Sanitary principles of school construction / by Edwin Chadwick.

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SANITARY PRINCIPLES

OF

SCHOOL CONSTRUCTION.

BY

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SANITARY PRINCIPLES OF SCHOOL CONSTRUCTION.

NOW that new school boards are preparing for the construction of new school rooms, it is of importance that they should be apprised of the sanitary defects that require amendment in the greater proportion of those existing of the elementary schools in this country. Medical officers of health have concurred in declaring that the common elementary schools, as now constructed and conducted, are the frequent centres of childhood epidemics. Of an excess of upwards of 7000 deaths in the metropolis, and of upwards of 50,000 annually throughout England and Wales, in the school stages of life, were pronounced by them, on the observation of the working of particular schools within their province, to be largely attributable to the structural condition of the school-rooms, and to the modes in which the children are kept in them.

The chief sanitary defects of these schools are, in my view, (1.) Defective ventilation ; (2.) Defective warming ; (3.) Bad drainage and foul latrines ; (4.) Want of means of maintaining personal cleanliness ; (5.) Bad lighting ; (6.) Bad arrangements of desks and seats ; (7.). Want of proper means of gymnastic exercises ; (8.) Insufficient, and ill-paved playgrounds. I would submit that it is important that school boards should require, in the competition for plans, that these evils should be first specially considered and provided for, and that the exterior architectural designs and elevations be made of secondary consideration.

I will, in the first place, treat of the warming of the schools, as that largely influences their ventilation. To me, it has always been most painful to observe the condition of children of the common schools, inwinter time, going there in cold and wet, in driving sleet and snow, frequently ill-shod, and commonly ill-clothed—kept in the school with feet and hands painfully cold—fingers often so benumbed as to be scarcely able to hold their slates and pencils ; the open fires at one end of the school, not freely to be approached, and when approached, the warming or heating on one side, "roasting in front and freezing behind," so as to give inflammations or colds from the disturbed and unequal circulation. The confinement of the children for five or six hours in such conditions, overtasked mentally, and painfully constrained bodily, are surely evil conditions requiring active intervention for their relief.

One consequence of the defective warming is, that doors and windows are shut "to keep out the cold." Then comes the pernicious effect of the confinement of the children in the atmosphere polluted by their breaths and by transpiration from their skins, usually unwashed, or only hands and face washed, and from dirty clothes. As a relief, some of the windows are in part opened, and the cold air is let in for ventilation. The corners where this is done have been called "rheumatism holes." Sometimes when the windows are kept closed, the confined air is heated to an extent that creates perspiration, even in winter time. Eruptive diseases are often the consequences of precedent functional derangements, and when there are outbursts of epidemics in children's institutions or in large schools, they frequently occur among the children grouped at one end, and the first case observed is a new comer, who has been for a time the centre of the group attacked, the infected breath having been pumped out upon the surrounding children for several days before the eruption has appeared on the new comer. In general hospitals, it is known, that if they are well ventilated, cases of typhus fever may be put in every second or third bed, with an interval of about four feet between each bed. Cases of scarlatina—it is considered as settled—must be placed at wider intervals, as of every seventh bed. But if the ventilation be defective and confined, a foul atmosphere is created which will endanger the nurses. By adequate dilution with fresh air the poison is rendered inocuous. By crowding and additional doses of foul air it is made destructive. Obstruct the ventilation, or crowd the cases still more, and an atmosphere is created which endangers the medical attendants. Thus in the ill-warmed schools, in which windows and doors are kept closed to keep out the cold air, foul atmospheres, poisoned by the incipient disease common amongst the poor, are created for the children. In some weathers and school conditions, a mother in sending her child to such schools, is sending it into a preparation of fever, or into measle-mixtures, or of small or chicken pock, or of some form of disease. Children, thus infected in the schools, frequently bring the infection into crowded and ill-ventilated homes, where several sleep in the same bed. If surprise is expressed at the sudden extensive outbursts of epidemics in crowded habitations, here is one contributary source of them. Compulsory attendance in ill-warmed and ill-ventilated long time schools is commonly compulsory bodily deterioration. Such conditions endanger, and frequently ruin, the constitutions of teachers. It is proper to mention, as respects the higher class of female schools, boarding schools as well as in second-class schools, that great pain is inflicted, and bodily disorder occasioned by heads kept heated by unduly protracted mental labour, and feet kept cold by bodily inaction.

By graded schools, as I have shown, especially by half-time schools, three children may be taught well in half the time in years, for the expence now commonly incurred for teaching one comparatively ill. The school board for London have set an important example in the adoption of large school organisation. But such provisions

entails the necessity of sanitary precautions, for if they be neglected, especially as respects the classes of children to be brought in by compulsion, considerable bodily injury will frequently be occasioned. I submit that the first object is to improve the method of warming as involving the method of ventilation.

Of the modes of warming, those by hot water pipes and iron surfaces are of inferior, and sometimes, when for high heats, are of pernicious effect, and are very expensive. Besides, they are apt to warm only the sides of rooms, or the upper parts of them, and to leave the feet cold, unless an inconvenient and objectionable degree of heat is created over the whole room. It is, moreover, matter of considerable experience that warming by earthenware surfaces, or stone surfaces, especially by heat diffused over wide earthenware or concrete surfaces, is more agreeable and more salubrious than any warming by iron surfaces.

Observing some ragged boys at night grouped upon a particular street-pavement, and apparently enjoying themselves, in very inclement weather, I found that the pavement on which they were assembled was warmed by a baker's oven beneath. It is observable that market women, with a foot warmer, sustain very inclement weather. The like facts, which I might multiply, appear to me to lead to the conclusion that there are no means of applying warmth, that are so economical as by applying it to the feet. There is extending experience of this in the use of hot water bottles, and vulcanised-macintosh hot water bags.

The class of facts on this topic lead me to recommend that we should adopt the practice of two empires, of Rome and of China.

