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Interlayer Shear Failure Evolution with Different Test Equipments

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Abstract

This research analyses the relationship between several configurations, failure mechanisms and states of stress imposed by testing machines, comparing the results of two devices. It focalizes on the evolution of numerous tests, performed on identical specimens, and reports the correspondent response curves obtained with two devices suitably designed to cover two kind of devices used in recent years and modified to ensure the comparison between the outcomes.
The observation of a regular trend in the results suggests a strict relationship between them and the specimens' features and also warrants the statistic reliability of the testing machines.

Keywords: Strength & testing of materials, Interface shear strength, Normal load, Testing machine

1. Introduction

The performance of a road pavement is significantly affected by the bond between the layers. Efforts have been made to investigate the stress distribution at the interface related to the interlayer bonding condition, because the lack of adhesion among the coats causes a greater deformation, changes the stress and strain distribution in the structure and, consequently, results in a shorter pavement service life.

According to Khweir [1], the pavement life reduction is estimated at 40%, in the case of deterioration at the interface between surface course and binder course, or as low as 16% of its potential life if the failure happens at the interface between binder and base layer.

Literature shows that a number of researchers have analyzed with experimental or numerical approaches the bonding conditions.
On one hand 3d models have been implemented to investigate the contact stress pressure, the stress and the strain inside the pavement [2,3].

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The most advanced models point to capture the interface behavior under various loading conditions, from the initial elastic response, when the interface is fully bonded, to the postpeak softening response, when the interface is in a debonding state so to evaluate the effects of interface condition on pavement life. To implement this softening type of debonding process, softening plasticity theory is used. Direct shear and pullout experimental tests are needed to provide parameters for this kind of models [4].

On the other hand, during the same years, many different test machines have been used to evaluate the interface bond strength of samples and cores, to assess the influence of principal factors: temperature, pavement type and texture, surface wetness and cleanliness.

Nonetheless the researchers have devoted most of their attention to shear failure condition, to detect the better tack rate or the more efficient type of emulsion, and so on, because of the specific interest of road material industry.

Two criteria have been used in the literature to determine the optimum tack coat application rate: maximum shear stress for monotonic tests or maximum number of failure cycles for cyclic tests.

If the second criterion is able to better simulate the real pavement situation, that can vary rapidly among very different loading conditions (pure tensile, pure shear, shear with tension, and shear with compression), the monotonic test is the most commonly used because of its simple operation and control during testing. Furthermore, according to Al-Qadi [5], who compare the two testing modes on its testing machine, was found that monotonic testing more precisely quantified the effect of interface characteristics than cyclic testing.

Therefore, studies are sparing about the themes of the validation of test machines and of the reliability, comparability and repeatability of the results. The present research wishes to give a contribution about those themes, regard to the more common kind of machines currently used.

2. Background

In prior years, different test methods have been presented from different countries to assess the degree of adhesion between two asphalt layers. All of them are aimed to detect the shear resistance at the interface, where the value is in general less than inside the layer. The selected shear test procedures derive from shear testing in soil mechanics; the devices evaluate the strength interface performance forcing failure in the interlayer zone.

The first device was achieved by Uzan [6]; it includes a shear mold divided in two parts. The lower part is screwed to the table while the upper part has a groove 5mm above the interface where the horizontal force is located. A frame applies the vertical load and four deflectometers measure the displacements. The samples were tested at horizontal displacement rate of 2,5mm/min leading to a distortion and a non uniform stress condition devise from the working scheme. The parameters plotted for the analysis were the shear stress and the displacements. The shape of the curve, non linear and decreasing after the peak stress value, is similar to one obtained in indirect shear test for soils or in Marshall Test for asphalt concrete.

In Germany, in the late 1970s Collop [7] developed the Leutner shear test (Figure 1e), a very simple device able to apply a shear displacement rate (50mm/min) across the interface of a cylindrical core, monitoring the resulting shear force. A normal load is not applied to the specimen and the general trend of the curve shear stress-displacements shows a correspondent increase of the two variables.

Another testing procedure was performed by Tschegg [8] with the Wedge Splitting Test, a particular device able to apply a force to a dual layer specimen by pushing a wedge, with an angle between 5-12° , into the interface between the two layers until they separate as a result of the horizontal component of the force. With this equipment is possible to evaluate the load-displacement curve to characterize the different ductile or brittle behavior of heterogeneous materials as a function of the fracture energy.

