

Tests Report

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| Client: | Sn Portugal, Lda. |
| Contact information: | Alex Hell (alex@studioneves.com) |
| Proposal ID: | PSO160/2025 |
| Report ID: | PSR0160/2025 – 3 rd version Cancels and replaces report PSR160/2025 – 2 nd version issued on 21/04/2025 |
| Report issued date: | 24/04/2025 |
| Sample receipt date: | 07/02/2025 |

| Revision history | | | |
|------------------|------------------------------|---|------------|
| Revision | Identification of the change | Reason for change | Date |
| 0 | | | 17/04/2025 |
| 1 | | Comparison with results previously obtained with <i>StudioNeves</i> plates. | 21/04/2025 |
| 2 | Vertical line on the side | Magnification of the y and x-axes on graphs is presented in Figures 3 to 7, as requested by the client. | 24/04/2025 |



1. Objectives

Determination of the multiaxial impact behavior of three plate samples provided by the client with the following references (Figure 1):



Comparison of the results with those obtained with *StudioNeves* stoneware plates and *Studioneves* bioplastic plates analysed in February 2025 (report PIEP PSR073/2025 issued on 26/02/2025).



Figure 1 – Plate samples provided by the client for analysis

2. Experimental procedure

The determination of the multiaxial impact behavior of three plate samples was carried out based on ISO 6603-2:2023 standard and under the test conditions presented in Table 1 (test conditions identical to those employed with the *StudioNeves* stoneware and bioplastic plates).

Table 1 – Experimental test conditions used to determine puncture impact resistance

| | |
|----------------------------|--|
| Test method | ISO 6603-2:2023 |
| Equipment | Ceast Fractovis Plus |
| Impactor | Hemispherical impactor with a diameter of 20 mm, non-lubricated (Figure 2) |
| Impact velocity | 2,8 m/s |
| Mass applied | 5,045 kg |
| Test temperature | (23±2) °C |
| Type of specimen used | Plates provided by the client (Figure 1) |
| Number of specimens tested | 10 plates per sample |
| Specimen conditioning | More than 24 h at (23±2) °C and (50±10) % relative humidity |
| Date of the test | 14/04/2025 |



Figure 2 – Test configuration to perform multi-axial impact tests on plates

3. Presentation and interpretation of results

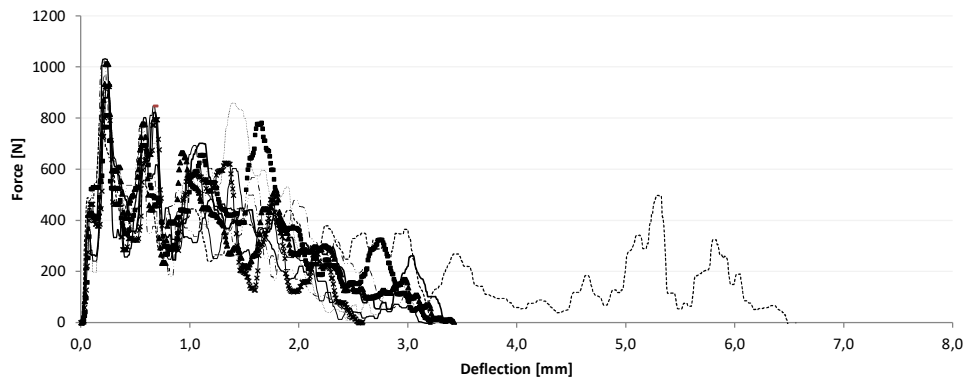
The force *versus* deflection curves recorded in multi-axial impact tests carried out on the plate samples [REDACTED] are shown in Figures 3 to 5. Figures 6 and 7 show the curves obtained with the *StudioNeves* stoneware and bioplastic plates, respectively.

The values of maximum force (F_M), deflection and energy at maximum force (I_M and E_M , respectively), puncture deflection (I_p) and puncture energy (E_p) determined from the aforementioned curves are presented in Tables 2 to 6.

