This equal stress condition on the two subgrades, under higher impact loads on the dry subgrade and the lower impact loads on the wet subgrade, is explained by the fact that the bending is much greater on the wet subgrade than on the dry subgrade It is interesting to note the high fiber stresses under impact loads in comparison with those under static loads

Another important observation gained from these impact results (shown briefly in Table I) is that the height of drop of the same wheel is less for the dry subgrade and gives higher impacts than on the wet subgrade A slab on a soft or wet subgrade will bend and deflect more, and thus offer greater cushioning to impact than a slab on a dry or hard subgrade Thus the falling mass, or wheel, is brought to rest much more quickly on the rigid slab and subgrade condition, with the result of a higher impact, or, in other words, the height of drop may be greater on the wet subgrade condition and the resulting impact be less

INVESTIGATION OF MOTOR TRUCK IMPACT

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This investigation is being carried on by the U S Bureau of Public Roads in cooperation with The Rubber Association of America and the Society of Automotive Engineers under the direction of a committee comprised of representatives of these organizations The objects are as follows

1 Determination of cushioning effect as influenced by tire design rubber composition, road surface roughness, load, speed, and truck design
2 Determination of stresses in slabs as influenced by motor wheel impacts

PROCEDURE

In the measurement of cushioning properties of tires, the part of the investigation concerned in this progress report, test trucks equipped with measuring apparatus are driven over special road sections and the impacts are computed by formula

TEST ROAD SECTIONS

The three roads used for this purpose are about 500 feet long and can be described as follows

1 Section of rough granite block pavement having an indicated vertical variation of 90 9 inches in 500 feet of length
2 Section of smooth concrete pavement having a vertical variation of 12 4 inches in 500 feet of length
3 Section of smooth concrete on which are set various types and heights of obstructions

Tests on sections 1 and 2 disclose the number and magnitude of impacts encountered in ordinary driving, while those on section 3 are

employed to study the detailed effects of speed, roughness, load, tire, and truck design

APPARATUS

Accelerations are indicated by a weight supported on a spring carried in a frame which contains rolls and recording paper The frame is attached directly to the rear wheel hub and the recording mechanism is driven by the rear wheel through a belt Spring deflections are recorded on the same paper simultaneously with vertical acceleration values by means of a system of gears and levers attached to both truck spring and body The road roughness is measured by a 16-wheel profilometer

CALIBRATION

Acceleration values for various recorded weight movements were determined by a calibration in which was shown that consistent agreement existed between accelerations computed from—

1 Accelerometer spring deflections under static loads
2 Maximum impact forces indicated by the Kreuger apparatus
3 Space time curves

The formula for computing impacts is—

$F = M(a+g)+s$, in which

F = Impact force in pounds
M = Mass of unsprung truck weight
a = Indicated acceleration (from records)
g = 32 2 gravity acceleration
s = Truck spring pressure at instant of impact (from record)

SCOPE OF WORK

This phase of the investigation contemplates static tests on 80 tires and impact tests on 105 combinations of truck and tire, and the present status is shown in the following table

TABLE I

Tires	Static tests		Impact tests	
	Completed	Total No	Completed	Total No
Under-inflated	2	4	4	5
Pneumatic	2	4	4	7
Cut-down cushion	4	19	1	25
Cushion	19	19	14	25
Worn solid	1	17	1	17
Solid	17	17	3	26
Total	45	80	27	105

The average number of truck runs required for each of the 105 impact tests is about 40. In many cases this number is exceeded, in some instances having reached 100

