Final Degree Project:

Bremerhaven's Christus-Kirchengemeinde restoration.

by

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1 Introduction.

Time never stops, and things are getting older second by second. That's why everything has an expiration date, when it stops doing its function. We can increase this date, by repairing and preserving.

This project is developed because of the necessity to find a solution for the problems in the Bremerhaven's church.

Not a lot time ago, the church was restored, but unfortunately a new problem with the adherence of the bricks with the mortar in some places has appeared. This is a humidity problem.

This problem can cause personal damages so is important to solve it, not just for the beauty of the church or to keep working for the architectonic destiny it was built, but also for the security of the people who walk near the façade of the building.

2 Aim of the project.

This project tries to find a solution in order to make impossible that bricks break down and keep the architectonic part were they are placed.

The solution we looked for was to find a new mortar with a high adherence strength that keeps the bricks together even the impermeable paint.

To find it, six different mortars have been chosen. These mortars will be tested and their strength will be measured. Then a decision will be taken and used in order to repair the churches problem.

3 Memory.

3.1 Background

3.1.1 Location

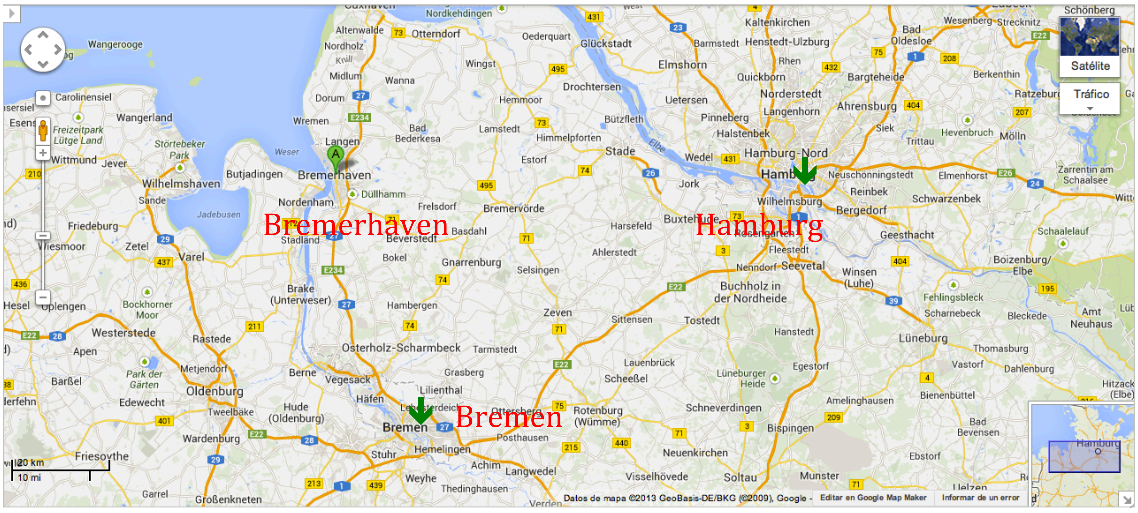
The Evangel-Luth. Pfarramt Christus-Kirchengemeinde is situated in Schillerstraße, Bremerhaven with 27570 as postcode. Between Bismarckstraße and Kehdinger Straße.

Pic.3.1.1.1 Situation map (Google maps)

At the east of the church about 1,2 kilometer far away from it we can find the entrance of the North Sea into the land.

Pic.3.1.1.2 Situation map (Google maps)

Bremerhaven is located in the north of Germany, approximately 63 kilometers from Bremen and at 120 kilometers at the South or Hamburg.



Pic 3.1.1.3 Location map (Google maps)

The building is easy to get to, with a good communication by public transport and a good highway network. And also the city has a well-known port, which provides the city to be communicated by sea and land.

3.1.2 Historical Context

In 1827, the city of Bremerhaven was set up. Almost twenty years later, at the south of Geeste, almost 3.000 new colons establish their new lives and built the port of Geestemünde. As a result of this new community, the Santa Maria medieval church was used as Gods house. But not in a lot of time, this church becomes not enough to harbor the increased population of the community. For this reason in 1863 the population decided to built a new and bigger church.

Pic 3.1.2.1 Churchs tower

The architect Rabbit was in charged to design the project. Despite being designed, it wasn't until the 19th of July 1872 when the first stone was placed.

The architectural style of this period was based on the style of the past, they didn't try to copy, and they just get the essence of previous centuries.

Three years were need by them to finish building the church. That's why in November 14th of 1875 the inauguration of the church toke place. However two years later, they saw problems with the mortar used in some parts of the construction was not good enough to withstand loads, so it can produce an overthrow. After the demolition and reconstruction of the tower the building was ended in 1880.

As is normal, the church is built with a lot of common things with other churches built in more o less the same age and relatively close to our. These are some examples of similar churches we can find.

Pic 3.1.2.2 Churchs new entrance.

3.1.3 Building description

The Christus-Kirchengemeinde consists in just one auditorium with a built-in choir in the facade of the tower. We can separate this auditorium in three subsections. The main one is in the middle and next to it we can find two shorter ones, separated by huge clover shape columns which base is one meter thick. These auditoriums are covered by a barrel vault each one. All vaults are covered by a gable roof, made of tiles.

Regarding the size of the building, 29 meters are the length and 18 meters the width. Bricks are the materials used to build the exterior walls. Buttresses situated between the gothic windows, which are part of the breast wall, help it. These buttresses are as tall as the windows. The shape of the top of them draws the same line as the roof, following the shape of the strength line and trying to make the water running easily. Although on top of each buttress the normal bricks are replaced by another type of bricks with a waterproof cover.

Pic 3.1.2.1 Bremerhavens church

There is one of the buttresses on each side of the church, which is bigger than the others. This one is supporting the tower. An orthogonal topping closes this squared section tower. It is more or less 60m high divided by five floors. The tower is over the principal facade being part of the main entrance. In each floor we can se an outgoing line which denotes where the floor structure.

3.1.4 Similar buildings

Pic. 3.1.4.1 Kirche Kalefeld, Kleiner Hagen, (Kalefeld, Germany).

As we can see, the church is also affected by the low temperatures, an also is built with enameled bricks.

Pic. 3.1.4.3 Pfarrkirche St. Dionysius, Hochstraβe, 27 (Kleneinbroich)

This church was restored because it had problems with bricks.

Pic. 3.1.4.4 Pfarrkirche St. Nikolaus in Übersee

In this last church we can appreciate that an impermeable plaque covers the top of buttresses, over a part of concrete.

That makes us think about the possibility of a change of material during a restoration. Maybe painted bricks, which didn't make their work properly and were changed by this final solution.

Besides the German architecture, in Spain the style of buildings in this age was really different, not only because of the climate. Also in Spain was taking place a development in the train infrastructure. So several train stations were built, but not buildings related with religion. The protestant movement did not influence Spain. Due to this, it will be hard to find protestant churches. This means that people in this age didn't need to build other churches. But is true that in Spain there is a high diversity of religious buildings. Muslims colonized a big part of Spain.

As regards to the Spanish buildings and the enameled bricks, it's hard to find buildings with this kind of bricks. However, during the XVI and XVII centuries the community of Valencia (Spain) started building emblematic churches in every town or city. These churches had a dome over them. To make this dome visible and showy were covered by blue smelted tiles.

Pic. 3.1.4.5 Blue smelted tiles over dome.

Anyway, it's impossible to compare these tiles with the bricks we are studying. First of all, in Valencia there is no problem with frozen water. Moreover the tiles are part of the cover the building, so they solve the permeability by overlap. This makes more difficult for water to go through the mortar.

Here there are some examples of the churches we just talk about. In fact, more buildings used this kind of tile, but only churches are still.

