SURFACES TREATMENT OF MONUMENTAL CONSTRUCTIONS USING FINE TOTAL ECOLOGICAL SAND-BLASTING

Amelitta **Legendi**[1], Associate professor PhD. Eng. - legendi@xnet.ro
Cristiana-Gabriela **Popescu-Ungureanu**[2], PhD. Eng. major professor - cristianapug@yahoo.com
Mircea **Degeratu**[3], Professor PhD. Eng. - mircead@hidraulica.utcb.ro
Ioan **Bărdescu**[4], Professor PhD. Eng. - ioan.bardescu@yahoo.com
1, 3, 4 – Technical University of Civil Engineering Bucharest-UTCB
2 – Scholar Industrial Group of Construction Railways

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Abstract

The technology of surfaces treatment refers to architectural or sculptural works such as monuments of art, statues, historical edifices, churches, monasteries, memorial houses. These buildings have sensitive surfaces that require a periodical cleaning without affecting the basic layer with the view of **depositions and impurities removal**, such as: dust, spots of mud, smoke, oils, greases, soot, residues of food substances, "graffitti" writings and more others.

The mechanized technological processes efficiently used in this direction are those of **sand-blasting**, processes that are using non-metallic sand-blasting granules having the hardness smaller than thatone of the basic layer; the technological equipments are realized in several constructive and functional alternatives, some of them being even quasiecological.

The theme studied by the authors refers to the realization of a certain total ecological constructive system, peculiar to monumental constructions. Theoretical, this equipment produces a diphasical tream of sand-blasting granules – air-compressed envelopped in a taper water tissue that is assuring **a curtain of total protection** for the diphasical tream along with particules detached from the construction surface.

Key words: blasting, surfaces treatment, cleaning granules non-metalic, total ecological.

1. INTRODUCTION

Sand-blasting means the preparation of surfaces using a **working agent** (for example granules) and a **drive fluid** (air-compressed, water under pressure).

This theme refers to the preparation of surface through **non-abrasive cleaning**, the so called **fine** (**easy**) **sand-blasting** with a view to giving back the initial aspect of some monumental construction.

In these sort of works, the technological process of sand-blasting is primarily done using **sand-blasting units**, namely the so called **sand-blasting systems with free jet** (open technological circuit); the sand-blasting process is realized either with lost granules (without recuperation), or with intermittent, manual recovery.

1.1. Sand-blasting processes

The sand-blasting through air fluidization is called **dry sand-blasting** or **pneumosand-blasting** (with diphase air-compressed+granules jet); sand-blasting with water is called **hidrosand-blasting** (sand-blasting with water, diphase water+granules jet). It is also used the **wet sand-blasting with three-phase air jet** = granules+water for humidification (about 50%) with a view to reducing the dust at surface impact.

1.2. Mixing systems granules+fluid

Considering the mixing way of the drive fluid with sand-blasting agent there can be distinguished the following systems:

- **Pressure blast**, case in which both the drive fluid and sand-blasting agent are moving as a mixture throughout a single hose until the sand-blasting nozzle;
- **Suction blast** also called open system, case in which the granules are put in a container at air pressure, from which they are sucked off.

2. SAND-BLASTING MOBILE UNITS WITH FREE JET

Three schemes reguarding the constitution and operating of sand-blasting mobile units with free jet are presented bellow.

2.1. Sand-blasting mobile unit with free jet, pressure- system

The scheme reguarding the constitution and operating of this type of sand-blasting mobile unit is presented in figure 1.