Covering certain truck and tire variables, nothing short of a comprehensive analysis and a voluminous report could do justice to the wealth of data being accumulated From a scrutiny, however, of the progress reports submitted to the Committee by J. A Buchanan and J. W Reid certain general relations in the impact results are evident. These involve rough and smooth road impacts with solid, cushion, and pneumatic tires, at capacity load and 12 miles per hour, impacts at different speeds over the 1½ by 30 inch inclined obstruction at capacity load, impacts for different loads at 12 miles per hour over the same obstruction, and impact values for the same speed and capacity load over inclined obstructions of different heights. The 1½ by 30 inch obstruction was selected for this comparison because at the same speed and same load it produced with each tire an impact agreeing closely with the maximum caused by the rough granite block road. For convenience of comparison all values are expressed in per cent of static capacity loads, which are 4,000, 3,400, and 4,400, respectively, for the solid, cushion, and pneumatic tires

The general indications of the tests are as follows

1 Impacts from pneumatic tires on smooth roads and up to speeds of 22½ miles per hour are practically negligible and on rough roads will probably not exceed 200 per cent of the static wheel load It is indicated also that this limit of impact will not be exceeded either when the wheel drops from an obstruction of 2-inch height, or when the load on the truck is increased by 50 per cent

2 Impacts from a new solid tire on a very smooth road are slightly greater than those delivered by pneumatic tires on a very rough surface, and are about 210 per cent of the static wheel load for a speed of 12 miles per hour. At the same speed on a rough road the impacts from a solid tire can be as great as five times the static wheel load From test runs over the obstructions, it is indicated that either increase of speed to 15 miles per hour or 50 per cent increase in load will increase these impacts to about 5½ times the static wheel load.

3 Impacts delivered by cushion tires range in magnitude from slightly above those of pneumatics to slightly below those of solid tires, depending upon the characteristics of the tires

4 The maximum impacts found on the rough granite block road for all tires at a speed of 12 miles per hour were equal to those developed by drops from an inclined obstruction 30 inches long by 1½ inches high.

5 Obstruction tests indicate that impacts do not increase directly with speed but rather that maximums are developed at certain definite speeds which are dependent upon a considerable number

of variables Tests made to date indicate a decided increase in impact when truck speed increases from 5 to about 15 miles per hour. A slight decrease occurs from this speed to about 20 miles per hour when a second increase is indicated which develops to a maximum at some speed beyond which the tests thus far have been made.

As regards the effect of road roughness on impact it may be of interest to both the maintenance and construction engineer, that even the slightest surface variations can, under certain conditions, greatly increase the forces delivered to the road The concrete road used in these tests is possibly more than ordinarily smooth and on the major portion of it impacts from even the solid tire were not appreciable The maximum of twice the static load occurred at but one point, which, although not in bad condition, could probably be improved and thus effect an increased safety factor against slab failure The next highest impact was about 1½ times the static This also shows the value of a recording apparatus of some type which will locate the troublesome surface variations

These indications are given at this time as general information and are not to be considered as final conclusions There does not seem to be much doubt as to accuracy of the data presented, but since it represents only several combinations of truck and tire it can not be considered applicable for all conditions In granting permission for the release of this information, it was the sense of the Committee that stress should be laid upon the fact that the relations shown are representative but should not be taken as final conclusions.

FATIGUE OF CONCRETE

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Loads are applied to materials in several ways (1) A fixed load continuously throughout extended periods, as books on the shelf of an unused library Here there is, in addition to elastic deformation, a plastic yielding that is especially marked in wood, stone, and concrete (2) Loads starting at zero and increasing to a maximum through periods of a few minutes, as in an ordinary laboratory test. (3) Suddenly applied loads ranging from the passage of a locomotive over a bridge producing stresses within the elastic range of the materials to an impact test of a specimen where the blow of a falling weight is intended to rupture the material (4) A large number of loads applied in close sequence without rest, either repetitive (all of the same sign, tension, or compression) or reversed (of opposite sign) as in the case of a rotating car axle (5) Alternating loads applied less rapidly than in (4) with periods of rest, as when trucks pass over a concrete road at intervals of 15 seconds with a rest over night

The term "fatigue limit" refers to the stress which can be applied many times before rupture occurs The somewhat misleading word