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# A STUDY ON SPECIAL BACKFILLING MATERIALWITH LOW THERMAL RESISTIVITY ENHACING INCREASE IN CURRENT CARRYING CAPACITY OF HV/MV CABLES BY SAFE DISIPPATION OF HEAT

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## EXECUTIVE SUMMARY

A study on the proposal made by consultant for the advancement of a particular backfill material for the safe dissipation of heat generated by high voltage and medium voltage buried cables. This will increase the current carrying capacity of electricity cables for UAE electric utilities.

The current application of red dune sand can reduce thermal resistance by 35%, increasing cable ratings by 9%-18%.

The goal of the study by consultant was to investigate the feasibility of backfilling materials with a thermal resistivity of 1.0 Km/W or less and produced with locally available material(s) in UAE , in order to increase the current carrying capacity of MV cables by 10-15%.

By using a special backfill material for trenches for medium voltage cables, such ratings can be raised economically and safely in medium voltage cable trenches. A backfill material with reduced thermal resistivity can be designed, created and tested in an actual medium voltage cable trench.

As a local material crushed rock and RED dune sand are available in market

For increase of the compaction of the backfill material, the moisture content of the backfill material to be increased to the optimum value.

The different parts of IEC 60287 determine the stationary current rating of cable systems. The current rating depends on both the maximum temperature of the insulation material (XLPE - 90 degrees Celsius) .There is significant material change above both maximum temperatures due to ageing (in the case of insulation material) or drying-out (in the case of soil surrounding power cables). Current ratings of cable systems must take into account the resulting maximum temperatures.

The thermal resistivity of the soil or sand surrounding the cable system is calculated from the IEC 602878787, part 1-1, model. There is significant impact on the current rating and determines 70% of the thermal rating for medium voltage cables. The application of superior backfilling material with a low thermal resistivity around the cable system is very interesting because it will increase the cable current rating. and desippate the maximum temperature of the soil around the power cable .

It is predicted that the existing MV cables will be loaded higher than normal due to an expected increase in electricity consumption. The cable trenches just outside the

substations contain the majority of cables and, therefore, can be considered thermal bottlenecks.

## Different backfilling materials

**There are a variety of backfilling materials available that can be used to increase the thermal resistance inside cable trenches.**

### Cement bound sand

Thermal resistivity depends on the ratio of soil to air and varies with soil type. Cement can be added to the backfilling material to create cement bound sand (CBS). Thus, the backfilling material will always contain some moisture, thereby increasing its thermal conductivity. A ratio of cement and sand can lead to concrete.

### Concrete

A concrete mix consists of gravel, sand, cement, and water. It is laid in a pipe from one joint to the next. The thermal resistance is independent of the groundwater level. Concrete's properties depend on its composition. The strength of concrete used for civil activities like road construction is great, but it is very difficult to remove, and it cannot be reused. A low strength concrete can also be produced by varying the ratio of the two compounds, which has less strength but is also independent of groundwater.

### Bentonite

It is a mixture of natural clay with water. It mainly contains montmorillonite. The unique rheological and thixotropic properties of bentonite make it a popular material in drilling and geotechnical engineering. In cable trenches, bentonite is rarely used since it has no strength by itself.

### Fluidized Thermal Backfill

FTB is a material mix with a low mechanical strength, but one that is able to dissipate the heat generated by the cable well. The material has been engineered to meet specific properties such as thermal resistance. It is a slurry containing medium stone, coarse sand, cement, fly ash, and water. In difficult access areas, such as narrow canals/tunnels and on connections that cannot be mechanically compacted, such as when refilling existing cable connections, this slurry is primarily used. Filling voids without mechanical movement is possible with the FTB. It possesses a uniform density and could reach a thermal resistivity of approximately 0.3 Km/W/20. Upon hardening, the FTB can only be removed by mechanical force and is not reusable after cable repair, cable replacement, or additional cable installation in the same trench. In light of this impact on maintainability, FTB was not further considered in this study.

### Sand

The different ingredients and composition depending on the location and the environment. Sand is usually made up of silica (like quartz) or calcium carbonate. The grain size distribution of sand with good thermal properties is balanced between large and small particles. Sand crushers can produce these particles. A crushed sand, on the other hand, has a more angled shape than natural sand. Sand with a rounded shape can be compacted to a higher density and, as a result, has a lower thermal conductivity than sand with an angular shape. The sand can also be thermally inefficient. A coarse sand or a sand with a very uniform grain size is typical for this type of sand.

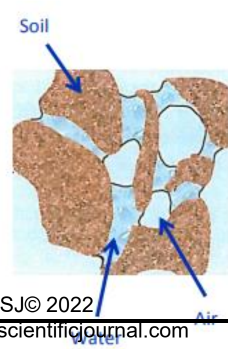
| Backfilling material | | Thermal resistivity (estimated) | Pros | Cons |
|---|---|---|---|---|
| Concrete | Not removable | <1.0 Km/W | Low thermal resistivity | Not removable |
| | Removable | < 1.0 Km/W | Low thermal resistivity, removable | To be produced at site |
| Bentonite | | < 1.2 Km/W | Low thermal resistivity | A cover is necessary |
| Fluidized thermal backfill | | 0.3 - 1 Km/W (dry) | Low thermal resistivity, easy to use | Local not available<br>Not removable |
| Sand | Natural | 0.5 (well graded) – 4 Km/W (not graded) | Local available on the site | Sensitive for drying out |
| | Crushed | 0.6 (well graded) – 4 Km/W (not graded) | Each particle size can be made | Sensitive for drying out |
| | Mixed | 0.3 (well graded) – 3 Km/W (not graded) | Less sensitive for drying out | Not very often natural available |

## Characterization of soil

In order to characterize the soil, different properties are used. Several properties are characteristics of the soil itself; other properties characterize the external influences on the thermal behavior of the soil. Both aspects will be briefly described in the following sections. **Thermal conductivity**

As mentioned, the cable environment plays an important role with respect to the current rating of cable systems. The following important characteristics are typically used to describe soils: the thermal resistivity, the thermal diffusivity, the maximum density, the minimum density, the dry density and the particle size distribution. Soil is a mixture of solid materials, water and air,

As shown in Figure soil is made up of solid materials, water, and air.






e 3-1: Typical composition of soil; soil, water and air

The three major heat transfer processes in soil are as follows .

