Calculus memory
Stone plated fixing.
01. Description

This memory shows a study on the façade hanged up on natural or artificial mass stones fixing system. There are two types of fixing. The first one is direct. The second one has an auxiliary profile. Direct fixing systems are classified, according to its norm into edge hidden anchorage, which is joined by bolts to the coating. Other items within this classification are the retention anchorage and, retention/sustain ones. The last ones have regulations in one or more directions fixed to concrete walls. Fixing systems with auxiliary profile generate an aluminium structural framework. This gives the resistant elements of the building normally to the forging edges. The profile fixing system gives independence to the closing façade of the building in case of having elements for closure that were not thought to receive weigh. At the same time, the plated stones are hanged up on a discrete anchorage specifically designed for this profile.
Direct fixing systems supposes the existence of capable façade closings to receive weigh. These closings can be walls (perforated or solid bricks) with an equal or major resistance than 150Kg/cm2 certified by the manufacturer. Concrete walls with a minimum characteristic resistance of 175Kg/cm2 can be used as well. Fixing systems that have an auxiliary profile, need resistant elements as forging edges to guarantee the correct fixation bearing in mind the effort received in these areas. There will be one or another kind of fixation cosidering the profile and reaccions produced on the anchorage centres. These reactions will be specified afterwards. So, the following analysis aims at determining anchorage systems resistance capacity facilitating some charts or abacus making easier the election according to the system parametres and giving propposals to possible modifications to make a better design. Also, as it has been stated, props reactions of anchorage systems will be fascilitated, so that the correct dimensions can be given to the building structure fixing elements.

02- Materials and Elements

Aluminium
Aluminum, quality alloy 6005/T6 EP/O (according to eurocódigo 9)
Elastic limit: 2250 Kg/cm2
Tension of rupture: 2550 Kg/cm2
Density: 2700 Kg/m3
Modulus of elasticity: 700000 Kg/cm2
Cross-sectional Modulus of elasticity 270000 Kg/cm2
Coefficient of thermal expansion 0,000023 1/Cº

Stainless Steel
Stainless steel quality AEX-120/250 (AISI-304/316)
Elastic limit: 3100 Kg/cm2
stainless Steel quality A2/A4
Elastic limit: ?8, ?10, and ?12: 5100 Kg/cm2
Elastic limit: ?14, and ?16: 4100 Kg/cm2
Density: 7850 Kg/cm2
Modulus of elasticity: 2100000 Kg/cm2
Cross-sectional Modulus of elasticity: 810000 Kg/cm2
Coefficient of Poisson, ? : 0,3
Coefficient of thermal expansion: 1.2?10-5 1/Cº

Elements:
The auxiliary profile is made up of aluminium. In addition to this, fixation systems to the walls or forging edges generally coincide with the auxiliary profile material that is held. The continuous anchorage and the horizontal profile fixed to the auxiliary profile is made up of aluminium with the same quality.

All the discreet systems of fixation, either they are the fixed ones to auxiliary profile like the walls of factory or concrete, they are folded and mechanized stainless steel plates, or, of extrusionado and mechanized aluminium. The spiral bars (screws and asparagus/ pegs) are of stainless steel with different detailed elastic limits in the materials.

03. Actions considered in the calculation and design of the anchorages

The anchorage subsystems will have to assure the stability of coatings before the combined action of the actions and to limit the deformation. According to UNE 41957-1: 2000 "Anchorages for coatings of facades of buildings" the anchorage subsystems will have to assure the stability the coatings before the combined action of the actions that are going to be mentioned and to limit the deformation of compatible values with the coating system.
The following actions will be due to consider:

Gravitational

The own weight of the plated material considering a maximum density of 2,800 kgcm3. With this density and the habitual thickness of the plated pieces, we found the following loads:
28 Kp/m2 (1 cm), 56 Kp/m2 (2 cm), 84 Kp/m2 (3 cm), 112 Kp/m2 (4 cm) and 140 Kp/m2 (5 cm)

Of the wind

They are the actions produced by the incidence of the wind on the elements that they are exposed to. For the determination of these actions it is considered that they act perpendicularly and with an angle of incidence ? 10º with respect to the horizontal.
The intensity of its action is evaluated directly from the speed with which it can move and run into against the resistant element. According to article 5,1 of the NBE-AE-88 two types of actions can occur: normal or exposed. In the same way, it is necessary to consider factors like the height of the building coronation (0 to 100 meters), dynamic pressure w (75, 100 or 125 Kp/m2) and the colic coefficients (C1=0.8 and C2=0.4)

