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COMPATIBILITY BETWEEN FLOORING MATERIALS ON CONCRETE

Development of test method

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Development of test method

Samverkan mellan golvmaterial på betong

Utveckling av provningsmetod

Bertil Persson

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PREFACE

This report outlines an investigation of emissions of volatile organic compounds, of relative humidity and of peel force on flooring materials on concrete. For this purpose 60 specimens in full-scale thickness and 0.25 m in diameter were cast of two concretes with water-cement ratio w/c=0.40 or w/c=0.60. Three identical specimens of each combination of flooring system were made in order to estimate the significance level of the tests. After 1 month of drying at 60% ambient relative humidity, self-levelling compound was placed on the concrete, in turn drying 1 month before placing of the flooring. The flooring consisted of linoleum, rubber or PVC, which were applied with either alkali-resistant adhesive or with standard polyacrylate adhesive, pre-drying for 15 or 25 min. Internal relative humidity of the flooring system was measured before flooring at 2 months' age, and after measurements of emissions of volatile organic compounds at 8 months' age. After the measurements of emissions of volatile organic compounds, peel tests were performed at 9 months' age together with ocular inspection of the fracture of the flooring system during the peel tests. The results indicate small variations of the results between the identical specimens, more or less the same internal relative humidity of the same concrete and small variations of the peel results of identical specimens. However, between specimens with different materials there were large variations of volatile organic compounds and peel force dependent on the substance mixture. The material combination also had a major influence on the results of emissions of volatile organic compounds, being largest for flooring with linoleum. The high accuracy of the results was a fundamental basis for the test method of the Swedish Research and Testing Institute being developed from this investigation. The project was performed at the Swedish Research and Testing Institute, Borås, and at Lund Institute of Technology, Lund University, Lund, 2004-2006.

Lund, March 2006

Bertil Persson

CONTENTS

SYMBOLS

a, b	peel force constants given in Table 5.1 (N/mm)
w/c	water-cement ratio, SS-EN 206-1
A	low-alkali self-levelling compound (Akzo Nobel Deco International Schönox CP)
Ad	Adhesive
B	low-alkali self-levelling compound (Bostik Golvspackel Fiber Quick)
C	alkali-resistant linoleum and PVC adhesive (Bostik Golvlim AlcaliTac AT)
C_i	concentration of volatile organic compound, VOC (µg/m^3)
D	standard polyacrylate linoleum adhesive (Akzo Nobel Deco International Cascolin 3449)
E	alkali-resistant rubber adhesive (Akzo Nobel Casco Proff Solid 3480)
Fl	flooring (covering)
FR	Freudenberg rubber flooring {noraplan mega, beige/fawn tiles (color 2674), batch no. 1331920000, blue tiles (color 2171), batch no. 1187220000}
G	standard polyacrylate rubber adhesive (Bostik Golv- och Vägglim MultiTac MT)
H	standard PVC adhesive (Akzo Nobel Deco International Casco Cascoproff 3448)
LCI_i	Lowest Concentration of Interest above which an organic compound may have some adverse affect on people in the indoor environment based on AgBB (Ausschuss zur gesundheitlichen Bewertung von Bauprodukten) list, July 2004 (µg/m^3).
Pf	peel force for 30-mm wide and 100-mm long strip peeled off at a speed of 100-mm/min. (N/mm)
PE	Polyethylene
PVC	Polyvinyl chloride
R	the sum of the ratio of C_i and LCI_{ii}, $\sum C_i / LCI_i$
RH	Relative Humidity (%)
$RH_{crit.}$	Critical RH (%)
TL	Tarkett linoleum flooring (as delivered)
TP	Tarkett PVC flooring (as delivered)
TVOC	total VOC (µg/m^{2}h)
VOC	volatile organic compounds (µg/m^{2}h)
40	water-cement ratio, w/c = 0.40 (%)

SUMMARY

In order to develop a new test method for flooring systems on concrete as regards the peel force, the relative humidity, and volatile organic compounds, 60 specimens were studied. The specimens, three identical one of each concrete in order to study the accuracy of the method, were built up as a real floor within a steel mould (standard steel duct pieces, end and flange) that remained around the specimen during the whole period of study. In the bottom of the mould, up to 8 mm from its upper edge, concrete was cast and dried for one month, two different qualities with either water-cement ratio 0.40 or water-cement ratio 0.60. On top of the concrete, within the mould, 8 mm of self-levelling compound was cast and dried for one month, using two different qualities of self-levelling compound. Three different types of covering were used, linoleum, rubber and PVC-flooring applied with either alkali-resistant adhesive or standard polyacrylate adhesive. Measurement of relative humidity, RH, was performed before the flooring was applied and after measurement of the volatile organic compounds, in turn performed half a year after the flooring was applied. After the measurement of the volatile organic compounds was performed, the peel force was detected on three strips of each specimen. On some identically built-up specimens the peel force was measured on heated specimens. The results indicate very high accuracy of the measurements of relative humidity, i.e. less than 1% both of standard deviation and of average variation coefficient, high accuracy of the measurements of peel force, i.e. less than 0.17 N/mm standard deviation with less than 10% average variation coefficient, and moderate accuracy during measurement of the volatile organic compounds. Of 10 identical series of specimens only two showed too low a peel force, i.e. 0.7 N/mm < 1 N/mm at RH = 85%. The low peel force was clearly related to one type of self-levelling compound in combination with a standard polyacrylate adhesive. The fracture at low peel force always took place in the self-levelling compound or between the self-levelling compound and the adhesive. Even at RH = 80% a peel force as low as 0.9–1 N/mm was observed for these two types of flooring. The peel force decreased on average by 30% when RH was increased by 10%. Less than half the peel force was seen at 10 °C higher temperature of the flooring system than normal. Results of different volatile organic compounds larger than 5 µg/m³ were compared with the lowest concentration of interest of each volatile organic compound, at which limit a possible adverse effect on people may be detected. The sum of the ratios was estimated and found to be less than 40%, the presumed limit of possible adverse effect on people being 100%. The largest sum of ratios of volatile organic compounds to the lowest concentration of interest of each volatile organic compound was found at the lowest RH. High RH does not seem to affect the volatile organic compounds from flooring systems at all, which was a most astonishing result not seen before. Linoleum systems clearly caused a larger sum of ratios of volatile organic compounds to the lowest concentration of interest of each volatile organic compound as compared with rubber and PVC flooring. One self-levelling compound that was studied caused less than half the largest sum of ratios of volatile organic compounds to the lowest concentration of interest of each volatile organic compound as compared to the other self-levelling compound. Alkali-resistant adhesive had a major effect in order to eliminate the sum of ratios of volatile organic compounds to the lowest concentration of interest of each volatile organic compound, i.e. when alkali-resistant adhesive was used the concentration of volatile organic compounds that may have a possible adverse effect on people was less than 5 µg/m³ (except for linoleum which shows that the material itself caused the emissions). Finally no correlation at all was found to exist between the sum of ratios of volatile organic compounds to the lowest concentration of interest of each volatile organic compound and the measured peel force on the very same specimen, indicating that adhesion-damaged flooring does not necessarily indicate high emissions. Based on the measurements, a test method for flooring materials was presented..

SAMMANFATTNING

I syfte att utveckla en ny provningsmetod för golvmaterial/system på betong beträffande fläkningskraft, relativ fuktighet och emissioner av organiska ämnen studerades 60 provkroppar. Provkroppen, tre identiskt lika av vardera i syfte att studera noggrannheten, byggdes upp som ett verkligt golv inuti en stålform (standard ventilationsdelar i stål – lock och fläns) vilken satt kvar under hela testperioden. I botten av formen göts betong upp till 8 mm under ovankanten vilken torkades under en månad, av två olika kvalitéer antingen med vattencementtal 0.40 eller med vattencementtal 0.60. Ovanpå betongen inuti stålformen göts 8 mm avjämningsmassa som torkades ut en månad, av två olika kvalitéer. Tre olika typer av ytbeläggning användes, linoleum, gummi och PVC, vilka applicerades antingen med alkalibeständigt lim eller med standard polyakrylatlim.

Mätningar av relativ fuktighet, RF, utfördes före det att ytbeläggningen lades och efter det att mätningar utfördes av emissioner av organiska ämnen, vilka i sin tur utfördes ett halvt år efter det att ytbeläggning hade skett. Efter det att mätningar hade utförts av emissioner av organiska ämnen bestämdes fläkningskraften på tre remsor på varje provkropp. På några likvärdigt uppbyggda provkroppar utfördes mätningar på uppvärmda provkroppar. Resultaten påvisar mycket hög noggrannhet vid mätningar av relativ fuktighet med mindre än 1% både i standardavvikelse och variationskoefficient, hög noggrannhet vid mätningar av fläkningskraft dvs. mindre än 0.2 N/mm i standardavvikelse och mindre 10% i variationskoefficient vid mätningar av fläkningskraft, moderat noggrannhet vid mätningar av emissioner av organiska ämnen.

Av 10 likvärdigt utförda serier av provkroppar uppvisade bara två för låg fläkningskraft dvs. 0.7 N/mm < 1 N/mm vid RF = 85%. Den låga fläkningskraften kunde helt klart relateras till ena typen av avjämningsmassa i kombination med standard polyakrylatlim. Fläkningen vid låg fläkningskraft ägde alltid rum i överkant av avjämningsmassan eller mellna avjämningsmassan och limmet. Även vid RF = 80% observerades så låg fläkningskraft som 0.9-1 N/mm för dessa bägge typer av golvsystem. Fläkningskraften minskade i medeltal med 30% då RF samtidigt ökades med 10%. Mindre än halva fläkningskraften uppmättes vid 10 °C högre temperatur i golvet än vid normal temperatur.

Resultat av olika emissioner av organiska ämnen större än 5 µg/m³ jämfördes var för sig med lägsta koncentrationen av intresse då en möjlig negativ effekt på människor skulle kunna konstateras. Summan av dessa kvoter beräknades och befanns vara mindre än 40% under antagande att gränsen för en möjlig påverkan på människor skulle vara 100%. Den största summa av kvoter av olika emissioner av organiska ämnen större än 5 µg/m³ jämfört med lägsta koncentrationen av intresse med en möjlig negativ effekt på människor konstaterades vid de lägsta uppmätta RF. Hög RF (upp till 92%) tycks således inte påverka emissioner av organiska ämnen från golvsystem alls vilket var i högsta grad ett överraskande resultat – vilket inte har konstaterats tidigare.

Golvsystem med linoleum förorsakade en klart högre summa av kvoter av olika emissioner av organiska ämnen större än 5 µg/m³ jämfört med lägsta koncentrationen av intresse med en möjlig negativ effekt på människor än golvsystem med gummi- och PVC-ytbeläggning. Den ena de bägge avjämningsmassorna som studerades förorsakade bara hälften så stor summa av kvoter av olika emissioner av organiska ämnen större än 5 µg/m³ jämfört med lägsta koncentrationen av intresse med en möjlig negativ effekt på människor som den andra studerade avjämningsmassan. Alkalibeständigt lim hade en avgörande betydelse i syfte att eliminera summan av kvoter av olika emissioner av organiska ämnen större än 5 µg/m³ jämfört med lägsta koncentrationen av intresse med en möjlig negativ effekt på människor, dvs. då alkalibeständigt lim användes var koncentrationen av uppmätta emissioner av organiska ämnen mindre än 5 µg/m³ (utom för linoleum då materialet i sig självt förorsakade emissionerna).

Slutligen kunde inget samband konstateras mellan summan av kvoter av olika emissioner av organiska ämnen större än 5 µg/m³ jämfört med lägsta koncentrationen av intresse med en möjlig negativ effekt på människor och de uppmätta fläkningskrafterna vilket antyder att vidhäftningsskadade golv inte nödvändigtvis behöver åtföljas av höga emissioner. Baserat på alla dessa mätningar presenterades en ny provningsmetod för golvmaterial/system.

1. BACKGROUND AND OBJECTIVE

1.1 Background

The flooring system is directly in contact with the indoor air and affects its quality in an important way [1-4]. The quality of the indoor air is thus affected by the volatile organic compound, VOC, originating from the flooring system. An example of this phenomenon is the destruction of adhesive and flooring material on account of the high pH and high relative humidity, RH, of the concrete when the material is placed directly on the concrete. Even though the flooring system is chosen in the most careful way related to the VOC from the different materials, large total VOC, TVOC, may occur when unsuitable combinations are made of the separate materials [2]. If no pre-testing is performed, great problems may be the case due to bad indoor air, in turn related to VOC from the different flooring materials when mixed unsuitable.

1.2 Objective

The objective of the project was to develop a test method for flooring systems taking into account peel force (adhesion and cohesion), relative humidity, RH, chemical VOC [4]. For this purpose the following parameters of the flooring system as a whole were studied:

1. Adhesion between adhesive and self-levelling compound
2. Adhesion between flooring and adhesive
3. Adhesion between self-levelling compound and concrete
4. Cohesion in adhesive
5. Cohesion in flooring
6. Cohesion in self-levelling compound
7. Moisture at equivalent depth, i.e. at 40% distance from surface in drying direction
8. Peel force of flooring system
9. Volatile organic compound of flooring system

2. PREVIOUS RESEARCH

2.1 Desiccation of concrete

In order to attach dense flooring with adhesive directly to concrete a certain desiccation of the concrete is believed to be required, so called critical relative humidity, $RH_{crit.}$, in the concrete. $RH_{crit.}$ indicates the maximum RH in the area close to the surface under the flooring. Before attaching the flooring on the concrete RH is to be measured at the equivalent depth of measurement (20% of the slab thickness with desiccation in two directions – 40% of the slab thickness with drying in one direction of the concrete). At this depth of the concrete RH is supposed to be equal the RH after long directly under a dense flooring. The actual depth the equivalence is somewhat smaller, about 15% of the slab thickness for two-way desiccation and about 30% of the slab thickness for one-way desiccation [2]. The values 20% and 40% are chosen taking into account some partial coefficient [2]. The following $RH_{crit.}$ values exist:

1. 85% for rubber and homogenous PVC-flooring
2. 90% for linoleum and PVC-flooring with more than 40% of filling filler
3. 95% for PE plastic foil without adhesive

The desiccation of the concrete is mostly dependent on the concrete quality. If a higher quality is chosen long-term and costly measures for desiccation are avoided, construction delays and so forth. Concrete with high quality will continue to self-desiccate even though it is exposed to water from for example rain at work-sites [5], Figure 2.1. Also in connection with moisture/water leakage a high concrete quality is to prefer since the moisture/water then only will penetrate the concrete a few cm, Figure 2.2 [6]. Figure 2.3 shows time of desiccation in two directions of a 0.25-m concrete slab [7]. For higher quality concrete the adhesive will get a resistance to penetrate the concrete and the moisture will assemble in the surface, Figure 2.4.

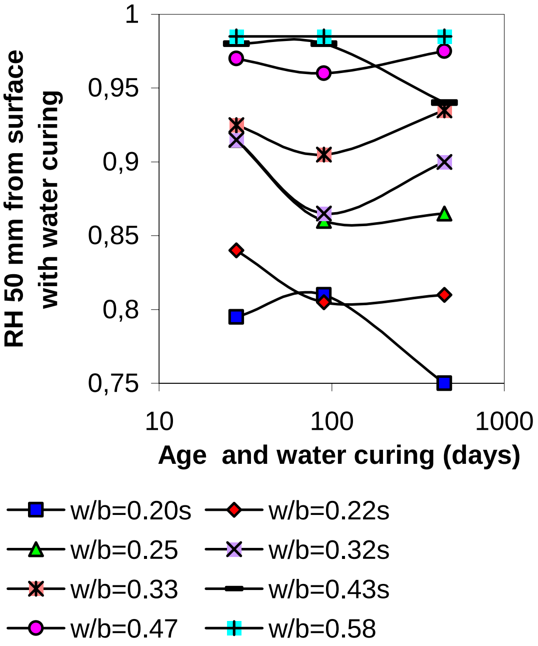


Figure 2.1 - RH 50 mm from surface with water curing. w/b = water-binder ratio [5].

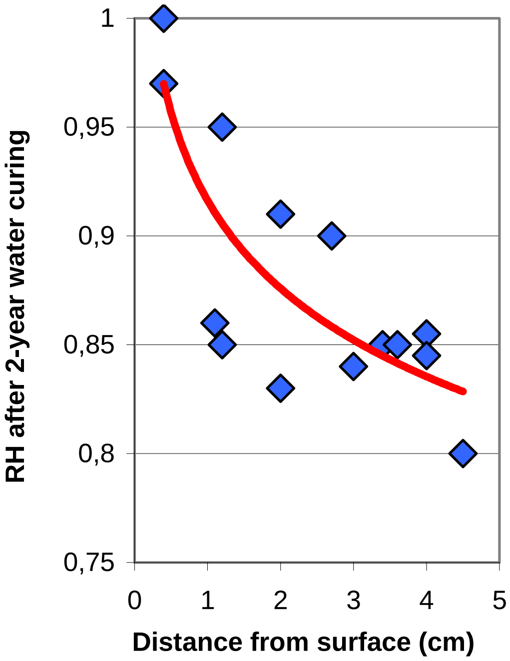


Figure 2.2 - RH after 2-year water curing versus distance from exposed surface [6].

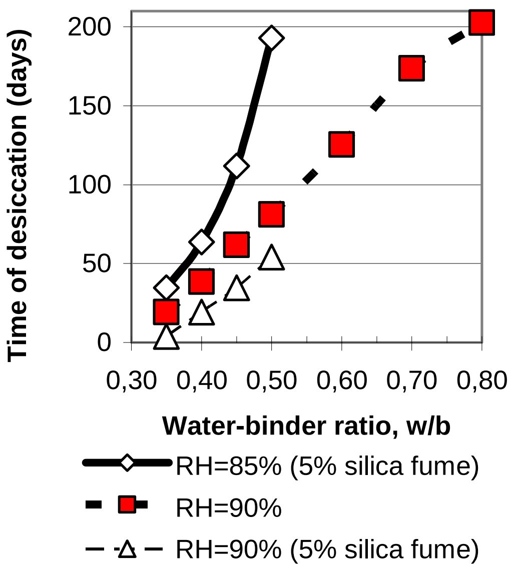


Figure 2.3 - Time of desiccation (days) [7].

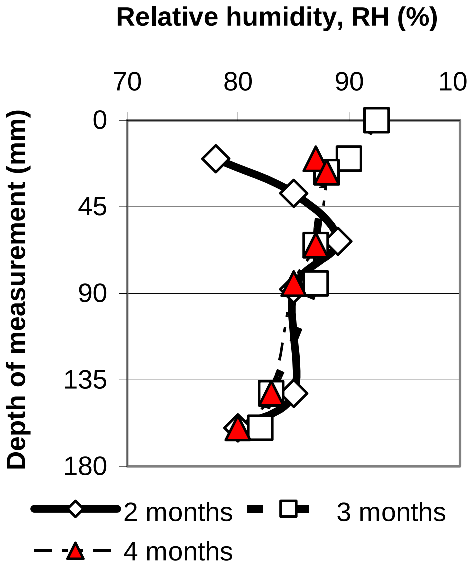


Figure 2.4 – Moisture profiles vs time [7].

Due to the risk of moisture concentration from the adhesive directly under the flooring and the risk of harmful alkali transport from the concrete to the adhesive and the flooring it is strongly recommended to place a layer of low-alkali self-levelling compound on the concrete. In a 1-cm layer of low-alkali self-levelling compound no concentration of moisture is observed since this layer is sufficient thick and permeable to absorb the moisture [2], Figure 2.5. As shown in Figure 2.5 no accumulation of moisture in the surface may be observed with a flooring system with 250-mm of w/c=0.38-concrete, 10-mm self-levelling compound, adhesive and PVC [2]. Another unforeseen parameter is the ongoing self-desiccation of concrete with low w/c. With higher w/c in the concrete the flooring system will show a constant RH after placing of a dense flooring material such as rubber or PVC but with low w/c in the concrete a continuous decrease of RH will be observed. Figure 2.6 shows an example of built-in moisture for concrete with w/c varying between 0.38 (38) and 0.70 (70). Still after half a year very high RH was observed for concrete with w/c=0.68-0.70 but rapidly decreasing for concrete with w/c=0.38-0.44, Figure 2.6 [2]. Figure 2.6 also show very little difference between desiccation of normal concrete and self-compacting concrete. For concrete with w/c=0.38-0.44 in Figure 2.6 the self-desiccation continues after placing the PVC at least until 6 months' age, i.e. about 15% RH for concrete with w/c=0.38-0.44 than for concrete with w/c=0.68-0.70. The ongoing self-desiccation thus generates a built-in moisture safety to avoid future moisture damages. Figure 2.7 shows an estimation of the equivalent depth of moisture distribution, i.e. the depth of equivalence before and after placing of flooring. In the example of Figure 2.7 20% of the total thickness was 45 mm but the depth of equivalence 30 mm, i.e. 33% smaller than 20% of the total thickness [2,8,9]. At the equivalent depth of measurement the same RH is obtained at placing of the flooring as after long directly under the flooring, after about 6 months. According to 180 measurements the equivalent depth of measurement became 27 mm instead of 45 mm, i.e. 12% of the total thickness instead of 20%. Smaller depth of the equivalent depth of measurement indicates a shorter time of desiccation. The influence of w/c of the concrete and of the ambient RH on RH in the surface is shown in Figure 2.8 [10]. At high ambient RH the difference between RH at equivalent depth of measurement and in the surface became small independent of the concrete quality [10]. At low RH concrete with low w/c requires much longer time for surface desiccation than concrete with high w/c due to lower moisture permeability of concrete with low w/c than that of concrete with high w/c, Figure 2.8 [21]. Large difference thus was observed at low RH.

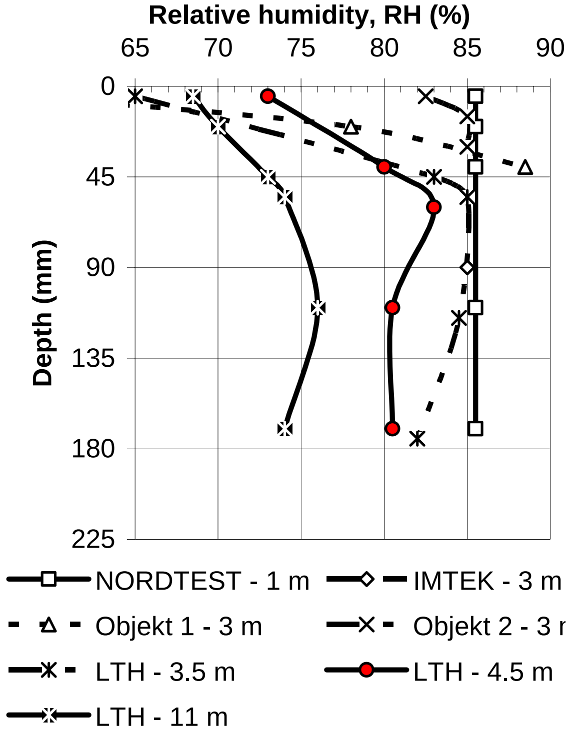


Figure 2.5 – Moisture in flooring system with 250-mm of w/c=0.38-concrete, 10-mm self-levelling compound, adhesive and PVC. m=months.

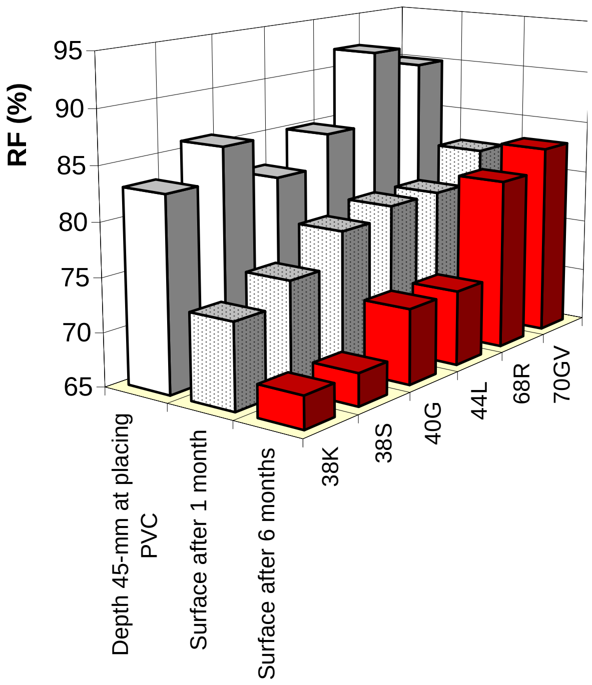


Figure 2.6 – Moisture at placing of PVC, after 1 and 6 months dependent on concrete quality. 70 = w/c (%). G=glass filler, K= superplasticiser+ air-entrainment, L= air-entrainment, R=reference, S=self-compacting, V=water glass [2].

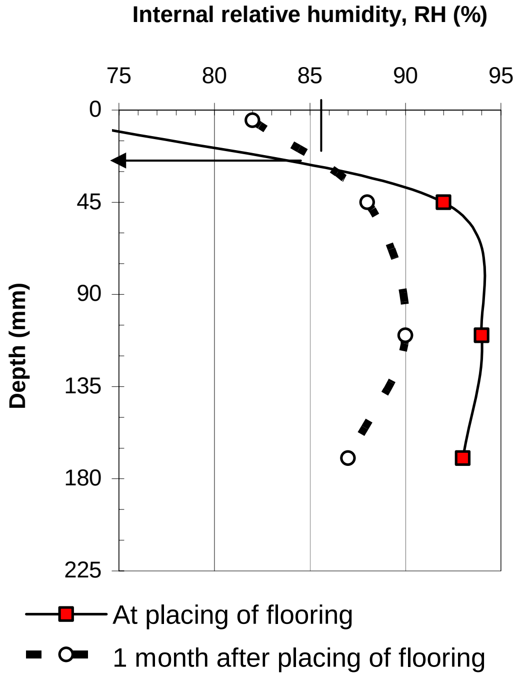


Figure 2.7 - Estimation of the equivalent depth of moisture distribution [2,8,9].

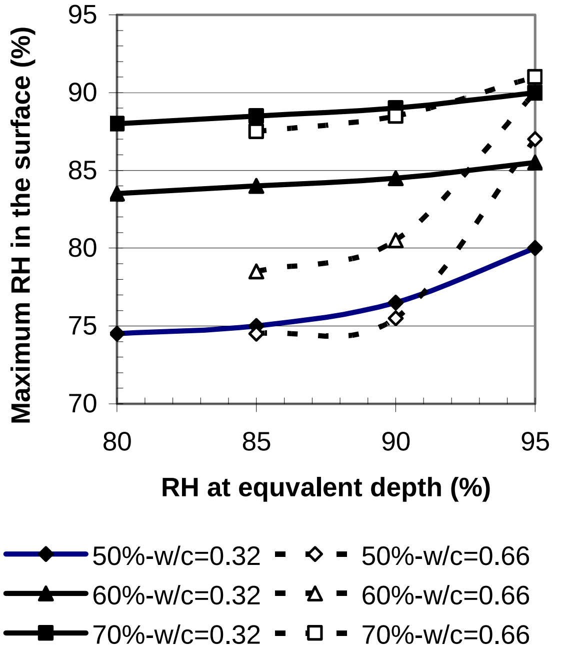


Figure 2.8 - Influence of w/c of concrete and of the ambient RH on RH in the surface [10].

The desiccation profile performed equally fairly independent of the concrete w/c, Figures 2.9-2.10 [10]. Both for concrete with low w/c=0.32 and for normal concrete with higher w/c=0.66 an increase of the surface RH of about 10% was observed after the placing of the flooring with adhesive [10]. However, a substantial difference was observed between concrete with low w/c=0.32 with initial RH=77% and concrete with high w/c=0.66 with initial RH=88%. Since the RH increase coincided well between concrete with low w/c=0.32 and concrete with high w/c=0.66 the maximum RH for concrete with low w/c=0.32 reach only 87% but as much as 97% for concrete with high w/c=0.66. In turn this indicates the risk of damages became substantially higher for concrete with high w/c=0.66 than for concrete low w/c=0.32, Figures 2.9-2.10 [10]. The influence of temperature on the desiccation of concrete with w/c = 0.37, 0.48 and 0.75 were investigated. The sample was 250 mm long and drying in two directions with the RH-device mounted 50 mm from the surface, i.e. 20% of the total thickness, Figure 2.11 [3]. The temperatures in the study were 15 °C, 20 °C and 25 °C. The measurements were performed at temperature in question and calibrated to 20 °C with 0.2 %RH/°C [11]. Figure 2.12 shows the RH-development of the specimens, average 3 measurements of each [3].

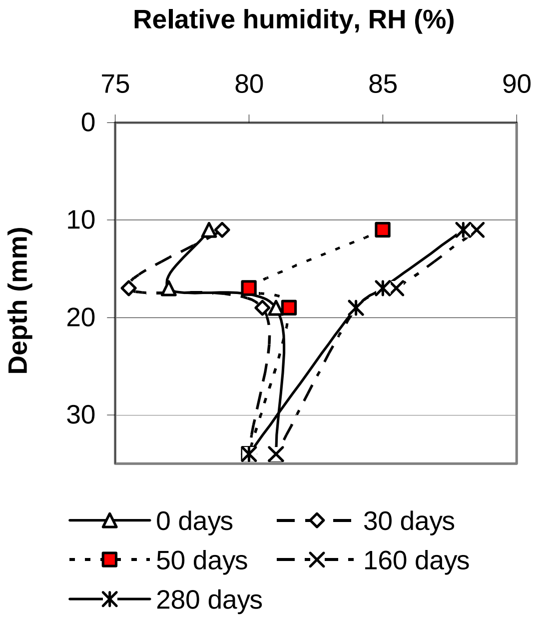


Figure 2.9 - Desiccation at w/c=0.32 [10].

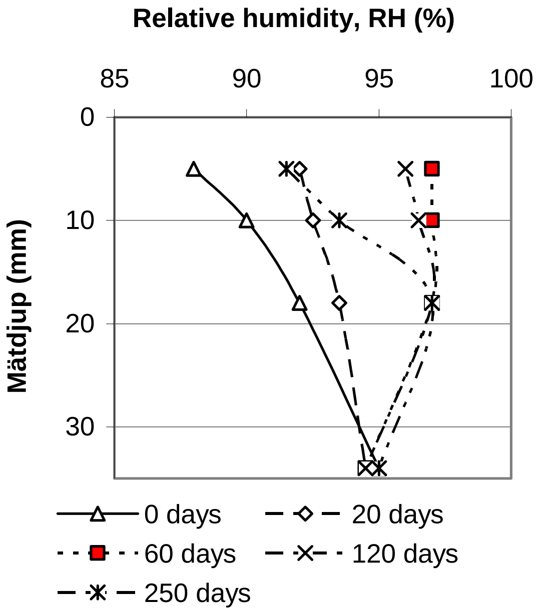


Figure 2.10 - Desiccation at w/c=0.66 [10].

Figure 2.11 – Specimen for temperature test.

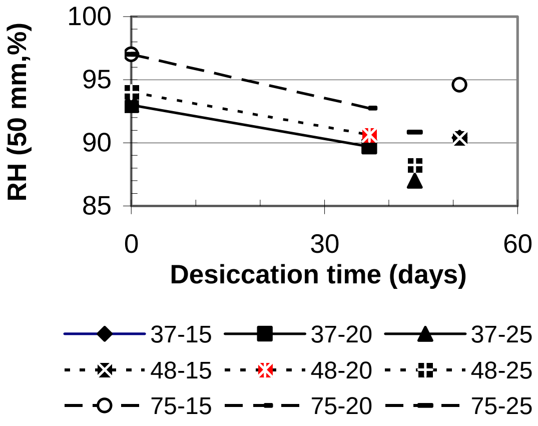


Figure 2.12 – RH vs time, 37=w/c; 20= T.

Figure 2.13 shows the dependence of maturity, temperature and w/c on desiccation after 1 month. When drying a young concrete directly after casting an increase of the temperature of 10 °C from 15 °C to 25 °C was comparative to a decrease of w/c with 0.05, Figure 2.13-2.14. At 200 days' age a decrease of w/c with 0.40 was required in order to obtain the same desiccation effect as an increase of the temperature with 10 °C [3]. These phenomena are dependent on self-desiccation of concrete, much more pronounced for young concrete than for mature [3]. For the effect of age on the relationship temperature/w/c on RH at desiccation in the interval between 15 °C and 25 °C, the following equation was obtained:

$$\Delta T/\Delta w/c = 0{,}00017\cdot t + 0{,}0051 \qquad (2.1)$$

The relationship temperature/w/c on RH at desiccation thus varied with the age of the concrete due the effect of self-desiccation, which normally only acts at an age less than 3 months. Furthermore, at low w/c the self-desiccation was much more pronounced due a finer pore system in the concrete than at higher w/c of the concrete, Figure 2.15. At w/c=0.75 the concrete was drying independent of the age since the self-desiccation then was small. In the Figure 2.16 desiccation after long is shown, also the effect of water on surface for ½ a day [3].

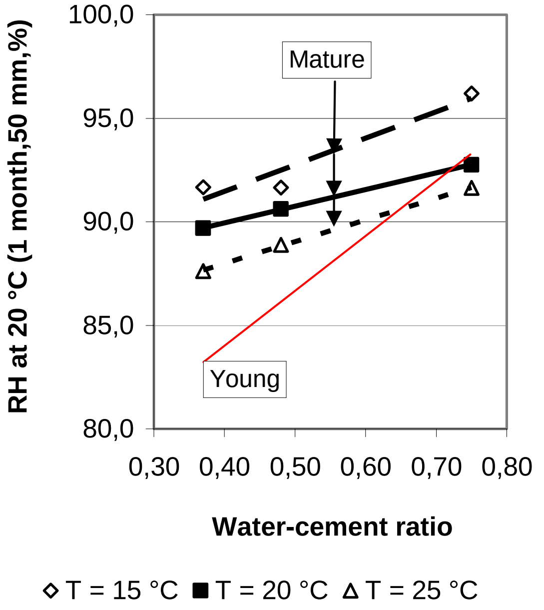


Figure 2.13 – Drying of mature or young concrete.

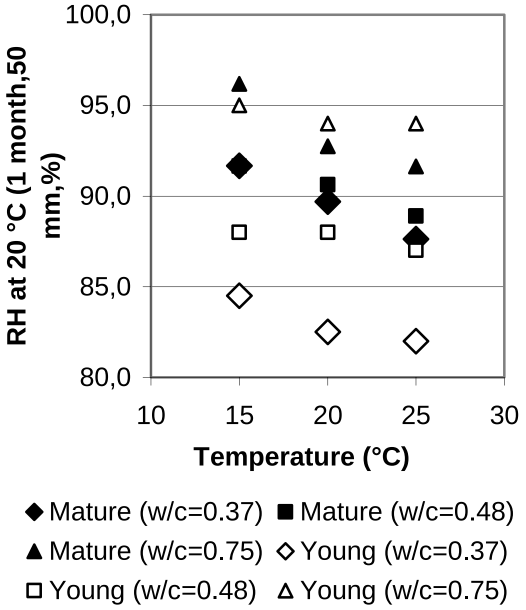


Figure 2.14 - Drying of mature or young concrete.

In connection with moisture measurements at 15 °C and 20 °C the effect of temperature change between 15 °C and 20 °C on RH was settled, Figure 2.15. Five specimens each at w/c=0.37, 0.48 and 0.75 were used. It was possible to observe the desiccation speed at each w/c, Figure 2.16. At lower w/c=0.37 a larger effect of temperature on RH was observed than at higher w/c. The following two alternative equations were estimated on the effect of temperature, T (°C), on relative humidity in concrete, RH (%):

$$\Delta RF/\Delta T = 0.1455\cdot(w/c)^2 + 1.0808\cdot(w/c) + 0.1069 \qquad (2.2)$$

$$\Delta RF/\Delta t = 0.096\cdot(w/c)^{0.385} \qquad (2.3)$$

where t denotes time (days), w/c the water-cement ratio and T temperature (°C).

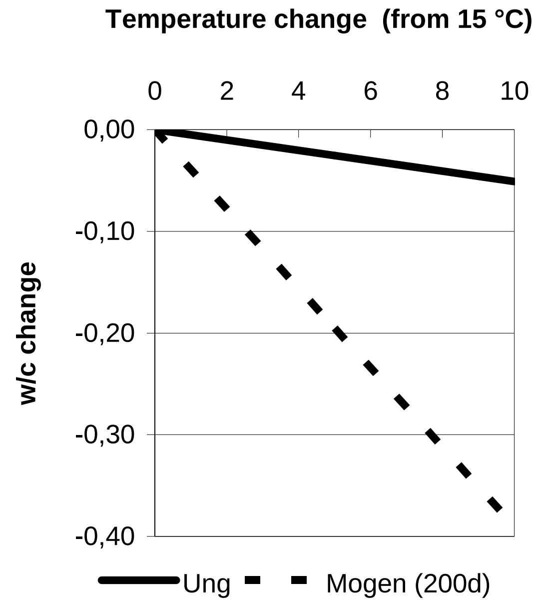


Figure 2.15 – Change of w/c vs temperature change to obtain the same effect on RH [3].

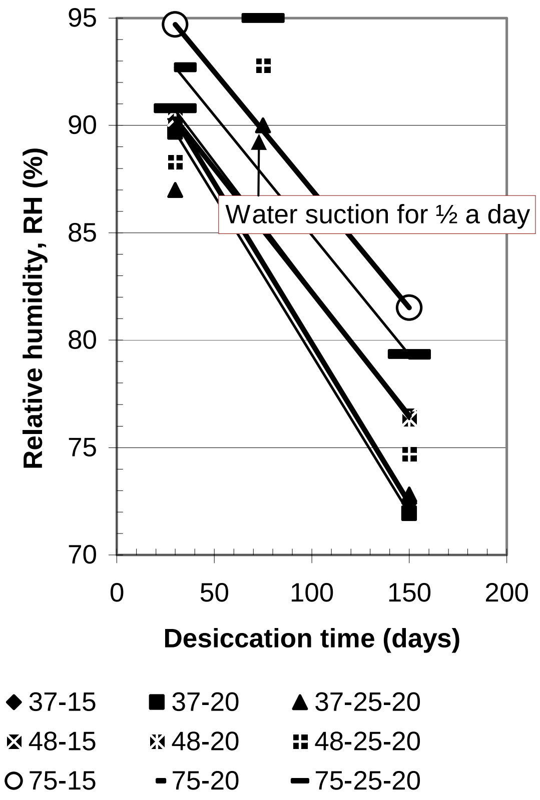


Figure 2.16 - RH at long-term desiccation of mature concrete without flooring. 15,20 = temperature (°C), 37,48,75 = w/c (%).

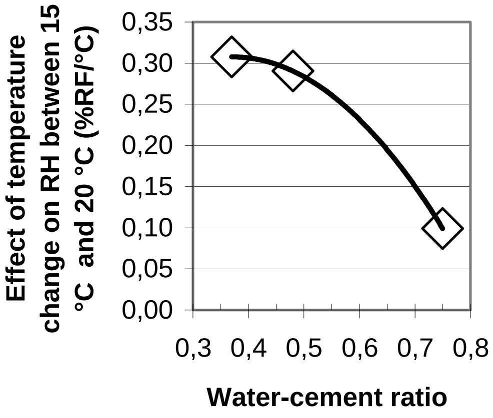


Figure 2.15 - The effect of temperature change on RH between 15 °C and 20 °C [3].

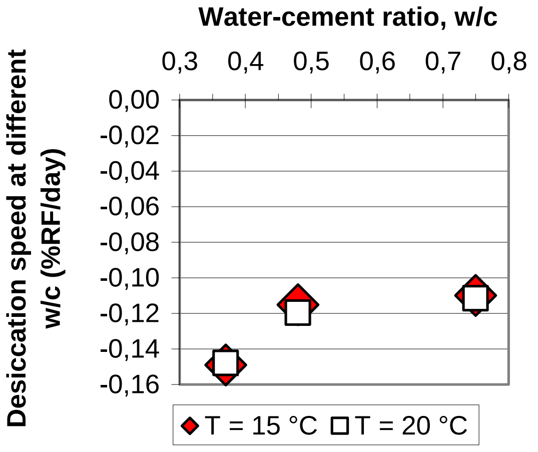


Figure 2.16 - Desiccation speed at different w/c [3].

Figure 2.17 shows one-way desiccation with PVC-flooring with filling filler on 130-mm concrete. The flooring was applied at 1 month's age. Calculations with TorkaS are also shown [12]. For concrete with w/c=0.75 about 2.5% too a low RH was calculated with TorkaS and at w/c=0.36 about 6% too a high RH. Figures 2.18-19 shows one-way desiccation profiles with PVC-flooring with filling filler on 130-mm concrete with w/c=0.37. The flooring was applied at 1 month's age. For concrete with w/c=0.37 the moisture profile became almost vertical due to self-desiccation but were inclined for concrete with w/c=0.75 due to some desiccation through the PVC-flooring, Figure 2.20 [3].

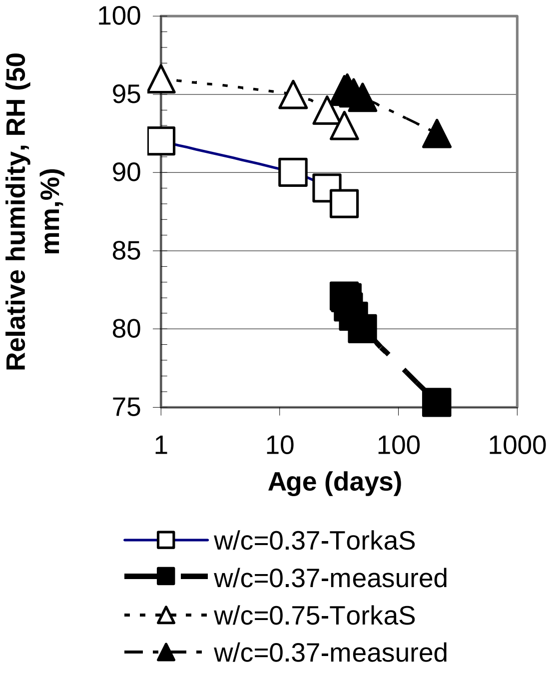


Figure 2.17 – One-way desiccation with PVC-flooring with filler on 130-mm concrete. Flooring applied at 1 month' age. Calculations with TorkaS [12].

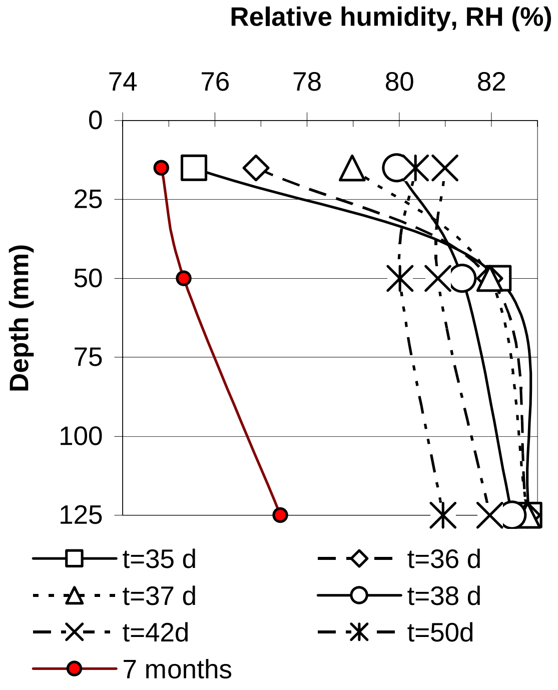


Figure 2.18 - One-way desiccation profiles with PVC-flooring with filler on 130-mm concrete with w/c=0.37. Flooring applied at 1 month' age. d=days' age.