Pic. 3.1.4.6 Blue smelted tiles over dome

Pic. 3.1.4.7 Blue smelted tiles over dome

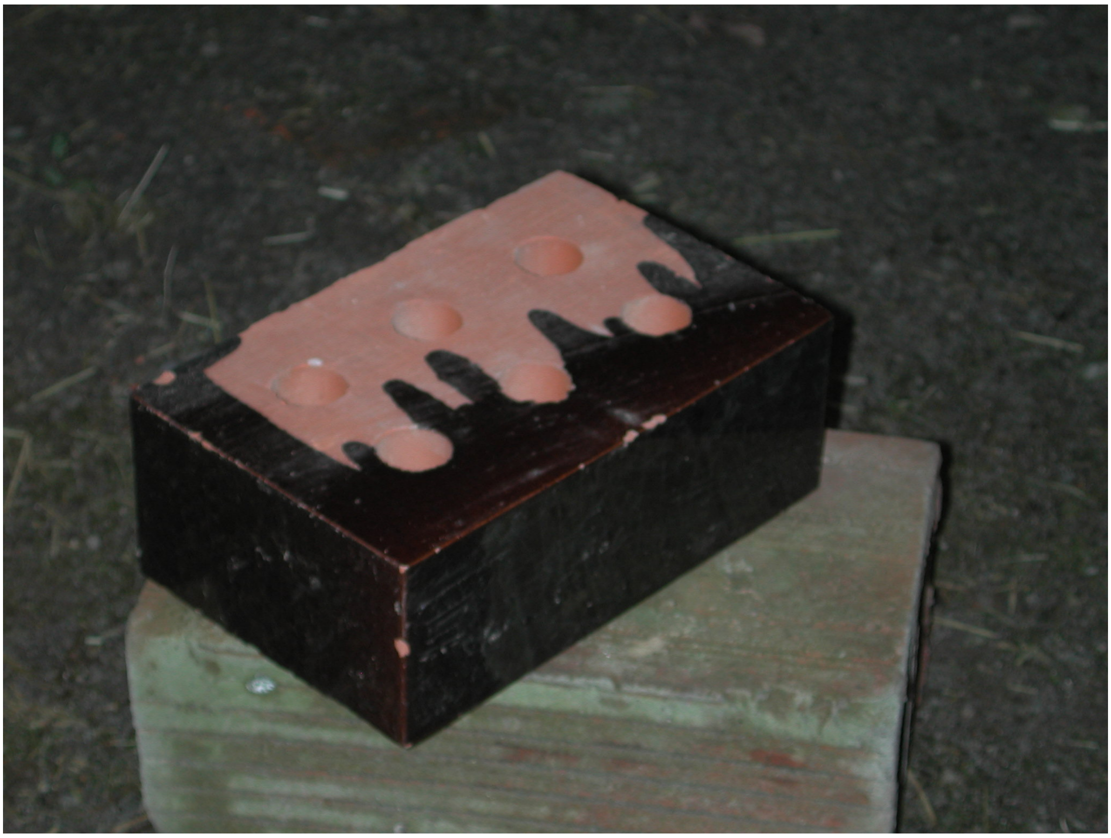
Pic. 3.1.4.6 Blue smelted tiles over dome (Serra, Valencia, Spain)

3.2 Intervention

3.2.1 Problem description

Bremerhaven's church has been restored not a long time ago. Even thought, it has some problems how still affecting the building. These problems are making the building not a safe place. Maybe, they are not affecting to the structural stability, but they are destroying the beauties of the façade. However, the most important is, that these problems can cause personal damage.

One of these problems is the one of which affects to the top of the buttresses. The buttresses were built with bricks, as all the façade. The ones on the top and on the sides are covered by a special impermeable paint in their visible surface. This paint is also over the not seen surface, as the next picture XXX shows.

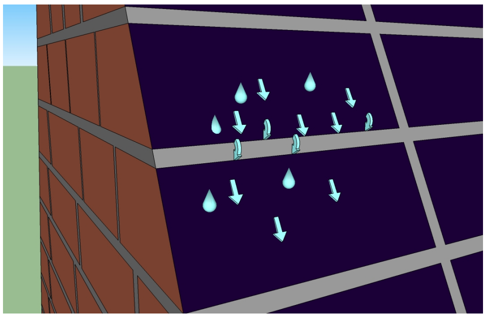


Pic. 3.2.1.1. Smelted brick.

The paint diverts water from the rain and humidity but also doesn't let the mortar paste properly in the surface in charged to receive it. That makes little holes between the mortar and the brick.

Pic. 3.2.1.2. Top of the buttress.

Because of this, water can come inside the already named holes and stay there after the rain. So when the temperature comes down, below cero degrees, this water becomes ice and increase it volume making the bricks not to stay in their place.



Due to this, the bricks are in risk to fall off caused by wind or other strength, which hits the affected bricks, causing damage. That's why it's important to find the way to keep them in their place. The solution can be to change the mortar into a special one.

The next mortar to be used needs to be a special mixture, containing special kind of glue, which keeps bricks together even in the part of this paint. This won't let water come between them, so it won't cause any damage again.

Besides, there are some bricks with out this impermeable paint that are damaged. This is probably caused by also the freezing of water, which is inside the internal pores, and comes from the rain.

Pic. 3.2.1.4. Spalling brick.

Anyway, is hard to see such so many problems in this side. It means, why in the south façade? It's supposed to be the driest side of the building. Is the place where the sun hits more time during the day. It's true that next to the church we can find water from the sea and also river. This cause a humid atmosphere that makes these problems works easily.

Therefore, maybe a preventive idea would be to avoid the entrance of water in the pores.