## Heat conduction

Heat conduction which involves the transfer of kinetic energy at the molecular level. Molecules in warmer areas vibrate more rapidly, resulting in collisions with, or excitation of, their colder "neighbors". This causes them to lose some of their heat and the heat is transferred to the surroundings. This is also accomplished by water bridging soil particles. In soils, conduction is the primary mode of heat transfer. This is the basis for IEC 60287 models.

## Heat Radiation

Heat is emitted by molecules through electromagnetic waves. Stefan Boltzmann's law states that all materials emit electromagnetic waves at temperatures above 0oK. Typically, radiation occurs between particles' surfaces. Due to the close proximity of particles and the fact that they are connected through water or air, in a compacted backfill material there is relatively little temperature difference between surfaces. Radiation therefore does not play a significant role in heat transfer.

## Heat Convection

Convection of heat involves the transfer of thermal energy with a "heat-carrying" mass, such as water. Due to the small space between soil particles, convection does not contribute significantly to heat transfer in soils. Therefore, the dominant process in soil is conductivity of matter. Thermoconductivity is defined as the amount of heat transferred through a unit area in a unit time under a unit temperature gradient. Soil thermal conductivity depends on the density of the matter, the water content, and the presence of air gaps. As density increases, the improved and increased contact between the solid particles increases thermal conductivity. Some space remains between the solid particles, and this space can be filled with either air or water. Due to the fact that water has a thermal conductivity roughly 20 times higher than air, the presence of water will increase the thermal conductivity of the soil. It is assumed that in this case, the air and water are both stationary (no convection, as explained previously). The thermal conductivity will increase significantly if flowing air or water are used in cooling systems.

| Material | Specific thermal resistivity in Km/W |
|---|---|
| Quartz | 0.11 |
| Organic material | 2.2-19.9 |
| Stationary water | 1.7 |
| Sandy soil | 0.3 (wet) – 5.0 (dry) |
| Stationary air | 40 |

As can be seen from above , Quartz and wet sand have very low thermal resistance, whereas air has a very high thermal resistance.

## Soil Parameters

Thermal resistivity is a measure of how well soil transports heat. The purpose of this investigation is to investigate the transport of heat from the cable jacket to the surface. As discussed in the previous section, conduction is considered to be the most important means of transporting heat away from cables. For maximum thermal conductivity, air gaps should be filled with moisture as much as possible, while the soil particle should be quartz or a similar stone-like material. Different parameters have been introduced to describe a soil. The most important parameters for cable system installation are the dry density, the proctor density, the particle distribution, and the moisture content.

## Particle size distribution

The dry density of a soil depends on the particle distribution. The smaller the particles, the less air-gaps can be expected between them, resulting in a higher density. A sieve test can be used to determine the particle size distribution of soil

## Dry density

The dry density of the soil is defined as the mass of solid particles in a given volume of soil without the presence of water or moisture. Thermal resistance is largely determined by the dry density of the soil or sand in the trench after the installation of the cable. Different soil types achieve different dry densities depending on their particle size distributions. In the cable trench, a dry density is created by compacting or not compacting the soil.

## Proctor density

The process of compaction of soil involves packing solid particles more closely together by mechanical means, thereby increasing the dry density of the soil. A soil's dry density is determined by the amount of compaction applied and the amount of water in the soil. In a laboratory environment, the relationship between density, water and compaction

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can be studied. A prescribed compaction method will result in the highest dry density for all soil types at an optimal point. Taking the standardised compaction method as an example, this is the proctor density, while the whole relationship between density and water content is the proctor curve. A soil can be compacted to higher levels than its proctor density by compacting better / more than the standardised compaction protocol prescribed in the proctor test. Soil compacted to 98% of its proctor density and soil compacted to 105% of its proctor density can both be described.

## Moisture content

Water is present in most soils. Moisture content is defined as the amount of water in a fully dried sample expressed as a percentage of mass. The moisture content of soil has an impact on its thermal behavior. The actual thermal conductivity of soil depends on the actual moisture content (together with the soil density) and therefore increases with varying moisture content. As a result, cable ratings are based on thermal resistance in cable trenches at the lowest moisture content. . The British Standard shows to be the most comprehensive and will be used for further references.

### Particle distribution

It is accepted that behind the particle distribution by using sieve curve and muller curve are the basic methodology study of particle distribution.

Using a sieve test, the particles present in the soil are separated according to their size. The final result is a sieving curve is as follows

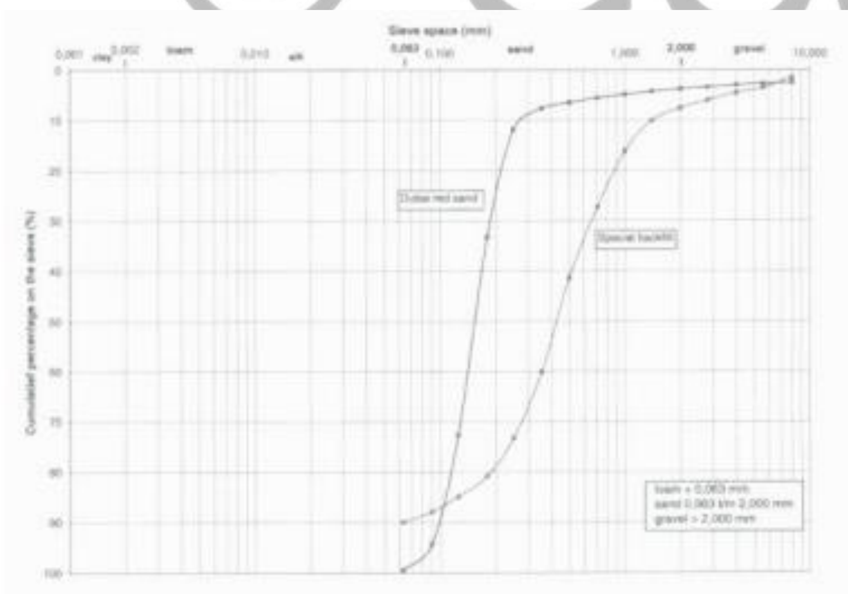



**Figure 3-2: Examples of sieve curve /16/.**

Is is assumed that a soil is well graded, meaning an optimal balance between smaller and larger grains, it is possible to fill up a volume quite precisely. From a theoretically point of view, the Fuller curve is often used as common reference

