The 6th European FWD User Group Meeting
Structural condition assessment
Belgian Road Research Center
Sterrebeek, on 10th and 11th June 2010

Dynamical analysis of FWD test on LCPC's Accelerated Load testing Facility

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This presentation in the 6^{th} European FWD User Group Meeting focuses on an evaluation of the dynamical time-domain modelling of Falling Weight Deflectometer results. This evaluation is realized by dynamical computations using the FEM Cesar-LCPC software. The computation results are compared to the FWD tests performed on the LCPC's Accelerated Loading Testing facility at Nantes, in France [1].

The multi-layer elastic theory based on the static modelling of the pavement structure and the simulation of the FWD impact by a static load has been used for more than thirty years. However, several research programs have been dedicated these last years to the interpretation of FWD results by mean of FEM dynamical modelling. It is certain that these dynamical approaches give more effectiveness to the simulation of the transient impulsive loading applied to the pavement. It finally leads to a more representative evaluation of the elastic modulus of the pavement layers by mean of back-calculation procedure.

Among other recent publications, the development and advantages of FWD dynamical analysis have been reported by Tu [2], Grenier [3], Picoux et al [4], and Broutin [5]. Although the encouraging results already produced, the evaluation of the FWD dynamical interpretation need still to be completed and several aspects of the computation procedures have still to be detailed, which has guided the present study.

The FWD signals that we used result from tests performed on the LCPC's ALT track, in the framework of the French national research project Recyroute [6]. The experimental track is composed of 8 different pavement structures designed for resisting to a cumulative traffic around 2 millions of the French standard 65 kN dual-wheel loads.

Seven structures consist in cement-treated recycled bituminous materials with or without metallic fibres (innovative structures). The eighth one is a conventional bituminous pavement used as the reference structure for this ALT experiment. This last structure consists in a surface layer with 3.5 cm thick of thin asphalt concrete and a base course with 12 cm thick of high modulus asphalt concrete. Both materials are in accordance with the European standard NF EN 13108-1. The subgrade consists in a 2.85 meters height compacted silty-sand. The whole structure and the subgrade are inserted in a waterproof concrete pit including a rigid raft at the depth of -3.00 meters. The main mechanical characteristics of the bituminous materials have been determined by laboratory tests (complex modulus and fatigue). The bearing capacity of the subgrade has been determined by dynamical plate tests (LPC Dynaplaque 2 and FWD tests) during the pavement construction.

The evolution of the structural behaviour of the 8 pavement structures with the traffic is followed up by mean of classical surface survey, strain-gauge and anchored deflectometer measurement, and FWD tests. Only one set of the FWD tests that were performed of the bituminous reference structure is presented and analysed in the present study. Simultaneously to the standard FWD signal acquisition, the deflection measured by the anchored deflectometer and the tensile strains measured at the bottom of the bituminous base course are monitored.

The numerical procedure used for the dynamical simulation of these tests is presented. We used the Cesar-LCPC FEM software [7]. The dynamical module implemented in Cesar-LCPC allows taking into account a time dependant loading (applied force or initial speed), the inertia forces in the whole structure, and the material damping assimilated to Rayleigh damping with mass and stiffness coefficient constant for all materials.

Two types of dynamical treatment are performed: the first one (MD1) includes the simulation of the real falling of the mass, which is taken into account by the vertical mass speed when the shock occurs. The second model (MD2) does not simulate the falling of the mass, but it considers the temporal vertical force signal measured by the FWD load cell device as the loading input for the FEM model.

The back-calculated elastic moduli resulting from both classical static analysis procedure and the dynamical one are compared, in regards to the values determined by direct laboratory tests (complex modulus) and bearing capacity tests. The temporal force and deflection signals given by the FWD measurement device and the numerical simulations are also compared.

The main conclusions of this study as follows:

- Temporal deflections signals provided by the FWD geophones and LCPC's anchored deflectometer are very similar.

- Dynamical modelling MD2, which simulates the falling of the FWD mass by mean of the initial speed of the mass when the shock occurs leads to a maximum force value and a signal period very close to the measured ones.

- However, the sinusoidal shape of this computed force signal doesn't reproduce exactly in detail the real force signal. Probable reasons of this discrepancy may be the linear-elastic behaviour of bituminous materials and subgrade considered by the computation, neglecting their real viscoelastic and/or elastoplastic behaviour. The same remark applies to the simulation of FWD rubber buffers and pads. The hypothesis of the same Rayleigh damping parameters for all materials may be also questionable.

- The two dynamical MD1 and MD2 deflection signals are in good accordance with the measured ones. The computed strains are also close to the measured values.

- For the two bituminous materials and the subgrade, the back-calculated moduli resulting from the usual static multi-layered model and the dynamical approach are weakly close. The dynamical modelling leads to significantly more realistic modulus values. In particular, the backcalculated moduli for bituminous materials are significantly better correlated to the values predicted by the complex modulus provided by the laboratory tests, considering to the temperature and to the frequency of the FWD test.

- Finally, it can be concluded that the analysis based on the time-domain dynamical approach allows a better valorisation of the whole data provided by the FWD test. This dynamical analysis leads to a more realistic characterization of the residual rigidity of the structure. Although these promising results, improvements of the Cesar-

LCPC modelling should be made yet, in order to provide a better simulation of the pavement material and subgrade behaviour.

References

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