In the shear tests is also included the equipment developed by Sholar [9], characterized by the adjustability of the gap between the shearing platens and of the loading modes (strain or stress).

In addition to these, West [10] developed a shear type test modifying the original NCAT's bond strength device, which was also able to apply an horizontal load. This condition of stress was designed to verify the research hypothesis that normal pressure is necessary to identify the benefit of friction due to the surface texture and consequently the quality of the performing bonds.

The equipment used by Miro [11] known as LCB test, Laboratorio de Caminos de Barcelona, performs the shear test holding the specimen horizontally over two supports 20 cm apart. Only one layer is clamped in a mould, held by one support; the interface must be placed 5 mm away from the edge of the mould and from the other support to avoid bending moments during the test.

Tashman [12] investigated the interface bond strength using not only a Torque Bond test and a UTEP Pull-Off test but also a direct shear test, known as FDOT Shear Tester. This device is characterized by two rings which fix the specimen with a diameter of 6 inch to reduce the testing variability in part due to the larger shear surface area.

Canestrari [13] evaluated the interlayer shear resistance through the ASTRA tester,a shear box able to simulate realistic pavement loading conditions allowing the application of a normal load joint with the shear load, as well as the LPDS or layer-parallel direct shear tester. In the first device, the sample is installed in two half boxes separated by an unconfined zone where the interface must be placed; the second equipment is a version of the Leutner test, modified to allow only a shear load on a sample clamped for a half part and suspended for the other part.

Furthermore, Wheat [14] designed a device where the specimen is tested in an inclined configuration under a load machine applying a vertical force (Figure 1a). In this scenario, the shear and normal stresses act simultaneously and their ratio is fixed by the angles of specimen's slope ranging from 0 to 45 degrees.

Al-Qadi [5] built a test device designed to apply a shear force and a normal one performing monotonic or cyclic tests (Figure 1b). The effects of a bending moment due to the eccentricity of the shear force were eliminated with a U-shaped loading arm.

Bae [15] developed the LISST, Louisiana Interlayer Shear Strength Tester (Figure 1d), to characterize the interlayer shear strength. The device is composed of a reaction frame, held stationary, and a shearing frame, free to move, where the load is applied. Two collars lock the specimen in the structure. The parameters selected to characterize the bond strength interface were the interlayer tangential modulus and the peak shear stress.

Recently, a direct shear device (Figure 1c) has been developed by Chen [16]. The equipment, similar to the device used in rock mechanics, applied one level of the shear load and four levels of the normal load on the specimen. The typical curve for shear stress versus horizontal displacement was divided in three zones: linear, transition and residual. To represent the mechanical behavior of the interlayer, the researchers evaluated the peak shear stress, the residual shear stress and the K-value (interlayer reaction tangential modulus) from the initial slope of the curve.

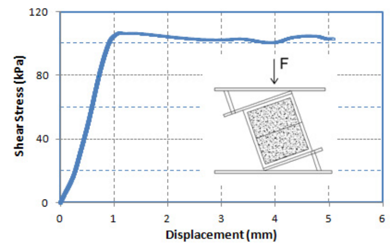
This overview on the existing shear tests used to characterize the interlayer bond of asphalt pavement heightens the researchers' interest in devices able to apply composed states of stress and contemporarily simple to install and to set. But, in absence of a standard procedure for evaluating the strength of the interface, in most cases a more complete description of the equipments would be of great interest.

Furthermore, only in a few cases the typical shear stress VS displacements curves obtained by the tests have been proposed but the details on the values of the parameters of execution are often not cited. The comparison between the graphs in terms of measurable results is therefore impossible, but their trends can be analyzed.

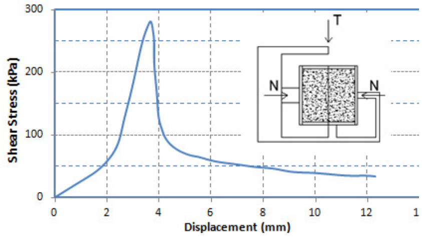
The summary of the cited curves shows that different working schemes result in very different shapes of the curves, as the figure 1depict.