The Roman plans of floor warming are displayed in the remains of villas found in the chief seats of their occupation in this country. Their hollow floors were mostly made by square slabs of stone, or of large tiles, supported by stone pillars eight inches high, or a foot or more, set upon a lower stone floor. The upper floors were covered with concrete, and often ornamented by tesserae. Some of their hollow floors in this country were evidently warmed by coal, from the remains of coal soot, in others they were warmed by wood. The fireplace, for the coal-warmed flooring, was mostly a small cylinder of red earthenware, contaiaing a mere hatfull of coal, through which the air was led by a down-draft, through the hollow of the floor, the draft being created by an upcast flue, on the side of the chamber opposite to the fireplaces; the tall chimney-flue acting as the longer leg of an inverted syphon. In some of the largest Roman contructions of this species, the heat appears to have been led underneath by long, distinct channels. But in some the warming was by the diffusion of heat through the floors, amidst the uprights, which, I conceive, would be done by low heat, led slowly, but long applied.

I have been unable to get any detailed accounts of the Chinese methods of construction for the purpose, and I shall be much obliged to any one who will give me some, but the testimony is strong and decided that the floor-warming there is the most comfortable

that has been experienced by Europeans. Marco Polo, the early traveller, notices it as extraordinary. The warming is effected with a comparatively inconsiderable amount of almost any sort of fuel.* I am informed that in the barracks in China, constructed on the English principle of the open fires, men were frost-bitten, whilst the Chinese, with their mode, were perfectly unharmed. The Army Sanitary Commission of the United States adopted the principle of this method of warming for field hospitals. A trench, covered with wide slabs of stones, was led from one end of the tent to the other. On the outside, at one end, a fireplace was sunk at the mouth of the trench; at the other end a chimney was erected of clay, held together by empty barrels piled on end. In this way a draft was created underneath the stone floor of the tent, warming it in the most equable and agreeable manner. Americans, attached to the ambulance corps, applied the same principle, with complete success, to the warming of the field hospitals in Paris. General Duff, of the United States Army, informs me that he applied the principle, by rough and ready methods, for the warming of field tents for his soldiers. The abuse of the method of warming will obviously be in getting up unduly high heats for the feet or for the whole of the air of a room. The warmed floor, in its proper use, however, appears to me to have the peculiar advantage in enabling a colder and thence more condensed air, a better quality of air breathed than any heat-expanded air.

To those who have not had occasion to attend to the subject, it may be observed that if a given quantity of air, with a given

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* A later traveller, Father Ripa, says, "By the European method of warming houses, our heads may be hot while our feet are cold, whereas, in Pekin, the feet are always well warmed, and a moderate heat alike pervades every part of the room. Wood is very scarce, but there are mountains in the neighbourhood which appear entirely composed of coal, like that of England, and this is the fuel in general use. While I was living in Pekin, some Muscovites arrived, who had never been there before. They built themselves stoves of the European kind, supposing they were to be preferred, but, soon perceiving their error, they pulled them down, and adopted those of the Chinese. They likewise discovered that the expence of heating their own stoves exceeded that of the Chinese a hundred-fold, for, in their own, they were obliged to use a great deal of wood, which, at Pekin, is exceedingly dear, whereas the cost of fuel for the Chinese stove is a mere trifle, the coals being very cheap, and the chimney not more than a foot square, and two deep. In the southern part of China, the land being universally cultivated, there is but little wood, and, as the expense of conveying coals would be very great, dry leaves, grass, weeds, and even the dung of animals, are used for fuel." The timber flooring in use in England obstruct the application of the principle; but Mr. Alfred Beaumont, when exercising his profession as an architect, applied it with perfect success to the warming of the stone floors of several offices, and without smoke, dust, and dirt, and a great economy of fuel. He says, "A perfect combustion having extracted the whole of the caloric from the fuel, the next point is to secure the delivery of the caloric in the apartment to be heated, and there only. This is done by extending the smoke beneath the floor of the apartment, desired to be heated, for such a length as shall deliver all the heat from the draught, save and except just enough to carry the draught up the chimney. In these ways, all the caloric producible from the fuel is distributed only in the place desired to be heated," (in the large offices he led it to the standing places of clerks, at a distance from the fireplace) "and a required degree of warmth of the purest kind is enjoyed.

quantity of oxygen, at a given temperature, be expanded in bulk by heat—say by a fourth—the inspirations of the lungs must be quickened in proportion, to obtain in the same time the same quantity of oxygen. In newly warming the *Palais de Justice*, at Paris, a warmed surface was placed for the feet of each judge. If the warmth were applied to the whole body so as to raise it to the same temperature given by the foot-warmer, the air breathed being more expanded would, I consider, be inferior in quality for the health.

Before it became a practice to use foot warmers in railway carriages the passengers were accustomed to close the windows as completely as they could. Since foot-warmers have been introduced windows are allowed to be more widely opened.

The effect of foot-warming is then to enable the body to sustain, with less discomfort, the impact of cooler currents of air. Foot-warming will, of itself, allow of doors and windows to be opened with less annoyance, and of itself will be conducive to freer ventilation. Indeed, Mr. Blackburn's method of ventilating cattle sheds, by an open diapragm along the roof, would, in some instances, suffice. In many others I would propose, in addition to the warmed floor, the introduction of open fireplaces, on Captain Galton's principle of warming with air pumped in that is fresh, as well as warm, and the more active removal of vitiated air through the smoke chimneys.

I have long advocated the principle of floor warming, but I find it expedient to propose particular means for the purpose, which I will describe hereafter, as architects may not have access to plans of the Roman methods of floor-warming.

