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INNOTRACK

Integrated Project (IP)

Thematic Priority 6: Sustainable Development, Global Change and Ecosystems

Deliverable D2.1.2

Adapted "Portancemetre" for track structure stiffness measurement on existing tracks

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PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
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Glossary

Abbreviation / acronym	**Description**
CECP	Centre d’Etudes et de Construction de Prototypes, division of CETE NC
CER	Centre d’Expérimentations Routières, division of CETE NC
CETE (NC)	Centre d’Etudes Techniques de l’Equipement (Normandie-Centre)
LCPC	Laboratoire Central des Ponts et Chaussées
A0	Theoretical displacement amplitude of vibration of a compactor (=me/M0)
A	Real displacement amplitude of vibration (half of the peak to peak displacement of the drum during vibration)
E	Elastic modulus of a platform
f	Frequency of vibration
FTA	Total applied force to the soil by a vibratory compactor
k	Stiffness
me	Eccentric moment of the vibration shaft in a compactor
M0	Vibrating mass of a compactor
M1	Static mass applied to the soil by a compactor
W	Moisture content of a soil

1. Executive Summary

The CETE NC, associated partner to LCPC, is involved in the design of a demonstrator for continuous track stiffness assessment. From an existing method called “Portancemetre” for platform modulus assessment, a technology transfer has been studied for application on rail tracks.

Technical characteristics have been defined from a feasibility study on a re-created track. Per rail, a minimal static force of 5000 daN and a dynamic one between 1500 daN and 4500 daN is a correct dimensioning to obtain the stiffness of the track, influenced by ballast and subgrade properties.

A validation test on a real shunt track near Paris with a vibrating roller having parameters approaching those expected for the demonstrator, and equipped with an innovative device for continuous variation of amplitude and calculation of stiffness, on this site 85 kN/mm, has shown that a vibration amplitude in the range 0.2 to 0.4 mm is able to perform the specifications in dynamic forces.

A version 1 demonstrator has been designed as an active axle with vibrator boxes in phase over the two rails, with separate treatment of measures. Logistics consists in transporting by road the demonstrator in kit elements and assembling them near each test site.

However, some difficulties more important than expected have occurred: the safety regulations to obtain railways agreement before doing the tests on real tracks are not easy to integrate in the demonstrator. A towed axle couldn’t be authorized to roll, even just for demonstration. Consequently, different contacts with railway establishments and manufacturers have been taken to design a demonstrator version 2 with a specific frame enclosing the active axle. This stage is in progress as well as the study of incidence on costs which may raise of 10 to 30% for the equipment, and on logistics to reach and to assemble the demonstrator on the tests sites.

The deliverable describes the activity done between September 2006 and July 2007.

2. Overview of the stages of development until august 2007

September-November 2006	Use of the study of feasibility (described in § 3.2 of the present deliverable) to establish demonstrator version 1 specifications (in § 5.1) and treatment of measurements (§ 6.6).
October 06-February 2007	Design of demonstrator version 1 (§ 5.2) on the basis of specifications and of the Munich short presentation (schemas) at SP2 meeting in November 2006
January 2007	First questions about demonstrator agreement for moving on real test track sites. The version 1 is not safe enough.
February 2007	Propositions for assessment on test sites (document in Annex 4, for SP2 meeting in Paris)
February-March 2007	Validation tests (described in § 4) on a real track with a vibratory compactor having variable parameters in the range of the demonstrator, and an electronic device to calculate the stiffness, allowing to precise technical specifications in vibration amplitude.
February-July 2007	Research of conditions to be agreed on real tracks (§ 5.3 and Annex 3); new hypothesis for the demonstrator (§ 5.4), work on a version 2 (§ 5.5), safer but more complex with an active axle and two small axles.
July 2007	preparation in supplying components: axle, power group, vibrator box, and continuation of studies of version 2 for agreement and logistics (road transfers of the demonstrator in kit elements, means of assembling on sites). Internal review of the next part of program, and timetable (§ 6)

Annex 2 of the present document gives a more detailed journal of the Task 2.1.5 actions done by CETE NC, with the dates of meetings.

3. Feasibility of a rail track stiffness measurement apparatus

3.1 Reminder of existing application on platforms

The construction of a road or a rail track platform has density values to be obtained on embankments, and also bearing capacity criteria at the end, to ensure good performance of road-base layers or subballast/ballast layers.

Some recent improvements in reception methods allow offering continuous methods like the "Portancemetre" one, with the advantage of a better surface covering than the local tests by loading on a plate.

3.1.1 Requirements on platforms

In France, 50 MPa is the minimal value of modulus specified on platforms, and higher values are often expected (80; 120 or 200 MPa), to save materials in road-base layers. The dimensioning of the road layers may be lower when a durable modulus of platform can be established.

In railway platforms for construction of new high speed lines, different specifications exist from one country to the other, depending of the methods and standards used. In France, minimal values between 80 and 120 MPa in Ev2, Dynaplaque, or Portancemetre are specified on capping layers and subballast layers. But in the domain of old lines, there are no particular specifications. This point has to be studied when some measurements through the rail and ballast could be obtained with the new continuous method, and especially regarding weak points.

3.1.2 The "Portancemetre" method

The "Portancemetre" apparatus (fig 1) is a rolling vibrating wheel. The parameters in masses, frequency and vibration amplitude have been studied to measure modulus in the range 30 to 300 MPa. It controls every meter length, and is able to make about 15 km of measurements a day.

Figure 1 – The "Portancemetre" apparatus

The main parameters are:

- static mass on the soil M1: 1 000 kg
- dynamic force applied to the soil: several times M1 x g, depending of the modulus of the platform
- amplitude of vibration: 0.5 mm
- frequency: 35 Hz
- inspected depth under the surface: 0.60 m
- rolling speed: 1 m/s (3.6 km/h)

The measurements consist in a real time calculation of the stiffness k, from sensors mounted on the apparatus. A calibration between stiffness and modulus E by plate tests (AFNOR NF P 94 117-1) has been experimentally found:

E (MPa) = 5.26 x k (kN/mm),

allowing to compare the results to the specified modulus of platforms.

A more complete description of the principle with schemas and example of results is given in Annex 1.

The method is used on road and rail track platforms in France, Spain, Portugal [1], [2], [3], [4], and other documents to be published soon: guide for users, articles with examples in France and in Portugal.

The transfer technology and adaptations to measure continuously the stiffness on a rail, to assess the characteristics of ballast and subgrade under the track, has been then experimentally studied, and is explained hereafter.

3.2 Feasibility study on a rail track

The study of feasibility has a complete description in the thesis ref. [5]. In this chapter, only the main results are presented.

The thesis contribution can be summarized in detail as follows:

- Study a new method and vehicle for continuous method to measure the dynamic vertical track stiffness.
- Dynamic excitation through a hydraulic jack and also the Portancemetre apparatus described in section 3.1.
- Excitation of the test track with arbitrary sinusoidal frequencies between 5 and 35 Hz while simulating the rolling condition and calculate corresponding dynamic track stiffness.
- Excitation of the test structure in two different conditions: new ant old, by reducing the track stiffness to simulate the fatigue situation.
- Presentation of dynamic track stiffness magnitude as a function of both applied force and frequency, in order to calculate the optimum combination.
- Presentation of maximum vertical displacement as a function of both applied force and frequency, to detect the resonance phenomena and dynamic behaviour along the track.

3.2.1 Objectives

At the present time, the most important inspections are track geometry measurements. The aim of the study is complementary to determine the root cause of problems or to conclude how changing of traffic conditions will affect the track. In this way, it is assumed that stiffness inspections may enrich track diagnosis and optimize maintenance programs.

The action depth of stiffness measurements is a major criterion. When an old track has to be repaired, it is considered that not only ballast has got poor characteristics, but also a part of the subgrade. A minimum

0.60 m under the sleeper has to be "seen" by the continuous method, through the rail. The feasibility study is done to point out the suitable parameters of excitation for this purpose.

3.2.2 Conditions of the experimentation at CER

A railway structure has been reconstructed in a test site of the CER under specific dynamic stresses carried out mainly by means of a gantry of loading (fig 2) and Portancemetre to variable parameters (forces obtained < 20 kN and possibilities in frequencies between 15 and 35 Hz). It is a full-scale size of a classical railway structure, completely instrumented in order to measure the various parameters.

The maximum applied loads to excite the structure by the hydrodynamic jack are in the range 10 to 75 kN and in a frequency range 5 to 35 Hz. The various combinations of force-frequency parameters, larger than for Portancemetre, allow testing the capacity of assessment of the dynamic stiffness of the structure. Three different points of applied loading are selected (fig 3): right over a sleeper (A), in halfway between two sleepers with good conditions of coupling ballast-sleeper (B), and right over a sleeper in a case of non-contact between sleeper and ballast (C).

Two subgrade moisture situations are studied for the series of the tests: the normal moisture content conditions to propose the higher stiffness value and the fully saturated structure to simulate the weak stiffness after a long period of service.

Figure 2 - Hydrodynamic jack and the gantry of loading

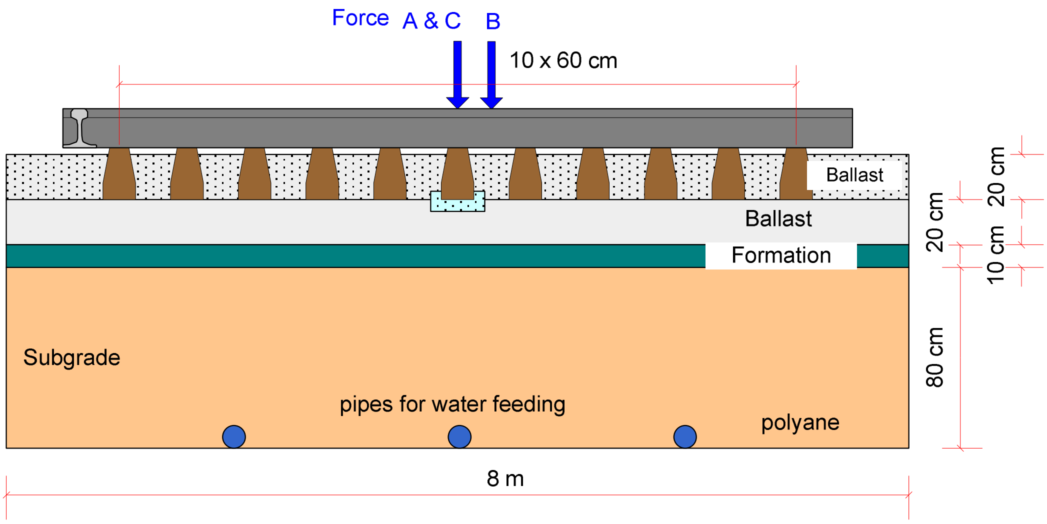

Figure 3 - Schematic sections of the structure

3.2.3 Material characteristics

The standard proctor dry density of the silty sand (10.8 % < 80 µm) of the subgrade was, $\rho_{dOPN} =$ 1.86 kg/m^3 at W_{OMC} = 9.3 %. This material was classified as B2 type according to the French standard [3]. The average water content during the compaction was about 6.4%, which corresponded to a dry state.

