Proceedings of the 10th World Congress on New Technologies (NewTech'24)
Barcelona, Spain - August 25-27, 2024
Paper No. ICCEIA 122
DOI: 10.11159/icceia24.122

Experimental Modelling of Washboard Phenomenon in Unpaved Roads.

María José Torres[1], Bernardo Caicedo[2], Pablo Alvarado[1], Laura Ibagon[1,2] Fabricio Yépez[1]
[1]Colegio de Ciencias e Ingenierías, Universidad San Francisco de Quito
Interoceánica y Diego de Robles, Quito, Ecuador.
libagon@usfq.edu.ec
[2]Universidad de los Andes
Cr. 1 #18a, Bogotá, Colombia

Extended Abstract

The washboard phenomenon is identified by the presence of ripples on unpaved roads, emerging as vehicles traverse surfaces composed of sand, gravel, or mud. These undulating patterns not only cause discomfort but also pose potential hazards to drivers by disrupting tire-road contact. Despite its significance, limited research has been conducted on ripple phenomena, and the primary cause of their formation remains uncertain. This study aims to unravel some mechanisms of these patterns by analysing key factors such as vehicle speed, weight, and granular material properties. The research draws inspiration from the foundational work of [1-6].

To investigate unpaved road ripples, experimental devices with rotating wheels at constant speeds have been employed. Previous observations suggest that ripples initiate as small waves, gradually growing to heights of up to 20 cm, with wavelengths ranging from 1 to 30 cm. Wave amplitude is influenced by factors such as vehicle speed, mass, shock absorbers, and tire inflation pressure [1-6]. Field studies indicate that ripples predominantly occur in turning zones and on inclined roads, where additional stresses from vehicles impact the road material [7,8].

Experiments conducted by [1-6] propose that unpaved road ripples result from repetitive vehicle passage at a critical speed, creating two distinguishable states: an apparently flat road and a road with ripples. Research findings suggest categorizing ripple phenomena into four modes based on vehicle speeds [4]. At low speeds, small deformations dissipate with vehicle transit. At speeds higher than the critical speed, ripples emerge while the wheel remains in contact with the road. Higher speeds lead to continuous ripple growth until the wheel jumps, and at extremely high speeds, vehicle instability causes the wheel to leap from crest to crest.

This research evaluates physical variables that influences ripple formation using an experimental multi-pass system. The system comprises an instrumented rotating wheel over a sandy path, revealing the evolution of soil ripples as the wheel passes over the track, which is the same device [9] used. Experimental simulations for various scenarios, including different wheel velocities, masses, and soil densities, were conducted. This device enables the assessment of soil plastic deformations, wheel trajectories, and dynamic forces.

Furthermore, the research provides insights into potential mitigation strategies for washboard roads. It suggests that controlling vehicle speed and improving road material properties could effectively mitigate the formation and severity of these patterns, aligning with theories proposed by [3, 10, 11]. The experiments confirm that speed defines ripple properties, such as amplitude and wavelength.

References

[1] Mather, K. B. (1962). The cause of road corrugations and the instability of surfaces under wheel action. Parts 1&2. Civil Eng & Public Works Review/UK/.
[2] Furry, R. B. (1973). Simulation of the road-corrugation phenomenon. Highway Research Record, (438), 54.
[3] Taberlet, N. (2012). Washboard Road, The Dynamics of Granular Ripples Formed by Rolling Wheels. Phd thesis, ENS Lyon.
[4] Bitbol, A.-F., Taberlet, N., Morris, S. W., and McElwaine, J. N. (2009). Scaling and dynamics of washboard roads. PhD thesis, Cambridge University.
[5] Percier, B. (2013). Dynamique d'un empilement granulaire: instabilité de tôle ondulée et fluage d'une colonne de grains. Phd thesis, ENS Lyon.

[6] Hewitt, I., Balmfort, N. J., and McElwaine, J. N. (2011). Granular and fluid washboard. PhD thesis, Cambridge University
[7] Abu Daoud, O., & Ksaibati, K. (2021). Studying the effect of gravel roads geometric features on corrugation behavior. International Journal of Pavement Research and Technology, 1-9.
[8] Abu Daoud, O., Albatayneh, O., Forslof, L., & Ksaibati, K. (2022). Validating the practicality of utilising an image classifier developed using TensorFlow framework in collecting corrugation data from gravel roads. International Journal of Pavement Engineering, 23(11), 3797-3808.
[9] Ibagon L., Caicedo B., Villacreses J.P., and Yepez F. Modelling of washboard effect on unpaved roads experimental evidence on non-cohesive materials. Transportation Geotechnics, 41:101015, 2023.
[10] Ibagon L., Caicedo B., Villacreses J.P., and Achury-Florian A. Theoretical model of the washboard phenomenon on unpaved roads. Transportation Geotechnics, (under revision), 2024.
[11] Ibagon L., Caicedo B., Villacreses J.P., and Lopez-Caballero F. Mitigating washboard effect: A study on geocells as soil reinforcement for unpaved roads. Geosynthetics International (under revision), 2024.