone since the block will be stronger in tension than one made entirely of Portland cement. The addition of such materials as bitumen, or emulsions of various types of asphalt will also result in amazing increases in strength and amazing increases in properties of stability. Here also, the phenomena are not thoroughly understood, but the results have been proved by numerous tests to be beyond dispute. A possible theory is that the addition agents cause the particles to enter into even more intimate contact and to produce a stone-like structure. The addition of the same material will have practically no effect if the degree of compression of the block is not carried to the proper point. The new properties resulting from the use of addition agents described occur only with the unusually high pressures disclosed herein. Thus, if the addition agents disclosed herein are utilized with pressures substantially below 500 pounds per square inch, the remarkable increase in strength and the remarkable acquisition of other desirable properties will not be noted.

Structures built of blocks as fabricated herein and tested have shown unusual stability and unusual strength and have indicated that such blocks can be utilized as an effective, inexpensive type of construction, one which can be made with material which exists in most localities, thereby eliminating transportation costs.

Reference is had to the accompanying drawings in which:

Figure 1 is a side elevational view of a portable hydraulic press unit for making blocks according to the invention.

Figure 2 is a top plan view of the unit disclosed in Figure 1.

Figure 3 is a detailed vertical sectional view disclosing the molding and compressing elements of the assembly.

Figure 4 is a transverse sectional view taken on line 4—4 of Figure 2.

Figure 5 is a detailed transverse sectional view taken on line 5—5 of Figure 2.

Figure 6 is a detailed view illustrating the manner in which the mold box may be opened to accomplish removal of a molded block therefrom.

Figure 7 is a detailed perspective view disclosing the piping system and controls for the press embodying this invention.

Figure 8 shows a typical earth block made according to the method of the invention.

Figure 9 shows a similar block with the addition of stabilizing or other material.

Figure 10 shows still another type or block with addition agents, such agents being applied only near one face.

Figure 11 shows a cross-sectional view of an earth block having a hollow cavity.

Figure 12 shows a cross-sectional view of the block shown in Figure 11 taken across the lines 12—12.

Figure 13 shows another form of earth block with inserts and passages.

Figure 14 shows a slab of compressed earth, suitable for use as paving material.

Figure 15 shows an insert to be utilized in making blocks such as shown in Figure 11.

The apparatus disclosed herein for formation of the blocks is intended as purely illustrative. Other apparatus may be used to serve the unique function performed by the herein disclosed apparatus, so long as the manner of compression is carried out in the same fashion. While a hydraulic mechanism is specifically described, it is understood that a mechanical press having the required strength, or a press using an explosive charge in a cylinder to drive the ram may also be used. Alternatively, compressed air can be utilized to replace the liquid utilized in the hydraulic cylinder.

In the drawings, wherein for the purpose of illustration is shown the preferred embodiment of this invention, the reference character 10 designates a generally rectangularly shaped chassis

frame which is mounted by means of the transversely extending springs 11 on the front and rear axles 12 and 13, respectively. A suitable draft bar 14 is connected to the front axle and functions to permit the unit to be transported when attached to a suitable motor vehicle.

Referring particularly to Figures 2 to 5, inclusive, there is disclosed therein a pair of longitudinally extending, transversely spaced angle irons 15 which run parallel throughout their lengths. The opposite ends of these angle irons 15 are suitably secured to the cross members which form the ends of the chassis frame 10.

Suitably mounted on the chassis frame 10, directly above the rear axle 13, is an upstanding, triangularly shaped post 16. Spaced longitudinally of the chassis frame 10 and suitably supported on the angle irons 15 is a second upstanding triangularly shaped post 17. These posts 16 and 17 are fixed relative to each other and to the frame of the unit. To reinforce and brace the upper extremities of these posts, a tie rod 18 extends between the same, as best illustrated in Figures 1 to 3, inclusive. These posts necessarily are of very rugged construction for they sustain the load developed during each compressing operation.