The UGM formation layer was a 0/31.5 entirely crushed quartzite (LA= 20, MDE= 3.4) with 5.6% of elements < 80 µm, whose modified proctor dry density was, $\rho_{dOPM} =$ 2.23 kg/m^3 at $W_{OMC} =$ 6.7%.

The ballast was of the class 31.5/50 mm and conforms to SNCF specifications for the LGV (High Speed Track) according to XP P 15/545 article 12. The geotechnical and mechanical properties of the material are resumed in Tables 1 and 2.

Table 1: geotechnical characteristics of the materials

Material	Thickness (cm)	W (%)	Wet density (t/m3)	Dry density (t/m3)	Compaction rate (%)
Silty sand	80 (*2*)	6.4 (*0.3*)	1.94 (*0.03*)	1.82 (*0.02*)	96.8 (*1.2*)
UGM gravel	10 (*2*)	4.63 (*0.45*)	2.17 (*0.04*)	2.11 (*0.09*)	94.5 (*4.0*)

Table 2: modulus of the different layers measured by different methods

Layer (Material)	Test EV2* (MPa)	Dynaplaque 2** (MPa)	Portancemètre (MPa)
Subgrade (silty sand)	78.6 (*15.5*)	73.1 (*7.7*)	79
Formation (gravel 0/31.5)	92.7 (*9.1*)		

- *The values in the parentheses are the standard deviation*

* EV2: Static plate bearing (loading) test (French Standard, NFP 94-117-1)

** Dynaplaque 2: Dynamic deformation modulus (French Standard, NFP 94-117-2)

3.2.4 Definition and calculation of track stiffness under hydrodynamic excitation jack

In the time domain, track stiffness (k) is generally defined as the ratio of track load F(t) and track deflection d(t) (Equation 1) in the linear part of the rising phase of the load. It is a function of frequency as well as of load. If track stiffness is studied in the frequency domain, the track receptance, α(f) or dynamic flexibility is preferable, which is the inverse of the dynamic track stiffness, and is often displayed with magnitude and phase.

$$k(t) = \frac{F(t)}{d(t)} \qquad (1)$$

The next figure displays a force-deflection diagram where the rail is loaded to 50 kN while the corresponding deflection is measured. Nearly every time, the curve is non-linear with a damping factor (hysteresis). In simplifying, the stiffness is often considered as a constant, which may be not valid in the certain cases of force-frequency. However, in order to use the concept of transfer functions, we assume that the system is linear in a limited part of the rising phase of the force-deflection diagram between 0.3 F_{max} to 0.9 F_{max}.

3.2.5 Type of results with the hydrodynamic jack

For evaluating the total dynamic stiffness of the structure, the various types of force-frequency have been selected with the hydrodynamic jack. The maximal forces were 10, 30, 50 and 75kN and the frequencies varied between 5 and 35Hz by intervals of 5. Before executing each experimental mode, the structure undergone a stabilization phase by generating a 500 000 loading cycles, with a force of between 20 and 50 kN at a frequency of 35 Hz.

Vertical track stiffness (k) can be defined as the ratio between track load (F) and track deflection of the rail (z) as a function of time (t), where can be state as: k(t) = F(t) / z(t). The z(t) is measured on the rail at the place where the cyclic load is applied by laser equipment.

Generally, the different parts of the track may be more or less non-linear, as for example the pad and soils. In many cases the sleepers can also have voids beneath them, which lead to a larger deflection with low load as compared with the normal sleeper with good connection with the ballast. One common definition, that may cover these cases, is the secant stiffness that can be calculated between two predefined force limits. In our study these boundaries were adjustable based on the maximum force and have been selected between 30 and 90% of the maximum force by a linear regression, fig 4, [5].

As explained above, the prepared structure was tested under two moisture content situations called dry and wet. The dry situation is referred to the normal moisture content just after the construction which indicates the high track modulus. The wet situation represents the low track modulus that has been made by artificially degrading the modulus by watering the subgrade under controlled conditions. Figures 5 to 9 show the typical result of two series of the tests for both wet and dry conditions and for different force – frequency combination [5].

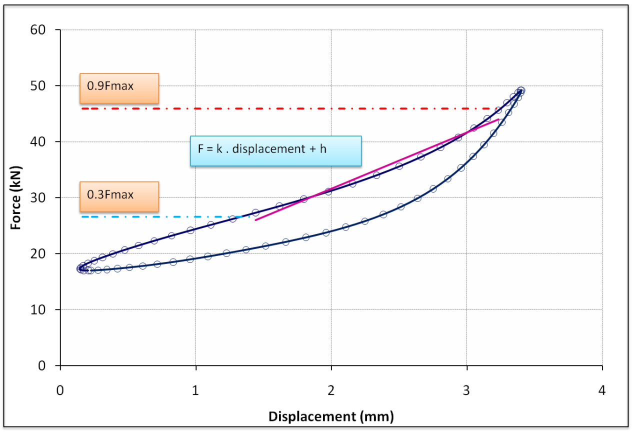

Figure 4 - Typical calculation of stiffness

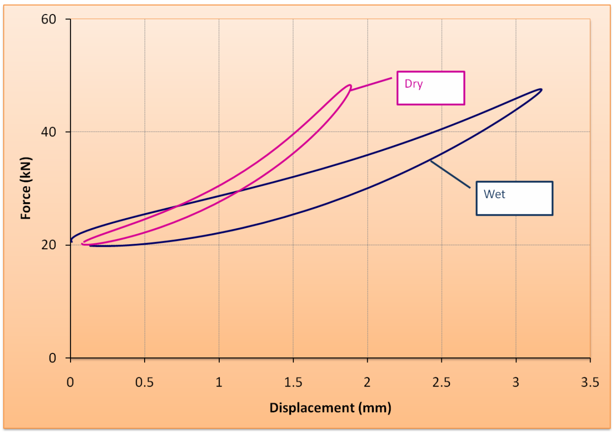

Figure 5 - Typical example of force – displacement curve for both dry and wet conditions of subgrade

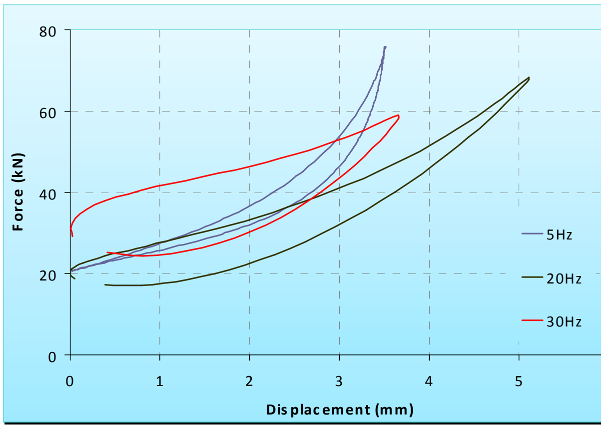

Figure 6 - Example of force – displacement curve for different types of vibration frequencies

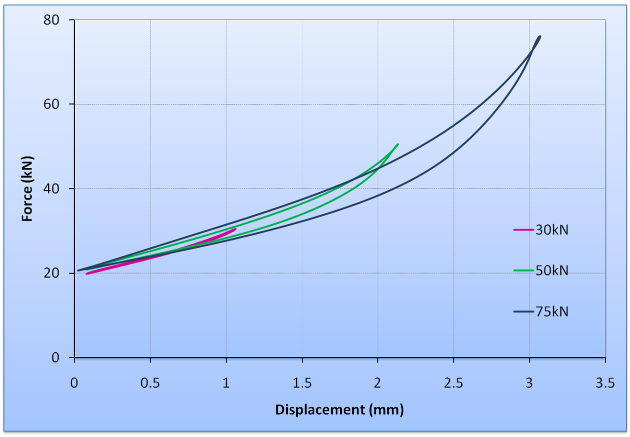

Figure 7 - Example of force – displacement curve for different levels of forces

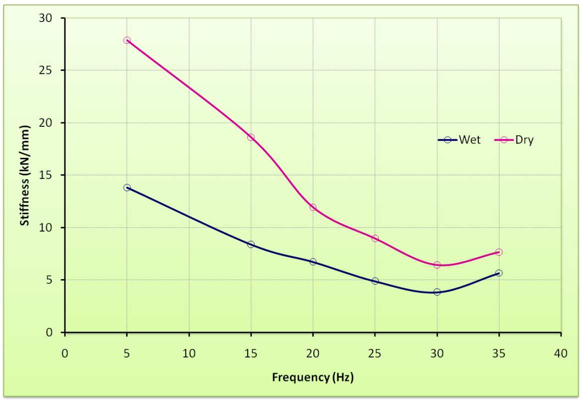

Figure 8 - Variation of stiffness versus the frequency for both dry and wet structure

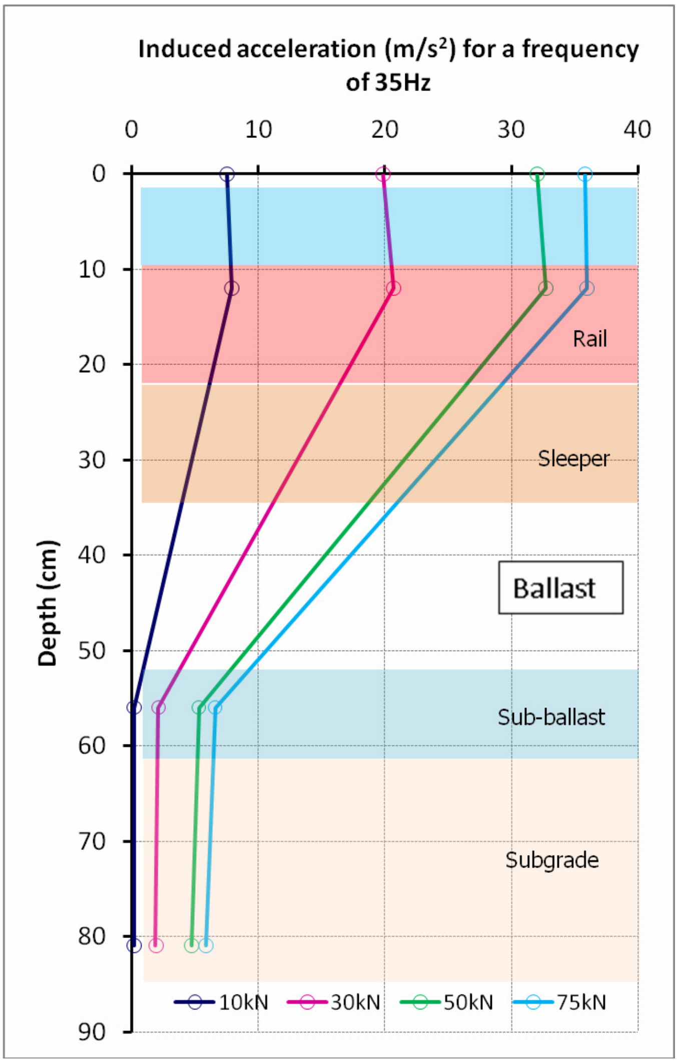

Figure 9 - Example of acceleration distribution in the structure for different loading forces