Next to the foul air from overcrowding, and from the breath and from transpiration, there is the foulness arising from congregation of dirty skins as well as of dirty clothes. Medical officers who have to do the work of vaccination with children of the lower and middle class, are aware of how small is the proportion of them who are ever properly washed, and how painful, and, at times, how dangerous, is the duty of operating upon numbers of them consecutively in confined rooms. The great sanitary success of the district orphan schools is largely due to the daily ablution of the children, and to the cleanliness maintained in the clothing as well as on the persons. On visiting the Central District School I always found the female children's pinafores most perfectly clean, as if they had just come fresh from the mangle. On expressing a doubt whether this was not a luxury of cleanliness, I was corrected by the answer :—that 300 soiled pinafores made an appreciable difference in the atmosphere. The answer expressed the sanitary principle of the importance of cleanliness—clean clothes, clean skins, clean air—as proportioned to the numbers aggregated. But the massing of numbers together, however cleanly, would be in some stagnant conditions of the atmosphere, injurious, even if they were massed together in the open air. Troops marched in close column carry their own atmosphere with them. In epidemic periods it has been found that the pro-

portion of attacks has been diminished by marching them in open columns or widely apart. People faint in crowds, not from the pressure of the crowd but from the atmosphere generated by the crowd. Of course this evil is aggravated by filthy personal conditions. In one ragged school the health of the teacher was frequently overcome by the stench of the scholars, and fever was frequent and rife upon them. In self-defence he forced the boys to wash in an adjoining room; but this thinned his school, for the washing was with cold water. Cold water washing is found to be a mistake in district schools where the children are under control. The circulation of children of the poorest classes is very low, and cold water is peculiarly painful to them;—besides, washing with water which is hard as well as cold does the work of washing imperfectly. It has been found that tepid water is necessary for the purpose. The master of the ragged school to whom I have referred as having failed when he insisted upon the pupils being washed with cold water, got steam passed through the water and warmed it, and he then succeeded. The washing ceased to be disagreeable;—indeed it was made, as it always ought to be, agreeable; and the scholars came, the atmosphere became tolerable, and fever was reduced, if not entirely abolished.

In the larger children's institutions, where children are boarded, the effects of progressive sanitary improvement have been distinctly marked. In one, where the death-rate had been about twelve per thousand, the foul air from cesspools and bad drains was excluded, the latrines were amended, and the ventilation was improved, when the death-rate was reduced to eight in a thousand. Next, regular tepid ablution, and, in summer time, cold water bathing, and careful skin-cleanliness was introduced, the death-rate was reduced to four in a thousand.

If you go into even first-class elementary schools in England whilst simultaneous class-teaching is going on, you commonly see dirty hands held up. If you go into a school of the like class in Holland, you see very clean hands held up. There, the moral, as well as the sanitary duty of personal cleanliness, as far as I saw of it, is well maintained. The children in the female schools are from time to time examined, and the duty of maintaining the cleanliness of their children is enforced upon the mothers. If any mother is frequently negligent, marked observations are made upon her, which are unpleasant, and they are avoided. By due exertion in this direction, the object is very generally obtained. But there are cases where the children have no proper mother's care. In some places, the poor people are absolutely destitute of the means of cleanliness, or of proper supplies of water. Accidents constantly occur to little children, and they fall down in the muddy streets, or dirty themselves in playing. To deal with these cases, there is, in well appointed schools in Holland, usually a female attendant on the schoolmistress, some old woman, who takes the dirtied children into an apartment and washes them, the schoolmistress herself being of an occupation of a quality above such service.

On such experience, it is to be insisted upon that every elementary school should be provided with a retiring-room or closet, with warm water, with the proper appliances for the cleansing of children. It is a provision of a very high order of importance for the infant schools of the lower districts.

Of the lessons they may be taught in schools, the practice of cleanliness is of the highest order of importance. The clergy who neglect to enforce the precept "wash and be clean" fail in the enforcement of Christian duty. A filthy population is everywhere a low moral population, but it is futile to enforce the duty in the absence of proper appliances for its practise. Of these all large schools should have one bath for teaching and practising swimming. For ordinary schools a swimming bath 30 ft. long by 10 ft. wide and 3 ft. deep may be made to suffice, and it should be constructed for about 50*l.* But for one of the larger schools, there should be a bath 60 ft. long, and 25 ft. wide, and 3 ft. deep, which should be made for about 200*l.* Besides, in crowded districts several schools might be united for the use of one swimming bath in turns, as well as for one drill ground. The objection to such appliances on the score of expense is an objection to the means of economy, for all efficient sanitary appliances are means preventive of waste. The general economical waste of productive force in this country, as I have expressed it, is as if a farmer, in order to obtain one working horse, had to raise two colts, and as if the horse, when raised, had only half its natural and proper working ability. The economical fact should be inculcated that a pig that is regularly washed puts on a fifth more flesh, and that flesh of a better quality than the pig that is unwashed; and that the same rule holds good with washed, as against unwashed children. Five washed children may be sustained, on the food requisite for four that are unwashed, to bring them up to the same condition. Besides, the washing itself is preventive of infections and of contagions, such as the itch and other diseases.

In the proper working of a school, with a due regard to the principles of physiology, as well as of psychology,—to the body, as well as to mind, the children ought not to be kept long together. The reduction of school hours to the proper time for efficient teaching, which is demonstrated to be half the usual school time, is in itself followed by marked reductions of non-attendances on account of sickness. They should, moreover, whensoever the weather permits, be turned out frequently into an open space or playground for exercise, and in fine weather for lessons. Much may be said for the Irish hedge-row schools, as against the dens in which English children are frequently kept.

The common playgrounds for children are either the natural soil, which is very dirty, or a gravel, which is sharp and wasteful in the excessive wear of shoes and clothes; children fall down upon it and seriously bruise or lacerate themselves, and the sharp grit gets into their eyes or the lungs.

In one institution, where the managers could not be induced to

improve the children's playground, which was of gravel, until after the prevalence of opthalmia, when it was flagged, or paved with York landing. It was then found that a saving of one-half the shoe-leather was produced by the new paving. But the paving with York landing is very expensive. A Val de Travers asphalted paving would be little more than half the expense, and would, with its peculiar elasticity of feel at the surface, serve much better, especially for gymnasiums. A tile paving, with concrete or celenite tiles, would be cheaper still, and these tiles, with the lock joints I have proposed and shall hereafter describe, would have the peculiar advantage of not being disturbed by "hopscotch," or any other form of play. In Germany, smooth concrete paving is used, with considerable saving of shoe-leather. Where very good smooth paving, of the quality in question is laid down, I do not see the necessity of children, or at least those of the poorest class, kept in public institutions, wearing either shoes or stockings in dry summer weather. If the feet be regularly washed and kept clean, I question whether they would not be better bare at such times. In Scotland children travel barefoot to school in all weathers, or carry with them their shoes and stockings which they put on there, dry, in which there is reason.