Thermal

Thermal actions have been taken into account in the auxiliary profile study. In the cases in which the existence of a thermal gradient has been considered as possible, fruit of the coefficient of thermal expansion of the materials and the corresponding thermal gradient has been put under the structure to deformations regimen which considers norm AE-88, in its articles 6,2 and 6.3.
The resulting actions of imposed deformations of geologic origin, of flow or by numbness as much of the own coating as of the support and the structure they have not been considered according to UNE-41957 - 1: 2000 in case of a correct design of the quartering of the platted material, correct work positioning and a rigorous respect of the meetings of such

Seismic

All the components (profiles, anchorages, subjections, etc.) they have been designed to be installed in zones whose seismic degree, measured in scale M.S.K., is equal or inferior to VII, with calculation accelerations, ac, not bigger than 0.08g. When the elements are arranged in seismic zones of degree VII (0.08<ac<=0.16g), the closing cloth will have to be anchored to rigid structures forming not greater portions than 20m2 or 5m; in zones of superior degree (ac>0.16g), the cloth will not exceed 10m2 or 3m.

Impact

In order to avoid the breakage of the plated material in situations of impacts, it is advised to make solid/fill up the exposed zones to impacts in a sufficient height. In this way, the studied anchorages do not have to answer to impact efforts.

Fire

For being outer elements without fire load, the application of the effective norm is not considered necessary. In case they were arranged for this type of systems in an atmosphere in inner zones or with fire load, it would require a special study

Ice

It has been rejected the action of the ice in the anchorages due to its correct design and work positioning, sealing all the meetings and holes with epoxy resins. Also the design of the precise anchorages and of the auxiliary profiles does not give rise to the appearance of these problems.

Environmental

The materials election for discreet anchorages and the auxiliary profiles guarantee a correct durability and resistance to unfavourable environmental conditions. The selected materials are (see section 2 “materials and elements”) the stainless steel and the aluminium that maintain their characteristics as much if they are separately as if they are together.

04/ Safety factors

Lessening of steel resistance: 1,10
Mayoración de solicitaciones:1,50
Lessening of the concrete resistance: 1,50
Mayoración de solicitaciones (cálculo de fábrica): 1,65
Mayoración de solicitaciones (cálculo de hormigón): 1.60
In the made calculations and verifications, a perfect behaviour of the vestment or coating fixation system has been considered.
Nei calcoli e verifiche realizzati si è considerato un comportamento perfetto del sistema di fissaggio al parametro.

05. Calculation Methods

For determining the efforts in the structural elements, it has been used, generically, the basic postulates of materials elasticity and resistance, applying them differently and through different methodologies, based on the element or set to analyse.
NBE-AE-88: “Building Actions”
NBE-EA-95: “Steel Structures in Buildings”
NBE-MV-107: “Screws of high resistance for the steels structures”
NBE-MV-201: “Brick Factory”
EHE: “Structural concrete Instruction”
UNE-41957-1: 2000: “Anchorages for coatings of buildings facades”
As well as the regulation of the “proposal” of EUROCÓDIGO N.3 “Metallic structures Project” (Part 1: general rules and rules for buildings, prepared by the Commission of the European Communities).
UNE-38-010-91: “Aluminium Anodización and its alloys. General specifications for the anodic coverings on aluminium”

06. Computer science programs of calculation used

For the definition of the efforts and tensional states
PÒRTICS: analysis linear page of bar structures
ESPAI: spatial linear analysis of bar structures
SHELL: linear analysis for finite elements of curved leaf bent in the space

07. Criteria determine proportions

To determine the proportions of the elements that take place in the structure, it has been guarded the satisfaction of the last states and the last states of use, limiting the maximum arrow of any susceptible element being considered to 1/500 of the light between props and, of 1/300 of the light in projection elements.

08. Discreet anchorages

The elements subdued to study consist of folded stainless steel plate pieces, that, on the one hand, pay attention to the coating prop and, by the other, receive a mechanism that is the one in charged of propping the elements of the natural or artificial plated stone. Also, the traditional anchorage with threaded stainless steel rod is included in the study for lifting walls.

Typologies: GR-CLM and GR-ESP

There are two dispositions of anchorages to be able of propping the facade plated stones:
In horizontal, 4 anchorages by stone, 2 in each horizontal side of the plated stone and placed to quarters of the length of the flank. The two inferior anchorages hold the gross weight of the stone, and the two superior ones maintain it in vertical. Q=50%P.
In vertical, 4 anchorages by stone, 2 in each vertical side of the plated stone and placed to quarters of the length of the side. Each anchorage must support 60% of the weight of the plated stone. The inferior anchorage and the superior ones are of load and retention. Q=60%P

Determination of the anchorage model GR-CLM according to the table.

CLM (20, 30 and 50) Rh $\geq$ 100
CLM (70) Rh $\geq$ 140

In case anchorage GR-ESP fulfils the condition of minimum altitude, the vertical range between drills must be equal or greater of 15 cm.