3.2.6 Synthesis

Full scientific developments of results obtained with the hydrodynamic jack and the road Portancemetre on the experimental rail track structure are given in the thesis. Figure 10 represent the pair values of stiffness-amplitude. The blue points are the results of various modes of force-frequency combination obtained by the gantry of loading: track stiffness (the values in blue, in kN) and peak to peak amplitudes (the values in red, in mm). These results show the average values of four repetitive series of tests for each mode. We have also simulated one excitation mode proposed by the author of RSMV and the existing Portancemetre for road application. The results of Portancemetre (the values on yellow background) and the result of RSMV-type (the value on blue background) are also added in the figure. All tests have been done in stationary points.

The study shows that the minimum operational exciting load is about 50 kN and there are different behaviours on different frequencies. So by resuming the results we obtained some criteria for load and frequency combination represented in the figure. Practically, from fig 10 where the quantitative elements: calculated stiffness and real amplitude at each combination force/frequency of the loadings, and qualitative observations during the tests are synthesised in this thesis [5]:

- the current Portancemetre used on platforms is too light for a railway track application over the rail

- a total dynamic load about 50 ± 30 kN (static load of 50 kN plus a dynamic load of 30 kN), must be applied to get significant influence from the subgrade
- a maximum amplitude A0 = 1.2 mm, possibly decreased till 0.5 mm, is sufficient to obtain these dynamic loads
- the resonance phenomena in amplitude between 20 and 30 Hz should not be used (red zone). Exciting frequency from 5 to 20 Hz is correct (green zone on the left),
- the second allowable range of frequency (green) is greater than 30 Hz, but the calculated stiffness is less than the values obtained from low frequency.
- the response signal is exploitable and repeatable in the adapted parameter zone,
- the validation of vehicle parameters and the influences of the running speed will be verified in the continuation of this study

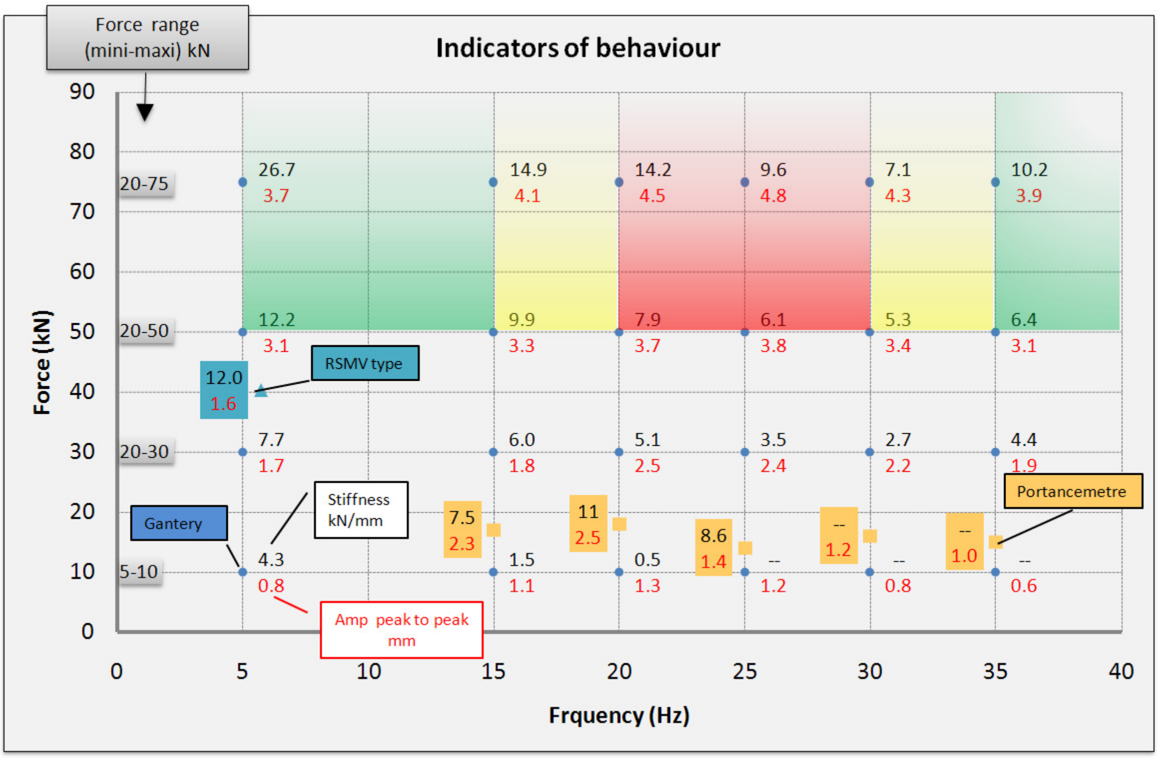

Figure 10 – Synthesis of the results

4. Validation of the feasibility study on a real track

The aim of the validation on a real track is to verify that the characteristics of the demonstrator, defined at the end of feasibility study in § 3.2, are the right ones, or eventually should be adjusted, according to possible differences in the behaviour between the re-created track in the feasibility study and a real one.

These differences may be caused by:

- feasibility tests done at one place without rolling,
- use of a track section with wooden sleepers,
- ballast in rather good conditions after the 500 000 cycles of pre-loadings for the stabilization before tests.

In fact, the values of stiffnesses obtained during the feasibility study, which don't exceed 20 kN/mm, seemed to be significantly lower than the values of expected current stiffnesses.

4.1 Choice of the equipment

The method used to exert cycles of loadings similar to those of the future demonstrator is a vibrating roller (fig 11) equipped with an innovative device ACE (Ammann Compaction Expert) having on one hand possibilities of continuous variations of amplitude and frequency parameters, and on the other hand automatic calculations of the total applied force, and of the stiffness.

Figure 11 – The vibrating roller Ammann ASC 110 on the shunt track

The characteristics of the compactor are:

- Mass on the rails M1 = 7 100 kg,
- Theoretical amplitude A0 variable between 0 and 1.85 mm,
- Frequency variable from f = 16 Hz to 35 Hz

The mass M1 is approaching the 10 000 kg expected for the demonstrator, and the amplitudes covers more than the range studied in the feasibility study. Frequency is limited in low values due to hydraulic transmission for vibration power.

4.2 Tests and results

The track is aside the main tracks Paris – Strasbourg, at Chelles, about 20 km from Paris. It is a track with monobloc concrete sleepers and U36 rails; the ballast thickness seems to be poor. A section of 20 meters is chosen for the tests.

The compactor passes several times on the section at 1 km/h, with different values of amplitude A0 first in the range 0.2 mm to 0.5 mm, making also variation in frequency in the range 16 - 35 Hz, and secondly with higher amplitudes A0 until 1 mm, but in this case only at the minimal frequency, in order to avoid disconnections between cylinder and rails. The real amplitudes may be 1.5 to 2 times A0 value, due to resonance frequencies (from about 20 Hz at A0 = 1 mm to 26 Hz at A0 = 0.2 mm).

The total applied forces raise with A0 and also frequency (fig 12), that is for the frequency a result a little bit different than on a soil structure. It is considered that a force higher than 2 times M1 x g (140 kN) induces disconnections and is not in the right domain for our objectives, in maintaining the contact with the rail.

The upper limit on A0 is therefore 0.5 mm for that condition.

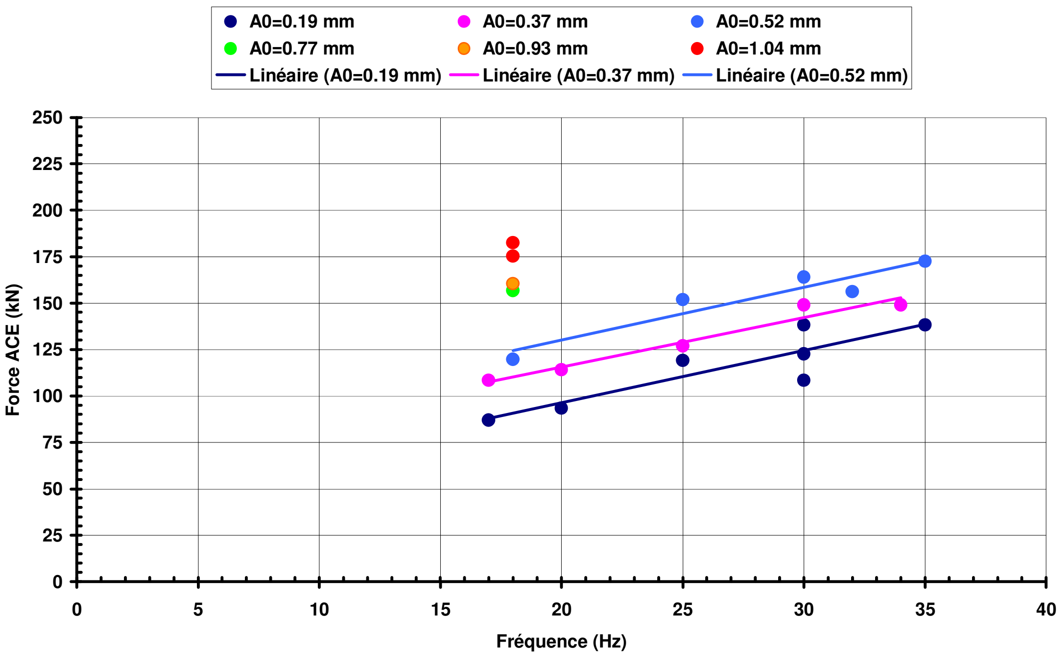

Figure 12 – Force ACE (maximum) applied to the 2 rails

The calculated stiffness is non-significantly dependant of the amplitude and frequency modalities (fig 13). This result is interesting to manage the future vibratory parameters. The average value of stiffness, which is about 85 kN/mm, confirms a more stiff structure than in the feasibility study at CER.