The devices characterized by the application of a normal force on the specimen are represented by a curve with a particular trend, shown in Figure 1c, 1d and 1e. At the beginning the shear increases rapidly until the peak value is reached, then the shear stress decreases as the displacement continues until the attainment of a residual strength.

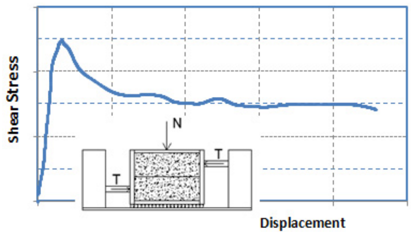
Authors	Wheat (a)
I.D. device	Shear Strength test
Size specimens	φ= 101,6 mm
Deformation rate	3 mm/min
Normal load	proportional to the Shear load
Study parameters	interface type and tack coat application rate



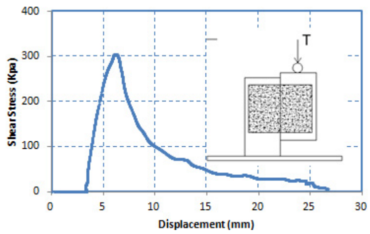
Authors	Al-Qadi; Carpenter; Leng; Ozer (b)
I.D. device	direct shear test
Size specimens	φ= 98.4(PCC) /100 (HMA) mm
Deformation rate	12 mm/min
Normal load	undeclared
Study parameters	HMA material, tack coat material and application rate; PCC surface texture, temperature and moisture conditions



Authors	Jian-Shiuh Chen; Chien-Chung Huang (c)
I.D. device	direct shear test
Size specimens	undeclared
Deformation rate	2,5 mm/min
Normal load	four levels of 138; 276; 414; 552 kPa
Study parameters	surface type, curing time, curing temperature, emulsion type and residual application rate



Authors	Bae, Mohammad; Elseifi; Button; Patel (d)
I.D. device	LISST
Size specimens	undeclared
Deformation rate	152,4 mm/min
Normal load	No normal force
Study parameters	temperature, tack coat type and application rate



Authors	*Collop; Thom; Sangiorgi (e)*
I.D. device	*Leutner test*
Size specimens	*φ=150 mm h=120 mm*
Deformation rate	*50 mm/min*
Normal load	*No normal force*
Study parameters	*surfacing materials and interface conditions*

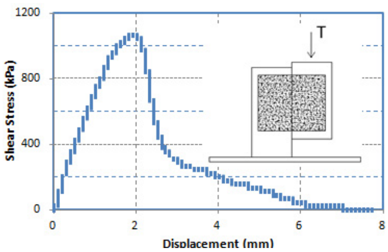


Figure 1: Typical plots and details of the shear test performed by: Wheat (a); Al-Qadi (b); Chen (c); Bae (d); Collop (e);

Different is the typical plot of shear stress recorded on the devices able to apply only a shear load. As indicated in Figure 1a and 1b, during the early stages of the test the shear stress and the displacements increase proportionally until the peak (shear strength); after that, the shear stress decays rapidly to zero as the interface fails, because no normal force can hold the two layers together.

It would be interesting to understand if the results obtained by the two device types can be correlated, but the comparison between outcomes of the various authors is turning out just about impossible. In fact, some other elements of variability are added to the differences in the equipments, such as the different states of stress, the deformation rates, the materials and the environmental conditions.

Furthermore, the repeatability of the tests is another important issue.

Consequently , the present investigation focalizes the comparison of two devices newly designed to reproduce a condition of stress, and consequently a response curve, which is for the first one similar to the first group of plots previously explained (Figure 1a, b), whereas for the other device is like the second group (Figure 1c, d, e).

3. Objective

This research deal with the application of composed state of stress to double layer specimens characterized by the same features.

In the past, several researchers have designed and developed several testing machines to assess the shear strength of a specific interface treatments but they didn't compare the outcomes in different loading schemes that may change the results. For this reason, many double-layer specimens have been manufactured without any treatments at the interface; then they have been tested in the same deformation rate under two machines suitably designed to apply different state of stress so to reflect the two kinds of typical plot of the response curve found in the literature from the shear test outcomes.

The research aim is to verify the hypothesis of reliability of both the testing machines with an analysis of the distinct achieved results considering the maximum shear stress, the corresponding normal stress, the displacements, the shape of the curve load/displacement and the interlayer tangential modulus.

