# Methods for testing the compaction quality

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## ABSTRACT

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In the specifications for earthworks for roads the values of compaction quality (degree of proctor density, resilient modulus, degree of air void) are defined as 10%-quantiles. In the tender papers must be said, in which way (testing methods) the testing must be organised. There are 3 methods:

Method M1: Testing on the base of a statistical testing plan
Statistical testing plans are well known from industrial production. For earthworks at first we have to define pieces which are produced: That shall be areas of 1 m². Then we have to limit a testing area. Next we choose a testing plan : sampling by attributes or sampling by variables in single, double or consecutive testing plans. To each testing plan belongs depending on the largeness of the testing area a fixed number of tests. The location of the tests is chosen by random. With the test results is calculated with the special rules of decision the quality-value. The-limits for the quality-value a given in the specifications. The comparison of the calculated quality-value with that one from the specifications leads to the result “accepting or refusing of the tested area”.

Method M2: Testing with a vibrating roller with special measuring equipment
Modern vibrating rollers have a special measuring equipment with is based on the comparison of the vibrating wave of the roller and the reflected ware from the compacted soil. These results are built for every 0,5 m way of the roller. So we get a result (with a width of the roller of 2 m) for every m². The results of the roller can be compared with conventional tests. So we get a correlation between the roller-results and the normal test results. From this correlation we can find a specification for the roller results as a quality of conformance but for the special characteristics of the constructing site. There is good experience with this testing method in soils with less than 15 M.-% under 0,063 mm.

Method M3: Testing with a description for work and single tests
On a new construction site at first we have to test the roller. He must be able to compact the special soil to the value of the specifications. This is tested on a testing field. The results lead to a description in behalf of the work of the roller-driver (max. thickness of the layer, number of passes of the roller, velocity of the roller, characteristics of the soil). Theoretically the compaction must be sufficient when the compaction is done in the same soil with the same description for work. For assurance of the quality a few single conventional tests should be carried out.

Méthode de contrôle de la qualité de compactage

Dans les spécifications pour les travaux de terrassement pour les routes en Allemagne (ZTVE-StB 94/97) la qualité de compactage (pourcentage de proctor-densité, module de déformation, teneur de l´air) est définit en tant que 10%-quantile. Dans l´appel des offres il faut d´écrire, comment les manoeuvres de control devoir exécutent. Il y a 3 méthodes:

Méthode M1: Contrôle a la base d´un dessein statistique
Les planes de contrôle statistiques sont adapté de la production industrielle. Pour les travaux de terrassement if faut défini les morceaux. Ces sont 1 m². Ensuit il faut fixer la plain de control et le plan statistique: test avec attribut ou avec variables, variable en simple, en double ou en successif. Pour toutes les plans est déterminé la nombre des contrôles. Les places des contrôles sont fixé par hasard (avec des nombres de hasard). Avec les résultat des contrôles est calculé la valeur de qualité. Les demandes pour les valeurs de qualité sont composées dans les spécifications (ZTVE-StB 94/97). La comparaison de les valeurs de qualité par les spécifications donne le résultat "acceptation" ou "refus".

Méthode M2: Contrôle avec un compacteur vibrant avec la instrumentation "compactomètre":
Les compacteurs modernes sont équipées avec une instrumentation "compactomètre " (La base est la comparaison de la onde réflexé de le sol et la onde de la machine). Pour chaque 0,5 m marche du compacteur on obtenue un résultat correspondant avec la qualité de la compactage. Les résultats sont comparés avec des contrôles traditionnelles. La corrélation des résultats dynamiques et les résultats normales rendent la possibilité la comparaison avec la spécification. Le system est propre aux sol avec moins que 15 M.-% sous 0,063 mm.