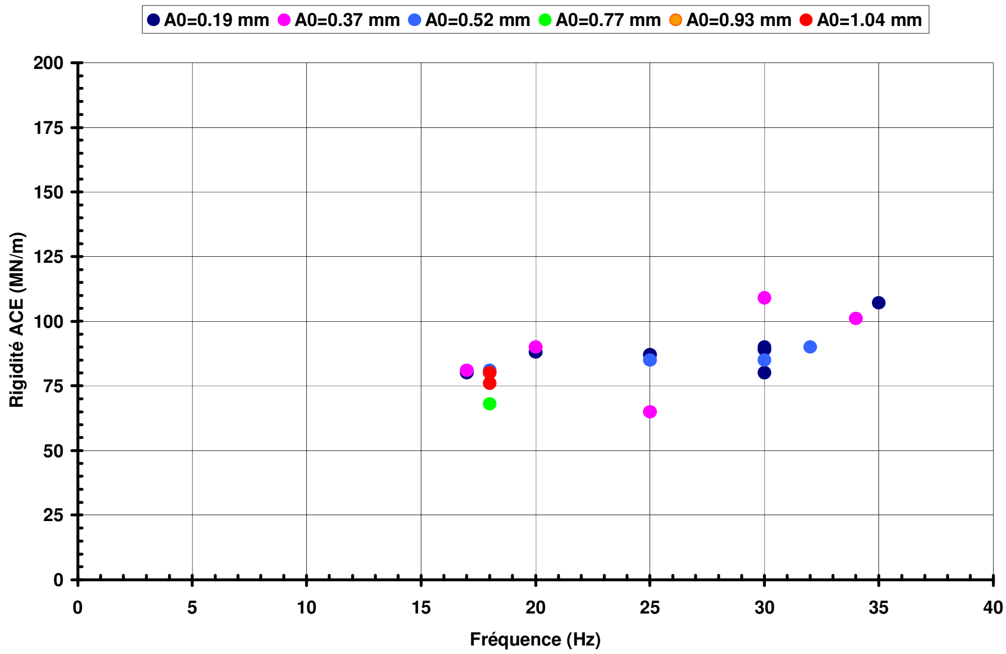

Figure 13 – Calculated stiffness ACE for the different A0, f modalities

In conclusion of these tests are, the validation of stiffness measurements by means of a vibrating wheel is established. However, the behaviour on a real track leads the design of the demonstrator to be adjusted with lower theoretical amplitude A0, in the range 0.2 to 0.5 mm, than previous in the feasibility study, to obtain suitable dynamic forces without any disconnection from the rail during cyclic loadings of the vibrating wheel.

5. Design of a demonstrator for rail-track measurements

5.1 Initial specifications (September 2006)

The main characteristics of the demonstrator are defined on the following basis:

- **Objective 1** circulation in safe conditions on the test rail track sections of classic lines in Europe (UIC regulations), after interception of traffic.
- **Objective 2** transfer of kit elements by road near the test sections, quickly assembling in place on a shunt track, and moving by an existing rail machine.
- **Objective 3** solicitation of the track with suitable parameters, simultaneously on the two rails.
- **Objective 4** measurements made on test sections, within periods of interception, and treatment of results at the end of each campaign. The test sections are supposed to be 20 km length maximum, and situated near a shunt track.
- **Objective 5** use of the demonstrator only in the frame of the INNOTRACK project, to show the capability of continuous stiffness measurement on the tracks and to obtain from the results a project of test method. The time life is consequently a few days of measurements.

The indicative criteria for objective 2 are to be able to assemble the demonstrator from the platform aside the shunt track, in no more than 4 hours.

The parameters for objective 3 are:

Static load applied to the rail track: mini 10 000 daN (5000 daN per wheel); maxi 11000 daN

Range of dynamic load per wheel around the static load: mini 1500 daN; maxi 4500 daN

Total applied load per axle during vibration: maxi 20000 daN

Frequency of vibration: mini 5 Hz; maxi 35 Hz

Travel speed during tests: maxi 30 km/h

Location by PK references and detection of sleepers when measuring.

5.2 Design of the version 1 (October 2006-February 2007)

From the experience on road platforms, and according to the conclusions of the feasibility tests, the first draft of the rail track demonstrator is designed as a technology transfer from the road apparatus "Portancemetre", with a new set of vibration and mass parameters.

A towed machine mounted on an axle, loaded by steel pieces, and equipped with a vertical vibrating box on each side is imagined (fig 14).

The vibrating mass beholds the axle, the beam on the bearings and the vibrators (total about 4 000 kg).

The unsprung mass is constituted of the frame and several steel pieces, each one of 1 300 kg (total about 6 000 kg).

The vibratory boxes are vertically excited, powered by electrical or hydraulic systems. To obtain the level of dynamic forces in § 5.1, which depends on the stiffness, it is assumed from the feasibility experiment in § 3.2 that a maximal amplitude of 1.2 mm is sufficient (validation tests on real tracks of § 4 are not yet done at this time). A lower value of about 0.5 mm may be expected after.

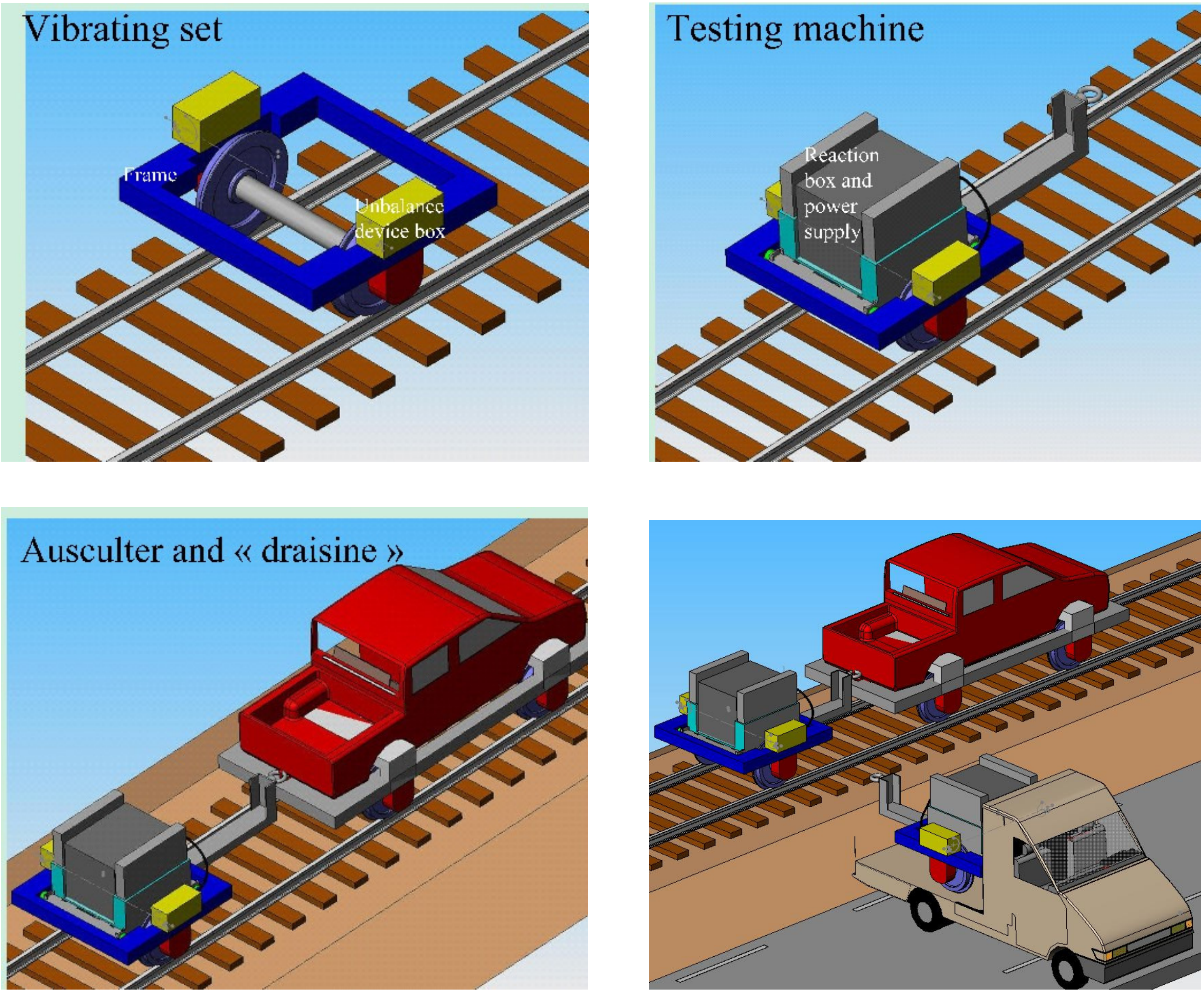

Figure 14 – Schema of demonstrator version 1: kit assembling, moving, and transfer by road

5.3 Critical aspects of agreement with safety regulations (February-June 2007)

With the principle of machine described above, a discussion has been attempted just after the SP 2.1 meeting in Paris, on February 21st, with the person in charge of agreement at the Infrastructure Department of French railways, to know how the regulations interfere with the headlines of the project.

No technical assistance can be obtained in this way, the Department having a procedure consisting in examining a detailed project, at the end of design, to pronounce the agreement. At this stage, the particular case of a demonstrator used a few days doesn't change any consideration about the examination.

As it is not the current job of Laboratories of Ponts et Chaussées to know the rail track regulations and to form the documentation for agreement, several contacts have been taken with rail track companies:

SECORAIL; to have a better view of track maintenance operations, locos and specific equipments rolling on rails, capacities of loading shovel, etc.

GEISMAR; in his manufacturer role, to benefit from their experience in preparing documentation for agreements, and expecting some convenient solutions for the project.

The journal of this is in Annex 2. In the same time, the standards concerning the requirements have been obtained and consulted.

At this stage, it appeared that the version 1 would be rejected. A towed single axle vehicle is unusual on rails; a doubt concerning the risk of leaving the track during assembling phase, or in case of disconnection from the loco, is existing.

The problem encountered has been analysed. Several points bring unforeseen difficulties:

- the delay to have a demonstrator ready for tests may be longer than expected if a long time for agreement examination occurs,
- the cost of equipment may also raise over than previous if some additional functions have to be implemented, like self braking system on the demonstrator.
- the ratio between high level requirements to build the apparatus, and low duration in demonstrations appears like a contradiction.