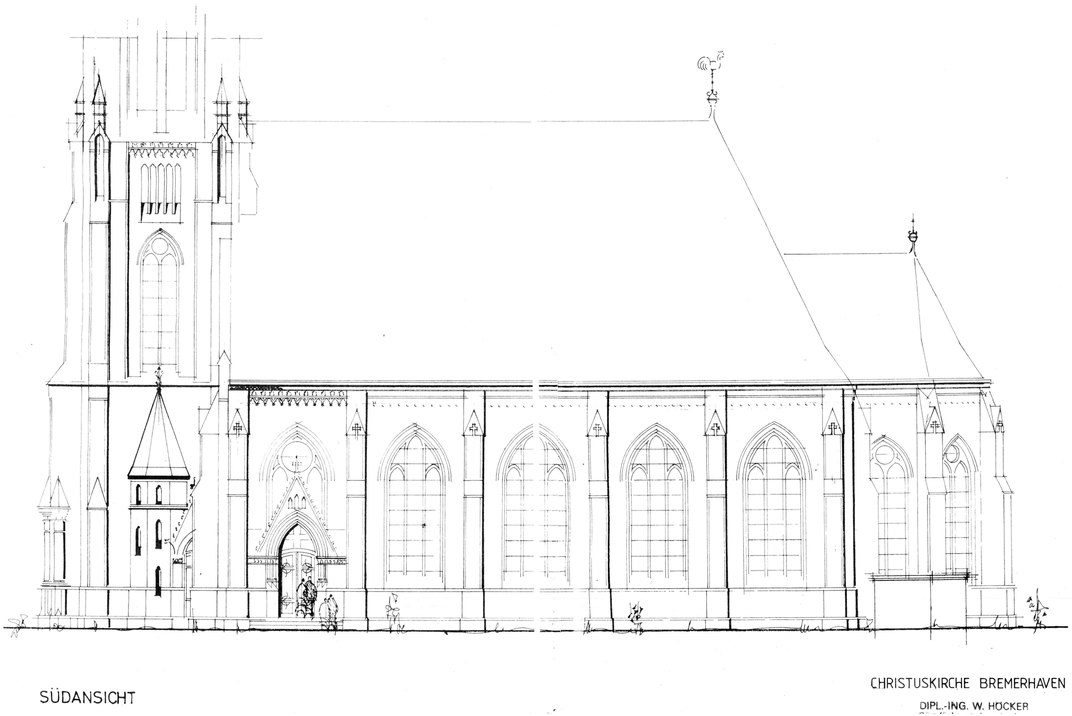
Pic. 3.2.1.5. *Vegetation in the wall*

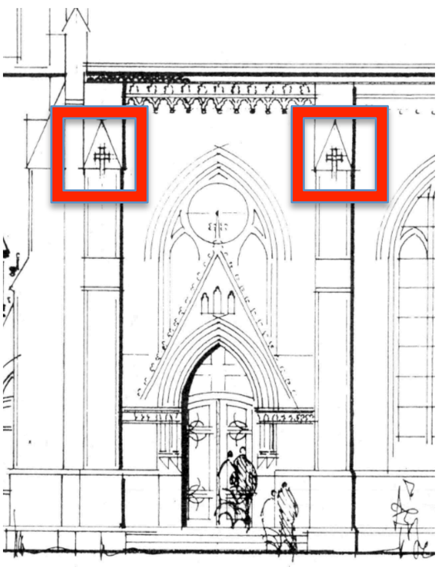
As is normal, there are other problems, which affects the north façade. These problems are produced because of the constant humidity of the north side. But we are not going to talk too much about them. The ones that has repercussion in our project are the already named ones.

Pic. 3.2.1.6. Humidity from the ground

3.2.2 Pathology mapping

The problems with the bricks are produced in one of the side façade. This is the south façade.





The loosed bricks are mainly on the top of the buttresses. Also there are worn brick all over this façade. In the previous picture we can see the named façade and were of most of the damage is.

3.3 Experimentation

3.3.1 Preparing mortars process.

Once we got to the point that we need to find a new mortar to kip bricks pasted in their correct place, was time to make as more type of testes as we can due to the fact, that we would get more information in this case. Then we need to test the mortar alone in a flexion and also compression way, bricks without mortar in just a compression way, and bricks with mortar together in this case in a traction way. The next paragraphs explains how was the mortars made.

In first case, we started making the mortar, so it could be used alone and in the traction tests between the mortar and bricks. So the process used to prepare these just named specimens, are based on the *European standard EN 1015-12 of February 2000, which* determinates the adhesive strength of mortars over supports and the *European standard EN 1015-11 determination of flexural and compressive strength.*

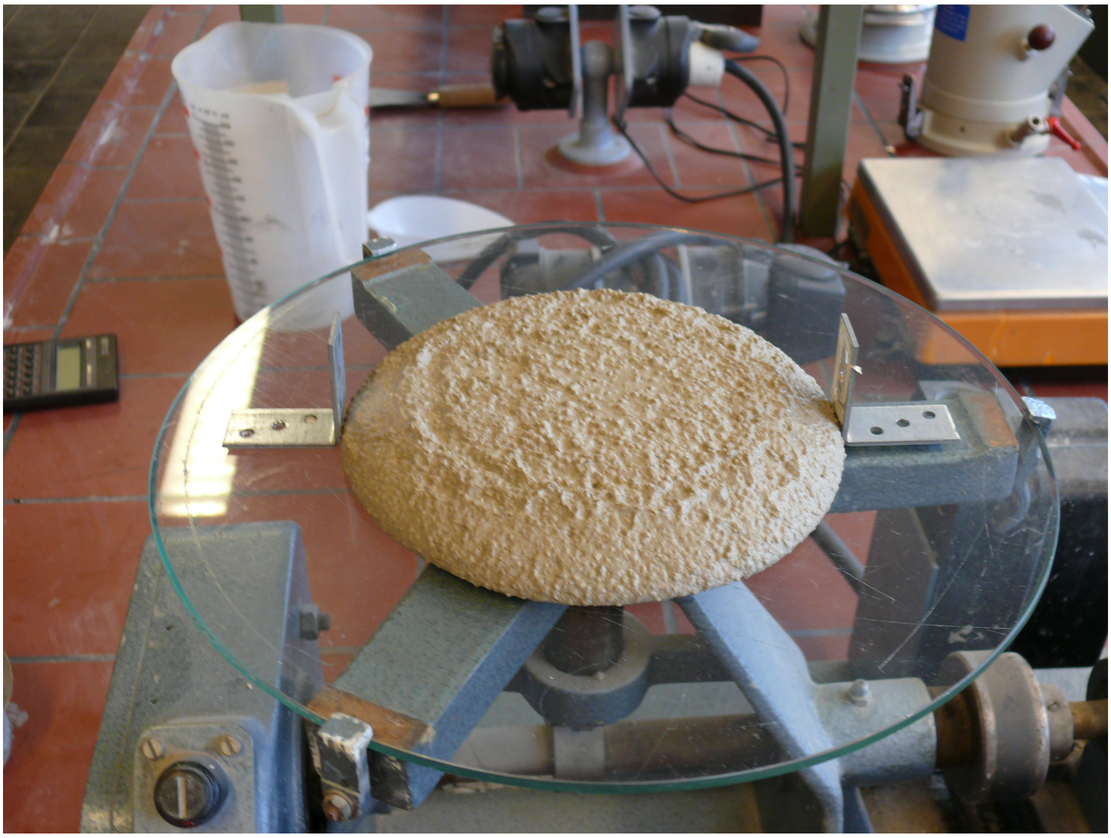
First of all, we need to find the proper proportion between water and cement to get a soft but not fluid consistence of the mortar. We find this proportion by trying with a small quantity of mix. Once we get the correct proportion by testing it in the flow table, we are able to make the mortar for testing.

The maximum mass of mortar we can do is three kg. So all the mixes were made of tree kg, counting the water and the cement together. Once we get the required amount, we put it inside a metallic recipient, wen all the ingredients are in the container we start mixing during 30 seconds, then we stop the machine and with a spoon we take the parts of the fund, we put the container again in the mixing machine during 90 more seconds. Now we have the mixt ready.

Pic. 3.3.1.1. Mortar mixer.

To prove that the mash has the correct consistence, we try it in the flow table. Attending to the *European standard EN 1015-03*, which explains how to get the value from the flow table, we need to place the metallic mold in the middle of the table, we introduce the mixt in the mold in two times, after each time its required to compact the paste hitting it with the pounder. During the fill up it's required to hang the mold hardly with the hand.

After we fill up, it's needed to take away the excess of mortar a ruler, after more or less 15 seconds, we take off the mold in a vertical way. Then we turn on the flow table and it will yield 15 shakes.



Pic. 3.3.1.2. Flow table.

Once we get the formed mortar cookie, we will measure the diameter of it, de diameter needs to be more or less 15 cm long.

When we have the mix and after its proofed that it has the proper consistence, we use the porosimeter of mortar to measure the quantity of air inside the mix. Before the test, we need to calibrate the tester with water. After the calibration, we test the mortar getting the percentage of air. This process is specified on the *European standard EN 1015-7.*

Pic. 3.3.1.4. Porosimeter.