The basic equation to calculate the maximum density gradation is:

$P = (d / D)^n$

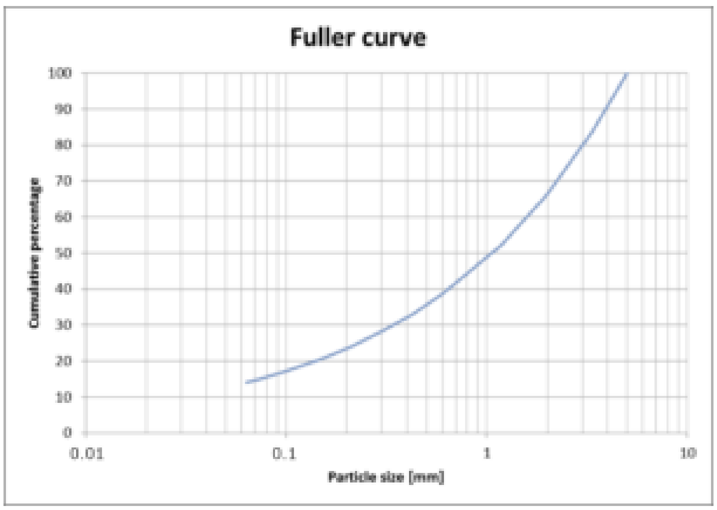
in which: P = percentage of material finer than the sieve

d = aggregate size being considered

D = maximum aggregate size to be used n = parameter which adjusts curve for fineness or coarseness, typically

n=0.45.

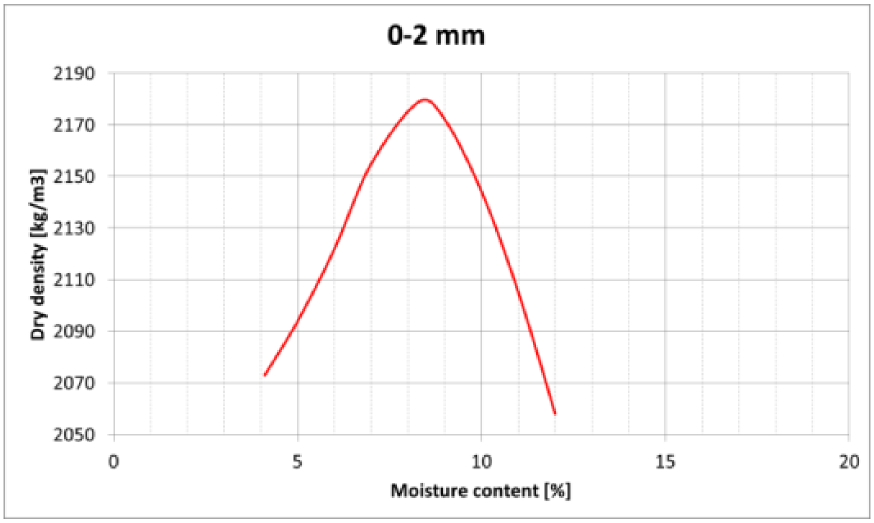
Fuller curve for n=0.45 with a maximum particle or aggregate size of 5 mm as is generally acceptable for use in cable trenches




**The Fuller curve shows optimum density of particle gradation**

## Proctor and dry density

In practice, a filling degree of 100% is never achieved according to the Fuller curve. Therefore, compaction is generally used to increase the density of the soil. Compaction is a method of increasing soil density by packing the solid particles closer together by reducing air spaces between them. Depending on the type of soil, cable and cable joint, compaction should not exceed or underpass certain limits. As a result of compaction, the thermal resistivity of the backfilling block will decrease, and future settlement of the cable trench will be reduced. It is usually necessary to add moisture to the soil to make it less stiff, in order to increase the efficiency of compaction. Adding too much water, however, will lead to the separation of solid particles, resulting in less compaction. So, the optimal water content can be determined in order to achieve the best soil density.




**The relationship of moisture content using prescribed compaction method according to BS 1377-4**

**Example of a dry density**

## External factors on moisture content

In addition to the characteristics of the soil, external factors can affect its thermal resistance, including its moisture content: groundwater level and vegetation. If the groundwater level is always higher than the level at which the cables are installed, the cables will always be surrounded by fully saturated soil with no air inclusions. In case of fluctuating groundwater levels, the thermal resistance of the soil is determined by the lowest groundwater level. It is important to measure the groundwater level during a soil analysis and to list the possible lowest groundwater levels along a planned cable route in order to determine the representative thermal resistivity and relate soil characteristics to this thermal resistivity. The vegetation may remove moisture from the soil. Plants can cause the soil around the cables to completely dry out if the cables are installed above groundwater level. Therefore, during a soil analysis in which thermal parameters are determined, consideration should also be given to the vegetation present along the planned route. Grass and bushes can cause the soil to dry out up to a depth of about 30 cm.Trees can dry out the ground up to a depth of 1 m. If such trees are found **during a** soil analysis for a planned route or an existing route, then it is recommended either to remove the trees, or to install the cable at a distance sufficient from these trees, or to investigate the soil's sensitivity to dry out under the influence of tree roots.