Referring particularly to Figure 6, there is disclosed a mold box in its opened condition. This box includes a bottom wall 19 and one rigidly connected side wall 20. To the free, longitudinal edge of the bottom wall 19 is hingedly connected a movable side wall 21. A movable top wall 22 is hingedly connected to the upper, longitudinal edge of the fixed side wall 20. Figures 1, 2 and 4 disclose the hingedly mounted walls 21 and 22 arranged in their closed position. To sustain these walls in this position, the free, longitudinal edge of the top wall 22 is provided with a lip 22*a* and a suitable number of transverse notches 23. The movable side wall 21 has mounted thereon to extend longitudinally thereof a rod 24. Pivotally connected to this rod is a series of tie bolt members 25 which are adapted to be positioned within the notches 23 of the cover 22. Journaled in the upper ends of these tie bolts 25 is a shaft 26. A handle 27 is fixed to this shaft and functions to enable an operator to rotate the latter. A suitable number of eccentrics or cams 28 are mounted on and fixed with respect to the shaft 26. It will be appreciated that when the side wall 21 is arranged with its free, longitudinal edge seated in the angle formed by the lip 22*a* and the bottom surface of the top wall or cover 22 with the tie bolts 25 positioned within the notches 23, rotation of the shaft 26 will actuate the cams or eccentrics 28 to tightly clamp these two wall members together.

Figures 3, 4 and 6 disclose the bottom wall 19 of the mold box as having extending longitudinally thereof a rib 29 which is rigid with respect to this wall. This rib 29 is received between the adjacent edges of the horizontally extending flanges formed by angle iron members 15. This rib 29 functions to support the mold box for longitudinal movements relative to the angle iron members 15 which function as guides during such movements. This longitudinal movement or floating action of the mold box is an essential and very desirable feature of the invention, as will be more fully explained hereinafter.

Figure 3 clearly illustrates the positioning of a fixed ram 30 within the rear, open end of the mold box. This ram is shaped peripherally to tightly but slidably fit within the bore of the closed mold box. It is rigidly secured to the rear post 16 by means of the centrally arranged column 31 and the radially positioned webs 32. This ram 30, of course, is arranged to line up with the longitudinal axis of the mold box.

Referring particularly to Figures 3 and 5, there is disclosed a cylinder 33 which is provided with a rigidly secured longitudinally extending mounting block 34 that rests upon the horizontal, top flanges of the angle irons 15. This mounting block 34, as is best illustrated in Figure 5, is shaped to provide a rib which fits between the opposed longitudinal edges of the angle irons 15. A rigid bracing bar 35 is suitably secured at one end to the upstanding post 17. This rigid bar 35 extends longitudinally of and overlies the cylinder 33. Clamping straps 36 are suitably bolted, or otherwise anchored to the side flanges of the angle irons 15 and extend around the cylinder 33 and the bracing bar 35. Two pairs of these straps 36 are provided. The upper ends of the same are suitably drawn together to tightly clamp the cylinder 33 in place.

This cylinder 33, preferably, is closed with a rounded end 37, as best illustrated in Figure 3. The remaining end of the cylinder, the end presented to the mold box, is closed by a head 38 which may be screw threaded or otherwise secured to the wall of the cylinder. This head 38 is provided with a protruding portion 39 which slidably receives the rod 40 of the packed piston 41 which is positioned within the bore of the cylinder 33. A suitable, heavy spring 42 surrounds the piston rod 40 and bears at its opposite ends against the piston 41 and the head 38. It is preferred that a suitable packing unit be associated with the bearing 39 and the piston rod 40. No attempt has been made to illustrate the details of such a packing unit. The principal function of such a unit would be to wipe the piston rod 40 as it moved through the bearing 39 into the cylinder 33 to remove foreign matter from this rod.

The outer end of the piston rod 40 has mounted thereon a movable ram 43 which is peripherally shaped to tightly but movably fit within the bore of the mold box to permit movement of this ram through the box. The ram is braced with respect to the piston rod 40 by means of the central column 44 and the radial webs 45.

Swung beneath the angle irons 15 and between the longitudinal beams of the chassis frame 10 is a tank 46 which is intended to receive the fluid employed in the hydraulic system of this press. A suitable filler spout 47 is provided for the tank.

A suitable hydraulic pump 48 is diagrammatically illustrated in Figures 1, 2 and 7. This pump preferably is of the rotary type and should be of a suitable size to be capable of handling pressure up to 1,000 lb. per sq. in. with a discharge delivery of not less than 3 gallons per minute and preferably 6 gallons per minute at a 500 lb. per sq. in. pressure. As many suitable pumps of this character can be purchased readily, no attempt has been made to illustrate the construction of the same.