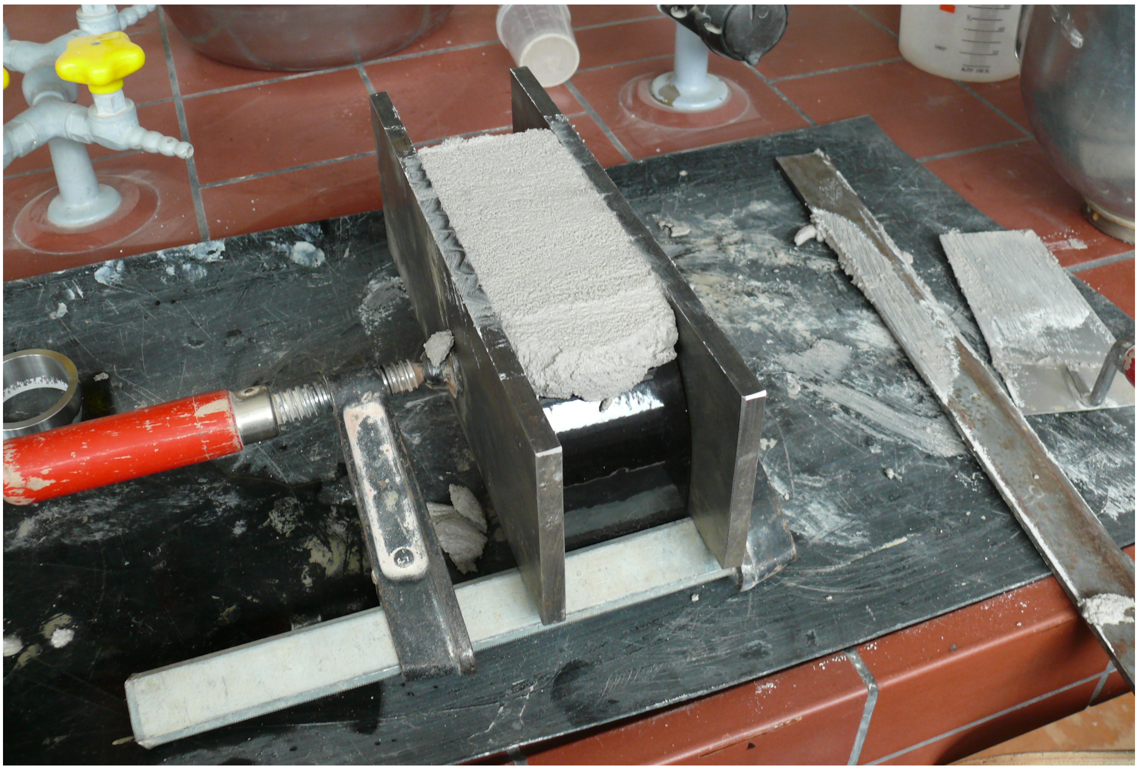
Now we need to make the mortar specimens by introducing the mix inside a triple prismatic shape. Again we need to introduce the mix in two times, after each we need to shake hardly the shape to take away all the bubbles. When it's full, we need to take away the excess of mortar with a ruler. Ones we finish, we need to write down the date, and introduce it in the special camera.

After two days we can take off the shape and leave the prismatic forms alone inside the chamber for one week. After being inside the camera, we will leave them at atmospheric temperature until they are 28 days old. Then we will be able to test them.

Pic. 3.3.1.4. Triple prismatic shape.

In the other side, to prepare the specimens for the adherence strength test, we will need the mortars which preparation is just explained, and four bricks, two of them with the impermeable surface and the others with the clay surface. In each brick, it's going to be two sides for making the traction test.

To prepare it, first we need to put in the correct place the formwork, so we can add one-centimeter dick mortar over the brick, then wait for a couple of minutes until the mix is enough dry to insert a conical ring, with the characteristics named on the *European standard EN 1015-12.*



Pic. 3.3.1.5. Preparing the brick.

Pic. 3.3.1.6. Prepared brick.

When the hole is done and staying, then we can put the brick in the same chamber as the prismatic specimens. After one week we will take the bricks out of the chamber and put them in a place with atmospheric temperature. At day 28 after the day they were made is time to use them for test.

The chamber where are this last two types of specimens, will be a t 20ª and with a relative humidity of 65%.

Pic. 3.3.1.7. Chamber

Before the traction test, we need to paste the mortar to a special stainless steel pieces with hard glue, which paste it in less than one hour. These pieces are 50 mm of diameter and 10mm high, with an attachment mechanism to hold it with the traction machine.

Pic. 3.3.1.8, 9 and 10 pasting the specimens.

There are two cases where, between the mortar and the brick, we need to extend a glue cement layer. For this glue cement we will need a more fluid mix, 20 cm in the flow table. The method used to mixt it is the same one as the others but it need to be mixed twice with five minutes of difference between each time. When we get the mortar and the glue, we extend the glue with a brush making a slim layer. Immediately after, we put the mortar over it.

Pic. 3.3.1.11 Painting the surface with glue mortar.

In none of these cases, we can remix it by throwing more ingredients to make more fluid or consistent.

3.3.2 Bricks preparation

The bricks are used in two types of tests. In one case, they are needed for testing the adherence strength. And in the other case, to prove the compression resistance they have. In each case they both need to be prepared.

For the compression testing, the machine needs to be in contact with the entire surface of the brick. That's why we need to treat the bricks and make their surface flat, so results will be as best as possible. Also the bricks had an irregular shape. We need to know the volume of them in order to calculate the compression strength per squared millimeter. There were not enough rectangular pieces for the test, so we took bricks with one corner rounded. Also it was needed to prove some bricks picked directly from the buttresses, these bricks were unstuck. The last ones had a trapezoidal section. In order to make them rectangular and flat, we used a buzz saw by cutting and abrading the bricks.

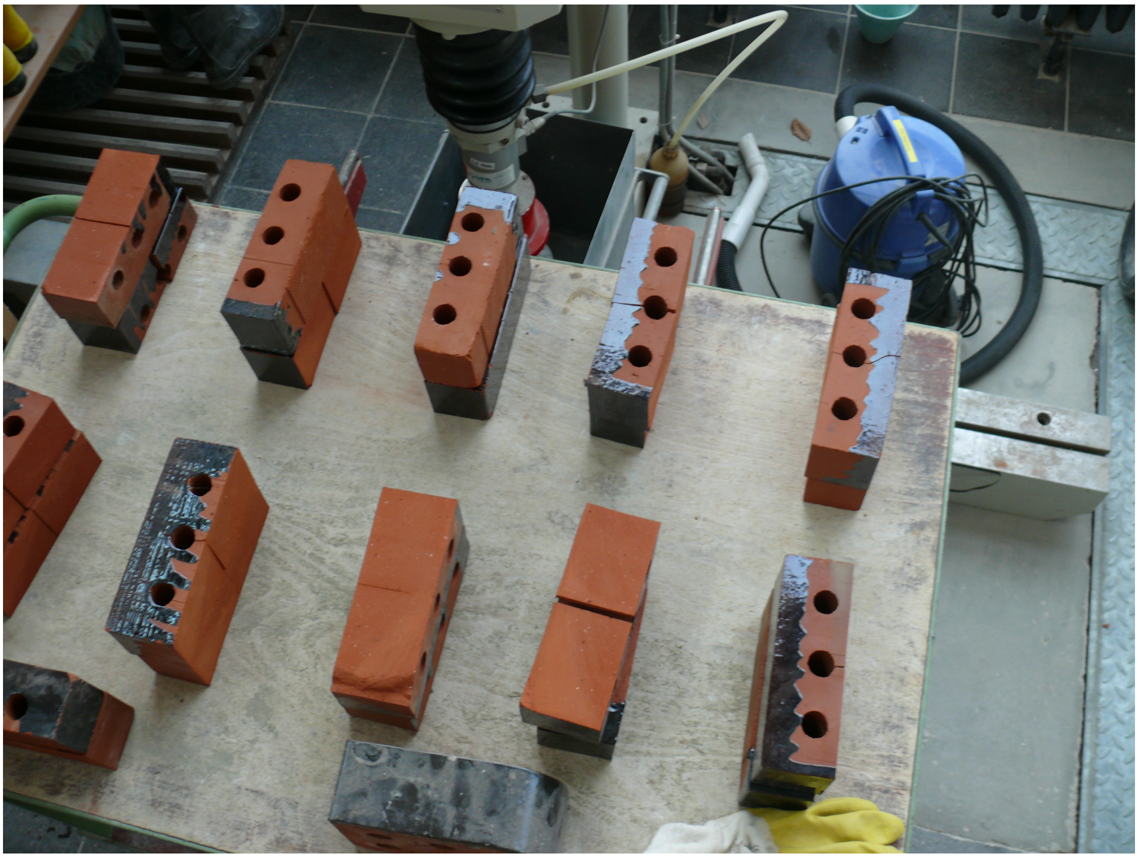
Pic. 3.3.2.1 Cutting bricks

Pic. 3.3.2.2 Bricks from the church.