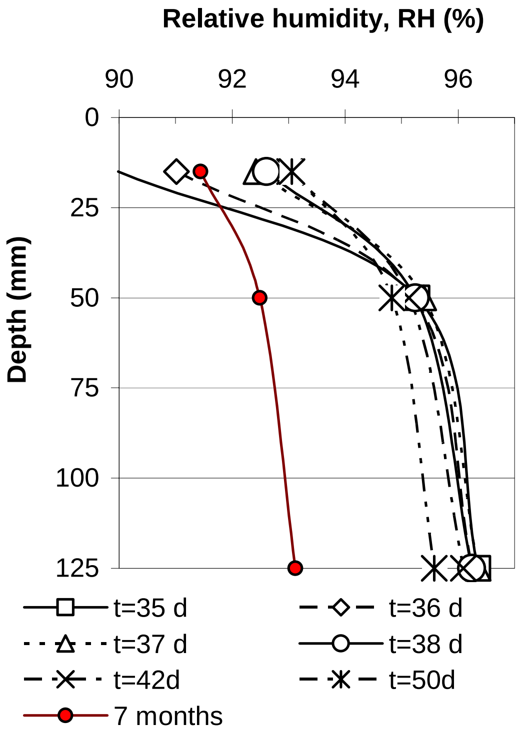


Figure 2.19 - One-way desiccation profiles with PVC-flooring with filler on 130-mm concrete with w/c=0.75. Flooring applied at 1 month' age. d=days' age.

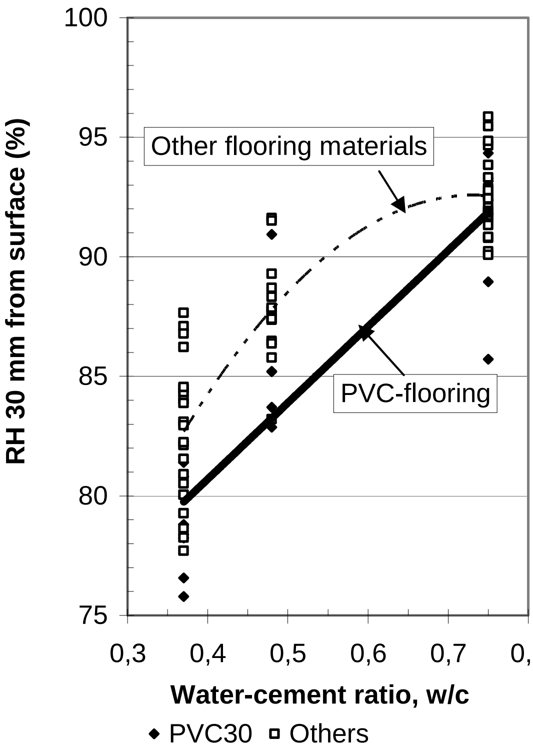


Figure 2.20 – One-way desiccation with PVC-flooring with filler on 130-mm concrete versus w/c. PVC-flooring with filling filler or others (polyolefin or rubber).

2.2 Volatile organic compound, VOC

2.2.1 Total VOC, TVOC and VOC of 2-etylhexanol

When a standard polyacrylate adhesive is used to make flooring directly on raw concrete large TVOC may occur due to alkali reactions with the concrete pore solutions, Figure 2.21 [3]. The amount of TVOC was dependent on the type of flooring being the largest for rubber flooring and the lowest for polyolefin flooring. TVOC was largest for PVC-flooring with filler filling. At higher RH the TVOC is clearly smaller, i.e. the moisture content of the concrete has little influence on the amount of TVOC, Figures 2.22-2.23. The concrete was first placed outdoor for ½ a year and then dried out for 1 month at 60%RH. The most harmful part of TVOC, etylhexanol, shows low values but still exists if and when a standard polyacrylate adhesive is used to make flooring directly on concrete, also due to alkali reactions with the concrete pore solutions, Figure 2.24 [3]. Also for VOC of 2-etylhexanol the influence of moisture was in contrary, i.e. at higher RH the amount of VOC of 2-etylhexanol decreases, Figure 2.25. The increasing VOC at lower RH was due to alkali reactions with the concrete pore solutions which in turn were the highest for concrete with high strength, i.e. with low RH. The test with TVOC were repeated in order to verify the test method, Figures 2.26-2.27. In the repeated test the concrete was dried 1 months indoor directly after casting, i.e. the surface was not subjected to curing of water from rain outdoor as in the first tests series [3]. Figure 2.28 shows TVOC versus RH with flooring with standard acrylate adhesive on raw concrete both for original tests with 7 months' age at flooring and of repeated test with 1 month age at flooring. Again it is shows that TVOC increases substaintally at lower RH in the concrete. RH plays a minor role as concerns TVOC. It is instead the alkali reactions of the adhesive and the flooring with the concrete pore solutions that dominates the effect on TVOC.

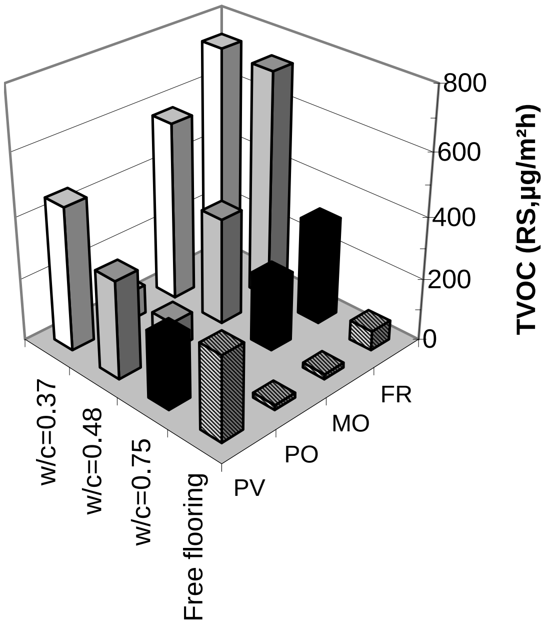


Figure 2.21 – TVOC of flooring system on raw concrete. R = raw concrete, S = standard polyacrylate adhesive [3]. w/c=water-cement ratio of concrete. Other symbols given in the section of Symbols.

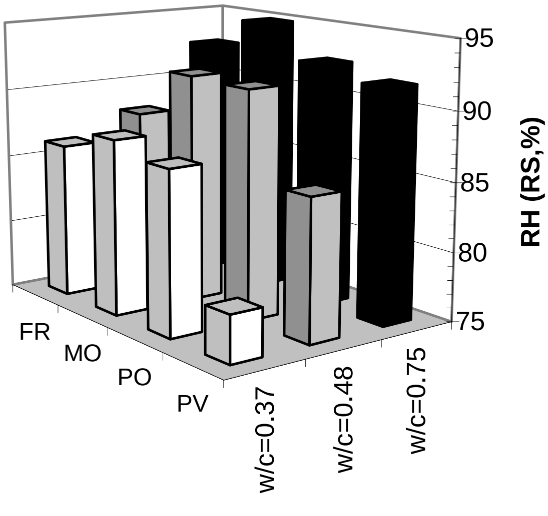
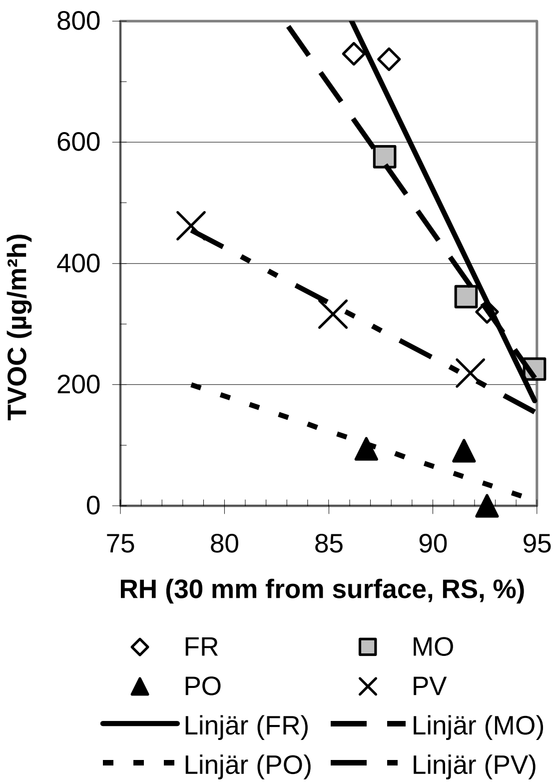


Figure 2.22 - RH 30 mm under the surface. R = raw concrete, S = standard polyacrylate adhesive [3]. w/c=water-cement ratio of concrete. Other symbols are given in the section of Symbols.



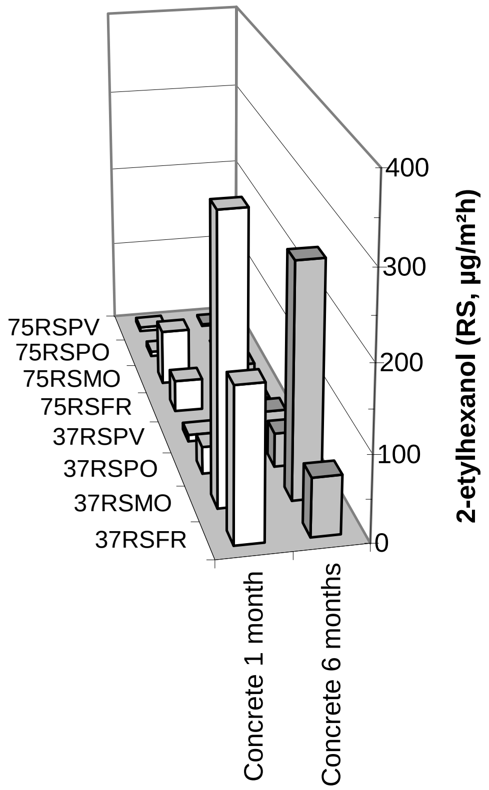
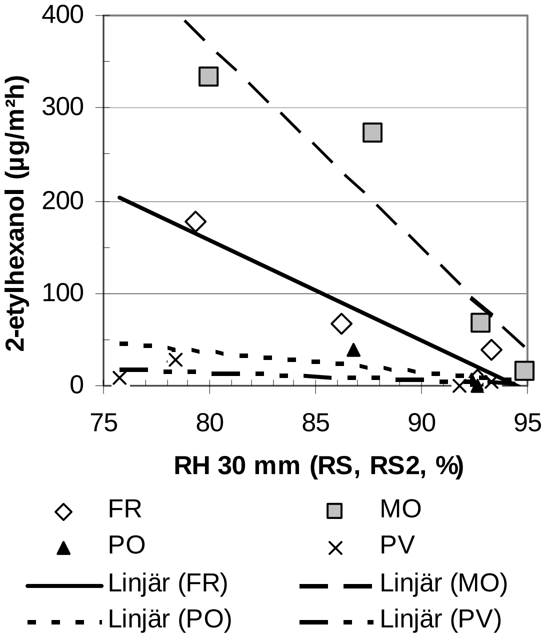


Figure 2.23 - TVOC versus RH with flooring with standard acrylate adhesive on raw concrete [3]. Symbols are given in the section of Symbols.

Figure 2.24 - VOC of 2-etylhexanol of flooring system. R = raw concrete, S = standard polyacrylate adhesive [3]. 37=w/c (%). Flooring at 1 or 6 months' age [3].



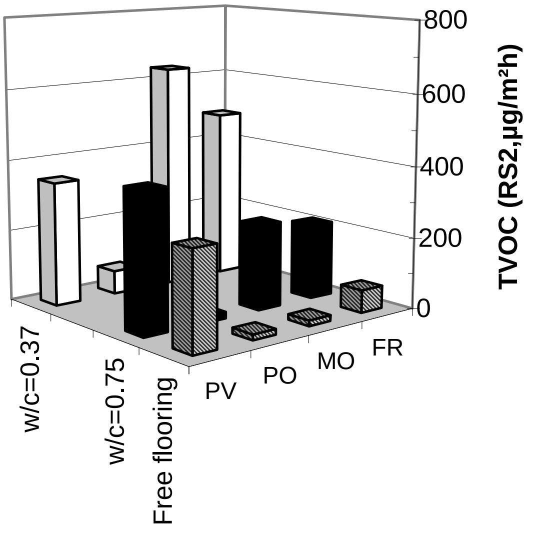


Figure 2.25 - VOC of 2-etylhexanol versus RH with flooring with standard acrylate adhesive on raw concrete [3]. 2= 1 months.

Figure 2.26 – Repeated TVOC of flooring system R = raw concrete, S = standard polyacrylate adhesive [3]. 2 = 1 months.

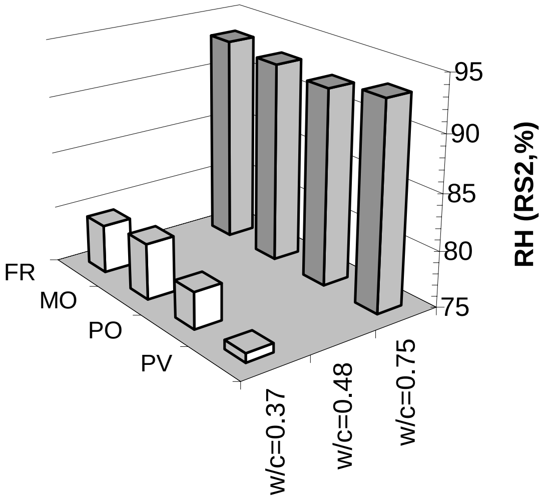


Figure 2.27 - RH 30 mm under the surface at repeated tests. R = raw concrete, S = standard polyacrylate adhesive [3]. w/c=water-cement ratio of concrete. 2 = 1 months drying before flooring applied [3].

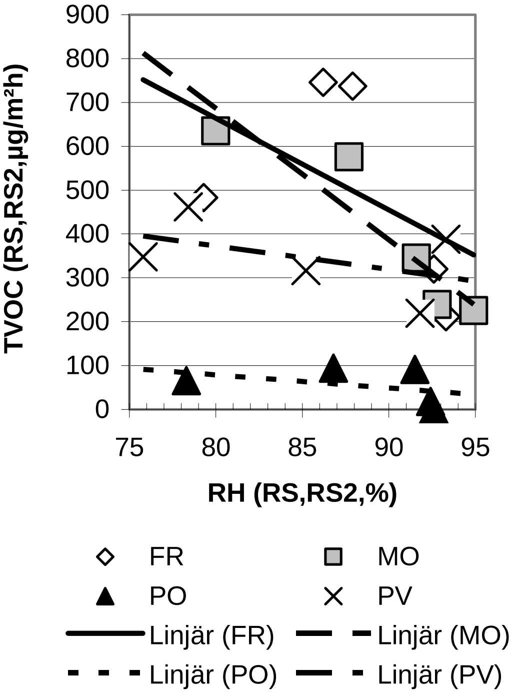


Figure 2.28 - TVOC versus RH with flooring with standard acrylate adhesive on raw concrete [3]. 2 = Repeated test (1 month age at flooring). Other symbols are given in the section of Symbols.

Since more alkalis are available in concrete with lower water-cement ratio, TVOC and also VOC of 2-etylhexanol increases in contrary with increasing RH. The limits RH = 85% and RH=90% thus are not at all consistent as concerns TVOC and VOC of 2-etylhexanol from flooring systems applied on raw concrete. The effect of alkalis from concrete on TVOC and VOC of 2-etylhexanol may be eliminates by use of alkali resistant adhesive or by use of minimum a 8-mm layer of low-alkali self-levelling compound on the concrete [3]. However, even when alkali resistant adhesive or by use of minimum 8-mm layer of low-alkali self-levelling compound large TVOC may occur but no VOC of 2-etylhexanol, which is supposed to cause bad odour [3]. Figure 2.29 shows a summary of TVOC of flooring systems with or without alkali resistant adhesive or with or without use of minimum 8-mm layer oflow-alkali self-levelling compound [3]. A fundamental condition to obtain low TVOC of the flooring system is to use a flooring with low TVOC from itself, especially PVC with filling materials showed high TVOC. Even though this precaution was taken and a low-alkali self-levelling compound was used, a low-alkali adhesive was needed for rubber flooring in order to limit TVOC to a reasonable level, Figure 2.29. Still, the worst case was to use standard acrylate adhesive on raw concrete, which should be avoided in any case even though RH in the concrete is low, Figure 2.28, i.e. TVOC = 650 µg/m²h for RH = 80% as an example.

2.2.2 VOC of 2-(2-butoxyetoxy)ethanol

Figure 2.30 shows VOC of 2-(2-butoxyetoxy)ethanol which mainly was related to one of the rubber flooring and/or standard acrylate adhesive even though low-alkali self-levelling compound was used. In order to avoid this VOC an alkali-resistant adhesive should be used [3]. Figure 2.31 shows VOC of 2-(2-butoxyetoxy)ethanol versus RH. It became clear that lower RH, i.e. lower w/c-concrete gave an increase of VOC of 2-(2-butoxyetoxy)ethanol [3].

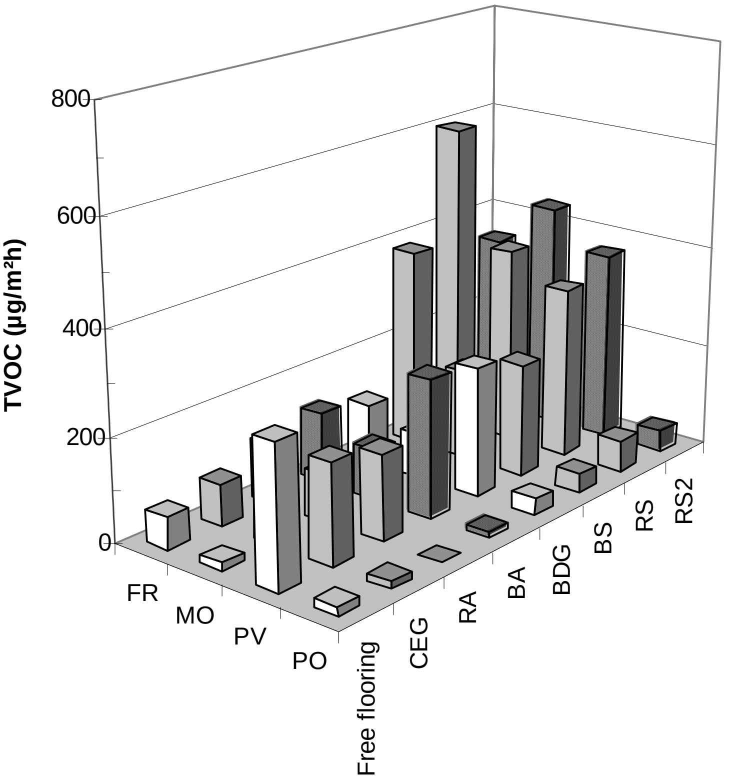


Figure 2.29 - Summary of TVOC of flooring systems with or without alkali resistant adhesive or with or without use of minimum 5-mm layer low-alkali self-levelling compound [3]. Symbols are given in the section of Symbols.

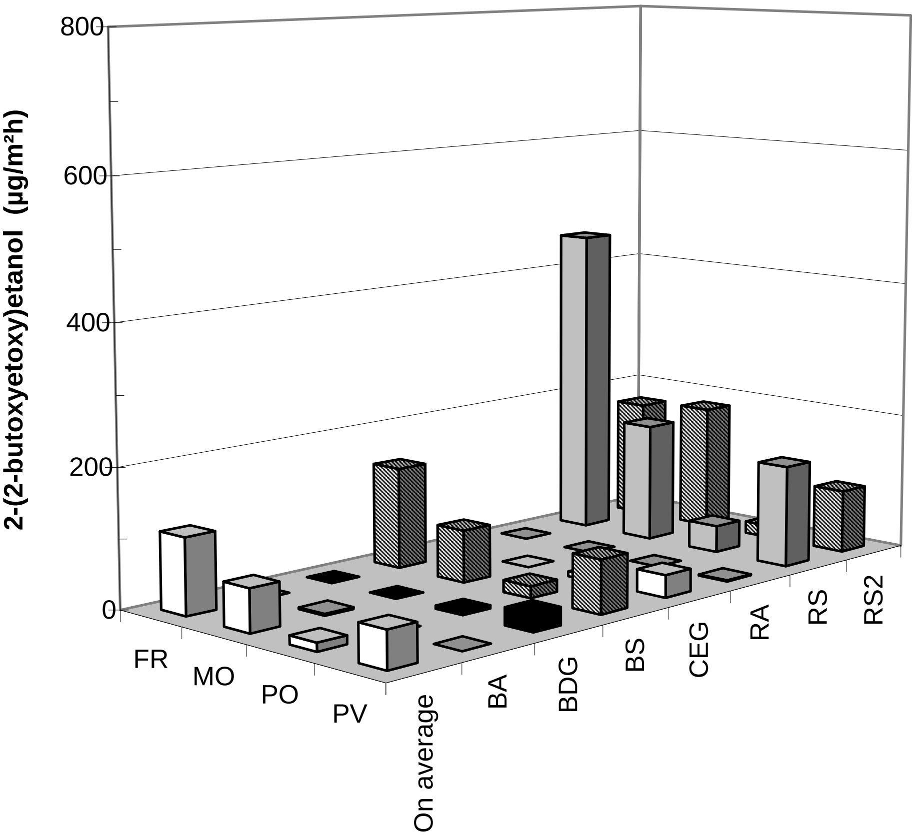


Figure 2.30 - VOC of 2-(2-butoxyetoxy)ethanol. Symbols are given in the section of Symbols.

2.2.3 VOC of 2-fenoxyethanol

Figure 2.32 shows small VOC of 2-fenoxyethanol related to one of the self-levelling compounds. The VOC of 2-fenoxyethanol was related to the self-levelling compound and it increased with increasing RH, Figure 2.33. If the self-levelling compound of type B is used the VOC of 2-fenoxyethanol may be limited by keeping RH at low level in the concrete [3].

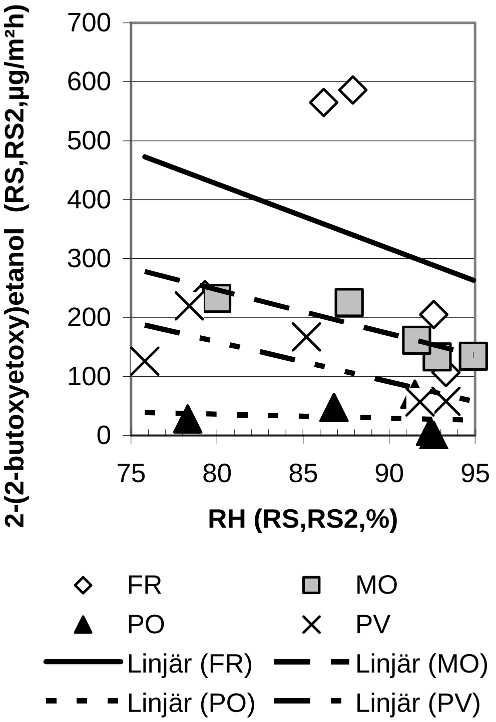


Figure 2.31 - VOC of 2-(2-butoxyetoxy)ethanol decreases with increasing RH RH. Symbols are given in the section of Symbols.

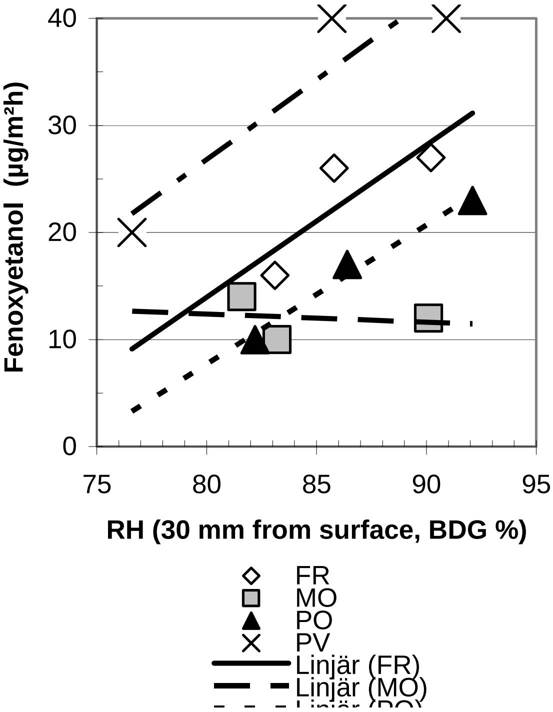


Figure 2.33 - VOC of 2-fenoxyethanol increases with increases RH since it is related to the self-levelling compound. Symbols are given in the section of Symbols.

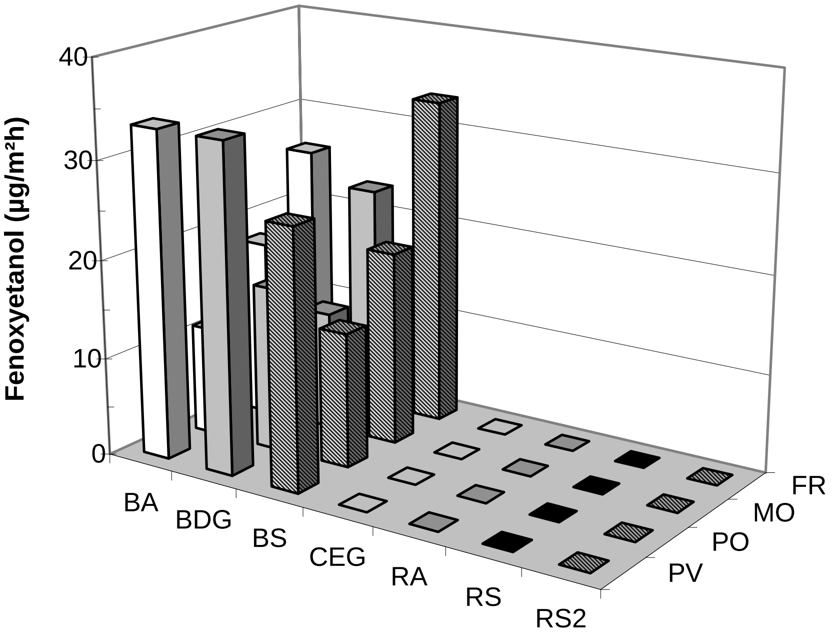


Figure 2.32 - Small VOC of 2-fenoxyethanol related to one self-levelling compound B. Symbols are given in the section of Symbols.

2.2.3 VOC of sequinterphines

Figure 2.34 shows small VOC of sequinterphines related to use of rubber flooring only as combined with either standard polyacrylate adhesive S or with alkali-resistant adhesive A. The VOC of sequinterphines was not dependent on RH [3].

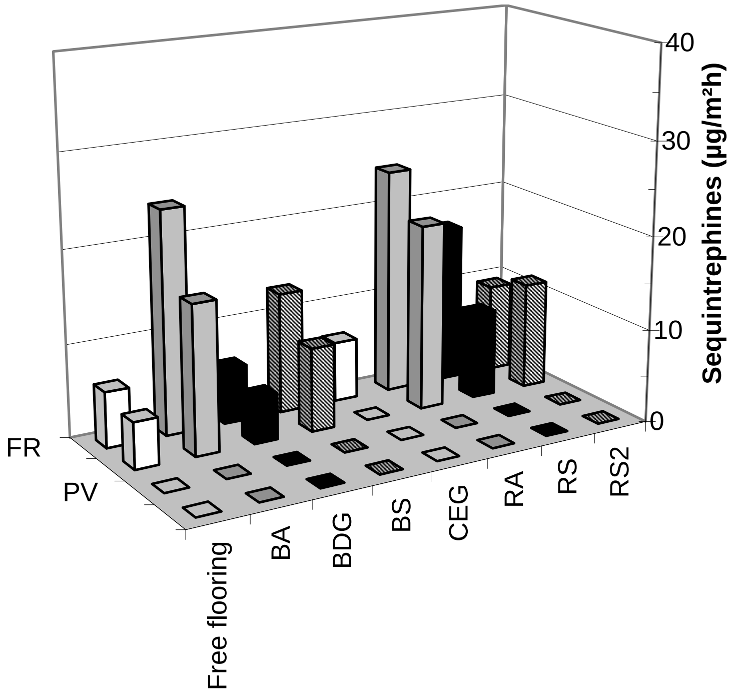


Figure 2.34 - Small VOC of sequintrephines. Symbols are given in the section of Symbols.

2.3 Adhesion

A summary of previous adhesion strength tests are shown in Figure 2.35 [3]. An approved value of adhesion was about 0.4 MPa. The peel force was material dependence. Figure 2.36 shows decreasing adhesion with increasing RH. At ½ a years' age, at which time the concrete had been exposed to outdoor conditions, i.e. rain, before applying the flooring, the adhesion became substantially higher since harmful alkalis then were rinsed from the surface.

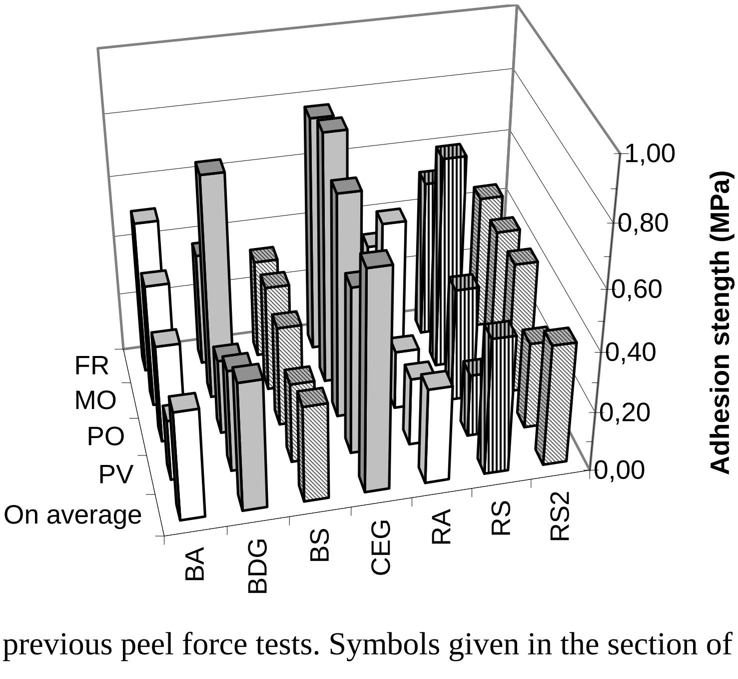


Figure 2.35 - Summary of previous peel force tests. Symbols given in the section of Symbols.

2.4 Peel force

Figure 2.37 shows peel force of previous tests of flooring systems with an approved value of 1 N/mm [12]. As for the adhesion strength the peel force became at the largest for rubber floorings. The lowest peel force was obtained for polyolefin flooring. Flooring system with alkali resistance adhesives showed significantly lower peel force than flooring with standard polyacrylate adhesive. The lowest peel force was obtained for flooring with the self-levelling compound B where the fracture took place in the upper part of the self-levelling compound about 0.5 mm from the surface [3]. Figure 2.38 shows decreasing peel force with increasing RH. When applied at ½ a years' age much of the alkalis were rinsed from the concrete which gave a higher peel force than for concrete that was cured indoor only, 2.38 [3].

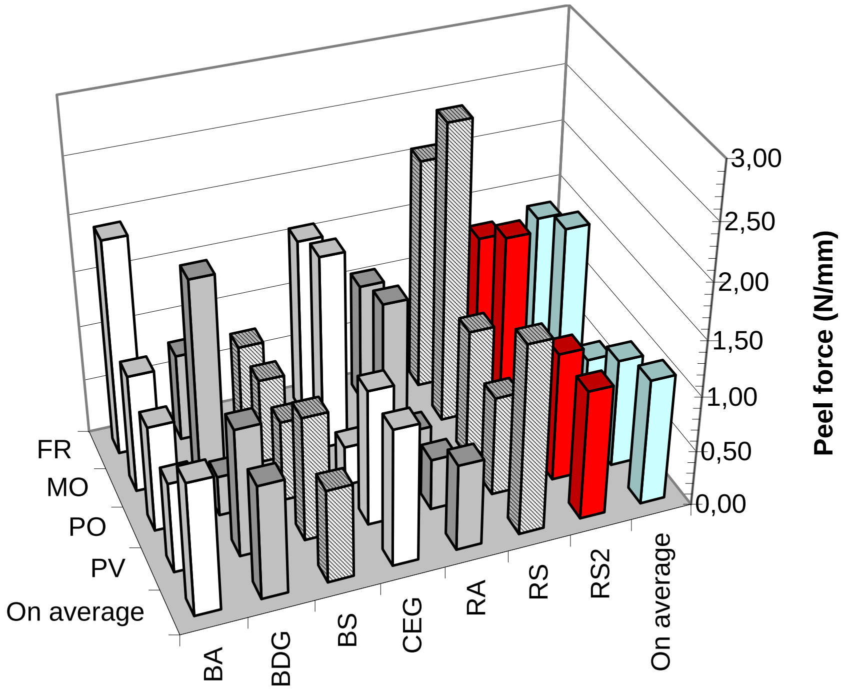


Figure 2.37 - Peel force of previous tests of flooring systems. Symbols given in Symbols.

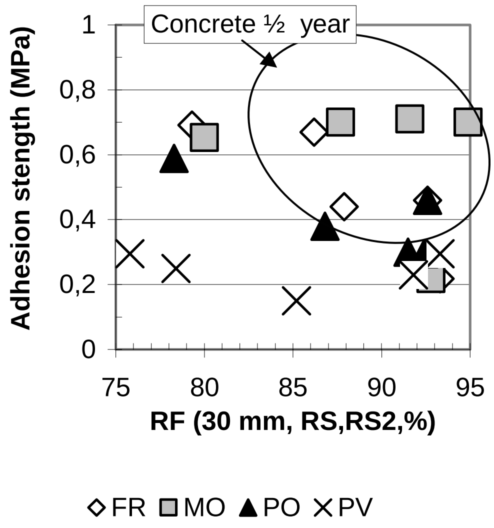


Figure 2.36 – Adhesion strength versus RH.

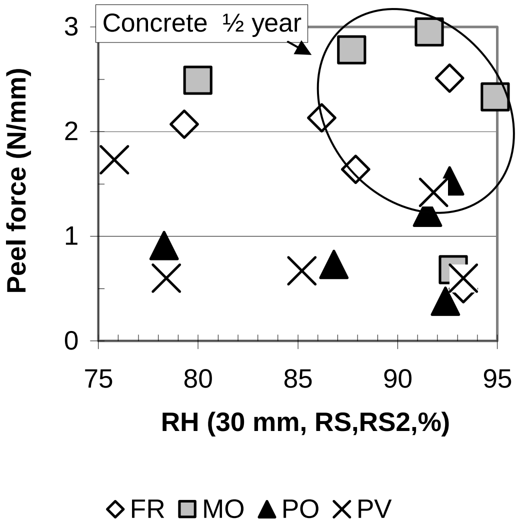


Figure 2.38 – Peel force versus RH [3].

3. GENERAL PERFORMANCE, MATERIAL AND METHODS

3.1 General performance

The following parts were included in the project:

1 Development of a new testing specimen that simulates in a broadly way a full-scale flooring system. In the specimen concrete, probable self-levelling compound, adhesive and surface flooring were included. *The objective* was to give recommendations for a type of specimen that simulates in a broadly way a full-scale flooring system
2 Application of a testing method of RH in the flooring system new testing method. Present methods were based on drying of concrete - without self-levelling compound, adhesive and surface flooring. The type of surface flooring has proven to be important for the development of RH in the flooring system. *The objective* for the testing method for moisture was to define the development of moisture in full-scale flooring systems including a judgement of the significance level of the results of measurement at three points.
3 Application of a testing method for chemical VOC with FLEC-equipment acc. to prEN 13419-2 at RH = 50% from the flooring systems that compares three equal specimens of the same type of flooring system related to the significance level. *The objective* of the testing method was to foresee the chemical VOC from the flooring systems before the construction was built and the floor may give bad influence on the quality of the indoor air.
4 Application of a testing method for peel test of flooring materials according to prEN 1372. *The objective* of the development of the testing method was to give a possibility to follow up, in a significant way, the peeling force of different flooring systems.
5 The testing method was to be applied on 60 full-scale specimens, 3 identical of each, in order to estimate the significance level of the testing method.
6 The fabrication of the specimens, testing of RH and peeling force will take place at Lund Institute of Technology, LTH, Lund. The Swedish Testing and Research Institute, SP, Borås, will perform the tests of VOC. *The objective* of the applications at LTH and SP was to obtain a scientific evaluation of the testing method.
7 The testing methods will be applied as an official SP Test Method. *The objective* of achieving a SP Test Method status was to implement the method in a more efficient way.

The time schedule is given in Table 3.1. The following persons were engaged in the project:

1. Lars-Göran Areschoug, Tarkett Sommer AB (flooring materials)
2. Stefan Backe, LTH Byggnadsmaterial (RH-measurents)
3. Thomas Davidsson, Akzo Nobel Deco International AB - Casco (flooring materials)
4. Per Folkesson, LTH (casting of concrete, peel tests)
5. Nils-Erik Hillenhage (flooring materials)
6. Joachim Holmberg, Freudenberg
7. Bo Jonasson, Bostik Findley AB (flooring materials)
8. Sarka Langer, SP (SP-method)
9. Thord Lundgren (ambient relative humidity)
10. Bertil Persson, LTH Byggnadsmaterial (general)
11. Per-Olof Rosenkvist, LTH Bärande konstruktioner (peel tests)
12. Maria Rådemar (measurement of VOC)
13. Lennart Sturefelt, LS Sealing (self-levelling compound, flooring performance)
14. Jost Thelen, Freudenberg, Weinheim (flooring materials)
15. Lars Östberg, PEAB (general)

Table 3.1 - Time schedule.

Quarter/Activity	2004	2005				2006		
………………………..……………	4	1	2	3	4	1	2	3
Workability, density of cast concrete		xxx						
Water curing		xxx						
Drying of concrete		x	xx					
Primer application			xxx					
Self-levelling compound application			xxx					
Drying of self-levelling compound			xxx					
Application of adhesive			xxx					
Drying of adhesive			xxx					
Application of flooring materials			xxx					
Application of adhesive tape			xxx					
RH-tube montage			xxx					
RH-measurement			xxx					
Measurement of VOC					xxx			
RH-tube montage					xxx	x	x	
RH-measurement					xxx	x	x	
Measurement of peel					x	xx	xx	
SP Test Method							x	xx
Final report							x	
Project meeting		23/3		20/10		23/3		21/9
Seminars								xxx
Articles								xxx

3.2 Material

The following material was used:

1. Concrete either with water/cement, w/c = 0.40 or w/c = 0.60, Appendix 1.
2. Self-levelling compound either type A (normal drying, normal alkali content) or type B (fibre, low alkali content)
3. Adhesive either type A (standard polyakrylate) or type B (alkali-resistant)
4. Flooring material either of type FR (rubber), type TL (linoleum) or type TP (PVC)

3.3 Methods

The following curing, handling, measurements and methods was applied, Appendix 2:

1. Mixing of concrete for 3 min. with all material all together.
2. Workability (slump with Abram’s cone) and density of the concrete
3. Casting of the concrete within an Ø250 x 140 mm steel ventilation tube with a socket tightened with a rubber sleeve. Smooth steel levelling at a 8-mm sublevel taking into account the thickness of a possible self-levelling compound, Figure 3.1.
4. Water curing of concrete for 1 months (Wettex clothes and double 0.2 mm plastic foil), Figure 3.1.
5. Drying for 1 months at 20 °C and RH = 60%.
6. Measurement of RH with Vaisala HMP 44 sensor drilled into concrete at 55-mm depth.
7. Drilling and montage of a measurement tube for RH measurement 55 mm from the surface of the concrete and 55 mm into the specimen, principal acc. to Figure 2.11.
8. Measurement of RH 3 days after the montage of the measurement tube.

9. Calibration of RH devices within one month from the measurement in a humidity generator in turn calibrated to ASTM E 104-85 or with ASTM E 104-85 only.
10. Application of primer, 0.25 kg/m², normally surface dry, Figure 3.1.
11. Application of self-levelling compound with 1 month drying at 20 °C and RH = 60%, Figure 3.2.
12. Adhesive application, 3.5 or 4 m²/kg, 15 or 25 min drying time at 20 °C and RH = 60%, Figure 3.3.
13. Flooring application tightened at the specimen edge with aluminium adhesive tape, Figure 3.3.
14. Measurement of VOC with FLEC-equipment acc. to prEN 13419-2, 6 months after application of flooring material, Figure 3.5.
15. Drilling and montage of a measurement tube for RH measurement 55 mm from the surface of the concrete and 55 mm into the specimen, 1 month after the VOC measurements.
16. Measurement of RH 3 days after the montage of the measurement tube.
17. Calibration of RH devices within one month from the measurement in a humidity generator in turn calibrated to ASTM E 104-85 or with ASTM E 104-85 only.
18. Measurement of peel with prEN 1372, 8 months after application of flooring material on a 30-mm wide strip on 100-mm length, 30 s time – 3 of each specimen, Figure 3.6.
19. Documentation of peel force and of adhesion – cohesion by photo.
20. Ocular judgement of peel fracture distribution on each surface, adhesion or cohesion, by percentage of each surface.

Figure 3.1 - Concrete casting within an Ø250 x 140 mm steel ventilation tube with a socket tightened with a rubber sleeve.

Figure 3.2 - Self-levelling compound, 8-mm. Drying for 1 month at RH = 60%.

Figure 3.3 - Adhesive application, 3.5 or 4 m²/kg, 15 or 25 min drying time at 20 °C and RH = 60%.

Figure 3.4 - Flooring application tightened at specimen edge with aluminium tape.

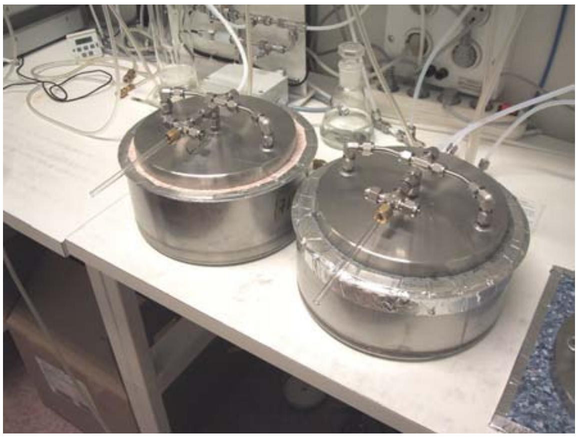


Figure 3.5 - Measurement of VOC with FLEC-equipment acc. to prEN 13419-2, 6 months after application of flooring.

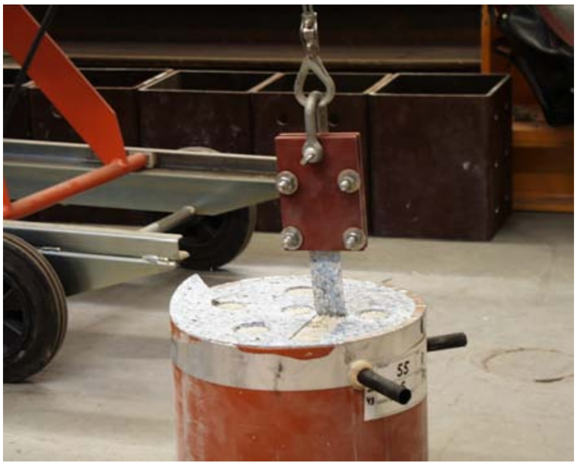


Figure 3.6 - Measurement of peel with prEN 1372, 8 months after application of flooring material on a 30-mm wide strip on 100-mm length, 30 s time – 3 of each specimen,

5. RESULTS AND DISCUSSION

5.1 Moisture in concrete

Table 5.1 and Appendix 3 show the relative humidity, RH, before flooring of the specimen. For both the concrete types, especially with w/c=0.60, RH > 85% and > 90% was observed. At 8 months’ age differences between RH dependent on the type of flooring material were observed, Tables 5.2-5.3 and Appendix 3. In floor systems with w/c = 0.40 RH on average was reduced from 86.4% to 82.7% over ½ a year due to (self-)desiccation. RH for flooring with linoleum was about half a percent lower than in flooring with rubber which flooring in turn obtained half a percent lower RH than RH in flooring with PVC. In floor systems with w/c = 0.60 RH was reduced from 92.7% to 91.1% over ½ a year due to (self-)desiccation. RH for flooring with linoleum was about 2% lower than in flooring with rubber which flooring in turn obtained the same RH as flooring with PVC. Both the standard variation and variation coefficient were less than 1%, which showed very high accuracy of the RH test method.