The shaft 49 of this rotary hydraulic pump 48 is suitably coupled to a gasoline engine designated in its entirety by the reference character 50. This power plant preferably is to consist of a 3 H. P., or better a 5 H. P., air cooled, 4 cycle engine. Several suitable engines are obtainable on the open market at this time, and for that reason no at-

tempt will be made to further describe the same.

The piping system interconnecting the cylinder 33, the tank 46 and the rotary hydraulic pump 48 is best disclosed in Figure 7, and will be described in connection therewith. The supply of fluid, preferably a light oil, is fed to the pump 48 from the tank 46 through the line 51. The outlet for the pump 48 is connected to the line 52. This line communicates with the bore of the cylinder 33 through the branch 53 at a point inwardly of the inner end of the piston stroke. Branching off of the line 52 is a line 54 which extends back to the tank 46. A suitable valve 55 is located in this line 54 and is provided with a control handle 56. This valve merely functions to open and close the branch line 54. When the valve 55 is open, the fluid discharged from the pump 48 will be returned to the tank 46 for the branch line 54 will constitute a path of least resistance for the flow of fluid. This, of course, is due to the fact that the piston 41 is backed up by the heavy spring 42. When the valve 55 is closed, the fluid discharged by the pump 48 will be fed into the cylinder 33 rearwardly of the piston 41. A pop-off or relief valve 57 is provided in a branch line 58 which extends from the line 52 back to the tank 46. This relief valve, which may be of any suitable construction, is set to open to any desired, predetermined pressure, which preferably will be 1,000 lb. This pop-off valve, therefore, will automatically operate to prevent the development of pressure within the cylinder 33 in excess of the desired maximum pressure.

A further branch line 59 extends between the tank 46 and a point or location relative to the length of the cylinder 33 which represents the position of the piston 41 after it has traveled its full forward stroke. In other words, after the piston has been moved throughout its full compression stroke, it will move past the point of communication 60 between the cylinder 33 and the branch line 59. This branch line, therefore, will be placed in communication with the cylinder 33 and the fluid will be released from the cylinder for return to the tank 46. A pressure gauge 61 communicates with the bore of the cylinder rearwardly of the full stroke of the piston 41 so that the operator of the device may manipulate the valve 55 in accordance with the desired pressure to be developed in the cylinder 33.

Figure 1 discloses a throttle control lever 62 for the engine 50. This throttle control lever is connected by a cable, or the like, 63 with the operating lever 56 for the valve 55. This connection is such that when the control lever 56 is in the position illustrated in Figures 1 and 7, the valve 55 is open and the engine 50 is idling.

When the valve 55 is closed, the piston 41 will be moved forwardly under the impulse of the compressing fluid forced into the cylinder 33 by the hydraulic pump 48. The complete cycle of operation is as follows: When the engine 50 is idling, and the valve 55 is in its open position, the liquid is moved from the discharge of the pump through the line 52 and through the branch line 54 back to the tank 46. When the valve 55 is closed, and the engine is accelerated, the pump 48 forces the fluid into the cylinder 33 in back of the piston 41. The piston 41 will be moved through the cylinder against the load of the spring 42 for the purpose of compressing the soil which is positioned within the mold box. The piston 41 is caused to travel through the cylinder 33 until it reaches its extreme point of forward travel. When this point is reached, the branch line 59 is placed in communication with the cylinder, at which time the liquid is bypassed back to the tank. If the operator fails to manipulate the valve 55 after the desired compressing operation has been performed, the relief valve 57 will function to prevent the development of an excessive pressure in the cylinder 33. After a compressing operation is performed, the operator should return the valve 55 to its opened position. The spring 42 then will return the piston 41 to its starting point and the fluid trapped in the cylinder in back of the piston will be forced out of the cylinder through the branch 53 into the line 52 where it returns to the tank 46 through the branch 54 along with the small amount of liquid which is being pumped by pump 48 driven by the idling engine. It will be appreciated that should any of the fluid leak past the piston 41, it will be permitted to flow back to the tank 46 through the by-pass line 59.

This hydraulic press unit has been developed primarily for the purpose of forming building blocks from ordinary earth or soil. Blocks produced by one of these units have been very successfully employed in the construction of buildings. It has been determined that extremely durable blocks may be formed from ordinary soil, although it is preferred to use soil in a slightly moistened condition. It is only necessary to have a small percentage of moisture content. Building blocks produced in this machine under a pressure of approximately 1,000 pounds per square inch have been found to possess the strength characteristics of a cement block. If desired, the blocks may be rendered entirely impervious to moisture by mixing the soil with an emulsified asphalt tempered with borax water. The percentage of emulsified asphalt and borax water is extremely low with respect to the percentage of soil employed in the mixture.