Miss Nightingale in her "Sanitary Statistics of the Colonial Native Schools and Hospitals," observes, on the necessity of the careful consideration of habits, as recorded in one of the returns from the Natal schools—"It might be supposed that one of the most obvious duties in bringing children to school would be to clothe them. But, nevertheless, clothing an uncivilised child requires care. In their natural state they expose themselves to torrents of rain, which runs off them, and they are easily warmed and dried at a hut fire. But it is stated that when clothed in flannel and jersey they get chilled by the rain, and pulmonary diseases come as a consequence." A closet for drying clothes should be provided in elementary schools. Captain Johnson, one of the Queen's messengers, has advocated the use of sandals for soldiers, made of matted flax, such as are in use with great advantage by the peasants in the Basque provinces. In those close neighbourhoods in urban districts, where there is absolutely no space for playground to be got, a flat roof should be constructed for the purpose, as is done with excellent effect in one large school near Long Acre.

As the efficiency and economy of teaching, by a division of educational labour amongst trained masters in graded schools, requires the children to be gathered from wider areas than heretofore, often from considerable distances, it will often be necessary to make provision of food for them. In the great middle class school of the City of London, it has been found requisite to provide cheap dinners for those boys who do not bring their food with them in what the Rev. Mr. Rogers the governor calls their "nose bags." In the great metropolitan Jews' school, which provides for 1700 children of the poorest class of Jews, and which is, in very important respects, a model of educational administration, I found that of its leading supporters, the Baron Lionel de Rothschild and the Baroness, of

their own munificent educational grants, have been accustomed to bestow on that one school 800*l.* per annum, to provide a portion of bread and some milk for the very destitute and necessitous children, to enable them to attend. On this subject my excellent and experienced colleague, Mr. Edward Tufnell, in writing to me on part of my draft paper, observes :—

"In many schools the children bring their dinners, usually miserable enough, and eat them between twelve and one, when there is an interval of school. Now, I think every school should have a small cooking apparatus, in which some girls should be taught to cook cheap soups, stews, &c., and then the children, girls at least, should be kept in school, and given dinners so cooked, which might be done, as I have ascertained, at a penny a head, the parents paying. I mention girls chiefly as they have often nowhere to go to between twelve and one, their parents being out at work, houses locked, and thus in London at least they run about in the streets, and sometimes get violated,—as I find from the reports of the Rescue Society. Hence you might kill three birds with one stone,—teach plain cookery,—make the children sit down to their dinners in a Christian-like way,—save the honour of the girls from the dangers of the streets, and the apparatus could easily be made to supply sufficient warm water to wash their faces and hands."

Of course I heartily concur in this suggestion, and can speak of the need of such a provision to keep boys as well as girls from the peculiar dangers of bad associations in the streets.

There is yet another very frequent and serious defect in the construction of the common schools, which requires to be guarded against, namely, the bad distribution of light. From a paper transmitted to me by the excellent sanitarian, Dr. Varrentrapp, of Frankfort, it appears that from the insufficiency of light, and from the bad distribution of light, in the schools in Germany, nearly a third of those who remain in them during and beyond the secondary stages, are subjected to short-sightedness. Professor Leibrich, our most eminent oculist, tells me that the injury is always done by the front light, and that the light, should always be got in from the left side, and that in towns where such light cannot be obtained, it should be got as the next best from the back of the desk, and never from the front. A great deal of distortions and curved spines are, as Dr. Varrentrapp shows, occasioned by the wrong adjustment of seats, a topic, as well as others of the wall colourings and school fittings, beside my immediate purpose. I consider, that schools ought to have more of window space; of windows made with double or with very thick glass, which is economical as saving heat, and is, moreover, advantageous, as lessening the transmission of sound from the streets.

For the reasons which now prevail in respect to the walls of properly constructed hospitals and cottages, the walls of schools should be made of impermeable materials and be washable, and of a proper colour.

The evils common to the schools of this country, are transplanted

to our colonial possessions. In few of these schools, as Miss Nightingale observes, "is any attempt made at combining the elements of physical education with the school instruction, and even where this is done the measure is partial and inefficient, being confined to a few exercises, or simply to bathing. The obvious physiological necessity of engrafting civilised habits on uncivilised races with great care, appears to be nowhere recognised, except at New Norcia (Benedictine) School, Western Australia, on the return from which there is the following very important statement. Gymnastics are stated to be necessary to prevent sickness, and the reporter proceeds, 'The idea of bringing savages from their wild state to an advanced civilisation, serves no other purpose than that of murdering them.' And the result of the out-door training practised at this school, is said to have been hitherto successful "in preventing the destructive effects of this error."