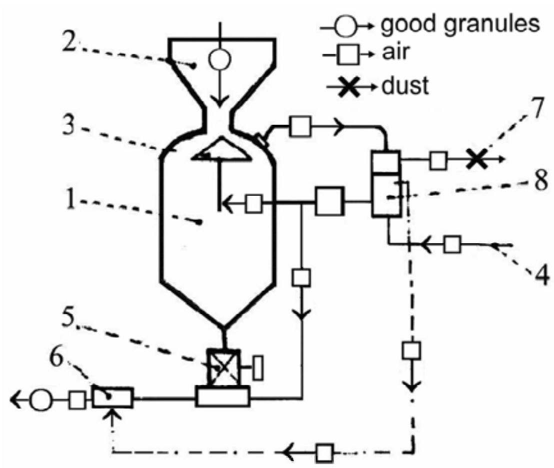


Fig. 1. Sand-blasting mobile unit with free diphase jet, pressure-system and discontinuous operating

1. sand-blasting pneumatic receptacle; 2. feeding hopper for sand-blasting granules; 3. cap-valve pneumatic receptacle; 4. air-compressed feeding hose; 5. granules+air-compressed manual feeding chamber; 5'. granules+air-compressed pneumatic feeding chamber; 6,6'. ejector with sand-blasting nozzle; 7. coupling hose with air filter; 8 – air filter.

The sand-blasting unit is realized with a single connection-ejector and granules regulation valve, manually driven.

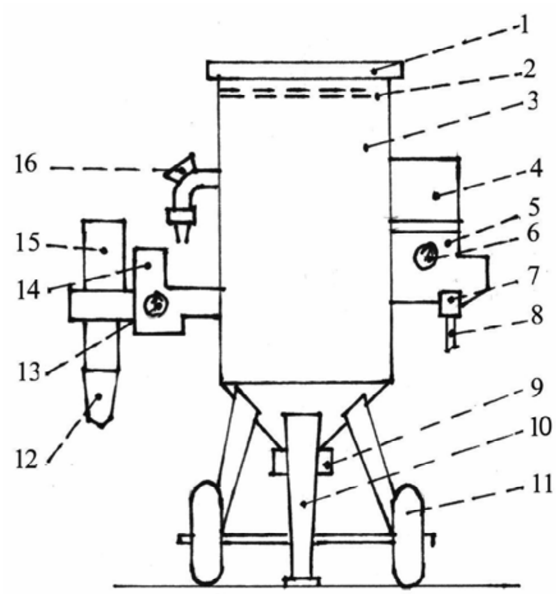
A main assembly of the sand-blasting system is the mixing-dosing granules + air-compressed chamber, in which the proper proportion is realized , as well as the proper feeding of the sand-blasting nozzle.

2.2. Mobile miniunit for dry/wet sand-blasting or for air/water free jet cleaning, pressure-system

The sand-blasting pneumatic receptacle has a 11; 24; 50 l volume (fig. 2). The special sand-blasting valve has 1…5 mm diameter. The air-compressed pressure is adjustable in a 0,5…7 bar range (2…4 bar usual). The sand-blasting mobile unit having a 24 l volume (V) has a mass of 105 kg; the ratio M/V = 4,38kg/l.

The constructive constitution of this sand-blasting unit offers four technological solutions [2]:

a. The **dry sand-blasting** with diphase mix, granules+air in the pneumatic receptacle; the miniunit doesn't use the water pump;
b. The **wet sand-blasting** with granules+air mix in the pneumatic receptacle with water, in a small proportion about 5%, injected in the **special nozzle** (different from that one used in dry sand-blasting) using the water pump; in this case a wet sand-blasting with three-phase air jet = granules + water for humidification with a view to reducing the dust;
c. The **surface cleaning** with diphase air-compressed+water under pressure jet;
d. The **surface cleaning** with **monophase jet** - air-compressed.