However, it is considered that the safety conditions must not be altered during the tests. So, the hypothesis for the demonstrator specifications has to be reconsidered.

For that purpose, an investigation (Annex 3; in French) containing detailed questions about logistics (available means on sites) and possible configurations of the demonstrator has been sent in April to the SP2 task leader.

Another possible re-orientation of the tests with the demonstrator could be to keep the version 1 and to test it on experimental rail track structures at CEDEX, as V. Cuellar kindly proposed it. However, in this case, some disadvantages have pointed out, like limitations in distance and in spatial variability of stiffness, perhaps difficulty to ask other methods to come at this place for comparisons. So, it has given preference to try to join the tests on real tracks, with some acceptable modifications of the design in a version 2.

5.4 New hypothesis for track measurements (June 2007)

From the different contacts and analysis above, and despite no response to the investigation on logistics and configuration, a specific meeting has been held on 12/06/2007 with the Direction de l’Ingénierie SNCF. The following solutions have then been identified:

- the axle for measurements must be enclosed by a frame on two small axles, to ensure the stability even when the connection with the loco may break off. This frame can’t be made of an old wagon, because of necessity to modify the chassis, and then difficulties for agreement.
- The demonstrator is not equipped with a self braking system (however, is not completely certain to maintain this hypothesis for agreement).
- The demonstrator, because of the previous condition, is always towed in the middle of a composition between two braked machines during the tests.
- The speed is limited to 15 km/h.
- The test sections are either on a single track intercepted, or on a multiple track on which the test track and also the track aside are intercepted.
- The vibration excitation doesn’t risk in any conditions to induce absence of contact between the wheel and the rail during a fraction of the period of vibration, in order to avoid the presence of a specific device to maintain the wheel in contact.

All these conditions aim to obtain the agreement on the basis of a design document, without any preliminary physical tests, if possible.

5.5 Design of the version 2 (June-August 2007)

The hypothesis in § 5.4 lead to a new concept of the frame (fig 15), in which the “heart” of the apparatus is similar to the one in version 1, with however some benefits in vibration characteristics coming from the validation of feasibility study on a real track (§ 4).

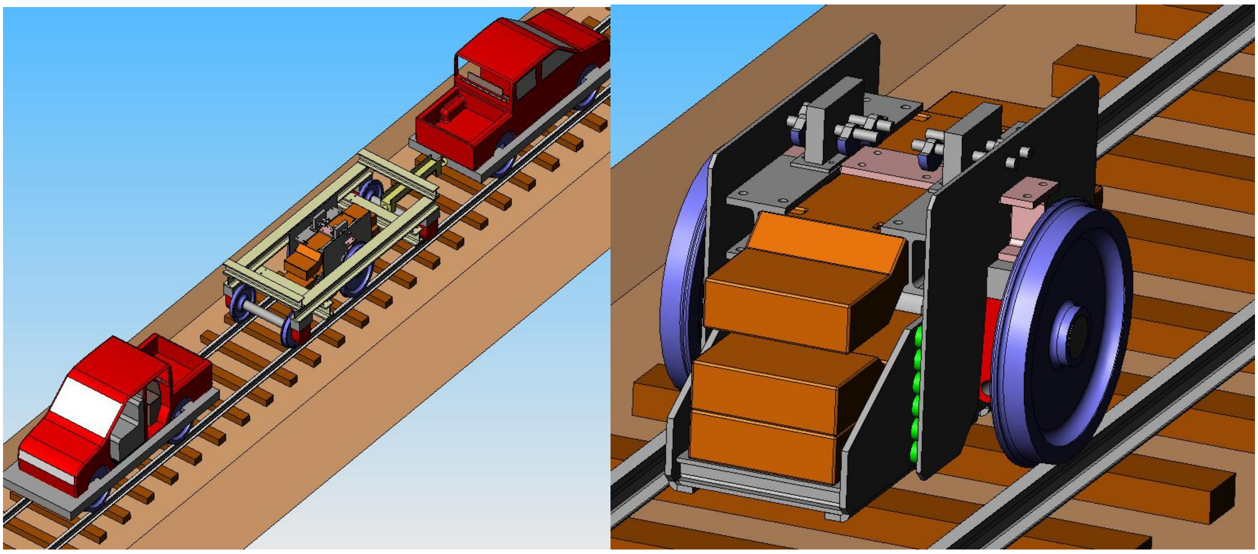

Figure 15 – Schema of demonstrator version 2: active axle; frame between 2 locos

The characteristics of the demonstrator version 2 are:
Static load applied by the active axle on the rail track: 5400 daN on each side (tot. 10800 daN)
Range of dynamic load per wheel around the static load: mini 1500 daN; maxi 4500 daN

Decomposition of masses:
- vibrating mass M0 (wheels + axle + beam + vibrator): 5500 kg
- unsprung mass on active axle: 5500 kg
- mass on each axle apart from the active axle: 1250< Mx < 5500 kg
- total static mass of the demonstrator: 13500< M_{tot} < 22000 kg

Eccentric mass of each vibrator (nb = 2): me = variable from 0.6 to 1.16m.kg
Theoretical amplitude of the vibrating mass: A0 = variable from 0.21 to 0.42 mm (= 2 x me / M0)
Frequency of vibration: f = variable up to 30 Hz

Wheelbase between extreme axles: 4.8 m max.
Maximal length: 8 m

The demonstrator is supposed to circulate on shunt tracks with curvature radius not inferior to 80 m

5.6 Treatment of the measurements (November 2006)

The principle is to have continuously the values of stiffness on each rail, separately, and to locate the position of the apparatus during measurements.
Each side has a set of sensors and its own treatment process with computers PC1 and PC2:

- one accelerometer on the vibrating mass,
- one accelerometer on the unsprung mass,
- one phase sensor between vibrator box and wheel vibration,

from which the calculations of dynamic vertical force and displacement are done, like in the Portancemetre method (§ 3.1). The rising branch of the loop force-displacement gives the stiffness (fig 4). However some additional criteria of calculation to the one of Portancemetre (average value of stiffness between 30% and

90% of the maximum level of force) may be used, especially if a non-linearity is existing with the level of force (example: value of stiffness between 60% and 90% of the maximum level of force). This would be studied during the campaign of tests.

A camera and a distance coder are able to detect the position of sleepers for:

- selection of stiffness calculations at some precise points when rolling (i.e. above or between sleepers),
- location of results versus distance in PK.

A PC Supervisor will manage all the treatment functions during the measurements.

After the tests, interpretation of results are performed with a computer program indicating variations of stiffness versus distance and locations of weak points

6. Following steps of the project

6.1 Agenda for end of design, assembling, and reception tests

6.1.1 End of design in detail (July September 2007)

In mechanics, some points have to be studied:

- the connection between the active axle and the beam supporting the vibrators (the “heart”):
  the type of axle with internal bearings has been found in a locomotive workshop near CETE – wheel diameter 1100 mm; one model would be soon in possession of CECP .
- the elastic bond between vibrating mass and unsprung mass:
  resonant frequency must be inferior to 7 Hz, with static settlement about 10 mm
- the link between the “heart” and the frame with the 2 small axles
  to respect the expected curvature radius on shunt tracks;
- the position of hydraulic power group for vibrators:
  the choice of hydraulic transmission has been preferred to electric one for flexibility in frequency; the group mustn’t get vibratory disturbances to measurements in the “heart”.

In electronics, the points to be studied are:

- the camera measurement system
- the sensors for angle phase in vibrators
- the computer program to be adapted for high stiffness and non-linearity
  the actual program on Portancemetre is limited to about 60 kN/mm. A new version has been tested for twice to three times stiffness

Some points in logistics for assembling kit elements in test sites have also to be precised.

6.1.2 Supply and availability of components (July-December 2007)

All the components, the definition of which is now stabilised from the specified characteristics of version 2 in § 5.5, can be purchased from July, provided that some delays for supplying are until 5 months (hydraulic group for vibrators).

6.1.3 Manufacture and assembling (November 2007-end January 2008)

The CECP will assemble the demonstrator, mechanically and electronically, during this period

6.1.4 Reception tests at CETE (February 2008)

An 8 meters straight piece of track exist at CETE, and it would be extended to 20 meters, in order to check the correct functioning of the demonstrator in quasi-static application, at a very low speed. However the stiffness may be different than the one on real track.

6.1.5 Reception tests near CETE (March-May 2008)

At a few kilometres from CETE, several places have tracks with no traffic or very few one, on which complementary reception tests may be done: safety probations (rolling until 15 km/h; travelling on curves and switches), measurements of real stiffnesses, training for assembling of kit elements in situ, etc.

This period will bring some feedback and probably include adjustments of the demonstrator. At the end, the apparatus should be ready to begin tests on real tracks, provided that the agreement would be fulfilled.

6.1.6 Agreement of the demonstrator (September 2007-May 2008)

A specific documentation from detailed design will be sent to the Infrastructure Direction in charge of agreement in September 2007. According to possible complementary inquiries, the delay for agreement may be several months.

6.2 Campaign of tests on real tracks

The campaign of tests would be available with the demonstrator from June 2008. Meanwhile, a contribution has been done by CER in February 2007, for the 21/02 SP2.1 meeting in Paris, giving propositions for assessments on tests sites, with the methods ready to come in 2007. These propositions have been written in a small document placed in Annex 4.

In 2008, as some tests sections would have already stored measurements with other methods, it is therefore interesting to try to do measurements with the demonstrator on some of these test sites, provided that the hypothesis in § 5.4 can be managed and the agreement obtained.

The tests sections chosen for the track Portancemetre demonstrator at SP2.1 meeting of 21/02/2007 are:

- France: Chambéry (but interception of two tracks is probably impossible, so that another site would be found)
- Germany: Bad Krozingen; subgrade in silty clay
- Spain: near Lerida; old line with settlements on embankment just before a bridge
- Sweden: to be defined, and depending on budget

7. Financial situation of Task 2.1.5

At the present time, the financial situation is controlled but design is not yet ended: extra time has of course been spent to study the re-orientation and to re-begin the design of version 2, in order to facilitate the agreement of the demonstrator on real tracks. This extra time is evaluated to 1.5 h.months up to now, that is not critical. The consequence is rather in a 3-4 months of extra-time between march and June during which design progress has been delayed in the interval of finding the right contacts, analysis of documentation and definition of the new hypothesis of work.