**Influence of moisture and dry density on thermal resistivity**

Based on DNV GL's experience, several empirical formulas have been developed to characterize the most important parameters of soil. Several studies were conducted on different sand sands from various countries in order to determine these formulas. The results are only valid for clay content ranging from 2%-10%, densities up to 1500 kg/m3, and moisture content of 2%-10%. The investigations have only been published in an internal report in Dutch /18/. The formulas should be confirmed for applicability for the materials available in each countries , and if necessary adapted according to the specific measuring results

The formula is used only to show and explain the impact of dry density and moisture content on thermal resistance in this section.

The following empirical formula can be used to calculate the thermal resistivity of sandy soils:

$$\log g = 1.350 - 0.00115\rho_d + \frac{0.0170}{w + 0.0179}$$

in which:

| | | |
|---|---|---|
| $g$ | = | thermal resistivity of sandy soil (Km/W) |
| $\rho_d$ | = | dry density of sandy soil (kg/m³) |
| $w$ | = | moisture content of sandy soil (weight part of dry density). |

According to Figure -1 and Figure-2 , a sensitivity analysis is performed by consultants regarding the of the relationship between thermal resistivity, soil density, and moisture content. It is necessary to make the soil in the cable trench 2000 kg/m3 dense in order to achieve a thermal resistivity of 1.0 Km/W.

Due to the fact that normal trench compaction methods are only able to achieve 90% of the proctor density, a proctor density of 2222 kg/m3 is the theoretical design requirement for the soil.

If moisture content is just 0.5%, the required proctor density drops to 2025 kg/m3.

**Therefore, it can be concluded that the inputs and obtained values are outside the validity range stated above; therefore, actual measurements should be performed in order to confirm the results.**

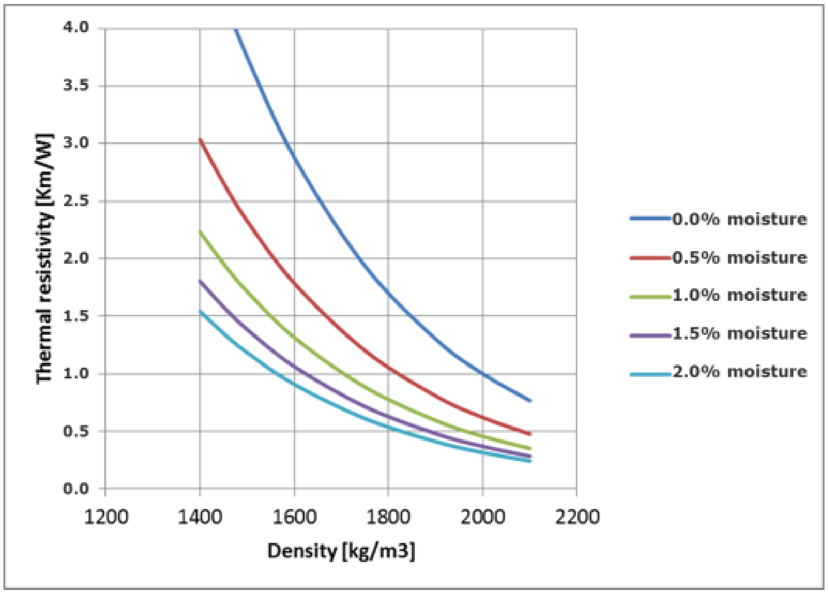



**Figure -1 Thermal resistivity as function of the soil density and moisture content**

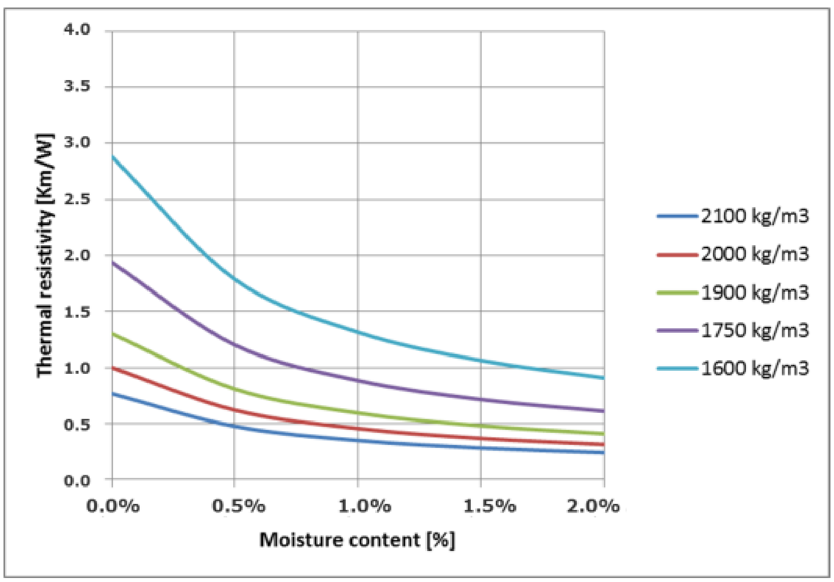



**Figure -1 Thermal resistivity as function of the moisture content and soil density**

## Findings and general study

As per the study conducted by consultant the required of electrical utility, local material availability is the best material due to its abundant quantity availability locally ,hence use of material available locally can reduce the overall cost

In UAE, RED DUNE SAND is locally available in abundant quantity and as per utility specification requirements should be , low moisture content of approximately 2% is expected, with a compaction rate of 90% compaction .

In Dubai, as per consultant study the following are concluded for backfilling material specially for medium and High voltage installation in order to reduce the heat dissipation .

- To increase the thermal conductivity with the expected low moisture content in Dubai, **the density of the backfill material should be considered as important variable**
- **The Fuller curve gives an optimum particle distribution** for a certain range of particles and will be taken as a reference for the definition of special backfill material to reach a certain soil density
- **The proctor density test gives the relation between a certain compaction method, the moisture content of the soil and the density of the soil** and is an useful measure to compare different soils
- **The empirical DNV GL formula to relate thermal resistivity with moisture content and dry density** cannot directly be used for the Dubai situation and additional measurements are required to confirm the result
  There are several samples od Sand taken from UAE and these samples have been analyzed as follows
- **Red dune sand**
  Red dune sand is being applied as backfilling material by electrical Utility company in UAE at this moment and is used for comparison with the other materials.

