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Mini Review



# Personal Reflections on Benchmarked Development in Pavement Engineering

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## Mini Review

Benchmarking is the process of measuring products, services, and processes against leaders or industry accepted quality or standards and is well known in the business environment in fields like competitive analysis. Benchmarking is also entrenched elsewhere in research and development environments as a legitimate comparison tool. The question arises what is the origin and validity of benchmarking in pavement engineering?

Benchmarking has a long history in the pavement engineering field preceding the use and coining of the word in the business world for competitive analysis. Roman road building is used even to date as benchmark or comparison of mobility provision, pavement strength and durability. In today's terms, the Romans over-designed their roads using rocks up to 1m thick to literally bridge subgrades. The real benchmark was roads that provided for fast deployment of the Roman armies. The need for rapid army deployment led to Frenchman, Pierre-Marie-Jerome Trésaguet [1], benchmarked his development against that of the Romans. This refinement provided a relatively thinner road base than the Roman roads with a base layer of large stone covered with a thin layer of smaller stone. The "Colossus of roads", Thomas Telford [1], further benchmarked against this improvement by using a road base with even smaller selected rock packing and void filling in between with alignment and riding quality improvement. John Louden McAdam [1] developed an improved road building technique with crowned roads, lifted above the surroundings for improved drainage, and in the process using even smaller rock sizes in the road base construction resulting in an even thinner base. The strength of McAdam's base construction was the rock-on-rock interlocking provided. The filler material spread on top of this rock matrix and swept in was the second step. Slushing with water lead to the branding as 'Waterbound Macadam' [2]. The performance of Waterbound Macadam roads set the standard for road building and performance worldwide.

A benchmark that really propelled the knowledge of pavement engineering forward was the development of the California Bearing Ratio (CBR) [3]. This empirical benchmark was developed by the roads engineer OJ Porter for the California Highway Department in the 1920s. In essence he used a good quality gravel or crushed stone as reference material based on observed relatively good wet weather performance on roads in California. This simple empirical laboratory benchmark test developed into the classical CBR rating and was used as a building block in the development of the CBR cover curve design method. This design method was catapulted to best practice during the second world war by the extrapolation of design curves for the higher tyre contact stress of the heavier airplane wheel loads. Today the CBR, even though empirical in nature, is basically still the 'golden standard' which persists in dominating material evaluation classification and road pavement design methods, 'warts and all'. Long term pavement performance (LTPP) [3] was the norm for pavement material and composition evaluation. It took too long to get definitive answers in the shorter term. A way to 'accelerate' LTPP had to be found.

Accelerated Pavement Testing (APT) as legitimate benchmark methodology thus developed. Various loops of experimental road sections that were trafficked by normal motorized traffic were done as early as 1910 as in Portland and New Berlin. Since that tentative start in accelerated pavement testing rigid pavement designs were benchmarked in the Maryland Road Test (1950 -1951) followed by the WASHO Road Test (1952-1954) for flexible pavement designs.

This was followed by the famous AASHO Road Test (1958-1960) [3] catering for both flexible pavements (468 sections) and rigid pavements (368 sections).

Only 1.12-million-wheel load repetitions were applied to these experimental road sections. The design methods that flowed from this major benchmark testing (e.g., Structural Number (SN) design method) was inherently empirical but was used to design road pavements even in the 1960s and 1970s to carry up to 50 million equivalent standard axles (18 kips or 80kN axles). It was clearly an extension far beyond the limited AASHO test of 1.12 million repetitions and constituted an inherent design risk associated with this extension into the 'blue yonder'. The impact of the AASHO Road tests as benchmark was significant though. It helped to develop and promote road condition assessment, measuring technologies such as the Benkelman Beam (BB) deflection measurement, road roughness, rutting and other basic material tests incorporating the Atterberg Limits (AL), importance of aggregate grading and incidentally cementing the position of the CBR test. The one concept that later on contributed to further accelerated pavement testing technology development, was the now well-known load equivalency factor (F=(P/18kip) n , where F is the load equivalency factor, P is the wheel load (kips), and n is the relative damage exponent (equal to 4.2) [3].

In South Africa the premier research institution in road research, the CSIR in Pretoria in South Africa, developed an Accelerated Pavement Test (APT) rig, the Heavy Vehicle Simulator (HVS) [4]. At the core of this HVS as APT was the acceleration achieved by basically overloading the wheel and achieve acceleration of the road distress development via the aforementioned AASHO equivalency factor. The HVS prompted the development of numerous measuring equipment such as the Multi-Depth Deflectometer (MDD) [5], the Road Surface Deflectometer (RSD) (modified Benkelman beam) capable of measuring the whole deflection bowl under a dual wheel bogey. Other contact and later laser contactless devices followed (e.g., the profilometer). The art and science of forensic investigation via postmortem test pit profiling and material sampling also experienced further refinement and development.

The fleet of four HVS machines in the period 1978 to the early 1990s managed to apply more than 300 times more load applications on various types of roads in South Africa than what was applied in the AASHO test. The benchmarking of new pavement designs, innovative materials, analysis procedures, laboratory testing and material classification directly led to the development and verification of the first truly mechanistic empirical (ME) pavement design procedure in the world. The research efforts associated with the HVS were well documented and presented at international conferences and published in peer reviewed journal publications. Clearly the HVS technology package took a pioneering position in benchmark testing and analysis and the benefit cost ratios of research with the HVS were recorded as ranging from above 1 to nearly 20 [6]. The success of the South African Mechanistic Empirical Design Method (MEDM) helped and facilitated the development of other mechanistic empirical design methods in the world. The benefit of the leg up provided by the HVS APT testing is that the design method is now in the process of being overhauled, refined and improved. An atmosphere is again created for the development of the next generation APT device that can take benchmarked road and material knowledge even further forward.

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## Conflict of Interest

No conflict of interest.

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