Therefore, the relationship between the several failure mechanism and the different configurations and state of stress imposed by the testing machine is investigated with the intention to demonstrate the influence of the normal load on the shear strength when the other parameters of variability have been removed.

4. Experimental Program

4.1. Specimen preparation

The specimens included the binder and the wearing course without any treatment at the interface.

The same binder, with a Penetration index (PI) of 60-70 d-mm (ASTM D5-97), was used to manufacture all samples. The binder course (BC) was prepared with a mixture of calcareous aggregates (20mm maximum size) and a bitumen content of 4,5%, while the wearing course (UC) with a mixture of basalt and calcareous aggregates (10mm maximum size) with a bitumen content of 6,5%.

The dual layer specimens were prepared in a cylindrical mould, 130mm high and with an interior diameter of 100mm, by compacting the mixture with a Marshall Compactor.

The compactions blows were applied only to the upper surface. The number of the blows to assign was determined considering as target the air void content computed for the 98% of the average bulk density (EN 12697) of the same mixture compacted in standard Marshall condition, as such a level of density is a common requirement in an Italian public work contract. At the end of the compaction, the first layer, about 60mm high, was allowed to cool to room temperature and, over this, the top half of the double-layer specimen was compacted in the same way.

Before performing the shear test, all specimens were left to cool for more than 24 hours.

4.2. Equipments

For the scope of this study, two devices have been developed at the Sapienza University of Rome in order to produce the failure at the interface between the two layers of the specimen, both in dynamic and static conditions.

These machines, are derived from existing models, but are especially designed to better compare the results of the tests carried on with the same kind of specimens.

The first one, named Sapienza Inclined Shear Test Machine (SISTM) is a direct shear test similar to the device used by Wheat [14]. The working scheme is shown in Figure 2a.

The cylindrical double-sample is clamped in two half moulds, with 100mm interior diameter. The moulds are welded on steel plates, and the inclination of these, from two horizontal plates which were hinged, is fixed with bolts and nuts at the beginning of the test series. The inclination can be varied from zero to 45° without problems.

The specimens must be tested placing the interface in a range of 5mm from both sides of the moulds.

The device is equipped with LVDT to measure the interface displacements, and with a ball bearing plate, to allow the lower attachment to move freely in the horizontal direction.

The most important SISTM modification in respect of the Wheat model is the change of the top attachment by a groove which engages the top half of the equipment at the loading machine, so to avoid that this upper part of the device could weigh the specimen. This weight is not at all negligible, as it was enough to break some Wheat's samples before they could be tested [14].

The individual attachments and the equipments are showed in Figure 2b, d.

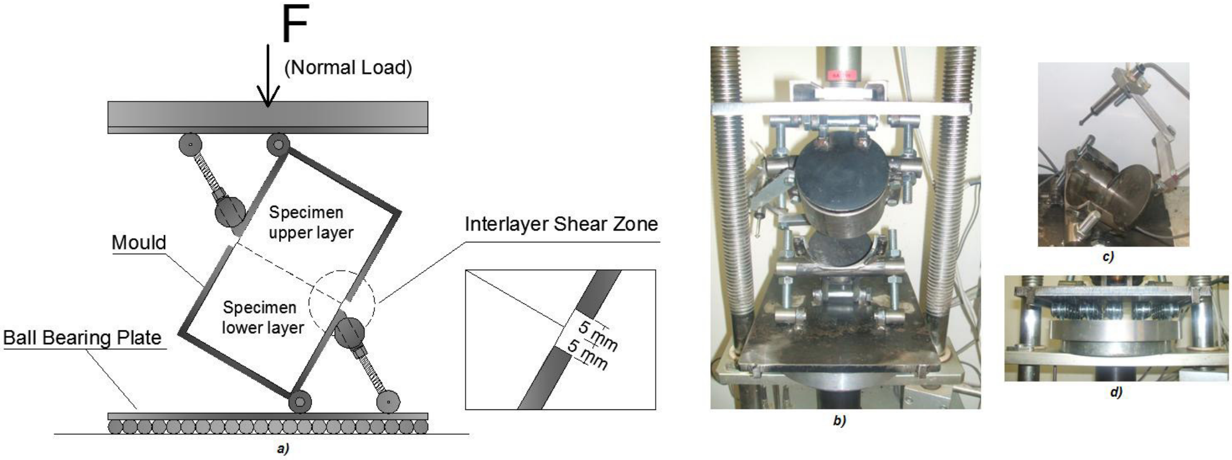


Figure 2: SISTM: a) the working scheme; b) the device; c) the LVDT; d) the ball bearing plate