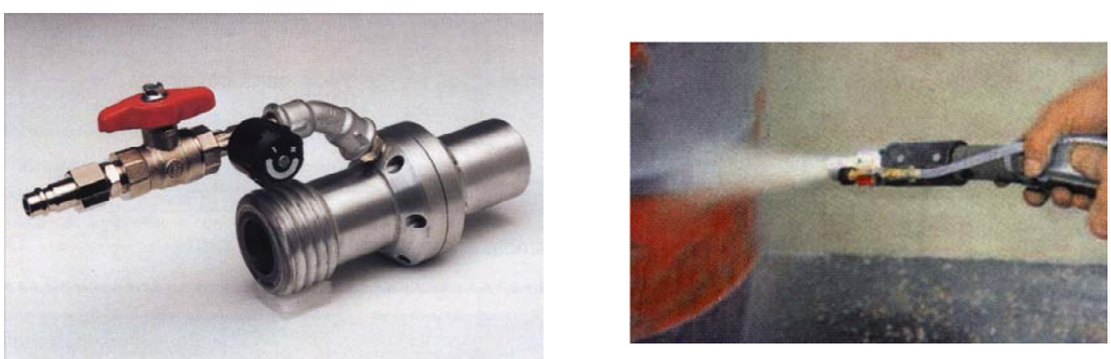


1. hood pneumatic receptacle
2. sieve
3. sand-blasting pneumatic receptacle
4. water pump with self-suction
5. air-compressed connection
6. manometer
7. water connection with filter on nozzle holder hose
8. hose water suction
9. feed chamber and sand-blasting granules+air-compressed mixture, with vibrator
10. bearer for positioning
11. wheels
12. condensed water separator
13. air regulator
14. safety valve
15. filter with active coal
16. valve for relieving receptacle

Fig. 2. Mobile miniunit for wet/dry sand-blasting, pressure – system, 18 or 25 l.

In the mobile miniunit for wet sand-blasting free jet, pressure-system**,** the water injection in the nozzle is generally done through a tube having holes disposed at the nozzle's interior.

Figure 3 a, presents a photo of a nozzle-holder ejector for splashing without dust, granules+air+water three-phase mixture; same ejector during working is presented in figure 3 b. In practice, this ejector system is also called "nozzle with water turbine".



a. ***b.***

Fig. 3. Nozzle-holder ejector for splashing without dust, granules+air+water three-phase mixture
a) ejector structure, nozzle with water turbine; b) in practice.

2.3. Sand-blasting low duty unit, with aluminium structure, free diphase jet

The sand-blasting low duty unit with aluminium structure is realized as a vertical construction, sustained by two wheels for motion and by two bearers for working, so that it is 430 mm maximum broad. It can be easily placed in tight or crowded places and can be easily transported on balusters and scaffoldings (fig. 4).

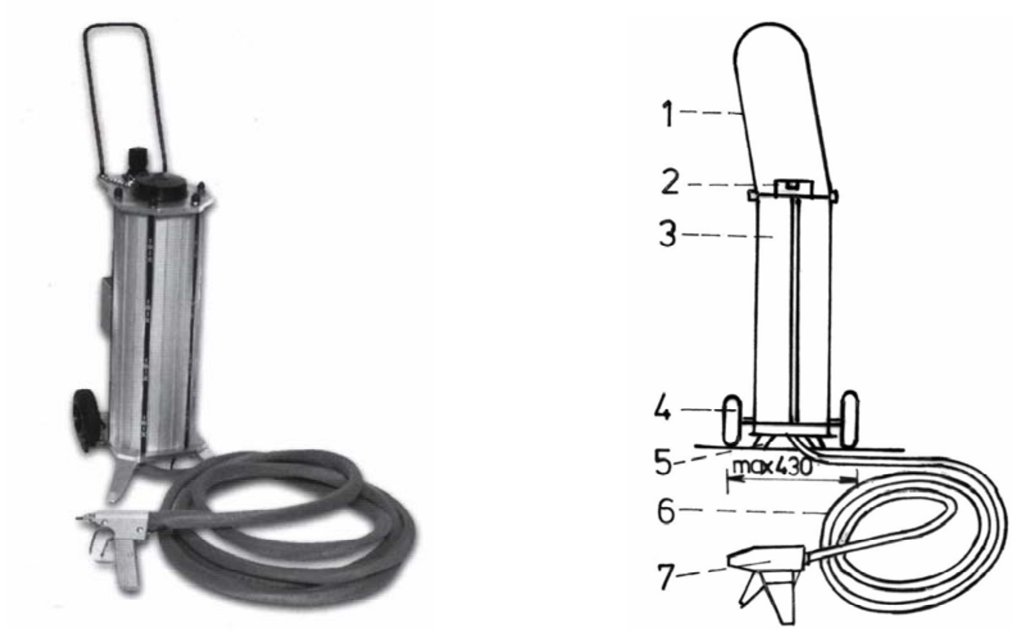


Fig. 4. Sand-blasting low duty unit, with aluminium structure, pressure- system
a. photo; b. structure scheme