Table 5.1 - Relative humidity before flooring of the specimen (%).

Total average for no 1-30 (w/c=0.40)	86.4
Total standard deviation for no 1-30	0.61
Total variation coefficient for no 1-30	0.70
Total average for no 31-33 (w/c=0.60)	92.7
Total standard deviation for no 31-33	0.29
Total variation coefficient for no 31-33	0.31

Table 5.2 - Relative humidity after VOC measurement of the specimen with w/c = 0.40 (%).

	RH auto-calibration	By hand
Average for linoleum flooring	82.0	81.7
Standard deviation for linoleum flooring	0.52	0.39
Variation coefficient for linoleum flooring	0.63	0.48
Average for rubber flooring	82.4	82.3
Standard deviation for rubber flooring	0.68	0.48
Variation coefficient for rubber flooring	0.82	0.58
Average for PVC flooring	82.8	82.8
Standard deviation for PVC flooring	0.90	0.56
Variation coefficient for PVC flooring	1.08	0.68

Table 5.3 - Relative humidity after VOC measurement of the specimen with w/c = 0.60 (%).

Average for linoleum flooring	89.4
Standard deviation for linoleum flooring	0.45
Variation coefficient for linoleum flooring	0.50
Average for rubber flooring	91.2
Standard deviation for rubber flooring	0.41
Variation coefficient for rubber flooring	0.45
Average for PVC flooring	91.4
Standard deviation for PVC flooring	0.60
Variation coefficient for PVC flooring	0.66

5.2 Peel force

Table 5.1, Figure 5.1 and Appendix 4 shows results of peel force tests. Some tests of floorings with concrete with w/c = 0.60 had to be repeated due to low peel force. In some cased tests of floorings with concrete with w/c = 0.60 failed due to very low, hardly measurable peel force. The relationship between RH and the peel force was estimated with the following equation:

$$Pf = a \cdot RH + b \qquad (5.1)$$

where a, b denotes peel force constants given in Table 5.1 (N/mm), Pf the peel force for 30-mm wide and 100-mm long strip (band) peeled off at a speed of 100-mm/min. (N/mm), and RH the relative humidity at 50-mm depth (40% of the slab thickness as it dried in one direction,%). Table 5.1 also shows relevant estimations of the peel force at RH varying between 80% and 90%. An acceptable level of minimum peel force is 1 N/mm, which is fulfil for all types of flooring systems except for rubber and PVC-floorings with standard adhesives but only on self-levelling compound of type A (systems AGFR and AHTP). For rubber flooring with identical adhesive but placed on self-levelling compound B about 340% higher peel force was observed (systems BHTP). Also for the PVC-flooring with an alternative on self-levelling compound B with the adhesive C (alkali-resistant) instead of adhesive H (standard) meant an substantial increase of the peel force, with about 280% (system BCTP instead of system AHTP), Figure 5.1.

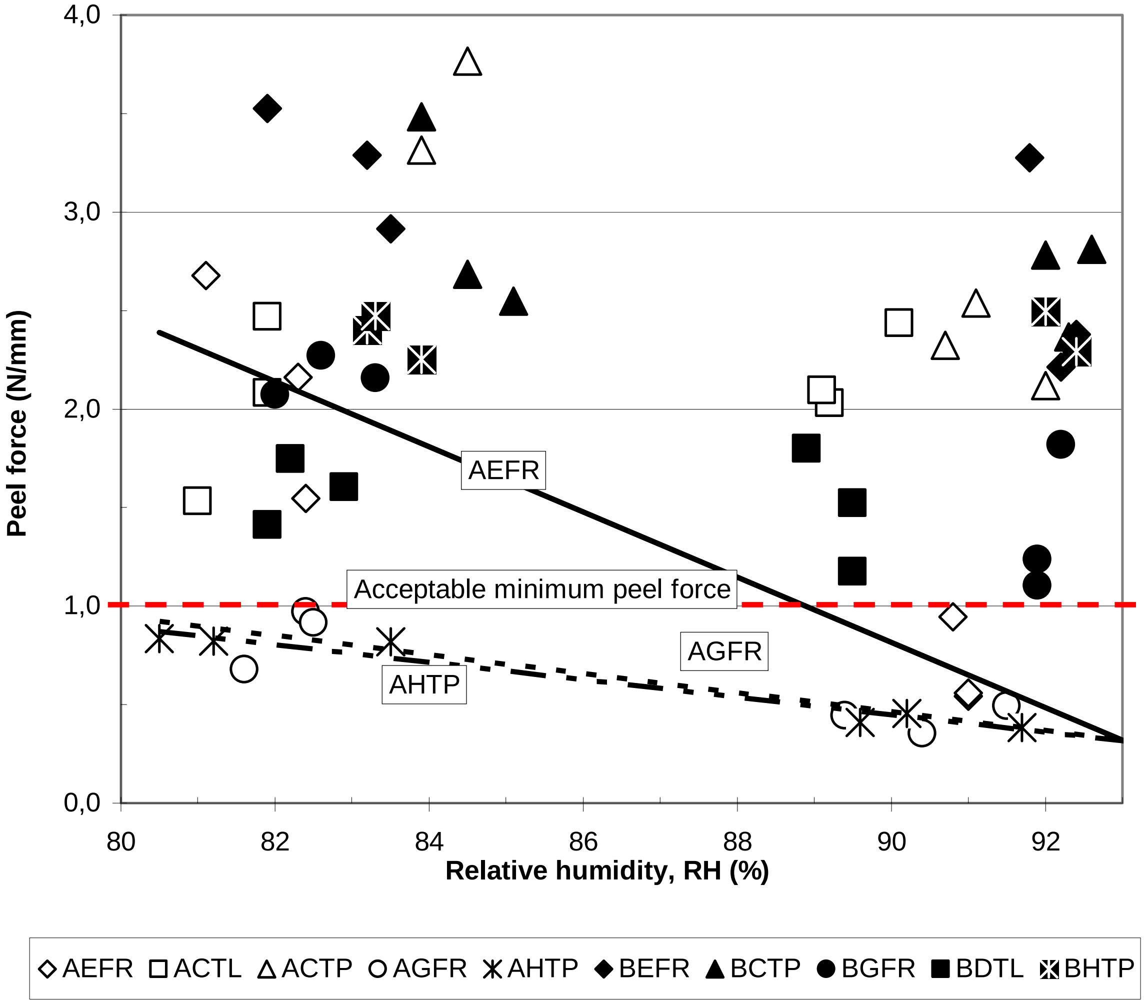


Figure 5.1 - Results of peel force versus RH (one value of ACTP not shown = 4.9 N/mm).

Table 5.1 – Constants a, b, estimation of peel force related to results of peel force test (N/mm)

Flooring system	a	b	RH=80%	RH=85%	RH=90%	Effect of 10% higher RH (%)	Grade of effect of RH
AEFR	-0.1653	15.7	2.5	1.6	0.8	-77	High
ACTL	0.0273	-0.2	2.0	2.1	2.3	13	Low
ACTP	-0.2205	22.4	4.8	3.7	2.6	-51	High
AGFR	-0.0481	4.8	1.0	0.7	0.5	-56	High
AHTP	-0.0446	4.5	0.9	0.7	0.5	-53	High
BEFR	-0.0721	9.2	3.4	3.1	2.7	-22	Low
BCTP	-0.0381	6.1	3.1	2.9	2.7	-13	Low
BGFR	-0.0813	8.9	2.4	2.0	1.6	-36	High
BDTL	-0.0142	2.8	1.7	1.6	1.5	-9	Low
BHTP	0.0073	1.8	2.4	2.4	2.5	3	Low
Average						-30	

For flooring system AEFR (rubber flooring on self-levelling compound A with alkali-resistant adhesive) the very highest effect of RH was observed, which indicated too a low peel force at RH > 89% (RH = 85% is a recommend limit of RH for rubber floorings). Generally self-levelling compound A was more sensitive to moisture than self-levelling compound A referring to the peel force. All flooring systems with self-levelling compound B fulfilled 1 N/mm even at RH = 92%, Figure 1. Only with rubber flooring on self-levelling compound B some effect of moisture was observed. For all other types of flooring on self-levelling compound B an increase of RH had no effect on the peel force at all. Still it was essential to confirm the location of the fracture of the flooring. Standard deviation was 0.17 N/mm, which is very good, and the variation coefficient 8% for system with w/c=0.40-concrete, 12% for w/c=0.60-concrete. Some completing peel force tests were performed with heating of the flooring for 1 year, 27 °C surface temperature and 30 °C concrete temperature at 50-depth, Table 5.2, Figure 5.2. The test took place at 20 °C or at elevated temperature. Less than half the peel force was observed with heating of the flooring system compared with an unheated flooring system. Since the RH-measurement took place at 20 °C some adjustment had to be done to obtain RH (%) at the elevated temperature, T (°C), Table 5.3, and Figure 5.3. Still heat decreased the peel force. For the test with peel force of heated slabs only self-levelling compound B was used. Almost all the fracture took place in the adhesive except for tendency adhesion fractures of the rubber flooring, 30% fracture but only half the number of slabs, Appendix 5. Still the cohesion fracture of the adhesive E was dominating, both at a peel force > 1N/mm (unheated specimens) and a peel force of < 1N/mm (heated ones).

Table 5.2 – Measured peel force after 1 year for floorings with and without heating (

Flooring system	Pl	Drying time	a	b	c	Average	Stddv	Var. coeff. (%)
40BEFR2h	2	4 weeks	0.74	0.88	1.16	0.93	0.21	23.1
40BEFR4h	4	2 weeks	0.67	0.82	0.88	0.79	0.11	13.7
40BEFR9	9	2 weeks	1.77	1.99	1.99	1.92	0.13	6.6
40BEFR10	10	4 weeks	1.94	2.14	2.16	2.08	0.12	5.8
60BEFR5h	5	2 weeks	1.51	1.3	1.12	1.31	0.20	14.9
60BEFR6h	6	4 weeks	1.14	1.31	0.98	1.14	0.17	14.4
60BEFR11	11	2 weeks	2.66	2.71	2.4	2.59	0.17	6.4
60BEFR12	12	4 weeks	2.5	2.66	2.89	2.68	0.20	7.3

h = heating, 27 °C in the surface and about 30 °C at 40% depth of the slab thickness.

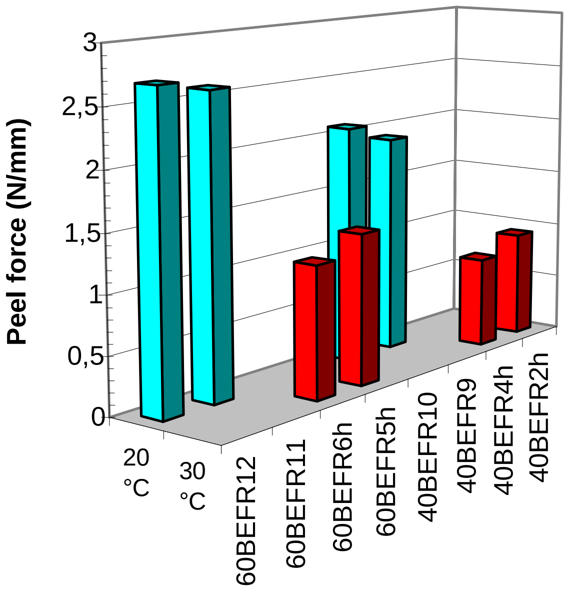


Figure 5.2 – Results of peel tests that took place at 20 °C or at the elevated temperature.

Table 5.3 – RH and temperature at the elevated temperature, T (°C).

Flooring system	Pl	RH (20 °C,%)	T (°C)	RH (T,%)	Measured peel force	Reduction of peel force (%)
40BEFR2h	2	82.0	29.2	84.8	0.93	55
40BEFR4h	4	82.0	30.8	85.2	0.79	59
40BEFR9	9	81.0	20.0	81.0	1.92	
40BEFR10	10	80.5	20.0	80.5	2.08	
60BEFR5h	5	83.5	29.3	84.9	1.31	49
60BEFR6h	6	86.0	28.6	87.3	1.14	57
60BEFR11	11	85.0	20.0	85.0	2.59	
60BEFR12	12	84.0	20.0	84.0	2.68	

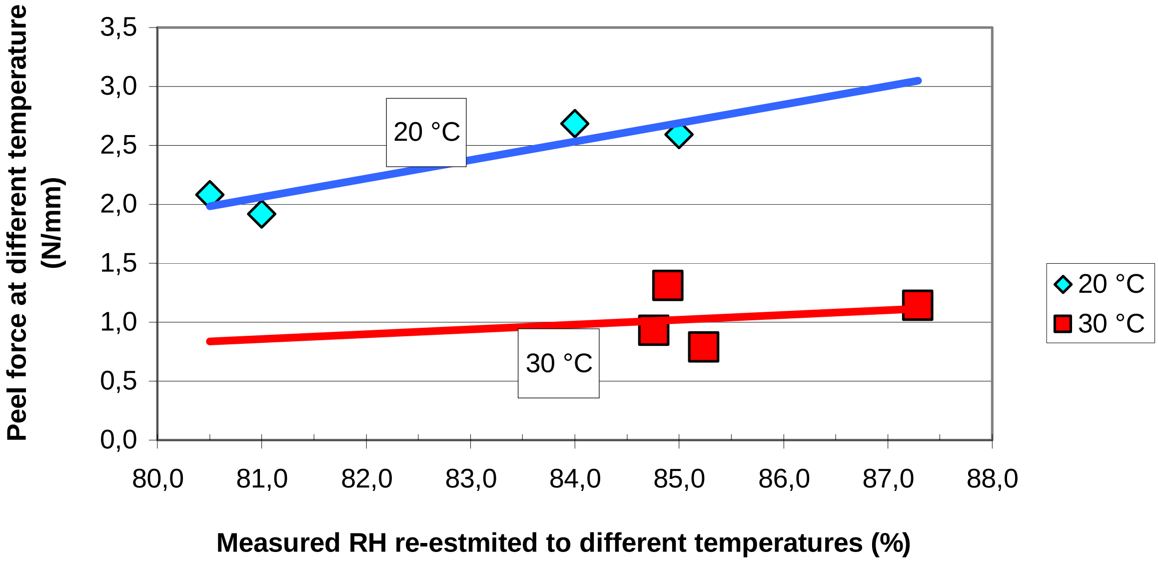


Figure 5.3 – Peel force of flooring system BEFR versus RH (%) at the elevated temperature.

5.3 Peel fracture views and allocation

Figures 5.4-5.5 and Appendix 5 show peel fracture views and partition of fracture of the flooring systems on sub-flooring of concrete with w/c=0.40 or w/c = 0.60 (%). Most of the flooring systems performed well as regards peel force, i.e. > 1 N/mm. From Figures 5.2-5.3 it was clear that fracture took place due to adhesion to flooring for systems of type and BHTP (2.4 N/mm at RH=85%), due to cohesion in the flooring itself for flooring systems ACTL (2.3 N/mm at RH=90%) and BDTL (1.5 N/mm at RH=90%), due to cohesion in the adhesive for flooring systems ACTP (3.7 N/mm at RH=85%) and BCTP (2.9 N/mm at RH=85%), due to adhesion fracture between the flooring and the self-levelling compound for flooring systems AEFR (1.6 N/mm at RH=85%), BEFR (3.1 N/mm at RH=85%), BGFR (2.0 N/mm at RH=85%) and 40AHTP (0.7 N/mm at RH=85%), and finally due to fracture in the self-levelling compound itself in flooring systems AGFR (0.7 N/mm at RH=85%) and in flooring system 60AHTP (0.7 N/mm at RH=85%). The main problems thus occurred due to adhesion fracture between the flooring and the self-levelling compound of the flooring system for combination 40AHTP and due to fracture in the self-levelling compound itself in flooring systems AGFR and 60AHTP. For all the problem cases with peel force < 1 N/mm self-levelling compound A was used as combined with standard polyacrylate adhesive G or H. Only for combination 40AHTP the fracture was due to adhesion between self-levelling and adhesive – for systems AGFR and 60AHTP the fracture took place in the self-levelling compound itself due to too a low tensile strength. The influence of adhesive or flooring type on the tensile strength of the self-levelling compound for flooring systems AGFR and 60AHTP is not understood and need more research to be explained. For all other combinations of flooring systems no fracture took place in the self-levelling compound even though the peel force was much larger. Some completing peel force tests were performed with heating of the flooring. Fracture view of flooring systems with heating are also shown in Appendix 5.

5.4 Volatile organic compound, VOC [14]

5.4.1 Measured values [14]

Results of VOC are given in Appendix 6 [14]. The effect of RH on TVOC was inconsistent, i.e. for some flooring combinations TVOC increased with RH and in contrary for others, Figure 5.6. Maximum TVOC = 359 μg/m²h for flooring system BDTL was observed for low RH = 82.9%, i.e. much lower than advised, RH = 90%. The results, again, shown that material combinations, compatibility, is of utmost importance in order to lower the TVOC. TVOC less than about 30 μg/m²h were obtained with flooring systems AEFR, ACTP, BEFR and BCTP, i.e. rubber or PVC-flooring with an alkali-resistant adhesive [14]. When standard polyacrylate adhesive was used instead of an alkali-resistant adhesive a substantial increase of TVOC was observed especially at low RH = 83-84% and as combined with self-levelling compound B, BGFR and BHFR as compared with flooring systems AGFR and AHTP. In this case the rubber flooring, BGFR, exhibited twice as large TVOC as the PVC-flooring, BHTP. However, maximum TVOC were obtained for linoleum floorings, ACTL and BDTL [14]. Even though alkali-resistant adhesive was used TVOC > 100 μg/m²h was obtained, ACTL. For floorings with linoleum and standard polyacrylate adhesive TVOC > 200 μg/m²h were observed, BDTL [14]. For maximum TVOC RH had a reversed effect, i.e. at higher RH lower TVOC was obtained which clearly show the effect of alkali of the self-levelling compound. When alkali-resistant adhesive was used instead less than half the TVOC was observed, c.p. BDTL with ACTL [14]. In Table 5.4 the effect of RH on TVOC is summarized, i.e. small effect of RH. However, for two flooring systems, AEFR and BDTL a substantial decrease of TVOC at higher RH was observed, Table 5.4. In both cases standard acrylate adhesive were used. Only for one flooring system, AGFR, an increase of TVOC was observed with increasing RH.

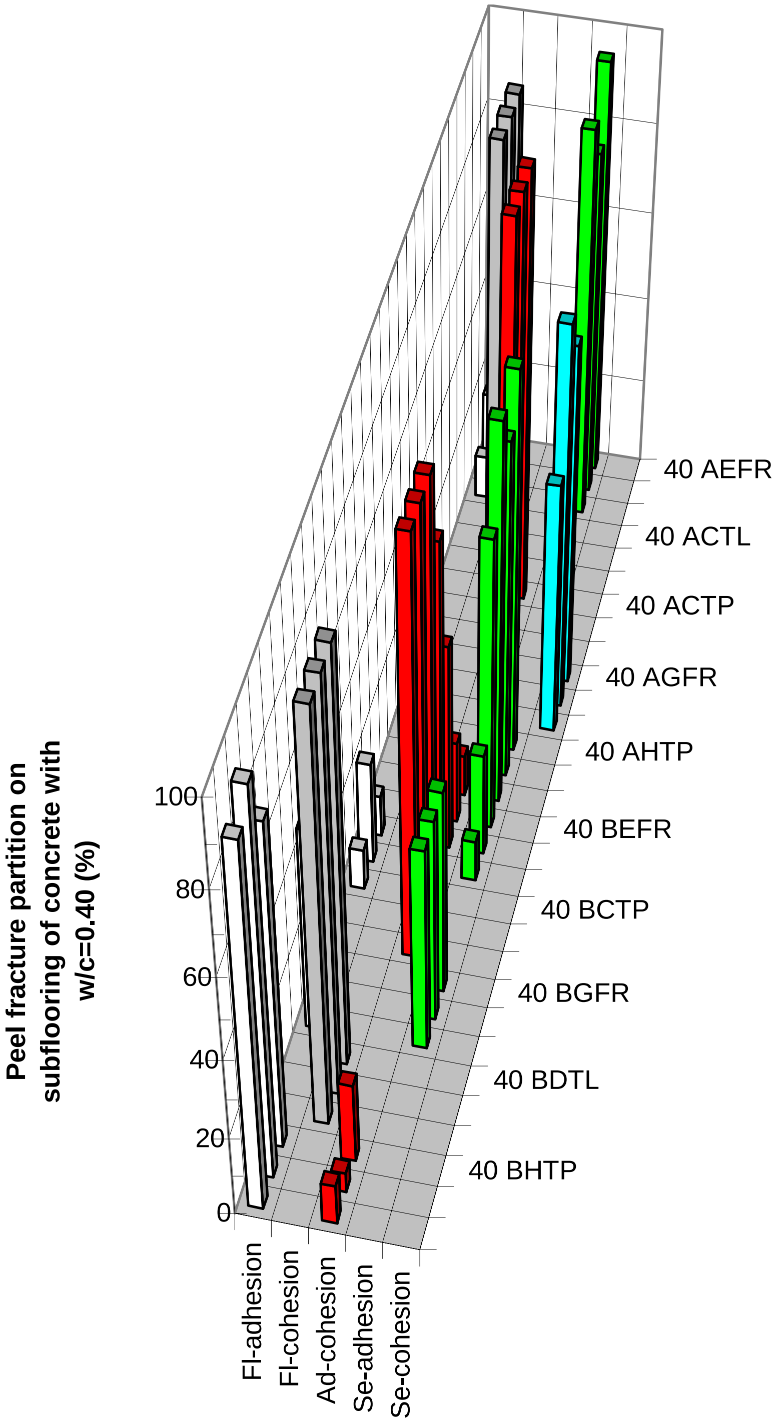


Figure 5.4 - Peel fracture partition on sub-flooring of concrete with w/c=0.40 (%). Ad = Adhesion, Fl = flooring, Se = self-levelling compound.

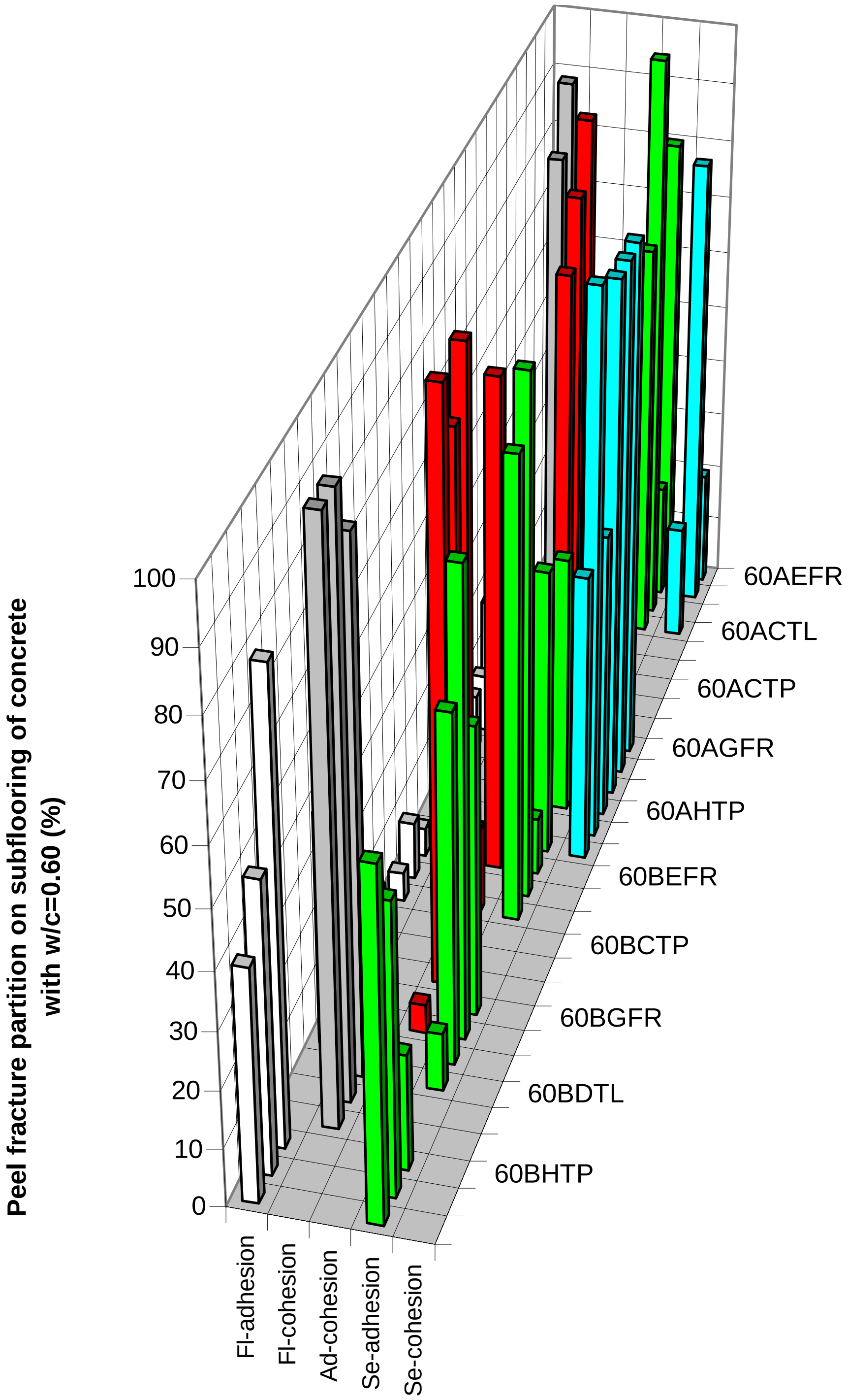


Figure 5.5 - Peel fracture partition on sub-flooring of concrete with w/c=0.60 (%). Ad = Adhesion, Fl = flooring, Se = self-levelling compound.

All other flooring system show no relevant effect of RH on TVOC, i.e. more or less the same TVOC from the floorings system at RH = 82% as at RH = 92%, which was astonishing. The following equation was obtained:

$$TVOC = a \cdot RH + b \quad (5.2)$$

where a, b are given in Table 5.4 (µg/m²h), Figure 5.7. Estimations were done at three RH varying between RH = 80% and RH = 90% in order to compare the results.

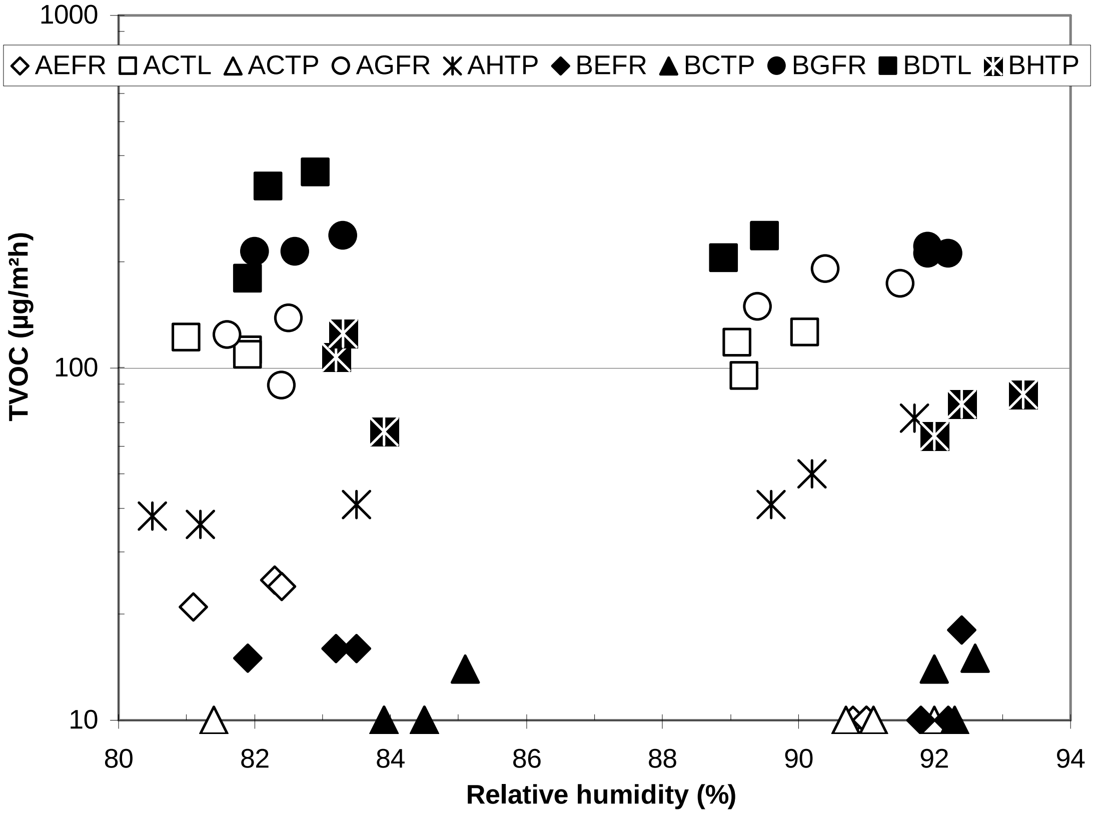


Figure 5.6 - The effect of RH on TVOC was inconsistent, i.e. for some flooring combinations TVOC increased with RH and in contrary for others [14].

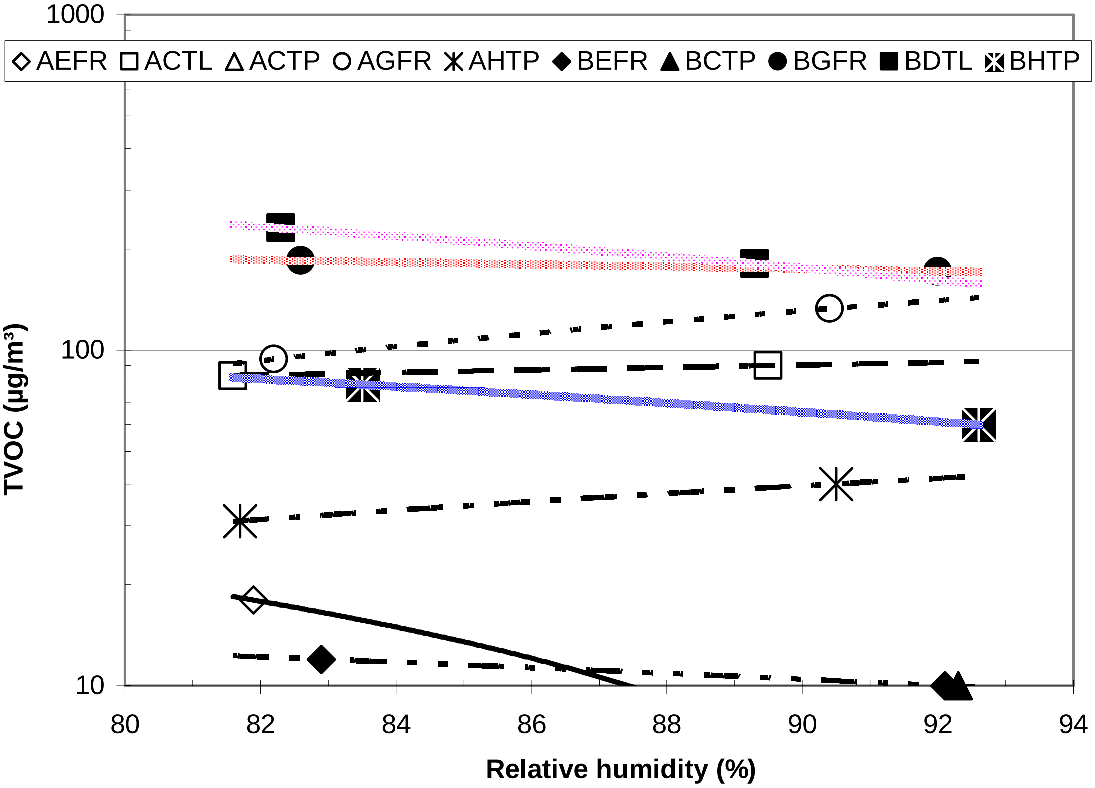


Figure 5.7 – Effect of RH on TVOC of flooring systems, i.e. little or no effect at all.

Table 5.4 – Constants in Equation (5.2) and estimated effect of RH on TVOC (µg/m²h) [14].

Flooring system	a	b	RH = 80%	RH = 85%	RH = 90%	Effect of RH-increase
AEFR	-1.4444	136	21	14	6	Decrease of TVOC
ACTL	0.7595	22	83	87	90	Constant
ACTP		5	5	5	5	Constant
AGFR	4.7561	297	677	701	725	Increase of TVOC
AHTP	1.0227	53	134	139	145	Constant
BEFR	-0.2174	30	13	12	10	Constant
BCTP			0	0	0	Constant
BGFR	-1.383	299	189	182	175	Constant
BDTL	-7.1429	819	247	212	176	Decrease of TVOC
BHTP	-2.0879	253	86	76	65	Constant

5.4.2 Lowest Concentration of Interest, LCI_i [14]

The results were evaluated according to LCI_i [14,15] with the requirement of TVOC < 1000 µg/m² which was fulfilled with good margin, Figure 5.8, $R = \sum C_i/LCI_i < 1$, was also fulfilled with good margin, Figure 5.8, and the sum of carcinogenic < 2 µg/m³, also fulfilled since no carcinogenic at all were detected. Still no relationship between TVOC and RH was seen, Figure 5.8. However, only substances with concentration > 5 µg/m³ were evaluated based on LCI_i since a low concentration of C_i as combined with small LCI_i may result in a high and misleading R value [14]. The material effect dominates on R – low RH is of low interest. Again the relation to RH was analysed, in case of $\sum C_i/LCI_i$ with the following equation:

$$\sum C_i/LCI_i = a \cdot RH + b \qquad (5.3)$$

where a, b are constants given in Table 5.5. Of all the floorings linoleum had the highest possible adverse effect on people, i.e. $26\% < \sum C_i/LCI_i < 40\%$, followed by the rubber flooring with $7\% < \sum C_i/LCI_i < 16\%$ and by the PVC-flooring with $3\% < \sum C_i/LCI_i < 9\%$. A way to minimize possible adverse effect on people was thus to use PVC-flooring. Another way was to use self-levelling compound A instead of B, which change gave a reduction to half the $\sum C_i/LCI_i$ for flooring systems with self-levelling compound A as compared with flooring systems with self-levelling compound B. The effect of alkali-resistant adhesive on the possible adverse effect on people, indoor, was also clarified, no $\sum C_i/LCI_i$ existed for rubber and PVC-flooring when alkali-resistant adhesive was used instead of standard polyacrylate adhesives.

Table 5.5 – Constants a, b in Equation (5.3) and estimated effect of RH on ∑Ci/LCI$_i$ (-) [14].

Flooring system	a	b	RH = 80%	RH = 85%	RH = 90%	Effect of RH-increase
AEFR			0	0	0	
ACTL	-0.0101	1.0863	0.28	0.23	0.18	Decrease of ∑Ci/LCI$_i$
ACTP			0	0	0	
AGFR	0.0012	-0.0302	0.07	0.07	0.08	Constant
AHTP		0.03	0.03	0.03	0.03	Constant
BEFR			0	0	0	
BCTP			0	0	0	
BGFR	-0.0011	0.2479	0.16	0.15	0.15	Constant
BDTL	-0.0243	2.3987	0.45	0.33	0.21	Decrease of ∑Ci/LCI$_i$
BHTP	-0.0033	0.3553	0.09	0.07	0.06	Decrease of ∑Ci/LCI$_i$

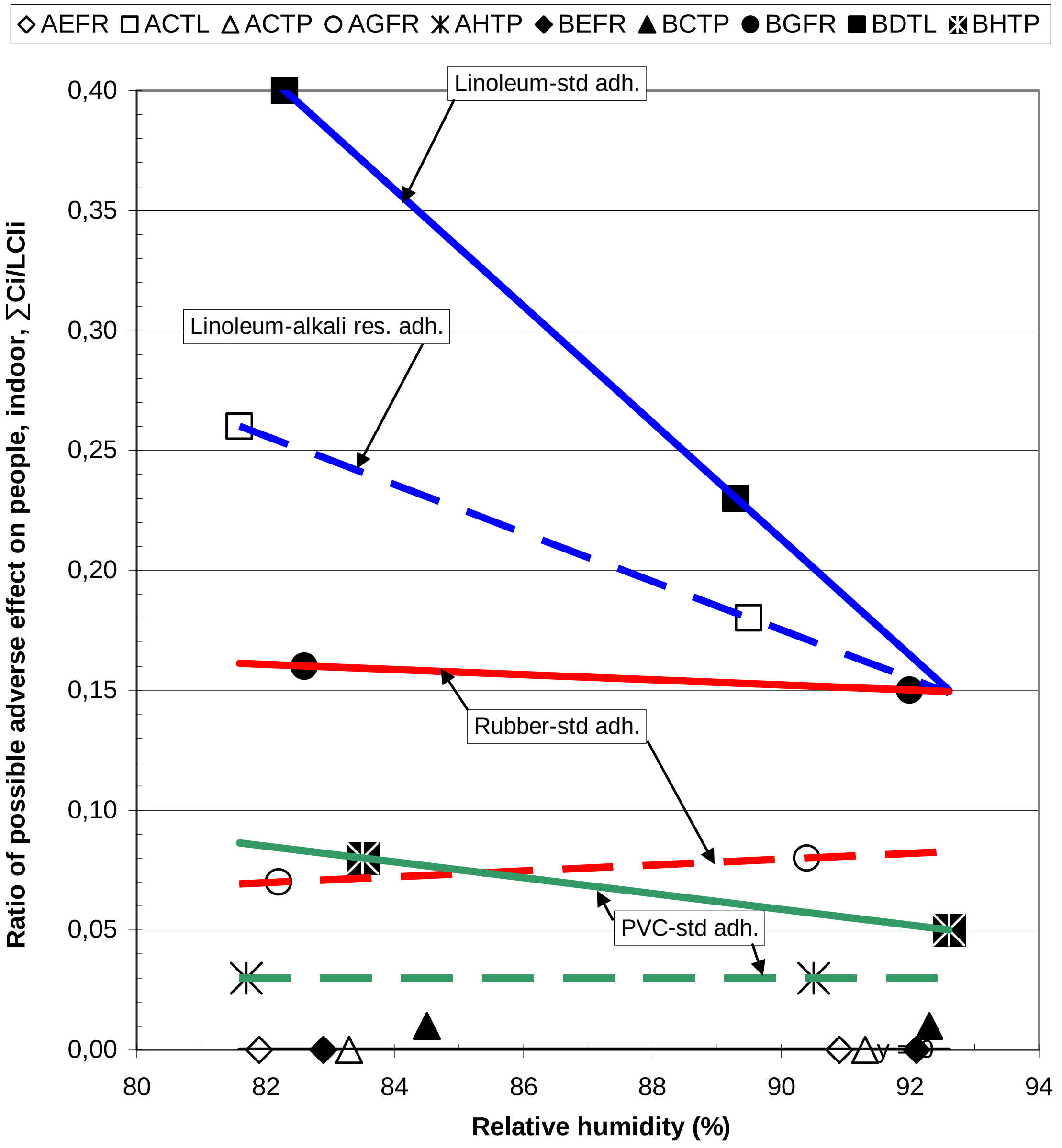


Figure 5.8 – The ratio of possible adverse effect on people, indoor, ∑C$_i$/LCI$_i$, decreased at higher RH, i.e. no rationale motive subsists to use low-w/c concrete to limit emissions. (Some difference exist between Figure 5.8 and Table 5.5 since Figure 5.8 show measured values and Table 5.5 shows values that were estimated at precise RH values.)

For linoleum flooring $\sum C_i/LCI_i$ existed even with alkali-resistant adhesive which showed that the flooring material linoleum itself caused the value of $\sum C_i/LCI_i$ [14]. Figure 5.9 shows no correlation between peel force estimated at RH = 80%, RH = 85% and RH = 90% and the $\sum C_i/LCI_i$ also estimated at RH = 80%, RH = 85% and RH = 90, which means that an adhesion damaged flooring not necessary shows high $\sum C_i/LCI_i$ or vice versa.

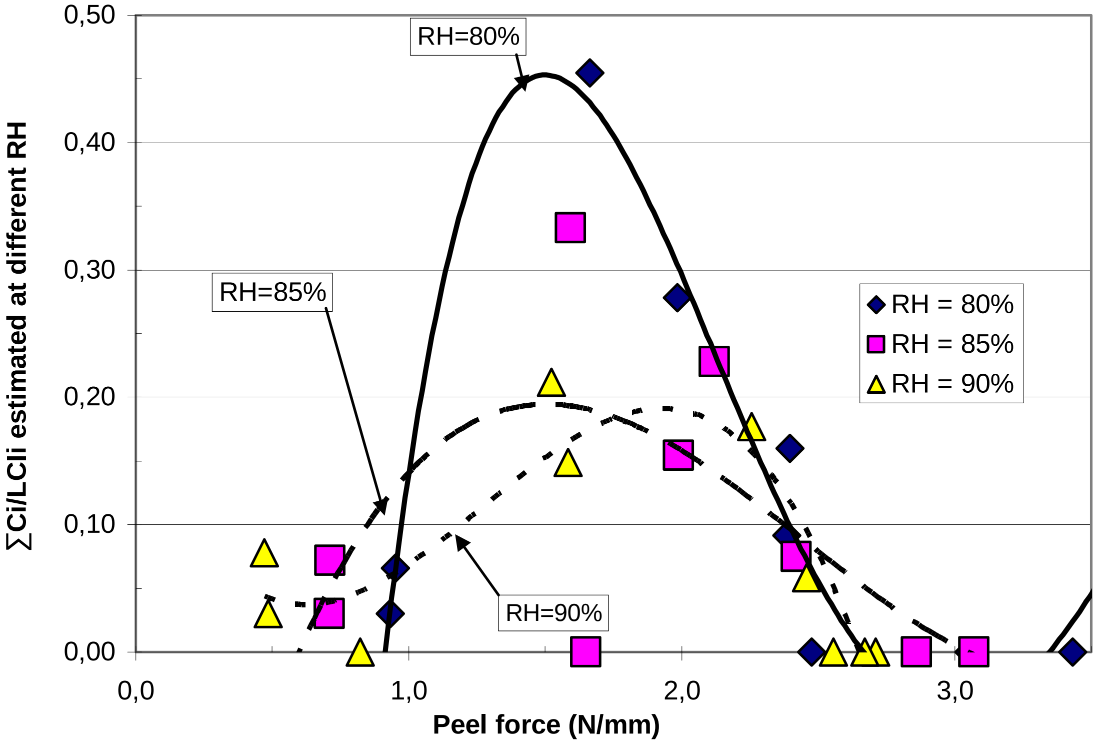


Figure 5.9 - Possible adverse effect on people, indoor, $\sum C_i/LCI_i$, as a function of peel force.

