What Causes Spontaneous Washboard (aka Corrugated) Roads in the Desert?
Toward a Multi-variate Factor Analysis Where WB = V_1 + S_2 + E_3

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We all know it when we feel it! That feeling when the off-highway vehicle starts to rock back and forth (or bounce up and down) on "a road or pavement so worn by traffic as to be corrugated transversely" (Merriam-Webster). So, why does it occur? What causes washboarding? If you want a quick answer and don't mind single factor reasoning (SFR), then it's the presence of cars!

Otherwise, there are many amateur untested speculations, some frequently cited ex cathedra assertions (e.g., Snopes.com), but only a handful of scientific refereed studies (e.g., an article in Physical Review Letters, 2007 or a 2011 popularized summary at Wired.com). Clearly, this phenomenon is not yet well understood. Whatever the cause, this topic is important given the need for expensive road maintenance especially in more remote areas, the unsafe speeds when drivers avoid the bucking by driving faster, the damage to suspension systems when they bottom out, and the potentially reduced braking capability and potential loss of control on these driving surfaces.

Early Observations

Not surprising, there is early discussion in highway maintenance sources which discuss the prevention and/or removal of corrugations. First, the Nevada Department of Highways in 1924 discusses "Maintaining the State Highway System" focusing on "Corrugations in Gravel Roads" on page 85ff with an illustration. In another example from latter that year, *Colorado Highways* reports on the "Prevention of Corrugations" in Indiana by the A.H. Hinkle, the Superintendent of Maintenance for the State Highway Commission (November 1924, page 7 and 11).

Otherwise, early use of word "washboard" appears newspapers such as *The San Bernardino County Sun* of 30 January 1930 which mentions that "for the next 52 miles, there is a washboard road [west of Tartron, Arizona], with loose gravel in several sections, and very dusty and tiresome to drive" (page 13) and an Oakland Tribune article about "Death Valley" road test of two new Plymouths sedans making "a 25 mile trip to the sand dunes over rough, washboard roads" (9 August 1931, page 70). By the early 1930s, it was enough of a problem that the Packard Motor Car Company had a "proving ground" which included a section of washboard road to test their new vehicles (*Detroit Free Press*, 3 December 1933, page 14).

Scholarly interest dates from 1927 when *Science* published UCLA physics Professor L. E. Dodd's correspondence about his Mohave Desert road trip and a theory of the "Corduroy Effect Due to Travel of Automobiles over Dirt Roads" (pages 214-216).

In a review of the literature including an extensive Google Scholar Search, the proximate causes can be sorted into different categories as follows:

Three Independent Variables

We can consider the relative loading of many potential variables which have been proposed that could explain the cause of washboarding. The objective is to identify, describe, and weight the relative contribution of each variable to the prediction of the presence or absence of washboarding. Below are the beginnings of operational definitions and the sources of their initial assertion, if possible.

Vehicle Components (V_1)

- Weight of the vehicle (heavy/light car versus truck)
- Speed of the vehicle (threshold for appearance of corrugation)
- Volume of traffic (density; *Colorado Highways*)
- Hard acceleration
- Braking
- Transmission shifts (Donna L. Bates)
- Wheels push the dirt backwards
- Vehicular draft (Ron Turner, California)
- Suspension stiffness (Tom Pettigrew, US Forest Service)
    - Low frequency vibration versus high frequency vibrations
    - Springy versus firm, which allows for varying wheel slip or spin
    - Semi-active suspension with electronic modulation (SAE)
- Wheel shape (balloon tires)

Substrate Characteristics (S_2)

- Alluvial washes
- Granularity, shaping and packing (fine sand versus coarse-grained gravel)
- Hill gradient (steep versus level surface; Mycajah)
- Density of the road bed (loose or hard packing; semi-cohesive binding material)
- Presence of road crown
- Road drainage
- Improper grading (Colorado Highways)

Environmental Conditions (E_3)

- Temperature (morning versus afternoons; Chris Gimblett, Australia)
- Relative moisture (rainy versus dry)
- Season of the year ("winter frost" versus "spring rutting")

An actual scientific study of the dependent variable (WB) and the three independent variables (i.e., Vehicles, Substrates, and Environmental conditions) would determine the relative contribution of each of these three variables in predicting the outcome, washboarding. In short, though, the presence of vehicles (where cars are hypothesized to be worse than heavy trucks) is certainly a likely major factor and secondly, the rate of speed (hypothesized to be below 5MPH (8 KPH) despite MythBusters' confirmed finding (that a vehicle's forward motion at a high rate of speed "resonates with the ridges") in the spontaneous development of washboarding on unpaved roads.

So, now we just need to obtain extra-mural funding and we will know definitively…

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