It has been found that strong blocks may be made without the use of any binder whatever. In the prior art, it had been considered necessary to use a binder of some sort, and to subject the units or structures to heat or to the binding action of some asphaltic compound. However, if the high pressures here specified are utilized, it is found that a strong block may be made of even sand and water, no other binder, either organic or inorganic, being required.

The ingredients which have been tried are ordinary top soil of the black type with organic decayed matter contained therein, soils of other types, clay, sand, sand and gravel mixtures, cinders, stone dust, powdered limestone, brick dust, powdered marble, and other granular inorganic materials. The one ingredient necessary besides these materials is found to be moisture. This may vary between the small amount ordinarily supplied by the atmospheric humidity, to approximately 7 per cent. The figure of 7 per cent has been found by experiment to yield the best results with most granular material. Ordinary earth as dug in its original state will often have approximately the correct moisture. If it has an excess, it can be spread out to dry partially; if it is deficient, it can be sprayed with water. The moisture is determined easily by weighing the soil before and after drying, the difference giving the percentage.

Various combinations of the ingredients mentioned may be mixed, and a successful strong block obtained. Thus, soils as ordinarily dug

from the ground in different localities will have widely different compositions. Some will be very sandy, some high in clay, others rich in decayed organic matter. However, I have not yet found a soil which would not yield good results when compressed as disclosed herein.

As stated previously, the minimum pressure for obtaining the results described is approximately 500 pounds per square inch. Below this, a weak formless unit is obtained, this being so weak that the block will often crumble if one attempts to remove it from the compression chamber. Above this figure, there is a rapid acquisition of strength. As the pressure is raised above 500 pounds the strength increases. The range between 1,000 pounds and 1,200 pounds is found to give the best results with most types of soil. Raising the pressure above 1,200 pounds generally does not give a proportionate improvement in strength, although very successful blocks have been made with pressures of 1,500 and 2,000 pounds per square inch. The cost of forming the block is partially dependent on the pressure utilized, since this represents the amount of work the engine must do and the consequent gasoline consumption. It is believed that the figure of 1,200 pounds per square inch gives the most value for the energy utilized.

An example of a typical earth block is shown in cross section in Figure 8. Such a block can be formed of earth having the indicated proportions of soils and sand and may include stones the size of a walnut or even larger without any appreciable loss in strength. Such a block is indicated generally as **65**.

Although it has been pointed out that no binder or addition agent need be added beyond the soil and moisture itself, it is found that the use of a relatively small percentage of addition agent will result in a very great improvement in stability and strength. Thus, the addition of approximately 10 per cent of Portland cement will double the strength of the block. As pointed out previously, there is some new and unexplained action here, since the resulting block is stronger than one made of Portland cement formed in the usual way. From the point of view of strength obtained for the Portland cement expended, the figure is far greater for the earth block with cement added than for other combinations of Portland cement made in other ways. The proportion of Portland cement may vary between 5 per cent and 20 per cent, and experiment with test blocks will often indicate the best percentage. Ten per cent has been found to be the amount which normally gives the most value for the Portland cement added.

Asphalt emulsion can also be utilized, being added in percentages of between 6 per cent and 12 per cent. The range between 8 per cent and 10 per cent is believed to give the most value for the asphalt emulsion added. Ordinary salt may be mixed with the earth or soil before compression, or may be dissolved in the water used to moisten the earth. The use of any of the three ingredients mentioned immediately above results in a stable block; one which maintains its strength over long periods of time and which does not appear to absorb moisture. The use of material such as salt appears to cause the block to absorb atmospheric moisture and to cause a condition of equilibrium within the block. Some of the soluble materials occurring in ordinary soil and ordinary earth act in the same way. For this reason, earth having high contents of soluble salts will be found to be satisfactory.

When a block has attained equilibrium in the manner described, it will ordinarily be impervious to moisture which splashes against it, as may happen in rain. This condition is obviously desirable.

In cases in which blocks are made without Portland cement, and even where the block is made with Portland cement or moisture absorbing materials, spraying with water shortly after formation appears to cause an improvement and to increase strength and stability. The block appears to gain in strength by standing, this improvement occurring rapidly for a period of about thirty days. After this, it appears to gain strength slowly so that over a period of approximately five years it should gain in strength appreciably as against its condition when first made.