- **20-2 mm crushed rock**
  This crushed rock is crushed from rocks in UAE by National Quarries. The largest particles in this crushed rock are 2 mm in size.
- **0-5 mm crushed rock**
  This crushed rock is crushed from rocks in UEA by National Quarries. The largest particles in this crushed rock are 5 mm in size.
- **Filler crushed rock**
  This filler is crushed from rocks in UEA by National Quarries. The largest particles in this filler are 0.3 mm in size.
- **Fine crushed rock**
- **Crushed rock particles are 0.3 mm in size but smaller in dimension compared to filler crushed rock.** Full reports are attached in Appendix A. The crushed rock has been subjected to a mineralogical investigation. Table 4-1 summarizes the results of the investigation presented in Appendix B.

**Composition of crushed rock used for backfilling**

| Material | Percentage [%] | Remarks |
|---|---|---|
| $SiO_2$ | 45% | Silicium Dioxide is a chemical compound of silicon and oxide and is commonly found in nature as sand or quartz. |
| MgO | 25% | Magnesium Oxide (also called magnesia) is a white hygroscopic solid mineral. The hygroscopic property means that MgO has the ability to bind to water molecules via hydrogen bridges. It therefore attracts and holds water molecules. |
| CaO | 12% | Calcium Oxide is commonly known as quicklime. |
| $Fe_2O_3$ | 9% | Ferric Oxide is also known as hematite. It is the main source of the iron for the steel industry. Hematite is ferromagnetic, dark red, and often called rust. |
| $Al_2O_3$ | 4% | Aluminium Oxide is a rock-forming material and occurs in nature as Corundum. |
| Other | 5% | |

An X-ray crystallography can be used to determine how the chemical elements listed in above are bound. By diffracting a beam of X-rays into many different directions, X-ray crystallography determines the atomic and molecular structure of a crystal. A crystallographer can determine the density of electrons inside a crystal by measuring the angles and intensities of diffracted beams. This electron density can be used to determine the mean position of the atoms in the crystal, their chemical bonds, their disorder, and various other information.



Based on this analysis, the three main elements in the crushed rock are:

1. Quartz

2 .Magnesium silicate

3 .Magnesium-Iron bonds.

All sieve curves are summarized in Figure 4-1. The theoretically Fuller curve is shown as well (“Fuller”).

The following observations can be made from these curves

- The red dune sand has a very steep particle distribution. Most particles are between 0.3 mm and 0.075 mm. This is badly graded sand, meaning that it is rather difficult to obtain a good compaction as will be shown later.
- The fine and filler materials show 70-90% particles smaller than 0.063 mm. In the fine material, almost 10% of several large stones or agglomerates of particles were observed. Generally it can be stated that this material can be used to adapt the lower part of the sieve curve if required.
  The 0-5 mm curve shows an almost well graded particle distribution. It shows high similarities with the Fuller curve and deviates maximal 12% to this curve. As a consequence, it shows a rather high maximum density as shown in following table

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**TABLE -A**

| Soil type | Proctor density | Optimum moisture content |
|---|---|---|
| Red Dune Sand | 1770 kg/m3 | 12% |
| 0-2 mm | 2180 kg/m3 | 8.3% |
| 0-5 mm | 2430 kg/m3 | 5.9% |
| Filler | 2020 kg/m3 | 12% |
| Fine material | 2160 kg/m3 | 9.5% |

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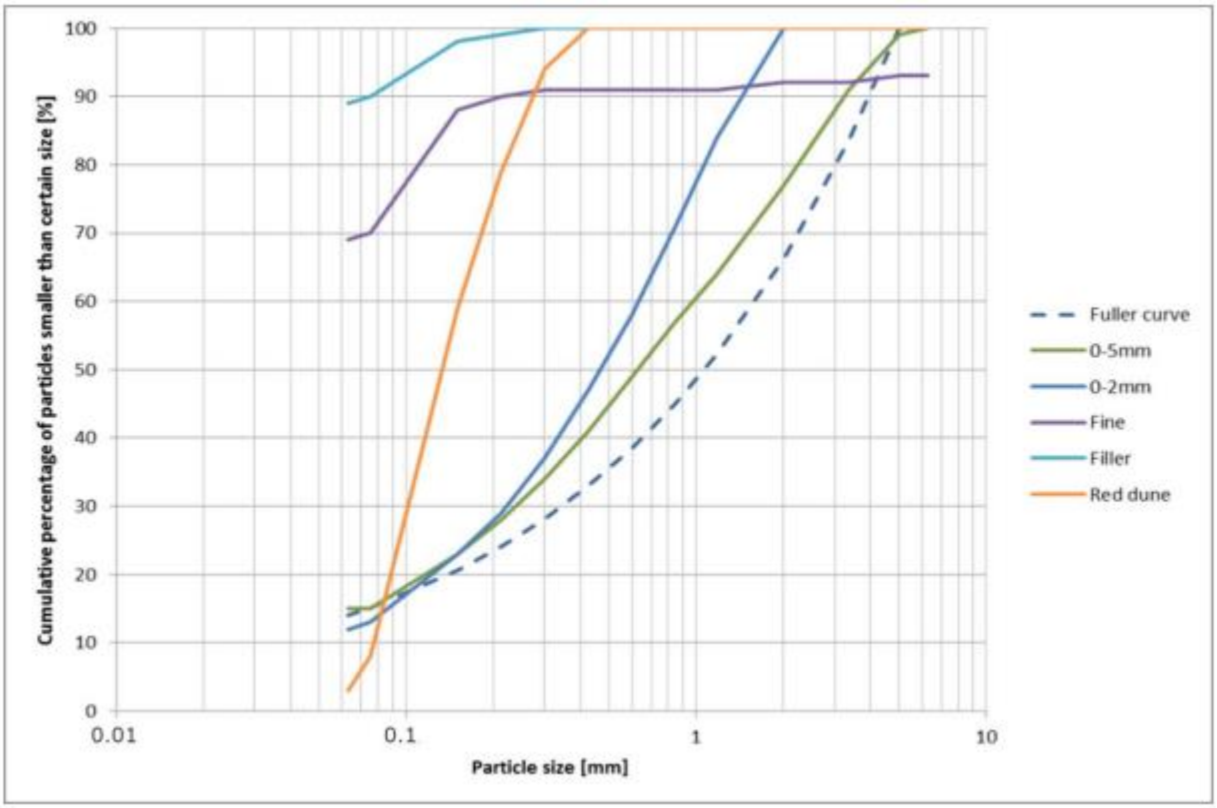



