“Stone-Sawing Machinery”

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The article begins:

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This article, which begins on the next page, is presented on the Stone Quarries and Beyond web site.

http://quarriesandbeyond.org/

Peggy Barriskill Perazzo
Email: pbperazzo@comcast.net
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STONE-SAWING MACHINERY.

At a recent meeting of the Society of Engineers, London, the following paper “On Stone-Sawing Machinery” was read by Mr. Henry Conradi:

The question of stone-sawing machinery came first under the consideration of the author during the period when the building trade in Paris was at its best, which was when the Municipal Board of Works, at the request of the Imperial Government, took the necessary steps for improvement of the sanitary condition of that city. The removal of manufactories to spots some miles outside the boundary of the city and the reconstruction of those quarters which, through the narrowness of the streets, with their old and unhealthy buildings or factories, endangered the health of the population, was, in spite of the enormous sacrifices imposed, a measure of necessity. The operations incidental to these improvements occasioned a considerable demand for all kinds of building materials and labor. Everywhere large stoneyards were to be seen with the stone being cut and wrought by hand. But even those yards, although numerous, were unable to meet all the demands at the requisite time. Places were therefore hired where the preliminary work of sawing and cutting the stone were carried on. Even the building sites were arranged to serve that purpose during the excavation. Labor became scarce, and its cost increased rapidly, and contractors and builders experienced a serious want of machinery to help them in their stonework. It was then that the author was asked to design a machine for cutting marble and stone.

Before entering into a description of the machine he designed, the author will briefly describe the principal machinery generally used for sawing, planing, and moulding stone. The first operation which the block has to undergo if used for other purposes than foundations, is sawing into smaller pieces for handiness in working. In France, as well as in this country, wherever the author visited stone works, he found the same kind of machinery employed for sawing stones by the wet process. The operation involves mainly two motions, namely, a horizontal to-and-fro motion, and a vertical motion of the saws effected by means of a suspended boom, the whole system moving within a fixed frame or stand. The sawing or cutting operation is effected through the friction of the saws along the stone by distributing sand and water along the rubbing surfaces.

The machinery in use for sawing stone at the New Law Court buildings is shown in sectional side elevation at Fig. 1. Four timbers, of about 9 in. square and about 12 ft. high, are driven into the ground, and are united at the top by cross timbers and by outside diagonal timber bracings, forming a compact and solid stand. Between the stand, and fixed to the top cross timber, is vertically suspended a timber called the swinging boom. Between the stand moves the saw frame, which is suspended at its four corners to the stand by means of chains. On the top are the necessary pulleys and drums. The sawing frame consists of two longitudinal cast-iron arms, about 12 ft. long and 4 in. deep, which are provided at their ends with longitudinal openings to receive two wrought iron bars, which are about 6 ft. in length, 2½ in. in breadth, and 2 in. in thickness, between which the saws are keyed. One end of the saw frame on each side is provided with a small arm bearing a slide piece, which serves as its guide and connection by sliding in the
vertical slotting which is fixed to the swinging boom, and comes into action by the down and upward motion of the saw frame. The suspension of the sawing frame is carried out as follows:—The chains attached to the end of the frame facing the swinging boom are coiled over and fixed to the drum which is placed on the front pillars, while another chain runs from the same point of the frame over the large pulley fixed to the shaft of the back drum, which is placed on the top of each pillar, carrying a counterbalance weight. The chains or ropes of the free back end of the saw frame are coiled over and fixed to the back drum, while another chain, fixed at the same point of the frame, having also a counterbalance weight attached to it, is running over the large pulley placed on the shaft of the front drum. On each side of the stand are placed winches, from which endless chains are running over the large pulleys for winding up or lowering the frame with its saws. In a similar arrangement, but less complicated, the suspension chains—as shown in Fig. 1—run from the two corresponding points of each side of the frame to a central drum on which they are fixed. Over a large pulley fixed on the same centre shaft, but placed outside the stand, is suspended a chain with a weight to counterbalance the saw frame, while a second endless chain running over the outer ring of the same pulley sets it in motion, thus lifting or lowering the frame. The forward and backward motion of the saw frame, which is connected through slide pieces to the swinging boom, is effected through the connection of the latter with a steam engine or to a main shaft driven by an engine. The saws are of malleable hammer iron, about 8 ft. long and 5 in. wide, by ½ in. thick, plain-faced, without teeth. There are from five to ten saws, and sometimes even more, in one frame. The blocks to be cut are either carried to the machine by trucks moving on rails, or are placed in position by means of steam cranes.

