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Ground-coupled radar database on samples of hot-mix asphalt layers

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1. GENERAL INFORMATION

This database was collected using several ground-penetrating radar (GPR) systems over hot-mix multi-layer samples, designed under controlled conditions. The experimentation campaign was conducted during the French research project ACIMP (ANR-18-CE22-0020), funded by the French National Research Agency (ANR). One of the project's objective was the detection of debonded asphalt layers. The database has been extended by hot-mix asphalt samples featuring varying tack coat dosages.

1.1. HOT-MIX ASPHALT SAMPLES DESCRIPTION

Different test specimens representing some initial structural layers of French roads have been created as benchmark for studying debonding using non-destructive testing (NDT) techniques such as GPR.

Two single-layer test specimens were produced to represent the wearing course and the binder course, compacted to 90% and 96% of the target density, respectively. Additionally, 16 two-layer slabs were constructed, comprising the wearing course and the binder course. These slabs had variations in the amount of tack coat applied between the layers and differences in the compactness of the two layers. All the manufactured slabs are presented in Table 1.

The construction of these test specimens was carried out using the MLPC plate compactor, a device that adheres to the French standard [EN 12697-33]. This standard enables the replication of road texture in the laboratory device known as "RETEX" [Hamlat et al., 2015]. The compactor is equipped with an adjustable-depth metal mold measuring 600 mm × 400 mm (in our case, 30 mm, 60 mm, and 90 mm), which allows for the creation of surface layers closely resembling real road conditions. The desired level of compaction is achieved through a twin-wheel system that moves longitudinally and transversely, following the guidelines set by the [EN 12697-33] standard.

All the aggregates utilized in the test specimens originate from the Carrières et Travaux de la Côte Vendéenne (CTCV) quarry situated in La Roche Guillaume, France. A total of over 800 kg of aggregate was employed for the entire production. The selected aggregates comprise a combination of rhyolite (a volcanic rock with a microlitic structure) exhibiting a dielectric permittivity ranging between $4.8 < \epsilon_{r_{\text{rhyolite}}} < 5.7$, and gneiss (a metamorphic rock) with a dielectric permittivity spanning from $4.9 < \epsilon_{r_{\text{gneiss}}} < 5.5$ [Araujo et al., 2016; Zheng et al., 2020].

Concerning the binder employed, it is a grade 35/50 bitumen, which signifies its viscosity changes across temperatures. This bitumen grade is commonly utilized in France, as per the standard [EN 12591]).

The wearing course utilizes Very Thin Bituminous Concrete (VTBC) with a targeted average thickness ranging from 25 mm to 30 mm. This particular mixture consists of a binder content of 5%. The particle size distribution ranges from 0-10 mm, with a gap between 2 mm to 6.3 mm. Regarding the binder course, a Semi-Thin Bituminous Concrete (STBC) mix design is employed, with an intended average thickness of 60 mm. The binder content remains also at 5%.

For the two-layer test specimens, the tack-coat comprises Emulpropre® bitumen emulsion containing 60% pure bitumen. This cationic emulsion exhibits rapid breakdown and is well-suited for the swift implementation of the bonding layer. The quantity of emulsion (no application: 0 gm^{-2} ; under-dosing: 200 gm^{-2} ; standard dosage: 400 gm^{-2} ; over-dosing: 600 gm^{-2}) and the level of compaction (low: 75% and high: 90% for the wearing course, and low: 91% and high: 96% for the binder course) vary within the two-layered test specimens. It's worth noting that during the construction of the two-layer samples, the VTBCs underneath the STBCs are compacted once more, resulting in a slight increase in their compactness.

Table 1 Characteristics of test slabs measuring 600×400 mm, featuring a targeted thickness of 30 mm for VTBC and 60 mm for STBC, under varying dosages of bituminous emulsion and compaction levels.

Name	Measured slab thickness (mm)	Binder course compactness (%)	Wearing course compactness (%)	Residual emulsion dosage (g/m^2)
P 01	87	91	75	0
P 02	91	91	90	0
P 03	89	96	75	0
P 04	89	96	90	0
P 05	86	91	75	200
P 06	87	91	90	200
P 07	90	96	75	200
P 08	84	96	90	200
P 09	90	91	75	400
P 10	88	91	90	400
P 11	89	96	75	400
P 12	93	96	90	400
P 13	91	91	75	600
P 14	88	91	90	600
P 15	93	96	75	600
P 16	93	96	90	600

P 17	60	96	-	-
P 18	30	-	90	-

The manufacturing protocol is meticulously adhered to, commencing with the categorization of aggregates by granular fraction through the use of series of sieves. Subsequently, the aggregates are rinsed, and their bulk density is assessed using a pycnometer in accordance with the [EN 1097-6] standard. Following a 24-hour period at 160 °C, the aggregates are blended with the heated binder until achieving complete homogenization. After compaction, the bitumen emulsion is administered using a non-fibered paint roller. The weight of the emulsion, the container functioning as a holder, and the application roller is measured to establish the tare. Taking into account the water content percentage in the bitumen, the appropriate quantity of emulsion is then applied to the bonding layer.

