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EXPERIMENTAL DETERMINATIONS WITH SAND-BLASTING MOBILE UNIT HAVING FREE DIPHASE JET

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Abstract. A sand-blasting mobile unit with free diphase jet, pressure- system, classical type, was used to perform the tests; this mobile unit is used by the firm for free diphase jet sand-blasting, **sand+air-compressed** (without sand-blasting material recovery). Focusing a sand-blasting modern technology, metallic granules were used instead of sand and the experiments to be done were realized in a view to accomplishing **minimal costs** and **real working conditions**. So, the sand-blasting unit was **essentially modified regarding the constructive design**, in a personal conception, using the **sand-blasting technology with discontinuous sand-blasting granules recovery,** with a minimal quantity of sand-blasting granules. Some sand-blasting technological parameters were measured and estimated, such as the diphase mixture speed at nozzle's outlet, the diphase dry mixture length and dispersion, the mass of particles detached from the basic layer, the speeds and kinetic energies of sand-blasting granules and particles detached.

1. INTRODUCTION

Within the *"Technologies and sand-blasting mobile units in constructions"* research paper performed in a view to develop a PhD thesis [1], there have been done some experimental determinations regarding sand-blasting in a private company SUTCAS s.r.l.-Bucharest, producing very light (under 100 kg/m^3) macro air-entrained polymeric concrete elements. The mechanical plant along with the manufacture hall are situated in Ciorogarla, Ilfov county. Tests were done using a sand-blasting mobile unit with free diphase jet, pressure-system, industrially used with sand, essentially modified regarding the constructive design, in a personal conception, in order to achieve: the testing essential demands, the use of metallic granules, a sand-blasting technology development with strained jet and discontinuous sand-blasting granules recovery, minimal testing costs.

2. SAND-BLASTING METALLIC GRANULES

The sand-blasting agent available that was used is made of metallic material- steel.

- **The sand-blasting granule's shape and dimensions that were used in experimentation**:
  - **Cylindrical granules** made and cut of steel wire, middle dimensioned, having the diameter d_{gc} = 2 mm and the length l_{gc} = 3 mm (fig. 1 a). Considering the diameter's size, these belong to big granules group with d_{gc} = 2,0…3,2 mm;
  - **Spherical granules – small shots** made of cast steel, d_{as} =1,5 mm. Considering the diameter's size, these belong to middle granules group with d = 1,0…1,9 mm.

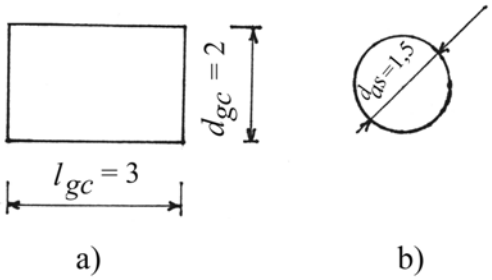

Fig. 1. Shape and dimensions of sand-blasting granules
a) cylindrical granules;
b) spherical granules –small-shots.

- **Apparent specific mass of sand-blasting granules**

These apparent specific masses were determined using volumetric analysis of mass, thus resulting ρ_{gc} = 4,92 kg/dm^3 for cylindrical granules and 4,10 kg/dm^3 for spherical granules – small shots.

Taking into account the apparent specific mass, the values obtained after tests done harmonize with those mentioned in the specialized literature *"Sand-blasting materials with main technical characteristics"*, namely steel granules have the apparent density ρ = 3687…4488 kg/m^3.

- **The hardness of sand-blasting granules**

Taking into account the hardness, that has a real effect on sand-blasting intensity, both cylindrical and spherical granules have a high hardness HRC = 54…61.

3. MODIFICATIONS AND CONSTRUCTIVE COMPONENTS FOR EXPERIMENTATION

The personal conception modifications were chasing the use of some components, previous warned by ISCIR, and some procedure achievement to assure the measurement conditions.