6. CONCLUSIONS

The following conclusions were drawn:

1. RH measurement with the method showed high accuracy (standard deviation and variation coefficient both less than 1%).
2. Peel tests performed acceptably with a standard deviation of 0.2 N/mm and a variation coefficient of 10%.
3. Variation between 3 identical specimens in the TVOC tests showed moderate values for standard deviation and variation coefficient.
4. The minimum peel force was mainly dominated by fracture between one of the tested self-levelling compounds and the adhesive or by fracture within this self-levelling compound itself, rubber or PVC flooring with standard polyacrylate adhesive.
5. For flooring systems with too low a peel force, the peel force decreased at higher RH but still the fracture occurred between this particular self-levelling compound and the adhesive or by fracture within this particular self-levelling compound itself.
6. For all other types of flooring systems, 8 out of 10, a peel force > 1 N/mm was observed and no influence of RH on the peel force at all was observed, not even at RH = 92%.
7. An opposite effect of RH was observed on volatile organic compounds, i.e. the sum of volatile organic compounds to the lowest concentration of interest increased to twice the value at RH = 82% as compared to the value of the sum of volatile organic compounds to the lowest concentration of interest at RH = 92%.
8. At 30 °C half the peel force was observed compared with the peel force at 20 °C.
9. The highest value of the sum of volatile organic compounds to the lowest concentration of interest, $\sum Ci/LCI_i$ (40% of the limits) was observed for linoleum floorings at RH = 82%: for the identical flooring a sum of volatile organic compounds to the lowest concentration of interest 20% of the limit was observed at RH = 89%.
10. For all other flooring systems without linoleum a low sum of volatile organic compounds to the lowest concentration of interest was observed (< 15% of the limit).
11. An effective way to reduce the possible adverse effect on people indoors, was to use self-levelling compound A instead of self-levelling compound B; this change gave a reduction to half the $\sum C_i/LCI_i$ for flooring systems.
12. The effect of alkali-resistant adhesive on the possible adverse effect on people indoors, was also clarified, since no $\sum C_i/LCI_i$ at all existed for rubber and PVC flooring when alkali-resistant adhesive was used instead of standard acrylate adhesives.
13. For linoleum flooring $\sum C_i/LCI_i$ existed even with alkali-resistant adhesive, which showed that the flooring material itself caused the possible problem.
14. High $\sum C_i/LCI_i$ was not at all correlated to a low peel force.
15. The project resulted in a newly developed test method which was a way to foresee too low a peel force and/or too high a sum of volatile organic compounds at the lowest concentration of interest that was detected and to avoid these unfeasible/unhealthy flooring systems during house construction.

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APPENDICES

APPENDIX 1 – MIX PROPORTIONS
APPENDIX 2 – SPECIMEN SCHEDULE
APPENDIX 3 – RELATIVE HUMIDITY
APPENDIX 4 - PEEL FORCE
APPENDIX 5 – PEEL FRACTURE VIEWS AND ALLOCATION
APPENDIX 6 –VOLATILE ORGANIC COMPOUND EMISSIONS [14]
APPENDIX 7 –TEST METHOD [16]

APPENDIX 1 – MIX PROPORTIONS

Appendix 1 – Mix proportions of concrete, properties (kg/m³, etc.)

Material/property, w/c	**0.40**	**0.60**
Date of casting	17.12.04	19.01.05
Blentarp 11-18 mm	385	431
Blentarp 4-8 mm	538	425
Bösarp 0-2 mm	695	709
Önnestad 0-1 mm	98	175
Baskarp 15	0	0
Glass filler	0	58
Byggcement Slite	484	355
Density	2397	2368
Water	194	213
Glenium 51 (wet weight)	2.90	1.4
Vct	0.40	0.60
Slump flow (mm)	270	250
Cube strength (28 days, sealed, 100 mm, MPa)	77.5	38.0
Cube strength, standard deviation (28 days, sealed, 100 mm, MPa)	0.7	0.1
Self-desiccation (28 days, %)	83.9	93.6
Self-desiccation, standard deviation, stdav (28 days, %)	0.2	0.5
RH (1 month sealed + 1 month drying with screeding, %)	86.4	
RH, stdav (1 month sealed + 1 month drying with screeding, %)	0.61	
RH, variation (1 month sealed + 1 month drying with screeding, %)	0.70	

APPENDIX 2 – SPECIMEN SCHEDULE

Appendix 2.1 – Specimen schedule (concrete with w/c = 0.40)

No	Legend	Casting	Screeding	RH	Flooring	VOC	RH	Peel test
1	40AEFR	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
2	40AEFR	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
3	40AEFR	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
4	40ACTL	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
5	40ACTL	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
6	40ACTL	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
7	40ACTP	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
8	40ACTP	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
9	40ACTP	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
10	40AGFR	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
11	40AGFR	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
12	40AGFR	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
13	40AHTP	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
14	40AHTP	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
15	40AHTP	17.12.04	17.01.05	14.02.05	16.02.05	16.08.05	19.09.05	26.09.05
16	40BEFR	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
17	40BEFR	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
18	40BEFR	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
19	40BCTP	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
20	40BCTP	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
21	40BCTP	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
22	40BGFR	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
23	40BGFR	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
24	40BGFR	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
25	40BDTL	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
26	40BDTL	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
27	40BDTL	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
28	40BHTP	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
29	40BHTP	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
30	40BHTP	17.12.04	17.01.05	15.02.05	16.02.05	16.08.05	19.09.05	26.09.05
No	Legend	Casting	Screeding	RH	Flooring	VOC	RH	Peel test

A = low-alkali self-levelling compound (Akzo Nobel Deco International Schönox CP)
B = low-alkali self-levelling compound (Bostik Golvspackel Fiber Quick)
C = alkali-resistant linoleum and PVC adhesive (Bostik Golvlim AlcaliTac AT)
D = standard polyacrylate linoleum adhesive (Akzo Nobel Deco International Cascolin 3449)
E = alkali-resistant rubber adhesive (AKZO NOBEL Casco Proff Solid 3480)
FR = Freudenberg rubber flooring {noraplan mega, beige/fawn tiles (color 2674), batch no. 1331920000, blue tiles (color 2171), batch no. 1187220000}
G = standard polyacrylate rubber adhesive (Bostik Golv- och Vägglim MultiTac MT)
H = standard PVC adhesive (Akzo Nobel Deco International Casco Cascoproff 3448)
TL = Tarkett linoleum flooring (as delivered)
TP = Tarkett PVC flooring (as delivered)

Appendix 2.2 – Specimen schedule (concrete with w/c = 0.60)

No	Legend	Casting	Screeding	RH	Flooring	VOC	RH	Peel test
31	60AEFR	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
32	60AEFR	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
33	60AEFR	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
34	60ACTL	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
35	60ACTL	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
36	60ACTL	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
37	60ACTP	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
38	60ACTP	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
39	60ACTP	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
40	60AGFR	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
41	60AGFR	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
42	60AGFR	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
43	60AHTP	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
44	60AHTP	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
45	60AHTP	19.01.05	16.02.05	14.03.05	16.03.05	12.09.05	12.10.05	19.10.05
46	60BEFR	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
47	60BEFR	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
48	60BEFR	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
49	60BCTP	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
50	60BCTP	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
51	60BCTP	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
52	60BGFR	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
53	60BGFR	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
54	60BGFR	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
55	60BDTL	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
56	60BDTL	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
57	60BDTL	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
58	60BHTP	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
59	60BHTP	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
60	60BHTP	19.01.05	16.02.05	15.03.05	16.03.05	12.09.05	12.10.05	19.10.05
No	Legend	Casting	Screeding	RH	Flooring	VOC	RH	Peel test

Appendix 2.3– Adhesive application (concrete with w/c = 0.40)

No	Legend	Amount (m^2/l)	Drying time (min.)
1	40AEFR	4	15
2	40AEFR	4	15
3	40AEFR	4	15
4	40ACTL	4	15
5	40ACTL	4	15
6	40ACTL	4	15
7	40ACTP	4	15
8	40ACTP	4	15
9	40ACTP	4	15
10	40AGFR	3.5	25
11	40AGFR	3.5	25
12	40AGFR	3.5	25
13	40AHTP	4	25
14	40AHTP	4	25
15	40AHTP	4	25
16	40BEFR	4	15
17	40BEFR	4	15
18	40BEFR	4	15
19	40BCTP	4	15
20	40BCTP	4	15
21	40BCTP	4	15
22	40BGFR	3.5	25
23	40BGFR	3.5	25
24	40BGFR	3.5	25
25	40BDTL	3.5	10
26	40BDTL	3.5	10
27	40BDTL	3.5	10
28	40BHTP	4	25
29	40BHTP	4	25
30	40BHTP	4	25
No	Legend	Amount (kg/m^2)	Drying time (min.)

A = low-alkali self-levelling compound (Akzo Nobel Deco International Schönox CP)
B = low-alkali self-levelling compound (Bostik Golvspackel Fiber Quick)
C = alkali-resistant linoleum and PVC adhesive (Bostik Golvlim AlcaliTac AT)
D = standard polyacrylate linoleum adhesive (Akzo Nobel Deco International Cascolin 3449)
E = alkali-resistant rubber adhesive (AKZO NOBEL Casco Proff Solid 3480)
FR = Freudenberg rubber flooring {noraplan mega, beige/fawn tiles (color 2674), batch no. 1331920000, blue tiles (color 2171), batch no. 1187220000}
G = standard polyacrylate rubber adhesive (Bostik Golv- och Vägglim MultiTac MT)
H = standard PVC adhesive (Akzo Nobel Deco International Casco Cascoproff 3448)
TL = Tarkett linoleum flooring (as delivered)
TP = Tarkett PVC flooring (as delivered)

Appendix 2.4 – Adhesive application (concrete with w/c = 0.60)

No	Legend	Amount (m²/l)	Drying time (min.)
31	60AEFR	4	15
32	60AEFR	4	15
33	60AEFR	4	15
34	60ACTL	4	15
35	60ACTL	4	15
36	60ACTL	4	15
37	60ACTP	4	15
38	60ACTP	4	15
39	60ACTP	4	15
40	60AGFR	3.5	25
41	60AGFR	3.5	25
42	60AGFR	3.5	25
43	60AHTP	4	25
44	60AHTP	4	25
45	60AHTP	4	25
46	60BEFR	4	15
47	60BEFR	4	15
48	60BEFR	4	15
49	60BCTP	4	15
50	60BCTP	4	15
51	60BCTP	4	15
52	60BGFR	3.5	25
53	60BGFR	3.5	25
54	60BGFR	3.5	25
55	60BDTL	3.5	10
56	60BDTL	3.5	10
57	60BDTL	3.5	10
58	60BHTP	4	25
59	60BHTP	4	25
60	60BHTP	4	25
No	Legend	Amount (kg/m²)	Drying time (min.)

APPENDIX 3 – RELATIVE HUMIDITY

Appendix 3.1 – Relative humidity of concrete before flooring

Legend	No	RH-probe	Read RH (%)	Temp °C	RH (%)	Av./Std/Var (%)
40 AEFR	1	44	81.2	19.4	86.0	86.3
40 AEFR	2	52	81.5	19.5	86.5	0.29
40 AEFR	3	44	81.5	19.4	86.5	0.33
40 ACTL	4	48	82.2	19.4	86.0	86.2
40 ACTL	5	48	82.4	19.3	86.0	0.29
40 ACTL	6	51	81.8	19.3	86.5	0.34
40 ACTP	7	52	81.6	19.4	86.5	86.2
40 ACTP	8	46	81.7	19.3	85.5	0.58
40 ACTP	9	46	82.4	19.2	86.5	0.01
40 AGFR	10	53	82.3	19.3	87.0	86.7
40 AGFR	11	46	82.5	19.2	86.5	0.29
40 AGFR	12	53	81.9	19.4	86.5	0.00
40 AHTP	13	52	81.4	19.4	86.5	86.5
40 AHTP	14	51	82.5	19.2	87.5	1.00
40 AHTP	15	44	81.0	19.3	85.5	0.01
40 BEFR	16	51	81.1	19.2	86.0	86.7
40 BEFR	17	50	83.4	19.1	87.0	0.58
40 BEFR	18	47	84.8	19.4	87.0	0.01
40 BCTP	19	47	84.3	19.4	86.5	86.8
40 BCTP	20	48	82.9	19.3	86.5	0.58
40 BCTP	21	49	83.6	19.3	87.5	0.01
40 BGFR	22	53	81.6	19.3	86.0	85.7
40 BGFR	23	53	81.1	19.4	86.0	0.58
40 BGFR	24	50	81.5	19.2	85.0	0.01
40 BDTL	25	51	82.5	19.2	87.5	86.8
40 BDTL	26	49	82.1	19.2	86.0	0.76
40 BDTL	27	50	83.4	19.2	87.0	0.01
40 BHTP	28	49	82.9	19.3	86.5	86.2
40 BHTP	29	47	83.1	19.4	85.5	0.58
40 BHTP	30	44	81.6	19.3	86.5	0.67
Total average for no 1-30						86.4
Total standard deviation for no 1-30						0.61
Total variation coefficient for no 1-30						0.70
60AEFR	31	27	81.7	20.2	93	
60AEFR	32	19	82.2	20.2	92.5	
60AEFR	33	37	89.7	20.2	92.5	
Total average for no 31-33						92.7
Total standard deviation for no 31-33						0.29
Total variation coefficient for no 31-33						0.31

Appendix 3.2 – Relative humidity of concrete after VOC (w/c = 0.40)

						Average		Average
						Std. Dev.		Std. Dev.
Legend	No	RH-probe	Read RH%	Temp °C	Calibr. RH%	Var. (%)	By hand	Var. (%)
40 AEFR	1	1	74.8	19.5	81.1	81.9	82.5	82.2
40 AEFR	2	23	73.1	19.7	82.3	0.72	82	0.29
40 AEFR	3	23	73.2	19.7	82.4	0.88	82	0.35
40 ACTL	4	14	70.8	19.7	81	81.6	81	81.3
40 ACTL	5	22	72.2	19.6	81.9	0.52	81.5	0.29
40 ACTL	6	18	73.2	19.7	81.9	0.64	81.5	0.35
40 ACTP	7	31	77.2	19.9	84.5	83.3	83.5	83.3
40 ACTP	8	30	72.8	19.8	81.4	1.64	82	1.26
40 ACTP	9	30	75	19.5	83.9	1.97	84.5	1.51
40 AGFR	10	5	76	19.9	82.4	82.2	82	81.8
40 AGFR	11	31	75.7	19.8	82.5	0.49	82	0.29
40 AGFR	12	33	75.5	19.7	81.6	0.60	81.5	0.35
40 AHTP	13	41	69.5	19.9	81.2	81.7	81.5	81.5
40 AHTP	14	18	74.6	19.7	83.5	1.57	82.5	1.00
40 AHTP	15	22	71.5	20	80.5	1.92	80.5	1.23
40 BEFR	16	42	75.8	19.5	83.5	82.9	82.5	82.8
40 BEFR	17	42	75.5	20	83.2	0.85	82.5	0.58
40 BEFR	18	1	75.6	19.8	81.9	1.03	83.5	0.70
40 BCTP	19	41	72.4	19.6	84.5	84.5	84.5	84.2
40 BCTP	20	31	77	19.9	83.9	0.60	83.5	0.58
40 BCTP	21	18	76	19.8	85.1	0.71	84.5	0.69
40 BGFR	22	23	74	19.7	83.3	82.6	83	82.3
40 BGFR	23	39	78.1	19.6	82.6	0.65	82.5	0.76
40 BGFR	24	39	77.5	19.9	82	0.79	81.5	0.93
40 BDTL	25	14	72.4	19.8	82.9	82.3	82.5	82.0
40 BDTL	26	14	71.6	19.7	81.9	0.51	81.5	0.50
40 BDTL	27	33	76.1	19.7	82.2	0.62	82	0.61
40 BHTP	28	39	79.3	19.6	83.9	83.5	83.5	83.5
40 BHTP	29	5	76.8	19.5	83.2	0.38	83.5	0.00
40 BHTP	30	33	77.1	19.8	83.3	0.45	83.5	0.00
Total average for no 1-30					82.7		82.5	
Total standard deviation for no 1-30					1.15		1.05	
Total variation coefficient for no 1-30					1.39		1.27	

Appendix 3.3– Relative humidity of concrete after VOC (w/c = 0.60)

						Average
						Std. Dev.
Legend	No	RH-probe	Read RH%	Temp °C	Calibr. RH%	Var. (%)
60AEFR	31	22	80.2	19.9	91.0	90.9
60AEFR	32	5	83.9	19.8	90.8	0.12
60AEFR	33	14	79.5	19.8	91.0	0.13
60ACTL	34	41	76.5	19.8	89.2	89.5
60ACTL	35	33	82.4	19.7	89.1	0.55
60ACTL	36	14	78.7	19.9	90.1	0.62
60ACTP	37	17	80.5	20.0	91.1	91.3
60ACTP	38	31	84.3	19.9	92.0	0.67
60ACTP	39	18	81.0	19.8	90.7	0.73
60AGFR	40	42	82.1	19.8	90.4	90.4
60AGFR	41	43	81.7	19.8	91.5	1.05
60AGFR	42	1	82.6	19.6	89.4	1.16
60AHTP	43	39	85.2	19.7	90.2	90.5
60AHTP	44	1	82.8	19.7	89.6	1.08
60AHTP	45	18	81.8	19.8	91.7	1.20
60BEFR	46	33	84.9	19.8	91.8	92.1
60BEFR	47	23	81.9	19.8	92.2	0.31
60BEFR	48	42	84.0	19.8	92.4	0.33
60BCTP	49	31	84.5	19.9	92.3	92.3
60BCTP	50	41	79.5	19.7	92.6	0.30
60BCTP	51	5	85.0	19.7	92.0	0.33
60BGFR	52	23	80.8	19.8	92.2	92.0
60BGFR	53	22	81.0	19.9	91.9	0.17
60BGFR	54	30	82.2	19.7	91.9	0.19
60BDTL	55	23	79.5	19.8	89.5	89.3
60BDTL	56	39	84.5	19.8	89.5	0.35
60BDTL	57	43	79.4	19.8	88.9	0.39
60BHTP	58	43	82.2	19.8	92.0	92.6
60BHTP	59	30	83.4	19.8	93.3	0.67
60BHTP	60	17	81.6	20.1	92.4	0.72
Total average for no 31-60					91.1	
Total standard deviation for no 31-60					1,24	
Total variation coefficient for no 31-60					1,36	

APPENDIX 4 - PEEL FORCE

Appendix 4.1 – Peel force of specimen with w/c = 0.40 (N/mm)

		Test							
Legend	No	A	B	C	D	E	Average	Stddev	Var. (%)
40 AEFR	1	2.77	2.69	2.57			2.68	0.10	3.76
40 AEFR	2	2.21	1.93	2.34			2.16	0.21	9.70
40 AEFR	3	1.63	1.56	1.45			1.55	0.09	5.87
40 ACTL	4	1.28	1.72	1.60			1.53	0.23	14.83
40 ACTL	5	2.14	2.50	2.77			2.47	0.32	12.80
40 ACTL	6	2.39	2.08	1.78			2.08	0.31	14.64
40 ACTP	7	3.90	3.88	3.52			3.77	0.21	5.68
40 ACTP	8	5.28	4.97	4.44			4.90	0.42	8.67
40 ACTP	9	3.09	3.23	3.62			3.31	0.27	8.29
40 AGFR	10	0.97	1.04	0.90			0.97	0.07	7.22
40 AGFR	11	0.89	0.90	0.96			0.92	0.04	4.13
40 AGFR	12	0.67	0.61	0.76			0.68	0.08	11.10
40 AHTP	13	0.60	0.97	0.90			0.82	0.20	23.87
40 AHTP	14	0.86	0.91	0.69			0.82	0.12	14.06
40 AHTP	15	0.86	0.76	0.89			0.84	0.07	8.14
40 BEFR	16	3.07	2.70	2.97			2.91	0.19	6.57
40 BEFR	17	3.05	3.52	3.30			3.29	0.24	7.15
40 BEFR	18	3.56	3.70	3.32			3.53	0.19	5.45
40 BCTP	19	2.36	2.72	2.97			2.68	0.31	11.43
40 BCTP	20	3.50	3.56	3.39			3.48	0.09	2.48
40 BCTP	21	2.59	2.80	2.25			2.55	0.28	10.90
40 BGFR	22	2.09	2.19	2.19			2.16	0.06	2.68
40 BGFR	23	2.35	2.08	2.38			2.27	0.17	7.28
40 BGFR	24	2.24	2.14	1.84			2.07	0.21	10.04
40 BDTL	25	1.68	1.59	1.55			1.61	0.07	4.14
40 BDTL	26	1.46	1.37	1.41			1.41	0.05	3.19
40 BDTL	27	1.79	1.59	1.86			1.75	0.14	8.02
40 BHTP	28	2.26	2.08	2.42			2.25	0.17	7.55
40 BHTP	29	2.29	2.51	2.40			2.40	0.11	4.58
40 BHTP	30	2.41	2.55	2.46			2.47	0.07	2.87
Average								0.17	8.24

Appendix 4.2 – Peel force of specimen with w/c = 0.60 (N/mm)

		Test							
Legend	No	A	B	C	D	E	Average	Stddev	Var. (%)
60AEFR	31	0.48	0.52	0.60	0.52	0.60	0.54	0.05	9.87
60AEFR	32	1.08	0.87	0.89			0.95	0.12	12.24
60AEFR	33	0.60	0.52	0.56			0.56	0.04	7.14
60ACTL	34	2.50	1.83	1.69	1.78	2.36	2.03	0.37	18.21
60ACTL	35	2.39	2.00	1.90			2.10	0.26	12.35
60ACTL	36	2.46	2.48	2.48	2.33		2.44	0.07	2.97
60ACTP	37	2.98	1.90	2.45	2.86	2.50	2.54	0.42	16.66
60ACTP	38	2.21	2.16	2.24	1.76	2.23	2.12	0.20	9.60
60ACTP	39	2.98	2.24	2.11	1.81	2.48	2.32	0.44	18.90
60AGFR	40	0.29	0.37	0.40			0.35	0.06	16.09
60AGFR	41	0.31	0.60	0.57			0.49	0.16	32.33
60AGFR	42	0.53	0.36	0.45			0.45	0.09	19.04
60AHTP	43	0.40	0.49	0.47			0.45	0.05	10.42
60AHTP	44	0.42	0.40				0.41	0.01	3.45
60AHTP	45	0.39	0.38				0.39	0.01	1.84
60BEFR	46	3.14	3.41				3.28	0.19	5.83
60BEFR	47	2.16	2.13	2.35			2.21	0.12	5.39
60BEFR	48	2.24	2.52				2.38	0.20	8.32
60BCTP	49	2.67	2.06				2.37	0.43	18.24
60BCTP	50	3.08	2.54				2.81	0.38	13.59
60BCTP	51	2.88	2.68				2.78	0.14	5.09
60BGFR	52	2.10	1.63	1.73			1.82	0.25	13.60
60BGFR	53	1.19	1.02				1.11	0.12	10.88
60BGFR	54	0.87	1.59	1.25			1.24	0.36	29.13
60BDTL	55	1.64	1.41				1.53	0.16	10.66
60BDTL	56	1.02	1.33				1.18	0.22	18.66
60BDTL	57	1.77	2.03	1.60			1.80	0.22	12.03
60BHTP	58	2.56	2.43				2.50	0.09	3.68
60BHTP	59	2.55	2.54				2.55	0.01	0.28
60BHTP	60	2.41	2.17				2.29	0.17	7.41
Average								0.18	11.80

APPENDIX 5 - FRACTURE VIEW AT PEEL TEST

Appendix 5.1 – Fracture view at peel test of specimen no 1

Appendix 5.2 – Fracture view at peel test of specimen no 2

Appendix 5.3 – Fracture view at peel test of specimen no 3

Appendix 5.4 – Fracture view at peel test of specimen no 4

Appendix 5.5 – Fracture view at peel test of specimen no 5

Appendix 5.6 – Fracture view at peel test of specimen no 6

Appendix 5.7 – Fracture view at peel test of specimen no 7

Appendix 5.8 – Fracture view at peel test of specimen no 8

Appendix 5.9 – Fracture view at peel test of specimen no 9

Appendix 5.10 – Fracture view at peel test of specimen no 10

Appendix 5.11 – Fracture view at peel test of specimen no 11

Appendix 5.12 – Fracture view at peel test of specimen no 12

Appendix 5.13 – Fracture view at peel test of specimen no 13

Appendix 5.14 – Fracture view at peel test of specimen no 14

Appendix 5.15 – Fracture view at peel test of specimen no 15

Appendix 5.16 – Fracture view at peel test of specimen no 16

Appendix 5.17 – Fracture view at peel test of specimen no 17

Appendix 5.18 – Fracture view at peel test of specimen no 18

Appendix 5.19 – Fracture view at peel test of specimen no 19

Appendix 5.20 – Fracture view at peel test of specimen no 20

Appendix 5.21 – Fracture view at peel test of specimen no 21

Appendix 5.22 – Fracture view at peel test of specimen no 22

Appendix 5.23 – Fracture view at peel test of specimen no 23

Appendix 5.24 – Fracture view at peel test of specimen no 24

Appendix 5.25 – Fracture view at peel test of specimen no 25

Appendix 5.26 – Fracture view at peel test of specimen no 26

Appendix 5.27 – Fracture view at peel test of specimen no 27

Appendix 5.28 – Fracture view at peel test of specimen no 28

Appendix 5.29 – Fracture view at peel test of specimen no 29

Appendix 5.30 – Fracture view at peel test of specimen no 30

Appendix 5.31 – Fracture view at peel test of specimen no 31

Appendix 5.32 – Fracture view at peel test of specimen no 32

Appendix 5.33 – Fracture view at peel test of specimen no 33

Appendix 5.34 – Fracture view at peel test of specimen no 34

Appendix 5.35 – Fracture view at peel test of specimen no 35

Appendix 5.36 – Fracture view at peel test of specimen no 36

Appendix 5.37 – Fracture view at peel test of specimen no 37

Appendix 5.38 – Fracture view at peel test of specimen no 38

Appendix 5.39 – Fracture view at peel test of specimen no 39

Appendix 5.40 – Fracture view at peel test of specimen no 40

Appendix 5.41 – Fracture view at peel test of specimen no 41

Appendix 5.42 – Fracture view at peel test of specimen no 42

Appendix 5.43 – Fracture view at peel test of specimen no 43

Appendix 5.44 – Fracture view at peel test of specimen no 44

Appendix 5.45 – Fracture view at peel test of specimen no 45

Appendix 5.46 – Fracture view at peel test of specimen no 46

Appendix 5.47 – Fracture view at peel test of specimen no 47

Appendix 5.48 – Fracture view at peel test of specimen no 48

Appendix 5.49 – Fracture view at peel test of specimen no 49

Appendix 5.50 – Fracture view at peel test of specimen no 50

Appendix 5.51 – Fracture view at peel test of specimen no 51

Appendix 5.52 – Fracture view at peel test of specimen no 52

Appendix 5.53 – Fracture view at peel test of specimen no 53

Appendix 5.54 – Fracture view at peel test of specimen no 54

Appendix 5.55 – Fracture view at peel test of specimen no 55

Appendix 5.56 – Fracture view at peel test of specimen no 56

Appendix 5.57 – Fracture view at peel test of specimen no 57

Appendix 5.58 – Fracture view at peel test of specimen no 58

Appendix 5.59 – Fracture view at peel test of specimen no 59

Appendix 5.60 – Fracture view at peel test of specimen no 60

Appendix 5.61 – Fracture view at peel test of specimen no 40BEFR2h

Appendix 5.62 – Fracture view at peel test of specimen no 40BEFR4h

Appendix 5.63 – Fracture view at peel test of specimen no 40BEFR9

Appendix 5.64 – Fracture view at peel test of specimen no 40BEFR10

Appendix 5.65 – Fracture view at peel test of specimen no 60BEFR5h

Appendix 5.66 – Fracture view at peel test of specimen no 60BEFR6h

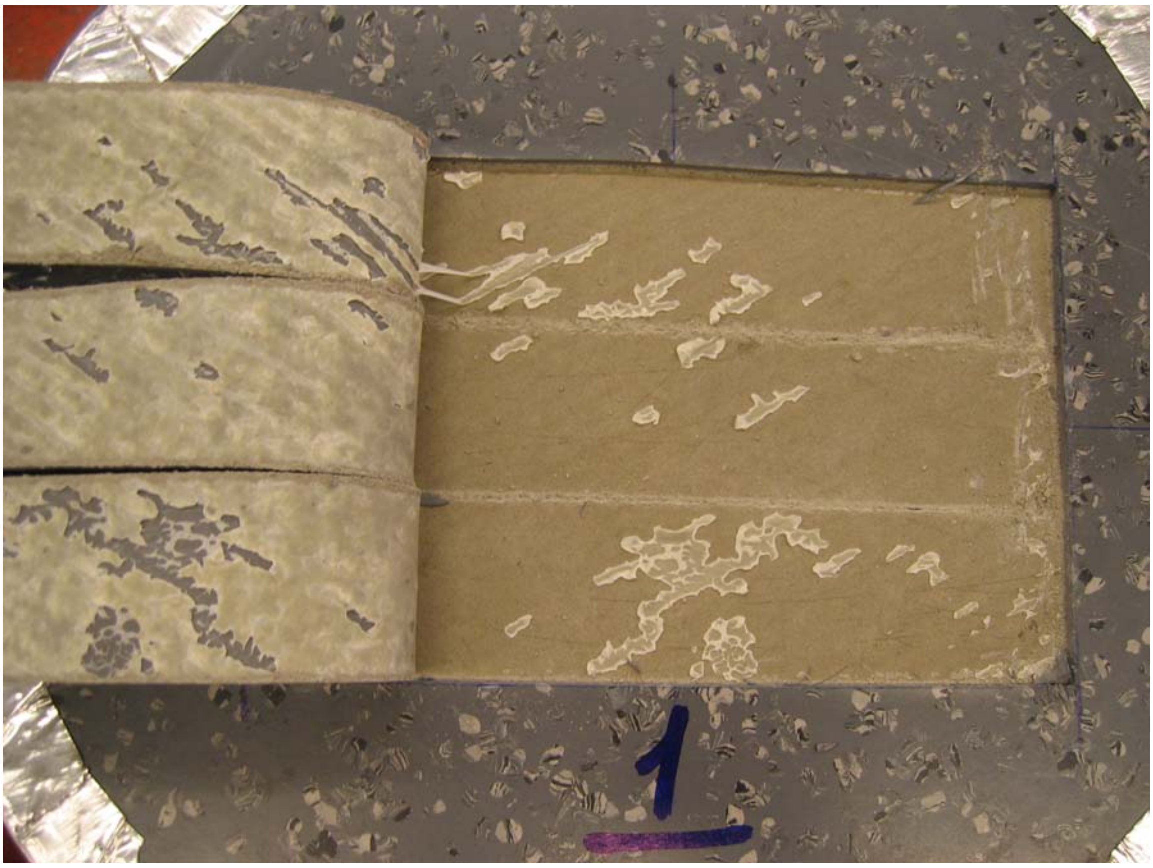
Appendix 5.67 – Fracture view at peel test of specimen no 60BEFR11

Appendix 5.68 – Fracture view at peel test of specimen no 60BEFR12

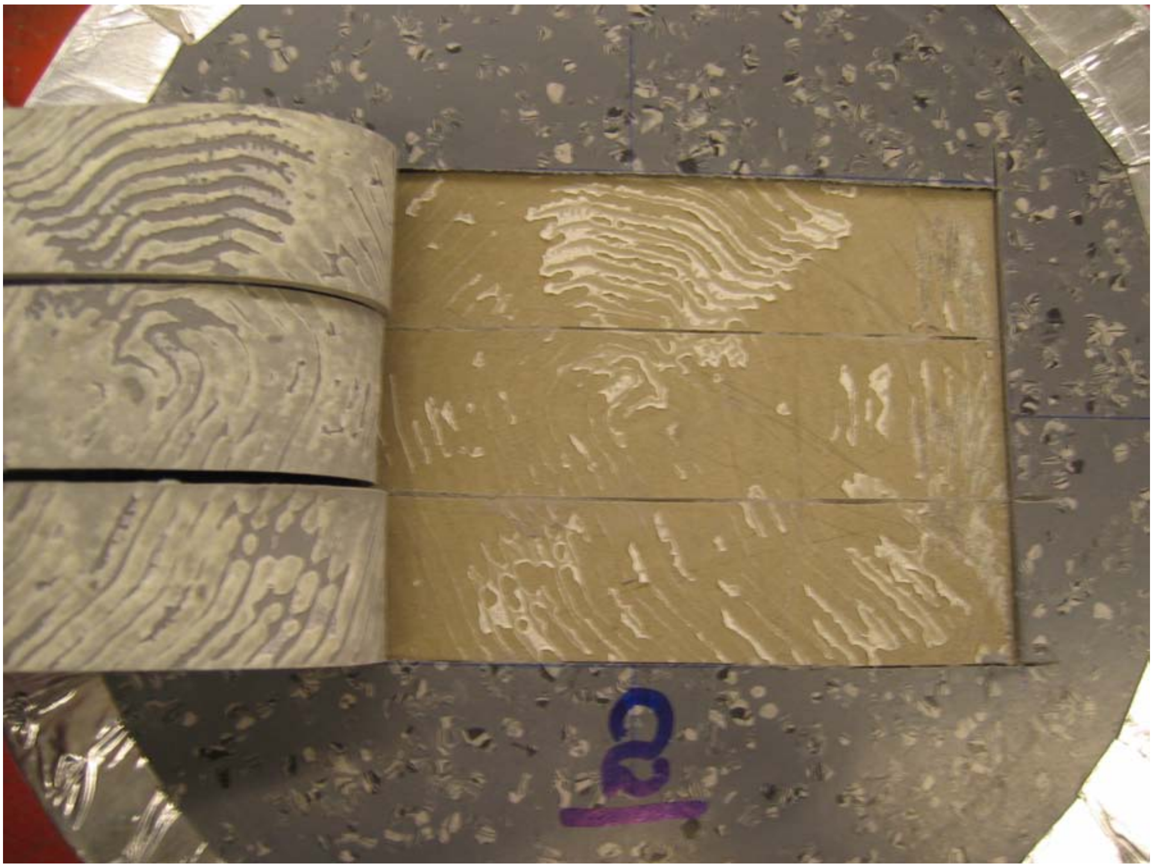
Appendix 5.69 – Fracture partition at peel test of specimens with w/c=0.40 (%)

Appendix 5.70 – Fracture partition at peel test of specimens with w/c=0.60 (%)

Appendix 5.1 – Fracture view at peel test of specimen no 1

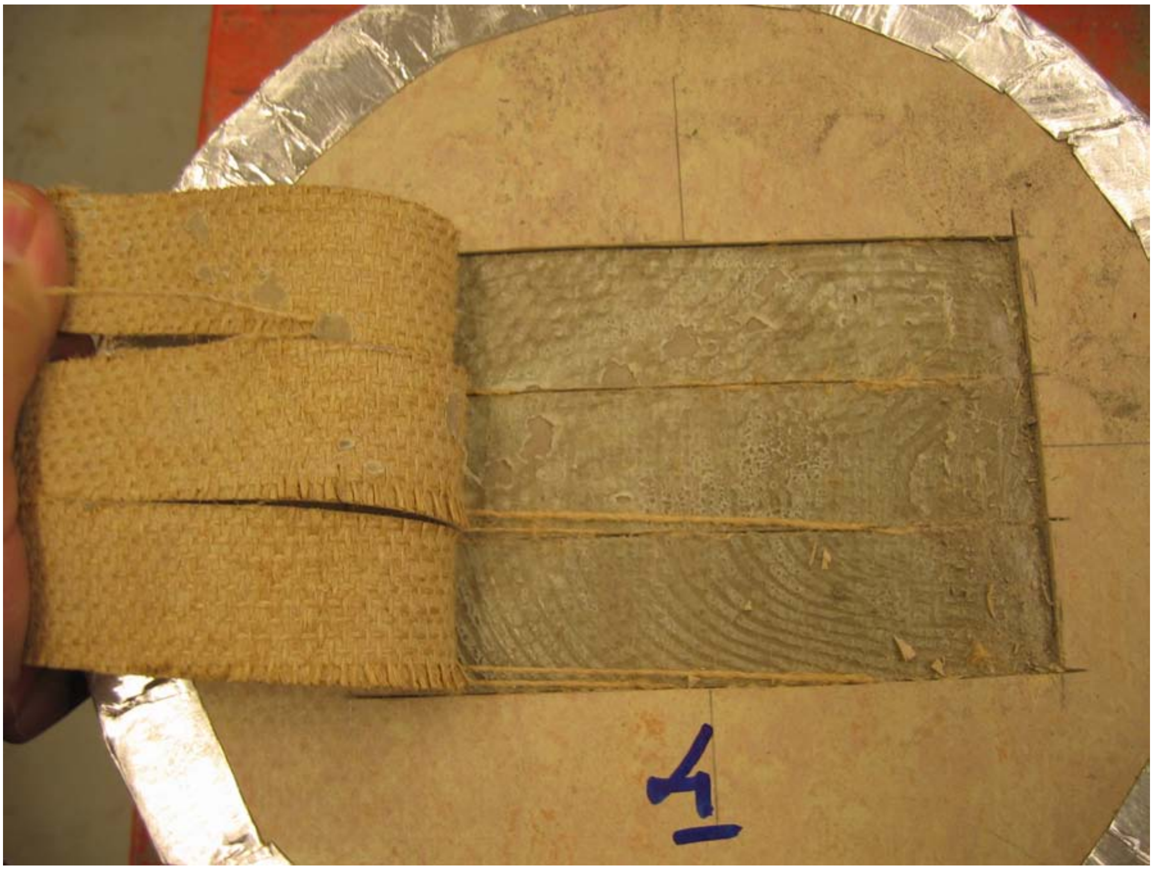


Appendix 5.2 – Fracture view at peel test of specimen no 2

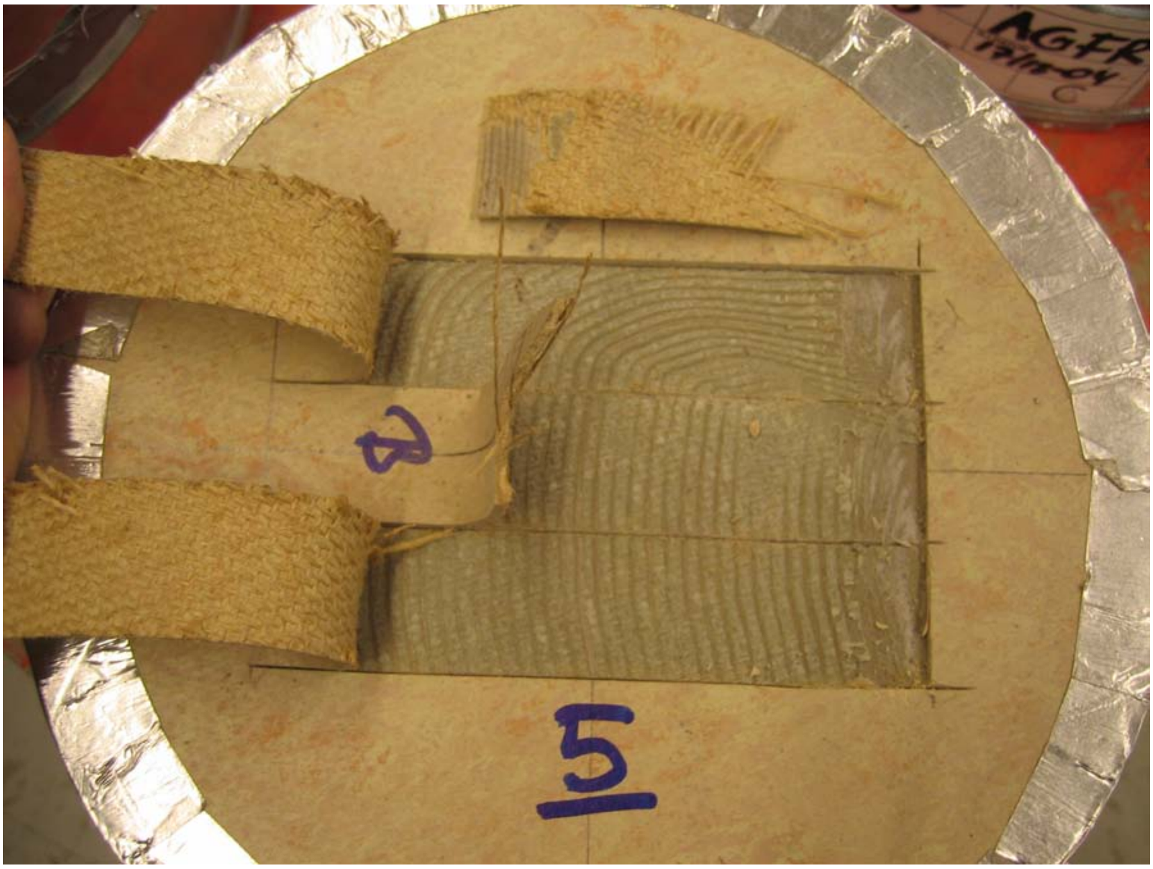


Appendix 5.3 – Fracture view at peel test of specimen no 3

Appendix 5.4 – Fracture view at peel test of specimen no 4

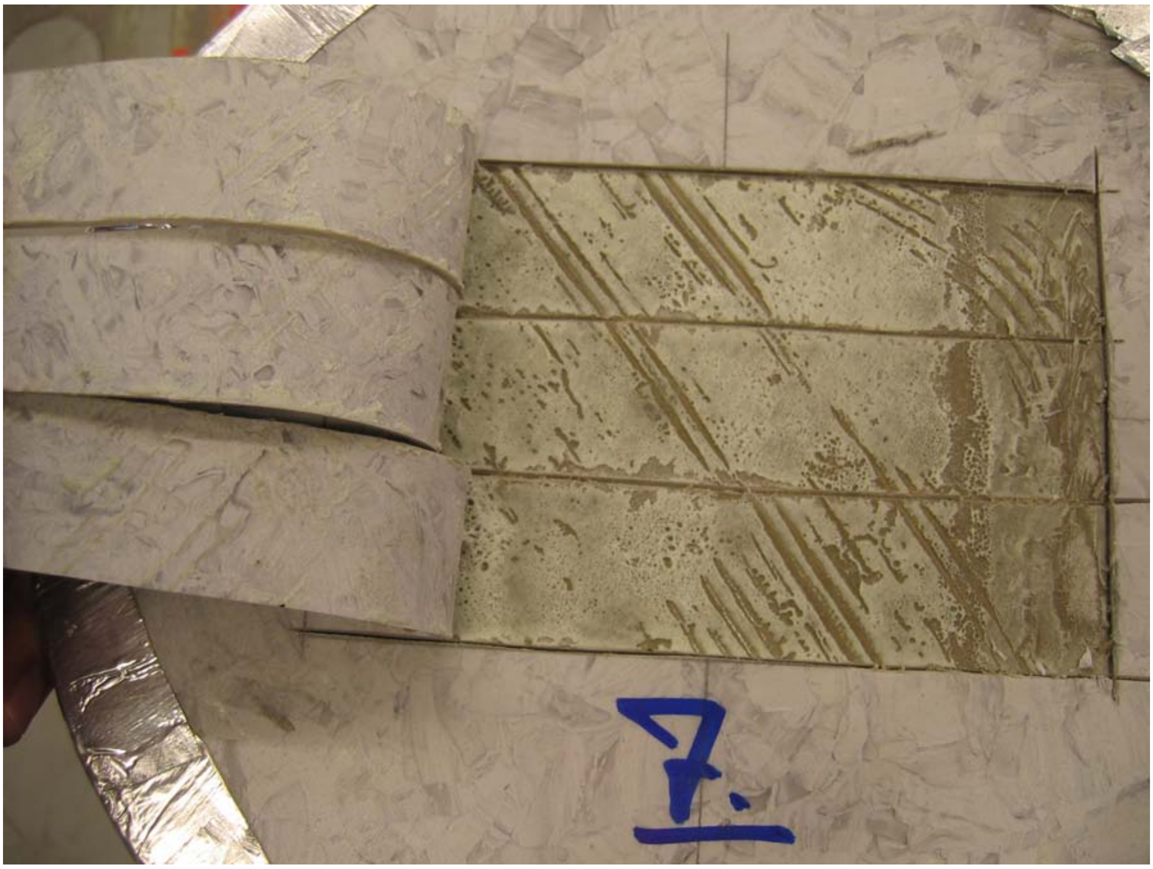


Appendix 5.5 – Fracture view at peel test of specimen no 5

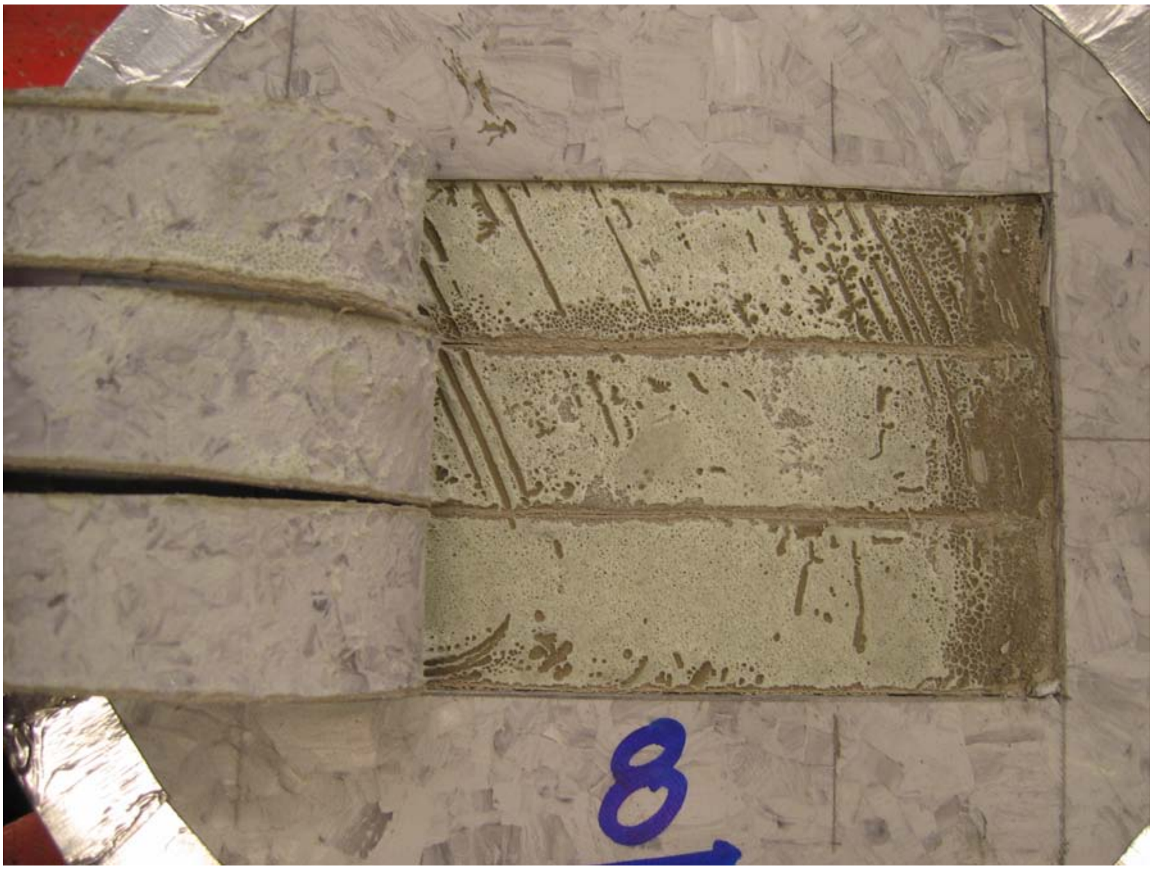


Appendix 5.6 – Fracture view at peel test of specimen no 6

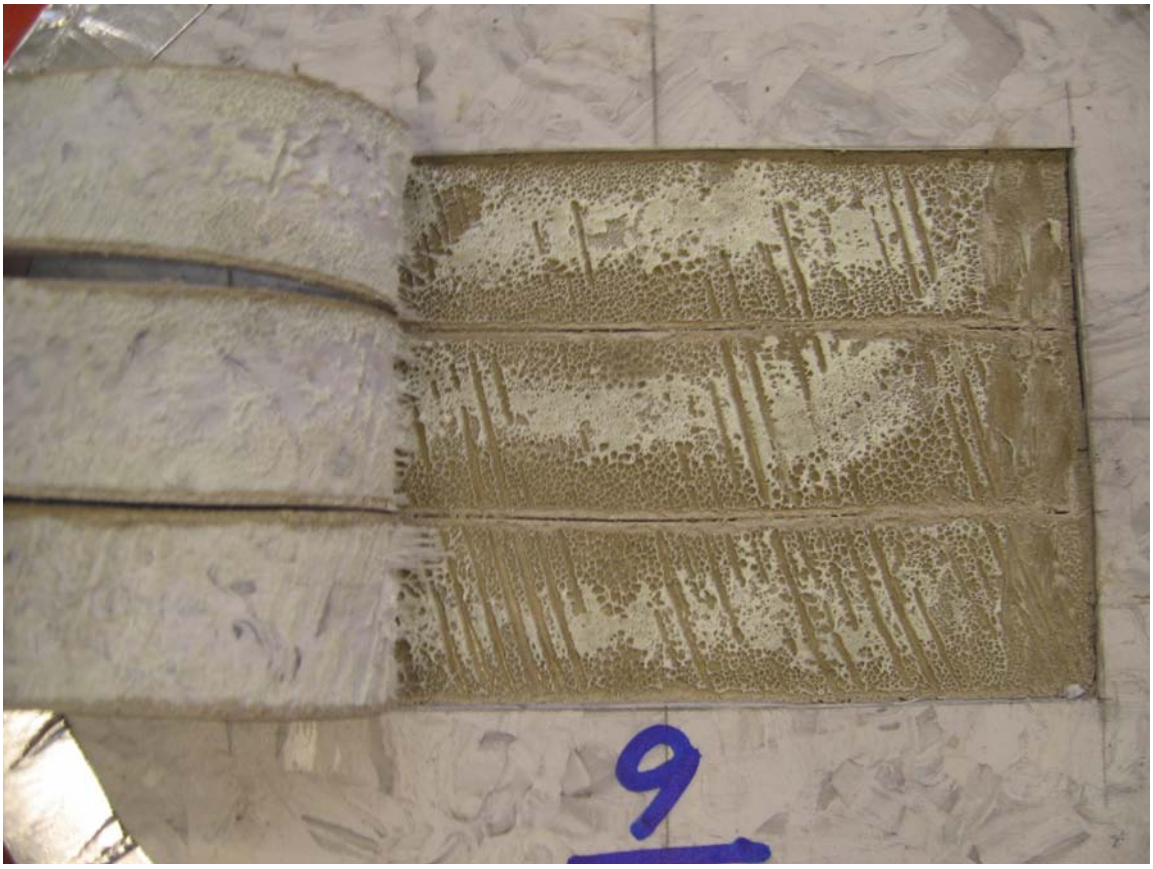
Appendix 5.7 – Fracture view at peel test of specimen no 7