1. motion handle; 2. feeding hood; 3. pneumatic receptacle granules+air; 4. wheels for motion; 5. bearers for working; 6. granules+air hose; 7. sand-blasting gun with drive handle.

The constructive type IBIFER 9-IBIX has a 9 l volume, V and 12 kg mass, M; the ratio M/V=1,33 kg/l.

For sand-blasting there are used both 3 mm standard **cylindrical nozzles** (cylindrical interior tube) or 1,5; 2; 2,5; 3; 3,5; 4; 4,5, adaptable and 2,5…4 mm **Venturi nozzles** – bitaper (fig. 5).

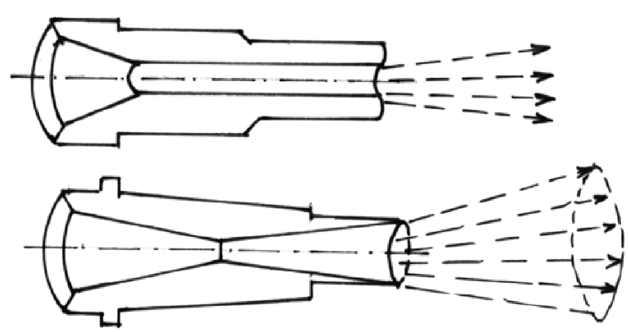


Fig. 5. Nozzle constructive types in accordance with the interior tube's shape

a) cylindrical interior tube;
b) cylindrical interior taper – **Venturi nozzle**.

The air-compressed pressure can be adaptable in the 0,2…7 bar range, not dangereous for operators and environment.

The sand-blasting material can be 0,125…1,8 mm size of grain, such as natural mineral, bicarbonate of sodium, spherical limestone, glass microspheres.

The sand-blasting system with aluminium structure is designed and constructed for ecological microsand-blasting; surface cleaning without splashing dust in the environment; high adaptability; granules quantity regulation in the diphase mix; air-compressed coupling with air regulation; maximum performances if mineral granules GMA Garnet are used, Australian mineral whose grains are not friable, that can't be grinded as sand, that doesn't spread dust and allows discontinuously recycling.

