A sustainable technical system for ventilated façades

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ABSTRACT: This paper studies industrial systems of facades ventilated from market products, detachable and recyclables. Also it assessments the probable durability of the components of the facade, it tracks his service life and it determines the environmental impact that it causes due to the energy and CO2 produced in the obtaining and manufacture of the materials that compose it.

1. CONSTRUCTION TECHNIQUES FOR THE FAÇADES OF RESIDENTIAL BUILDINGS

Façades of residential buildings in Spain have been built usually out of brick. The most commonly used construction technique (from inner to outer) has consisted of: plaster siding, a 7.5 cm partition wall, an air chamber with neither ventilation nor drainage, thermal insulation of variable thickness and an exterior wall made of brick, either 11.5 or 14 cm, with or without exterior cladding. Carefully implemented, this construction technique complies fairly well with the Technical Building Code's current basic requirements for façades: (1) safety in the event of fire, thermal and acoustical insulation, resistance and stability against wind loads, and impermeability (waterproofness).

The appearance and fast growth of the construction model known as "rain screen" (2), or "ventilated façade," has come about because of an inability to insulate properly the edge of the framework, generating thermal bridges; compatibility problems resulting from the wide dimensional tolerances of the concrete structures; and above all, the architects' desire to experiment with new products and materials in the building of façades. This new construction technique (technique 1) consists (from inner to outer) of: one or two sheets of plasterboard attached to flashings, an 11.5 or 14 cm brick wall, thermal insulation of variable thickness, a ventilated and drained chamber, and a cladding system of rigid plates with specific fastenings. The cladding system is usually attached to the wall and to the edges of the framework.

At present, various cladding systems have been developed and optimised for this type of façade; in particular, asbestos cement, thermo-hardened resin or porcelainised stoneware plates. This construction technique complies well with some of the demands imposed upon the façade: thermal and acoustical insulation and impermeability; but a thorough analysis is required with regard to the problem of safety in the event of fire, because of the risk of a fire spreading through the chamber to the entire façade (3).

One cannot disregard wind activity either; suction and/or pressures, usually weak, that may act on the plates as a result of the compartmentalization of the air chamber, or on the inner masonry wall (4). Despite these inconveniences, this type of construction technique is gaining ground on façades for residential, administrative, hospital, and school buildings.

Lately, a further step has been taken. In some projects, mainly in hotels and dwellings, the brick wall has been substituted by a sandwich made of steel plate sections that act as resistant elements, acoustical and thermal insulation, one or more sheets of plasterboard as cladding for the inner side, and a special asbestos cement plate as cladding for the side that is exposed to the elements. Sometimes the asbestos cement side is clad with complementary thermal insulation to minimise the thermal bridges caused by steel plate vertical girders or by the edges of the framework. This construction technique (technique 2) is complemented, similarly to the prior technique, with a system of exterior cladding made of rigid plates with specific fastenings. The tremendous popularity of this technique is a result both of the elimination of humid conditions in the façade's building stage, and of the search for more industrialised building processes that generate less waste during construction, waste that is lighter and not as thick as that generated by previously described techniques.

Nonetheless, the substitution of one type of façade construction technique for another cannot be automatic, inasmuch as the brick wall unquestionably helps to achieve technical benefits that could not otherwise be easily accomplished. We refer in particular to acoustical insulation, impermeability to wind, safety in the event of fire, and even resistance and stability of the cladding system.

First and foremost, the façade must be solid and durable; must create comfort, primarily thermal, acoustical and with reference to light, in inner spaces; must be waterproof; must be safe in case of fire; and must be energy efficient.

This paper analyses various ventilated façade techniques that are being built in Spain at present, with similar technical benefits: construction techniques 1 and 2, with different types of cladding systems: (A) porcelainised stoneware plates, (B) thermo-hardened resin plates, and (C) asbestos cement plates, comparing different parameters: weight per square meter – energy consumption of materials – CO_2 production.

2. CONSTRUCTION FEATURES AND TECHNICAL BENEFITS OF THE DIFFERENT TYPES OF FAÇADE ANALYSED

2.1 *Construction technique 1.*

Composition (from inner to outer): two sheets (13 mm) of plasterboard on sections of galvanised steel, 14 cm perforated brick wall (1500 k/m³), 1 cm plaster mortar, 50 mm rockwool panel (50 k/m³), ventilated and drained air chamber.

Technical features:
Thermal transmittance: U = 0.59 W/m2 K
Global index of acoustical insulation: Ra > 46 dBA
EI > 120’

2.2 *Construction technique 2.*

Composition (from inner to outer): two sheets (13 mm) of plasterboard on sections of galvanised steel, 50 mm rockwool panel (50 K/m³), 22 mm asbestos cement plate, 30 mm rockwool plaster and mortar. In order to meet the resistance function, this technique incorporates a substructure of 100 x 50 x 1.5 cm tubular piping, at every 1200 mm vertically and 700 mm horizontally.