1.2. GPR DEVICES

Two GPR systems were employed during the experimental campaign:

- The SIR4000 GPR system, produced by GSSI, was used in conjunction with a 2.6 GHz impulse ground-coupled antenna. The setup parameters were as follows: 2045 sampling A-scans, a time range of 5 ns, and a spatial sampling of 2 mm.
- The GP8800 GPR system, manufactured by Proceq, operated using a stepped-frequency continuous wave method and was paired with a [400 – 6000 MHz] ground-coupled antenna. The setup parameters were: 655 sampling A-scans, a time range of 16 ns, and a spatial sampling of 5 mm.

1.3. ACQUISITION METHODOLOGY

The mono- and two-layer samples are positioned on a metallic plate prior to data acquisition. The standard arrangement entails placing the wearing course on top, while the reverse configuration involves positioning the binder course on top. These configurations allow for the collection of duplicated GPR data.

To simulate debonding, the wearing course (VBC) is placed over the other course (STBC) at varying elevations: 0 mm, 2 mm, 3 mm, 4 mm, and 5 mm.

The impulse GPR acquisitions were carried out along various longitudinal, transverse, and diagonal profiles, as illustrated in Figure 1. The L3G and L3D profiles are situated 30 mm away from the central profile LC. In terms of the transverse profiles, T3G and T3D are positioned 30 mm apart from the central profile TC, while T6G and T6D are separated by a distance of 60 mm. Finally, the diagonal profiles are designated as D1 and D2.

Regarding the SFR acquisitions, they were exclusively conducted along the central longitudinal and transverse profiles (LC and TC).

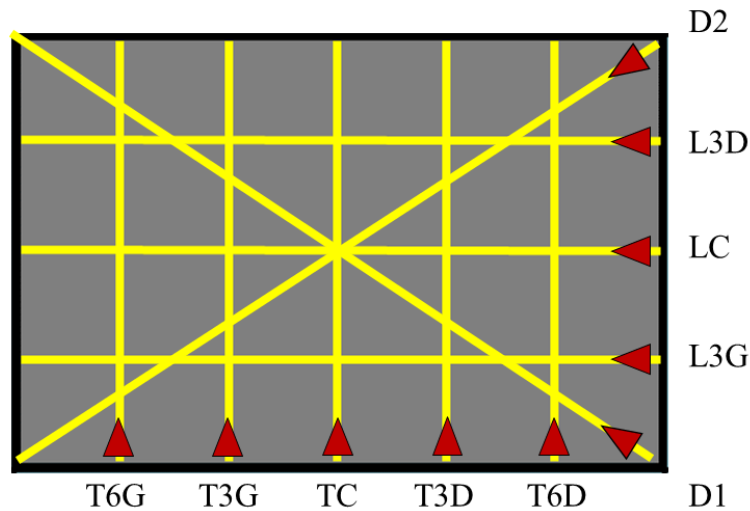


Figure 1. Strategy to collect the B-scans on the asphalt samples and file nomenclature

2. DATA PRESENTATION

The database comprises raw B-scan data collected for all the configurations outlined in the previous section (§1.3), utilizing the two distinct radar techniques. The database is organized into folder trees, with the first-level folders dedicated to each configuration. These folders are named as follows:

- /Pi/ or /PiR/ for the reversed configuration of Pi (STBC layer positioned above the VTBC layer) when considering the two-layer slabs (index I ranging from 1 to 16).
- For the debonded configurations, they are named as /VBC_STBC_X/, where X corresponds to the debonding in millimetres (0, 2, 3, 4, 5).

Within each configuration folder, two sub-folders house the GPR files, namely /Impulse/ and /SFCW/ respectively.

Lastly, the filename convention for each B-scan data file is structured as follows:

Config_Emission_Orientation.

where:

- Config: Pi or VTBC_STBC_X
- Emission: Impulse or SFCW
- Orientation: LC, L3D, L3G, TC, T3D, T6D, T3G, T6G, D1 or D2

The data are stored in a binary format for impulse acquisitions (with a .dzt extension), accompanied by a parametric file of the same name and a .dxt extension for the SIR4000 system. For the GP8800 B-scans, the data are in the conventional SGY format.

All the B-scan data can be visualized and processed using either custom-made softwares or commercial options such as RADAN for GSSI data, Proceq-GPR for Proceq data, or Reflexw from Sandmeier Geophysical Research.

CONCLUSION

The database is accessible to the GPR and road communities, and it can serve as a reference benchmark for developing and testing various processing techniques. These techniques can be focused on tasks such as detecting debonding, assessing tack-coat quantities, or evaluating levels of compactness.

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