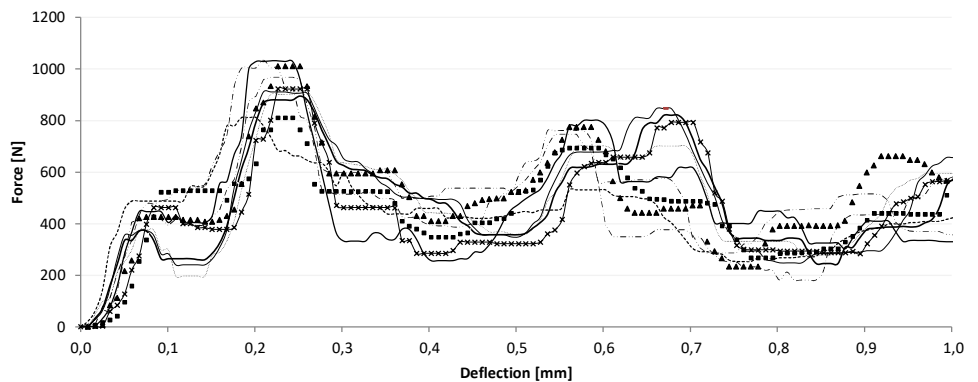
The *StudioNeves* stoneware plates exhibit the highest maximum impact force (F_M), which indicates the material's ability to resist initial puncture, followed in decreasing order of maximum impact force by [REDACTED] alumina stoneware (approximately 25 % lower), *Costa Nova* stoneware (approximately 47 % lower) [REDACTED] porcelain (approximately 69 % lower) and *StudioNeves* bioplastic plates (approximately 82 % lower), as shown in Figure 8.

Concerning impact energy, which reflects the material's ability to absorb energy (E_M) and resist crack propagation (E_p), *StudioNeves* bioplastic plates exhibit a notably higher value (Figures 9 and 10). The energy at maximum force (E_M) of the *StudioNeves* bioplastic plates is about 7 times greater than that of *StudioNeves* stoneware plates, 11 times greater than that of [REDACTED] stoneware plates, 24 times greater than that of *Steelite* alumina stoneware plates and 40 times greater than that of [REDACTED] porcelain plates.

The reduced ability to absorb and dissipate impact energy effectively makes *StudioNaves* stoneware, [REDACTED] porcelain plates more susceptible to cracking (once a crack is initiated, it can rapidly propagate through the material, leading to catastrophic failure), as shown in Figure 11.



