# REVISION OF THE SPANISH QUALITY CONTROL PROCEDURE FOR ROFILLS AND RANDOM FILLINGS

**Evelio Teijón-López-Zuazo**
Professor of Construction Engineering, University of Salamanca, Spain
**Ángel Vega-Zamanillo**
Professor of Roads and Traffic, University of Cantabria, Spain
**Miguel Ángel Calzada-Pérez**
Professor of Roads, University of Cantabria, Spain

**ABSTRACT**

Infrastructure quality control must be done through an adequate control process, which must be well planned, programmed and executed. It implies the revision of the specific control procedures as part of the general objective of continuous improvement. It must be applied to the construction of quarries with stone materials, called rockfills for large sizes or random fillings for intermediate products. There continues to be a problem in terms of compacting control methods in the execution of these diggings, with little practical development of new techniques when the spread is of good – quality material an aspect that must be revised in order to ensure the quality of the final result extended and compacted. The current procedures for Quality Control in rock compaction have limited operability. For example, the granulometric analysis with macro-pits ($4m^3$) it is have done with heavy fractions, being a destructive testing. The average density control by nuclear methods has high heterogeneity, low performance and low thickness tested. The topographic measurement settlement is the most accurate, but it is a poorly referenced method. For the wheel impression test, the required values do not impose any limitation.

This research studies the application use to granites, slates and granitic alteration soils stabilized using cement. The necessary field and laboratory works were developed in order to elaborate new test procedures for a proposed compaction control in rocks. The compaction control procedures revised were wheel impression test, topographic settlement and plate load test (PLT). Doing simple regression on SPSS, in which any predictor outcome variable (dependent) should be placed (independent). An analysis of variance ANOVA shows the sums of squares and the degrees of freedom associated with each: is significant at $p < 0,05$. There is less than 0,5% chance that an F Levene – ratio this large would happen if the null hypothesis were true.

## 1. INTRODUCTION

Infrastructure quality control must be done through an adequate control process, which must be well planned, programmed and executed. It implies the revision of the specific control procedures as part of the general objective of continuous improvement.

The classical sense of road geotechnics implies that stone materials, with a high maximum size, were rejected. This meant that high quality materials were underused. Today, there is a less restrictive trend towards the use of materials to achieve the highest environmental efficiency. There is a need to review the quality control compaction at rockfills and random fills. Optimization of the compaction control means a reduction of the inspection times, adapting the quality to the high construction performance shown in figure 1.

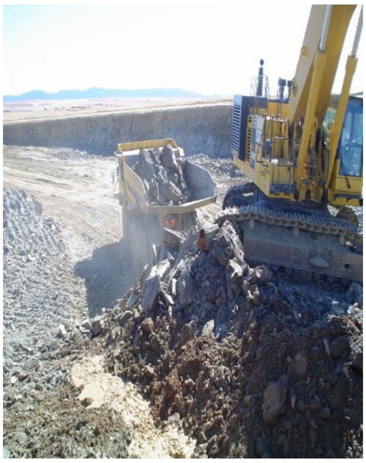

**Figure 1. Rock diggings with high construction performance**

This research is applied to the construction of quarries with stone materials, called rockfills for large sizes or random fills for intermediate products. With a high variety of rocks, this study has been particularized to granites rockfills, figure 2, and slates in random fillings.

**Figure 2. Granitic rock excavation associated to rockfill**

## 2. STATE OF THE ART

For Teijón-López-Zuazo et al. (2020), grading with pits, weighing different rock fractions presents a limited operability. The control of topographic settlements defined in the General Specifications for Roads and Bridges Works, PG-3 (2002), presents reference values and thresholds that are not very practical. The wheel impression test, UNE 103 407 (2005), usually complies. The plate load test, UNE 103 808 (2006), is only representative for plate load sizes five times the maximum of the aggregate.

There are limitations in the nuclear density methods UNE 103 900 (2013) due to the high particle sizes, the layer thicknesses to be tested, greater than 30cm, and the lack of reference in the Proctor test UNE 103 501 (1994). So, there continues to be a problem in terms of compacting control methods in the execution of rockfills and random fills, figure 3, with little practical development of new techniques when the spread is of good – quality material an aspect that must be revised in order to ensure the quality of the final result.


**Figure 3. Execution of random fill**

The French Standard includes in a more detailed way the use of rocky materials. Thus, the technical guide "Construction of embankments and esplanades" GTR (2003), published by the LPC (Laboratoire Central des Ponts et Chaussées), classifies within the group $R_6$ magmatic and metamorphic rocks (granites, andesites, gneisses, metamorphic schists and slates, etc.). The classification is made conforming to the values of resistance to fragmentation UNE-EN 1097-2 (2010), resistance to wear (micro-Deval) UNE-EN 1097-1 (2011) and dynamic fragmentation test, XP P 18-574 (1990). Sopeña (2007), with experimental sections, considers that the topographic settlement is the most important test in stone materials. It obtains graphically the number of passes from which the deformation ends, that is, the pass with which the stabilization of the settlements is reached, figure 4.