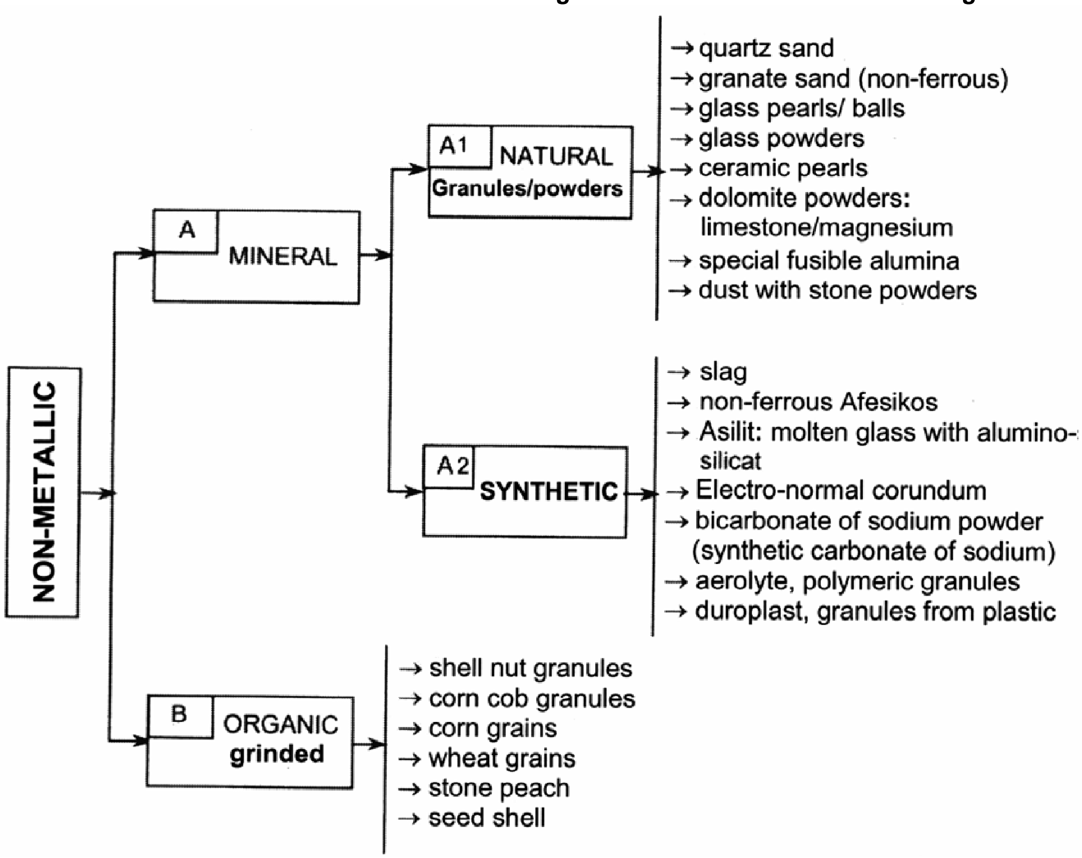
This sand-blasting system allows the execution of some easy, high accuracy, surface cleaning works, without affecting the basic layer, leaving untached the so called "time patina" on stone, marble, brick, wood, metal a.s.o. (collage1).

Collage 1. Fine sand-blasting fine surface cleaning, before and after surface

3. SAND-BLASTING NON-ABRASIVE AND NON-METALLIC AGENTS USED IN SURFACE CLEANING FOR MONUMENTAL CONSTRUCTIONS

Sand-blasting non-abrasive and non-metallic agents are structured in two main groups, mineral and organic; the last one is subdivisioned in natural organic grinded agent and synthetic agent (structural scheme 1).

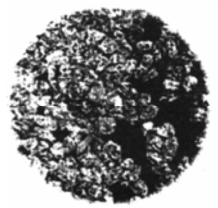
Structural Scheme 1. Sand-blasting non-abrasive and non-metallic agents



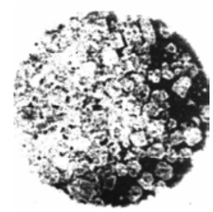
The microstructure of some fine sand-blasting agents for sensitive surfaces cleaning is shown in the second collage (collage 2).

Collage 2. Sand-blasting non-metallic agents: microstructures

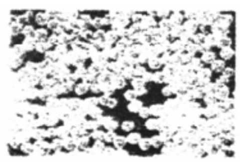
A. Mineral



1. Granate sand (non-ferrous)

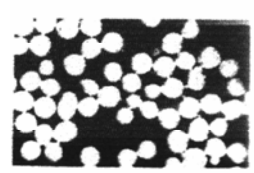


2. Dolomite powders



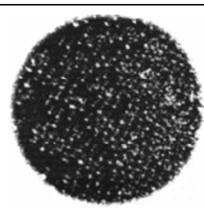
3. Glass pearls

4. Glass granules

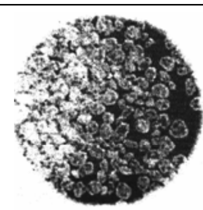


5. Ceramic pearls

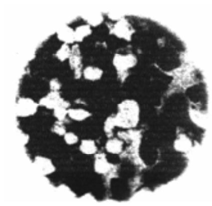
B. Organic



6. Ceramic pearls



7. Bicarbonate of sodium



8. Duroplast, granules from plastic

9. Shell nut granules

10. Corn grains

4. DIPHASE AIR-COMPRESSED+GRANULES JET

The diphase jet's length

The diphase jet's length (L_{jb}) was experimentally measured in the sand-blasting – discontinuously recycling chamber's interior, on perpendicular direction as distance between the interior diameter's surface at the outlet of Venturi long nozzle (d_{vl}) and the concrete sample's surface or thatone of natural stone (fig. 6).