It has been found that the addition of a small percentage of asphalt emulsion, as taught herein, has the effect of strengthening the block and giving it better resistance to moisture. The addition of a small percentage of Portland cement will also have the same effect. Such a block, indicated generally as **66**, is shown in Figure 9 with the addition agent interspersed throughout the entire mass of material. Such addition agents may be incorporated in the original mixing of the material for the block. In many cases, the use of the addition agent is necessary only on an outer face of the block, although such agent may be applied on two faces or indeed on all the faces with the central portion omitted. This results in a saving of cost of the addition agent, such cost being high relative to the cost of the earth itself, which is usually very low. Such a block is indicated generally as **67** and is shown in Figure 10. The portion having the addition agent is represented as **68**. While this portion has been shown on one face only, it is obvious that the addition agent might be used on the material forming all of the faces or any desired combination. Further still, an addition agent may be used for the material in the central part of the block where conditions make this construction desirable. The manner of forming a block such as **67** would be to put some earth with addition agent admixed on the bottom of the compressed block with the addition agent incorporated on one side thereof.

Alternatively, the outer portion may have one addition agent and the inner portion still another addition agent. A possible addition agent would be material to discourage the attack of insects or rodents on the building. Thus, by adding ground glass to the block, rats and similar rodents can be discouraged from gnawing on it. It is found that cattle like the taste of the compressed earth and are likely to lick the block. This can be discouraged by the addition of creosote. The creosote, in addition, will act as an insect repellent, and will also serve to protect any wood which may be placed in contact with the block.

Another addition agent is sodium silicate, which would tend to make the block more stable and to repel moisture. Another addition agent would be a material which would be deliquescent. Calcium chloride is an example. It has been found that the maximum strength is developed in the blocks if they are kept moist for a period of as much as thirty days after being formed. This moistening is often done by spraying with

an ordinary garden hose. However, by the addition of a material such as calcium chloride, which material will absorb water, the wetting may be done automatically, the moisture from the air being attracted and held in the pores of the material.

Molasses or sugar are considered as desirable addition agents to improve the strength of the blocks. These may be mixed directly in the earth mixture or dissolved in water used to moisten the earth or the finished block.

Because of the very great strength of highly compressed earth, it is not necessary that the blocks be solid throughout. Thus in Figure 11 and Figure 12, are shown two views of a block having a cavity in the center. Such a block is shown generally as **69**, with the central portion indicated as **70**. This cavity may be formed or filled with a large stone or may be formed with a material which will dissolve or melt out of the block. Thus a formed block of ice might be placed in the center of the mass of earth in the compressing chamber, compression accomplished, and the finished block removed with the ice in the center.

The ice block may be formed in molds and frozen by the techniques usual in this art. Figure 15 shows such a block **77** with a projecting ridge **78**, which is designed to give more strength to the block without adding to the weight thereof. A small hole may be punched in the block from the outside after forming, thus providing a drain from which the melted ice can escape. Further advantage of this method is that the melted ice will keep the block moist for some time and automatically effect the curing which has been indicated as being so desirable.

In many cases it is desired to fasten pieces to the blocks after they are laid in place. Although such fastenings as lag screws or expansion bolts can be so placed, it is more convenient to have an insert molded into the block. Figure 13 shows a block **71** with an insert marked **73**, which insert is made of metal and is provided with a threaded hole **74**. The insert may be held in the compressing chamber and the earth compressed about it. If it has a dovetailed form as shown, it will be held firmly in the block after compressing. In other cases, as also shown in Figure 13, it is desired to provide passages or grooves in the blocks. Grooves such as **75** may be formed for running pipe, conduit, electric power, or signaling wires. This is formed by providing a longitudinal piece of corresponding shape in the compression box. Such a piece may either be held loosely, to be placed each time the block is to be compressed, or may be formed in the walls of the chamber itself, a notch of corresponding shape being cut in the end compressing members so as to clear such a longitudinal piece.

A similar technique may be used to form longitudinal holes or passages **72** in the block to allow the running of electric wires or pipes. Such passages can be formed by having a rod placed within the interior of the chamber and having the end members drilled to allow the rod to clear when compression is accomplished.