09. Vertical beams/girders

The vertical beams present a geometric aspect with four different versions according to their length (40, 60, 80 and 100) with the intention to cover the needs of every work.
The 40 and 60 versions are adequate for facades with resistant closure elements or for distances among small forged surfaces. The 80 version can extend to the typical distances between forged materials keeping some reasonable separations between posts and finally, the 100 version is thought to reach extreme distances.
Beams of articulated aluminum

The force test (in kilograms) that acts on the anchorage or the articulated subjection element is the following:

Cutting in the screw (Rv): Rv = 50 + 1540·H ·S· e
Traction in the screw (Rht): Rht=100·H·S

Beams of embedded aluminum

The force test (in kilograms) that acts on the anchorage or the articulated subjection element is the following:

Cutting in the screw (Rv): Rv = 100+ 3080·H·S·e
Traction in the screw (Rht): Rht= H·S· (3080· e· X + 8· 3 H) +15.8
b
Compression in the support (Rhc): Rhc = H· S· (3080· e· X +8.3 H) +15.8
b

Aluminum beams with a wind element

The force test (in kilograms) that acts on the anchorage or the articulated subjection element is the following:

Traction/compression in the screw (Rht): Rht= 55·H·S

Special anchorages to support large loads:
The force test (in kilograms) that acts on the anchorage or the articulated subjection element is the following:
Cutting in the superior screw (Rv): Rv= 5·H·S· (1540· e·X +2.8) + 50
Traction in the front screw (Rht) : Rht= 40·H·S
Where it says:
*H, separation between support elements (m)
*S, separation between vertical posts (m)
*e, thickness of the stone (m)
*X, eccentricity of the stone according to the support (m)
*b, arm of embedding (m)

10. Discrete anchorages fixed to the auxiliary beams

There are two kinds of anchorages to be fixed to the auxiliary beams: the individual and the running anchorages.
The individual anchorage is composed of elements or subjection staples fixed to some vertical girders that in general have two functions: support the load that derives from both, the weight of the plating and the strength of the winds.
The running anchorage releases the rigidity of the previous disposition as it allows independent quartering of the distance between the posts.
Types of individual anchorages: GR-CLA, GR-PL and GR-CER
There are three ways of arranging the staples so as to support the plating of the facades:
In a horizontal way, 4 staples per stone, 2 in each horizontal side of the plating and arranged in quarters from the side length. The two inferior staples support the total weight of the stone and the superior ones keep it in a vertical position. (GR-CLA,GR-PL and GR-CER)
In a vertical way, 4 staples per stone, 2 in each vertical side of the plating and arranged in quarters from the side length. Each staple has to support 60% of the plating weight. The inferior and the superior staples are of load and retention. (GR-CLA)
In a horizontal intersection, 4 staples per stone, 1 staple in every corner of the plating. The two inferior staples support the total weight of the stone and the superior ones keep it in a vertical position. (GR-PL and GR-CER)

11. Horizontal beams GR-HPL-7500

Types:
There are three ways of arranging the staples in order to support the plating of the façade:
GR-HPL-P/S: the staple that supports the weight and the strength of the wind. This model of staples is arranged in the areas of the plating that are not extreme.
GR-HPL-T/I: the staple that supports the weight and the strength of the wind and which is in the inferior extreme of the plating.
GR-HPL-T/S: the staple that supports the strength of the wind and which is in the superior extremes of the plating.

It is necessary to arrange the vertical girders inversely, that is to say, showing the flat face or otherwise, with a thickening that places the horizontal beams to the same lead of the wings of the beam.

12. Horizontal beams GR-HPI-6500

The running beam is formed by two elements: an extruded aluminum beam that is fixed to the posts with auto-perforating screws and the staple GR-PI that is fixed to the plating.
It is necessary to arrange the vertical girders inversely, that is, showing the flat face or , otherwise, with a thickening that places the horizontal beams to the same lead of the wings of the beam.
Types:
There are two ways of arranging the running beams so as to support the plating of the façade:
PF-AL-HPI-/6500/P: the running beam that supports the weight and the strength of the wind. This model of staple is arranged in the areas of the plating that are not extreme.
PF-AL-HPI-6500/T: the running beam that supports the weight and the strength of the wind and which is in the superior extreme of the plating and arranged inversely, supporting only the strength of the wind. It is arranged in the superior extreme.
These beams are never in charge of supporting the plating in the last term, as there are auxiliary staples that have been designed to do that.

13. Horizontal beams PF-AL-HTR-7500

The horizontal beam is made of extruded aluminum fixed to the vertical girders with auto- perforating screws. The plating is joined to the beam mechanically by means of four aluminum staples GR-TR. In order to guarantee a perfect fixing between the staple and the beam, some clips are added so as to avoid any horizontal movement.
It is necessary to arrange the vertical girders inversely, that is, showing the flat face, or otherwise, with a thickening that places the horizontal beams to the same lead of the wings of the beam.