The vertical load (F) recorded by the data acquisition system must be decomposed into normal (N) and shear load (T) as a function of the specimen's angle α measured from vertical:

The vertical load (F) recorded by the data acquisition system must be decomposed into normal (N) and shear load (T) as a function of the specimen's angle α measured from vertical:

$$T = F \cdot \cos\alpha \quad \text{and} \quad N = T \cdot \sin\alpha$$

Once set the specimen angle, the ratio between the normal and shear stress is determined and cannot be changed during the test.

The Sapienza Horizontal Shear Test Machine (SHSTM) device is the second shear test machine developed to evaluate the interface bond strength on cylindrical double-layer specimen with 100mm diameter

With the addition of a normal force, the device, derived from the Miro machine, has been modified in the configuration of supports so to eliminate the rotational problems due to the application of a compression load during the test. In fact, if a normal load is applied to that machine, the loaded half specimen rotates around its support, the two contact surfaces lose their parallelism and this leads to a not proper solicitation.

Other than the shear box, the sample is held horizontally in two collars, as shown in the working scheme (Figure 3a), to remove the dead load of the specimen and the upper part of the device on the shear strength.

Only one collar is supported by a link; the other is free to move vertically due to a low friction guide placed on the back side of the specimen.

The interface must be placed with an edge of 5mm from both sides of the collars.

The loading machine applies a vertical load on the unrestricted half specimen, while a piston connected with a pneumatic compressor provides the horizontal load. The data acquisition system records the shear load and the interface displacements measured by an LVDT. The compressor pressure must be set at the beginning of the test and remains steady.

In this condition the two stress components are unrelated and can reproduce several load conditions.

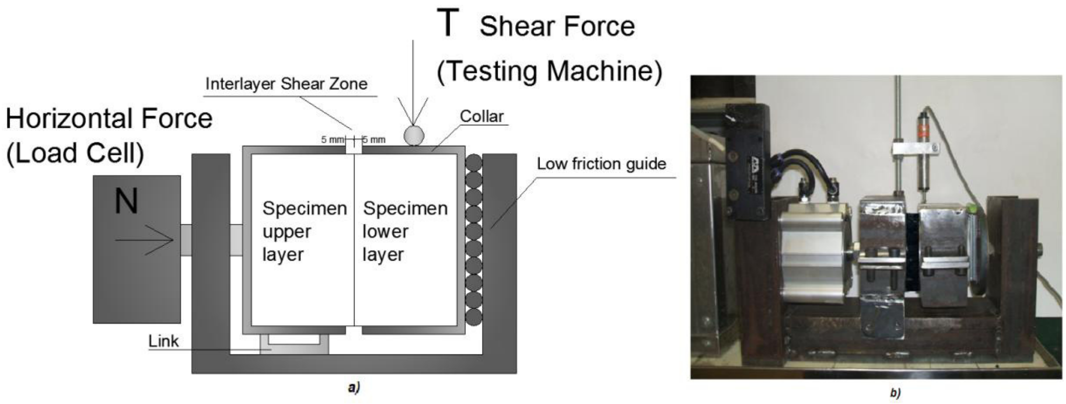


Figure 3: SHSTM: a) working scheme; b) the device

4.3. Testing mode

The interface strength was investigated by performing on both devices tests in several load conditions.

The loading system was a Universal testing machine working at a loading rate of 1,27 mm/min, according to the CBR standard.

At the beginning, to verify the statistic reliability of the testing machines, thirty samples were tested on the SISTM fixing the specimen inclination on an angle of 30°, to have the prevalence of the shear load compared to the normal one.

For the same purpose, also on the SHSTM thirty samples were tested setting the normal pressure on the half of the average maximum normal load recorded in the previous SISTM tests. Note that in the SISTM the normal load increases during the test, whereas in the SHSTM the normal load is fixed at the beginning of the test and keep the same value till the end.