For the next steps of § 6 (6.1.1 to 6.1.3), on one hand, it is assumed that costs of equipment may increase of 10 to 30% due to the re-orientation with 2 small axles in addition to the active axle, but the reality will be known more precisely in October 2007. This doesn't raise doubts about success in the project, but other factors may also be mentioned:

- the main part of incertitude is the risk of non-agreement at the first time, having to bring modifications before coming on real tracks, with extra costs and delays again.
- The more complex becomes the demonstrator, the more difficult is to transfer it to test sites, to assemble it quickly as expected in § 5.1, to have suitable machines during assembling, and locos to move it. In this way number of tests sites might be reduced at constant budget.
- These two points may induce, in case of severe difficulties in early 2008, an evaluation. Tests on real tracks may eventually retreat, and come to the CEDEX proposition to manage them on experimental tracks, if the consequences of agreement for tests on real tracks take a too large part in the costs for demonstrator and logistics.

On the other hand, a good cooperation and technical assistance take place recently between CECP and the locomotive maintenance workshop near CETE. This is a precious help from now until the reception tests § 6.1.5, which would probably be done in majority there.

8. Conclusions

The design of the demonstrator for continuous stiffness measurement on the 2 rails has begun on the basis of the principle of the road platform apparatus called “Portancemetre”.

The feasibility experiment on a re-built track at CER showed a first set of convenient parameters, with higher masses (5 times) than the road apparatus, to feel the influence of subgrade, and not only ballast, in the result.

A validation of these elements on a real track has got some complementary indications for the characteristics of the demonstrator. The real track, having a higher stiffness than re-built track, needs lower amplitude of vibration (about 0.3 mm) than the road apparatus (0.5 mm). The validation test has been done with a vibratory compaction rolling at low speed, and having parameters near to the expected ones. It was furthermore equipped with an innovative device able to calculate the stiffness continuously. The value of 85 kN/mm was found on the shunt track used for the tests, and was very few dependant of the vibration frequency.

These results allowed to conclude on the choice of the parameters on the demonstrator.

The aim of a demonstrator is to show the capacity to get continuous measurements of stiffness on test sections having some problems of poor subgrade or ballast, or heterogeneous conditions, and to enhance the diagnostic of the location of weak points through the use of other methods in SP 2.1.

The design of the demonstrator started as a transfer of technology from the road apparatus, with the new set of parameters above, but it appeared that the use on real tracks couldn’t be agreed with this first design like a single axle towed by a loco, according to safety regulations.

After contacts with rail-track maintenance contractors and manufacturers, documentation, and analysis, the design of a demonstrator version 2 is in progress.

The report shows the principle of the new frame of the demonstrator, with two additional axles apart from the active axle, and describes the reviewed hypothesis for the use on test sites.

The following stages of implementation are presented, each with a schedule. It is expected to have a demonstrator ready to come on test sites in June 2008, provided that the agreement to move on real tracks may be obtained simply before this term.

The agreement is in fact the most critical stage of the project. The financial situation could bear extra human time spent up to now to re-orientate design of version 1 to a version 2, but some 4 months delay occur with the complexity of the problems.

The consequences of safety regulations on the further stages of implementation are tried to be evaluated. If a 10 to 30% overvalue on the equipment seems to day a reasonable estimation, more precisions can be obtained after detailed design, in October 2007. However, uncertainties may still continue if the agreement is not obtained on the basis of detailed design documentation, and if obligations to get again complexity to the demonstrator appear, although it is only a demonstrator, built for a very few time of use. Logistics to transfer the demonstrator on tests sites and to assemble it will also increase in this way, reducing the possibilities of tests.

The continuation of the project don’t raise in doubt, despite these unforeseen difficulties, but a retreat strategy is suggested in the case of a too large part of costs coming for agreement on real tracks: it consists in showing measurements with the demonstrator just built for this purpose on experimental tracks at CEDEX.

The present priority remains to fulfil the objective of measurements on real test sites. Any consideration for the other strategy can be really established before early 2008, according to a certain delay for agreement examination.

In conclusion, this report is a stage document on design of the demonstrator, pointing out interesting technical validations of the feasibility with a test of an innovative compactor measuring stiffness on a shunt track, but also showing some difficulties to apply safety regulations to the design of the demonstrator for tests on real tracks.

9. Bibliography

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10. Annexes

10.1 Annex 1 - Description of the "Portancemetre" method

ministère
de l'Équipement
des Transports
et du Logement

centre d'Études
techniques
de l'Équipement

CETE
Normandie
Centre
centre d'Études
et de Construction
de Prototypes

THE PORTANCEMETRE

Continuous measurement of platform modulus

The **PORTANCEMETRE** is a high yield apparatus which measures continuously earthwork platform modulus.

Platform load-bearing capacity is used for work structure measurement. A good appraisal of deformation modulus, at embankment upper-layer and capping layer levels, is particularly important when regarding technical and economical aspects.

Extensive testing carried out during the development stages of the apparatus showed a good correlation with traditional testing methods: static plates, dynaplaque test. Continuous plotting makes weak spot detection safer thanks to these high yields.

Recommended area of use

The **PORTANCEMETRE** measurement range goes from 30 to 300 MPa. The depth covered is 0,60 m. All platform modulus requirements within these measurements can be checked by this apparatus.

Areas may include :

- Road embankment levelling courses and capping layers,
- Railroad infrastructure platform at capping layer and under-layer levels before setting ballast,
- Harbour or industrial platform, or specific areas,
- Conversion of unused roads into walking or cycling paths,
- Urban road system platform,

The **PORTANCEMETRE** will be particularly appreciated when sounding long distances, yet, as it is easy to operate and move during transfer, this equipment will operate efficiently even on smaller sites.

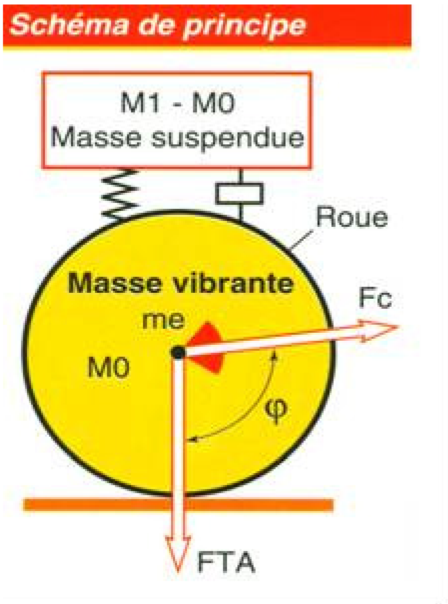
Conditions and limits o f use

Measurements are reliable for longitudinal gradients below 7 % and transversal gradients below 5 %. Beyond these limits measurements could be slightly less accurate.

Material can either be tre sted or not. Possible local treatment deficiencies can be detected.
Nevertheless, material must allow satisfactory surface movement for the measuring wheel. Very hollow granular material where surface shearing could occur cannot be included in the appraisal area. This open material "runs" in front of the measuring wheel thus generating a rut.

Such material would also make heavy machinery surface movement on sites difficult.

The **PORTANCEMETRE** can display this deficiency, but its main function, which is to measure soil body modulus, cannot be carried out. This was the case when we worked on heavy bodies with a fines rate of only 1 % < 80 µm.



Measure principle

An implemented narrow vibrating wheel, towed at regular low speed, inspects the material layer. Its implements measure acceleration of vertical components of vibrating and suspended masses and, phase variation between vibration vertical amplitude and the centrifugal force applied to the wheel.

An associated calculation algorithm determines the vertical effort inspecting the ground and the corresponding deflexion.
After having calculated an average over 30 successive impacts, it processes the recorded force-deflexion curve to calculate layer stiffness at the given spot.
The apparatus appraises without interruption the platform stiffness profile on the chosen survey course thanks to a measurement for every meter covered at the recommended speed of 3,6 km/h (+or- 0.5 km/h).
The expression of FTA is (equation 1):

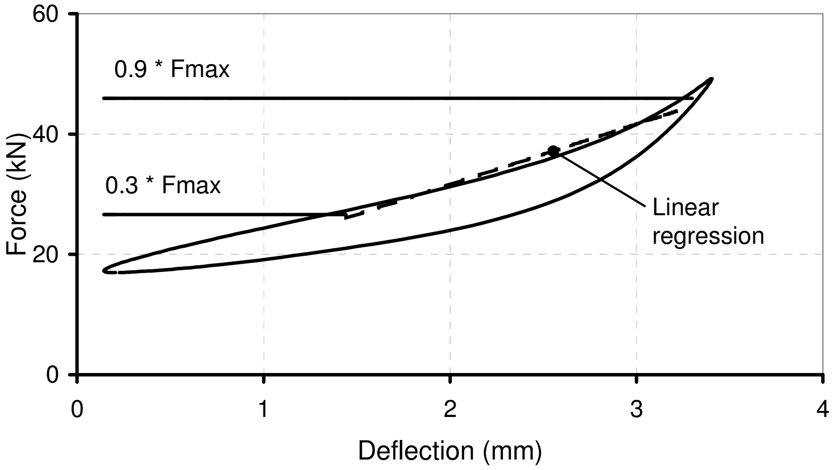
$$\mathrm{FTA} = M_1.g + M_0.\Gamma_b + (M_1 - M_0).\Gamma_c + m.e.\omega^2.\cos\varphi \qquad (1)$$

In which, M_1 is the total mass of the unit (trailer), M_0 is the mass of vibrating wheel, Γ_b is the vertical acceleration of the vibrating wheel, Γ_c is the vertical acceleration of the suspended mass, ω = 2π.frequency and φ is the angle of rotation.

The double integration of the wheel vertical acceleration, Γ_b , determines the vertical displacement of the vibrating wheel, d, (equation 2).

$$d(t) = \iint \Gamma_b(t)\,dt\,dt \qquad (2)$$

The calculated total force, FTA, and the corresponding deflection, d, allow one to determine the stiffness, k, over an average period on platforms. The apparatus establishes a continuous profile of stiffness versus the measured distance along the swept trace.



Force-Deflection diagram and determination of stiffness k by linear regression in the 0.3-0.9Fmax (example), K=slope of $\Delta F/\Delta d$

Equipment

The **PORTANCEMETRE** is a towed assembly, vehicle + trailer, which can move at low speed when inspecting sites and be driven on the road at allowed speed limits during transfers.

Towing vehicle (supplied by the buyer)

A 4 wheel drive, double cabin « Pick-up » truck :

- It allows to move the apparatus at the required speed of 3,6 km/h during inspections.
- It guarantees very good surface movement for platform access.
- It carries an hydraulic unit which vibrates the measurement wheel. Thanks to this, the wheel itself is not subjected to residual vibrations.
- The cabin houses the test monitoring post and the data acquisition equipment which processes the measurement figures.

It is fitted with all necessary legal road signs required for site vehicles.