In opposition to the wet process stands the dry process of sawing—that is to say, sawing without the application of water. The author does not know to what extent machinery of this kind is used in France, but he thinks that building stones there being harder than the stones used here, the use of this kind of machinery will not be very extensive. The machines previously described are in use here, and the author had the opportunity of seeing them at work at the new Law Courts.

There were several powerful circular sawing machines having two horizontal saw discs. The machines consist of a strong cast iron frame to receive the requisite gearing. The saw discs are carried on vertical spindles and revolve horizontally. A strong vertical table can be moved backwards and forwards over the bed which carries the stone. The saws are adjustable vertically to suit the work. The saw disc has on its circumference a number of receptacles, into which the cutting tool is driven, the latter being a kind of steel nail, the head of which is shaped like that of a countersunk rivet, the edge of the conical head being the cutting surface. The stone is worked by the two saws from both sides. The machine is especially used for converting the blocks coming from the quarry into slabs or pieces of any size, and for squaring and facing them. These machines are constructed to work any size of stones, but are generally made for working stones of an average size from 8 ft. by 3 ft. by 3 ft. to 9 ft. by 4 ft. 6 in. by 4 ft. 6 in., and requiring from two to three horse power to drive them. There is no doubt some waste of material, but this loss seems to be com-
pensated for by using the dust for polishing the stones in the surfacing and rubbing tables. The author had further opportunity of seeing there a stone-moulding and a planing machine. They are provided with the same shaped steel cutter, placed in a series of tool-holders, fixed either on horizontal or vertical shafts. The stone is carried on a bed plate or travelling table moving backwards and forwards. A horizontal or a vertical shaft, called the cutter barrel, bears a series of tool-holders carrying the steel cutters, which are so arranged that the diameters of the different series of tools correspond to the outline of the required moulding. The tool-holders are placed vertically on the horizontal shaft and horizontally on the vertical shaft. The stone passes slowly the cutters at the rate of about 4 in. per minute. To finish the work the cutter shaft is raised, and a steel scraper of the exact form of the moulding is passed three or four times over the stone with an increased speed of about 12 in. per minute. The machine with the horizontal cutter works stones from about 6 feet by 2 feet 6 inches by 2 feet 6 inches to 9 feet by 4 feet by 3 feet 8 inches, with an average of from 2 to 3-horse power. The machine with the vertical shaft is adapted for working smaller stones, such as steps, string courses, and sills. The author saw fine mouldings carried out with these tools, but he believes that only the very best stones will stand the great strain brought upon them, as any impurity, softness, or hard fibers, will probably cause the stone to break. The surfacing and rubbing tables are composed of a strong revolving iron disc fixed to a vertical shaft. A circular iron trough is placed around the disc to catch the waste sand and water used. Timbers fixed above the disc divide it into compartments, in each of which a stone block can be placed, being held by the timbers while the disc revolves. The tables are from 8 feet to 14 feet diameter, requiring from 3 to 6-horse power to drive them.