Technical features (5):
Thermal transmittance: U = 0.62 W/m2 K
Global index of acoustical insulation: Ra > 46 dBA
EI > 60’

2.3 *Cladding system A.*

Composition: 120 x 60 cm and 12 mm thick porcelainised stoneware plates. Anodised aluminium sections according to DITE 353 (6).

3.2 *Cladding system B.*

Composition: 10 mm thick thermo-hardened synthetic resin plates. Anodised aluminium sections according to DITE 240 (7).

3.3 *Cladding system C.*

Composition: 6 mm thick asbestos cement plates. Sections of folded galvanised steel according to DITE 403 (8).

3. RESULTS OBTAINED

Resulting values as to weight (K/m²), energy utilised (MJ/m²) and CO_2 production (K/m2) are recorded on the spreadsheet attached to this paper, obtained from ITEC's DB Table (9), for façade construction techniques 1 and 2, as well as for the three types of exterior cladding (A, B and C).

4. CONCLUSIONS

4.1 *Concerning construction techniques 1 and 2.*

- Construction technique 2 is lighter than technique 1 (0.584 KN/m² against 2.51 KN/m2). In buildings with a large number of stories, this feature allows a reduction in the amount of material needed for construction of the structure and foundation, which is a positive result because of a reduction in the level of CO_2 emitted during manufacture of these materials, as well as in the energy consumed in said processes.

- Construction technique 2 requires more energy per square meter than technique 1 for its manufacture (1032.40 MJ/m² against 694.65 Mj/m²). Moreover, construction technique 2 produces larger quantities of CO_2 in the manufacture of its materials than construction technique 1, (88.23 Kg CO_2/m² against 54.93 Kg CO_2/m²). One could evaluate for a particular building the influence on the final result of the reduction in materials for structure and foundation because of the lighter weight of construction technique 2. Another conclusion derived is that construction technique 2 should have a smaller thermal transmittance value so as to compensate during its useful life for the excess energy and CO_2 production that it has as opposed to construction technique 1. This conclusion, arising as it does from the sustainability approach, agrees with the thermal comfort approach, inasmuch as construction techniques with little thermal inertia, as is the case with construction technique 2, require more thermal insulation to compensate for their quick thermal response to outside weather changes.

4.2 Concerning the exterior cladding of plates.

- All three claddings present a similar surface weight (weight of cladding A = 0.274 KN/m²; weight of cladding B = 0.179 KN/m²; weight of cladding C = 0.199 KN/m²).

- The three claddings present considerable differences as to the energy required to manufacture the various materials of which they are composed (cladding A, of porcelainised stoneware plates, 1223.81 Mj/m²; cladding B, of thermo-hardened synthetic resin plates, 702.53 Mj/m²; cladding C, of asbestos cement plates, 303.62 Mj/m²). These differences particularly have to do with the material used in the manufacture of the metallic sections that comprise the substructure, thus, the use of a material requiring less energy would improve the cladding solution. An important point, unavailable to us, would be to ascertain the useful life of each cladding, which would allow an evaluation of the energy rate consumed for each year of useful life. The materials that comprise the chosen claddings allow closing of their respective cycles by means of recycling.

- Similarly, the three claddings present considerable differences regarding CO_2 emissions produced when manufacturing the various materials of which they are composed (cladding A, of porcelainised stoneware plates, 166.23 Kg CO_2 /m²; cladding B, of hardened synthetic resin plates, 84.18 Kg CO_2 /m²; cladding C, of asbestos cement plates, 29.02 Kg CO_2 /m²). These differences particularly have to do with the material used in the manufacture of the metallic sections that comprise the substructure, thus the use of a material that would emit less CO_2 during its manufacture would improve the cladding solution. An important point, unavailable to us, would be to ascertain the useful life of each cladding, which would allow an evaluation of the rate of CO_2 that has been emitted for each year of useful life.

4.3 Concerning the whole of the construction techniques for ventilated façades.

- Different combinations of construction techniques (1 and 2) and exterior claddings present big differences with regard to the energy required and CO_2 emitted in manufacture of the materials:

Construction technique 2 + cladding A: (2556.21 Mj/m2 and 255.16 Kg CO_2 /m2)

Construction technique 1 + cladding C: (998.27 Mj/m2 and 83.95 Kg CO_2 /m2).

These differences cannot be taken as definitive when selecting materials for the ventilated façade, but rather as a clear reference; as it has been said earlier, the cladding material's useful life is an important piece of information that depends on the environmental characteristics of the site where it is placed.

4.4 Final conclusions.

- Generalised adoption of industrialised construction techniques to build façades will imply larger energy consumption and CO_2 emissions that can only be compensated by a decrease in the amount of material for structure and foundation because of its lesser weight.

A possibly negative final impact with regard to the environment should be balanced by improvement of the thermal insulation for the techniques and with a larger useful life for these.

- Despite the larger energy consumption and CO_2 emission, industrialised and light construction techniques for façades permit a better use of the materials that integrate them when they are able to close the life cycle through recycling or even through reuse of the materials.

- It is possible that industrialised construction techniques for wood with simple fastenings may add a reduction in energy consumption and CO_2 emissions during manufacture to the better use and recycling of the materials.