Measurement trailer

This compact trailer comprises a tubular chassis and an elastomer spring suspension system , it also has an inertia brake, a knuckle articulated tow bar and «European standard» electric connections.

It carries the vibrating wheel and the suspended reaction chassis. Each of these items is fitted with a vertical axis accelerometer. An hydraulic systems lifts and lowers at ground level the reaction chassis-vibrating wheel assembly.

During transfers, a mechanical device with ball-ended spindles locks the lifted wheel.
It is fitted with a Doppler effect radar to determine speed and location of measurements.

The vibrating wheel (diameter: 1m, tread width: 20cm, mass: 600kg) vibrates thanks to an unbalance system which is rotated by a 16cm3 fixed cylinder hydraulic engine.

Two photoelectric beams measure vibration frequency and phase variation between centrifugal force and vibration amplitude.

The available vibration parameters are :

0.3 m.kg of eccentric moment, giving a theoretical amplitude of 0.5 mm, with a frequency of 35Hz, for current inspection modes, allowing to cover a nominal range of 30 to 300 MPa.

Hydraulic Unit

It is located on the platform of the towing vehicle and supplies the energy required to vibrate the measurement wheel. It consists of a thermal diesel engine (30 l diesel fuel tank) power 19 kW at 2500 revs/min, an electric starter, a variable cubic capacity hydraulic pump (maximum cubic capacity : 28cm3) with 2 all or nothing settings, and an hydraulic oil tank (capacity 50 l) fitted with an air/oil exchanger blast cooler.

The hydraulic pump electric control that initiates wheel vibration is connected to the monitoring post in the cabin.

Monitoring post

This post is in the towing vehicle cabin. It is a tactile screen computer which comprises a keyboard to enter identification data and a printer. The computer gathers identification and initialisation functions for the test sequence, acquisition and location of measurement results and controls; it supervises the good performance of the operation during tests.
An operator can follow in real time the evolution of measured module values and he can check at that stage homogeneity levels (in terms of quality) and the possible occurrence of unsatisfactory areas.

Post treatment software

The great advantage of this apparatus, in addition to its high yield, is that it obtains continuous measurement which does not leave out any empty data spaces that punctual measurements would do. So, interpretation can focus on weak points that can be assessed to see whether or not they comply with specified minimum modulus conditions.

The associated measurement result operation software can either be operated in situ from the monitoring post as soon as an inspection has ended or later on a desktop computer. The equipment comprises a removable hard disk for transfer of measurement files. Other standard media can be used.

Validation of measurement calculations

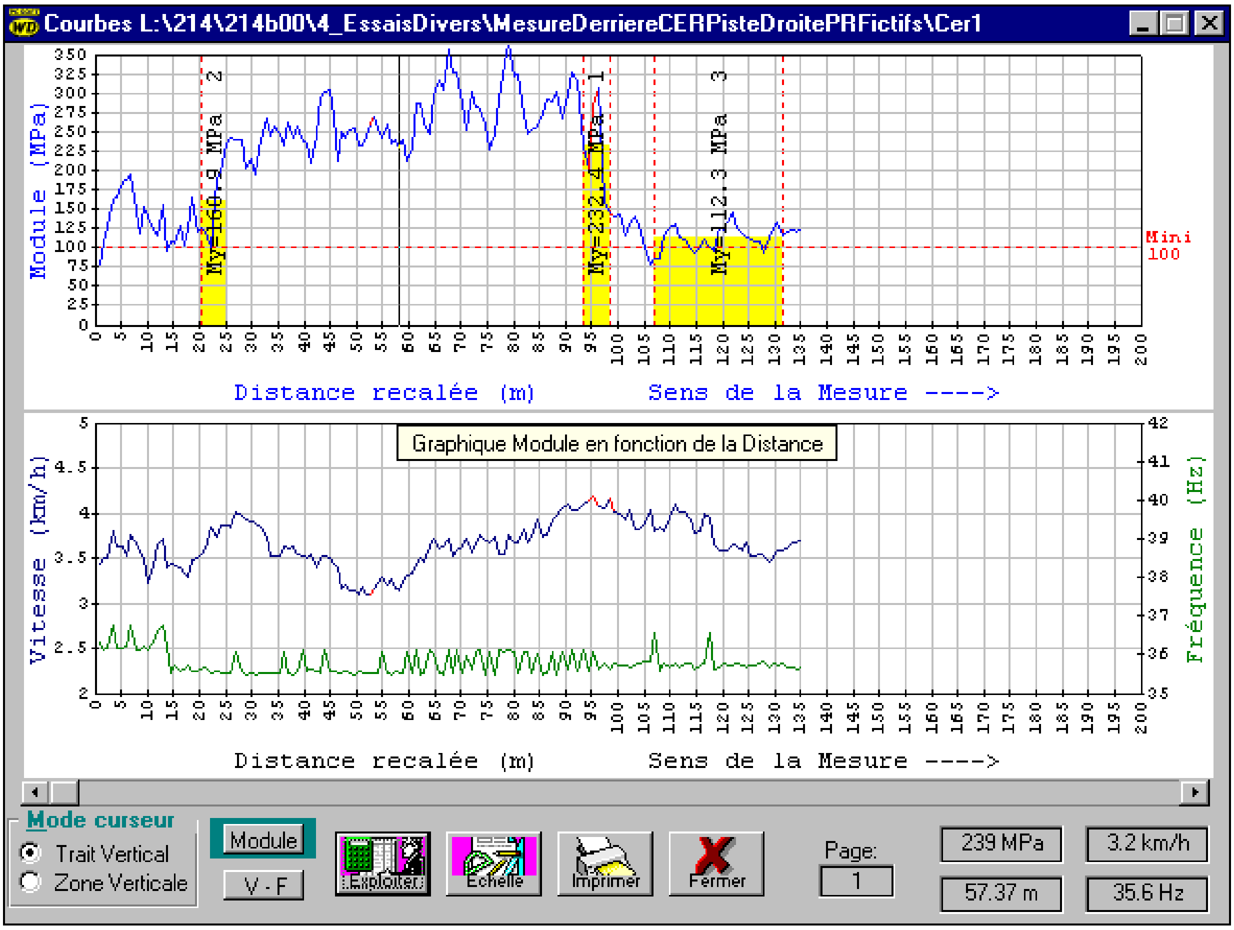
Published graphs express measured modulus in terms of lengths inspected, inspection speed and vibration frequency. Possible areas operating outside prescribed tolerances are displayed.

These areas are cancelled to calculate average modulus.

Exploitation of measurements

To exploit measurement results, technicians have access to various functions that they can implement according to their needs.

- Readjustment of measurement location – distance scales, between the initial and end blips which are used to position measurements determined by the device located in the apparatus, can be corrected proportionally, when the actual distance has been determined with greater accuracy.



- Establishment of modulus profile from calculations and display of the average and typical variance of actual measurements. In the event of a stated prescribed modulus, areas outside specifications are displayed.
- Focus and specific analysis of plotted areas on request.
- Some tools to facilitate perception and reading of results.

Editing test report

It contains :

- Site identification – location, nature of inspected layers, location marks of beginning and end of survey, inter-profile distances, length tested, traces (number, location in cross section).
- Equipment and control procedure identification – apparatus number, implementation procedure.
- Test operation conditions.
- Required specifications and measurement results.
- Diagnosis and comments derived from results reading.

Characteristics

Range of use

Module : 30 à 300 MPa.

Depth inspected : 0,60 m.

Vehicle

4 wheel drive double cabin pick-up truck, to be chosen with the user.

Fitted with signs complying with road traffic regulations

Hydraulic unit

Installed power : 19 kW

Variable cubic capacity pump (maximum cubic capacity 28 cm^3)

Continuous pressure : 15 MPa, maximum pressure : 30 MPa

Hydraulic tank : capacity 50 l

Thermal diesel engine type

Trailer

Total weight mass 1625 kg (E driving license compulsory)

Length : 4,01 m. Width : 2,00 m.

Ground clearance : 0, 23 m.

Fitted with signs complying with road traffic regulations

Testing device

Wheel : diameter 1m, width 0,2m

Vibrating Mass : 600 kg

Suspended mass : 400 kg

Vibration frequency: 35 Hz

Survey speed : 3,6 km/h

Monitoring post

Shoe box type micro computer with remote keyboard and tactile screen.

Peripherals : printer and removable HD recorder

Range of rough measurement recordings : 10 km per session without interruption

The number of sessions is not limited.

The global yield of the apparatus depends on conditions on the site. In usual conditions on linear infrastructures, an operational rhythm of 5 to 10 km per day can be achieved by double tracing survey (20 km of measurements).

Technical documentation

The equipment comes with:

- A technical booklet with a chapter dedicated to maintenance
- A guide for post treatment software
- A delivery part list
- An EC certificate of compliance
- A certificate of compliance with standard model
- Usual terms include a day’s introduction training at CETE NORMANDIE CENTRE.

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[2] Workshop on advanced testing for unbound materials: Lisbonne – *Janvier 1999* "New in situ devices to evaluate bearing capacity and compaction of unbound granular materials" – A.QUIBEL

[3] Guide Technique LCPC (à paraître, en français): Portance des plates-formes – Mesure du module en continu par le Portancemètre

10.2 Annex 2 - Journal of actions SP 2.1.5 – CETE NC

It gives the main stages, contacts, meetings of the project:

All the in house CER-CECP meetings have a statement of decisions and documentation, in French.