Based on the sieve curves and **Table A it** can be concluded that:

- The red dune sand and filler materials have a very steep sieve curve and as such, not the most preferred materials to be applied as backfilling material.
- The 0-5 mm material shows the highest proctor density and the best fit with the Fuller curve. It can be concluded that this material shows the best properties to obtain a low thermal resistivity.

## The basic study on backfilling material using local materials in UAE

Based on the materials obtained in the UAE, the theoretical background and the Dutch experiences, it is believed that it is feasible to create a backfilling material with a thermal resistivity of 1 Km/W.

For further investigations, the 0-5 mm material has been used as base material.

Because the price of the crushed rock is about 20% - 40% higher than the price of red dune sand, the 0-5 mm crushed rock has been mixed with red dune sand in different ratios and the particle size distribution, proctor density and thermal resistivity has been determined to obtain the optimal mixing ratio.

Particle size distribution The different materials have been investigated using wet sieving. The results of these investigations are shown in Following figure B.

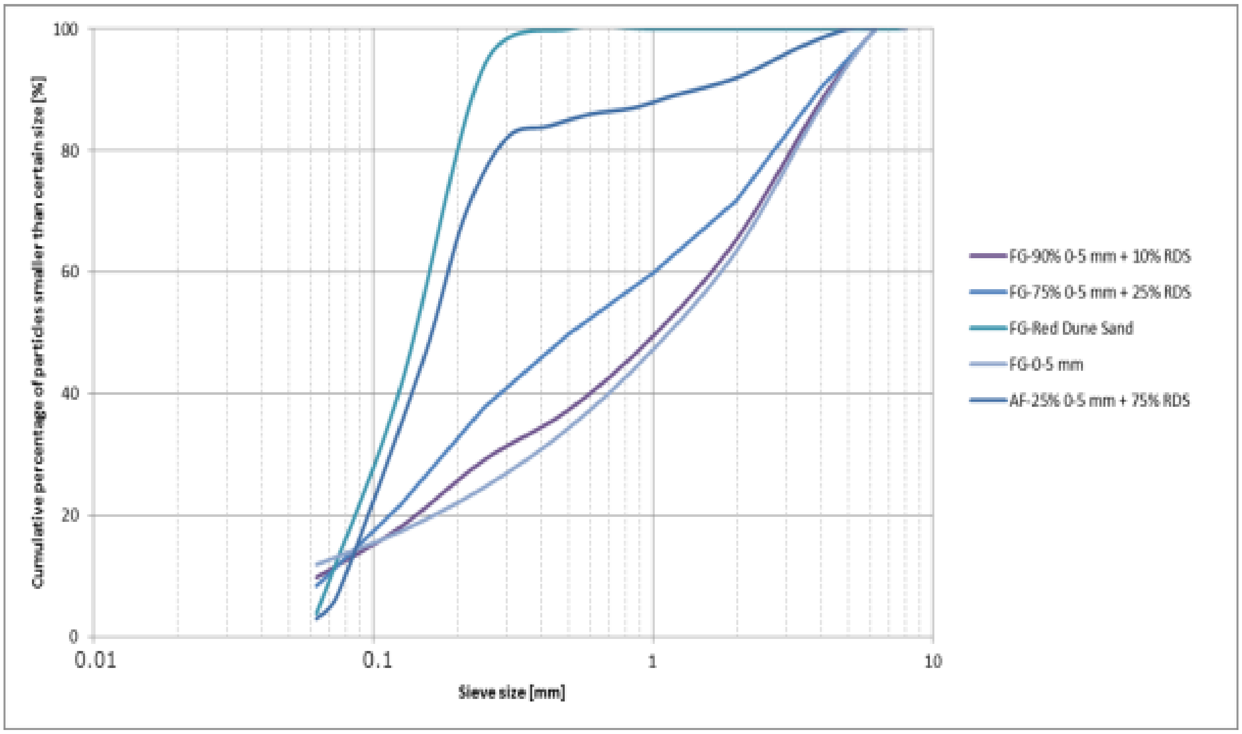



**Figure :B Overview of sieve curves for the different investigated backfill materials with 0-5 mm crushed rock as base material**

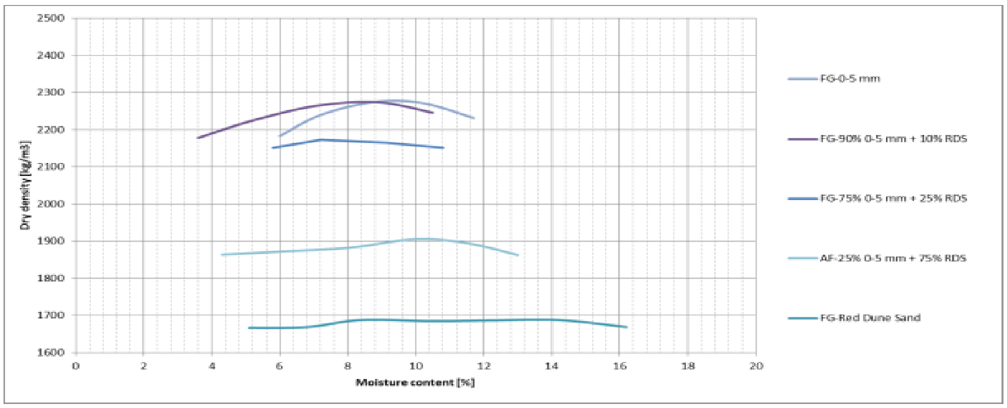
The results show the impact of mixing different materials. The higher the red dune sand content in the mixture, the more the sieve curve of this mixture is shifted to the left (increased smaller particle size content). The more crushed rock is used, the more the sieve curve of the mixture is shifted to the right (increased larger particle size content