The saw designed by the author was for the purpose of sawing blocks of costly marble into very thin slabs with as little waste as possible. The slabs cut out of the same stone were to be either of equal or different thickness, but were to have as nearly as possible a parallel cut. The machine was to occupy the smallest space possible, to be easily removed, and to be driven either directly by a steam engine or from shafting. Under these conditions the author came to the conclusion to reverse the principle of the marble and stone sawing frames generally used. The principle of the ordinary saw system consists mainly in a to-and-fro and an up-and-down motion of the saws, carried on by means of a freely-suspended movable boom attached to the engine, the saw frame being moved in a fixed frame. The author transforms the fixed stand into a movable one, carrying the saw frame with it in its forward and backward motion, the latter receiving its up-and-down motion by means of a suspension arrangement. The arrangement is shown in Fig. 6 in sectional side elevation. In the author's first design the frame consisted of four cast iron columns bolted firmly together at top and bottom, the front pair being directly connected to the engine by means of connecting rods, while the other pair was guided by means of a guide bar bearing on a chair placed behind it. They were provided with vertical grooves running inside from top to bottom for the reception of the saw bearers. For greater stability, and to obtain the cuts in the marble as straight and as parallel as possible, the columns run on square slides instead of rails, thus avoiding as much as possible the influence of vibration.

(Note: The article continues after the engravings below.)
"Stone-sawing Machinery." Fig. 12 & 13.
to which the frame may be exposed through irregularities in the engine by the saws encountering layers of different hardness in the material to be cut.

The saw frame consists of two cast iron transverse beams provided with longitudinal openings for the reception of the saws which are keyed on one of the booms moving up and down in the grooves of the front columns, the other in those of the back columns, which are bolted firmly together, as shown in Fig. 13. The saw bearers are fixed to a longitudinal beam running from center to center of the saw bearers by means of vertical connecting rods, the beams being suspended by means of ropes or chains, which running over guide pulleys, are coiled round the drum of an ordinary hoisting crab, provided with a brake fixed on the drum shaft.

The brake is worked by a counterbalance weight on a lever, thus regulating the speed of the drum, and with it through the winding up or unwinding of the chain, the up-and-down motion of the saw bearers. At intervals of about ten minutes the attendant distributes the sand and water used for sawing, and also effects the lowering of the saw bearers and places the frame in equilibrium by altering the position of the counterbalance weight on its lever. The pulleys for the chains of the beam suspension arrangement are carried by chairs or plummer blocks fastened to the ceilings, the driving of loose pulleys being placed on the shafts. The saw frame works with five saws.

The practical difficulties found in setting the machine to work were the tightening of the saws and preventing the wear of the slide pieces from the water and sand falling on them. The first difficulty has been overcome by means of strong stays, which keep the columns and saw bearers at the required distances. The second difficulty was met by fixing a cover to the foot of the column, and thus preventing the water and sand spreading around.
As regards the stays of the saw bearers, they are usually straight wrought iron bars of about 1 inch in diameter. They are made curved in order to allow any size of stone to be brought under the machine, and to avoid making the framework of too great width. In some instances the author found that the sawing could be effected without fixing the stays to the saw bearers, if the nature or the stone did not require the saws to be very strongly tightened up.

With regard to the work done by the machine, the cutting being obtained through the pressure exercised by the saw on the stone, the grit used thus entering into the pores of the soft iron produces a rough cutting surface. The resistance of friction to be overcome along the rubbing surfaces, the travel of the saws and the pressure, are therefore the data to be considered. It is to be observed that some saws working with a swinging motion cut only four-fifths of their length, the saws being shaped accordingly, while others cut with their entire length. The pressure of the saws on the stone varies according to the softness or hardness of the latter, and it is not much greater in a steam saw than in a hand saw, as the greater pressure does not give a truly clean cut, but will rather tear pieces off the stone, or, if the material is too hard, will heat the saw. Therefore the saw is balanced until its pressure on the stone is equal to that exercised by a man, which the author assumes to be about 20 lb.