$$d_{vl} = 15 \text{ mm}; \quad L_{jb} = 240 \text{ mm} \tag{1}$$

The diphase jet's length depending on the interior diameter at the outlet of Venturi long nozzle, in practice is L_{jb} = 80…250 mm; L_{jb} = 10…30 d_{vl} .

$$\boxed{L_{jb} = 16\ d_{vl}} \tag{2}$$

The diphase jet's dispersion after quitting the Venturi long nozzle

It is focused the fact that, although the sand-blasting charge was one of low capacity, **after just a single splash, the print remained very visible**. The fact that, both the print on the concrete sample, and thatone on the natural river stone were of **cvasicircular**

shape, having the print's diameter (D_{as}) equal, confirms the accuracy of the measurements.

$$D_{as} = 60 \text{ mm} \quad (3)$$

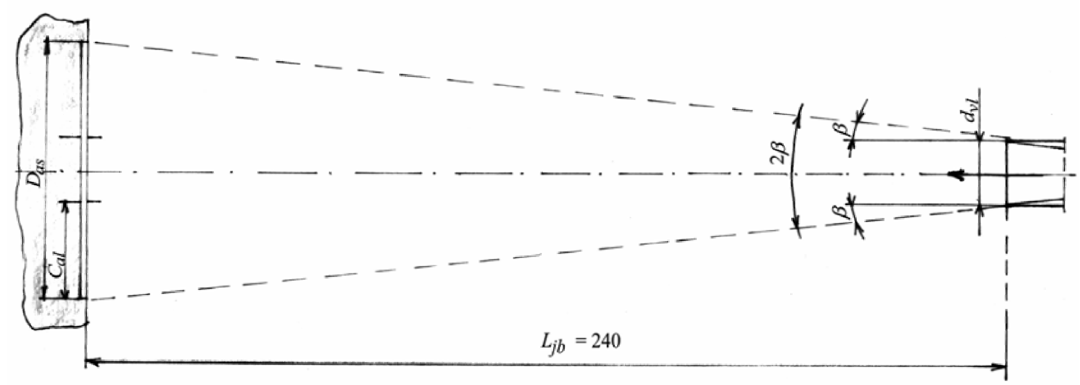


Fig. 6. The diphase air-compressed +granules jet's length and dispersion.

The geometrical representation and the calculus done show that **the angle of dispersion** (2β) is:

$$\boxed{2\beta \cong 11^\circ} \quad (4)$$

This value is closed to values known from practice.

It is underlined the fact that the angle of dispersion depends on the **diphase jet's average speed** (v_{jb}):

$$\boxed{2\beta = f\left(v_{jb}\right)} \quad (5)$$

5. SAND-BLASTING DIPHASE GRANULES+AIR-COMPRESSED JET ENVELOPPED IN A TAPER WATER TISSUE

The envelopping solution of the diphase granules+air-compressed jet with a taper water tissue is conceived to prevent the dipersion of dust in the environment (fig. 7).