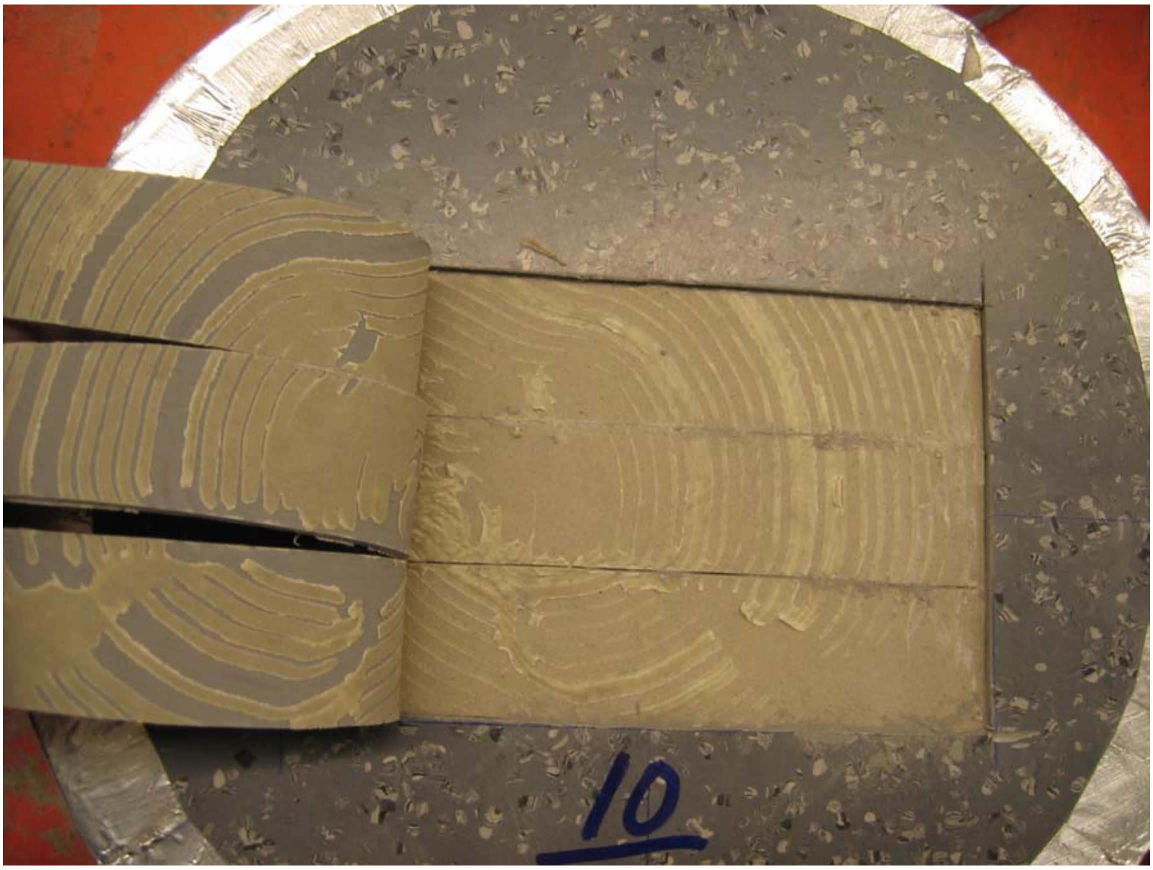
Appendix 5.8 – Fracture view at peel test of specimen no 8



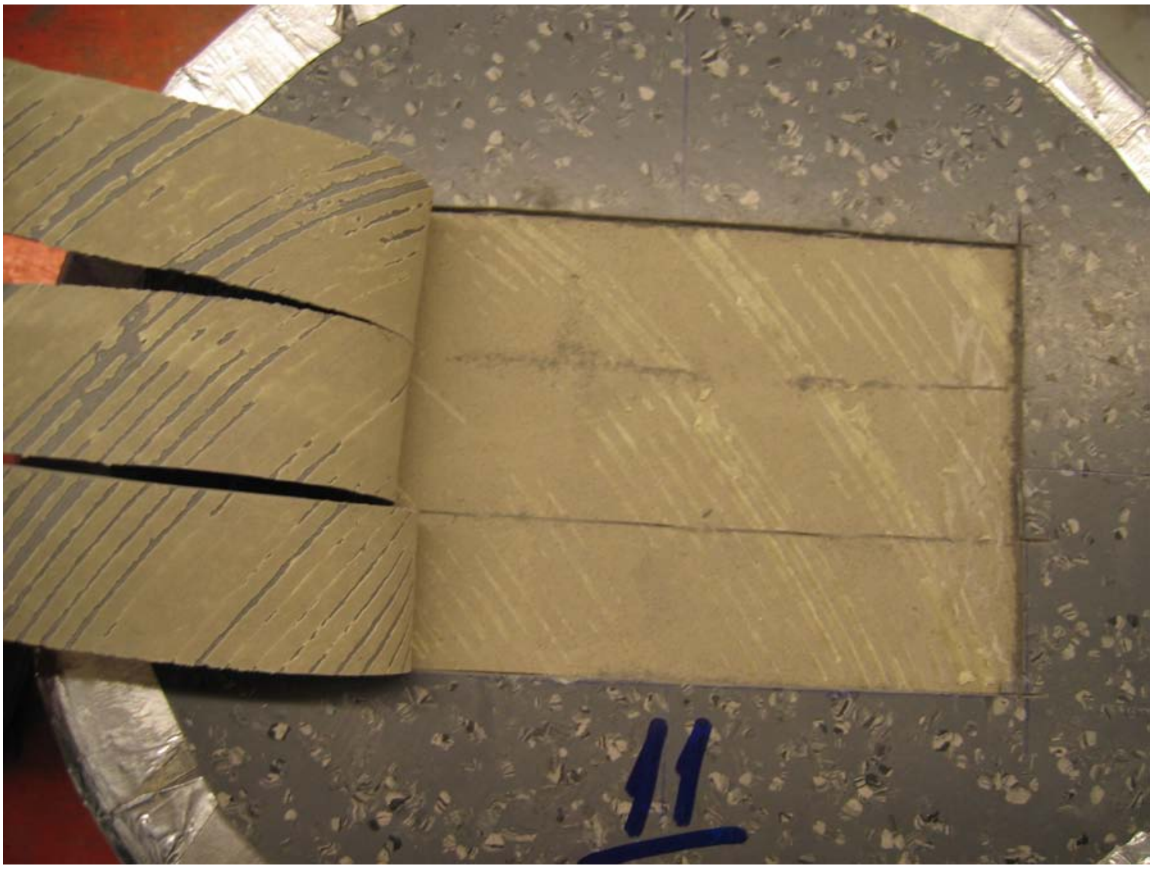
Appendix 5.9 – Fracture view at peel test of specimen no 9



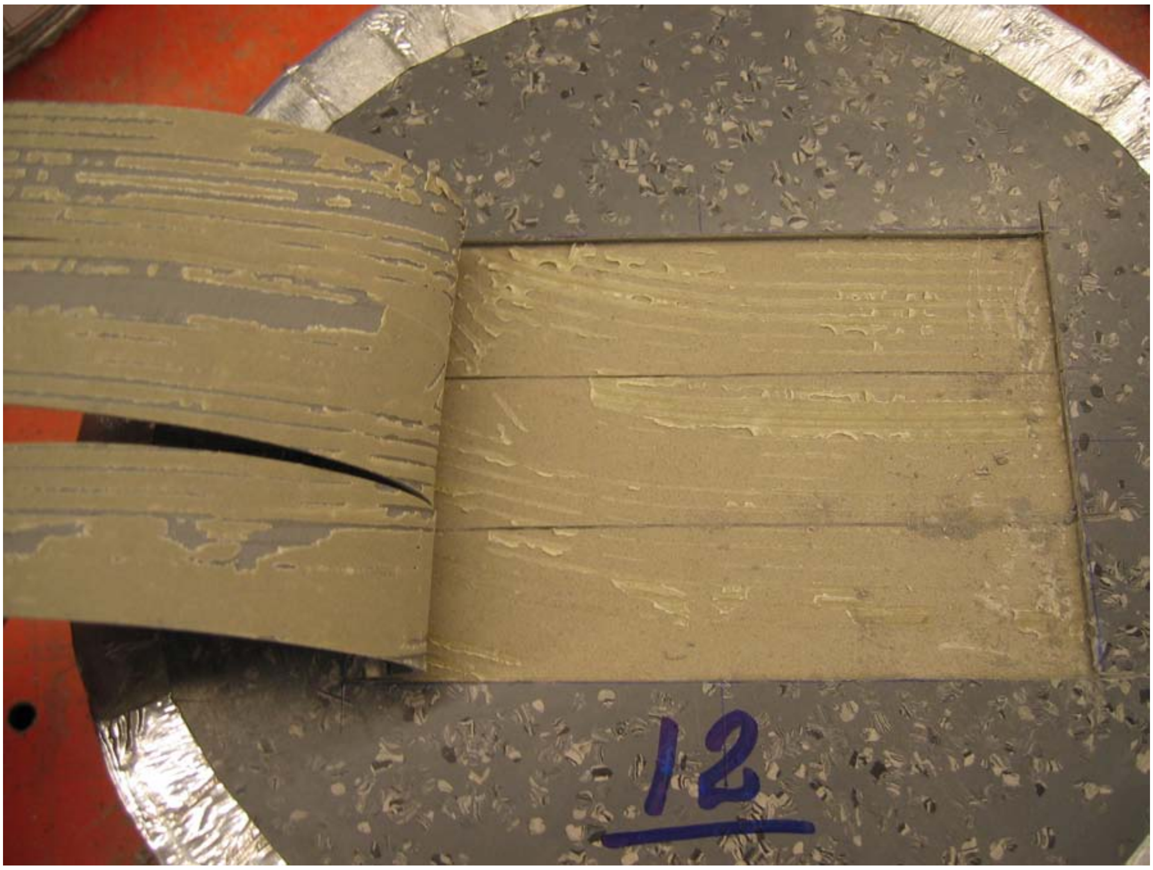
Appendix 5.10 – Fracture view at peel test of specimen no 10



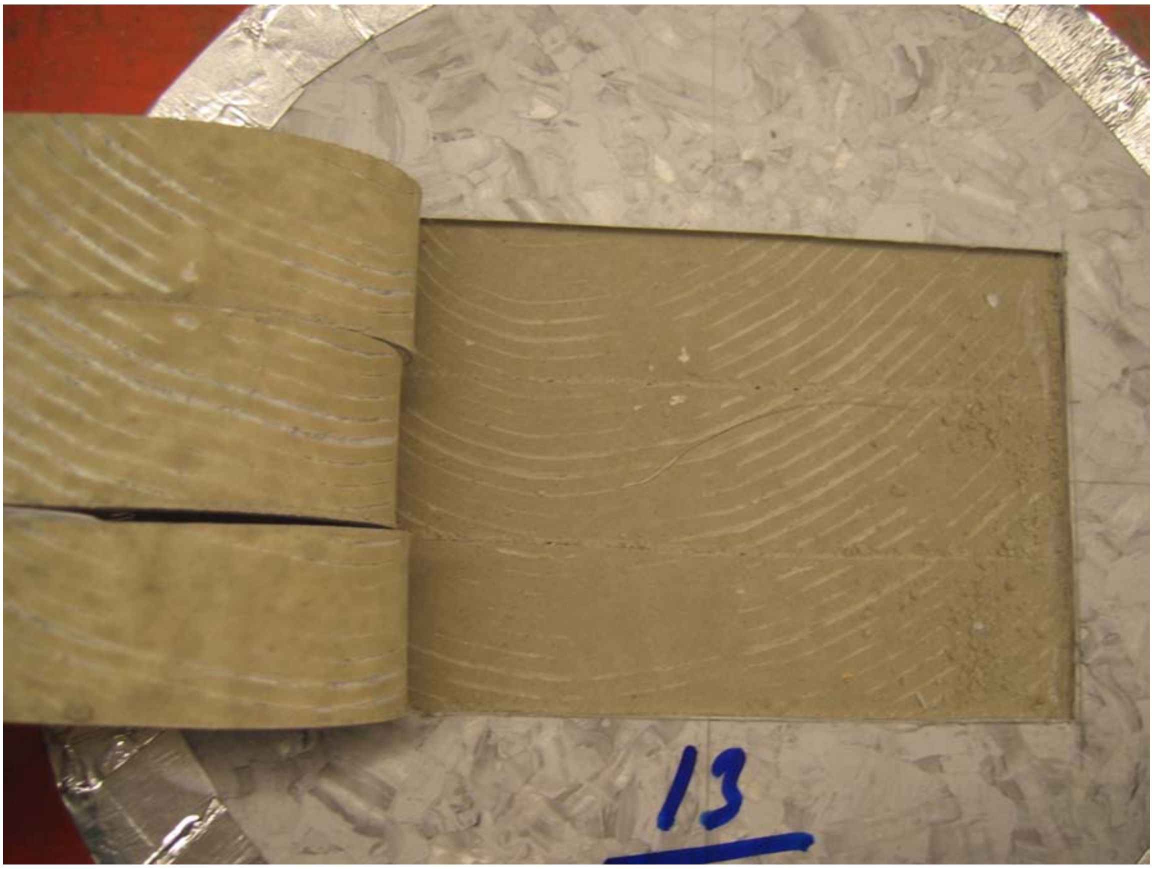
Appendix 5.11 – Fracture view at peel test of specimen no 11



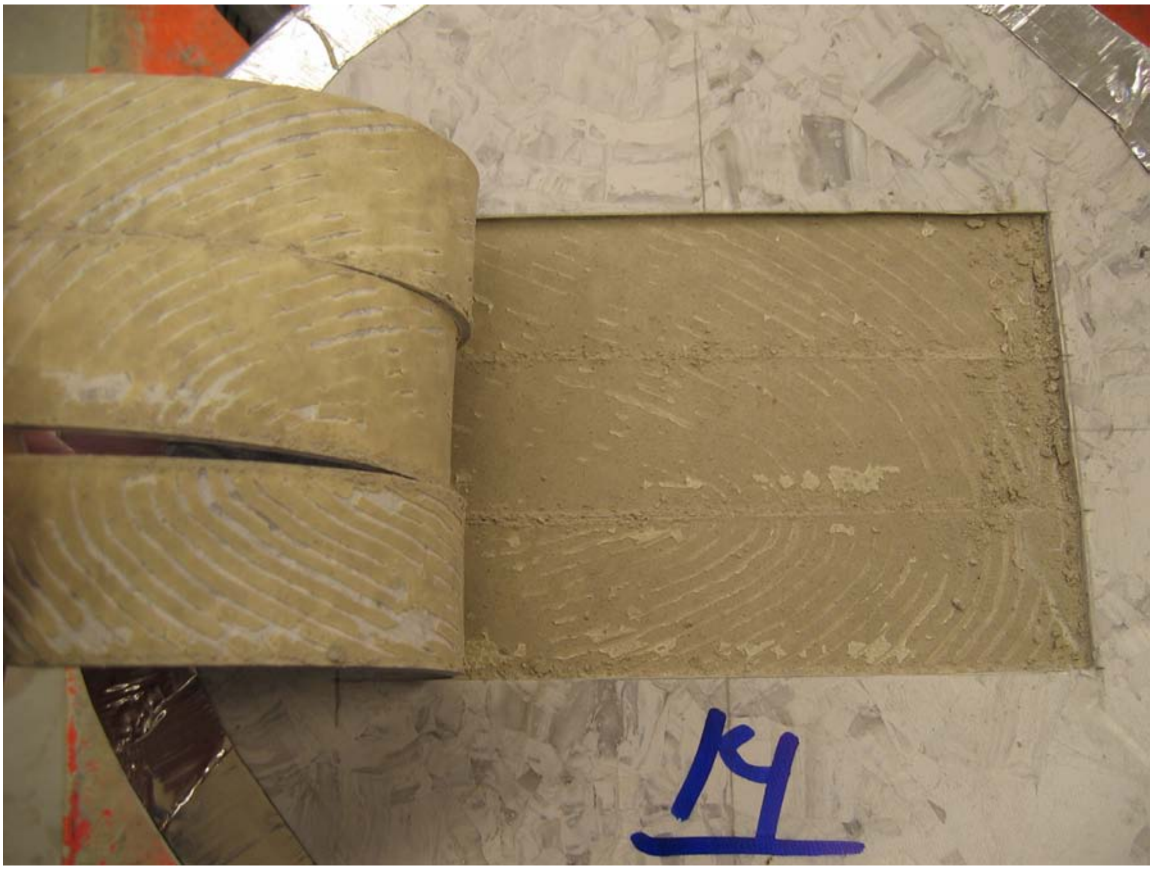
Appendix 5.12 – Fracture view at peel test of specimen no 12



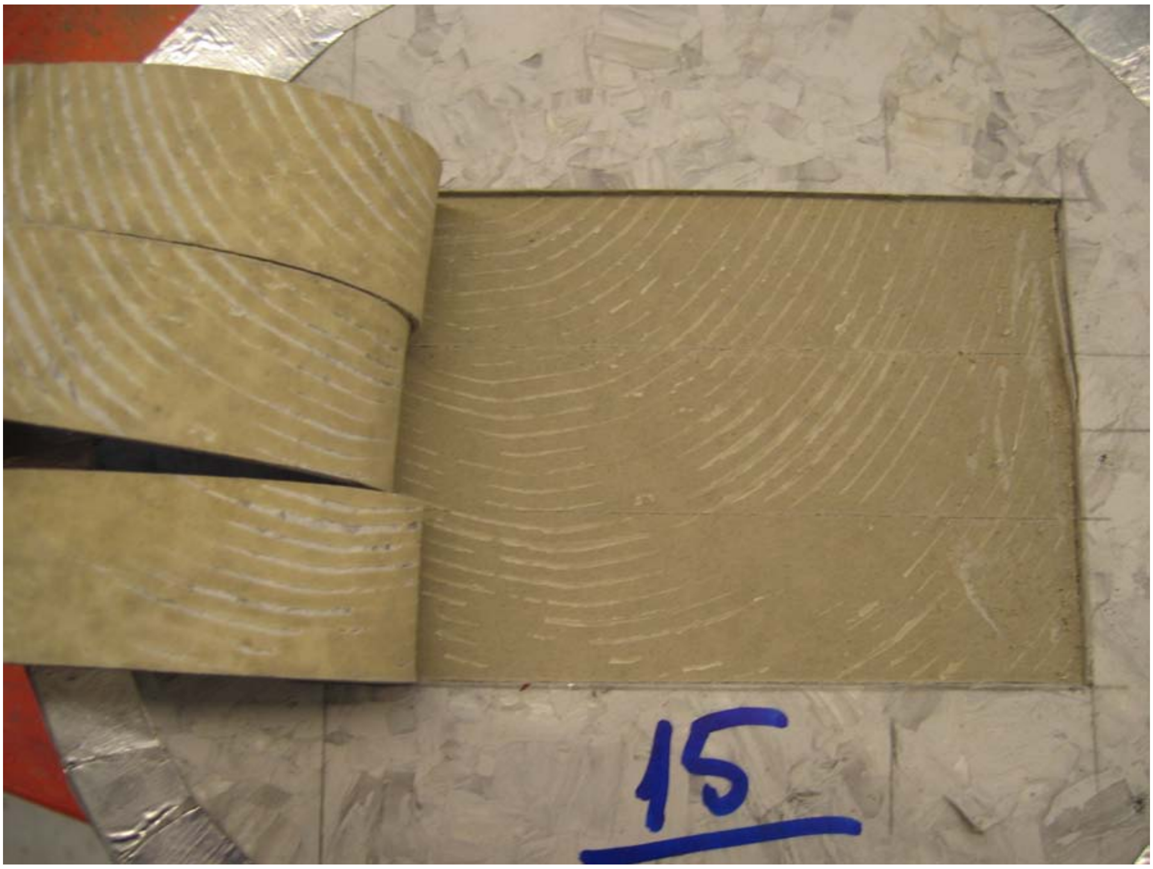
Appendix 5.13 – Fracture view at peel test of specimen no 13



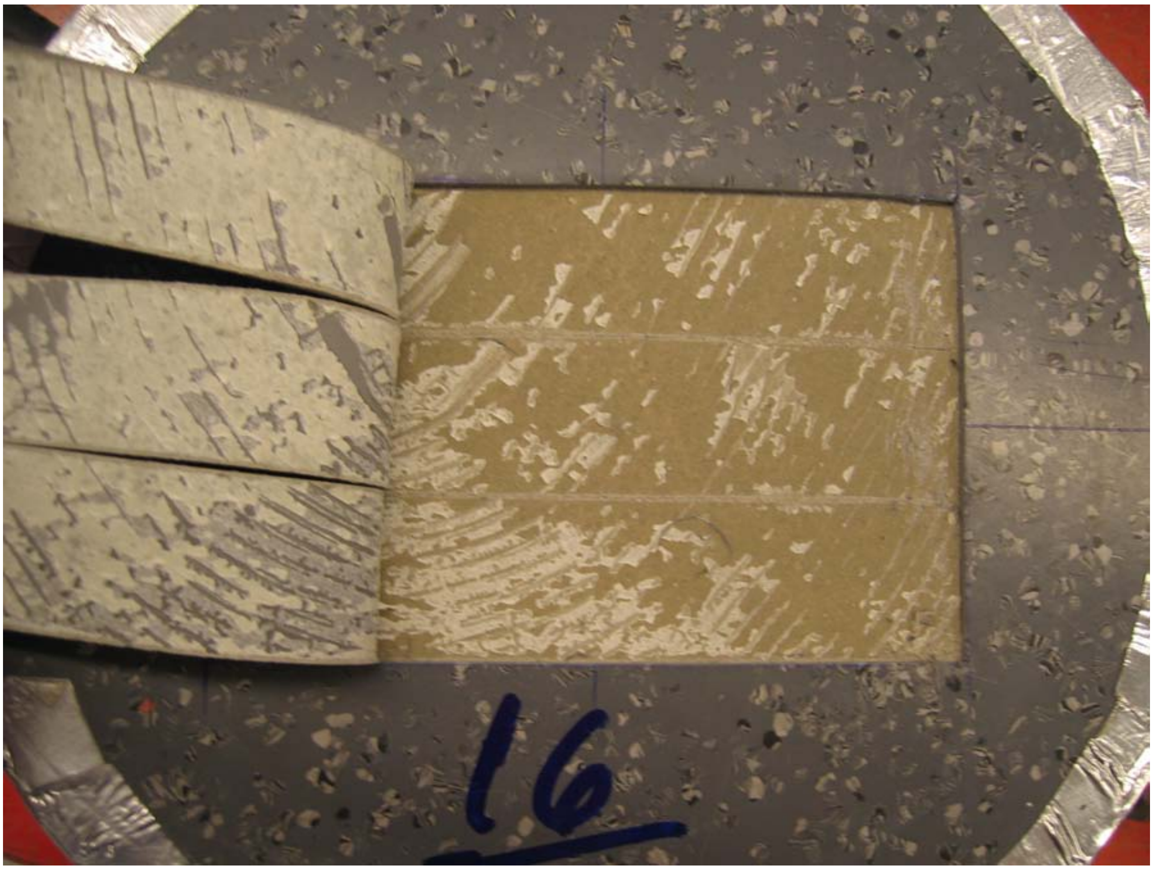
Appendix 5.14 – Fracture view at peel test of specimen no 14



Appendix 5.15 – Fracture view at peel test of specimen no 15



Appendix 5.16 – Fracture view at peel test of specimen no 16



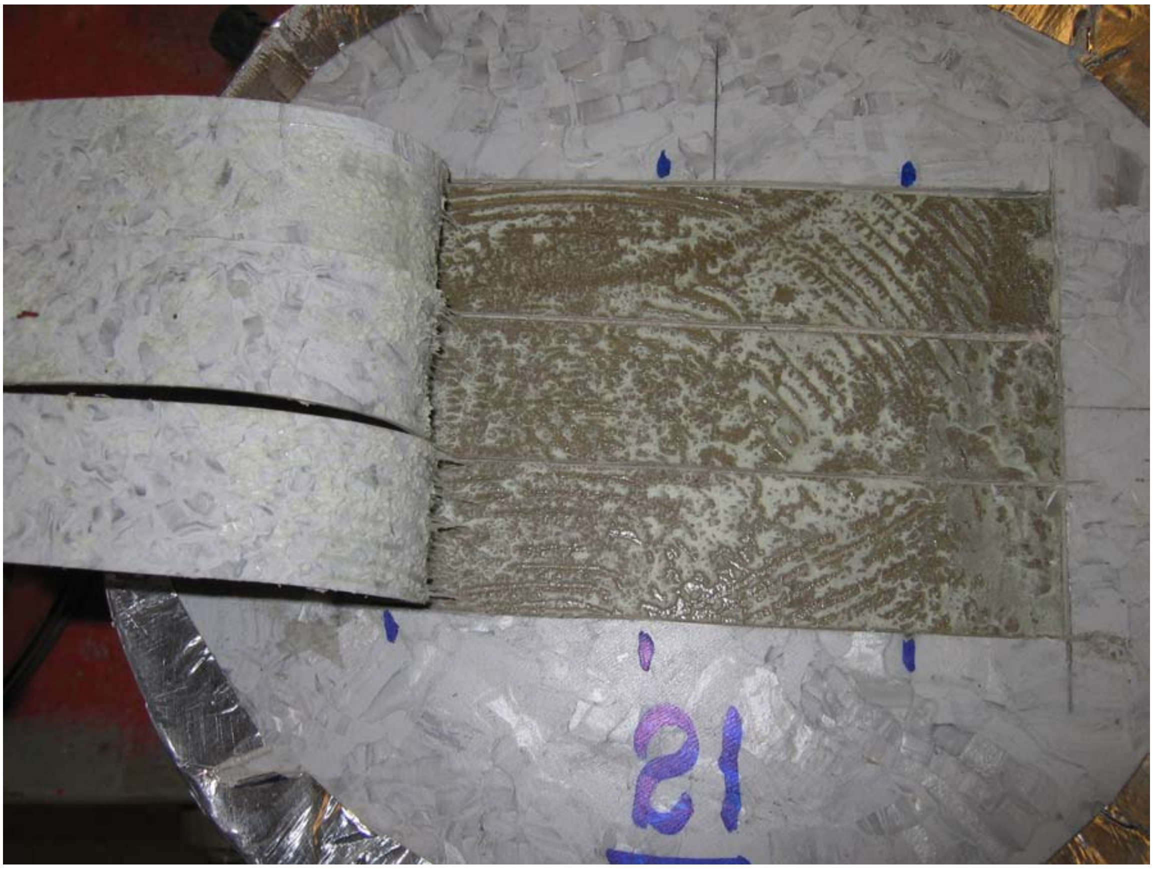
Appendix 5.17 – Fracture view at peel test of specimen no 17

Appendix 5.18 – Fracture view at peel test of specimen no 18

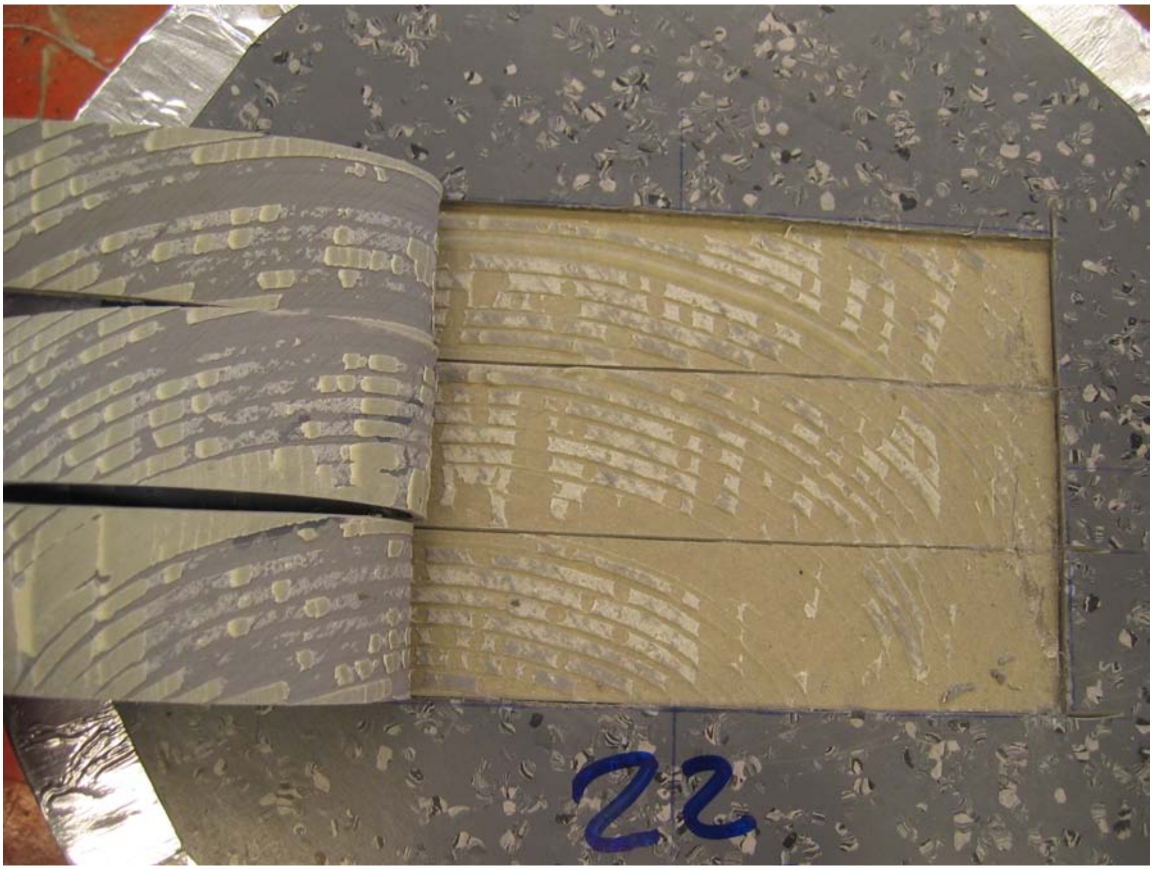
Appendix 5.19 – Fracture view at peel test of specimen no 19

Appendix 5.20 – Fracture view at peel test of specimen no 20

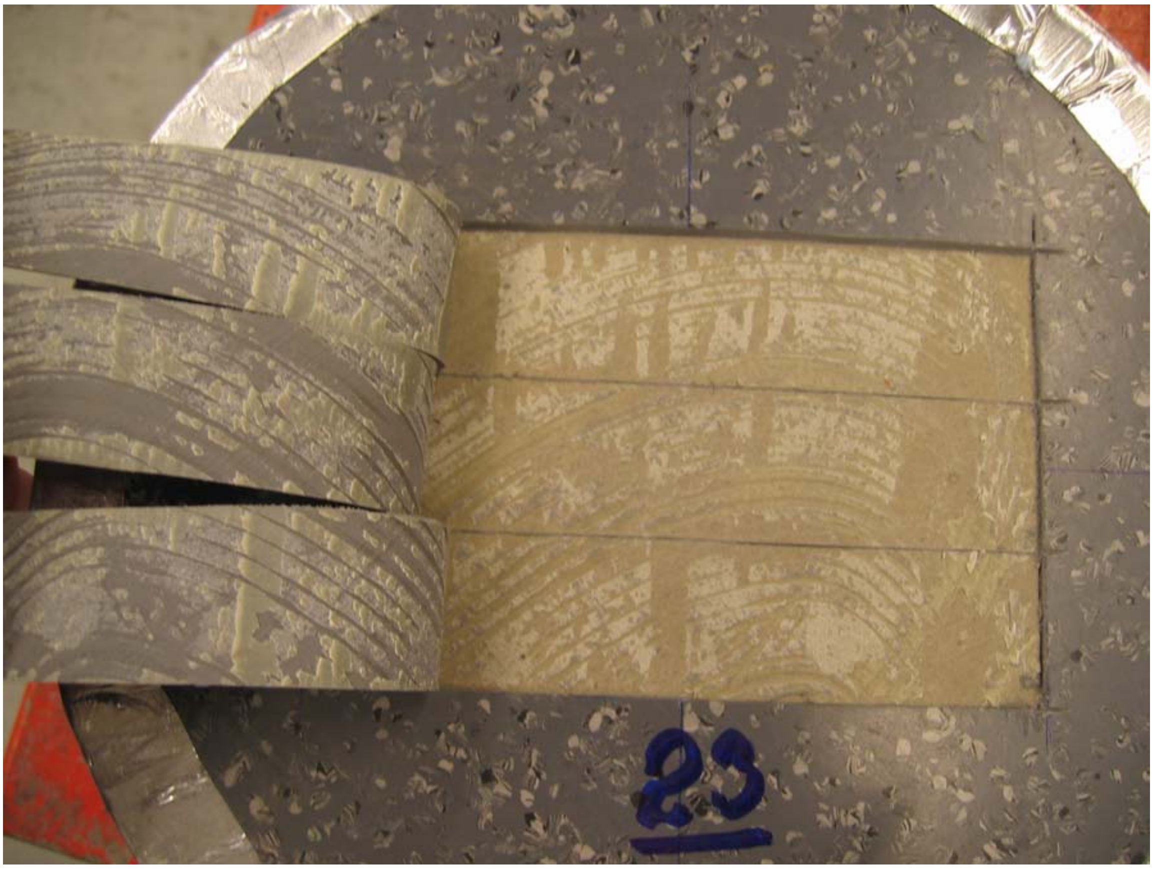
Appendix 5.21 – Fracture view at peel test of specimen no 21



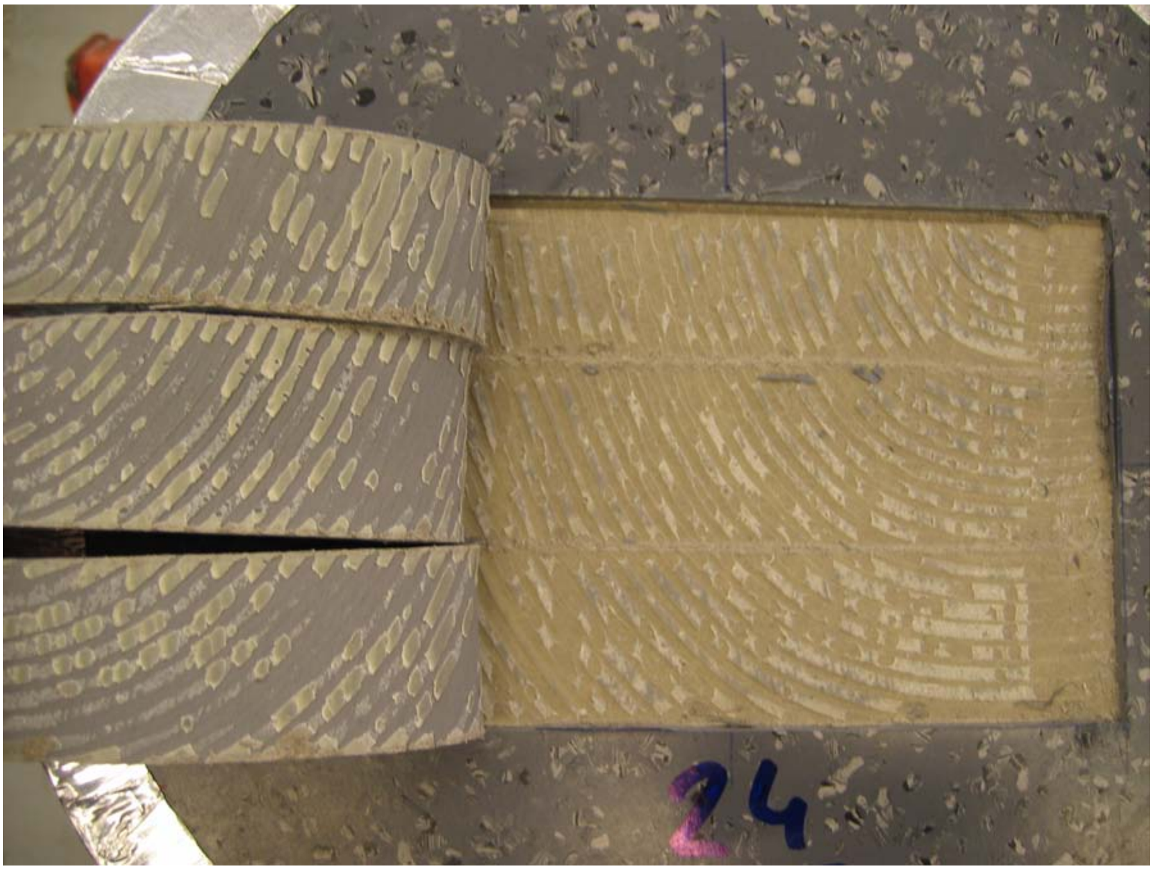
Appendix 5.22 – Fracture view at peel test of specimen no 22



