straight line in order that bad hills may be skirted instead of being crossed directly over their summits. By these means a considerable saving in steep grades may often be effected. The minimum rate of grade, too, depends upon the class of pavement used. It must be sufficient to allow prompt drainage of the surface water into the catch-basins. The expedient, however, of what is known as false grading in the gutters will allow roadway, curbs and sidewalks to be laid with a level longitudinal grade, if necessary, but the gutters will have to have sufficient grade to create a flow of water. The minimum grade for this purpose should in no instance be made less than four-tenths of one per cent., and this should be used as sparingly as possible.

The choice of kind of paving materials to be employed in the construction involves a great number of considerations which, however, can be investigated along scientific lines. Experience has already established that certain materials are undoubtedly best adapted for certain purposes, and the results may be made use of without further investigation. For instance, no one denies that Portland cement is the proper material for any permanent street pavement base and for the sidewalks, and the truth is equally as much evident that certain materials for the wearing surface of the roadway pavement are adaptable under certain climatic conditions while not under others. In considering the pavement base, however, we shall need to design the thickness and proportions of the concrete to safely withstand the loads and stresses to which it will be subjected. Ordinary practice has held pretty closely to the limits of four and eight inches, varying with the nature of the traffic and the condition of the sub-base. It is advisable to make an analysis of the bearing power of the soil and the stresses which will be produced by the traffic in each particular case where conditions vary materially from other cases which have been investigated. The principal stresses induced in the base are due to climatic forces and the loads causing compression. Variation in temperature tends to cause disintegration by expansion and contraction of the concrete, and water tends to penetrate through to the sub-base, making it soft and reducing its bearing power. Therefore, the base must be designed so as to expand and contract without breaking the bond, and the water must be kept out by an impervious surface. The loads tend to push the pavement into the sub-base, and hence the base must have strength and rigidity enough to distribute this force safely. In general, the safe load which may be allowed for the sub-base is two or three tons per square foot. It is probably needless to say that the width of tires will be considered as to the manner of transmitting loads to the base.

In designing the pavement wearing surface for the roadway a greater number of considerations enter. First, in the way of stresses we have to consider forces caused by impact, shearing and suction, as well as compression and temperature stresses. The forces caused by impact are received by the wearing surface only, and hence the wearing surface should have sufficient resilience to absorb these forces without damage. Standard tests have been devised for use in this connection. Shearing is induced by the tractive power of the wheels of a self-propelled vehicle and the feet of horses. The wearing surface must have sufficient strength to resist this force, and must have stability enough to prevent its being torn away from the base from the same cause. Hence the study and testing of the bonding properties are obligatory. Suction forces result from the partial vacuum created behind a rapidly moving motor vehicle. The individual parts of the wearing surface must be held together in order to resist this force. Compression and temperature stresses will be handled in a manner similar to that outlined for the concrete base.

Second, a comparison of the value of the different wearing surfaces should be made with especial reference to cost, durability, maintenance, cleaning, traction resistance, slipperiness, sanitary qualities, noise and possibly other qualities made desirable by local conditions. The U.S. Office of Public Roads, working along these lines some years ago, collected reports from the engineers of a number of American cities. The results of this enquiry were published in the form of a table which is reproduced below. Under the percentage column the various qualities desired in a pavement are assigned proportionate values, the total being 100 points. The pavement ranking first under any given quality is given the full quality percentage, the rest grading down from this value in proper proportion.

The table is not given here in order that the results shown may be taken as applying to any particular case, but merely to suggest the proper procedure for the investigation. In any one problem certain conditions of a local nature are bound to enter.

Comparative Value of Different Pavements.

Pavement qualities.	Percentage.	Granite.	Sandstone.	Sheet asphalt.	Asphalt block.	Brick.	Macadam.	Creosoted wood.
Cheapness (first cost)	14	4.0	4.0	6.5	6.5	7.0	14.0	4.5
Durability	20	20.0	17.5	10.0	14.0	12.5	6.0	14.0
Ease of maintenance.....	10	9.5	10.0	7.5	8.0	8.5	4.5	9.5
Ease of cleaning	14	10.0	11.0	14.0	14.0	12.5	6.0	14.0
Low traction resistance ..	14	8.5	9.5	14.0	13.5	12.5	8.0	14.0
Freedom from slipperiness (average of conditions).	7	5.5	7.0	3.5	4.5	5.5	6.5	4.0
Favorableness to travel ..	4	2.5	3.5	4.0	3.5	3.0	3.0	3.5
Acceptability	4	2.0	2.5	3.5	3.5	2.5	2.5	4.0
Sanitary quality	13	9.0	8.5	13.0	12.0	10.5	4.5	12.5
Total number of points.	100	71.0	73.5	76.0	79.5	74.5	55.0	80.0
Average cost per sq. yd. laid in 1905		$3.26	$3.50	$2.36	$2.29	$2.06	$0.99	$3.10

Note: Favorableness to travel is dependent chiefly upon smoothness and freedom from dust and mud, secondarily upon the qualities composing "acceptability." Acceptability includes noise, reflection of light, radiation of heat, emission of unpleasant odors, etc. It chiefly concerns the pedestrian and the adjoining resident. Cost per square yard includes concrete, but not excavation, curbing, etc.: except for macadam, which is not usually laid on concrete.