Once we get the appropriate shape, is time to remove all the wetness they can have inside the internal pores. This is impossible just leaving the pieces in the open air, because the water of inside the internal pores will never disappear. That's why it's needed to leave the bricks inside an oven for 24 hours at 105 degrees. After this time when the bricks are dry and cold, is time to measure and weigh them.

Pic. 3.3.2.3 Oven.

On the other side, for the adherence strength tests we need the bricks, as is mentioned previously, with their impermeable surface and with their clay surface. To get the clay surface, we just cut them with a parallel cut to the painted face. This cut is in the middle of the brick so we can use both sides of it. Before we put the mortar over the brick we have to clean the surface with a dissolvent.



Pic. 3.3.2.4 Cut bricks.

3.3.3 Tests

Adhesive Strength:

Referenced standard UNE-EN 1015-12.

For this test, we need a special traction machine. This machine, applies the traction strength in a perpendicular direction. The machine holds the pasted pieces and pulls them. The charge needs to be uniform and without acceleration. The specimens should break between 20 an 60 seconds. If they break in the glue zone the specimen is rejected.

The machine automatically gives the adhesive strength. The equation the traction machine uses to get the strength is:

$$f_u = \frac{F_u}{A}$$

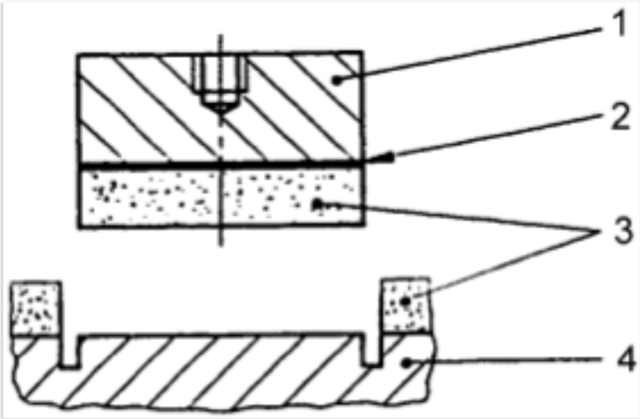
Where:

f_u = Adhesive strength (N/mm2)

F_u = tensile strength (N)

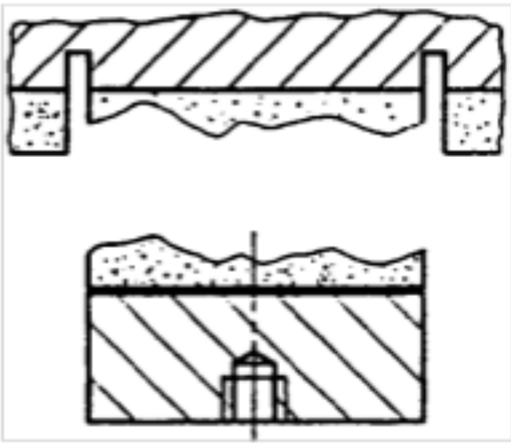
A = area of the specimen surface (mm2)

After the specimens break down, it's needed to take note of the type of fissure we can see. Three are the different types, which can be come out. The next pictures show the different types we can get.

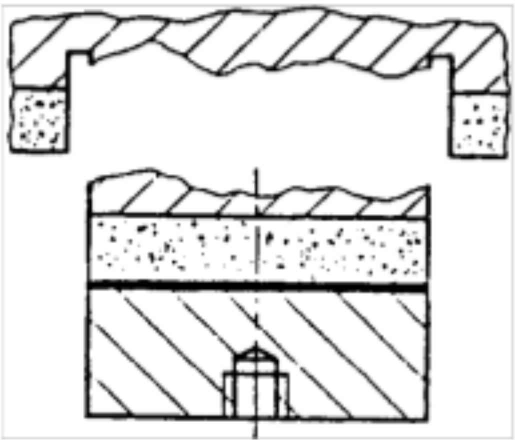


1: Piece connected to the machine
2: Glue
3: Mortar
4: Brick

Type a-Broken in the interface of the mortar and the brick.



Type b-Broken the mortar.



Type c-Broken the brick.

The standard says that we need to test five specimens, but we will test four specimens over the impermeable paint and four more over the clay surface. Then the average between the four results will give the adhesive strength of the mortar.

Bending tensile strength.

Referenced standard UNE-EN 772-6.

We need to know the bending tensile strength of the different mortars we made. In order to get the wanted results, we need to use a bending device formed by two cylindrical rollers, over where specimens rest. These two rollers are separated 100 millimeters. Also it has another cylindrical roller, which applies the strength. This one is situated in the middle of the other two, but this one is on the top.

Pic. 3.3.3.1 Bending machine.

To introduce the specimen between the rollers, the surface, which was uncovered when they were inside the formwork, can't touch them.

The strength is applied, increasing it in a gradual way in order to break the specimens in between 30 an 90 seconds.

The machine will give us the maximum strength applied in N. So to get the bending tensile strength we need to solve the next equation:

$$R_{tf} = \frac{F \cdot l}{b \cdot h^2}$$

Where:

R_{tf} = Bending tensile strength (N/mm^2)

F = Tensile strength (N)

l = distance between supports (mm)

b = width of the specimen (mm)

h = height of the specimen (mm)

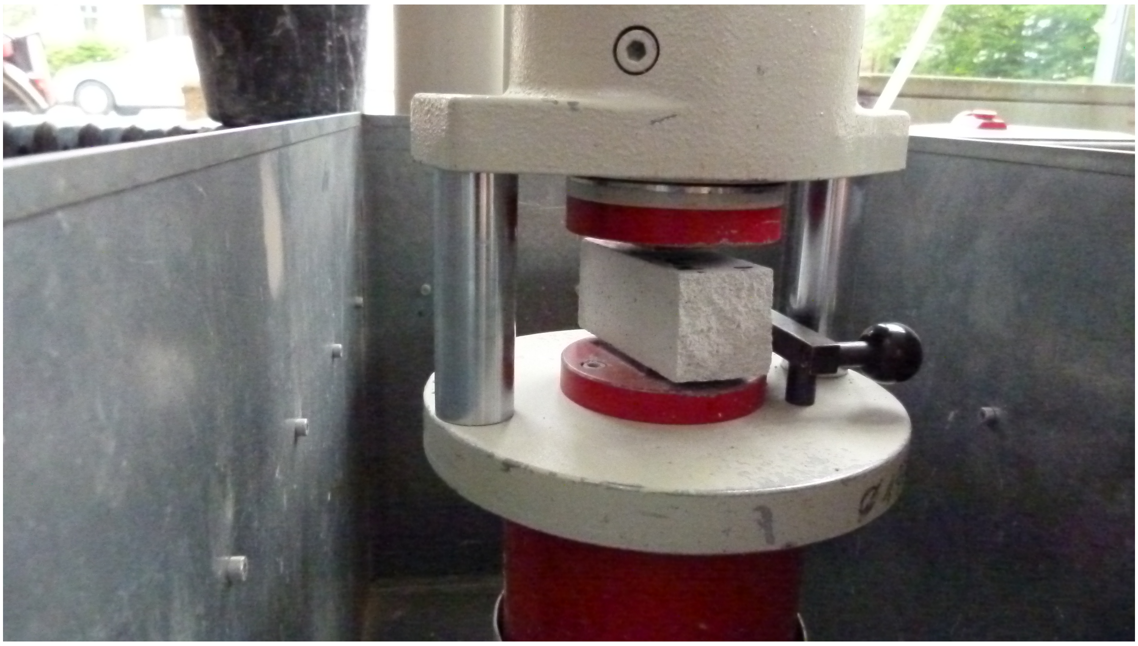
Three specimens of each mortar will be tested, so the final result will be the average of these three. If there is any problem with any test, we will just avoid this result.