Assuming the engine to be making 120 revolutions per minute, and the travel of the saw to be about 5 feet, we have: Speed of saw = 120 × 5 feet × 2 = 1200 feet. The coefficient of friction of stone on stone being = 0.71 in case of repose, that of motion being = coefficient of repose × 0.7, we obtain, therefore: Work of cutting = 1200 feet × 20 lb. × 0.71 × 0.7 = 11,928 foot-pounds per minute. Assuming further, in round figures, the weight of the cast iron framework, with its accessories, to be = 4 ton, it follows that the pressure on the slides will, with 1 foot 6 inch stroke of saw, become 120 rev. × 3 × 1.5 feet = 360 feet of travel, thus the work produced = 360 feet × 1120 lb. × 0.18 × 0.7 = 50,803-20 foot-pounds, giving as the work of cutting = 11,928 foot-pounds, work of frame motion = 50,803-20 foot-pounds, a total of = 62,731 foot-pounds per minute, or \( \frac{62731}{50803} = 1.24 \) H.P. Taking the frame composed of five saws, the work of cutting will be as above: 1200 feet × 20 lb. × 5 feet × 0.71 × 0.7 = 59,640 foot-pounds, work of frame motion as before = 50,803-20 foot-pounds, making a total of 110,443-20 foot-pounds, or = 3.34 H.P. per frame.

This result is somewhat higher as shown by practical results, the coefficient of friction and pressure on the saws becoming somewhat reduced during motion, and therefore losing some of their direct influence and amount by working several saws together. With one frame a stone from 6 feet
to 8 feet in length will be cut, according to its softness, to a depth of from 3 feet to 2 feet 6 inches per day of nine hours. The machine designed by the author, and containing about three-quarters of a ton of cast iron, quarter of a ton of wrought iron, and from 30 to 35 cubic feet of timber, will cost, with its fittings complete, including wheelwork and saws, about £75. The price of the saws varies, according to the market, from £12 to £16 per ton; the price of the timber work being from £4 to £5. The author was prevented making further practical experiments with the machine in consequence of the outbreak of the Franco-Prussian war.

A further improvement made by the author consists in fixing the winding drum directly on the apparatus, and in setting the machine on rollers for the purpose of cutting ordinary stones, as shown in Figs. 2, 3, 4, and 5. This led the author to transform it into a portable machine, and to enable it by means of timber framing, bearing the suspension arrangement of the saw frame, to be used on open ground, and to be carried from one building site to the other, thus enabling the builder or contractor to have the stones cut directly on the spot instead of being sent to the stone sawing yard. The economy in time and labor thus obtainable is worthy of consideration. It is specially applicable for small buildings, where the contractor, after having the stones cut in one place, could send the machine to work at another place.

The author conceives the requirement of this kind of work to be fully met in this machine, the practical value of which is increased by providing it with a lifting arrange-
ment, and in using the drum for the up-and-down motion of the saw frame for lifting and lowering the stone. The machine thus effects all the manipulations required. The stone coming from the quarry is carted directly under the machine, where it is lifted into position ready to be cut, and when finished is replaced in the cart to be taken away. The timber framing shown as driven into the ground, can also be placed on rollers and steadied by means of wedges or similar arrangements. The cast iron framework, as shown in Fig. 6, is placed on ordinary road rollers, travelling over ground laid with gravel. The lifting apparatus is fixed to a bracket provided with a shaft, and which is either fixed to the boiler of the engine in a temporary or permanent manner. In the former case several iron bands carrying the brackets are bolted to the boiler and secured by set screws, as shown at Figs. 7 to 11. A driving belt runs from the engine pulley to a pulley on the shaft of the lifting apparatus, where from another pulley another driving belt is carried to the driving pulley, which is keyed to the drum shaft of the saw frame.