Although water has been mentioned as the agent to wet the earth before compression, other liquids may be utilized. Thus, mineral and vegetable oils, organic liquids such as alcohol, gasoline, and other products of petroleum distillation may also be employed. Obviously, the cost will be higher for such substances than for water. However, special conditions might make the use of these other wetting agents advisable. In the case of alcohol, the reduced surface tension is helpful to enable the liquid to wet very small particles which are difficult to wet with water.

In the case of the facings, the outer part of the block may be made of a material having an addition agent to obtain decorative effects. Many of the ordinary earths have an agreeable color, some being red, others tan, still others black. To obtain a desirable decorative effect, a layer of earth of the proper color may be put at the bottom of the compression box, any other earth placed thereover, and the combination compressed. Alternatively, the bottom layer may be of earth artificially colored with mineral coloring matter of non-fading variety. Further still, the external surface might be made very smooth by using a polished metal face in the appropriate position in the compressing chamber and utilizing a material such as finely ground marble in the bottom layer and ordinary earth in the remainder. It is possible to produce designs and streaks to simulate real marble by dusting fine granular material of one color in a definite pattern on the bottom of the compression box, dusting granular material of another color in a uniform layer thereover, putting earth on top of the combination carefully so as to avoid disturbing the material underneath and afterwards conducting compression. Obviously, the design should be elongated in the direction of the compression stroke since its features will become compressed when the compression operation is conducted.

Because of the high strength and relative imperviousness of highly compressed earth as taught herein, other forms such as tubes and troughs may be formed by the techniques described.

Because of the high strength of highly compressed earth, it is suitable as a paving material. Figure 16 shows a relatively thin slab **76** formed of highly compressed earth as described herein. This will be superior to many of the other materials utilized for paving in that its tensile strength will be high and will therefore resist cracking. Another advantage is that its thermal-coefficient of expansion is very close to that of the underlying earth, resulting in a minimum of strain being set up by temperature differences. In the making of these paving blocks, it is understood that addition agents will preferably be used to make the blocks stronger and more moisture repellent. Such addition agents can best be added to the surface which will lie uppermost when the block is compressed. In other cases, as for instance when the block is to be used as paving material near the edge or on the shoulders of the road or to be used in a drainage ditch, the material can best be left as highly pervious as possible so as to permit the drainage of water. It is understood that to form such a relatively thin block, the dimensions of the compression chamber, such as shown in Figure 3 will be altered to give the proportions shown.

Another addition agent beside those named above is an asphalt emulsion sold under the trade name of "Bitubode." Another suitable addition agent is dried blood. Still another is albumin. Still another is copper sulphate.

The blocks are best cured after being formed by being kept out of sun and wind and sprayed to keep damp for approximately seven days. The curing may be omitted and the blocks laid immediately, spraying being performed, or if desired

omitted, after laying. Particularly when asphalt emulsion is used with the blocks, the curing period may be omitted.

The blocks may be laid in the usual manner employed for laying either concrete blocks or brick. The standard mortar is applied with a trowel and the blocks laid thereupon. A more speedy and economical method may be utilized, however, in view of the unique properties of the blocks. Since the blocks are very dense and will absorb relatively little moisture, the mortar may be made very thin, of the consistency of paste and may be applied with a white-wash brush instead of a trowel, or better, may be applied from a tank and spray unit which will spray a stream of the thinned mortar on the blocks. Another feature of the blocks which makes this procedure possible is the fact that they are relatively smooth and very close to dimension. In using other types of building units it is necessary to use a thick mortar so as to make up for the inequalities of the building material. The earth blocks being very uniform require little adjustment in the mortar to enable them to lay properly. The use of thinned mortar will result in a much thinner joint. This will make for greater strength on the building itself and will reduce the cost and time of laying the blocks and will further reduce the amount of mortar required. Obviously, thinner mortar is easier to mix, and easier to transport and use.

By the use of less mortar, the cost of the building can be much reduced since the cost of mortar is high relative to the cost of the blocks. In general, more desirable results are obtained when the percentage of mortar relative to the weight of the entire building is kept low.

After the blocks are cured and laid, they may be coated with thin tar or with the standard cement waterproofing paint. The blocks may also be covered by stucco in the conventional way. In cases where extreme vibration or extreme tensile stress are expected, wire mesh may be incorporated in the block. This may be laid in the compressing chamber in layers, the pieces being cut short enough so that their length will approximately equal that of the compressed block. Alternatively, the mesh may be crumpled or folded, and placed in the block to give added strength.

