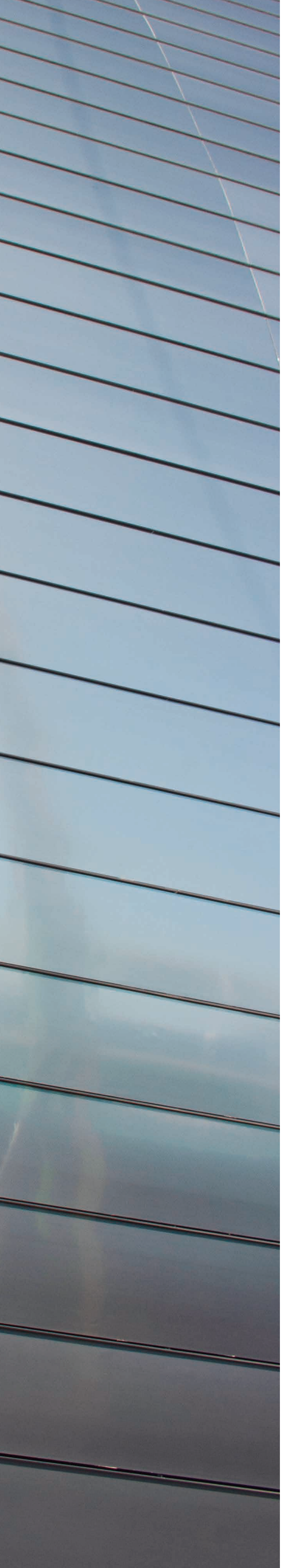

OPTICAL CHARACTERIZATION OF THE SURFACE OF STAINLESS STEELS INTENDED FOR BUILDING LINING

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The incorporation of stainless steel on the exterior of buildings has become an avant-garde element that identifies those buildings that want to mark certain references in the architectural world.

Although historically stainless steel has been a little used material in this sector, since its cost is somewhat higher than that of conventional metals used in construction, it is recognized as a material with a tremendous value in terms of durability and low maintenance.

In addition, environmental and saving energy reasons could be added that would also justify its use in the lining of buildings.

The thin and invisible layer of chromium oxide that develops naturally in the stainless steel surface converts it into a thermal and solar reflector almost perfect. This means that its use on facades and roofs allows saving of energy in the air conditioning systems, both in hot and cold climates.

Likewise, it reduces what is known as the heat island effect in urban environments, as well as contributes to mitigate climate change, not only by reducing the energy needed both to heat and cool buildings, but also for the efficiency with which stainless steel reflects light, without producing infrared thermal radiation, which returns solar energy to space without the component responsible for global warming.

Nor should we forget the important aesthetic component that the use of different finishes of stainless steel contributes to buildings. The lustre and shine, which in forms more or less curves, contribute to the exterior of buildings add a unique attraction to the use of this material.

However, its use is not free of controversy because of the impact that have in the surrounding environment, especially when accompanied by employment of concave curved surfaces, inducing significant local overheating points in buildings and surrounding spaces. To this effect we must add the dazzle that the reflection of the sun, or other light sources, on these surfaces can cause drivers and people that transit or live in said environment.

The incorporation of micro-textures in the finish of stainless steel can mitigate these unwanted effects, transforming the purely specular reflection, with a unique angle of reflection, typical of highly stainless steel polished, to a diffuse reflection, where the reflected intensity is distributed in multiple directions.

Although energy studies have determined that the use of micro-textures in the finish does not undermine the advantages of stainless steel in relation to the energy efficiency, its undeniable visual impact is a very important factor to consider. The degree and extension of these micro-textures will condition the balance between specular reflection and diffuse reflection of a certain finish of the stainless steel, and, therefore, between the satin or matt appearance of the surface of the edification.

For the weighting of these factors it is necessary the characterization of the stainless steels destined for building, with a quantitative parameter that accounts of said balance. In this way, building technicians can have an objective criterion, before making decisions, on the reflector characteristics sought for the lining in stainless steel of a certain building.