**Figure 4. Topographic settlement control after roller pass**

An example of other control techniques is the compactometer, Rahman et al (2012), which is used on the vibration equipment itself. These are the rollers with intelligent compaction (IC rollers). They have an accelerometer in the transducer and a measurer in the dashboard.

As a curiosity, as an example of the great possibilities of developing other techniques, space exploration has developed procedures to estimate soil density by remotely controlled drone raking from Earth. Gertsch et al. (2013) have deduced the density of the lunar soil raked with the raking force.

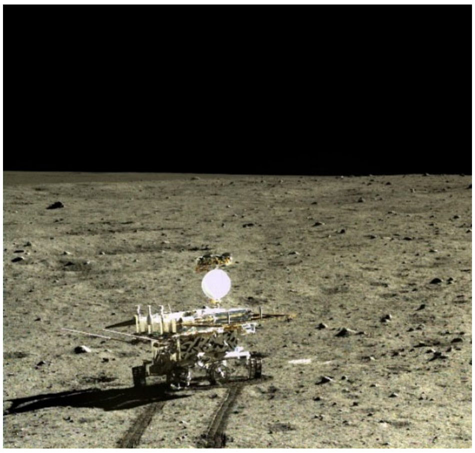

**Figure 5. Lunar exploration (NASA)**

Scale models with JSC-1a (artificial lunar regolite), have provided relationships between the density of the soil or regolite rock, the shale and the scarifiers of the ship.

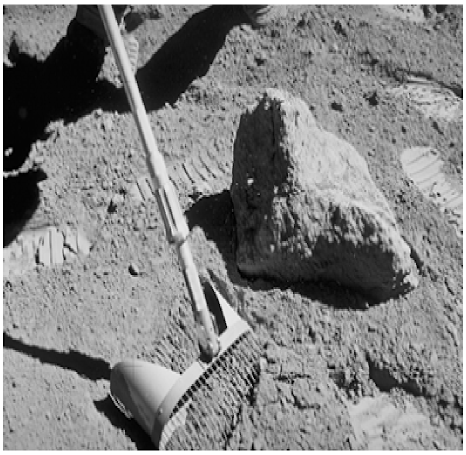

**Figure 6. Apollo 16 photograph (NASA)**

## 3. MATERIALS

The tests were carried out as part of the Quality Assurance Plan for the A-66 motorway on the Cáceres (N) - Aldea Cano section attached to the Ministry of Public Works, where were used granites, slates and slate alluvial materials. Table 2 provides a summary, including examples of the tests that were conducted on the slate alluvial material. The last row showing average values.

| Ref. | # 100.0 | # 20.0 | # 2.0 | #0.40 | #0.08 | LL | LP | IP | d (g/cm$^3$) | H (%) | CBR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CC-007 | 100.00 | 62.00 | 28.00 | 22.00 | 18.70 | 33.00 | 23.00 | 9.00 | 2.11 | 9.60 | 5.00 |
| I-0933/04 | 100.00 | 68.00 | 33.00 | 20.00 | 17.10 | 39.00 | 28.00 | 10.00 | 2.08 | 7.20 | 21.00 |
| I-0948/04 | 100.00 | 83.00 | 45.00 | 28.00 | 19.70 | 34.00 | 25.00 | 9.00 | 2.16 | 6.60 | 19.00 |
| I-0932/04 | 100.00 | 70.00 | 52.00 | 26.00 | 20.30 | 35.00 | 24.00 | 11.00 | 2.08 | 7.90 | 14.00 |
| I-0947/04 | 100.00 | 70.00 | 46.00 | 32.00 | 26.20 | 36.00 | 28.00 | 9.00 | 2.08 | 8.50 | 11.00 |
| CC-018 | 100.00 | 37.00 | 15.00 | 10.00 | 7.80 | 32.00 | 24.00 | 9.00 | 2.13 | 7.80 | 11.00 |
| CC-024 | 100.00 | 100.00 | 54.00 | 44.00 | 40.70 | 37.00 | 24.00 | 13.00 | 1.98 | 13.00 | 7.00 |
| I-1018/04 | 100.00 | 72.00 | 43.00 | 30.00 | 20.50 | 27.00 | 22.00 | 5.00 | 2.12 | 6.90 | 25.00 |
| Averages | 100.00 | 70.25 | 39.50 | 26.50 | 21.38 | 34.13 | 24.75 | 9.38 | 2.09 | 8.44 | 14.13 |

**Table 1. Examples of physical parameters for slate alluvial material identification**

## 4. METHODOLOGY

Thus, the necessary field and laboratory works are developed in order to elaborate new test procedures for a proposed compaction control in rocks. Compaction control procedures revised: wheel impression test (figure 7), topographic settlement, plate load test.