Méthode M3: Contrôle avec une description pour les travaux de compactage et quelque peu des contrôles normales:
Au chaque chantier la effectivité de le compacteur est essayé. Il faut de gagner la qualité de les spécifications. Avec les résultats d´un surface d´essai on gagne une description pour les travaux: grosseur de couche, nombre de les passages, vitesse du compacteur, les caractéristiques du sol. En théorie la qualité de la compactage faut être suffisant, si la description est observé. Pour sûreté sont réalisé quelque peu des contrôles normales.

**KEY WORDS**
ERTHWORKS, TESTING, STATISTIC QUALITY CONTROL, COMPACTOMETER, DESCRIPTION OF WORKS.

## 1. INTRODUCTION

The high quality of the earthworks is the condition for a durable pavement structure of roads. Most important in carrying out earthworks is a good compaction. The compaction leads by reducing the air void to an increase of share strength and the reduce of settlements. These parameters are the base for slope stability of the embankments and the evenness of the road surface.
In the beginning must be said, that a good compaction is not done by intensive testing – it is done only by the effective working of the compaction machines. But to

find out whether the compaction is sufficient or according to the specifications, tests for the compaction quality have to be carried out.

## 2. NEW SPECIFICATIONS

The world-wide most usual specification for the compaction quality is the degree of proctor density. For the test of this parameter have to be measured

- the density of the compacted soil,
- the moisture content for changing the normal density to the dry density,
- the proctor density.

This procedure needs a lot of time (and so a lot of money), and it has a serious bias of test result.

When an area has to be tested, which seems to be ready compacted (ready means: in accordance to the specifications), it cannot be presumed that the whole area has an equal degree of proctor density. It will have a statistical distribution. It can be assumed that this is a “normal distribution”.

With this precondition it gives no sense to fix the specification as a “minimum” value of the degree of proctor density. In Germany has been made a research to find the quantity of parts of an embankment with a lower compaction quality than the specifications although the specifications were set as minimum values.
This quantity was found with about 10 % all over several embankments which were tested it the research. These 10 % were found independent on the value of proctor density of the specifications: Was the specification low (f.i. 95 % of proctor density) the distribution of the values was flat, was the specification high (f.i.100% of proctor density) it was steeper, but in every case the percentage of values lower than the specification was about 10 % (pic. 1).

Picture 1: Curves of distribution for different specifications

So it was left the old “minimum – value – specification” and introduced a specification as a “10 % - minimum-quantile”.
Maybe that a specification in this form is unknown for earthworks till now – but it is well known for the strength of concrete, cement etc..
In another research the bias of test results for measuring the degree of proctor density was found out. The repeatability standard deviation (1 testing equipment, 1 lab technician) amounts to 1,5 – 2 % of the proctor density, the reproducibility standard deviation (several testing equipment, several lab technicians) 3 – 4 %.
When the bias of test results is known it is to be decided in which form the test results shall be compared with the specifications: Must the results reach the specifications by adding or subtraction the bias – or are the measured test-results compared without consideration of the bias. It was decided to the last variant.

## 3. METHODS OF TESTING THE COMPACTION QUALITY

In Germany a “method of testing” does not mean the testing procedure itself (in the field or in the laboratory), it means a systematic plan for the testing works in the constructing site. This plan has to be set before the testing procedure. Three approaches are possible:

1. Testing on the base of a statistical testing plan,
2. Testing with a vibrating roller with a special measuring equipment (compactometer),
3. Testing with a description for work and single tests.

Besides the “specifications for earthworks in road constructing” (the German name is ZTVE-StB) it gives a collection of instructions for soil testing. In this collection will be found the details of the three methods of testing.

### 3.1 TESTING ON THE BASE OF A STATISTCAL TESTING PLAN.

The first method seems rather complicated, but it is similar to the testing of the strength of concrete which is produced in a concrete mixing plant.
At first a special testing plan is chosen: sampling by attributes or sampling by variables; furthermore in single, double or consecutive testing plans.