The earth and addition agent, or the earth alone are best thoroughly mixed by standard equipment such as a standard mortar mixer. What is known as a clod breaker or pug mill may also be used to advantage. Thorough mixture improves the finished block. The correct percentage of moisture will often vary depending upon the exact composition of the earth. It is often considered desirable to press test blocks of the earth with varying proportions of moisture, afterwards subjecting the blocks to mechanical tests to determine the best proportion.

It has been determined that the earth or soil within the mold box compresses to approximately two-thirds or better one-half its original volume. The ram **43**, therefore, should be caused to move approximately one-third or better one-half the length of the mold box during movement of the piston **41** from its starting position to the position where the by-pass line **59** is opened or placed in communication with the cylinder **33**.

It will be appreciated that the compressing of the soil within the mold box is accomplished by the movement of one ram. To cause all of the soil within the mold box to be subjected to a uniform pressure, the said box is permitted to float or move forwardly with the ram **43** and relative to the fixed or stationary ram **30**. To effect return of the mold box to its normal or starting position, springs **64** are connected to the box and to the chassis frame **10**. These springs are best illustrated in Figures 1 and 2.

After a block has been properly formed within the box by the forward movement of the ram **43** and the movement of the mold box relative to the fixed ram **30**, the mold box may be opened and the formed blocks removed therefrom. It will be appreciated that suitable cores may be provided for forming hollow blocks of any desired character.

A very important feature of compressed earth blocks, as disclosed herein, is their ability to resist fire. Tests conducted on individual blocks and on walls made therefrom show that fire has little if any destructive effect on the blocks. Further still, high temperatures followed by chilling with water will leave the blocks unaffected. The use of walls made of earth blocks as "fire stops" to prevent the spread of fire will be found especially effective. For indoor installation where exposure to weather is not of importance, blocks made of earth without any addition agent whatever, but merely compressed, will be found to last indefinitely and to serve to prevent spread of fire.

The metal used in constructing the various parts of the machine will usually be steel or iron, in the interests of obtaining an inexpensive unit. However, when it is desired to move the machine to relatively inaccessible localities, in which case it might have to be transported by mules or by plane, it is desirable to construct the various parts of light alloy such as duralumin. It is to be noted that the assemblage has been so constructed that it is easily demountable for this type of transportation. Thus, by removing the longitudinal tierod and unbolting, the compression chamber may be removed separately, as may the end pieces. The engine can be removed separately, and the hydraulic cylinder **33** may be unbolted by loosening the clamps **36** and removing as an entire unit. If one removes the wheels and axles, only the outside frame **10** and the longitudinal angle pieces **15** remain, together with the transverse springs **11**, the latter of which may be removed if desired. Whether or not the springs are removed, the frame remains as a light and relatively flat unit which may be easily transported. If desired, the frame and the angle rails **15** may be fastened by bolting instead of welding. Thus, this frame itself might be disassembled.

It is to be understood that the wheeled structure has been shown for use in localities where the parts are to be hauled over roads. However, where transportation is to be by pack animal or by plane, rails **10** may be extended about a foot on either end of the structure, thus constituting carrying handles for the entire apparatus. If desired, the gasoline engine, pump, and reservoir can be constructed as one portable unit to be coupled by the various connecting tubes to the hydraulic cylinder and compressing box assembly. This arrangement will reduce the size and weight of each unit, so that in many cases, it will be found unnecessary to disassemble the parts any further than would be involved in the mere disconnecting of the engine-pump unit from the cylinder-compressing box unit.

The demountable features mentioned above are of great importance in view of the nature of the apparatus. In many regions, transporting build-

ing materials becomes exceedingly difficult, since transportation can be accomplished only by plane or pack animal. In these cases, one need only transport the compressing machine to the site of operation. The only material then required will be the earth found on the site of operation. Even if addition agents are found desirable, they will ultimately constitute no more than 5–10 per cent of the total weight of the building, thus making possible a saving of transportation of the remaining 90–95 per cent of the weight of the building.

The scope of the invention is indicated by the appended claims.