Through personal means, the following seven additional components of the original sand-blasting unit, used with sand granules, were realized:

- **The cannular chamber** (cylindrical), low capacity, for controlled charges, that allows the use of small and measurable quantities of steel granules.
- **The spherical chamber** of mixing-dosing granules+air compressed.
- **The sand-blasting-recovery chamber** of metallic granules in sand-blasting process; gauge 310×380×420 mm, volume about 50 dm^3.
- **The mobile spatial frame** for **air compressor** and components.
- **The mobile spatial support** for the sand-blasting recipient and components.
- **The force cell** for force indirect measurement through pressure.
- **The sand-blasting nozzles** in three constructive versions.

3.1. The spherical mixing-dosing chamber of metallic granules+air-compressed

The spherical mixing-dosing chamber is the main component of the sand-blasting recipient that realizes the connection with the sand-blasting nozzle holder ejector. Using this chamber the metallic granules and air-compressed mixing and dosing could be done so that an adequate ratio between the metallic granules and air-compressed volume was obtained. In this sand-blasting unit case, this ratio was obtained manually, using a handle (fig. 2).

3.2. The sand-blasting-recovery chamber of metallic granules in sand-blasting process

In a view to reduce up to elimination the lost of metallic granules, a sand-blasting nozzle holder chamber (box) was conceived, having a volume about 50 dm^3 for the sand-blasting granules intermittent recovery. So, a bath from a washing machine was obtained and processed to assure its tight position and so to avoid the metallic granules lost. Thus the free-jet sand-blasting unit became an unit with discontinuous sand-blasting − recovery head. The samples were put in this chamber assuring so a closed space during the sand-blasting process that allows the granules recovery after each splashed burden (fig. 3) and the prints measurement after sand-blasting.

Fig. 2. Spherical granules+air-compressed mixing-dosing chamber

Fig. 3. Discontinuous sand-blasting-recovery chamber

3.3. Non-metallic material sample

In order to do the tests, some samples of different non-metallic material were obtained and used: concrete, processed stone and river stone.

- **The concrete sample** has an irregular shape, a rectangle and a trapeze combination. The middle thickness δ_b = 5 mm, the greatest width 17 cm, the greatest length 18 cm, having a 260 cm^2 surface (fig. 4 a).
- **The natural river stone sample** has an oval shape with middle thickness δ_p = 6 cm, the greatest width 23 cm, having about 276 cm^2 surface (fig. 4 b).

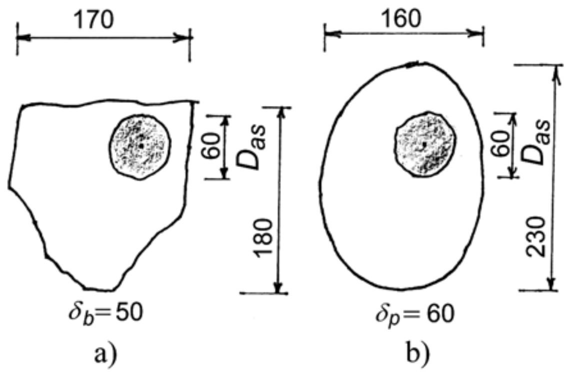

Fig. 4. Samples used in tests done having the prints on after sand-blasting
a) concrete sample;
b) natural river stone sample

3.4. Sand-blasting nozzles

Three types of splashing nozzles were designed and realized suitable to the metallic granules type and dimensions and to the samples' material also: **long Venturi** type (fig. 5 a), short **Venturi type** (fig. 5 b) and the **cylindrical** one.

- **Long Venturi type nozzle** has the outlet diameter d_{vl} = 15 mm and the length l_{vl} = 170 mm; the outer diameter that joints the sand-blasting hose is d_{fg} = 27 mm. The passage diameter starting from the expanding input with a 6º angle is d_{tl} = 9,8 mm.
- **Short Venturi type nozzle** has the outlet diameter d_{vl} = 11,8 mm and the length l_{vs} = 100 mm; the outer diameter that joints the sand-blasting hose and the passage diameter between expandings have the same values as the above type, meaning d_{fg} = 27 mm, and d_{ts} = 9,8 mm.
- **Cylindrical nozzle** has a constant input and outlet diameter d_{tc} = 9,8 mm, the same as the outlet diameter of the two Venturi nozzles and the length l_c = 100 mm, the outer

diameter that joints the sand-blasting hose being d_{fg} = 27 mm, same as the two Venturi types.