Afterwards, a series of five specimens were tested on the SHSTM, setting the normal pressure at two thirds of the peak value recorded on the SISTM and another series at the minimum value of the normal load which ensures the correct positioning of the specimen.

The load conditions are resumed in Table 1. These load levels are coherent with those proposed by others researchers.

Table 1: Summary of the load conditions

ID. Device	number of specimens	α [°]	Normal Stress [kPa]	Shear Stress [kPa]	Deformation rate [mm/min]
SISTM	30	30	variable	1.5*N	1.27
SHSTM	30	-	241 (mean value)	variable	1.27
	5	-	300 (2/3 max value)	variable	1.27
	5	-	50	variable	1.27

5. Results

The outcomes of the tests performed on the two devices will be now analyzed.

Referring to the two series of thirty samples, the peak shear stress data have firstly been used to verify the statistic reliability of the two devices and the normal distribution of the results by the Shapiro-Wilk test and the χ-squared test. They evaluated the acceptability of the assumed distribution with a confidence level of the 5%.

Instead, the basic statistical functions of mean and standard deviation have been derived for all the 4 groups of tests performed in different load conditions.

In each group the significant parameters have been the maximum shear stress, the corresponding displacements and the interlayer tangential modulus, then the average response curves have been calculated.

The analysis of the results goes on, in the next sections, with a separate observation of the typical shape of the response curves recorded on the two devices and with the comparison between these two equipments and the tests performed.

5.1. SISTM Results

The typical shape of the average curve shear strength VS displacement recorded on the SISTM with the inclination of 30° is presented in Figure 4a.

The initial trend shows a slight increase of shear stress. This state goes on until the components of stress achieve values high enough to ensure a significant level of normal load. Then the curve increases its slope with an inclination k until the peak of the shear force, which corresponds to the specimen's maximum strength; beyond this, increasing the displacements, the force decreases up to zero where the separation of the two layers of the specimen occurs. This final part of the graph, with a decreasing trend, is characterized by an inclination m.

The shape of the curve, similar to the first group of figures previously discussed in the background, is due to the prevalence of the shear stress on the normal stress ensured by the 30° inclination; the two layers remain joined until the adhesion is high, but, when this strength drops, the compression force falls correspondingly without counteracting sliding and separation of the layers.

Regarding the outcomes' processing, the initial part of the response curve, that shows points with some displacements but low shear strength, is cut off carrying the axis origin at the intersection between the x-axis and the tangent at the increasing branch of the curve before the peak. The aim of this procedure is to delete the negligible part of the curves , that has very different lengths in the various tests.

This method, consisting of a modification of the displacements, can be justified because the sliding at low force seems due to a settling before the interlocking between the aggregates of the two layers, which are disposed

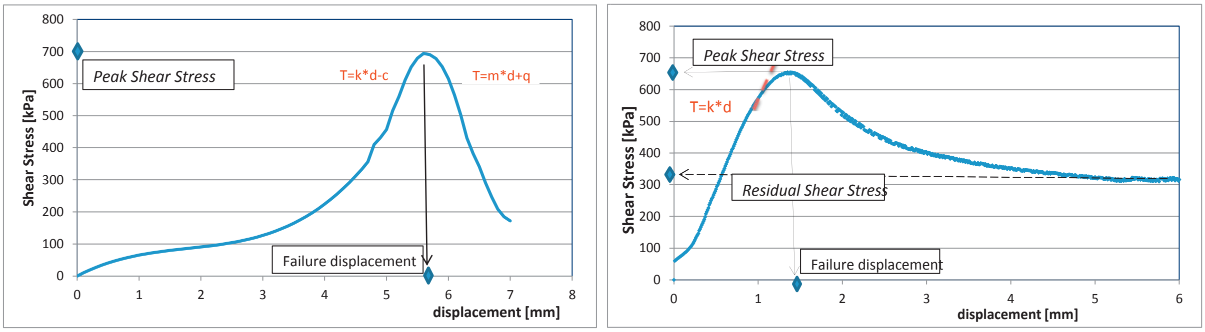


Figure 4: The typical trends of the curves shear stress VS displacement recorded on the SISTM (a) and SHSTM (b)

in random order at the specimen's interface during manufacturing.