Compressive strength

Referenced standard UNE-EN 772-1.

We need to know the compressive strength of the bricks and also of the mortar. The bricks we are going to use for this type of test are two. One type was not used before and the other was taken directly from the building. The mortar specimens came from the pieces we got after the bending tensile test.

The machine for both types of specimens is the same. But because of one is smaller than the other, we will use a special adapter for small pieces. But in both cases the method to test them is the same.



Pic. 3.3.3.2 Compression adapter.

The specimens need to be placed in the middle of the plates. These plates are the one who makes the strength, so they need to touch the whole surface of the specimens. The strength will be applied gradually.

The machine needs to know the size of the specimens in order to calculate the compressive strength per squared millimeter.

Also after the results, in case of the bricks we need to apply a coefficient because they were cut. The coefficient we need to apply comes from the nest table.

Anchura mm / Altura[a] mm	50	100	150	200	≥ 250
40	0,80	0,70	–	–	–
50	0,85	0,75	0,70	–	–
65	0,95	0,85	0,75	0,70	0,65
100	1,15	1,00	0,90	0,80	0,75
150	1,30	1,20	1,10	1,00	0,95
200	1,45	1,35	1,25	1,15	1,10
≥ 250	1,55	1,45	1,35	1,25	1,15

As we don't have all the measures to take the correct coefficient, we can interpolate

$$y = y_a + (x - x_a)\frac{(y_b - y_a)}{(x_b - x_a)}$$

3.3.4 Results

Mortar 1:

Date of made: 15-may-2013

Date of test: 12-jun-2013

Characteristics of the specimens

Specimens	Size [mm]			Weight [kg]
	a	b	c	
I	41	40	160	404,7
II	41	40	160	402,4
III	41	40	160	400,6

Test results

Specimens	Traction [N]	R_{tf} [N/mm²]	Compression [N/mm²]	
			.1	.2
I	1199,47	1,83	6,8	6,7
II	1147,32	1,75	6,65	6,7
III	1168,04	1,78	5,45*	5,9
Average		1,79	6,6	

*Not counted in the average, dispersed value.

Density

$$D = 1534,2 \ Kg/m^3$$

Flexion:

$$R_{tf} = 1,79 \ N/mm^2$$

Compression:

$$C = 6,6 \ N/mm^2$$

Quantity of air:

23%

Mortar 2:

Date of made: 17-may-2013

Date of test: 14-jun-2013

Characteristics of the specimens

Specimens	Size [mm]			Weight [kg]
	a	b	c	
I	41	40	160	429,4
II	41	40	160	431,2
III	41	40	160	428,3

Test results

Specimens	Traction [N]	R_{tf} [N/mm²]	Compression [N/mm²]	
			.1	.2
I	1481,33	2,26	9,15	9,35
II	1500,69	2,29	9,30	9,30
III	1420,89	2,17	9,00	8,95
Average		2,24	9,2	

Density

$$D = 1637{,}3\ Kg/m^3$$

Flexion:

$$R_{tf} = 2{,}24 N/mm^2$$

Compression:

$$C = 9{,}2 N/mm^2$$

Quantity of air:

21%

Mortar 3:

Date of made: 21-may-2013

Date of test: 18-jun-2013

Characteristics of the specimens

Specimens	Size [mm]			Weight [kg]
	a	b	c	
I	41	40	160	317,52
II	41	40	160	315,80
III	41	40	160	316,72

Test results

Specimens	Traction [N]	R_{tf} [N/mm²]	Compression [N/mm²]	
			.1	.2
I	512,14	0,78	3,15	3,50
II	589,15	0,90	3,15	3,50
III	544,29	0,83	3,40	3,30
Average		0,84	3,3	

Density

$$D = 1206,9\ Kg/m^3$$

Flexion:

$$R_{tf} = 0,84\ N/mm^2$$

Compression:

$$C = 3,3\ N/mm^2$$

Quantity of air:

25,2%

Mortar 4:

Date of made: 22-may-2013

Date of test: 19-jun-2013

Characteristics of the specimens

Specimens	Size [mm]			Weight [kg]
	a	b	c	
I	41	40	160	486,64
II	41	40	160	483,42
III	41	40	160	478,12

Test results

Specimens	Traction [N]	R_{tf} [N/mm²]	Compression [N/mm²]	
			.1	.2
I	4928,73	7,51	59,95	58,60
II	5027,10	7,66	58,45	60,60
III	4709,93	7,18	60,70	59,75
Average		7,45	59,7	

Density

$D = 1839{,}7\ Kg/m^3$

Flexion:

$R_{tf} = 7{,}45\ N/mm^2$

Compression:

$C = 59{,}7\ N/mm^2$

Quantity of air:

13,4%

Mortar 5:

Date of made: 28-may-2013

Date of test: 25-jun-2013

Characteristics of the specimens

Specimens	Size [mm]			Weight [kg]
	a	b	c	
I	40	40	160	489,45
II	40	40	160	485,34
III	40	40	160	485,73

Test results

Specimens	Traction [N]	R_{tf} [N/mm²]	Compression [N/mm²]	
			.1	.2
I	2001,06	3,13	18,50	18,30
II	2044,66	3,19	17,00	18,30
III	1934,77	3,02	16,80	17,45
Average		3,11	17,7	

Density

$D = 1901{,}7\ Kg/m^3$

Flexion:

$R_{tf} = 3{,}11\ N/mm^2$

Compression:

$C = 17{,}7\ N/mm^2$

Quantity of air:

10,55%

Mortar 7:

Date of made: 28-may-2013

Date of test: 25-jun-2013

Characteristics of the specimens

Specimens	Size [mm]			Weight [kg]
	a	b	c	
I	41	40	160	286,32
II	41	40	160	289,93
III	41	40	160	290,25

Test results

Specimens	Traction [N]	R_{tf} [N/mm²]	Compression [N/mm²]	
			.1	.2
I	702,43	1,07	3,35	3,35
II	689,79	1,05	3,30	3,35
III	650,13	0,99	3,40	3,40
Average		1,04	3,4	

Density

$$D = 1100{,}7\ Kg/m^3$$

Flexion:

$$R_{tf} = 1{,}04\ N/mm^2$$

Compression:

$$C = 3{,}4\ N/mm^2$$

Quantity of air:

17%

Adherence strength.

Mortar 1

Date of made: 15-may-2013 (.1 and .2), 31-may-2013 (.3 and .4)

Date of test: 12-jun-2013 (.1 and .2), 01-jul-2013 (.3 and .4)

Diameter: 50 mm

Type of surface		Traction [N/mm^2]
Impermeable	.1	-
		-
	.2	-
		-
Normal	.3	-
		-
	.4	0,449
		0,201

Results:

Impermeable surface:

Without resistance

Normal surface: (two specimens tested)

f_u = 0,325 N/mm^2

Type of break:

Type a. broke in the union between mortar and brick.

Mortar 2

Date of made: 17-may-2013

Date of test: 14-jun-2013

Diameter: 50 mm

Type of surface		Traction [N/mm²]
Impermeable	.1	-
		-
	.2	-
		-
Normal	.3	-
		0,431
	.4	-
		0,487

Results:

Impermeable surface:

Without resistance

Normal surface: (two specimens tested)

f_u = 0,459 N/mm^2

Type of break:

Type a. broke in the union between mortar and brick

Mortar 3

Date of made: 21-may-2013

Date of test: 18-jun-2013

Diameter: 50 mm

Type of surface		Traction [N/mm²]
Impermeable	.1	-
		0,009*
	.2	0,036
		0,035
Normal	.3	0,292
		0,25
	.4	0,337
		0,106

*Not counted in the average, dispersed value.