I claim:

1. In a process for forming a high strength and moisture resistant unit for building purposes, the steps of admixing a stabilizing agent to granular earth material, of placing the said earth with the stabilizing material into position in a compressing chamber in such relation that the earth with the stabilizing material will be on at least one of the exterior faces of the unit after compression thereof, of adding other granular earth material free of the said stabilizing agent the moisture content of the earth material being adjusted so as to be substantially seven percent by weight, of subsequently applying a pressure in excess of 500 pounds per square inch to the combination of earths, the said pressure being applied from at least two directions so as to obtain uniform compression of the earth material, of subsequently removing the pressure, the aforesaid combination of steps furnishing a building unit having at least a portion thereof stabilized and resistant to moisture and aging, the pressures further serving to give a unit of high tensile strength.

2. In a method of forming a building unit, the steps of moistening granular earth material with an insecticide, the quantity added being such as to leave the moisture content substantially within 7 per cent by weight, of compressing the earth and insecticide with a pressure in excess of 500 pounds per square inch, to form a shaped building block, thereby obtaining a building unit having incorporated in it a material which will prevent attacks by, and be toxic to insects.

3. In a method of forming a building block of relatively rigid characteristics, the steps of adjusting the moisture within earth material to approximately 7 per cent by weight, of subjecting the earth mixture to a uniform pressure in excess of 500 pounds per square inch, thereby forming a shaped building unit, and of curing the shaped unit by repeated wetting with water for a period of substantially 30 days after the formation of the said unit.

4. In a method of forming building blocks of high strength characteristics, with a decorative facing thereon, by compressing within a compressing chamber, the steps of applying decorative material in substantially dry form to the interior of the compression chamber in such relation that said decorative material will be on an exterior surface of the block after compression has taken place, of adding earth material so as to lie adjacent to and be bound to the said decorative material the moisture content of the said earth material being adjusted so as to be substantially seven percent by weight, of applying a pressure to the compression chamber in excess of 500 pounds per square inch, thereby forcing the earth material and the decorative material into intimate contact, thereby forming a high strength building unit with a permanent decorative facing thereon.

5. In a method of forming a building unit of high strength, and stability, the steps of combining granular earth material, between 1 percent and 15 percent of asphalt, of adjusting the moisture content to approximately 7 percent of the weight of the earth material, of applying a pressure of at least 500 pounds per square inch, on a plurality of surfaces thereof, and of removing the said pressure.

6. In a method of forming an earth block to include a material repellent to harmful living organisms, the steps of thoroughly admixing the material repellent to living organisms with earth material, of adjusting the moisture content of the said mixture so as to be substantially 7 percent of the weight of the earth material, of exerting a pressure on a plurality of surfaces of the block in excess of 500 pounds per square inch, and of removing the said pressure.

7. In a method of forming a high strength stable earth block with a decorative facing thereon, the steps of placing dry decorative facing material in a thin layer on the bottom of a compression chamber, of superposing on the aforesaid layer earth material, of adjusting the moisture content of the said earth material so as to be substantially 7 percent by weight of the earth material, of exerting a pressure in excess of 500 pounds per square inch on a plurality of surfaces of the block, and of removing the said pressure, whereby a strong block with a decorative facing firmly bound therein will be formed.

8. In a method of forming a building block of high strength and high stability characteristics, the steps of adjusting the moisture of earth material to substantially seven percent of the weight of the earth material, of compressing the said earth material on a plurality of surfaces thereof with a pressure in excess of 500 pounds per square inch, and of removing the pressure.

9. In a method of forming an earth block with a facing composed of decorative material adversely affected by admixture with water, the steps of applying the said material in dry form, contiguous to a wall of a compression chamber, of placing earth material close thereto, the said earth material having its moisture content adjusted so as to be substantially seven percent by weight of earth material, of subjecting the combination of decorative material and earth to a pressure in excess of 500 pounds per square inch on a plurality of surfaces thereof, and of removing the said pressure.

10. In a method of forming an earth block with a surface composed of a material to which a stabilizing agent has been added, the steps of applying a relatively thin layer of a mixture of earth and stabilizing material contiguous to a wall of a chamber, of placing moist earth without stabilizing material in the said chamber so as to lie close to the layer of earth with stabilizing material the moisture content of at least one of the said earths being adjusted so as to be substantially seven percent by weight, and subjecting the combination of earth with stabilizing material and earth without stabilizing material to a pressure in excess of 500 pounds per square inch on a plurality of surfaces thereof, thereby obtaining a block with a stable surface with a minimum quantity of stabilizing material used therein.

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