Notwithstanding the differences in the initial trend of the curves, all curves show a comparable gradient in the initial and ending part around the peak.

The results also suggest that equal load conditions and same samples' features, as in this case, lead to a similar slope of the curves before and after the maximum shear strength because the samples' shear behavior is ruled by the interlocking ability of the interface.

On that contact surface, the protuberances of one layer aim to slide on the other until the locking is generated thanks to the increasing normal force and the encounter of the opposite protruding. Conclusively, the ratio between the stress and the increasing displacements, once the interlocking between the layers happened, until the failure is the same for all the specimens; without treatments at the interface its value seems to depend only on the material used to manufacture the specimens.

5.2. SHSTM Results

Figure 4b shows the trend of the response curve peculiar of the second device, named SHSTM.

The constant contribution of the normal load leads to a regular initial increasing trend until the peak of the shear stress, regarded as the specimen's strength; after the peak, the normal load doesn't allow the interface failure.

In fact, similar to the first series of figures shown in Figure 1, after the peak the shear stress decreases and tends asymptotically to a residual value without dropping to zero because the normal load maintains the two layers in compression. After the maximum, the interface shear reaction due to the interlocking decreases quickly with the shear failure and the reduction of the contact area, but remains the rate depending on the contact between the aggregates of the layers, accomplished by the normal load. During the tests the shear stress reaches the residual value at about 6mm and holds the strength constant while the displacement increases, according to the previous statements; for this reason the data acquisition has been led until the displacements of 7 mm. As described above, the constant value of the normal stress, set at the beginning of each series of tests, was fixed referring to the outcomes achieved on the SISTM device.

5.3. Comparison between the devices

The outcomes of specimens with the same features, tested in different load conditions with two devices, are now analyzed shifting the curves to overlap the peaks.

For every series of tests, the mean values of the study parameters and the average curves have been calculated to easily compare the results. As appear in Figure 5, the trends recorded during the shear tests have different shapes and different peak values. The diagram depicts the dissimilarities of the curves in the peak of the shear strength as well as in the correspondent displacements and in the failure behavior.

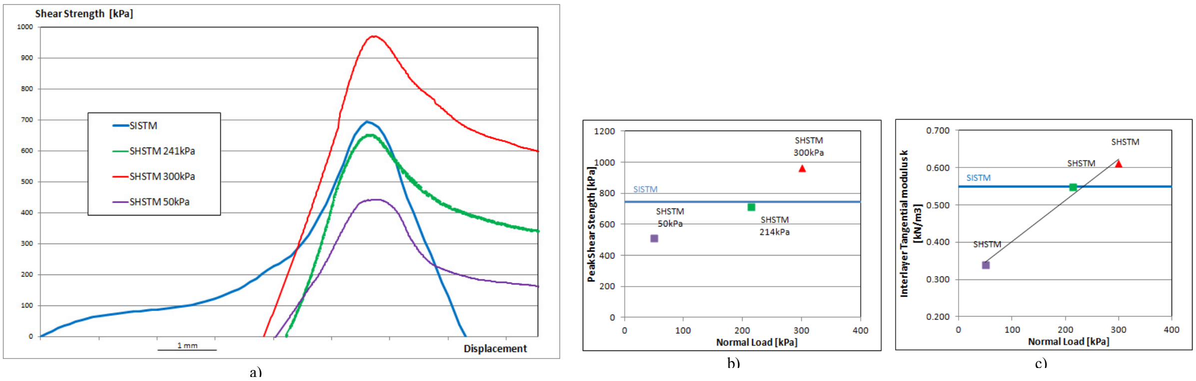


Figure 5: Summary of the response curves (a) and effect of the normal load on: b)Peak Shear Strength; c) Interlayer tangential modulus;

Initially, the failure mechanisms carried by the devices differentiate the behaviors showing a quick decrease of the shear stress until zero in the SISTM and the achievement of a positive constant value in the SHSTM.

Referring to the condition of stress imposed during the tests, it can be observed that the maximum and the residual value of the shear strength are related to the normal load; the higher values of the shear stress correspond to high compressions applied on the specimen. Moreover, the values of the residual strength reported during the tests on the SHSTM are rising in relation to the increasing of the normal load.