01/09/2006: Beginning of the project

08/09/2006: Meeting (in-house) CER-CECP: Results of the CER feasibility study; application to the demonstrator

27/09/2006: Meeting CER-CECP: Headlines, specifications of demonstrator version 1

05-06/10/2006: Kick-off meeting - Paris

09/10/2006: Meeting CER-CECP: Decomposition of the tasks in SP2.1.5: CETE organisation

06/11/2006: Meeting CER-CECP: pre-design of demonstrator and associated machines for moving it

09/11/2006: SP2.1 Meeting – Munich – Presentation of demonstrator version 1 principle

29/11/2006: Meeting CER-CECP: validation of principle of version 1 after Munich meeting

10/01/2007: Meeting CER-CECP: dimensioning version 1 and logistics on sites

16/01/2007: Meeting SP2.1.5 (Paris) with L. Schmitt, A. Robinet on draft version 1and agreement questions

05/02/2007: Meeting CER-CECP: review of demonstrator design; preparation of Chelles tests on a shunt track

13/02/2007: Visit to SECORAIL Les Mureaux (78 – F); characteristics of maintenance equipments

20/02/2007: Meeting CER-CECP: Preparation of SP2.1 Meeting of 21/2

21/02/2007: Meeting SP2.1 – Coordination – Paris – Presentation of design demonstrator version 1

27/02/2007: Validation tests of vibratory parameters on Chelles track with a vibratory roller

02/03/2007: Meeting CER-CECP: first exploitation of results Chelles track

28/03/2007: Meeting CER-CECP – Conclusion of Chelles tests; preparation of contacts with GEISMAR

23/04/2007: Meeting with GEISMAR – Cooperation for technical assistance on agreement

25/04/2007: List of questions for agreement to SNCF: L. Schmitt and A. Robinet

12/06/2007: Meeting with A. Robinet, SNCF – Definition of new hypothesis to facilitate agreement

15/06/2007: Meeting CER-CECP – demonstrator version 2 design with new hypothesis; review of tasks

11/07/2007: Meeting CER-CECP – preparation to supply components having long delays

19/07/2007: Meeting CECP-contact with maintenance SNCF establishment: active axle; solutions for agreement

20/07/2007: Meeting CER-CECP: elements for redaction of deliverable D2.1.2

10.3 Annex 3 - Questions for agreement of the demonstrator

This document, in French, has been sent to the French railways on 25/04/2007:

DONNEES D'ENTREE POUR CONCEVOIR LE DEMONSTRATEUR EN INTEGRANT LES CONTRAINTES D'HOMOLOGATION ET DE LOGISTIQUE

Le démonstrateur doit réaliser des mesures dans les campagnes d'essais sur les sites-tests. L'homologation est nécessaire pour les réaliser en respectant les conditions de sécurité. Il ne circule qu'aux fins des essais de validation sur les sites-tests, et auparavant sur un tronçon de voie à définir près de Rouen pour mise au point préalable. Ses durées d'interventions globales sont donc courtes.

Le rapport entre les coûts résultant de l'homologation et les coûts de base du démonstrateur doivent être acceptable.

L'objet de ce document est de collecter les hypothèses de travail auxquelles le démonstrateur sera soumis, pour mettre au point les solutions envisageables et élaborer le descriptif technique à soumettre à la Dir . Infrastructures.

Caractéristiques des sites-tests

La voie où ont lieu les mesures est par hypothèse interceptée, caténaire non alimentée.

- Durée d'interception minimale envisagée ?
- La voie contigüe est-elle sous trafic ?
- Distance maximale entre le PK de début des mesures et une voie de service (de garage) pouvant permettre les préparations (montage en configuration B – cf plus loin) avant mesures ?
- Longueur concernée par les mesures ?
- Le démonstrateur peut-il circuler dans les 2 sens sur la voie testée (corollaire : La voie de service pour garage et démontage après mesures est-elle la même ?
- Rampe maxi sur les voies empruntées ?
- Délai admissible pour la préparation du démonstrateur sur voie de service ?

Moyens matériels:

- Dispose-t-on d'une draisine pour tracter-pousser depuis la voie de service ?
- Est-il envisageable d'encadrer le démonstrateur par 2 draisines pour des questions de freinage ?
- L'opérateur qui pilote le démonstrateur peut-il prendre place dans la cabine de la draisine? Combien d'autres personnes au maximum peuvent être avec lui ? Est-il autorisé de suivre à pied le convoi pendant la mesure ?
- Peut-on éviter d'avoir à auto-dérailler, ré-enrailler pour passage de convois ?
- Doit-on rechercher d'autres moyens de traction qu'une draisine ? Lesquels ?

Configuration A: démonstrateur associé à un wagon

L'axe avec les roues de mesure serait inséré dans un wagon ordinaire à 2 essieux mis à disposition et dédié pendant la durée des mises au point, et des essais sur sites-tests. Les adaptations seraient faites par le CECP Rouen. L'acheminement aux sites-tests se ferait en étant rattaché à un train

- Cette configuration est-elle envisageable ?
- Quelles contraintes cela amène-t-il ?

Configuration B : démonstrateur « en kit » monté à proximité de chaque site :

L'axe avec les roues de mesure, le lest, les roues encadrantes seraient amenées par route à proximité des sites-tests, montées sur une voie de service, et reliées à un engin tracteur adapté pour les séquences d'essais. Opération inverse pour le démontage.

- Cette configuration est-elle envisageable ?
- Quelles contraintes cela amène-t-il ?

Configuration C : idem B monté-démonté sur le site-test lui-même :

On suppose qu'une voie de service n'existe pas à priori à proximité, et que le démonstrateur est assemblé ou démonté sur le site-test près d'un passage à niveau ou d'une voie d'accès.

- Cette configuration est-elle envisageable ?
- Quelles contraintes cela amène-t-il ?

Quelle serait à priori la hiérarchisation des configurations du plus au moins favorable, en estimant à priori les difficultés globales concernant l'homologation et la logistique des essais?

Autres éléments utiles à prendre en compte ?

10.4 Annex 4 - Propositions for assessments on tests sites

10.4.1 Introduction

These propositions are made on the demand of WP2.1 leader at the 9th November meeting in Munich.

10.4.2 General objectives

The target is to of optimise the maintenance of old railtracks.
The tests-sites in the different countries will aid:

- to introduce new methods for a more complete diagnosis,
- to improve the efficiency of the diagnosis by the combination of these methods and a suitable methodology,
- to enhance a better understanding of the evolution of the quality of railtracks in service,
- and also to forecast the behaviour under higher speeds and/or higher axle loads.

The tests-sites may answer partly or in totality to these objectives, depending on the priorities in each country.

10.4.3 Qualitative analysis from background

Requirements, properties

Settlements must not affect the safety of traffic.

Lower settlements lead to lower maintenance.

It can be assumed that differential settlements, and then poor geometry, are related with total settlements.

Stiffness low stiffnesses may characterise poor subgrades or aged ballasts. They induce heavier elastic deformations under traffic. Permanent deformations under cumulated traffic increase with higher elastic deformations.

Heterogeneities in stiffnesses may annulate the benefit of adjacent good sections.

Others => « Pollution » of ballast may result from production of fines, majorated by higher elastic deformations, and higher accelerations into the ballast.

=> Poor drainage increase temporary saturated conditions in subballast or subgrades, increase periods of low stiffnesses and higher elastic deformations, may cause movements of fines particles and reinforce the pollution of ballast.

Disorders and assessments

Settlements total settlement is the sum of settlements coming from different levels of railtrack structure:

<u>Ballast</u>: in the stable domain, they may be low and homogeneous after the stabilisation period. There are limits of stability for high speeds combined with high axle loads. Internal accelerations are more than 1g when obtaining this phenomenon,

The state between large unstability (liquefaction) and stability (always contacts between grains) may include and intermediate state (beginning of mobility of some local grains, not repeated at the same place). The upper part of the ballast is important, to give a minimal weight (stress) on the sollicited lower part, to be within the stable domain.

<u>Subballast and subgrade</u>: stresses and accelerations are much lower than in ballast – water effect may be sensitive, inducing low stiffnesses, higher elastic deformations, attrition and consequences for mechanical characteristics of materials.

The settlements on old lines coming from the 1 m under ballast may be concentrated in the upper part. But after several ten years, if something more than centimetric occurs un this meter, it means that normal behaviour is overpassed (see : drainage, ...).

Embankments: the major part of settlements is during construction. But, before asymptotic conditions, settlements may be important during several decades, depending on the state of compaction at the construction and moisture equilibrium. Some road embankments had settlements of several 10 cm. Intermediate seasons induce variations in speed of settlement.

Stiffness stiffness may be interpreted complementary to geometry assessment: it can explain why some areas are more frequently concerned by maintenance, and what type of treatment these areas should receive. The indicator of stiffness versus distance is useful with different approaches:

Absolute values

Values locally under a certain minimal value must be pointed. This minimal value is however not well known. Some correspondences with consequences factors must be studied. The minimal value is probably depending on the level of service, traffic, axle load.

Relative values

Campaigns periodically made with stiffness measurements (every one to two years for instance) may show some stability of quality, or to the contrary, some decreasing zones, on which attention has to be focused. For these relative observations, the measurements have preferentially to be made at the same seasonal periods.

Homogeneity

Irregular stiffnesses may introduce higher accelerations in transition zones, and, if other defaults on geometry are shown, must be treated.

Propositions for assessments on tests-sites

Purposes of test-sites

They are complementary to track-box experiments. In track-boxes systematic tests can be done, varying on parameter from the other, with adequate instrumentation put into the structures during construction.

Tests sites are really aged structures under traffic, with one history, and preliminary observations concerning maintenance. Sections may be chosen with characteristics properties: weak points, heterogeneity, unexplained repetitions in periods of maintenance.

Tests sites may on one hand validate some innovating methods or methodologies already tested in some experiments comparing them, and on the other hand allow to precise interpretation of assessment methods and to optimize diagnosis, combining some of them.

Global methodology

The organisation of the tests should include successive phases:

- gathering of historical dates from anterior investigations and practical observations from exploitants,
- measuring with continuous methods assessment = state 0,
- heaving a first step of interpretation with dates above,
- making local measurements on particular events to achieve understanding at state 0,
- taking samples if convenient to confirm measurements by tests in labo,
- having a more complete interpretation,
- re-beginning assessments at a state 1 with a certain delay from sate 0, to point out evolutions,
- concluding with a proposition of schema of investigations.

Example for one test-site

- Choice of the site : 500 to 1000 meter – knowledge of history and problems,
- Choice of the period for state 0 and further states (note that if state 0 is in spring and further state in favourable period like end of summer, results may be better),

- Choice of continuous methods:
  - geometry (Mauzin)
  - geophysics (georadar targeted on the 1 m under sleepers)
  - stiffness measurements (RSMV, demonstrator of Portancemètre when ready). Test of repeatability (5 passages at the same moment).
- Choice of local measurements :
  - wave propagation on ballast and on subgrade between sleepers (decovering ballast)
  - dynamic small plate tests on subgrade between sleepers
  - light penetrometer on weak stiffness values, and/or contrasted zones
  - geoendoscope on some of these points, and samples of ballast and subgrade for granulometry and moisture conditions.
- Possible additional investigations, depending on the local results :
  - value of displacement of railtrack under traffic (recording from LVDT or accelerometer).
- Exploitation of datas: table of correspondances between datas on characteristics zones (a few meters length). Relations between parameters. Evolution in these zones when several periods.
- Conclusions :
  - Pertinence of each indicator from assessment methods.
  - Optimising interpretation rules for each method.
  - Criterias for surveying before maintenance – Diagnosis – Classification of sections based on different levels of the indicators (in combining certain method).
  - Conservation of table of results from different tests-sites – Concordance between conclusions from each test-site – Problems remaining for assessment quality.