**Figure 7. Wheel impression test: passing over the alignment pegs**

The revision to the wheel impression test (UNE 103 407) implies modifying several aspects, such as the marking with plaster by levelling picks, figure 8, going from 10 points aligned at 1 meter to 2 rows of 5 points spaced 10 meters. This means an increase in the test length from 9 to 40 meters. It also moves from initial leveling over land to over pikes. Instead of taking readings on a wheelbase, the two truck tracks are measured, figure 9.

**Figure 8. Wheel impression test: leveling over pikes**


**Figure 9. Schematic diagram of wheel impression test**

Another revised test is the topographic settlement control, as shown figure 10. A measuring reference has been changed from the first roller pass to the penultimate one.

According to results in experimental sections, the criterion of settlement between the first and last pass of less than 1% has not been accepted (for a thickness of 1m, admissible settlement 10 mm). It has been proposed as a measurement criterion the settlement between the penultimate and last pass of the compacting roller, which in case of rockfills, should be less than 5mm. The measuring system has been changed from being undefined to having levelling picks distributed in 2 rows of 5 points spaced 10 m.

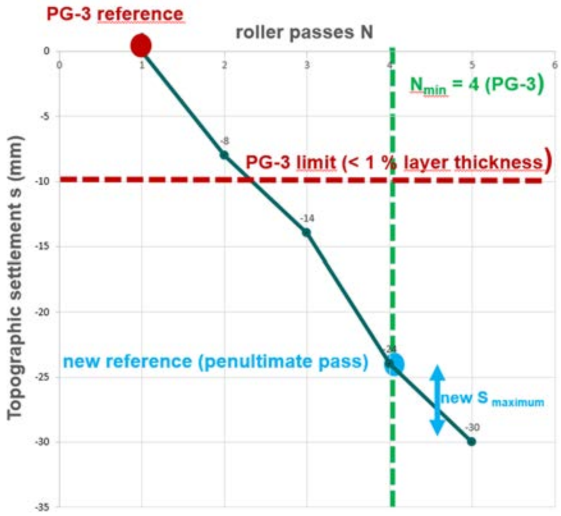


**Figure 10. Revised topographic settlement test**

According to the PG-3, the PLT test is representative when the plate diameter is at least 5 times the maximum size. This would result plates of 4300 and 2000 mm when the biggest standard size is 762 mm, figure 11. Traditionally the 300mm plate has been used, which gives positive results independently of the compaction conditions. It is more correct to use the 762 mm, which corresponds to the limit of manageability. It is proposed to review by size, using the Ø 762 mm plate in stone fillings and the Ø 600 mm plate in random fillings.

**Figure 11. standard load plates (300, 600 and 762mm)**

The PG-3 recommends not to use nuclear tests except when correlated with the sand method, although this test is also not representative for stone materials, figure 12. The determination "in situ" of density of soil by the sand method (UNE 103 503) is performed on soils with a maximum size of less than 5 cm and in a 15 x 20 cm sand hole when the maximum size is bigger than 30 cm. The Proctor test rejects the 20.0 UNE sizes, substituting them with fine particles: therefore, it is not representative for stone materials.

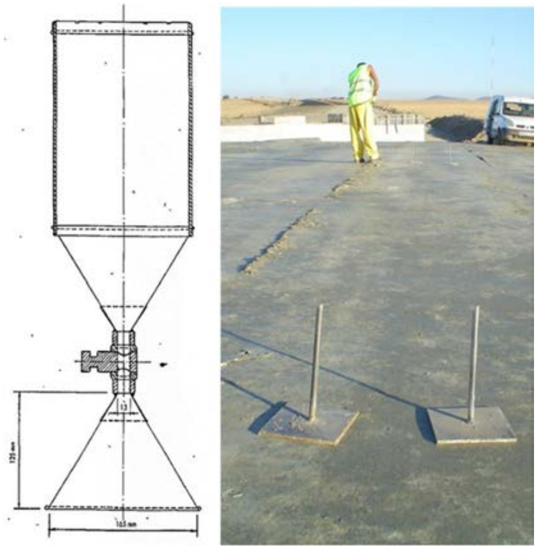

**Figure 12. Sand method (UNE 103 503) and nuclear method for low depths**

In PG-3, grain sizes are determined by pits, in the case of rockfills with a minimum volume of 4 m3 and a minimum surface area of 4 m2. In random fills, a minimum volume of 1 m3 and a minimum surface area of 1 m2 are required. These inspections are considered without practical use. Thus, the weighing of different fractions of rocks presents limited operativity. In addition, they are destructive tests, with minimum surfaces of 4 or 1 m2 of great difficulty of repair like located fillings. They also pose problems of safety at work, due to instability within the tasting walls.