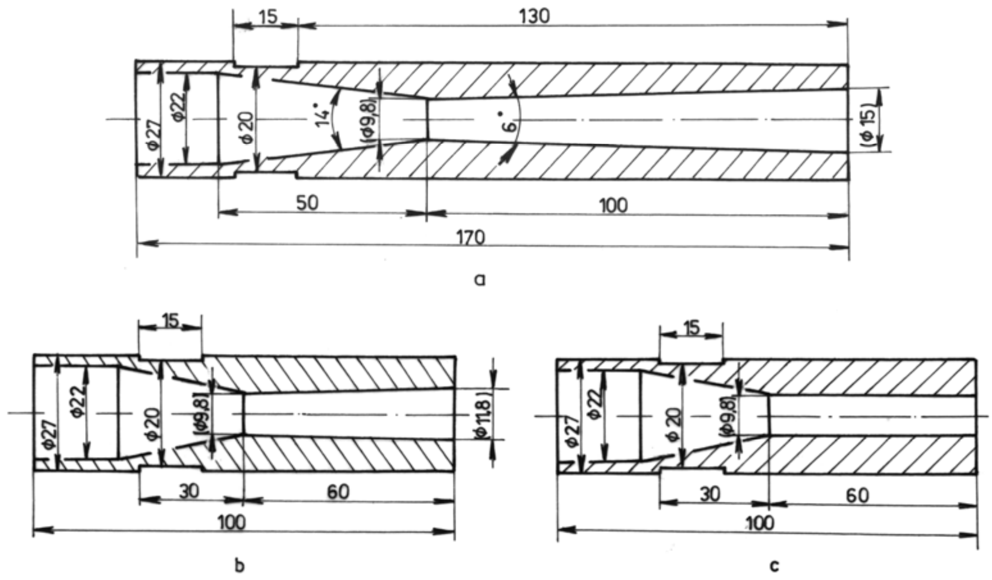

Fig. 5. Nozzle constructive types used in tests done:
a) long Venturi type nozzle; b) short Venturi type nozzle; c) cylindrical nozzle

4. SAND-BLASTING TECHNOLOGICAL PARAMETERS MEASURING AND DETERMINATION

Some direct and indirect measurements through geometrical and technological parameters were done during tests running in a view to determine volumes, masses, speeds, energies and impulses. Experiments were mainly done using the long Venturi type nozzle, having the granules+air-compressed mixture outlet diameter d_{vl} = 15 mm (fig. 5 a) and the cylindrical granules diameter d_{gc} = 2 mm. The $d_{vl}/d_{gc} = 7{,}5 > 5$ ratio is the technological condition assessed.

4.1 Geometrical parameters

The granules feeding cannular chamber – the spherical mixing-dosing chamber and granules+air mixture pressing hose assembly is shown in figure 6; this setting was used to determine the geometrical parameters in table 1.

Table 1. Geometrical parameters of the cannular-spherical chamber assembly

Crt. No.	Geometrical parameter	Symbol	MU	Value
1.	The **cannular chamber** volume	V_{ct}	dm^3	0,58
2.	The mixing-dosing spherical chamber volume	V_{cd}	dm^3	0,033
3.	The mixture pressing-transport hose at the nozzle			
	− Diameter	d_{fg}	dm	0,3
	− Length	L_{fg}	m	10
4	The length of granules+air-compressed mixture cylindrical charge in the pressing hose	l_{ca}	dm	0,465

4.2 The granules+air-compressed mixture outlet speed

- The measured time in which the cylindrical granules charge passes the inner side of the hose

$$t_{ca} = 0,4 \text{ s} \quad (1)$$

- The outlet diameter of granules – air-compressed mixture

$$v_{1p} = 25 \text{ m/s} \quad (2)$$

■ **The granules+air-compressed mixture theoretical outlet speed from the nozzle**