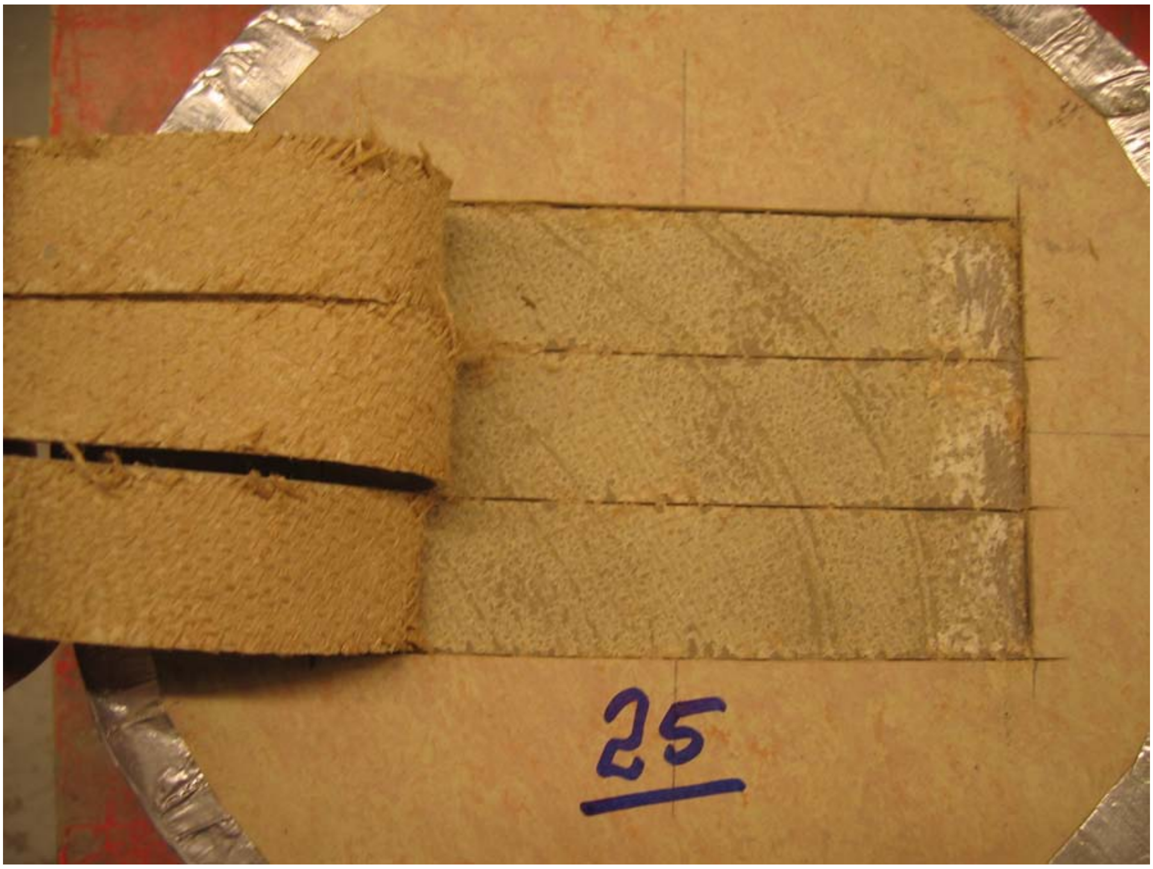
Appendix 5.23 – Fracture view at peel test of specimen no 23



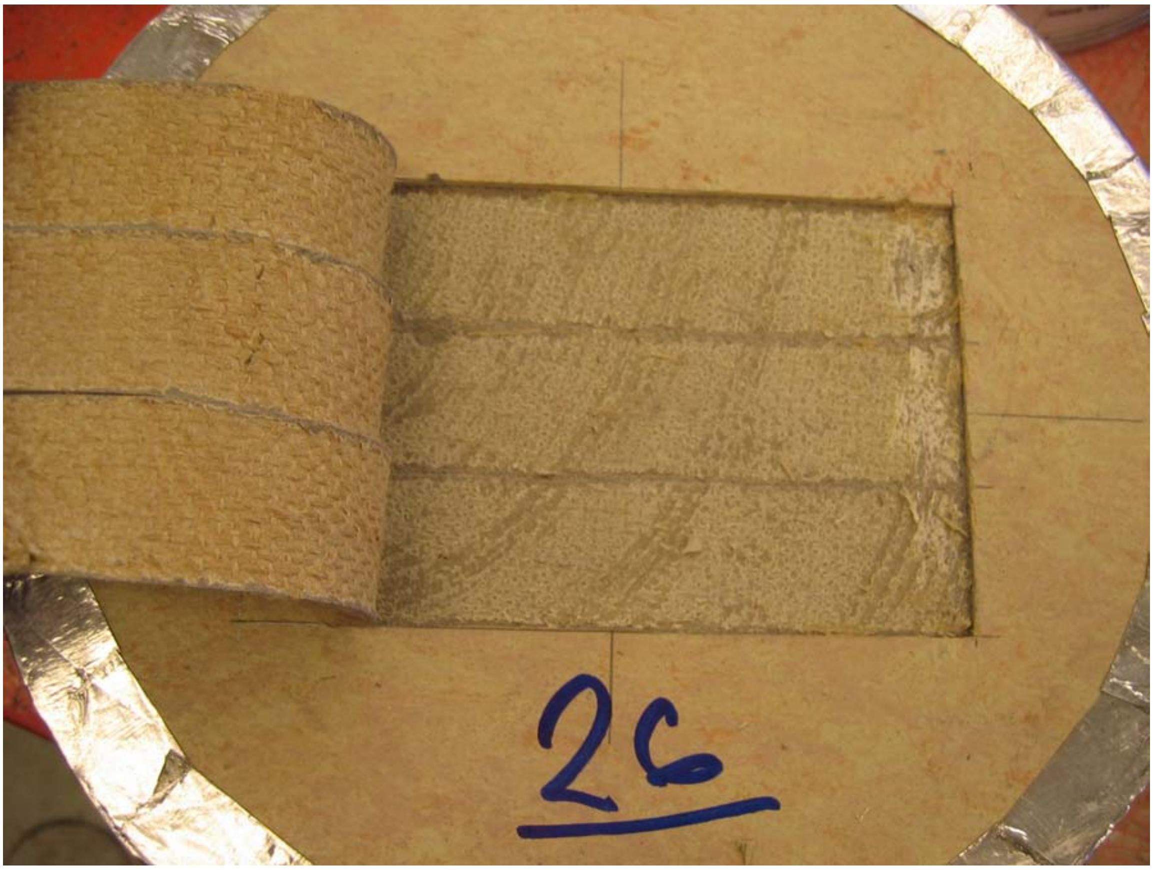
Appendix 5.24 – Fracture view at peel test of specimen no 24



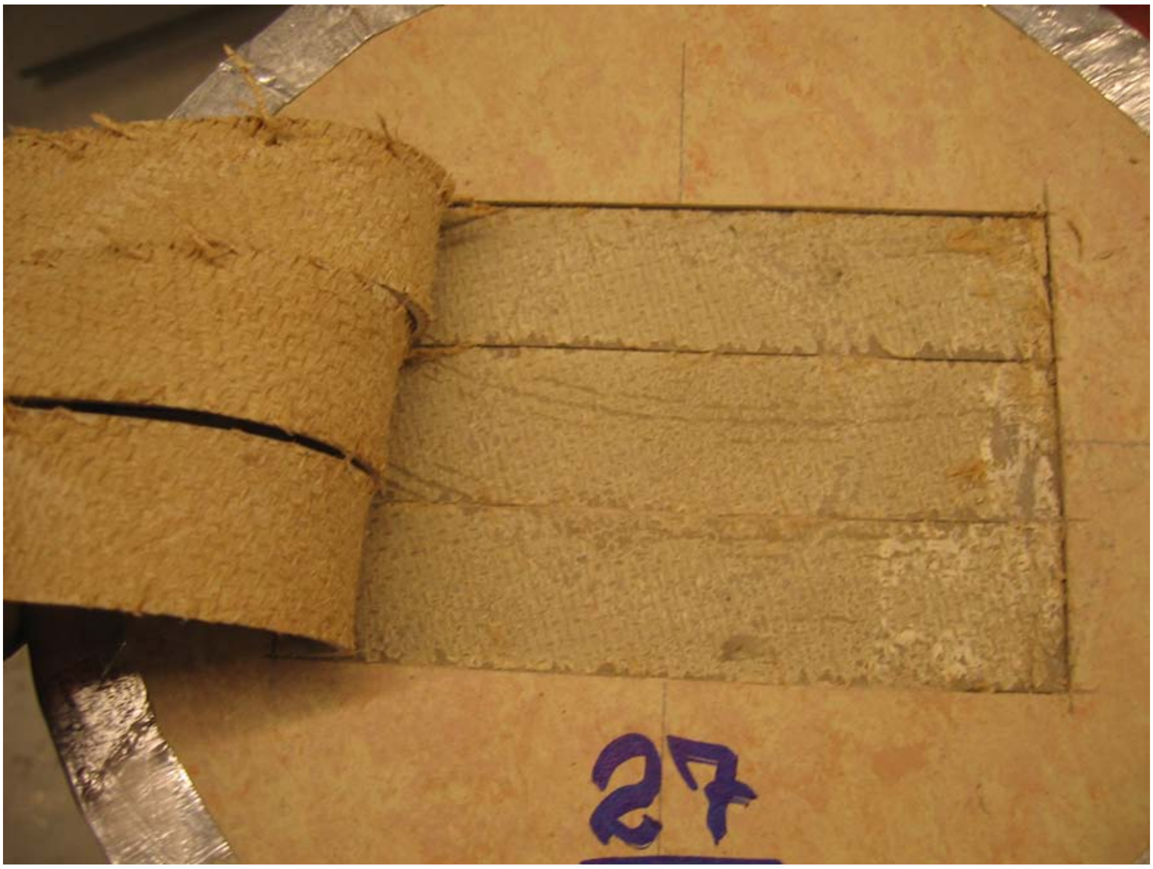
Appendix 5.25 – Fracture view at peel test of specimen no 25



Appendix 5.26 – Fracture view at peel test of specimen no 26



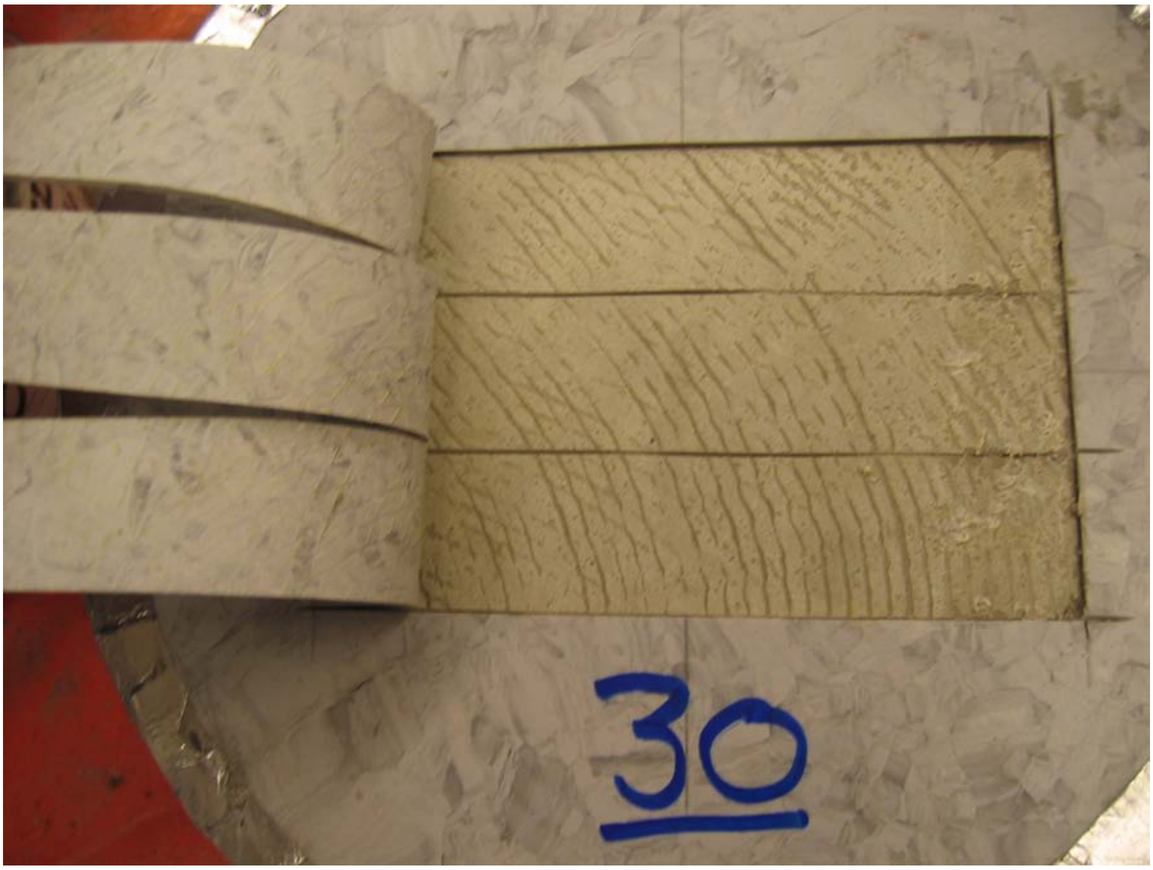
Appendix 5.27 – Fracture view at peel test of specimen no 27



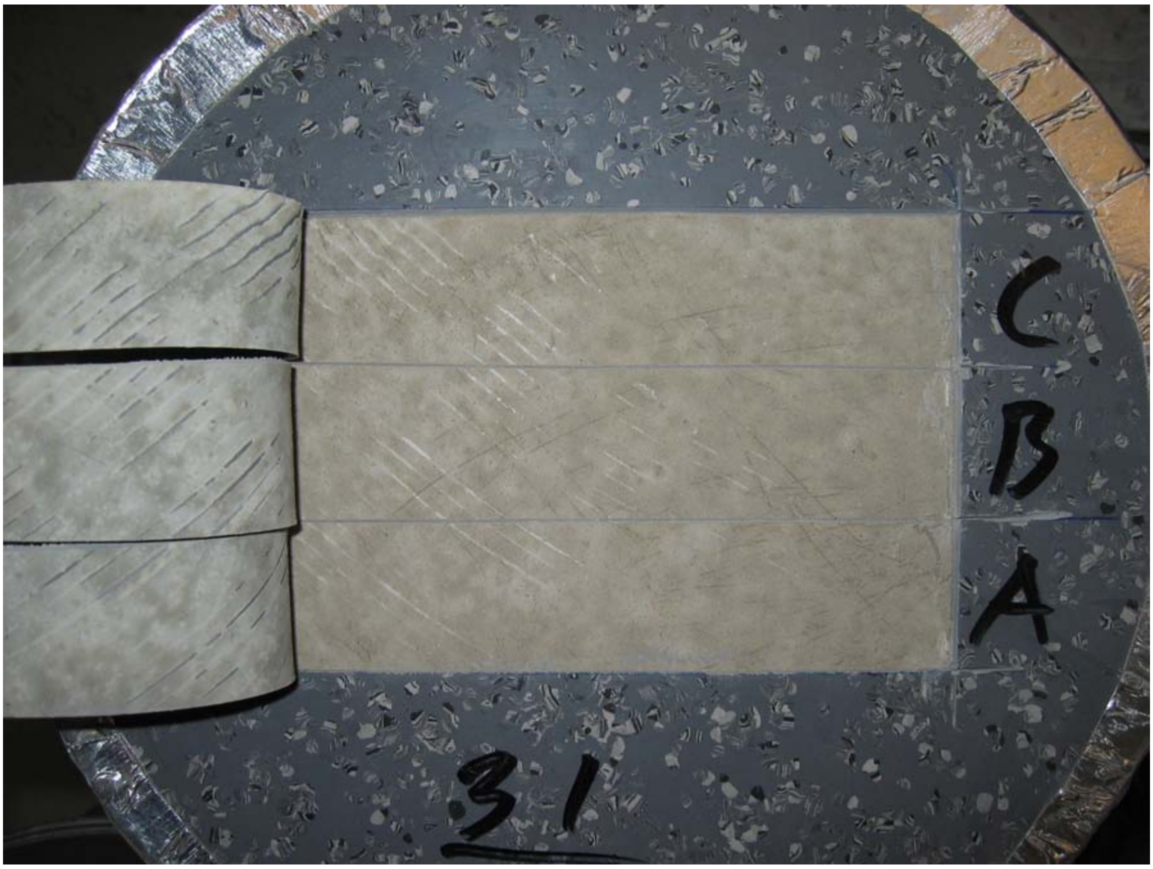
Appendix 5.28 – Fracture view at peel test of specimen no 28

Appendix 5.29 – Fracture view at peel test of specimen no 29

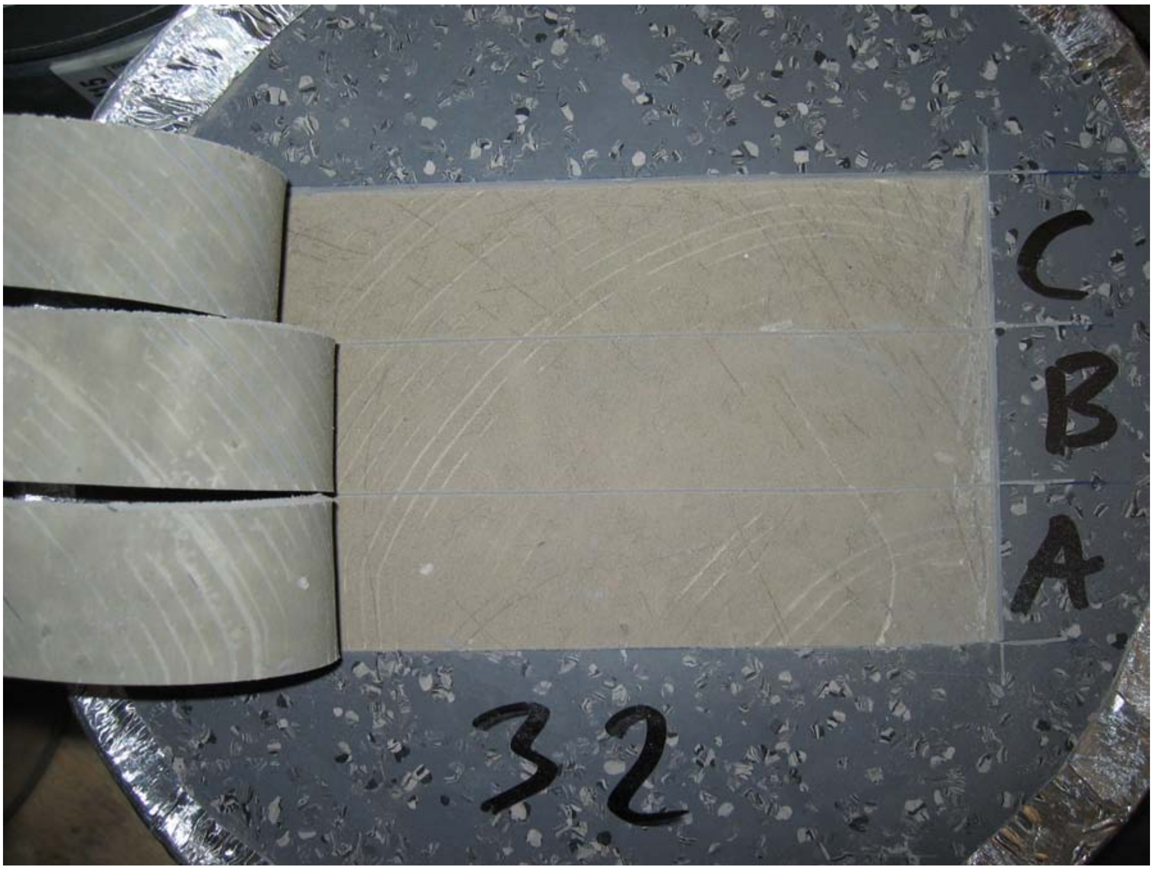
Appendix 5.30 – Fracture view at peel test of specimen no 30



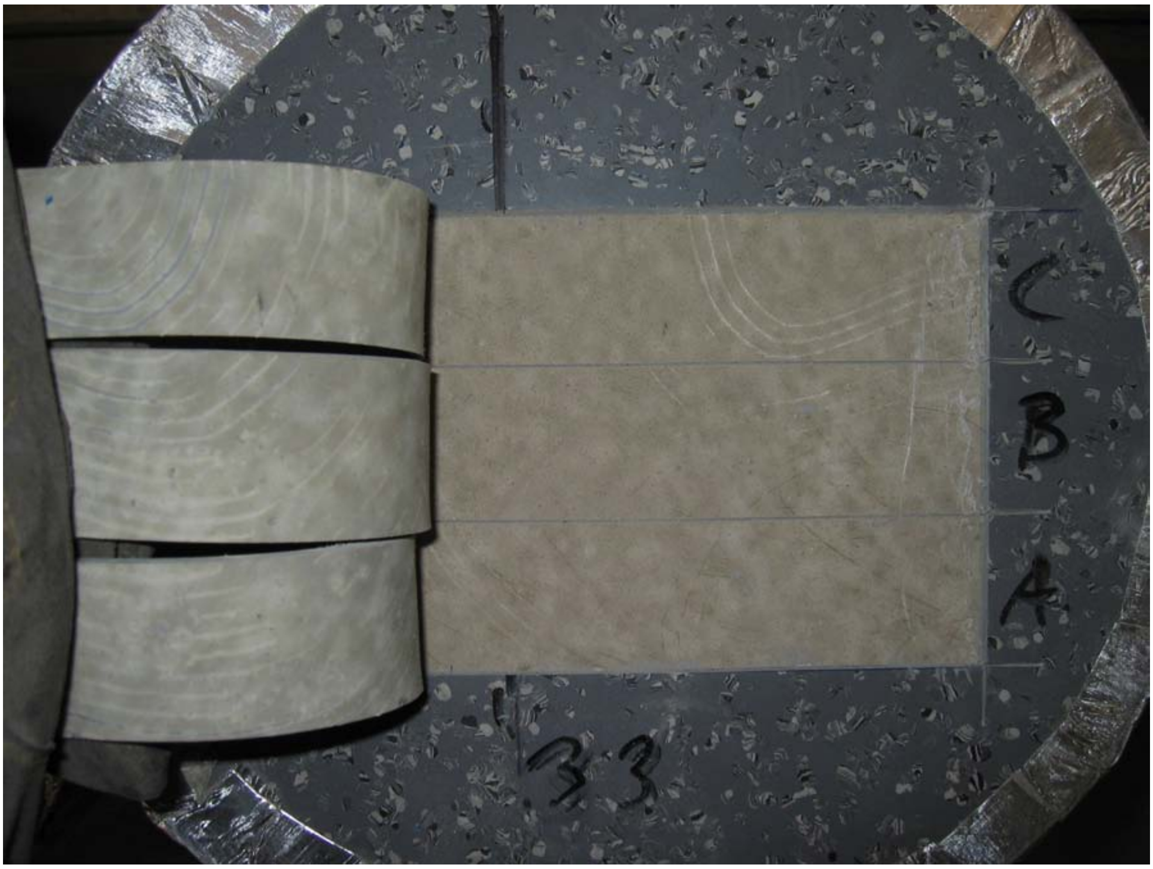
Appendix 5.31 – Fracture view at peel test of specimen no 31



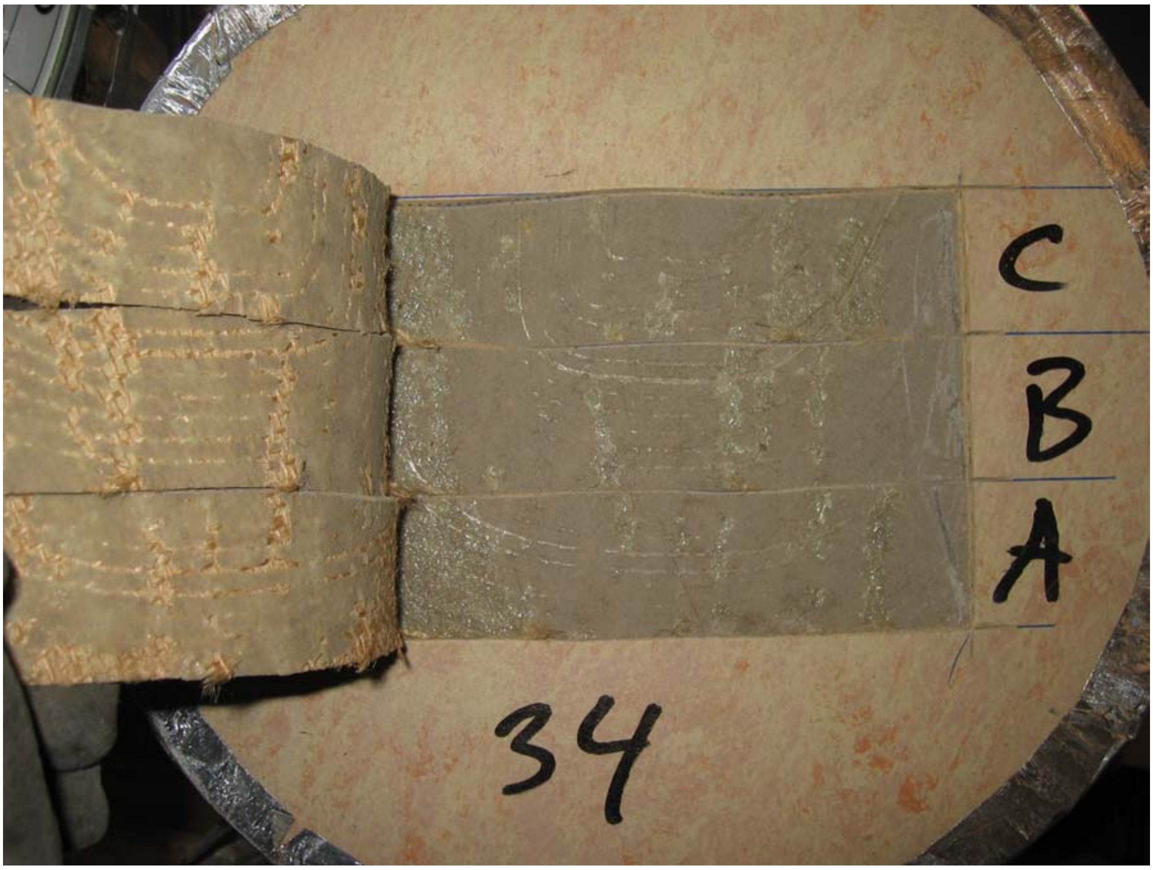
Appendix 5.32 – Fracture view at peel test of specimen no 32



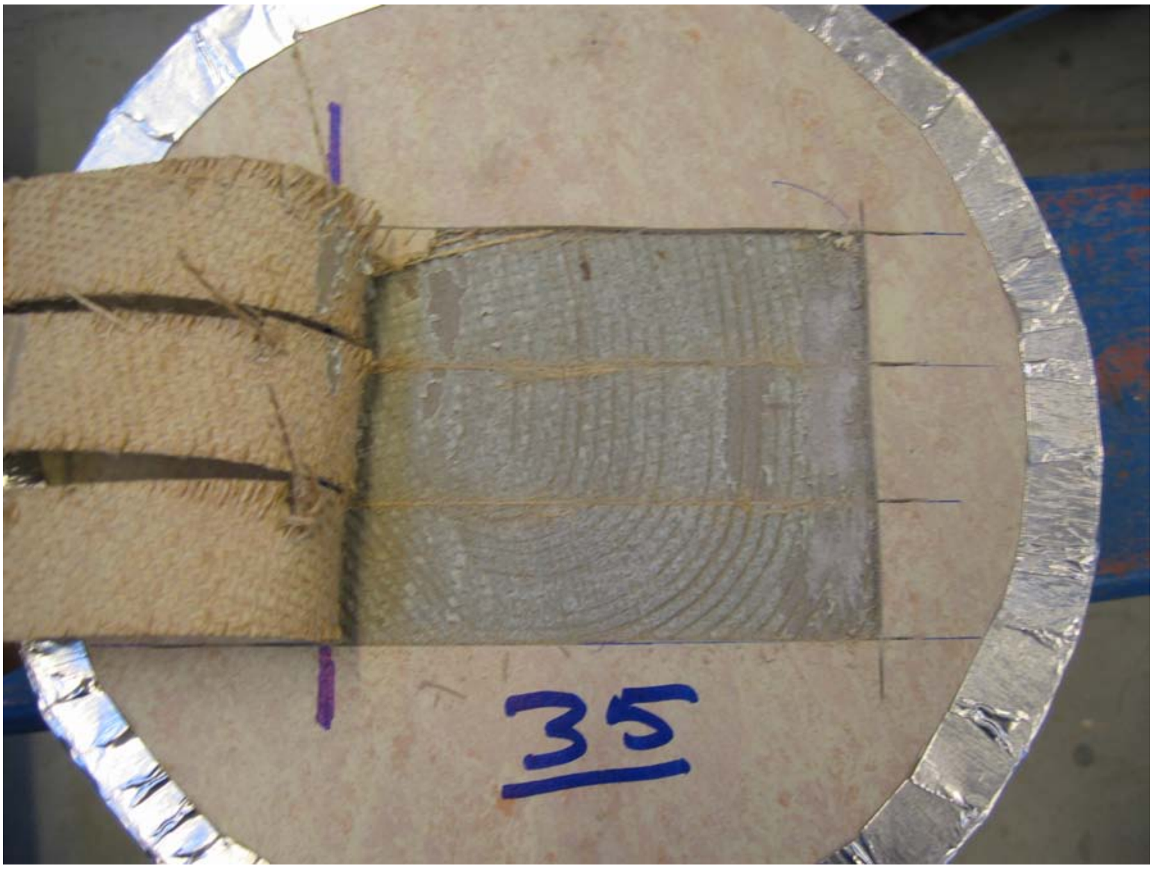
Appendix 5.33 – Fracture view at peel test of specimen no 33



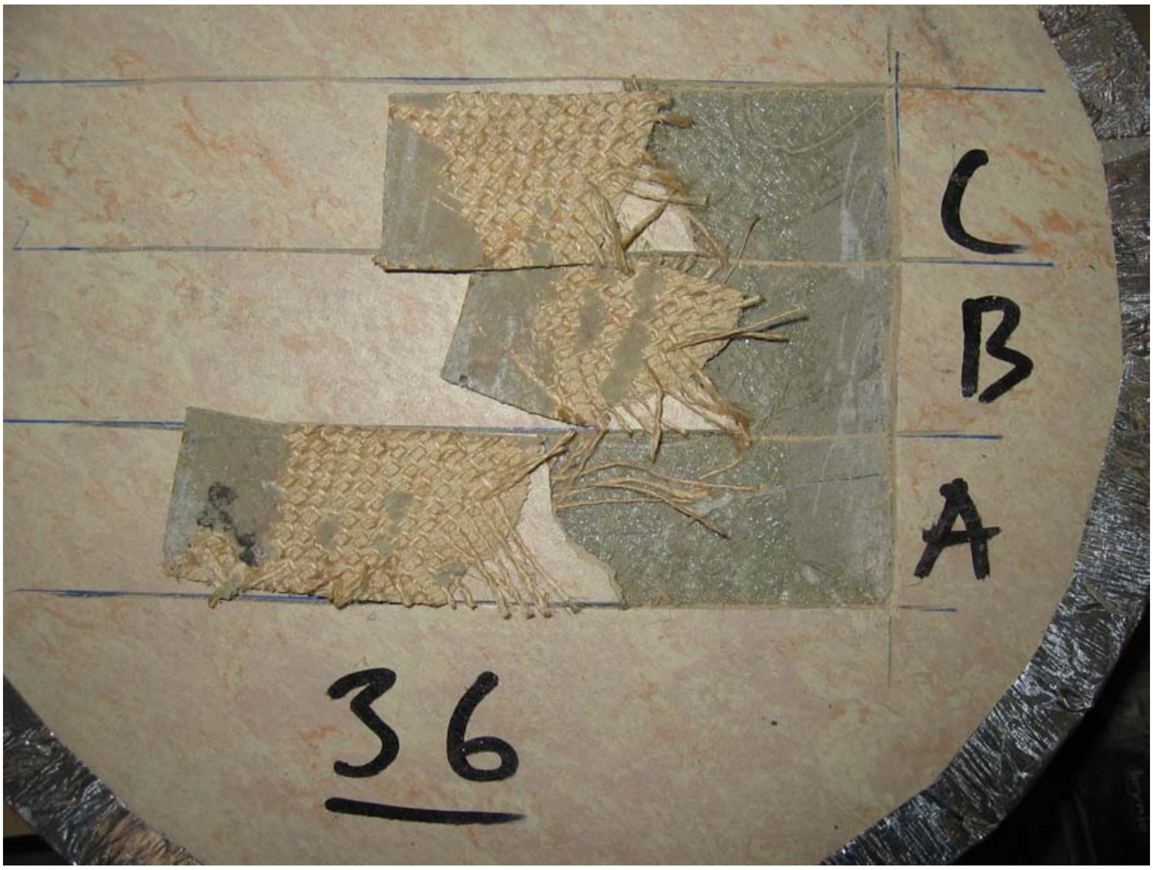
Appendix 5.34 – Fracture view at peel test of specimen no 34



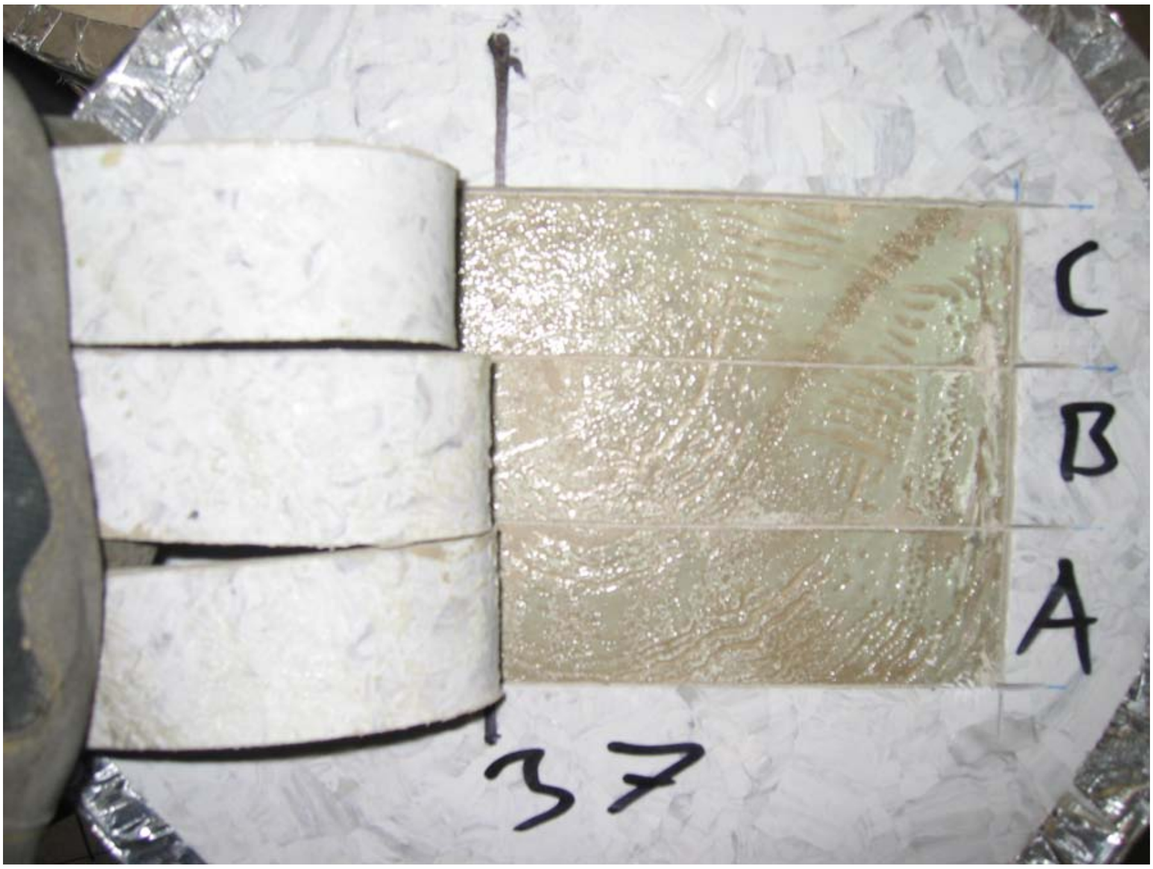
Appendix 5.35 – Fracture view at peel test of specimen no 35



Appendix 5.36 – Fracture view at peel test of specimen no 36



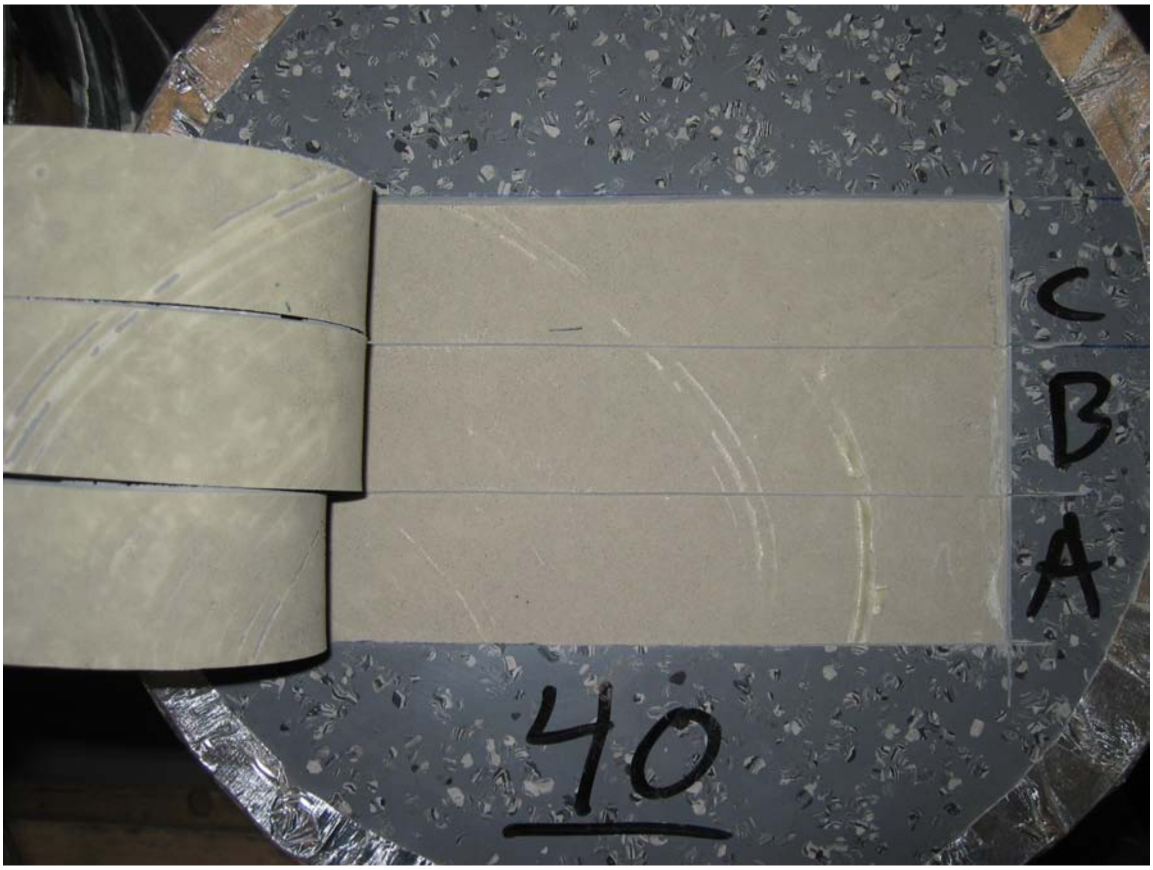
Appendix 5.37 – Fracture view at peel test of specimen no 37



Appendix 5.38 – Fracture view at peel test of specimen no 38

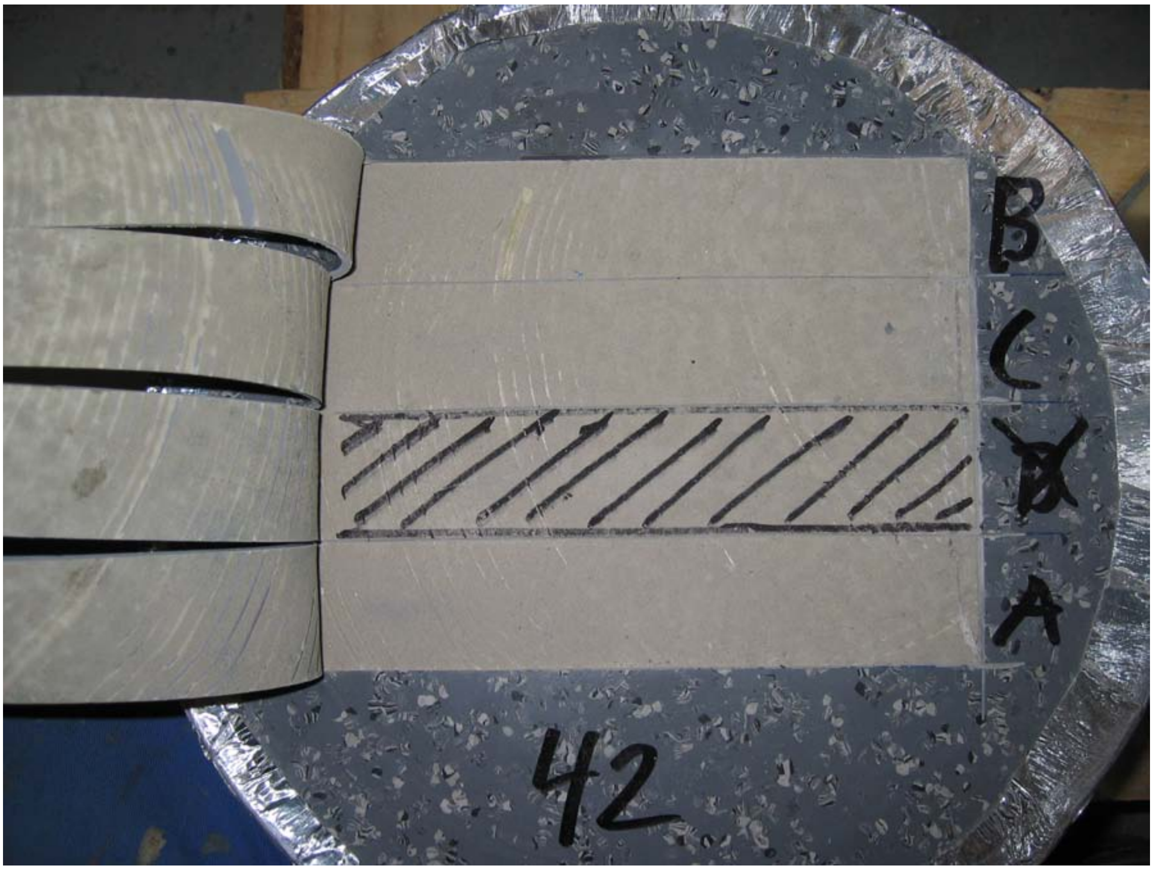
Appendix 5.39 – Fracture view at peel test of specimen no 39