In the instruction papers will be found for every testing plan

- the number of tests depending on the size of the area which has to be assessed,
- the behaviour of fixing the points for testing in the site (no subjective influence is allowed),
- the way of contributing the test results for the chosen testing plan,
- the rule of decision according to the testing plan and the specifications.

A flow chart for a single testing plan for sampling by variables is given in picture 2.

This method is very clear. But the disadvantage is the high number of tests which have to be carried out.

Picture 2: Flow chart for a single testing plan for sampling by variables

## 3.2 TESTING WITH A VIBRATING ROLLERWITH A MEASURING EQUIPMENT (COMPACTOMETER).

From a large research including the theoretical and practical aspects a lot about the dependency of the oscillation of a soil and the state of compaction or stiffness is known. For soils with a maximum part of particles passing the 0,063 mm – sieve of 15 M.-% this dependency is describable by a linear statistical correlation with a factor of correlation mostly better than 0,7. On every construction site this correlation between the behaviour of the roller
and the soil of the site has to be found on a testing field.

A system of a roller with the compactometer - instrumentation is shown in picture 3.

Picture 3: Roller with compactometer instrumentation

In the above mentioned instruction papers for this method are found
- details how to lay out a testing field,
- the number of tests for measuring the degree of proctor density or the plate bearing ratio, in several levels of compaction – quality,

- the aids for the statistical calculation to find the compactometer-value for the degree of proctor density or a plate bearing ratio from the specifications.

With this value the assessment of the compaction-quality is possible in a very simple and a quick way.
The advantage of this method is the possibility to get an assess for every m² of the compacted area – proposed the soil in the area is sufficient homogeneous and similar to the soil of the testing field. The test results of an area of about 2400 m² are shown in picture 4.

Picture 4: Results of a compacted area

Another advantage is the fact, that the driver of the roller gets an information about the compaction quality while he is working. So he can reach the requested quality more easily without any special testing works and without doing unnecessary compaction . No additional time for the qualitytests is needed – time and works which hinder the construction works.
Should the situation appear, that an unsuitable soil has been filled into the embankment, it will be found out when the roller is going over it.
This method works blanket covering in compactionintegrated.

## 3.3 TESTING WITH A DESCRIPTION OF WORKS AND SINGLE TESTS.

The basic idea of this method is, that the compactionquality in the construction site must be sufficient, when
- the soil of the construction site has been tested in a testing field,
- the same roller is used as in the testing field,
- the layers in the construction site have the same thickness as in the testing field,
- the number of the passes of the roller is the same as in the testing field,
- the velocity of the roller is the same as in the testing field

and when the tests of the compaction – quality give a positive result.
In a more comprehensive testing field it is possible to optimise the compaction works. (pic.5).

Picture 5: Testing field with 1 test area, for 1 thickness of layer and 1 number of passes of the roller

The results of the testing field are summarized in a description of work. In the construction site the driver of the roller has to work in accordance to that description. As proof for the sufficient quality the constructor has to give a documentation that he has followed the description of work. Furthermore he has to carry out single conventional tests of measuring the degree of proctor density.

This method is the mostly used one. If no special method is fixed in the tender papers, this method is valid as part of the contract. It can be used in every sort of soil, though for every sort is required an own testing field.

## 4. CONCLUSION

By the careful suiting of the specification for the compaction quality and the testing methods has been found a theoretical and practical accurate system for quality control.
In the beginning of the testing works must be fixed the area to which the results will belong. The results of the tests in method 1 and 3 describe the quality level of the whole area. If the results are negative the results are valid for the whole area – not only a part of it, where the negative result of a single test was found.
A very detailed assessment is possible by using the method 2. It is integrated into the construction works.
Method 1 is totally independent from the sort of soil and the constructing works.
Using method 3 the construction works have to be carried out in accordance to the results of a testing field. But it is independent of the sort of soil which is to be compacted.

So it is possible to find the best method for the special peculiarities of any constructing site.