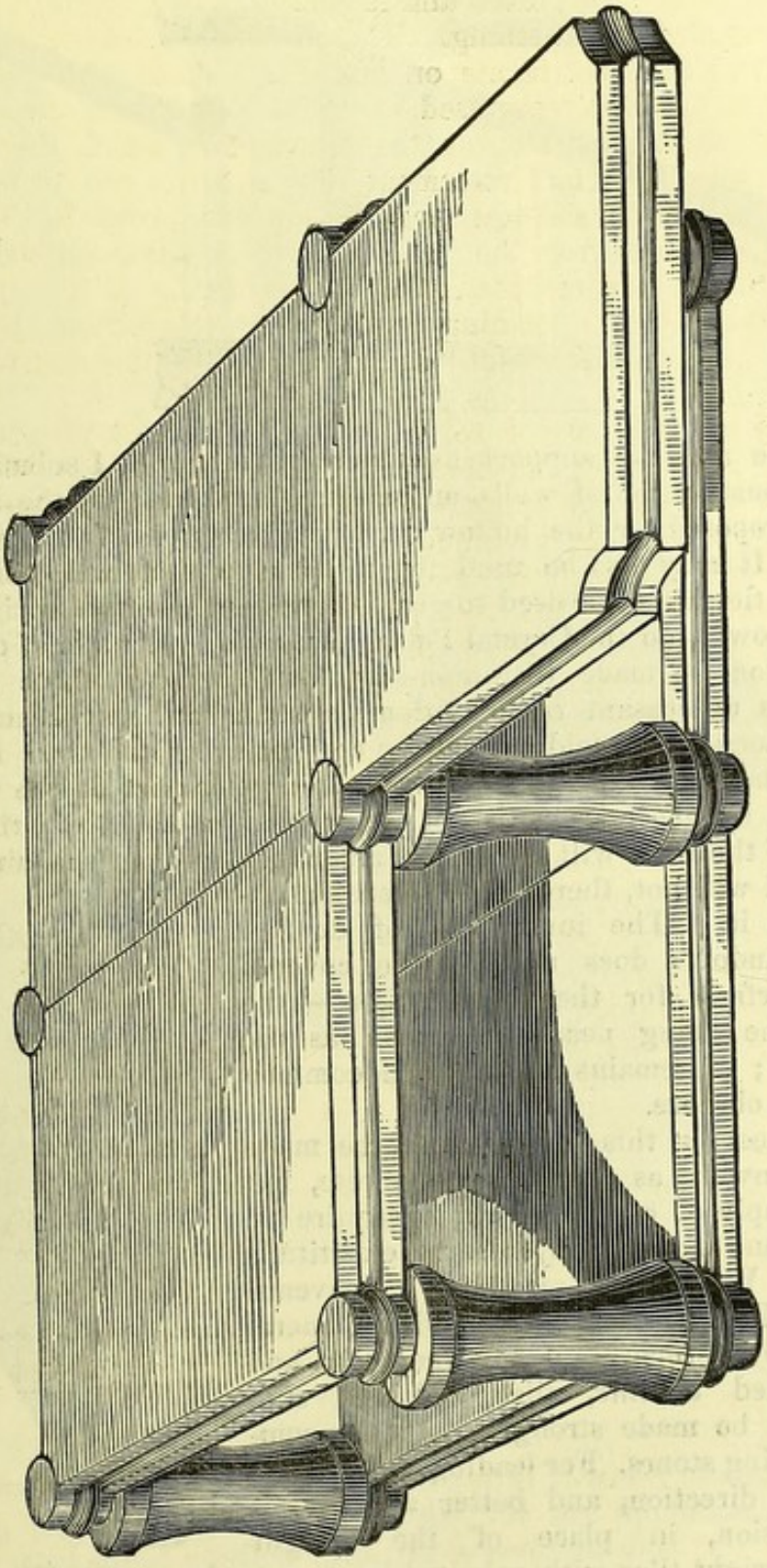
Enough has been stated to show that the school, properly considered as an efficient implement for training the young, is not the mere barn with an architectural elevation, according to the common conception, but for the avoidance of serious evil as well as for the attainment of the requisite good, is an implement which must be carefully fashioned by the best practical sanitary science. Enough too has been stated to show the deplorable state of the central administration,—which, having received warning from school inspector after school inspector, and also from the medical officers of health in the metropolis,—which, having the aid of a very expensive medical council, passes over these evil conditions unheeded and unprovided for in the school plans issued as models for local authorities, and sends additional masses of children into those insanitary conditions, in violation of clear laws of psychology as well as of physiology. Surely some action ought to be taken for the public protection in respect to such an administration!

With the advantage of some practical suggestions by Mr. Canon Cromwell, the principal of St. Mark's Training College, I have directed a plan of one school, with the primary requirements, to be got out by Mr. Samuel Sharp, the architect, for 500 children, with what I must call the Roman floor warming by hollow tile floors, and with solid concrete walls, with a lavatory, but without a swimming bath and without a playground, would be within the cost of the common constructions.

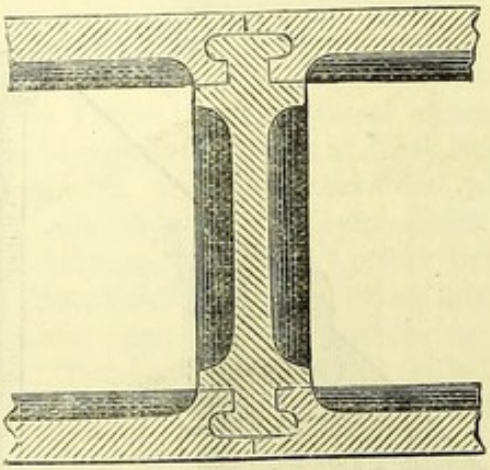
I will now describe the tile and the support, with which I propose to effect the important object of floor-warming efficiently and economically.

The tile forming the hollow floor, may be of concrete, or of earthenware, or of slate, to be tongued or rabetted at the sides, so as to fit into each other, and, when cemented, not be easily shifted, or so as to obstruct the passage of highly warmed air or smoke, if accidentally loosened. The upright supports are made with tongues to lock in at the corners of the tiles.