The mixture theoretical outlet speed from the nozzle was theoretically determined (v_{1t}) using the Voicu Victor's formula in the paper "*Air dust removal technique*", Editura Tehnică, Bucureşti 1988, being mentioned there that this formula was taken over from the author Dalla-Valle

$$v_{1t} = \frac{\rho_{gc}}{\rho_{gc}+16} d_{gm}^{0,4} = 20 \frac{4920}{4920+16} 2^{0,4}; \quad (3)$$

$$v_{1t} = 26,32$$

The resulting deviation from the value theoretically determined through tests done is about 5%, acceptable due to different variable factors.

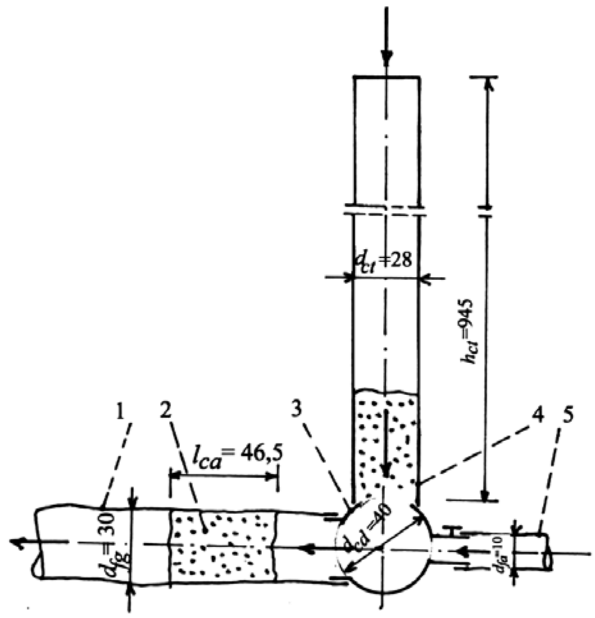

Fig. 6 Granules feeding cannular chamber – spherical mixing-dosing chamber and granules+air mixture pressing hose assembly

1 - granules+air mixture pressing hose; 2 - mixture charge granules+air inside the pressing hose; 3 - mixing-dosing chamber; 4 - granules feeding cannular chamber placed in the sand-blasting recipient; 5 - supplementary air hose for granules+air mixture dosing-transport to the nozzle

■ **The granules+air-compressed mixture practical outlet speed from the nozzle proposed by the authors**

For practical applications, a simplified calculus relationship for the granules+air-compressed dry mixture speed at the nozzle outlet is proposed:

$$\boxed{v_{1p} = 20 \cdot d_g^{0,4}} \quad \text{[m/s]} \quad (4)$$

where: v_{1p} is the granules+air-compressed dry mixture outlet speed from the nozzle, in m/s; d_g – is the granule's diameter, in mm.

The proposed relationship − (4) − gives a very little deviation from the theoretical expression – (3) – under 5%, thus being recommended to be used in situ.

4.3. The granules+air-compressed diphase jet

■ **The diphase jet length**

The diphase jet length (L_{jb}) was perpendicularly measured in the discontinuous sand-blasting-recovery chamber's interior, as distance between the inner outlet diameter surface of the Venturi long nozzle (d_{vl}) and the concrete surface, respectively the natural stone one (fig. 7).

$$d_{vl} = 15 \text{ mm}; \quad L_{jb} = 240 \text{ mm} \quad (5)$$

The diphase jet length depending on the inner outlet diameter of the Venturi long nozzle

$$\boxed{L_{jb} = 16\ d_{vl}} \quad (6)$$

■ **The diphase jet dispersion after the exit of the Venturi long nozzle**

The visible print dimensions remained on the sample's surface were measured after a sample's sand-blasting (fig. 4). The diphase jet is represented in figure 7.