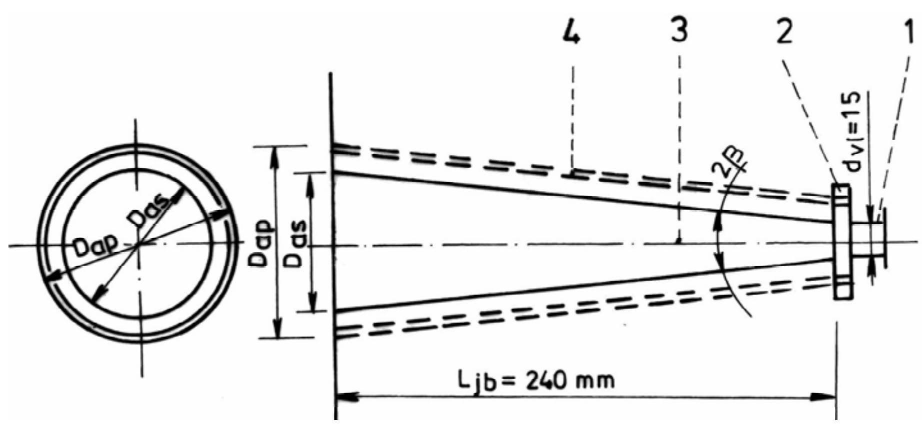


Fig. 7. Diphase granules+air-compressed jet envelopped in a taper water tissue.

1. granules+air-compressed mixture nozzle; 2. water nozzle-holder rim; 3. diphase granules+air-compressed jet; 4. taper water tissue.

The dust gets rid both through particules detached from material **settlings** on sand-blasted surface, and from the material granules **grinding**. The relieves of dust resulted following the sand-blasting are retained in the interior of the **taper water tissue**, assuring that the sand-blasting technological process is **total ecological**.

The taper water tissue preventing the dust dispersion in the environment is realized using a launching device- **water nozzle- holder rim**- which is attached at the end of nozzle's outlet of mixture.

During the incoming tests is important to verify some constructive and technological parameters theoretically determined, such as: number of nozzles and their position, the angle of water jet's dispersion and the thickness of the water tissue a.s.o.

6. THEORETICAL FOUNDATIONS REGUARDING THE DIPHASE GRANULES+ AIR-COMPRESSED JET

The jet used in fine sand-blasting is a gas jet that holds ithin fine particules of sand-blasted material and so it could be considered as a isotherme diphase jet. The sand-blasted material in suspension is a fine material having a low stiffness and it can be considered theoretically as evenly distributed in the gas mass.

Taking into account the small solid+gas volumic ratio, the almost unitary solid+gas massic ratioand the characteristics of particules in suspension, we can admit an unitary solid speed+gaz ratio and thus the simplifier assumption of monophase jet.

Theoretically, we can start from the motion quantity proposed to be constant along the jet:

$$\dot{m}_p w_{0_p} + \dot{m}_g w_{0_g} = \int_0^A \left(C_y + 1\right)\rho_g w_y^2 dA = \text{ct} \tag{6}$$

where $\dot{m}_p$ and w_{0p} are the mass and the initial speed of particules in suspension, $\dot{m}_g$, w_{0_g} and ρ_g are the mass, initial speed and density of gas stage, C_y is the mixture concentration in point *y*, and dA is an element of transverse section of the jet.

Taking into account the fact that, in a circular section jet $dA = 2\pi\left(ax\right)^2 \varphi \cdot d\varphi$ where a is the turbulence coefficient, and $\varphi = y/ax$, the equation becomes:

$$\dot{m}_g w_{0_g}\left(1 + \frac{\dot{m}_p w_{0_p}}{m_g w_{0_g}}\right) = 2\pi\left(ax\right)^2 \rho_g w_x^2 \int_0^{\varphi_{gr}} \frac{w_y^2}{w_x^2}\left(C_y + 1\right)\varphi d\varphi \tag{7}$$

Decomposing the integral from the (7)-th equation, admitting that the dimensionless speed w_x/w_y depends only on φ, ordinate, replacing φ with η ($\varphi/\varphi_{gr} = y/R_{gr} = \eta$ and $R_{gr}/R_0 = 3{,}4a_x/R_0$) and supposing that the environment concentration in the jet's axis $C_m = 0$ ($\Delta C_x = C_x$ şi $\Delta C_y = C_y$), the following equation comes out:

$$2\pi\left(ax\right)^2 \rho_g w_x^2 \int_0^{\varphi_{gr}} \frac{w_y^2}{w_x^2}\left(C_y + 1\right)\varphi d\varphi = 2\pi\left(ax\right)^2 \rho_g w_x^2 \left(0{,}535 + 0{,}3C_0 \frac{w_x}{w_{0_g}}\right). \tag{8}$$