NORMATIVE

Europe does not have yet specific rules for quantifying optical properties optics of stainless steels. However, we find a growing approach of *façadist* to have optical parameters that allow them to know the behaviour of a surface finish of a stainless steel.

The closest we find in terms of regulations, in the British Standard of United Kingdom, in its standard “Light reflectance value (LRV) of a surface - Method of test”, BS 8493: 2008 + A1: 2010. This standard, as indicated in its introduction, arises from the need to quantify the optical contrast of surfaces, to ensure adequate visibility and legibility of text or pictograms, to people with some degree of visual disability.

REFLECTING VALUE OF LIGHT (LRV)

The referenced LRV parameter in the standard is an indicator of the amount of light that a person perceives when being reflected by a surface. This parameter, which in English we can call Luminous Reflectance Value, is defined in the ICD 15: 2004 standard on colorimetry, of the International Commission on Illumination (CIE).

It is important to keep in mind that in the observation of any surface by a person, using the sense of sight, visual perception will be influenced by the light source used and the sensitivity to visible light of the eye of the observer. Therefore, the perception will not be the same using artificial or natural light, or in this case, if it is at dawn, noon or sunset. And in the same way, the perception will not be the same for an eye with some limitation in its sensitivity or a healthy eye, and in this case, the sensitivity will not be the same at noon (photonic vision), at dawn or dusk (mesoscopic vision), or at night (scotopic vision).

Thus, in the definition of the LRV parameter lighting is considered, corresponds to the standard illuminant D65, whose spectrum describes the conditions lighting stockings at noon in Western Europe, and it is considered, likewise, an observer with a standard sensitivity in his perception of colours.

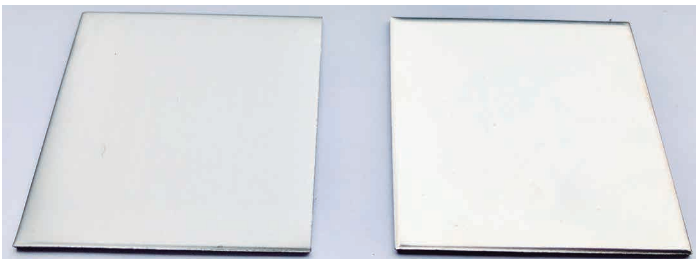
Under these measurement conditions, the LRV parameter is set, which in the mentioned ICD 15: 2004 standard is referred to as the Y10 value of the triple tristimulus values, which model how the human eye perceives primary colours red, green and blue.

The specifications of both the equipment and the conditions of measurement, for the determination of the LRV parameter, are established in the CIE standard 130: 1998, in which the relationship between the angle of incidence of light on the surface and the collection of reflected light is indicated using a sphere integrator

The measurement geometry allows discriminating between reflected light of specular or diffuse form. This is of interest, as has been commented previously, to characterize the behaviour of a surface with respect to its satin or matt finish, respectively. In particular, the CIE standard 130: 1998 establishes the geometries 8°/di (specular included) and 8°/de (speculate excluded), as well as its complementary di/8° and de/8°, for the colorimetry of surfaces from optical reflection measurements.

In view of the above, it is inferred that stainless steel with high value of LRV parameter would have a clear surface, while a low value indicates that its surface would be darker. Additionally, if we observe similar values in the LRV parameter, in both optical geometries, that is, both with light specular included (di) as excluded (de), it indicates that it is a matt surface. If the LRV values are different, then it would be a bright sample; the brighter the higher the difference between the LRV values.

All of the above illustrates the utility of the LRV parameter when quantifying the optical contrast between surfaces, as well as to have an objective indicator of the clarity of a surface. However, the reflection of light by a surface is a complex process, which in the case of LRV is simply averaged and it is only in the integration of the energy of the reflected radiation, but nothing says about how this reflected light is distributed spatially.



Stainless steel test samples supplied by ACERINOX, S.A .: Left. 01VSAP (finish 2B) with LRV (di) 57,868 and (de) 55,450; Right 03V3MCB (Finish BA) with LRV (di) 56,384 and (de) 10,521.