During the operation of lifting or lowering the stone, the saw frame with its suspension arrangement is taken off, but the pulleys guiding the rope or chain being fixed to the timber frame remain. Instead of using a somewhat complicated arrangement of bracket and shafting, fixed either permanently or temporarily to the boiler, the author simplified this arrangement by fixing it to the timber frame, as shown in Fig. 6. An apparent difficulty here arises, the length of the bracket from the drum shaft to the timber frame forming an overhanging part of a long leverage. This has to be overcome by increased strength of material. Thus, considering this bracket as a cast iron girder, fixed at one end and loaded at the other, the load being represented by the pressure exercised through the weight of the stone to be lifted, while the distance from the timber to which the bracket is fixed to the center of the rope or chain which lifts the stone is to be considered as its lever. Assuming that a block of marble measuring 3 feet × 2 feet 9 inches × 2 feet 6 inches, has to be lifted, which corresponds to a weight of 1½ ton, and further that this weight acts with a leverage of 3 feet 10½ inches, the centre of the bracket shaft to the centre of suspension of the stone being 3 feet 10½ inches, and further that the above distance from the timber to the centre of the rope be 2 feet 3 inches, the length of the bracket acting as a lever, then we obtain as momentum pressure on bracket, 1½ ton × 3 feet 10½ inches = 13,020 with a leverage of 2 feet 3 inches, giving a momentum of 13,020 — 2.25 feet = 29,295, say 13.5 tons; cast iron being safely strained in tension at 2 tons per square inch, it follows that 13.5 = 6.75, or in round numbers seven square inches will be the required section for the horizontal bar.
The author has shown by the dotted lines in Fig. 6, the different positions of the machine during its travel. The operation of lifting the stone from the cart and placing it under the saw frame is seen at Fig. 12, the stand being there represented for the purpose of cutting stones on road rollers, showing that there is no difficulty in moving the sawing apparatus placed on slides or on rollers, the machine being arranged so as to allow the one to be replaced through the other, according to the kind of work to be executed. After the stone has been placed the lifting apparatus is thrown out of gear by uncoupling the whole arrangement or by shifting the driving belt on a loose pulley, as shown in Fig. 13. The shaft of the lifting arrangement is provided, as shown in Fig. 13, with a fly-wheel, but as the operation of lifting and lowering the stone takes only a very short time, the author thinks that these operations could be effected without it and with a gain in economy. The saw frame, consisting of its bearers and saws, as shown in Figs. 12, 13, and 14, the beams are then put in position by attaching the ropes, which have again become free, to the suspension arrangement. The machine is then set to work until the cutting is finished, when the suspension arrangement and the saw frame are again taken away and the lifting apparatus thrown into gear to lift the stone on to the cart to be carried away.

The engine is two-wheeled and of two horse-power, such as is frequently used by contractors in France. It is of great simplicity and solidity, working expansively at two-thirds of its stroke at 120 revolutions per minute, with a consumption of 15.5 lb. of coal per hour, its price being about £70. The engine can be placed standing on its wheels, or the wheels can be taken off and the engine placed on a foundation.

The author considers it necessary that a safety apparatus should be attached to the lifting apparatus to prevent accidents. Figs. 15 to 18 show an apparatus of this kind, the invention of M. Mége, and which is in use in France. It consists of a box-shaped loose pulley, containing a cylindrical spring covered with leather, which presses against the internal sides of the pulley. This spring is provided with a number of projections against which works an internal cam, which is fixed to a disc keyed on to the same shaft as the loose pulley. By turning the shaft the disc turns with it, imparting its motion to the spring, which, through its fric-
tion against the inside wall of the loose pulley, imparts its motion to it. To the side of the loose pulley is partly cast on, and partly bolted to the frame, the receptacle for the chain. By turning the handle in one direction, say to the right, the spring being pressed against the pulley produces its motion, drawing the chain, and therefore lifting the load, this loose pulley being in the meantime under the constant control of a continuously acting brake. For lowering the load the outside brake is loosened, the loose pulley being actuated only through the weight of the descending load, the descent being regulated by the man in charge governing the lever of the brake. The operation of lifting is therefore conducted by turning the main shaft by means of its handle, and governed through the friction of the internal spring, thus preventing too heavy a load being taken, as the excessive friction of the internal spring against the loose pulley would prevent the latter from moving. The operation of lowering loads is conducted by the free motion of the loose pulley governed by the outside brake, the advantage in the latter case is that of keeping the main shaft at a stand, thus preventing the handle turning, and accidents occurring to workmen in lifting or lowering. In ordinary winches, the handle may suddenly turn, or, slipping out of the hands of the man, injures him, the load breaking down in its rapid fall. In the case of the Mégee pulley, the workmen has only to leave the apparatus to itself; the heavy strain from the slightest rapid descent of the load brought on the loose pulley imparts the same to its internal spring, producing considerable friction between both, thus bringing the falling load to a stand.