Results:

Impermeable surface: (three specimens tested)

$$f_u = 0{,}036\ N/mm^2$$

Normal surface: (four specimens tested)

$$f_u = 0{,}246\ N/mm^2$$

Type of break:

Type a. broke in the union between mortar and brick

Mortar 4

Date of made: 21-may-2013

Date of test: 18-jun-2013

Diameter: 50 mm

Type of surface		Traction [N/mm²]
Impermeable	.1	-
		-
	.2	-
		-
Normal	.3	0,67
		0,651
	.4	0,421
		0,32

Results:

Impermeable surface:

Without resistance

Normal surface: (four specimens tested)

$f_u = 0{,}516\ N/mm^2$

Type of break:

Type a. broke in the union between mortar and brick

Mortar 5

Date of made: 28-may-2013

Date of test: 25-jun-2013

Diameter: 50 mm

Type of surface		Traction [N/mm²]
Impermeable	.1	-
		-
	.2	-
		-
Normal	.3	-
		0,185
	.4	0,217
		0,151

Results:

Impermeable surface:

Without resistance

Normal surface: (three specimens tested)

f_u = 0,184 N/mm^2

Type of break:

Type a. broke in the union between mortar and brick

Mortar 6

Date of made: 28-may-2013

Date of test: 25-jun-2013

Diameter: 50 mm

Type of surface		Traction [N/mm²]
Impermeable	.1	0,01*
		-
	.2	0,421
		0,318
Normal	.3	0,03*
		-
	.4	0,081
		0,484

*Not counted in the average, dispersed value.

Results:

Impermeable surface:

$$f_u = 0{,}370\ \ N/mm^2$$

Normal surface: (three specimens tested)

$$f_u = 0{,}283\ N/mm^2$$

Type of break:

Type b. broke in the mortar.

Mortar 7

Date of made: 29-may-2013

Date of test: 26-jun-2013

Diameter: 50 mm

Type of surface		Traction [N/mm²]
Impermeable	.1	-
		-
	.2	-
		-
Normal	.3	0,684
		0,541
	.4	0,736
		0,534

Results:

Impermeable surface:

Without resistance

Normal surface: (four specimens tested)

$f_u = 0,624\ N/mm^2$

Type of break:

Type b. broke in the mortar.

Mortar 8

Date of made: 31-may-2013

Date of test: 01-jul-2013

Diameter: 50 mm

Type of surface		Traction [N/mm²]
Impermeable	.1	0,117
		0,197
	.2	-
		-
Normal	.3	0,912
		-
	.4	1,151
		1,395

Results:

Impermeable surface: (two specimens tested)

$$f_u = 0{,}157 N/mm^2$$

Normal surface: (three specimens tested)

$$f_u = 1{,}153 N/mm^2$$

Type of break:

Type a. broke in the union between mortar and brick

Bricks compression.

Characteristics:

Bricks from storage: Date of test: 02-jul-2013

Bricks	Size [mm]			Weight [kg]
	a	b	h	
a	195	129	70	2954
b	195	128	69	2884
c	190	123	66	2898
d	195	128	70	2930
e	192	126	69	2904
f	122	121	67	1804
g	121	122	70	1806
h	121	121	68	1778
i	122	121	68	1817
j	121	121	69	1804

Bricks toked directly from the church: Date of test: 04-jul-2013

Bricks	Size [mm]			Weight [kg]
	a	b	h	
a.1	228	75	50,1	1628
b.1	229	72	50,6	1586
c.1	123	71	50,6	777
d.1	118	75	52	837

Test results:

Bricks from storage:

Bricks	Compression [N/mm²]	Interpolated coeff.	Final strength [N/mm²]
a	62,73	0,705	49,68
b	61,5	0,705	48,83
c	30,99*	0,71	24,92
d	61,67	0,705	48,97
e	41,47	0,708	33,09
f	72,61	0,806	58,67
g	49,08	0,808	39,56
h	95,74	0,808	77,36
i	66,86	0,806	54,02
j	68,01	0,808	54,95
Average			51,68

*Not counted in the average, dispersed value.

Bricks toked directly from the church:

Bricks	Compression [N/mm²]	Interpolated coeff.	Final strength [N/mm²]
a.1	27,08	0,8	21,66
b.1	24,97	0,806	20,13
c.1	24,77	0,808	20,01
d.1	28,13	0,8	22,50
Average			21,08

4 Conclusion

Once finished testing, analyzing and compering the results, is time to make a decision and pick up the solution in order to solve the problem with the church.

The problem, on which we have focus, is the one, which affects to the adherence between the mortar and the enamel bricks. Several ideas came to our minds to keep the bricks pasted. But, after analyzing the cause of the problem, which was the non-adherence between the impermeable surface and the mortar, we decide to look for a different mortar, due to the fact that we can't change the bricks. The decision was taken after regretting the possibility of the apparition of salts.

This new mortar needs to solve the lacks the previous mortar has. So we need to find a mortar with a high adherence with the impermeable surface and also a minimal strength in order to support loads.

A high percentage of the mortars we tried had a good adherence with the clay surface. Nevertheless, some of them were detached before even we made the test with the painted surface. This makes us to regret this mortars, because even they have good adherence with the clay surface, we need, as we said previously, to take a mortar with adherence with the enameled one.

There are two mortars with good adherence with the enameled surface. These are the MORTAR 6 and the MORTAR 8. They have an adherence-strength of 0,370 N/mm^2 and 0,157 N/mm2 respectively.

In order to the obtained results, we think the MORTAR 6 will be the best solution to replace the existing one.

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UNE-EN 772-6: *Methods of test for masonry units. Part 6: Determination of bending tensile strength of aggregate concrete masonry units.*

UNE-EN 1015-2: *Methods of test for mortar for masonry. Part 2: Bulk sampling of mortars and preparation of test mortars.*

UNE-EN 1015-3: *Methods of test for mortar for masonry. Part 3: Determination of consistence of fresh mortar (by flow table).*
UNE-EN 1015-6: *Methods of test for mortar for masonry. Part 6: Determination of bulk density of fresh mortar.*

UNE-EN 1015-7: *Methods of test for mortar for masonry. Part 7: Determination of air content of fresh mortar.*

UNE-EN 1015-11: *Methods of test for mortar for masonry. Part 11: Determination of flexural and compressive strength of hardened mortar.*

UNE-EN 1015-12: *Methods of test for mortar for masonry. Part 12: Determination of adhesive strength of hardened rendering and plastering mortars on substrates*

6 Photos

Church:

Bricks:


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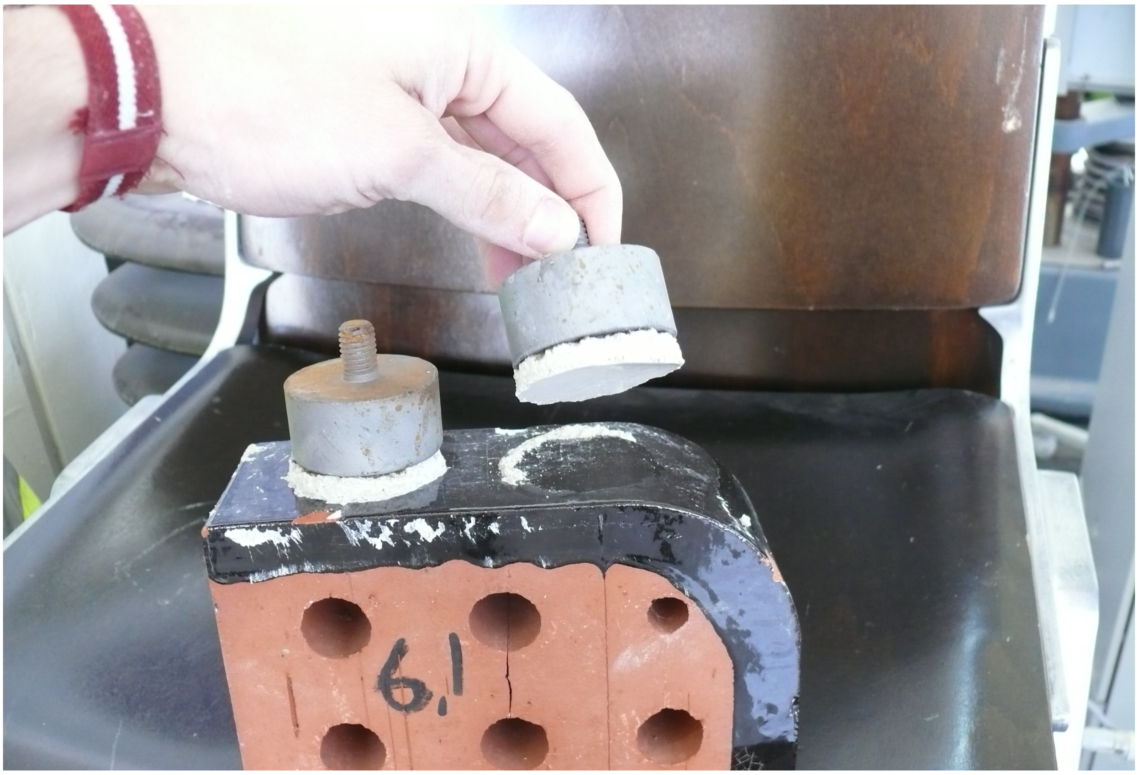
8.1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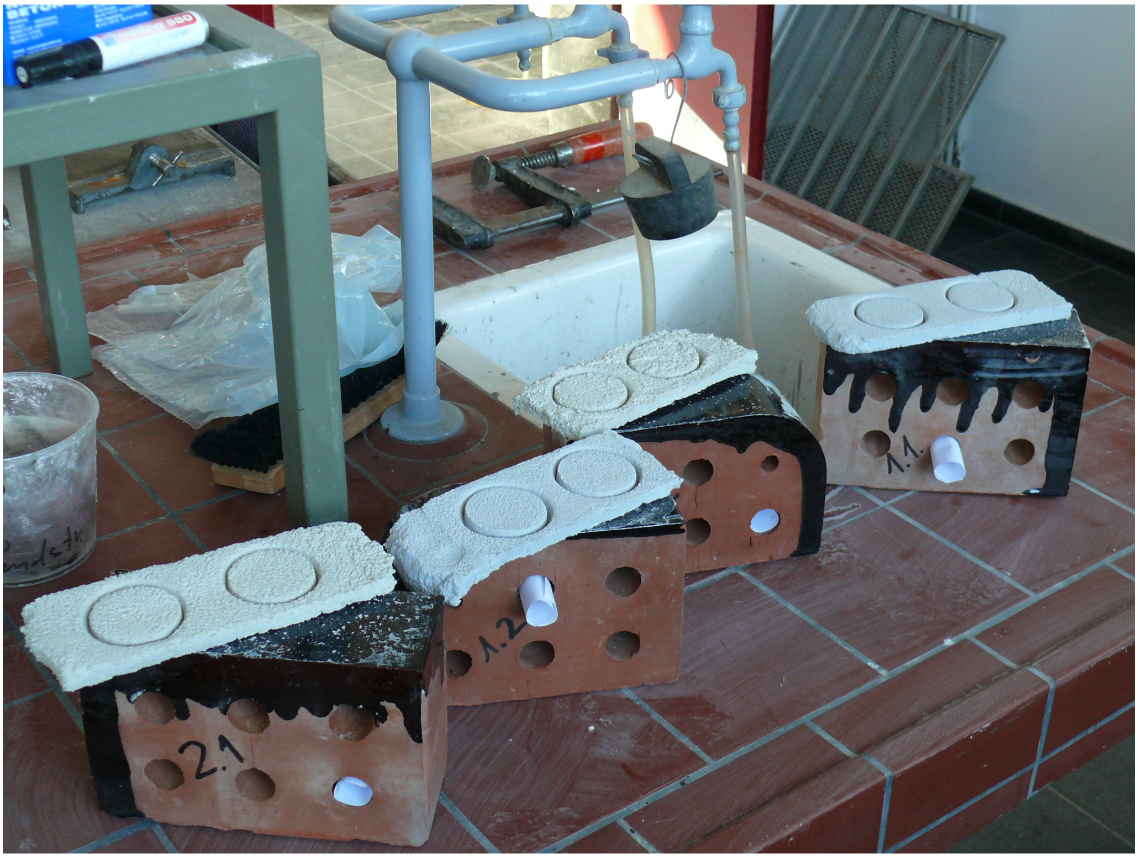
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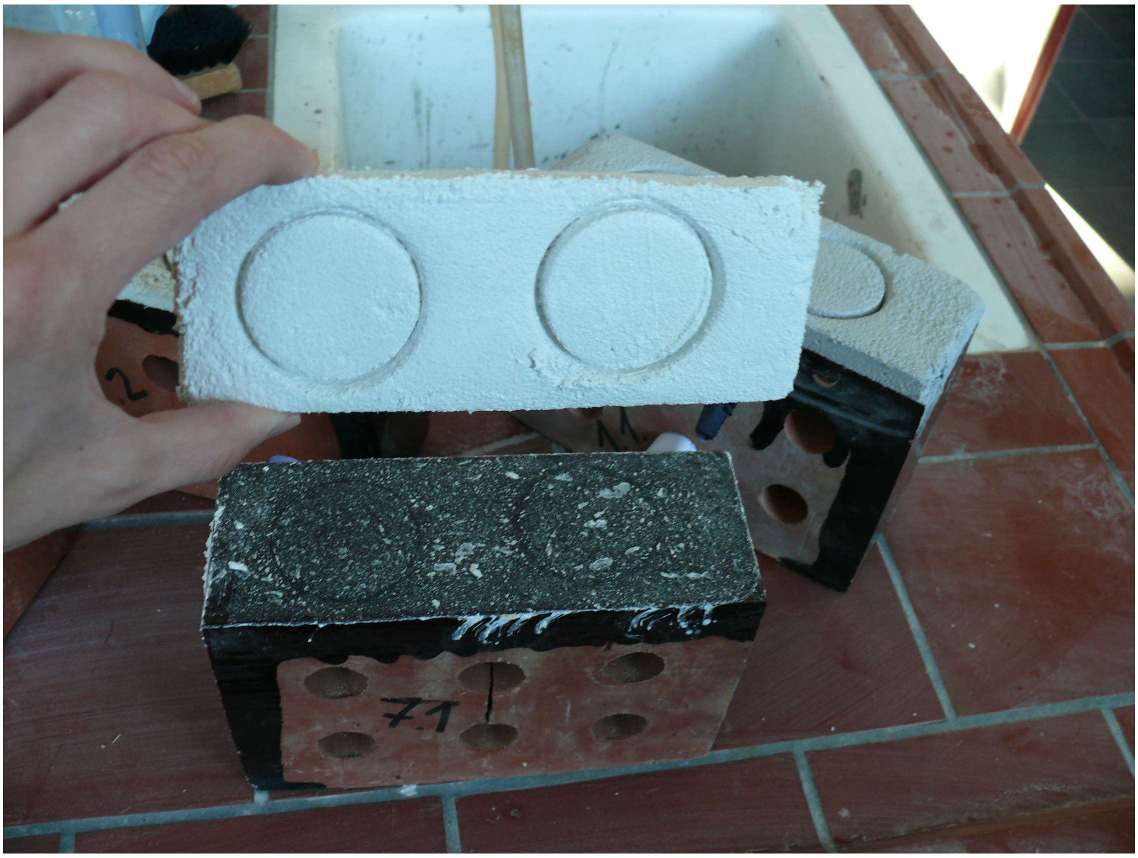
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