## Conclusion

Based on the investigations performed, **at least 75% of crushed rock is required to stay sufficiently close to the theoretically optimal particle size distribution as described by the Fuller curve**

Proctor density

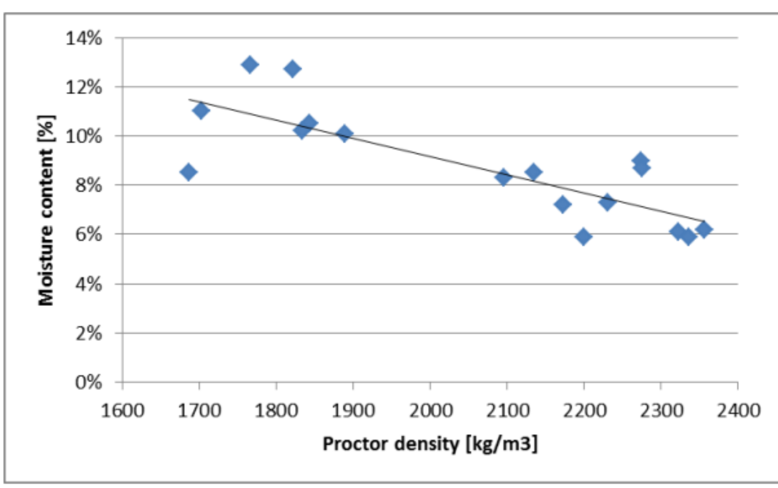
The study had been conducted by consultant on the proctor density of different materials .The results of these investigations are shown in following Figure.




**<u>Overview of dry density – moisture content relationships for the different investigated backfill materials with 0-5 mm crushed rock as base material</u>**



One observation is that the peak in the dry density is shifting to the left with increasing dry density value. This can be explained by the fact that higher dry density materials have less space between the different particles because the particle size distribution is such that gaps are filled with smaller particles. As a result, less space is available for water molecules and also due to the better particle size distribution, less water is needed to get the particles organized. Another interesting observation was made in the moisture content in correlation to the proctor density value, see FigIt It shows that lower moisture contents are required for higher proctor densities. Less water is required during the on-site mixing process, which saves costs for water and its transportation to site.




<u>ntent</u>

**<u>Conclusion</u>**

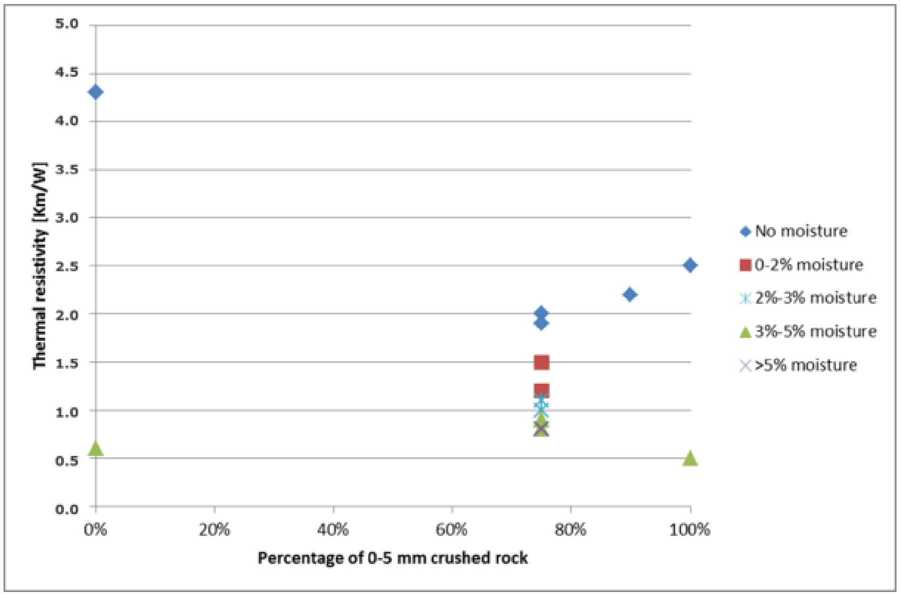
Based on the investigations performed, at least 75% of crushed rock is required to achieve a proctor density higher than 2100 kg/m

**Thermal resistivity values**

By laboratory experiments the consultant had determined the thermal resistivity values of several mixtures. The laboratory reports are attached for reference. The results are summarized in the following table and **Figure C**. Unfortunately, the number of tests is limited and more results will increase the accuracy of the results and the relationship between the moisture content, ratio and proctor density. Consultant recommended to develop a database for the information to be gathered from future projects

| 0-5 mm crushed rock [%] | Red dune sand [%] | Proctor density [kg/m$^3$] | Moisture content [%] | Thermal resistivity [Km/W] |
|---|---|---|---|---|
| 0% | 100% | 1687 | 0.0% | 4.3 |
| 0% | 100% | 1687 | 0.0% | 4.3 |
| 75% | 25% | 2290 | 7.0% | 0.8 |
| 75% | 25% | 2290 | 6.0% | 0.8 |
| 75% | 25% | 2290 | 4.5% | 0.8 |
| 75% | 25% | 2290 | 3.4% | 0.9 |
| 75% | 25% | 2290 | 3.0% | 0.9 |
| 75% | 25% | 2290 | 2.7% | 1.0 |
| 75% | 25% | 2290 | 2.1% | 1.1 |
| 75% | 25% | 2290 | 1.1% | 1.2 |
| 75% | 25% | 2290 | 0.6% | 1.5 |
| 75% | 25% | 2290 | 0.5% | 1.5 |
| 75% | 25% | 2290 | 0.0% | 2.0 |
| 75% | 25% | 2199 | 0.0% | 1.9 |
| 90% | 10% | 2274 | 0.0% | 2.2 |
| 100% | 0% | 2275 | 4.0% | 0.5 |
| 100% | 0% | 2275 | 0.0% | 2.5 |
| 100% | 0% | 2275 | 0.0% | 2.5 |