Taking into account the (7)-th equation, we obtain:

$$\dot{m}_g w_{0_g}\left(1 + \frac{\dot{m}_p w_{0_p}}{\dot{m}_g w_{0_g}}\right) = \pi R_0^2 \rho_g w_{0_g}^2 \left(C_0 v_0 + 1\right), \tag{9}$$

in which $C_0 = \dot{m}/\dot{m}_g$, iar $v_0 = w_{0_p}/w_{0_g}$.

Including relations (9) and (7) and processing the termes, the speed variation in the diphase jet's axis can obtained as:

$$0{,}96\frac{w_{0_g}}{w_x}\frac{\sqrt{C_0v_0+1}}{\sqrt{0{,}56C_0\frac{w_x}{w_{0_g}}+1}}=\frac{x}{R_0}a. \tag{10}$$

Considering the jet is homogenized before its development, we can admit that at nozzle's exit, the two phases have the same initial speed ($v_0=1$). In this case, peculiar for the isotherme diphase jet used in fine sand-blasting, the axial jet's speed variation can be expressed through a **practical relation**:

$$\frac{w_x}{w_0}=\frac{0{,}96R_0}{ax}\cdot\frac{\sqrt{C_0+1}}{\sqrt{0{,}56C_0\frac{w_x}{w_0}+1}} \tag{11}$$

Based on this relation we can estimate the axial diphase jet's dimensionless speed variation (w_x/w_0) depending on a ax/R_0.

7. DISCUTIONS AND SHORT CONCLUSIONS

The sand-blasting technology and equipment for surfaces cleaning at monumental constructions is an up-to-date issue reguarding the aesthetic and ecological protection aspects of environment. These issues can be resolved through researches and tests using the experience in this field.

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[3]	* * *	Prospecte: ACF-ECOSAB; IBIX.

9. DESPRE AUTORI

■ **Amelitta LEGENDI**, Associate professor PhD. Eng., Technical University of Civil Engineering Bucharest-UTCB, Faculty of Technological Equipment, Mechanics and Mechanisms Department, teached disciplines: Mechanisms, Mechanics, Techologies in Ecological Constructions. Graduated the Faculty of Technological Equipment – ICB (1985), PhD. in mechanical engineering (1998), postgraduate studies majoring in: Pedagogy certificate (1999), Technological Education Diploma (2000), assistant at ICECON Bucharest

■ **Cristiana-Gabriela POPESCU-UNGUREANU**, PhD. Eng. teacher major in Machines and equipments in constructions, the Scholar Group for Railways Constructions Bucharest, PhD. in mechanical engineering (2005), Member in the General board of directors, the Romanian Association for Technologies, Equipments and Mechanisation in Construction – AROTEM.

■ **Mircea DEGERATU**, Professor PhD. Eng., Technical University of Civil Engineering Bucharest-UTCB, Faculty of Hydrotechnics, Hydraulics and Environment protection Department, Master Laboratory of Aerodynamics and Wind Engineering; Disciplines: Mechanics of Fluids and Hydraulic machines; Guest professor at Paris 7 Denis Diderot University and at Paris 12 Valde Morne University. Scientific conselor of Divers Centre of Constantza from Naval Forces.

■ **Ioan BĂRDESCU**, Professor PhD. Eng., Technical University of Civil Engineering Bucharest-UTCB, Faculty of Technological Equipment, Machines and Equipments in Constructions Department, disciplines: Technology and Mechanisation in Constructions; Constructions machines optimization; Small mechanization equipments – finishing operations; PhD. Scientific Master (from 2000) in technical sciences – mechanical engineering; Coordinating programmes at Didactic Staff Preparing Department – DPPD (dppd@utcb.ro). Prime vice-president AROTEM (www.arotem.ro), Chief Editor of AROTEM monitor (www.monitorul.arotem.ro).