This complex characterization is required on three processes: bench, spread and fill. PG-3 proposes to carry out a test section on stone materials and to establish a procedural control.

The revised procedure consists of fixing, from the test section results, the control parameters of the compacted layer.

**5. RESULTS**

The big number of compaction lots processed (450) made it necessary to classify them by material types: granites in rockfills and slates in random fillings. Finally, they have been subdivided by their use in core or crown. The general quality control specifications, that have been satisfactorily applied to the quality control, are shown in the table 2.

| material | zone | N | GC (%) | h (mm) | s (mm) | PLT Ø (mm) | $Ev_1$ (MPa) | $Ev_2$ (MPa) | k |
|---|---|---|---|---|---|---|---|---|---|
| granite | core | 5 | --- | ≤ 4 | ≤ 5 | 762 | ≥ 50 | --- | < 3.2 |
| | crown | 5 | 98 | ≤ 3 | ≤ 5 | 762 | --- | ≥ 120 | < 3.6 |
| slate | core | 4 | 95 | ≤ 4 | ≤ 4 | 600 | ≥ 30 | --- | < 3.0 |
| | crown | 4 | 98 | ≤ 3 | ≤ 4 | 600 | --- | ≥ 120 | < 3.6 |

--- not applied

**Table 2. General specifications**

The variables have been entered into the IBM SPSS Statistics calculation program. An analysis of variance ANOVA shows the sums of squares and the degrees of freedom associated with each: is significant at p < 0,05. There is less than 0,5% chance that an F Levene – ratio this large would happen if the null hypothesis were true. A multitude of non-linear models have been analysed, although finally all the adjustments have been linear because no curve has been found that has significantly improved the adjustments.

As shown in table 3, an optimisation of the compaction control system has been achieved in rockfills and in random fillings, obtaining a reduction in the control time and a higher production rate.

| material | zone | nuclear methods | wheel impression test | topographic settlement | PLT Ø(600mm) | PLT Ø(762mm) |
|---|---|---|---|---|---|---|
| granite | core | | | ■ | | ■ |
| | crown | ■ | | ■ | | ■ |
| slate | core | ■ | | | ■ | |
| | crown | ■ | | | ■ | |

■ significative test

**Table 3. Optimisation of the compaction control system**

## REFERENCES

FRENCH ASSOCIATION FOR STANDARDISATION AND CERTIFICATION AFNOR (1990). P 18-574. Dynamic fragmentation test.

LABORATOIRE CENTRAL DES PONTS ET CHAUSSÉES [LCPC]. SERVICE D´ÉTUDES TECHNIQUES DES ROUTES ET AUTOROUTES [SETRA], CENTRE DE SÉCURITÉ ET DES TECHNIQUES ROUTIÈRES (2003). Technical Guide Embankments and upgrades [GTR]. Fascicle 1. General principles.

MINISTRY OF PUBLIC WORKS (2014). General Specifications for Roads and Bridges Works (PG-3). 3th Part Explanations, 50-312.

SOPEÑA, L.M. (2007). Compaction control and in-situ tests. II Journal on marginal materials in road works, ATC-AIPCR World Road Association.

SPANISH ASSOCIATION FOR STANDARDISATION AND CERTIFICATION AENOR (1994). UNE 103900, In situ determination of density and moisture content of soil and granular materials by nuclear methods: low depths.

SPANISH ASSOCIATION FOR STANDARDISATION AND CERTIFICATION AENOR (1994). UNE 103501. Geotechnics. Compaction test. Modified Proctor.

SPANISH ASSOCIATION FOR STANDARDISATION AND CERTIFICATION AENOR (2005). UNE 103407, Wheel impression test.

SPANISH ASSOCIATION FOR STANDARDISATION AND CERTIFICATION AENOR (2006). UNE 103808, Load test of plate soils.

SPANISH ASSOCIATION FOR STANDARDISATION AND CERTIFICATION AENOR (2010). UNE-EN 1091-2, Test for mechanical and physical properties of aggregates. Part 2: Methods for the determination of resistance to fragmentation.

SPANISH ASSOCIATION FOR STANDARDISATION AND CERTIFICATION AENOR (2010). UNE-EN 1091-1, Test for mechanical and physical properties of aggregates. Part 1: Determination of resistance to wear (micro-Deval).

TEIJÓN-LÓPEZ-ZUAZO, E VEGA-ZAMANILLO, Á. CALZADA-PÉREZ, M.A. JULI-GÁNDARA, L. (2020). Modification Tests to Optimize Compaction Quality Control of Granite Rockfill in Highway Embankments, Materials 13, 233.