Appendix 5.40 – Fracture view at peel test of specimen no 40



Appendix 5.41 – Fracture view at peel test of specimen no 41

Appendix 5.42 – Fracture view at peel test of specimen no 42

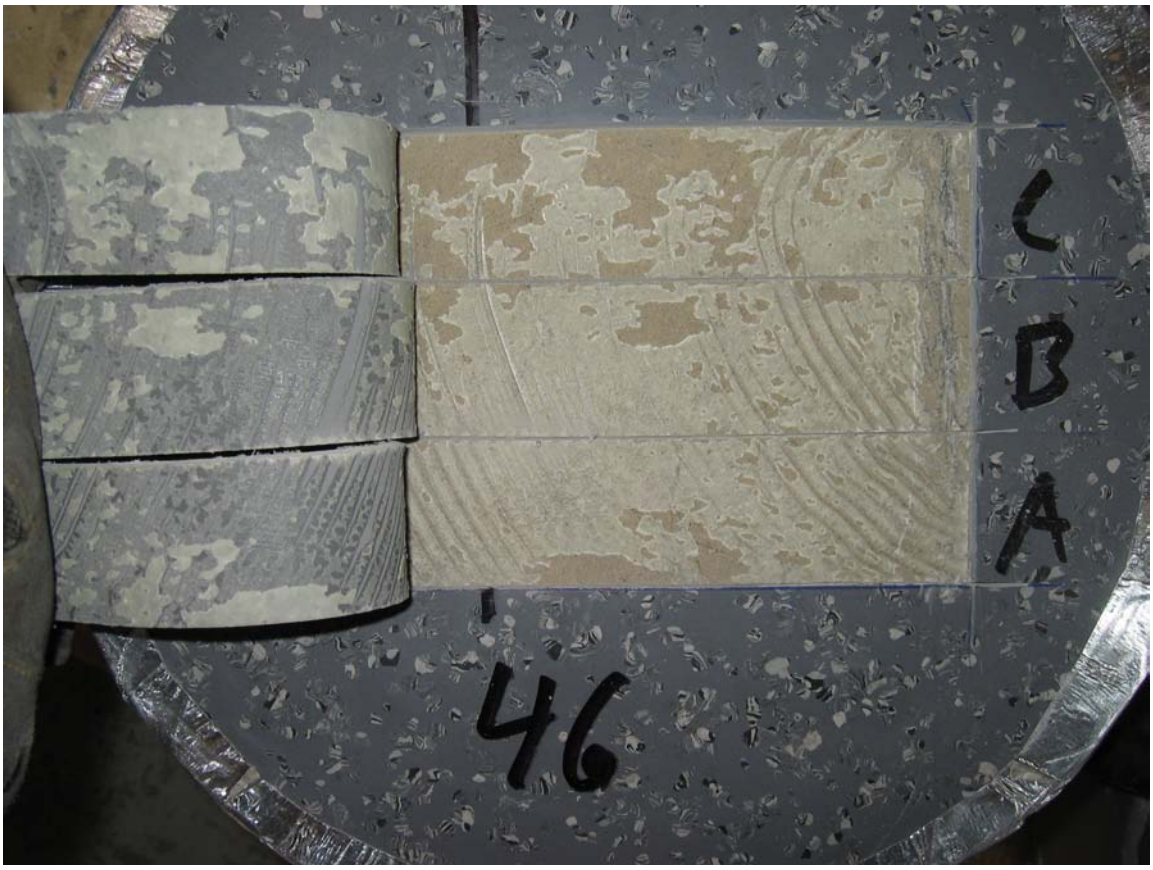


Appendix 5.43 – Fracture view at peel test of specimen no 43

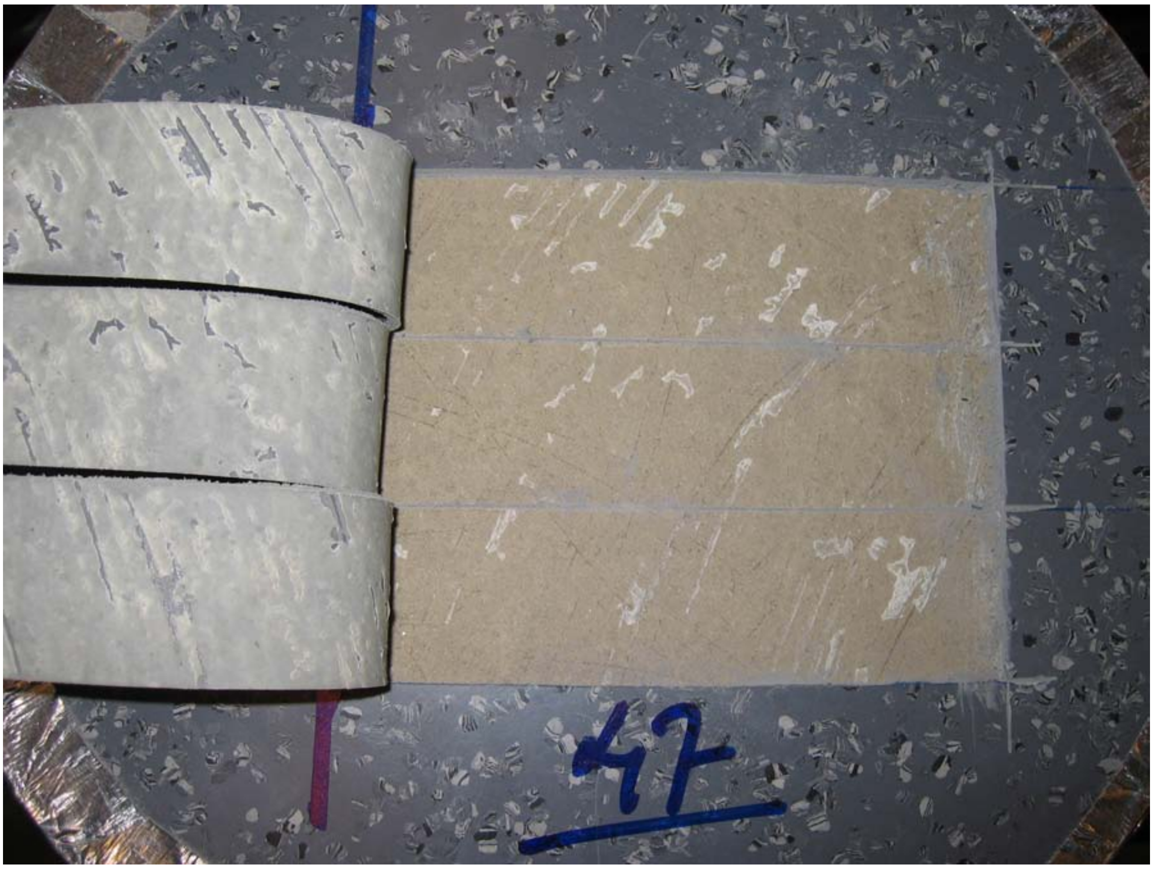
Appendix 5.44 – Fracture view at peel test of specimen no 44

Appendix 5.45 – Fracture view at peel test of specimen no 45

Appendix 5.46 – Fracture view at peel test of specimen no 46



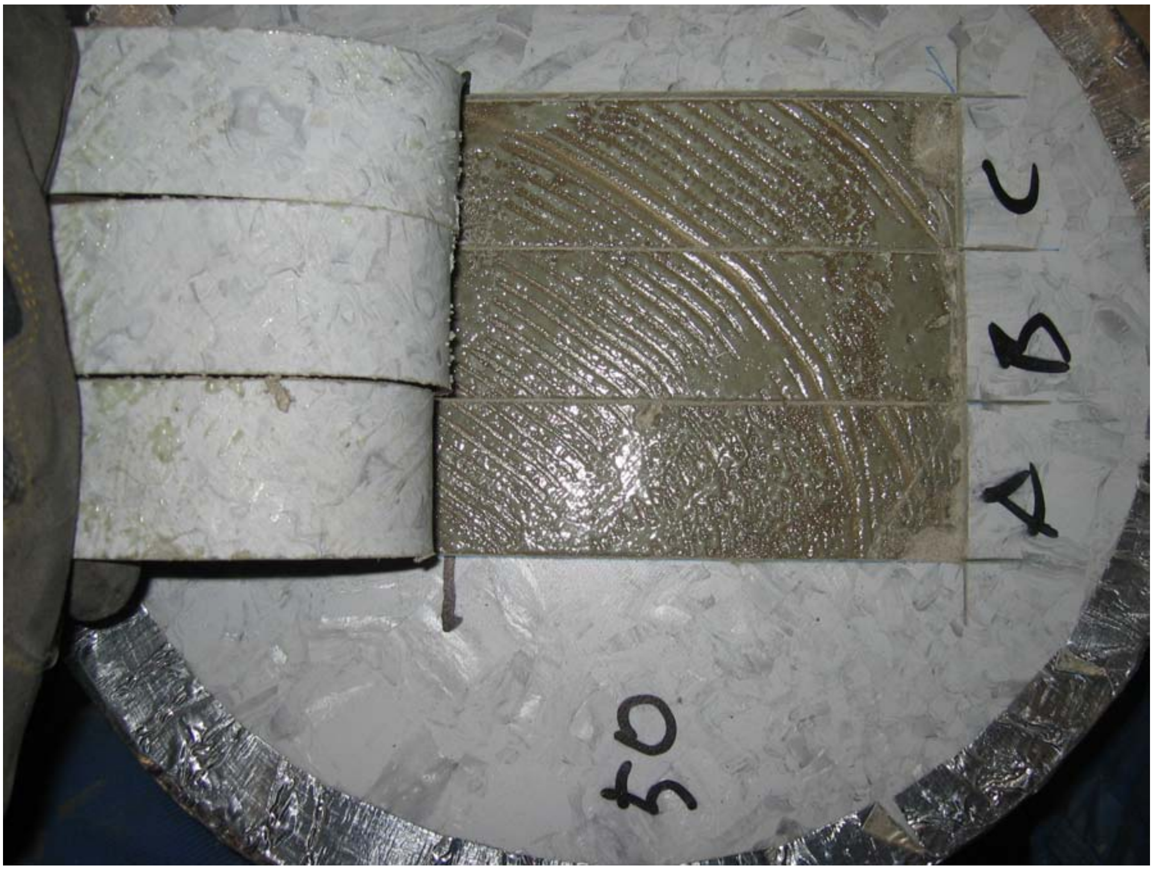
Appendix 5.47 – Fracture view at peel test of specimen no 47



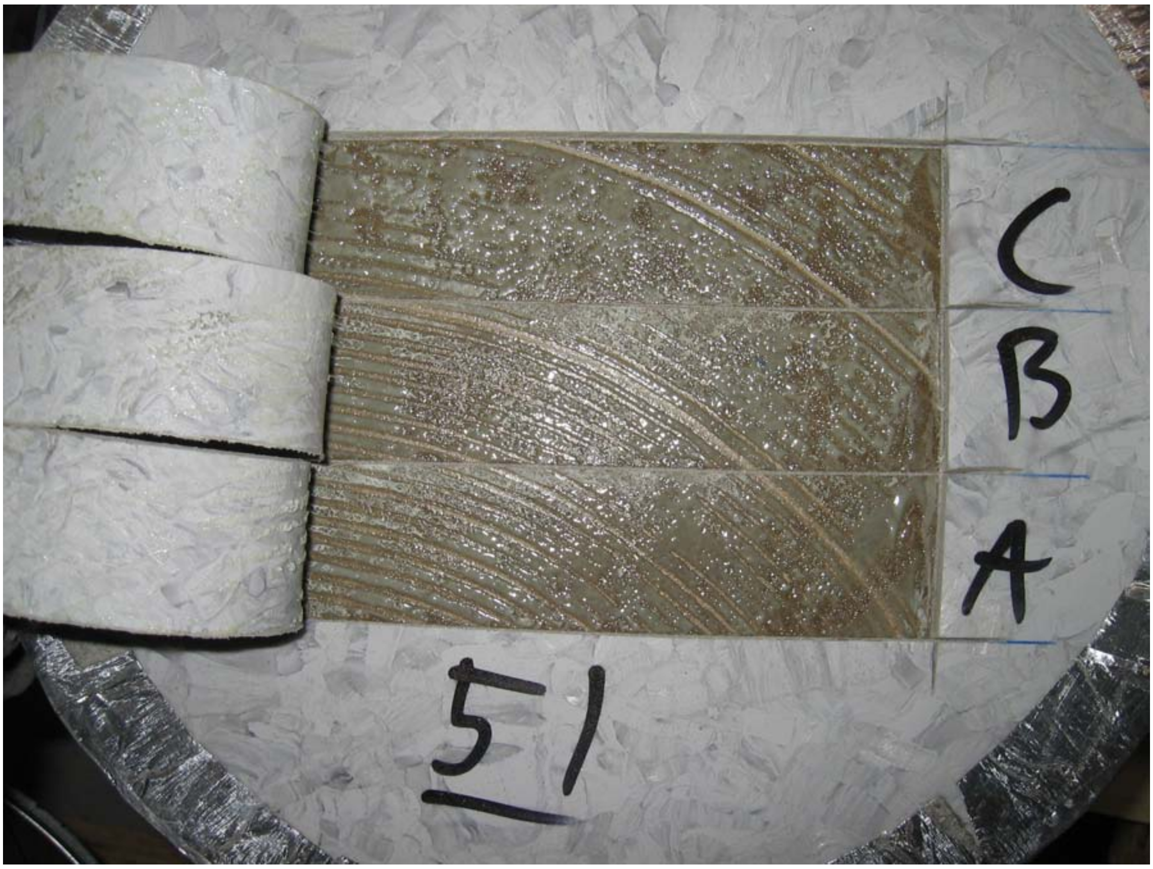
Appendix 5.48 – Fracture view at peel test of specimen no 48

Appendix 5.49 – Fracture view at peel test of specimen no 49

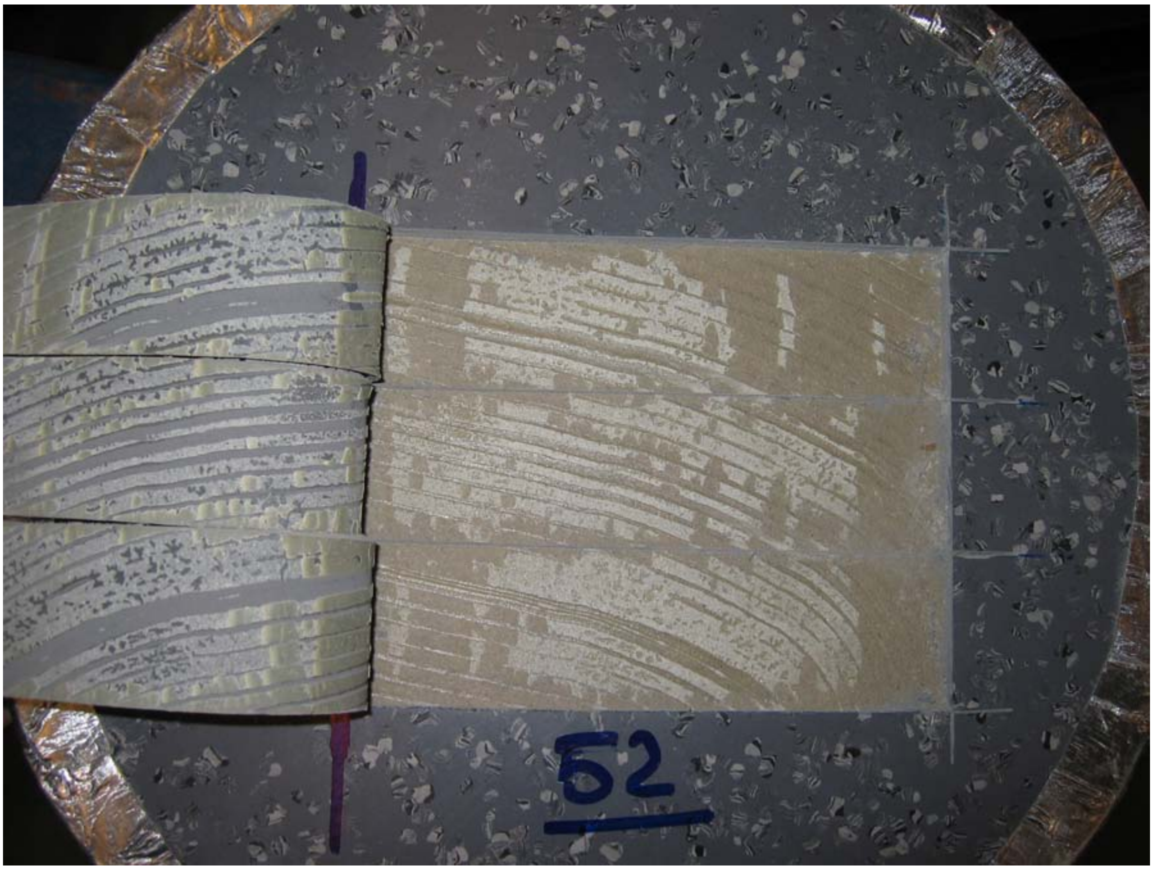
Appendix 5.50 – Fracture view at peel test of specimen no 50



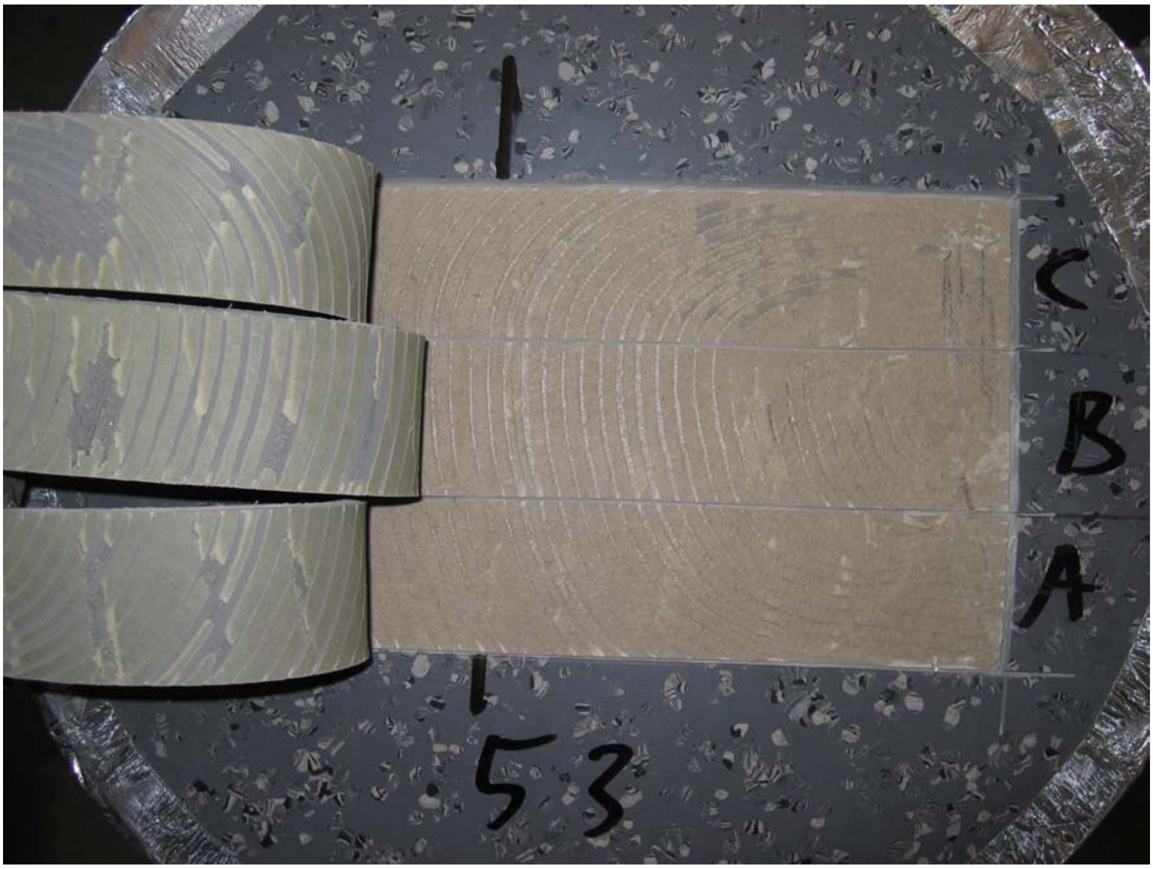
Appendix 5.51 – Fracture view at peel test of specimen no 51



Appendix 5.52 – Fracture view at peel test of specimen no 52



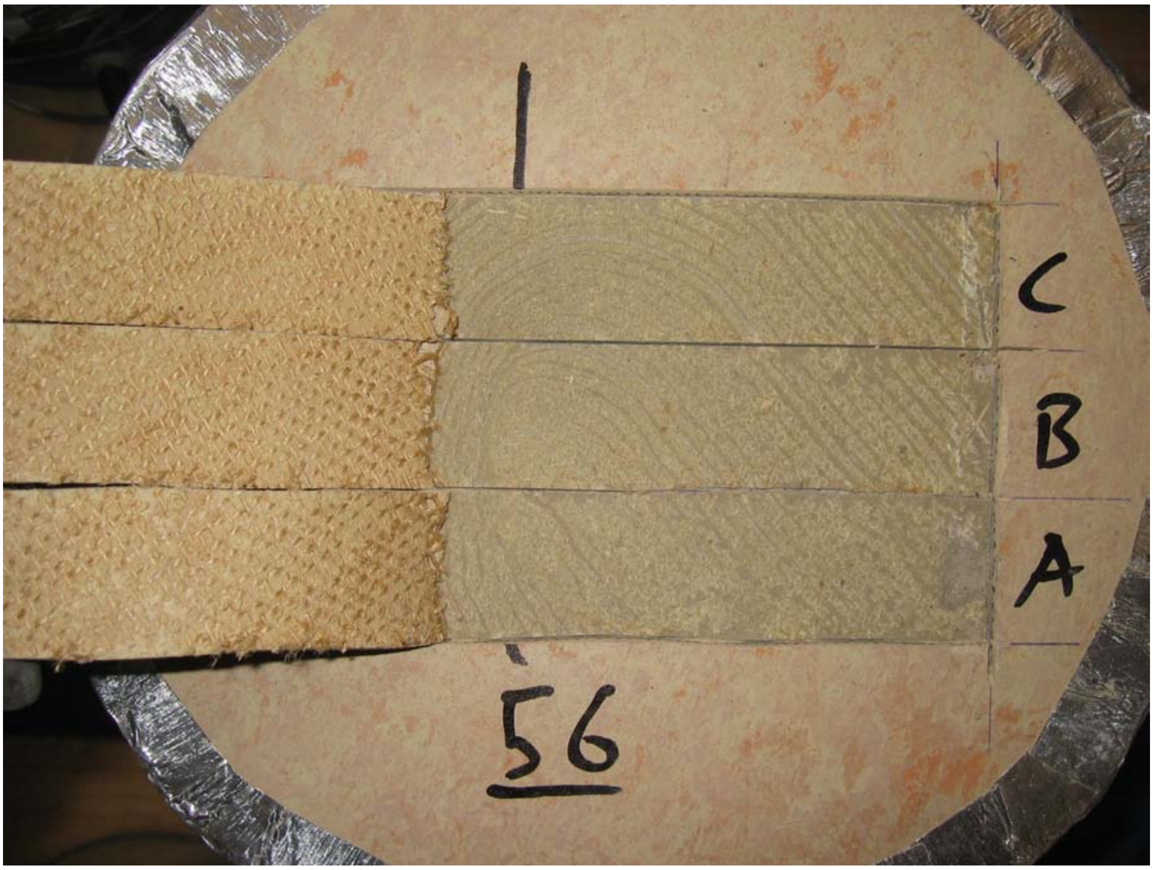
Appendix 5.53 – Fracture view at peel test of specimen no 53



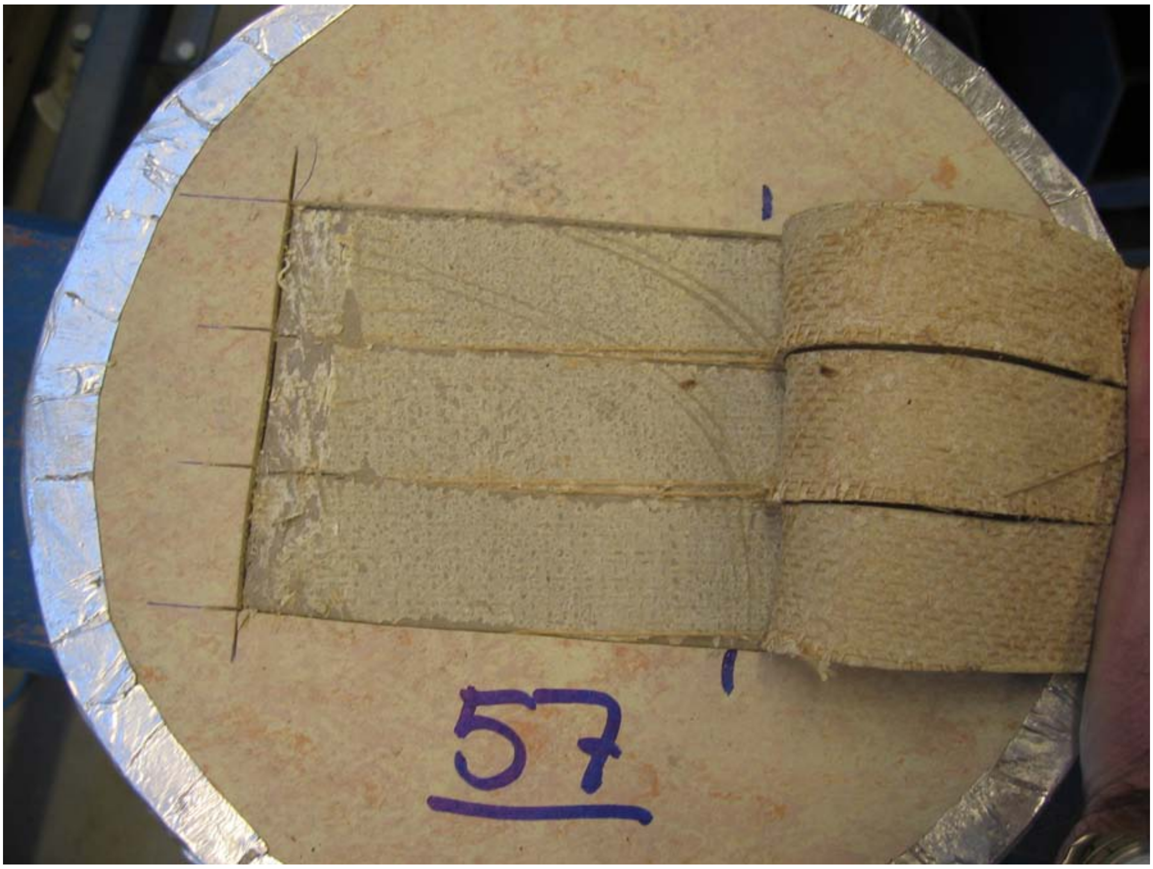
Appendix 5.54 – Fracture view at peel test of specimen no 54

Appendix 5.55 – Fracture view at peel test of specimen no 55

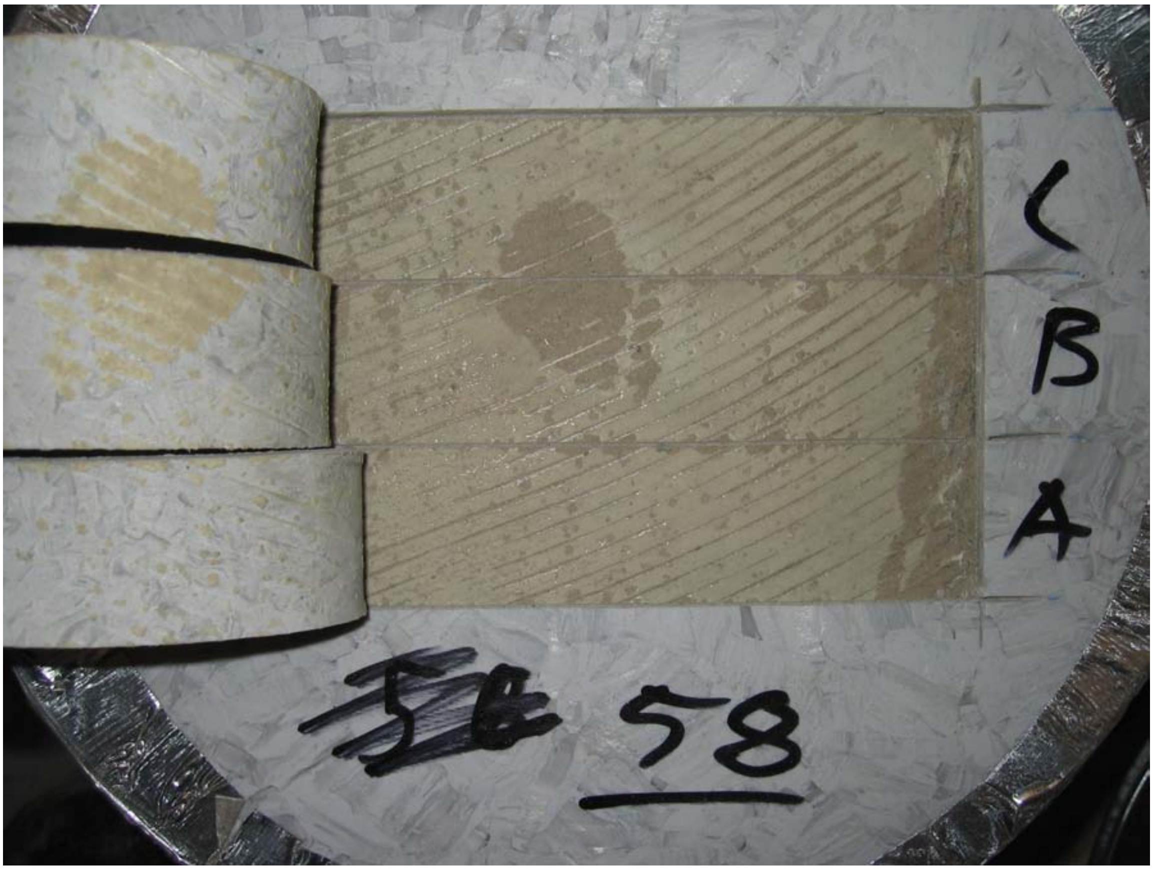
Appendix 5.56 – Fracture view at peel test of specimen no 56



Appendix 5.57 – Fracture view at peel test of specimen no 57



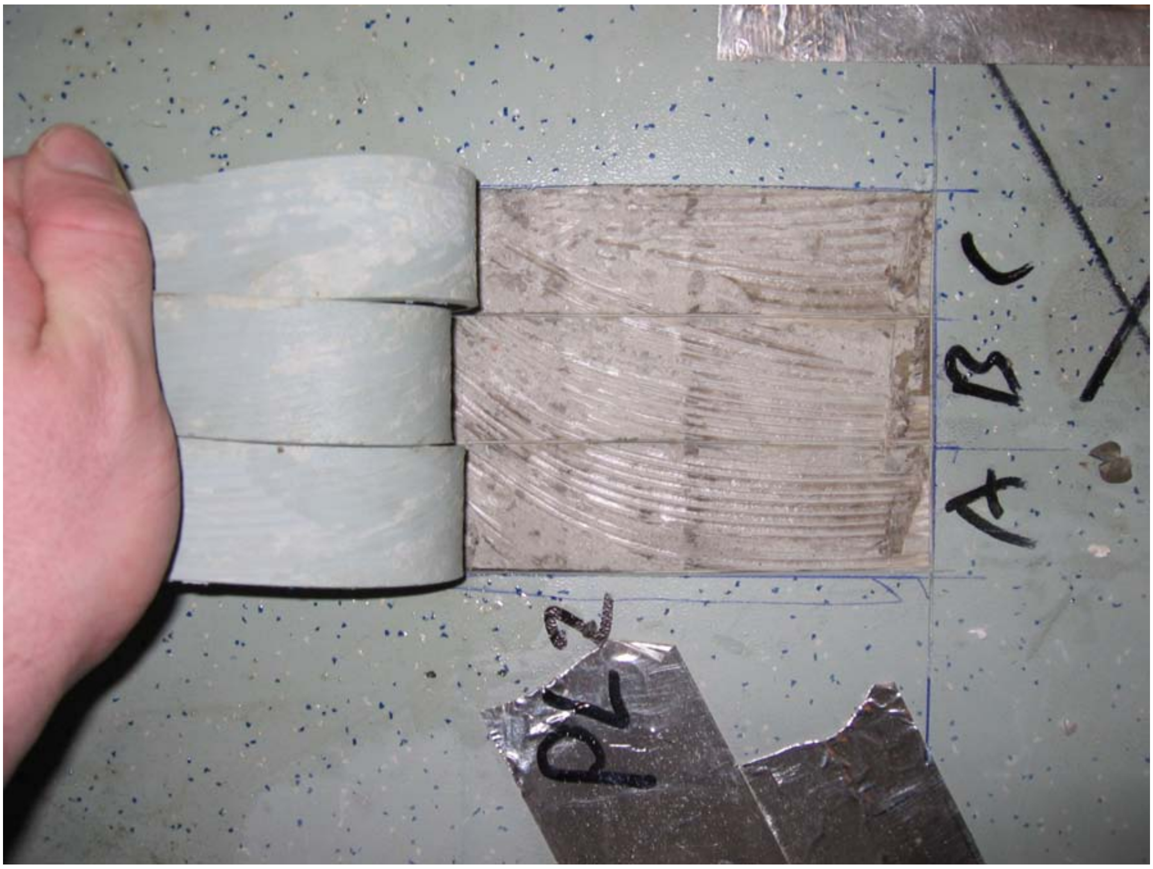
Appendix 5.58 – Fracture view at peel test of specimen no 58



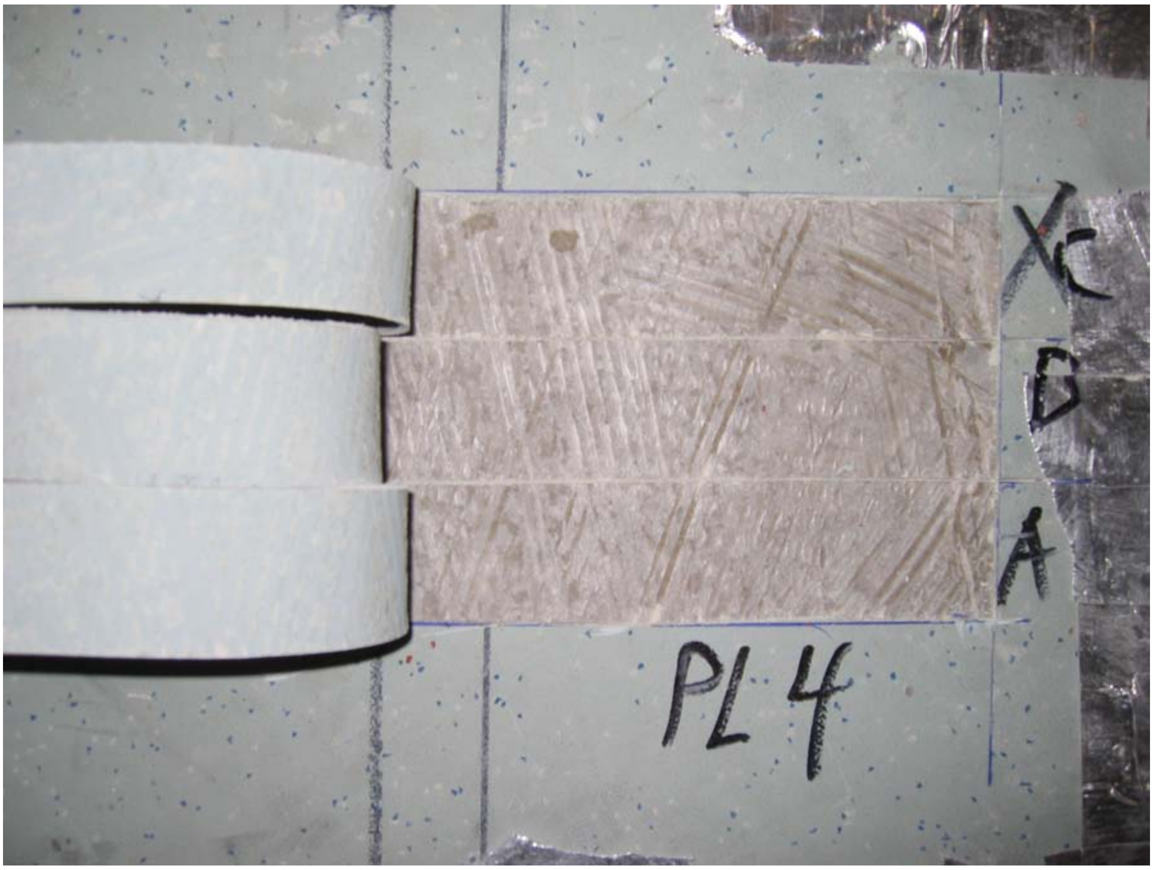
Appendix 5.59 – Fracture view at peel test of specimen no 59

Appendix 5.60 – Fracture view at peel test of specimen no 60

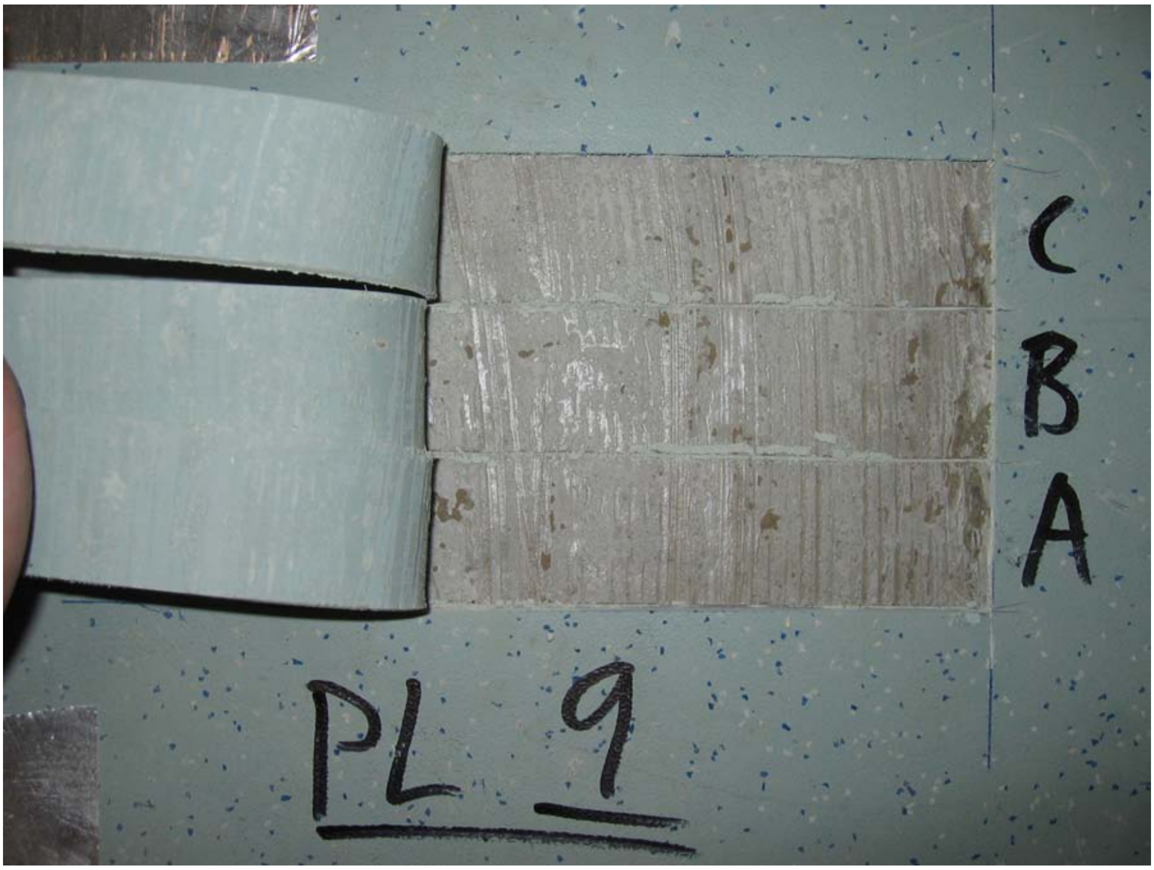
Appendix 5.61 – Fracture view at peel test of specimen no 40BEFR2h



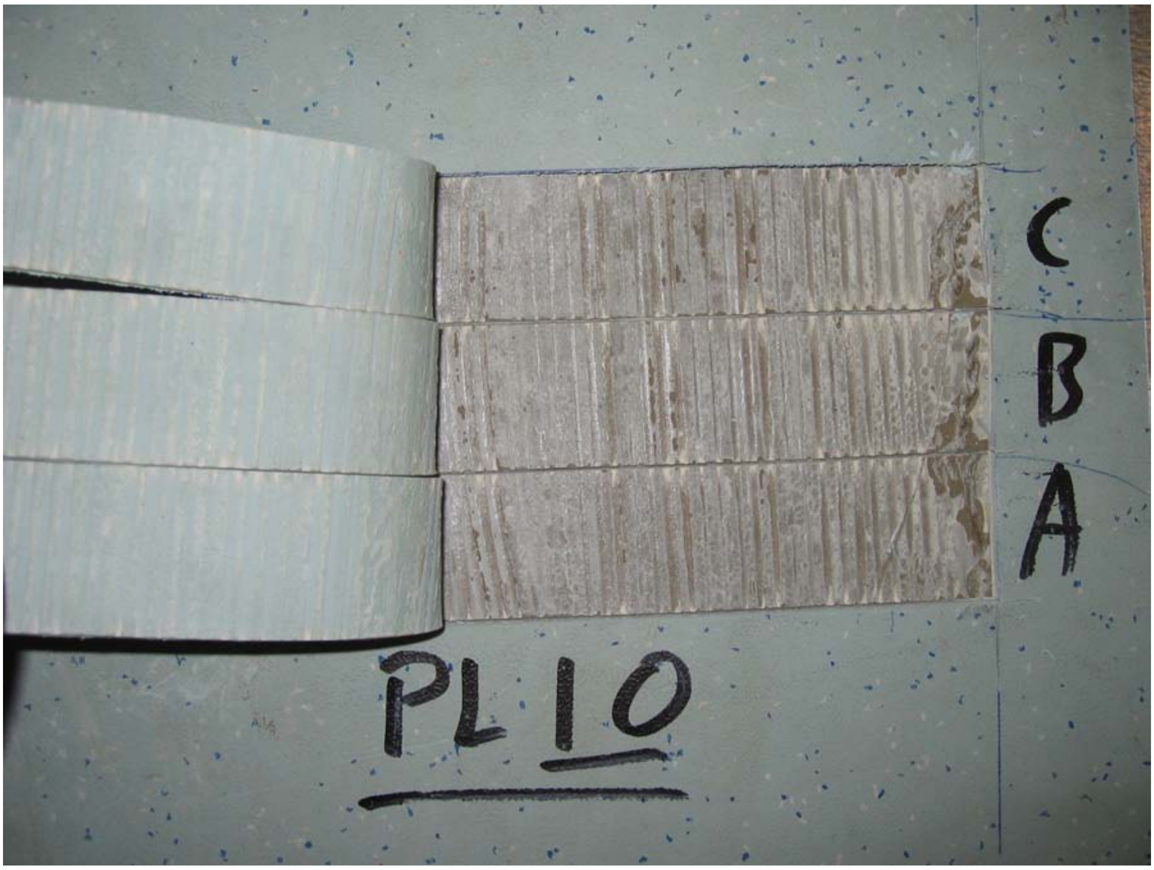
Appendix 5.62 – Fracture view at peel test of specimen no 40BEFR4h