Apparatus for heavy loads for steam power constructed on the same principle is provided with the necessary gearing. The author has observed that oil or water brought between the rubbing surfaces, instead of diminishing the friction between the pulley and the spring, increases it; the reason being that water or oil makes leather swell, the coefficient of friction being about 0.20.
We add to the foregoing illustrations of stone-sawing machinery, the devices of Mr. F. Darby, of Freeman’s Stone Wharf, Deptford, a very simple, but efficient though roughly made machine, which he has used at the above wharf for about four years. During this time the machine has cut between 70,000 and 80,000 superficial feet of stone, principally Portland, and most often in pieces of large size. Mr. Darby’s apparatus cost him only about £20, and although it is a roughly made tool, it is not very likely that it could be repeated for less than 50 per cent. more than that amount.

We give a rough illustration of the machine, which is, in its simplicity and efficiency, an example of the excellent “makeshift” which men thoroughly versed in the practice of the work to be done, and with sufficient mechanical skill to carry out their ideas, sometimes bring forward to accomplish an object. It will be seen that the machine consists principally of four uprights, each made of two semi-balks placed sufficient distance apart to admit of the vertical motion of the cross-beam, $a$, carrying friction rollers, $c$, upon which the saw frame reciprocates. The latter consists of two longitudinal pieces of angle iron connected together at the ends by two pieces of flat iron, as shown at Fig. 2, which form the means of holding the saws at different or equal distances apart. The saw frame is thus very light, and requires little power to move it. It will be seen from the figure that the bearers, $a$, are suspended from chains running over short barrels mounted, at the top of the uprights, on shafts, carrying also grooved pulleys, over which run chains from balance weights, by means of which the whole or any portion of the weight of the saw frame and saws may be brought to bear upon the cut.

The simple manner in which the saws received the necessary lift at each end of the stroke to allow the sand to run under their edges is the point most worthy of remark. At the under side of each end of the saw frame is fixed a wedge-shaped piece of wood covered with iron, forming an inclined plane, $e$ (Fig. 3), which at each end of the stroke runs up on the friction roller $c$, thus lifting the saws and allowing of the supply of new sand to the cutting portions just as they begin a new stroke. The vibrating arm, $f$, from the engine, by which the saw frame is moved, is attached to a flat bar, $d$, with several holes in it, into which the pin connecting the vibrating arm, $f$, therewith, may be shifted as the saws descend into the block of stone. This vertical bar is firmly stayed, and in such a manner that it may be readily fixed in the position shown by the dotted lines, so as to keep the end of the arm, $f$, at such a level, that it may not tend to lift the saw frame when it is on the top of a large block of stone, nor throw any pressure in an oblique direction upon it when at the bottom of a block. The end of the arm, $f$, is attached to a crank pin, the shaft carrying which is of a fixed level, so that the angle which would be assumed by the arm without such an arrangement as that described would be occasionally sufficient to greatly decrease or increase the pressure on that end of the saws when at the top or bottom of a block respectively.

In the case of the machine described, the engine of the 13-ton crane which commands it also works the saws. The engine is about 2½ horse-power, and with it this rough machine will cut 100 superficial feet of hard Portland stone in ten hours. About seventy strokes per minute is found to be the best speed, and 16 inches to be the best length of stroke, the sand being worn out after having travelled that distance. Feeding in the sand by hand-supplied water is adopted, as the saws most needing it may be given a larger quantity.

We are indebted to The Engineer, London, for the foregoing illustrations and information.

In this country, the introduction of circular saws for stone cutting is being attended with much success, resulting in economy of time and power.