As the residual shear strength is characteristic only of the SHSTM device, the peak value and the tangential modulus along the increasing branch of the curve before the peak can be chosen as the parameters of comparison between the two proposed equipments.

In the figure 5, the effects of the normal load on the study parameters are also shown; the SISTM outcomes are depicted with a blue line because the normal load changes during the test.

In Figure 5a, the blue SISTM series and the red SHSTM one with a normal load of 214 kPa have an equal mean value of compression applied during the test and the strength of the specimen is the same although the initial trend is different.

The average curves of the SISTM and the SHSTM at 214 kPa achieved the peak between 600-700 kPa of the shear stress. For lower values of the normal load, the peak in the SHSTM drops to 500-400 kPa; whereas, for a compression of 300kpa, the maximum shear stress varies between 900-1000 kPa.

These achievements confirm the direct relationship between the shear strength and the normal load.

Looking at the interlayer tangential modulus when the average value of the normal stress is equal, the same modulus characterize the response curves before the peak (blu line and green square in Fig.5b).

On the contrary, at the beginning of the test the trend is quite different (Figure 5) : in the SHSTM, where the normal load is immediately set at a constant value of 214 kPa, the growth starts immediately reaching earlier the peak of the shear strength at a low displacement; in the SISTM, the curve has a low inclination in the initial part and the increment of slope happens when the normal load became relevant.

As the summary graph depicts, the change of the curve's inclination in the SISTM occurs at about half of the maximum shear stress; this higher slope remains until the peak.

In accordance with this statement, higher values of the normal load than the average evaluated on the SISTM, set on the SHSTM, should not lead variations in the interlayer shear modulus. That has been confirmed by the tests performed on the SHSTM setting a normal load of 300kPa.

On the other hand, lower values lead a decrease of the initial slope of the curve, as shown in Fig. 5 by the curve of the SHSTM at a normal load of 50 kPa.

As result of the different failure mechanism due to the devices, the displacements at the peak exhibit a significant difference particularly in the SISTM's curves where the first part frequently records a considerable sliding. In these cases, the translation of the curve obtained by fixing the origin at the intersection between the x-axis and the tangent at the increasing trend before the peak, allows to have more comparable results.

If specimens with the same features are tested in a condition of normal load equal in the average value, then the two devices are able to reproduce the same outcomes in terms of shear behavior. Unless the different sliding behavior exists, the achievement of similar values of peak shear stress and interlayer tangential modulus leads to attach this shear behavior at the specimen's features in terms of materials, compaction, interface condition and so on. Then, the devices, SHSTM and SISTM, designed with opportune modifications to the previous machines,

are capable to test the specimens in several conditions of stress evaluating the significant contribution of the normal load and give the same performance when all the other elements of variability are removed. The useful and comparable parameters are the peak shear stress and the interlayer tangential modulus, whereas the displacement at the failure can be considered only if reduced in the previous shown way.

In the end, the reproducibility of the same value during the tests on two different machines may be considered as an important factor to assess the reliability of the result and the precision of the test method.

6. Conclusions

This research analyzed the shear behavior of double-layer specimens with the same features tested in different state of stress but in the same deformation rate. The tests were performed on two devices, named SISTM and SHSTM, designed to reproduce the most common stress/deformation histories found in literature, but suitably modified to allow the comparison of the results.

The aim was to verify the statistic reliability of both the machines and to investigate the relationship between the several failure mechanism and the different configurations and state of stress imposed by the devices.

The maximum shear stress, the corresponding normal stress, the displacements, the shape of the curve load/displacement and the interlayer tangential modulus were evaluated by the tests.

Based on the results, the following conclusions have been achieved:

- the devices don't produce fluctuations on the performance of the interlayer shear strength, showing a normal distribution of the peak shear stress data with a confidence level of the 5%.
- the devices give the same outcomes in terms of shear behavior if specimens with the same features are tested in a condition of normal load equal in the average value.
- the value of the normal load, achieved or assigned as a constant, shows a direct influence on the shear response. These are related the maximum and the residual shear strength are directly proportional to the normal load while the interlayer tangential modulus in the SHSTM maintains the same value for compression load higher than the mean value achieved on the SISTM.

The similar outcomes in terms of peak shear strength and interlayer tangential modulus recorded on the two devices suggest that there is a relationship between these parameters and the specimens' features.

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