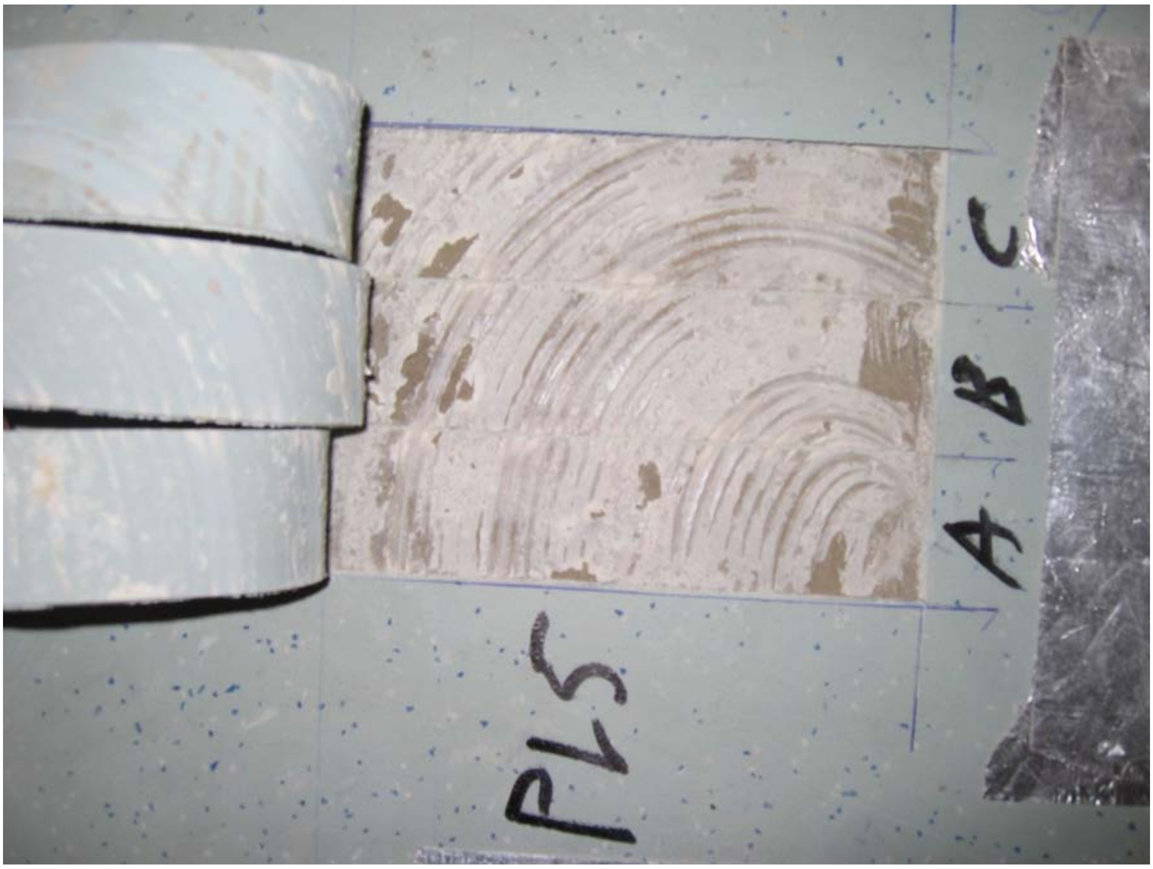
Appendix 5.63 – Fracture view at peel test of specimen no 40BEFR9



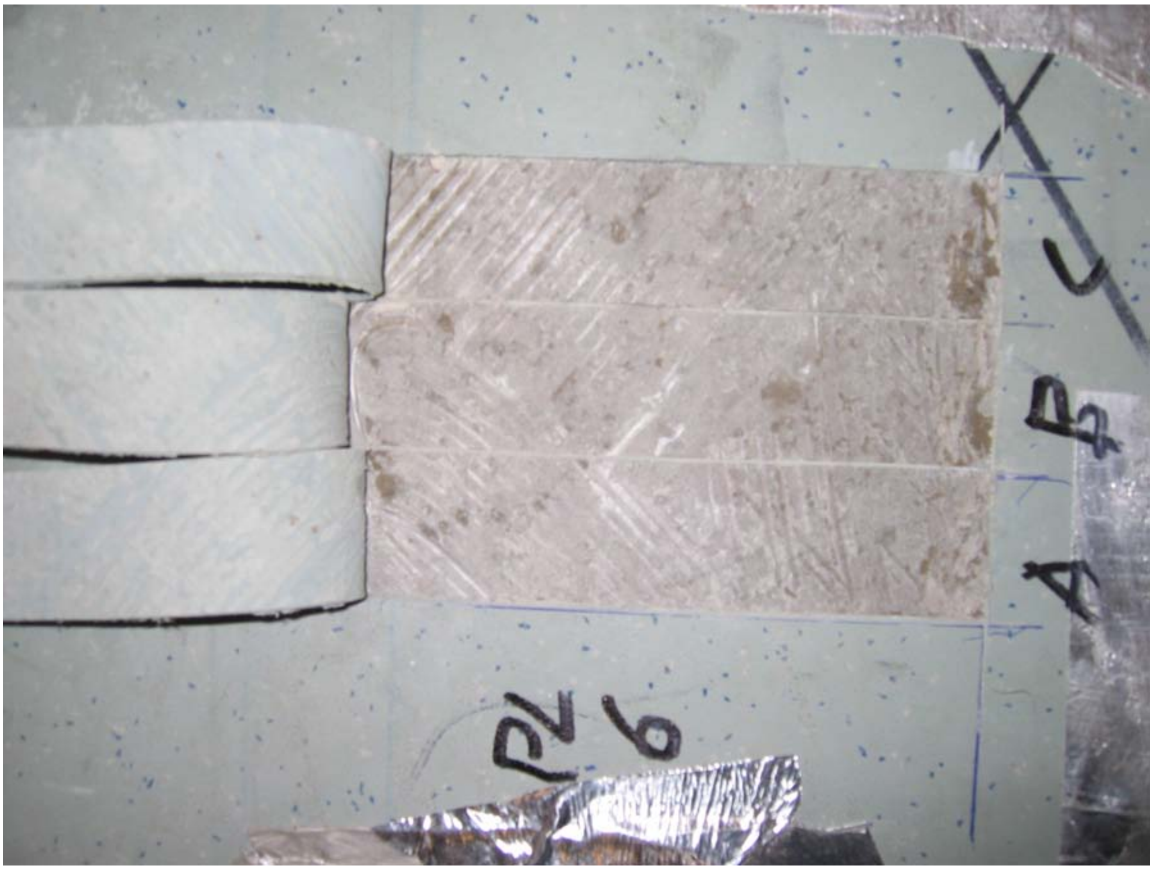
Appendix 5.64 – Fracture view at peel test of specimen no 40BEFR10



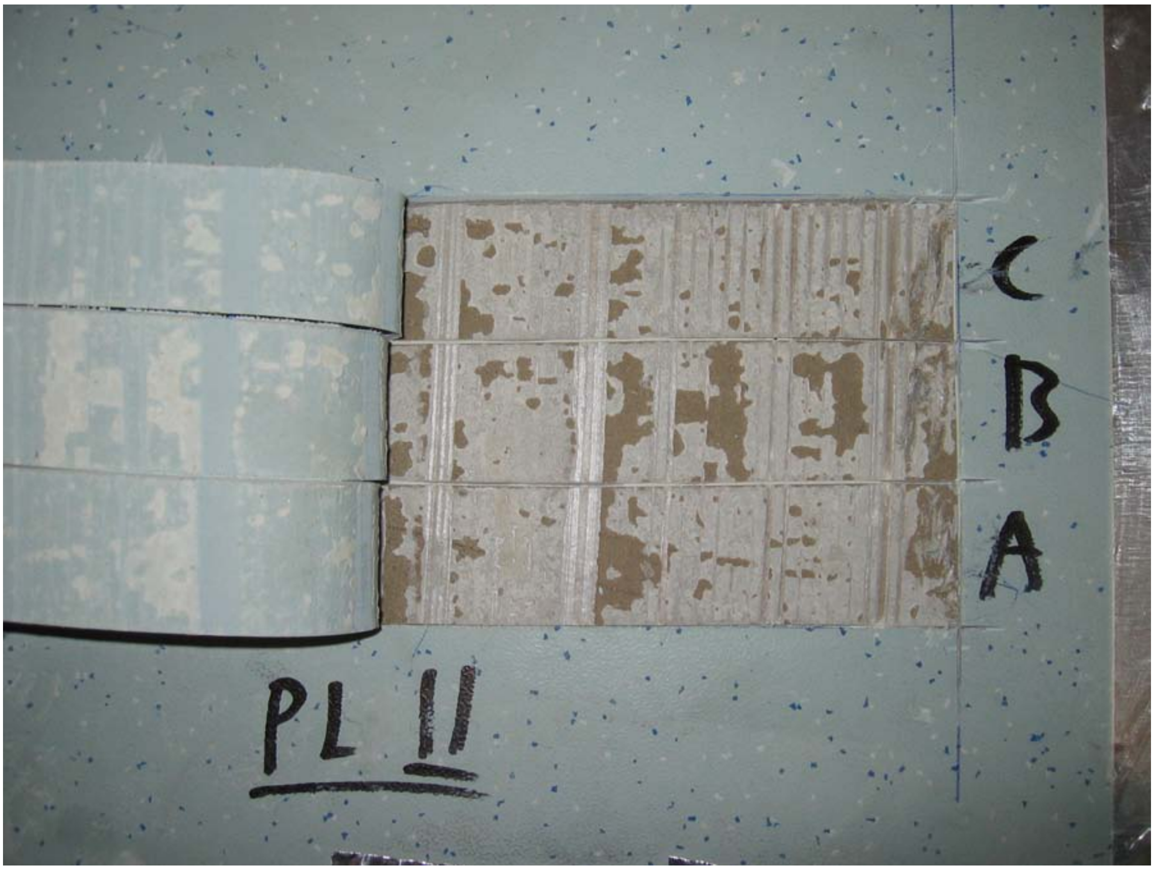
Appendix 5.65 – Fracture view at peel test of specimen no 60BEFR5h



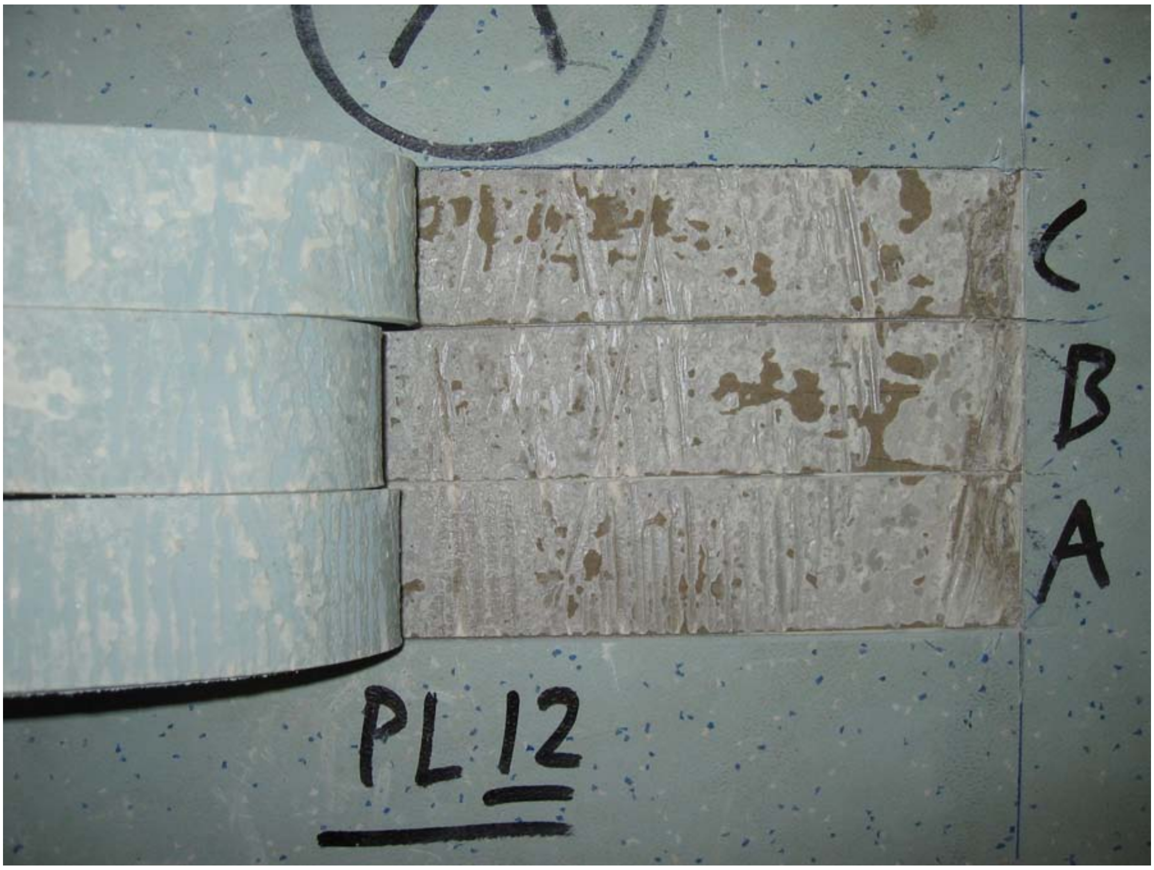
Appendix 5.66 – Fracture view at peel test of specimen no 60BEFR6h



Appendix 5.67 – Fracture view at peel test of specimen no 60BEFR11



Appendix 5.68 – Fracture view at peel test of specimen no 60BEFR12



Appendix 5.69 – Fracture partition at peel test of specimens with w/c=0.40 (%)

No	Flooring system	Flooring-adhesion	Flooring-cohesion	Adhesive-cohesion	Self-leveling c.-adhesion	Self-leveling c.-cohesion
1	40 AEFR	5			95	
2	40 AEFR	20			80	
3	40 AEFR	10			90	
4	40 ACTL		100			
5	40 ACTL		100			
6	40 ACTL		100			
7	40 ACTP			100		
8	40 ACTP			100		
9	40 ACTP			100		
10	40 AGFR					80
11	40 AGFR	20				90
12	40 AGFR	10				60
13	40 AHTP	10			90	
14	40 AHTP				80	
15	40 AHTP			10	90	
16	40 BEFR			20	70	
17	40 BEFR	10		50	25	
18	40 BEFR	25		80	10	
19	40 BCTP	10		100		
20	40 BCTP			100		
21	40 BCTP			100		
22	40 BGFR	50			50	
23	40 BGFR	50			50	
24	40 BGFR	50			50	
25	40 BDTL		100			
26	40 BDTL		100			
27	40 BDTL		100			
28	40 BHTP	80		20		
29	40 BHTP	95		5		
30	40 BHTP	90		10		
Sl2	40BEFR2h	30		70		
Sl4	40BEFR4h			100		
SL9	40BEFR9			100		
Sl10	40BEFR10			100		

Sl = slab

Appendix 5.70 – Fracture partition at peel test of specimens with w/c=0.60 (%)

No	Flooring system	Flooring-adhesion	Flooring-cohesion	Adhesive-cohesion	Self-leveling c.-adhesion	Self-leveling c.-cohesion
31	60AEFR				80	20
32	60AEFR				20	80
33	60AEFR				100	
34	60ACTL		10		70	20
35	60ACTL		100			
36	60ACTL		90		10	
37	60ACTP			100		
38	60ACTP	5		90		
39	60ACTP	20		80		
40	60AGFR	10				90
41	60AGFR	10				90
42	60AGFR	10				90
43	60AHTP	5			45	50
44	60AHTP	5				95
45	60AHTP				50	50
46	60BEFR	5		85	10	
47	60BEFR	10			90	
48	60BEFR	5		15	80	
49	60BCTP			100		
50	60BCTP	10		90		
51	60BCTP			100		
52	60BGFR	50			50	
53	60BGFR	15		5	80	
54	60BGFR	40			60	
55	60BDTL		90		10	
56	60BDTL		100			
57	60BDTL		100			
58	60BHTP	80			20	
59	60BHTP	50			50	
60	60BHTP	40			60	
Sl5	60BEFR5h	30		70		
Sl6	60BEFR6h			100		
Sl11	60BEFR11			100		
Sl12	60BEFR12			100		

Sl = slab

APPENDIX 6 –VOLATILE ORGANIC COMPOUND EMISSIONS [14]

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REPORT
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Date	Reference	Page
2005-12-30	F4 17361/rev	1 (8)

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Rev.date
2006-02-02

Lunds Tekniska Högskola, LTH
Bertil Persson
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Emission measurements

(1 appendix)

Objects

Sixty specimen of composite floor structures were delivered by Lund Institute of Technology.

Sample marking:	No 1 - No 60 (see results)
Arrived at SP:	2005-08-16: No 1 - 30
	2005-09-20: No 31 - 60
Sampling dates:	2005-08-22--2005-09-23 (No 1 - 30)
	2005-09-28--2005-10-21 (No 31 - 60)

The specimens were stored until they were tested in controlled climate conditions of 23 ± 2 °C and 50 ± 5 % RH.

Work requested

Emission measurements of volatile organic compounds according to prEN 13419-2 :2002 “Building products – Determination of the emission of volatile organic compound – part 1: Emission test cell method”.

Method

The emission was measured by using a test cell, FLEC (Field and Laboratory Emission Cell), according to prEN 13419-2. The emission was measured after 24 hours of ventilation. Tenax TA was used as adsorption medium.

Conditions of the test:

Test chamber volume	0.000035 m^3
Area of sample	0.0177 m^2
Air exchange rate	634 h^{-1}
Area specific air flow rate	1.25 m^3/m^2h
Temperature	23 ± 1 ^oC
Relative Humidity	50 ± 5 % RH

The Tenax tubes were thermally desorbed and analysed in accordance to accredited SP method 0601. This means an analysis in a gas chromatograph and detection with a flame ionisation detector (FID) and mass selective detector (MS). The FID signals are used for compound quantification.

SP Swedish National Testing and Research Institute

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Results

The results of the emission measurements regarding the total volatile organic compounds (TVOC) are presented as area specific emission rates in the two tables below:

No	**Legend**	**TVOC**	**Mean TVOC**	**SD**	**RSD**
		(µg/m^{2}h)	(µg/m^{2}h)	(µg/m^{2}h)	(%)
1	40AEFR	21	23	2,2	9,6
2	40AEFR	25			
3	40AEFR	24			
4	40ACTL	122	114	7,1	6,2
5	40ACTL	112			
6	40ACTL	109			
7	40ACTP	< 10	< 10	n.a.	n.a.
8	40ACTP	< 10			
9	40ACTP	< 10			
10	40AGFR	89	117	25,2	21,5
11	40AGFR	138			
12	40AGFR	124			
13	40AHTP	36	38	2,5	6,5
14	40AHTP	41			
15	40AHTP	38			
16	40BEFR	16	15	1,5	10,2
17	40BEFR	16			
18	40BEFR	15			
19	40BCTP	< 10	< 10	< 10	n.a.
20	40BCTP	< 10			
21	40BCTP	14			
22	40BGFR	237	231	15,3	6,6
23	40BGFR	243			
24	40BGFR	214			
25	40BDTL	359	288	96,0	33,3
26	40BDTL	179			
27	40BDTL	327			
28	40BHTP	66	99	30,3	30,5
29	40BHTP	107			
30	40BHTP	125			

No	Legend	TVOC (µg/m²h)	Mean TVOC (µg/m²h)	SD (µg/m²h)	RSD (%)
31	60AEFR	< 10	< 10	1,1	n.a.
32	60AEFR	< 10			
33	60AEFR	< 10			
34	60ACTL	95	113	16,0	14,2
35	60ACTL	118			
36	60ACTL	126			
37	60ACTP	< 10	< 10	2,7	n.a.
38	60ACTP	< 10			
39	60ACTP	< 10			
40	60AGFR	191	166	21,9	13,2
41	60AGFR	173			
42	60AGFR	149			
43	60AHTP	50	50	15,3	30,4
44	60AHTP	41			
45	60AHTP	72			
46	60BEFR	< 10	< 10	7,7	n.a.
47	60BEFR	< 10			
48	60BEFR	18			
49	60BCTP	< 10	< 10	8,6	n.a.
50	60BCTP	15			
51	60BCTP	14			
52	60BGFR	211	214	5,8	2,7
53	60BGFR	221			
54	60BGFR	211			
55	60BDTL	236	226	18,5	8,2
56	60BDTL	237			
57	60BDTL	205			
58	60BHTP	64	76	10,1	13,4
59	60BHTP	84			
60	60BHTP	79			

Evaluation according to prEN 15052:2004

Requirements according to prEN 15052:2004 (Resilient, textile and laminate floor coverings – Evaluation and requirements of volatile organic compounds (VOC) emissions):

Requirements after 28 days:

TVOC	≤ 1 000 µg/m³
$R = \sum C_i / LCI_i$	≤ 1
∑ Carcinogenics	≤ 2 µg/m³

For definitions, see appendix 1.

Results presented according to prEN 15052:2004:

No	**Legend**	**TVOC** (µg/m^3)	**R** =$\sum C_i/LCI_i$	**∑ Carcino-genics** (µg/m^3)	**∑ VOC without LCI** (µg/m^3)
1-3	40AEFR	18	0	n.d.	13
4-6	40ACTL	84	0,26	n.d.	9
7-9	40ACTP	< 5	0	n.d.	< 5
10-12	40AGFR	94	0,07	n.d.	19
13-15	40AHTP	31	0,03	n.d.	< 5
16-18	40BEFR	12	0	n.d.	< 5
19-21	40BCTP	< 5	0,01	n.d.	< 5
22-24	40BGFR	185	0,16	n.d.	23
25-27	40BDTL	231	0,40	n.d.	24
28-30	40BHTP	79	0,08	n.d.	< 5
31-33	60AEFR	< 5	0	n.d.	< 5
34-36	60ACTL	90	0,18	n.d.	< 5
37-39	60ACTP	< 5	0	n.d.	< 5
40-42	60AGFR	133	0,08	n.d.	23
43-45	60AHTP	40	0,03	n.d.	10
46-48	60BEFR	< 10	0	n.d.	< 5
49-51	60BCTP	< 10	0,010	n.d.	< 5
52-54	60BGFR	172	0,15	n.d.	13
55-57	60BDTL	181	0,23	n.d.	23
58-60	60BHTP	60	0,05	n.d.	< 5

n.d.= not detected

Individual compounds:

No 1-3 (40AEFR) **Compound**	**CAS number**	**SER** (µg/m^{2}h)	**Quanti-fication**	**C$_i$** (µg/m3)	**LCI$_i$** (µg/m^3)	**R** (C_i/LC_i)
nonanal	124-19-6	3	A	4	640	
benzoic acid	65-85-0	3	B	3		
benzothiazole	95-16-9	6	B	4		
butylated hydroxytoluene	128-37-0	3	B	2	100	

No 4-6 (40ACTL) **Compound**	**CAS-number**	**SER** (µg/m^{2}h)	**Quanti-fication**	**C_i** (µg/m3)	**LCI_i** (µg/m^3)	**R** (C_i/LC_i)
propanoic acid	79-09-4	10	A	27	310	0,09
pentanal	110-62-3	4	A	5	1700	0,00
butanoic acid	107-92-6	3	A	6	310	0,02
hexanal	66-25-1	9	A	11	640	0,02
pentanoic acid	109-52-4	4	A	7	310	0,02
heptanal	111-71-7	3	A	4	640	
hexanoic acid	142-62-1	15	A	22	310	0,07
octanal	124-13-0	9	A	9	640	0,01
heptanoic acid	111-14-8	4	B	3	310	
1-octanol	111-87-5	3	B	2	2700	
nonanal	124-19-6	17	A	17	640	0,03
octanoic acid	124-07-2	5	B	4	310	
nonanoic acid	112-05-0	6	B	5		
2-decenal	2497-25-8	3	B	2	10	
benzothiazole	95-16-9	2	B	2		
2-(2-butoxyethoxy)ethanol, acetate	124-17-4	1	B	< 2	1000	
2-undecenal	2463-77-6	3	B	2	10	

No 7-9 (40ACTP) **Compound**	**CAS-number**	**SER** (µg/m^{2}h)	**Quanti-fication**	**C_i** (µg/m3)	**LCI_i** (µg/m^3)	**R** (C_i/LC_i)
2-ethylhexanol	104-76-7	1	A	< 2	2700	

No 10-12 (40AGFR) **Compound**	**CAS-number**	**SER** (µg/m^{2}h)	**Quanti-fication**	**C_i** (µg/m3)	**LCI_i** (µg/m^3)	**R** (C_i/LC_i)
nonanal	124-19-6	4	A	4	640	
benzoic acid	65-85-0	5	B	4		
2-(2-butoxyethoxy)ethanol	112-34-5	32	B	26	1000	0,026
benzothiazole	95-16-9	6	B	5		
2-(2-butoxyethoxy)ethanol, acetate	124-17-4	54	B	43	1000	0,043
butylated hydroxytoluene	128-37-0	3	B	3	100	

No 13-15 (40AHTP) **Compound**	**CAS-number**	**SER** (µg/m^{2}h)	**Quanti-fication**	**C_i** (µg/m3)	**LCI_i** (µg/m^3)	**R** (C_i/LC_i)
1-butanol	71-36-3	< 2	A	< 2	3100	
2-ethylhexanol	104-76-7	5	A	6	2700	0,002
2-(2-butoxyethoxy)ethanol	112-34-5	19	B	15	1000	0,02
2-(2-butoxyethoxy)ethanol, acetate	124-17-4	20	B	16	1000	0,02

No 16-18 (40BEFR) **Compound**	**CAS-number**	**SER** (µg/m^{2}h)	**Quanti-fication**	**C_i** (µg/m3)	**LCI_i** (µg/m^3)	**R** (C_i/LC_i)
nonanal	124-19-6	3	A	3	640	
benzoic acid	65-85-0	4	B	4		
2-phenoxy-ethanol	122-99-6	6	B	4	1100	
benzothiazole	95-16-9	5	B	4		
butylated hydroxytoluene	128-37-0	2	B	2	100	

No 19-21 (40BCTP) **Compound**	**CAS-** **number**	**SER** (µg/m^{2}h)	**Quanti-** **fication**	**C_i** (µg/m3)	**LCI_i** (µg/m^3)	**R** (C_i/LC_i)
2-ethylhexanol	104-76-7	5	A	5	2700	0,002
2-phenoxy-ethanol	122-99-6	12	B	9	1100	0,01

No 22-24 (40BGFR) **Compound**	**CAS-** **number**	**SER** (µg/m^{2}h)	**Quanti-** **fication**	**C_i** (µg/m3)	**LCI_i** (µg/m^3)	**R** (C_i/LC_i)
1-butanol	71-36-3	1	A	2	3100	
nonanal	124-19-6	5	A	5	640	0,01
benzoic acid	65-85-0	4	B	3		
2-(2-butoxyethoxy)ethanol	112-34-5	46	B	37	1000	0,04
2-phenoxy-ethanol	122-99-6	19	B	15	1100	0,01
benzothiazole	95-16-9	8	B	7		
2-(2-butoxyethoxy)ethanol, acetate	124-17-4	127	B	102	1000	0,10
butylated hydroxytoluene	128-37-0	3	B	2	100	

No 25-27 (40BDTL) **Compound**	**CAS-** **number**	**SER** (µg/m^{2}h)	**Quanti-** **fication**	**C_i** (µg/m3)	**LCI_i** (µg/m^3)	**R** (C_i/LC_i)
1-butanol	71-36-3	2	A	3	3100	
propanoic acid	79-09-4	10	A	25	310	0,08
pentanal	110-62-3	4	A	5	1700	0,003
butanoic acid	107-92-6	3	A	5	310	0,02
hexanal	66-25-1	9	A	10	640	0,02
pentanoic acid	109-52-4	3	A	5	310	0,02
heptanal	111-71-7	4	A	5	640	
hexanoic acid	142-62-1	15	A	22	310	0,07
octanal	124-13-0	7	A	8	640	0,01
heptanoic acid	111-14-8	4	B	3	310	
nonanal	124-19-6	16	A	17	640	0,03
octanoic acid	124-07-2	7	B	5	310	0,02
2-(2-butoxyethoxy)ethanol	112-34-5	16	B	13	1000	0,01
2-phenoxy-ethanol	122-99-6	5	B	4	1100	
nonanoic acid	112-05-0	7	B	6		
2-decenal	2497-25-8	5	B	4	10	
benzothiazole	95-16-9	6	B	5		
2-(2-butoxyethoxy)ethanol, acetate	124-17-4	160	B	128	1000	0,13

No 28-30 (40BHTP) **Compound**	**CAS-** **number**	**SER** (µg/m^{2}h)	**Quanti-** **fication**	**C_i** (µg/m3)	**LCI_i** (µg/m^3)	**R** (C_i/LC_i)
1-butanol	71-36-3	2	A	3	3100	
2-ethylhexanol	104-76-7	6	A	6	2700	0,002
2-(2-butoxyethoxy)ethanol	112-34-5	25	B	20	1000	0,02
2-phenoxy-ethanol	122-99-6	29	B	23	1100	0,02
2-(2-butoxyethoxy)ethanol, acetate	124-17-4	49	B	39	1000	0,04

No 31-33 (60AEFR) **Compound**	**CAS** **number**	**SER** (µg/m^{2}h)	**Quanti-** **fication**	**C_i** (µg/m3)	**LCI_i** (µg/m^3)	**R** (C_i/LC_i)
butylated hydroxytoluene	128-37-0	4	B	3	100	

No 34-36 (60ACTL) **Compound**	**CAS-number**	**SER** ($\mu g/m^2h$)	**Quanti-fication**	C_i (µg/m3)	LCI_i ($\mu g/m^3$)	**R** (C_i/LC_i)
propanoic acid	79-09-4	9	A	22	310	0,07
pentanal	110-62-3	4	A	5	1700	0,003
butanoic acid	107-92-6	2	A	4	310	
hexanal	66-25-1	8	A	9	640	0,01
pentanoic acid	109-52-4	2	A	4	310	
heptanal	111-71-7	3	A	3	640	
hexanoic acid	142-62-1	11	A	16	310	0,05
octanal	124-13-0	7	A	7	640	0,01
nonanal	124-19-6	16	A	16	640	0,03
octanoic acid	124-07-2	4	B	3	310	
nonanoic acid	112-05-0	4	B	3		
2-decenal	2497-25-8	5	B	4	10	
benzothiazole	95-16-9	2	B	2		
2-(2-butoxyethoxy)ethanol, acetate	124-17-4	3	B	2	1000	
2-undecenal	2463-77-6	2	B	< 2	10	

No 37-39 (60ACTP) **Compound**	**CAS-number**	**SER** ($\mu g/m^2h$)	**Quanti-fication**	C_i (µg/m3)	LCI_i ($\mu g/m^3$)	**R** (C_i/LC_i)
2-ethylhexanol	104-76-7	1	A	< 2	2700	
2-(2-butoxyethoxy)ethanol, acetate	124-17-4	1	B	< 2	1000	

No 40-42 (60AGFR) **Compound**	**CAS-number**	**SER** ($\mu g/m^2h$)	**Quanti-fication**	C_i (µg/m3)	LCI_i ($\mu g/m^3$)	**R** (C_i/LC_i)
nonanal	124-19-6	3	A	3	640	
2-(2-butoxyethoxy)ethanol	112-34-5	45	B	36	1000	0,04
benzothiazole	95-16-9	4	B	3		
2-(2-butoxyethoxy)ethanol, acetate	124-17-4	61	B	49	1000	0,05
butylated hydroxytoluene	128-37-0	2	B	2	100	

No 43-45 (60AHTP) **Compound**	**CAS-number**	**SER** ($\mu g/m^2h$)	**Quanti-fication**	C_i (µg/m3)	LCI_i ($\mu g/m^3$)	**R** (C_i/LC_i)
2-ethylhexanol	104-76-7	3	A	3	2700	
2-(2-butoxyethoxy)ethanol	112-34-5	19	B	15	1000	0,02
2-(2-butoxyethoxy)ethanol, acetate	124-17-4	19	B	15	1000	0,02

No 46-48 (60BEFR) **Compound**	**CAS-number**	**SER** ($\mu g/m^2h$)	**Quanti-fication**	C_i (µg/m3)	LCI_i ($\mu g/m^3$)	**R** (C_i/LC_i)
2-phenoxy-ethanol	122-99-6	3	B	3	1100	
benzothiazole	95-16-9	2	B	5		
2-(2-butoxyethoxy)ethanol, acetate	124-17-4	0	B	4	1000	
butylated hydroxytoluene	128-37-0	3	B	2	100	

No 49-51 (60BCTP) **Compound**	**CAS-number**	**SER** ($\mu g/m^2h$)	**Quanti-fication**	C_i (µg/m3)	LCI_i ($\mu g/m^3$)	**R** (C_i/LC_i)
2-ethylhexanol	104-76-7	1	A	5	2700	0,002
2-phenoxy-ethanol	122-99-6	6	B	9	1100	0,008

No 52-54 (60BGFR) Compound	**CAS-number**	**SER** ($\mu g/m^2h$)	**Quanti-fication**	**C_i** (μg/m3)	**LCI_i** ($\mu g/m^3$)	**R** (C_i/LC_i)
1-butanol	71-36-3	1	A	< 2	3100	
nonanal	124-19-6	1	A	2	640	
2-(2-butoxyethoxy)ethanol	112-34-5	60	B	48	1000	0,05
2-phenoxy-ethanol	122-99-6	17	B	14	1100	0,01
benzothiazole	95-16-9	4	B	3		
2-(2-butoxyethoxy)ethanol, acetate	124-17-4	115	B	92	1000	0,09
butylated hydroxytoluene	128-37-0	3	B	3	100	

No 55-57 (60BDTL) Compound	**CAS-number**	**SER** ($\mu g/m^2h$)	**Quanti-fication**	**C_i** (μg/m3)	**LCI_i** ($\mu g/m^3$)	**R** (C_i/LC_i)
1-butanol	71-36-3	1	A	< 2	3100	
propanoic acid	79-09-4	5	A	14	310	0,04
pentanal	110-62-3	2	A	3	1700	
hexanal	66-25-1	6	A	7	640	0,011
pentanoic acid	109-52-4	2	A	3	310	
heptanal	111-71-7	3	A	4	640	
hexanoic acid	142-62-1	8	A	12	310	0,04
octanal	124-13-0	6	A	6	640	0,009
heptanoic acid	111-14-8	2	B	2	310	
nonanal	124-19-6	14	A	14	640	0,02
octanoic acid	124-07-2	5	B	4	310	
2-(2-butoxyethoxy)ethanol	112-34-5	18	B	15	1000	0,01
2-phenoxy-ethanol	122-99-6	5	B	4	1100	
nonanoic acid	112-05-0	5	B	4		
2-decenal	2497-25-8	4	B	3	10	
benzothiazole	95-16-9	4	B	4		
2-(2-butoxyethoxy)ethanol, acetate	124-17-4	117	B	93	1000	0,09

No 58-60 (60BHTP) Compound	**CAS-number**	**SER** ($\mu g/m^2h$)	**Quanti-fication**	**C_i** (μg/m3)	**LCI_i** ($\mu g/m^3$)	**R** (C_i/LC_i)
1-butanol	71-36-3	1	A	< 2	3100	
2-ethylhexanol	104-76-7	4	A	4	2700	
2-(2-butoxyethoxy)ethanol	112-34-5	21	B	17	1000	0,02
2-phenoxy-ethanol	122-99-6	19	B	15	1100	0,01
2-(2-butoxyethoxy)ethanol, acetate	124-17-4	28	B	22	1000	0,02

The revision was made 2 February 2006 and concerns correction of R values according to the definition of LCI. There is also an addition of an appendix with the relevant definitions.

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Appendix

1. Definitions

Appendix 1

Definitions

VOC:	All individual substances with concentrations ≥ 0.002 mg/m^3 within the retention range $C_6 – C_{16}$.
TVOC:	Sum of the concentration of all individual substances within the retention range $C_6 – C_{16}$, in toluene equivalent.
SD:	Standard deviation.
RSD:	Relative standard deviation.
C_i:	Concentration of volatile organic compound (VOC) in µg/m^3.
LCI:	Lowest Concentrations of Interest - Lowest concentration above which, according to best professional judgment, an organic compound might have some adverse affect on people in the indoor environment. The list is based on AgBB (Ausschuss zur gesundheitlichen Bewertung von Bauprodukten) list of July 2004. Substances with a concentration exceeding 5 µg/m^3 are evaluated based on LCI. Low concentrations, in combination with very small LCI values around 10 µg/m^3 may result in high and “false” R values.
Carcinogenic compounds:	the list to be considered is the consolidated list of carcinogenic compounds realted to point 29 to annex 1 of the European Directive 76/769/EEC
∑ VOC without LCI:	The toluene equivalent concentration of the sum of all non-assessable compounds (with unknown LCI).
Quantification::	A = quantified as compound specific B = quantified as toluene equivalent
SER:	Area specific emission rate

Legend:

A	low-alkali self-levelling compound (Akzo Nobel Deco International Schönox CP)
B	low-alkali self-levelling compound (Bostik Golvspackel Fiber Quick)
C	alkali-resistant linoleum and PVC adhesive (Bostik Golvlim AlcaliTac AT)
D	standard polyacrylate linoleum adhesive (Akzo Nobel Deco International Cascolin 3449)
E	alkali-resistant rubber adhesive (AKZO NOBEL Casco Proff Solid 3480)
FR	Freudenberg rubber flooring {noraplan mega, beige/fawn tiles (color 2674), batch no. 1331920000, blue tiles (color 2171), batch no. 1187220000}
G	standard polyacrylate rubber adhesive (Bostik Golv- och Vägglim MultiTac MT)
H	standard PVC adhesive (Akzo Nobel Deco International Casco Cascoproff 3448)
TL	Tarkett linoleum flooring (as delivered)
TP	Tarkett PVC flooring (as delivered)
40 or 60	Water-cement ratio, w/c, of concrete (%)

APPENDIX 7 –TEST METHOD

Appendix 7.1 - Compatibility between flooring system and concrete – pre-testing method for determination of internal relative humidity, emission of Volatile Organic Compounds and adhesion

Appendix 7.2 - Kompatibilitet av golvsystem – förprovningsmetod för bestämning av inre relativ fuktighet i betong, emission av flyktiga organiska ämnen och fläkningskraft

Appendix 7.1 - Compatibility between flooring system and concrete – pre-testing method for determination of internal relative humidity, emission of Volatile Organic Compounds and adhesion

1. Objective

The method is developed for assessment of a floor construction consisting of concrete, floor screed, adhesive and resilient surface flooring taking into account the internal relative humidity (RH%) in the concrete, emission of Volatile Organic Compounds (VOC) to the air adhesion of the surface flooring to the concrete.

The objective of this method is to be able to predict/estimate the emission of organic compounds from the flooring system based on the assumption that the flooring system is performed precisely as in the reality with respects to both the construction and influence of time.

2. Principals

The test specimens are prepared (casting) that simulates in a broadly way a full-scale flooring system. Concrete, probable floor screed, adhesive and surface flooring are included in the specimen. The specimen is prepared with exactly the same components that will be included in the final flooring system. The time aspects shall simulate the pre-tested flooring system in a realistic way with respect to the curing of the concrete (temperature, time and relative humidity in air), drying time and relative humidity for floor screed, opening times for adhesion and pressure at the application of the surface flooring. The specimen is prepared in triplicate.

The parameter to be measured after casting at specified time points:

1. Internal relative humidity in the concrete *before* the measurement of chemical emission – according to SOP-6 method (1)
2. Emission of volatile organic compounds according to European standard prEN 15052 (2)
3. Internal relative humidity in the concrete *after* the measurement of chemical emission – according to SOP-6 method (1)
4. Adhesion by a peeling test according the European standard EN 1372 (3)

3. Equipment

Equipment is specified in the respective method.

4. Execution

4.1 Casting of the specimen

Specimen in triplicate is casted in a way that simulate the real construction in the most realistic way according to specification from the commissioner.

4.2 Testing

The internal relative humidity in the concrete will be measured two weeks after application of the surface flooring system according to the SOP-6 method *before* the emission measurements. Arithmetic mean and standard deviation will be calculated from the three measurements.

The emission of volatile organic compounds according to the prEN 15052 will be measured three and/or six months after the application of the surface flooring. Results are expressed in accordance with the prEN 15052. Arithmetic mean and standard deviation will be calculated from the three measurements.

The internal relative humidity in the concrete will be measured two weeks *after* the emission measurements according to the SOP-6 method. Arithmetic mean and standard deviation will be calculated from the three measurements.

Adhesion using a peel test according to the standard EN 1372 will be measured two weeks after the second measurement of the internal relative humidity in the concrete, alternatively after the emission measurements. Arithmetic mean and standard deviation will be calculated from the three measurements.

5. Documentation

The following documentation is required for the testing:

1. A list of all components included in the specimen
2. Dates of casting, the first measurement of the internal humidity, emission testing, the second measurement of the internal humidity and adhesion test
3. Compilation of results
4. Report

6. References

1. SOP-6. Standard Operation Procedure for Measurement of Internal Relative Humidity in Concrete, IRH CONCRETE®. Standard Operation Procedure at Division of Building Materials, Lund Institute of Technology, Lund, Sweden. 14 April 2005.

2. Draft prEN 15052:2004 Resilient, textile and laminate floor coverings – Evaluation and requirements of volatile organic compounds (VOC) emission.

3. EN 1372. Peel test.

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Appendix 7.2 - Kompatibilitet av golvsystem – förprovningsmetod för bestämning av inre relativ fuktighet i betong, emission av flyktiga organiska ämnen och fläkningskraft

1. Syfte, användningsområde

Metoden är framtagen för bedömning av en golvkonstruktion bestående av betong, avjämningsmassa, lim och ytbeläggning med avseende på den interna relativa fuktigheten i betongen, emission av flyktiga organiska ämnen (VOC = volatile organic compounds) till luft samt vidhäftning av ytbeläggningen till betongen.

Metoden syftar till att kunna förutse emission av organiska ämnen från golvsystem före det att konstruktionen är utförd. Metoden för förprovning bygger på att golvsystemet utförs så lika som möjligt som i verkligheten med avseende på vilka komponenter som ingår samt proceduren som används i byggandet både konstruktions- och tidsmässigt.

2. Princip

Provkroppar bereds så att de så långt som möjligt simulerar ett golvsystem i full skala. I provkropparna skall ingå betong, avjämningsmassa, lim samt ytbeläggning. Provet tillverkas med de komponenter som skall ingå i det slutliga golvsystemet. Tidsförhållandena skall vara sådana att de simulerar det förprovade golvsystemet på ett realistiskt sätt med avseende på härdningssätt för betong (temperatur, tid och omgivande relativ luftfuktighet), torktid och omgivande relativ luftfuktighet för avjämningsmassa, öppethållandetid för limning samt presstryck vid ytbeläggning. Provkroppar bereds i triplikat.

Vid bestämda tidpunkter efter provberedningen skall mätas:
1. Relativ fuktighet i betongen före mätning av kemisk emission– enligt SOP-6 metoden (1)
2. Emission av flyktiga organiska ämnen enligt europeisk standard prEN 15052 (2)
3. Relativ fuktighet i betongen efter mätning av kemisk emission– enligt SOP-6 metoden (1)
4. Vidhäftning genom ett fläkningstest enligt europeisk standard EN 1372 (3)

3. Utrustning

Utrustningen är specificerad i respektive metod.

4. Utförande

4.1 Beredning av provkroppar

Provkroppar i triplikat bereds för att så noga som möjligt simulerar den verkliga konstruktionen enligt uppdragsgivarens specifikation. LINDAB muff och aluminiumfolie används vid provberedning.

4.2 Provning

Två veckor efter appliceringen av ytbeläggningen mäts inre relativ fuktighet i betongen enligt standarden SOP-6 före emissionmätning. Medelvärde och standardavvikelse beräknas för de tre mätningarna.

Tre och/eller sex månader efter applicering av ytbeläggningen provas kemisk emission enligt prEN 15052. Medelvärde och standardavvikelse beräknas för de tre mätningarna.

Två veckor efter emissionsmätning mäts inre relativ fuktighet i betongen enligt standarden SOP-6. Medelvärde och standardavvikelse beräknas för de tre mätningarna.

Två veckor efter den andra mätningen av inre relativ fuktighet, alternativt efter emissionsmätningen mäts fläkningskraft av ytbeläggningen enligt standarden EN 1372. Medelvärde och standardavvikelse beräknas för de tre mätningarna.

5. Dokumentation

För provningen krävs följande dokumentation:
1. Beteckningen för komponenter ingående i provkroppar.
2. Tidpunkter för provberedning, 1:a fuktmätning enligt SOP-6, emissionstest enligt prEN 15052, 2:a fuktmätning enligt SOP-6 och vidhäftningstest enligt EN 1372.
3. Resultatsammanställning
4. Rapport

6. Referenser

1. SOP-6. Standard Operation Procedure for Measurement of Internal Relative Humidity in Concrete, IRH CONCRETE®. Standard Operation Procedure at Division of Building Materials, Lund Institute of Technology, Lund, Sweden. 14 April 2005.

2. Draft prEN 15052:2004 Resilient, textile and laminate floor coverings – Evaluation and requirements of volatile organic compounds (VOC) emission.

3. EN 1372. Peel test.

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