Construct system **1**: Wall clay brick.	Gypsum plasterboard, 13 mm (x2).	20,54	162,26	9,66
	Vertical girder from Galvanized steel	1,88	75,2	7,33
	Wall of thickness closing supported 14 cm, of brick perforated of 29x14x7,5 cm, taken with mortar for industrialized masonry M 5 (5 N/mm2).	204,82	363,07	28,62
	Mortar continuous stucco of 1 cm (Portland cement with limestone proportion 1:4).	21,15	32,15	3,72
	Insulation rock wool 86 to 95 kg/m3 of 50 mm of thickness, placed with mechanical fixations.	2,79	61,97	5,6
	TOTAL	**251,18**	**694,65**	**54,93**

Construct system **2**: Light weight wall.	Gypsum plasterboard, 13 mm (x2).	20,54	162,26	9,66
	Stud of galvanized steel, wide post of 46 mm, placed each 40 cm and channel of 46 mm fixed mechanically.	2,78	111,2	10,84
	Structure galvanized steel profiles 100X50X2 + Horizontal reinforcement crosspiece of 50x50x2	7,54	301,6	29,41
	Insulation rock wool 86 to 95 kg/m3 of 50 mm of thickness, placed with mechanical fixations.	2,79	61,97	5,60
	Cement fibreboard, 12,5 mm	21,88	335,34	27,56
	Insulation rock wool 86 to 95 kg/m3 of 30 mm of thickness, placed with mechanical fixations.	2,92	60,03	5,16
	TOTAL	**58,45**	**1032,40**	**88,23**

Cladding of Stoneware **(A)**	Aluminum profile for anchorage to the plate.	0,83	169,90	25,02
	Aluminum Vertical profile	2,59	530,17	78,06
	Aluminum Horizontal profile	1,34	274,30	40,39
	PUR adhesive	0,05	2,23	0,33
	Plates Stoneware, thickness 12 mm.	22,68	247,21	23,13
	TOTAL	**27,49**	**1223,81**	**166,93**

Cladding of Synthetic Composite **(B)**	Aluminum profiles for vertical frame thickness to 1.8 mm width profile 40 mm.	1,29	264,06	38,88
	Aluminum Horizontal profile	1,06	216,98	31,95
	Square of galvanized steel regulation.	0,15	5,88	0,57
	Board of thickness 10 mm, reinforced synthetic resins with wood fibers.	15,4	215,6	12,78
	TOTAL	**17,90**	**702,53**	**84,18**

Cladding of Composite Cement Febreboard **(C)**	Vertical Profiles galvanized steel of 1.5 mm of thickness and length 6m, dimensions 29x50x40.	3,67	146,8	14,31
	Squares of fixation to the galvanized steel support, thickness 2.5 mm, dimensions 48x80x60 mm.	0,07	2,92	0,28
	Composite cement febreboard, espesor 9 mm.	16,2	153,9	14,42
	TOTAL	**19,94**	**303,62**	**29,02**

Summary of environemental impact of emissions and energy			Mass Kg/m2	Energy Mj/m2	Emissions KgCO2/m2
1	**A**	Construct system 1: Wall clay brick + Cladding of Stoneware	**278,67**	**1918,46**	**221,86**
	B	Construct system 1: Wall clay brick + Cladding of Synthetic Composite	**269,08**	**1397,17**	**139,12**
	C	Construct system 1: Wall clay brick + Cladding of Composite Cement Febreboard	**271,12**	**998,27**	**83,95**
2	**A**	Construct system 2: Light weight wall + Cladding of Stoneware	**85,93**	**2256,21**	**255,16**
	B	Construct system 2: Light weight wall + Cladding of Synthetic Composite	**76,34**	**1734,93**	**172,41**
	C	Construct system 2: Light weight wall + Cladding of Composite Cement Febreboard	**78,39**	**1336,02**	**117,25**

REFERENCES

1. Código Técnico de la Edificación. Ministerio de la Vivienda. (España 2006).
2. J.M. Anderson and J.R. Gill, Rainscreen cladding: a guide to design principles and practice. (Butterworths, London 1988).
3. Sara Colwell and Brian Martin, Fire performance of external thermal insulations for walls of multi-storey buildings. (Building Research Stablishment 2003).
4. D.R. Inculet and A.G. Davenport, Pressure-equalized rainscreens: A study in the frequency domain. (Journal of Wind Engineering and Industrial Aerodynamics 53. 1994)
5. Technical sheet W380 E, Aquapanel Outdoor.(Knauff, 2006).
6. Agreement nº 353 "Sistema de fachada ventilada Mecanofas Karrat S-7. (Instituto de Ciencias de la Construcción Eduardo Torroja).
7. Agreement nº240 "Cerramiento para fachadascon placas de material sintético termoendurecible TRESPA". (Instituto de Ciencias de la Construcción Eduardo Torroja).
8. Agreement nº 403 "Sistema de revestimiento de fachadas ventiladas con placas planas Naturvex TC". (Instituto de Ciencias de la Construcción Eduardo Torroja).
9. Metabase de la construcción (Institut de Tecnologia de la Construcció de Catalunya. ITEC).