**Thermal resistivity values and moisture content for different mixtures of 0-5 mm crushed rock and red dune sand**




**Thermal resistivity values for different mixtures of 0-5 mm crushed rock and red dune sand with different moisture content level**

Based on the measuring results, the theoretical model as described in section 3.2.6 was modified. The main reasons for this modification lie in the facts that the theoretical model is valid for proctor values below 1500 kg/m3 and moisture content between 2%-10%. As a result, the model /formulae indicated below : ref paragraph (**Influence of moisture and dry density on thermal resistivity )**

$$\log g = 1.350 - 0.00115\rho_d + \frac{0.0170}{w + 0.0179}$$

in which:

| | | |
|---|---|---|
| g | = | thermal resistivity of sandy soil (Km/W) |
| $\rho_d$ | = | dry density of sandy soil (kg/m$^3$) |
| w | = | moisture content of sandy soil (weight part of dry density). |

is not valid for the operating conditions in Dubai

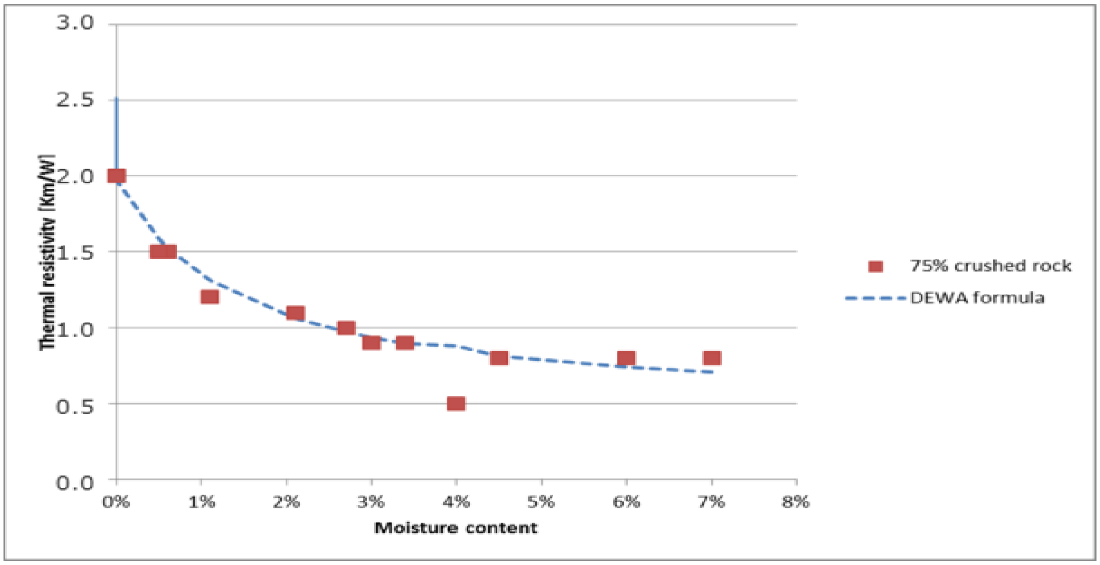
In fact, two correction factors as follows were introduced when fitting the measuring results to the model,

1) 0.027387 to be added to the moisture content instead of 0.0179 in the original formula
2) 2 the final result is divided by 0.13

$$g = \frac{10^{1.350-0.001155\rho_d+\frac{0.0170}{w+0.027387}}}{0.13} \qquad (2)$$

in which:

| | | |
|---|---|---|
| g | = | thermal resistivity of sandy soil (Km/W) |
| $\rho_d$ | = | dry density of sandy soil (kg/m³) |
| w | = | moisture content of sandy soil (weight part of dry density). |




**Measured thermal resistivity values as function of the moisture content for different ratios of crushed rock and red dune sand**

**As a result, this formula is only valid for the 75% 0-5 mm crushed rock and 25% red dune sand mixture of DEWA with a density between 2200-2300 kg/m3 .**

Based on this modified formula, we can conclude as follows

- **A moisture content of 2% will give a thermal resistivity of approximately 1 Km/W at a proctor density of 2200 kg/m3** .
  However, it is noted that the empirical formula from DNV GL has been adjusted by consultant based on a limited number of experiments and should thus be carefully used. It is recommended to use results obtained during the quality control of future projects to improve the accuracy of the formula

## Summary and conclusions

As a result of the investigations described in this section, the following conclusions can be drawn:

- Local natural materials in UAE can be used to produce a backfill that can reach 1 km/W.

- Sandy material will not damage the cable sheathing The crushed rock material of 0-5 mm can be used to create a more optimal particle size distribution that will be used to form the final mixture
- The higher the proctor density, the lower the moisture content required during compaction. A higher percentage of crushed rock 0-5 mm results in higher proctor densities.
- Therefore, a mixture composed of 75% in weight of 0-5 mm crushed rock material and 25% in weight of red dune sand should achieve a thermal resistivity of approximately 1 Km/W with 2% moisture
- The empirical formula from DNV GL has been adjusted based on limited experiments and should therefore be used with caution. Consultant recommend that future results be fed back into the formula to improve its accuracy.
- It is now possible to reach a backfill thermal resistivity of 1 Km/W. Mixing 25% red dune sand and 75% 0-5 mm material will result in a thermal resistivity value of 1 Km/W.

**Hence it is desirable to use the backfilling material with 75% of 0-5mm crushed rock and 25% of Red dune sand, which will give thermal resistivity of 1KM/w as required for the electrical utility standard for backfilling of HV & MV cable trenches. Further the study had been elaborated by consultant with current rating of cable which are not discussed in this article.**

**References:**

Consultant Study reports

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