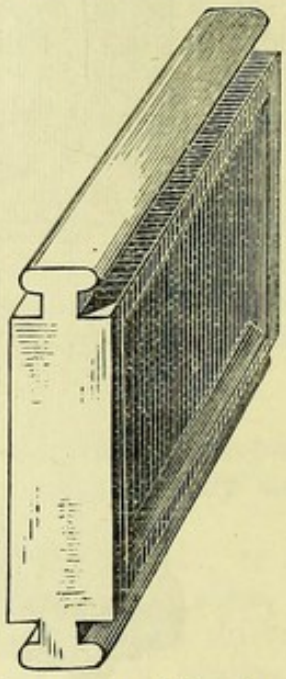
The following is a sketch of a portion of hollow floor, with the tiles in position, on the principle of the Roman hollow floors :



The following is a section of another form of support, by a cross tile upright pillar, with its junction in the tiles :

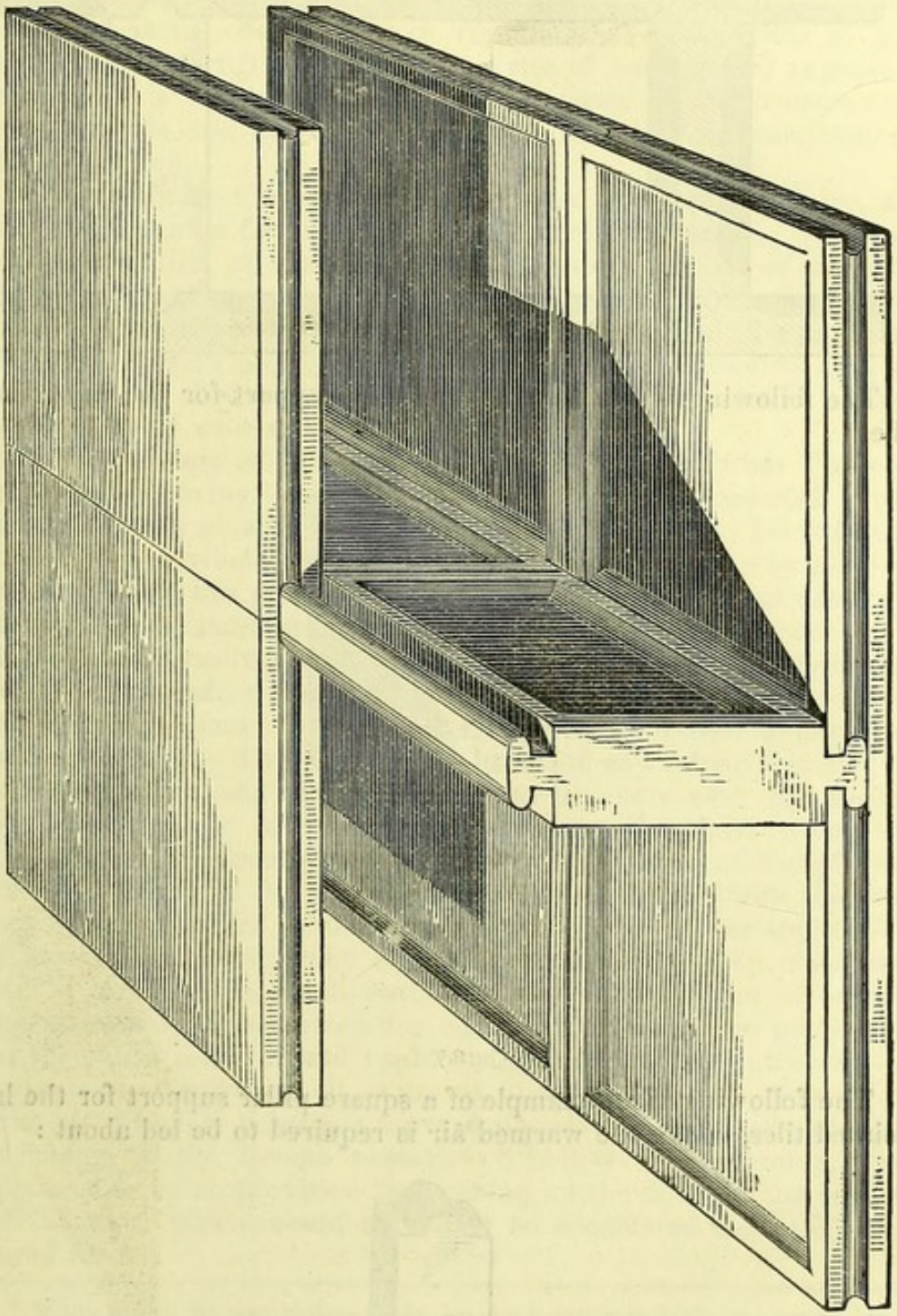


The tile and the support used as a cross-tie will, I submit, serve for the construction of walls, and attain more perfectly the sanitary ends I proposed for the hollow brick construction of the walls of houses. It may also be used for roofs as well as walls, in which case iron ties are to be used to give it cohesion, and iron uprights for bearing power, on the Crystal Palace principle. If walls of ordinary construction be made with non-absorbent surfaces, there may be sometimes unpleasant condensation on such surfaces, because they will be sometimes colder than the dew print of the air. If, however, contact of the outer air with the inner part of the wall be prevented by the interposition of a layer of confined air, the inner surface of the wall will never be much colder than the air of the room, and will not, therefore condense moisture from it. The inner glass of double-paned windows does not become covered with hoarfrost for the same reason — the inner pane being nearly as warm as the inner air; it remains clear when common panes are obscure.



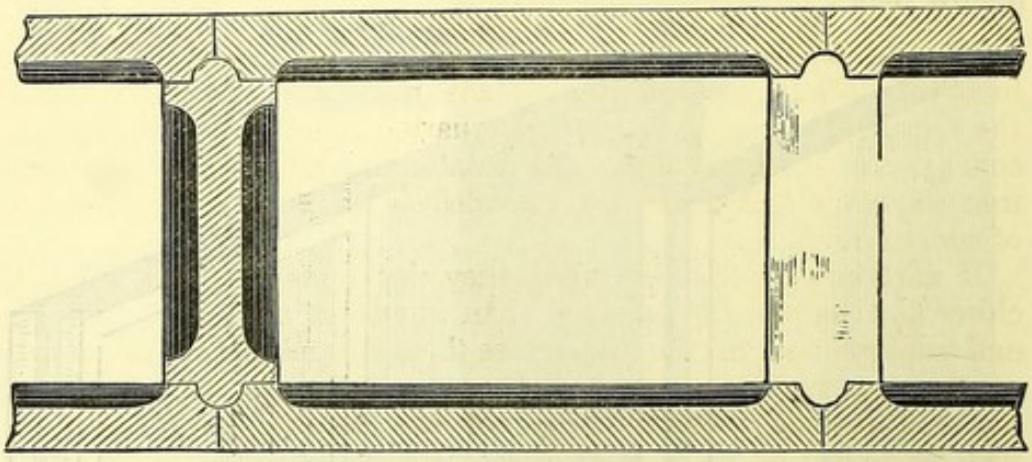
The tiles, for this purpose, may be made of earthenware as well as of concrete, but most cheaply of concretes which require no burning, and most readily receive exactitude of form. With about one sixth or seventh of good Portland cement, or with General Scott's new preparation of lime clay and sand, called *celenite*, tiles and the supports may be made stronger than the common building stones. For leading the warmed air in any direction, and better diffusing it on admission, in place of the upright pillars, upright tiles with rabetted joints may be used. The above displays the longitudinal upright position.