As we have already advanced in previous paragraphs, the light reflected by a surface may have a specular component, which complies with the law of reflection, and a diffuse component, related to roughness or superficial texture. Diffuse reflection presents a strongly angular distribution related to surface roughness or texturing. In certain cases, if the texturized presents some periodic pattern, with a spacing of the order to the wave length of visible radiation, you can observe phenomena of optical diffraction.

BIDIRECTIONAL REFLECTANCE

If we wanted to rigorously model the behaviour of the light that effects on a surface of a particular stainless steel finish, for example, to include it in the rendering of an infographic of a project that includes this material in a façade, we cannot simply use the LRV value and assume that the distribution of the diffuse light component is isotropic, but we need to know what exactly this angular distribution is like.

Errors in the approximations will be more evident in the case of highly textured or rough surfaces and at high angles of incidence and/or observation.

The necessary measure to fully characterize the reflection of light by a surface of an exact shape is known as bidirectional reflectance. The referring to it as bidirectional is due to the fact that it is a function that depends both on the direction of incidence of the radiation on the surface as from the direction of the observer. This geometry is considered in the coordinates system with which these studies are addressed, and which is illustrated in the figure 1.

The distribution function of bidirectional reflectance (BRDF), built from these measurements, would be the function that would allow for a given position of the light source on a surface and a position also given for the observer, to know what luminous intensity would be reaching the observer.

It would be a function of 4 variables, while on the reference system above, 2 angles are needed to characterize the position of the source, and 2 angles for the position of the observer.

The BRDF would also give us information about where we would find higher concentration of light radiation around that surface, in case, for example, it would be façades or covers that could produce effects of concentration of solar radiation in the vicinity of the building.

We refer the reader interested in deepening the details of measurement and modelling of the BRDF to the literature that can be found in specialized journals. However, we do not want to end the article without highlighting that the Photometry and Radiometry Service of the University of Cádiz works with Acerinox Europa in the optical characterization of its stainless steel finishes for façades and visible building elements, and collaborates in R+D+i tasks for the development of unique optical techniques for the optical characterization of their products.

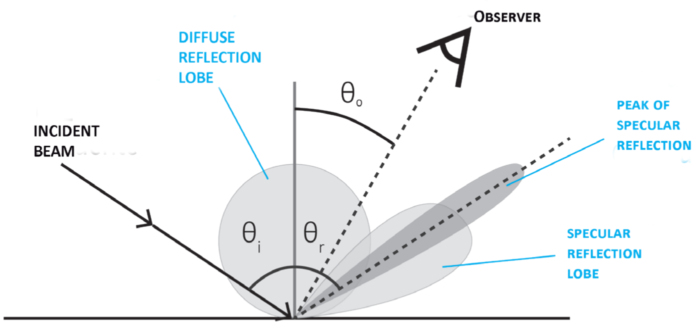


Figure 1: Illustrative diagram of the effect of roughness on the spatial distribution of the intensity of reflected light on a surface.

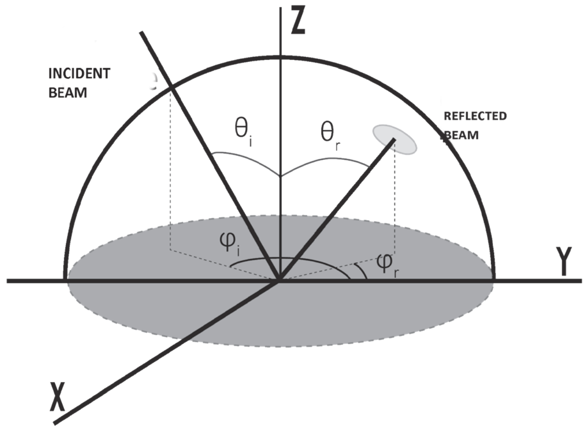


Figure 2: Illustration of the reference frame used for the measurement of bidirectional reflectance.