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The standard for vitrification must, therefore, also be arbitrary, and it depends not only upon the degree of desirable toughness, but also upon the properties of the raw materials used.

Defects in clay pipe are fire cracks, blisters and laminations. These imperfections should be avoided so far as practicable, because to some extent they reduce the strength of the pipe. The reduction is found particularly when the fire cracks in a pipe are abundant and extend far into the shell. It is also found when the material is laminated and particularly when the breaking shows splitting between layers of material. Blisters, unless very deep, do not affect the strength, but rather the serviceability, of a pipe.

The permissible limits of these defects should, therefore, also be arbitrary standards, depending upon the purposes for which the pipes are to be used.

Where high strength is required, fire cracks should be rare. Where they occur they should never extend into the shell more than $\frac{1}{8}$ in., irrespective of the test for strength. Where laminations occur in pipes such should cause rejection, unless the tests for strength are quite satisfactory for the proposed use of the pipes.

Hair cracks are caused by shrinkage of the cement during the process of drying and setting, and when exposed to a material drop in temperature soon after setting.

The permissible limits must be arbitrary and should depend upon the purposes for which the pipes are to be used. Such cracks unquestionably lower the strength of the pipe. They should therefore be rare, and never destroy the continuity of the material of a section of the shell more than 1 sq. in., and such depreciated cross-sections should not be less than 6 ins. apart. Such individual hair cracks should not exceed 0.1 mm. in width, and should not be more than 2 ins. long, and not penetrate the shell more than $\frac{1}{8}$ in.

Thickness of Shell.—The thickness of the shell of a pipe, to resist external and internal forces, strictly speaking, should vary with the qualities of the original material from which the pipe is made and with the treatment during its manufacture. A thinner shell of tougher and denser material may resist greater pressure than a thicker pipe which is less tough and compact.

The committee therefore believes it would be unsafe to specify a definite relation between diameter of pipe and the thickness of shell, and that it must be left to the guarantee of the manufacturer that the pipe which he offers for sale shall be, in all cases, of sufficient thickness to withstand the standard crushing loads specified.

The committee favors the establishment of a minimum thickness for each size of sewer pipe and submits, as a result of all the available information, Table III. for consideration.

The committee is of the opinion that there may be a demand at times, for cheaper pipes with thinner shells than those above specified, but it believes that in such cases the understanding should be clear that such pipe is not classified as standard pipe.

There may also be a demand at times, for pipe which must safely sustain a greater weight than the above standard. In such exceptional cases, means should be provided for securing the necessary increase of strength, either by embedding standard pipes in concrete or by surrounding them with concrete of sufficient thickness to resist the greater weight.

Ends of Pipe.—The ends of pipe should be so shaped as to permit the making of a joint which, in strength, approaches the strength of the pipes in resistance to shear,

bending moment and crushing stresses, and which is also sufficiently impervious to the passage of water. In vitreous materials it is impracticable to obtain that accuracy of dimensions which will permit close contact at all points of the pipe ends, and for this reason the strength of jointed pipes in these materials is to be secured by means of the jointing material. For this purpose it is best to have space for ample jointing material such as is furnished by extra wide and deep sockets. The outside surface of the spigot end and the inside surface of the hub or socket end should be unglazed, or else these surfaces should be scored with V-shaped depressions to provide for a bond with the jointing material.

Where the ends of pipes can be finished to true surfaces, as with cement-concrete pipes, it is practicable to shape these ends as male and female bevels which can be brought into close contact throughout. Such a joint, when covered with a suitable layer of cement mortar to increase the rigidity and to prevent the passage of water, is quite as satisfactory as the hub-and-spigot type with

Table III.—Minimum Thickness of Shell.

| Diameter of Pipe, in. | Minimum Thickness of Shell, in. | |
|-----------------------|---------------------------------|----------------------|
| | Vitrified Clay Pipe | Cement-Concrete Pipe |
| 6 | $\frac{5}{8}$ | $\frac{3}{4}$ |
| 8 | $\frac{3}{4}$ | $\frac{7}{8}$ |
| 10 | $\frac{7}{8}$ | 1 |
| 12 | 1 | $1\frac{1}{4}$ |
| 15 | $1\frac{1}{4}$ | $1\frac{1}{2}$ |
| 18 | $1\frac{1}{2}$ | $1\frac{3}{4}$ |
| 20 | $1\frac{2}{3}$ | 2 |
| 22 | $1\frac{5}{8}$ | $2\frac{1}{4}$ |
| 24 | 2 | $2\frac{1}{2}$ |
| 27 | $2\frac{1}{4}$ | ... |
| 30 | $2\frac{1}{2}$ | ... |
| 33 | $2\frac{5}{8}$ | ... |
| 36 | $2\frac{3}{4}$ | ... |
| 42 | $3\frac{1}{2}$ | ... |

extra wide and deep sockets, although it does not appear to have any particular advantage over the latter except possibly some economy in handling and laying. The ends of cement-concrete pipe furnish good bonding surfaces for the jointing materials and, therefore, do not require to be scored. Table IV. gives minimum values for depth of socket and annular space for various diameters of pipe.

No pipe should be used until pipes cast in the same factory of equal age are strong enough to meet the specified crushing test.

Recommendations with respect to the making of joints have been furnished in the proposed Tentative Recommended Practice for the Laying of Sewer Pipe, as heretofore reported by the committee and published in the 1915 Year-Book.

Gasket and mortar joints, in vitrified pipe sewers, shall be made in the following manner:—

A closely twisted hemp or oakum gasket of suitable diameter, in no case less than $\frac{3}{4}$ in., and in one piece of sufficient length to pass around the pipe and lap at the top, shall be solidly rammed into the annular space between the pipes with a suitable caulking tool. Before being placed, the gasket shall be saturated with neat cement grout. The remainder of the space shall then be completely filled with plastic mortar mixed 1:1 and the joint wiped inside and finished to a smooth bevel outside.