The following gives a view of the same tile, in position for the hollow floor :

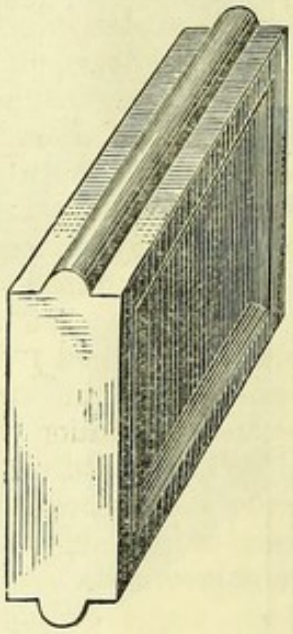


In some cases, in the place of tiles with rabetted joints, tiles with overlap joints may be found eligible, for the application of rapid second mechanical vertical pressure in construction.

The following is a cross section of the supports on this principle



The following is the form of the tile support for the lap-jointed tiles:



The following is an example of a square pillar support for the lap-jointed tiles, where the warmed air is required to be led about:

The concrete tiles may be moulded in the yard, and kept to harden there, and to be tested there, and then carted to the spot and be set up rapidly, without any other mechanical process there. The advantage of the tile construction of walling is, that with the cross-ties included, about one quarter of the material will suffice to give the requisite strength. Only one quarter of cartage and expense of conveyance is required, and the total expense of the construction, iron supports and cross-ties included, is less than the common cost of construction.

If earthenware tiles are used, they pack closer in the kilns, and closer and lighter for carriage than any solid materials. The form and construction of the tiles gives them the maximum of strength, of density, and non-absorbency or dryness, with the minimum of material and of weight. Some of the advantages of the hollow wall construction of tiles, in respect to non-conductability of heat, are like those of the double window—they will be cooler in summer and warmer in winter.

One advantage of the tile construction is, that from the very considerable saving which the plan effects in the *material*, a proportion may be given to the improvement of the tile. Its flat shape admits of power being applied at a ready and cheap rate by a second pressure when the material is half dried, to give it great density of substance and exactitude of form. With this second pressure they may be made absolutely non-absorbent, and to throw off driving wet as well as ascending wet, and may be made absolutely damp-proof. The inner tiles would be washable on the surface, in itself an important sanitary quality. They may be coloured of any colour that may be deemed suitable, and that with a great economy over the usually unwashable paper and absorbent plaister. By these means the warming and, indirectly, the ventilation, may be most cheaply and efficiently provided for. When these tiles are made with the accuracy of form and of joints that is attainable by proper applications of mechanical power, they might almost be jointed up close dry; and in any case they will require a very small amount of cement, and may easily be separated for cleansing or any other purpose, or for the entire removal and rapid changes of whole structures. As respects floor-warming, it is to be observed, that the down draft from the fireplace occasions a great amount of smoke consumption. In many of the Roman remains of hollow floor-warming, there appeared to be no provision for opening up the floor for the removal of the soot, which would appear to be considered too little to be cared for.*

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* Many of the Roman hollow floors, besides being very high, are covered with concrete of considerable thickness, as much as six inches. This might be necessary to prevent the escape of smoke into the room through the joints of rude slabs of stone, and also to serve as reservoirs, as it were, of heat, but it would not be necessary with tiles of better construction. Americans who have been accustomed to room-warming with iron surfaces, who go into Sweden and some parts of the north of Germany, find the room-warming there, by the earthenware tile surfaces of the very large stoves, peculiarly agreeable. These stoves are three feet square

A better conception of the eligibility of the principle of construction proposed, will be obtained by examining and considering the specimens of the tiles, rudimentary as the specimens produced yet are. The ends sought and the chief advantages claimed for them may be thus summed up—Giving maximum of strength and durability of each tile, with the minimum of material;—a maximum of defensive power for shelter at a minimum of cost; a cheap and salubrious means of diffusing warmth in winter, and of defence against excessive heat in summer;—giving non-absorbent and washable interior surfaces, defensive against vermin and noxious deposits;—means of cheap and permanent washable colouring and ornamentation; facility of transport, rapidity of construction and alteration; cheap, and dry, and smooth surfaces for playgrounds. In the selection of materials for the tiles, those of the greatest non-conducting power are of course to be preferred. The common tiles and bricks being usually absorbent of moisture, are rapid conductors of heat, and when we were consulted at the General Board of Health, we advised that they should not be allowed, but only wood for the floors of schools, inasmuch as the common tiles, instead of giving warmth *to* the feet, aggravated the evil in question by taking warmth *from* the feet. I need not specify the various constructions to which the principle in question and the means of applying it will be applicable.

