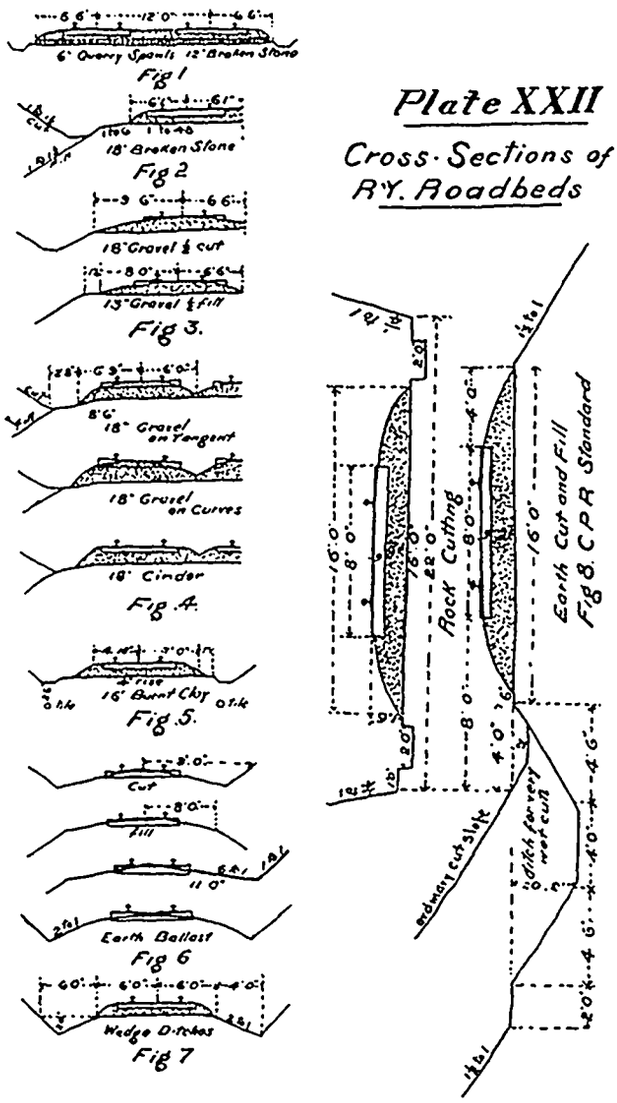
at each point bearing in mind what the ballast is costing, the expense of re-lifting sunken track and the large amounts of extra high-priced material needed if this allowance for shrinkage is not made before grading is completed ; on page 150 the per cent. of shrinkage of different materials is given, which will serve as a basis for estimating how much extra height should be given to the banks ; if construction has been completed in one season at least one-half these amounts are necessary.

ARTICLE 2—BALLAST.

The quantity of ballast used is a purely financial question, and up to a usual limit of 12 inches underneath the ties, the more the better, can track be maintained for the same cost ; 12 inches under ties takes about 3,000 cubic



yards per mile; 6 inches under ties takes about 1,800 cubic yards, including filling around ties as in Fig. 8, Plate XXII., but with no allowance for sunken banks and extra material. The functions of ballast are:

(1) To afford lateral, longitudinal and vertical support to the ties sufficient to keep the track in line and surface without incessant track labor.

(2) To carry off all water as rapidly and thoroughly as possible after rain storms or thaws.

(3) By drainage to lessen the action of frost in heaving track during the winter and spring.

(4) To give elasticity to the roadbed.

The following materials are used more or less extensively for ballasting and are given in order of merit as nearly as may be:

(1) Broken stone to a 2-inch ring; coarser underneath.
(2) Furnace slag and cinder.
(3) Coarse, clean gravel.
(4) Broken bricks or any form of very hard burnt clay.
(5) Sand not so light as to be easily blown away.
(6) Earth, usually compact clay, seldom loam.

Broken stone ballast, although expensive and hard to tamp and surface with, gives the most durable and satisfactory track with least labor for maintenance; only roads with heavy traffic can afford to have it, as it costs from 75 cents to $1.25 per cubic yard in place. When used, it is generally flush with the top of the ties for about 1 foot beyond their ends, thus giving lateral support, and side slopes rather steep (about 1 to 1). A very finished appearance can be given by laying a margin of stones to line by hand, and keeping the rest of the roadbed, outside, free of ballast and grass. The slag from blast furnaces, if properly cooled and broken, makes a very good and durable ballast, but its use is evidently limited in area and the price will vary according to circumstances ; cinder also is a valuable ballast, but limited in quantities. Probably gravel may be looked on as the ballast more generally used in America than all other forms combined, because of its wide distribution and general utility. When clean and fairly free from sand and large boulders, it drains well, surfaces easily, and holds track from all but lateral movement ; in this it is deficient as it will not stand steep enough to admit of the ends of the ties being fully submerged, unless a very wide roadbed is used. (See Figs. 3, 7 and 8, Plate XXII.). The cost of gravel ballast in place varying with length of haul, may be put at 15 cents to 20 cents per cubic yard if loaded with steam shovels from a good pit and unloaded by ploughs, but will run as high as 40 cents when material is manually handled from pits with heavy stripping. In all cases the stripping of pits should be attended to, and all inferior material wasted or put on low or narrow banks. The ballast material should be of a uniform quality, as any patches of loam or clay mean just so many sunken spots in the track.

Sand ballast creates dust in summer which injures the rolling stock, does not hold a track well to surface or in line under heavy traffic, and has a tendency to hold water and heave track in the spring ; unless very coarse it is not at all a good investment if other ballast can be obtained. In such situations many roads have resorted to burnt clay or broken brick, but unless well and uniformly burnt, almost to vitrifaction, it is not a very durable material. In mild climates, such as Southern U.S.A., many railways have ballasted with clay taken from ordinary cuts, either from the cut slopes or hauled by train from the nearest point. If the clay is of a compact nature, and such a cross-section as one of those in Fig. 6, Plate XXII. is used, it will soon get beaten down and shed ordinary rains without any water permeating the roadbed. It is evidently a very cheap way to ballast, and in the absence of other cheap materials may be very justifiably used in such climates by roads of light traffic and meagre resources. Except in the case of broken stone, laid with teams, from adjacent fields, the ballast is put on, after the track is laid, by train loads, and, in so doing, unless the newly laid track is at once roughly surfaced, and trains run very slowly over it until a light "lift" is first put on and the track fairly well lined and surfaced before the ballast trains are allowed to run at a high speed, we may expect permanent injury in the form of bent rails and cracked angle bars, especially as the track is often not fully tied, spiked or bolted. In surfacing and lining track it is well to remember some general principles applicable to all materials and at all times.

(*a*) The coarser material available ought to be put underneath, *i.e.*, on the first lift.