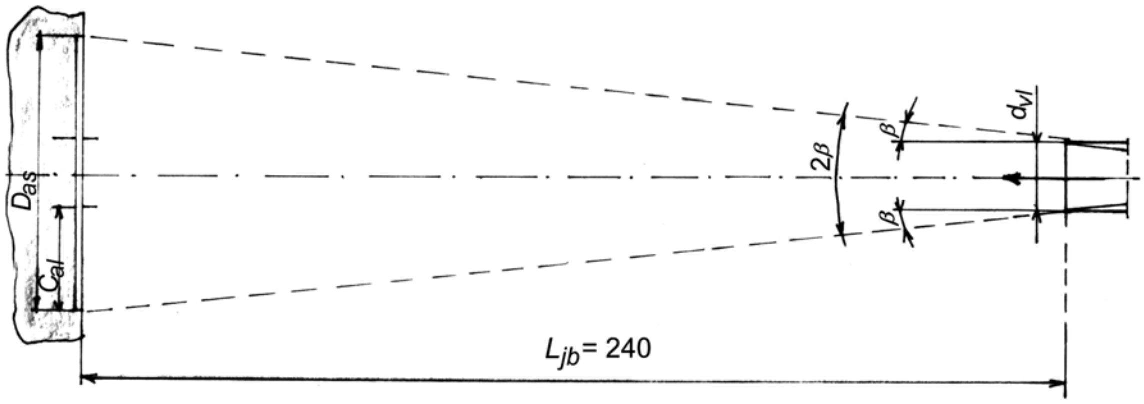

Fig. 7 The granules+air-compressed diphase jet length and dispersion

We can conclude that, although the discontinuous sand-blasting charge was of low capacity, **after a single splash, the print remained visible**. Both the print on the concrete sample and the print on the natural river stone were quasi-annular, having the prints diameter (D_{as}) equal (fig. 4), confirming so the accuracy of measurements

$$D_{as} = 60 \text{ mm} \tag{7}$$

The geometrical disposal (fig.7) and the calculus done focus that the **dispersion angle (2β)** is:

$$\boxed{2\beta \cong 11^\circ} \tag{8}$$

This value is closed to those practically obtained.

The dispersion angle depends on the sand-blasting granules+air-compressed diphase jet average speed (v_{jb}):

$$\boxed{2\beta = f\left(v_{jb}\right)} \tag{9}$$

5. CONCLUSIONS

This theme deals with the testing first part done for a PhD thesis [1]. This paper focuses the **conceived solutions for experiments** to be done using an existing sand-blasting technological equipment which has been **essentially transformed** and **endowed with test specific components**. The modifications done, using **original technical and technological solutions**, pursued a **test prototype** manufacture that allows **real working conditions** in sand-blasting process, using a small quantity of sand-blasting granules (about 100 kg) and a **discontinuous recovery** technology. It is to mention that financial efforts were done, and the sand-blasting equipment necessary manufactures for transformation for tests were realized with great efforts and so, much gratitude to all people that helped to make this project become real.

Measurements done during tests and compared to those mentioned in the specialized literature were enough precise, max ± 5%. This proofs that **reasoning and calculus** done before experiments were correct conducted.

The **sand-blasting procedure** is a model for trial workings done before sand-blasting in given conditions which can realize the **sand-blasting technological parameters regulation** due to real conditions.

A real importance for practical applications has the simplified calculus relationship for the **dry mixture speed** determination granules+air-compressed at the nozzle's outlet (relation 4); this speed conditions most of sand-blasting technological parameters.

Results obtained in this paper are used for the other sand-blasting parameters determination, such as:

- mass of metallic granules thrown from the nozzle that hits the sample's surface and realizes the sand-blasting print;
- mass of particles detached from the element to be sand-blasted;
- granules+air-compressed mixture pressure at the nozzle's outlet;
- equivalent mass of sand-blasting granules speed and kinetic energy at nozzle's outlet;
- sand-blasting granules ricochet speed and the proper kinetic energy;
- particles detaching and ricochet speed from the element to be sand-blasted and the proper kinetic energy;
- impulses: of the granules charge at the nozzle's outlet; of the ricocheted granules at collision with the element's surface to be sand-blasted; of the detached and ricocheted granules of the element to be sand-blasted.

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