My friend the late Dr. Emile Braun, the Prussian archæologist at Berne, and Mr. Semper, the professor of architecture of Dresden, the architect of the Dresden theatre, men perhaps as highly versed in the principles of architecture as any in Europe, were of opinion that a tile construction,—if suitable tiles could be manufactured,—would be preferable to the hard burnt hollow brick constructions which I advocated, as means of getting rid of the evil of absorbent and damp walls. I concurred with them in believing that constructions on the principle of *cohesion*,—that is to say, on the principle of the Crystal Palace, only with opaque tiles instead of glass,—would in many cases have great advantages over the common constructions, on the principle of *solid masses and weight*. The improvement in the manufacture of cements, and especially of Portland and of celenite, with which materials can be compounded stronger than common brick, and as strong as the common building stones, and can be readily and cheaply moulded in exact forms,—and also some improvements in

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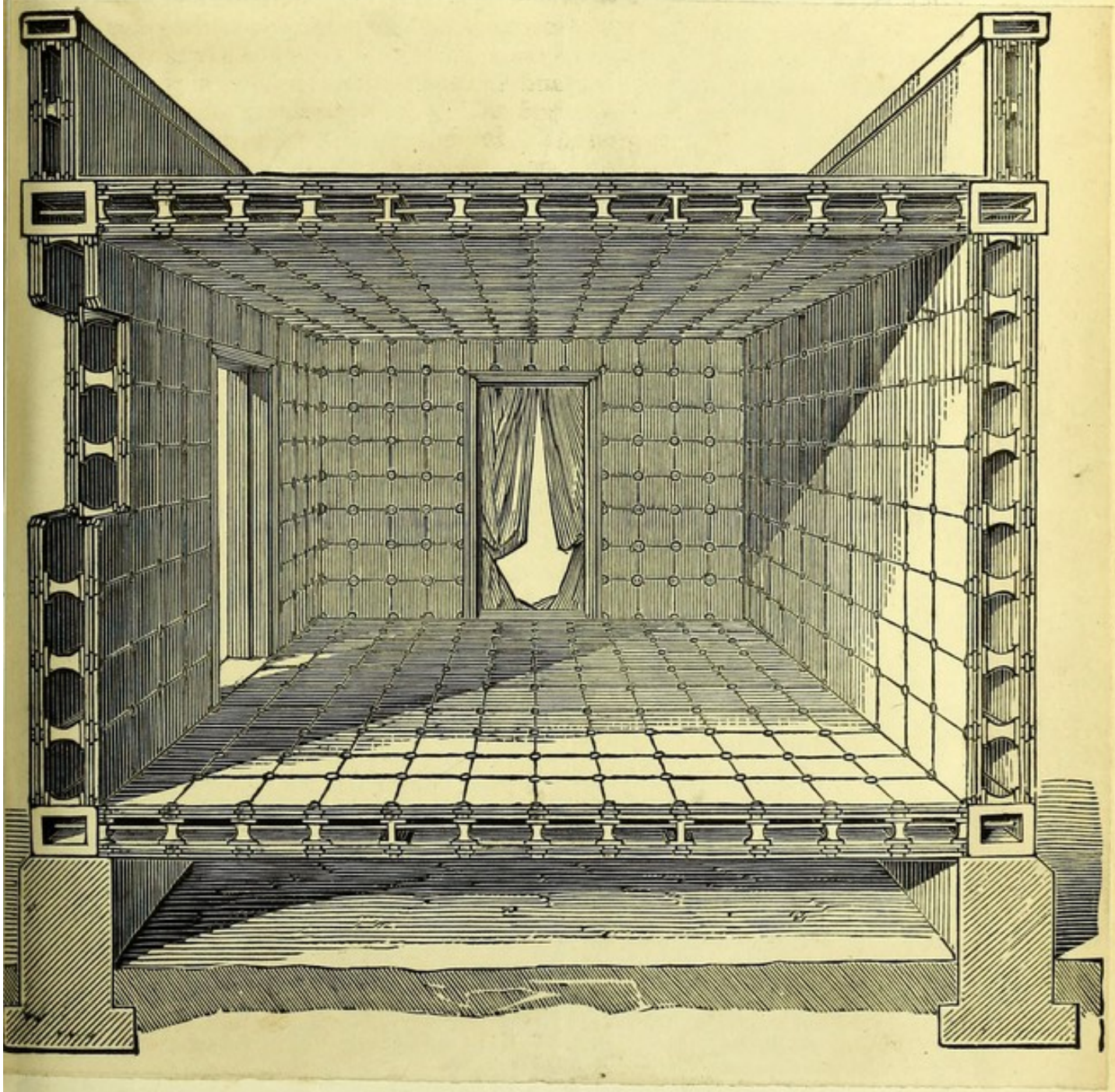
or more, built of tiles of such dimensions as are proposed, and as high nearly as the room. A small quantity of fuel is put into them, by which they are warmed up in the morning, and they diffuse through the day the heat they have received. The effect which these *perpendicular* tile stove wall constructions produce, may, it is assumed, be better produced by similar *horizontal* floor constructions. In the application of the principle to schools, it would be the business of the schoolmaster to see before the school was opened that the floor was warmed to the extent which experience would soon determine. Earthenware tiles of nine inches square and about an inch and a half thick, are getting into use as economical foot warmers, on account of the length of time they retain heat. An arrangement of tiles, such as is proposed for floors, would retain and diffuse warmth equally at lower heats.

the manufacture of clay tiles, which give them great density and strength,—will now enable the principle of cohesion to be applied, so as to enable walls to be kept warm as well as dry in winter, and cool in summer. The following cross section displays the principle of the new tile construction in walls, ceilings, and roofs :—



The artist might have curved the upper roof somewhat for the discharge of wet. As against wet, a coating of Val de Travers asphalte, which resists great solar heats, and is uninflammable, would serve excellently, as also over much of other tile surfaces.

It is estimated that this construction can be made with tiles of Portland cement cheaper than similar constructions with the best solid brick construction, with plastered and papered walls and wooden floors; and can be made cheaper still by one-third of celenite tiles, apart from the great differences in quality. A basement floor, warmed on the Roman principle, would, at an exceedingly cheap rate, diffuse an equable and pure warmth over the upper rooms, including passages and corridors, the great desideratum in house-warming.

The interior wall tiles may be made of various forms, and with any amount of art decoration that taste or luxury may require; and if of tiles, they may be made with porcelain surfaces.