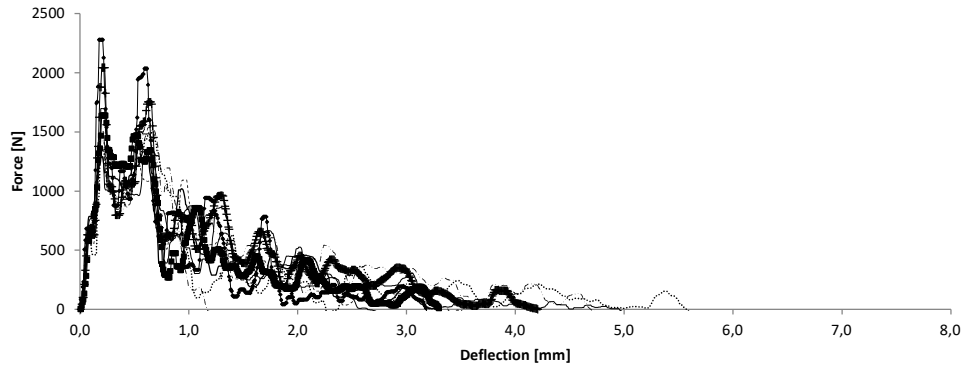
(a) Full-scale axis



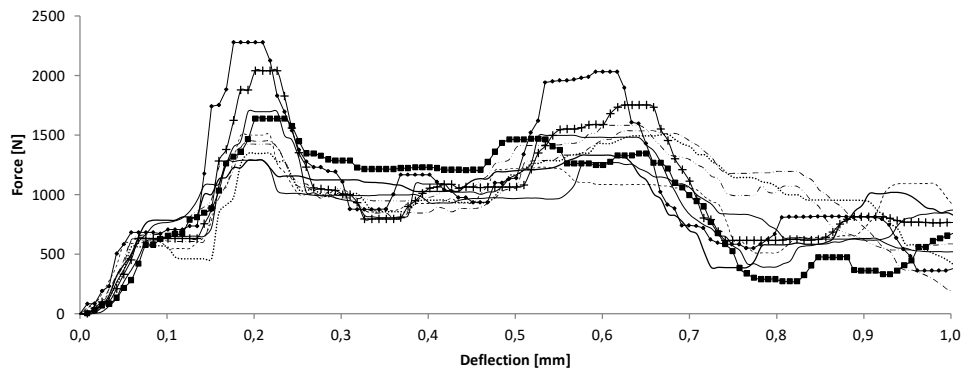
(b) Magnification on the x axis

Figure 3 - Curves of force versus deflection recorded in multi-axial impact tests carried out on [REDACTED] porcelain plates





(a) Full-scale axis



(b) Magnification on the x axis

Figure 4 - Curves of force versus deflection recorded in multiaxial impact tests carried out on [REDACTED] stoneware plates

Table 2 – Puncture impact behaviour [ISO 6603-2:2023] of the [redacted] porcelain plates

| Specimen | F _M (N) | l _M (mm) | E _M (J) | l _p (mm) | E _p (J) |
|---------------------------|--------------------|---------------------|--------------------|---------------------|--------------------|
| 1 | 911 | 0,21 | 0,06 | 0,44 | 0,22 |
| 2 | 896 | 0,25 | 0,10 | 0,44 | 0,21 |
| 3 | 812 | 0,18 | 0,08 | 0,68 | 0,34 |
| 4 | 811 | 0,23 | 0,09 | 0,38 | 0,18 |
| 5 | 1034 | 0,21 | 0,10 | 0,29 | 0,17 |
| 6 | 923 | 0,23 | 0,07 | 0,37 | 0,17 |
| 7 | 914 | 0,25 | 0,09 | 0,39 | 0,19 |
| 8 | 1011 | 0,23 | 0,09 | 0,38 | 0,20 |
| 9 | 1032 | 0,22 | 0,09 | 0,29 | 0,15 |
| 10 | 969 | 0,22 | 0,08 | 0,60 | 0,33 |
| Average | 931 | 0,22 | 0,09 | 0,43 | 0,22 |
| Standard deviation | 81 | 0,02 | 0,01 | 0,13 | 0,07 |



Table 3 – Puncture impact behaviour [ISO 6603-2:2023] of the [redacted] stoneware plates

| Specimen | F _M (N) | l _M (mm) | E _M (J) | l _p (mm) | E _p (J) |
|---------------------------|--------------------|---------------------|--------------------|---------------------|--------------------|
| 1 | 1289 | 0,18 | 0,12 | 0,81 | 0,76 |
| 2 | 1582 | 0,60 | 0,62 | 0,86 | 0,93 |
| 3 | 1536 | 0,63 | 0,58 | 0,90 | 0,93 |
| 4 | 1500 | 0,18 | 0,10 | 0,75 | 0,71 |
| 5 | 1331 | 0,58 | 0,57 | 0,71 | 0,72 |
| 6 | 1636 | 0,20 | 0,13 | 0,72 | 0,81 |
| 7 | 1503 | 0,67 | 0,63 | 0,93 | 0,93 |
| 8 | 2041 | 0,20 | 0,15 | 0,30 | 0,30 |
| 9 | 1695 | 0,19 | 0,12 | 0,33 | 0,28 |
| 10 | 2041 | 0,18 | 0,12 | 0,30 | 0,34 |
| Average | 1615 | 0,36 | 0,31 | 0,66 | 0,67 |
| Standard deviation | 256 | 0,22 | 0,25 | 0,25 | 0,26 |

Table 4 – Puncture impact behaviour [ISO 6603-2:2023] of the [REDACTED] alumina stoneware plates

| Specimen | F_M (N) | l_M (mm) | E_M (J) | l_p (mm) | E_p (J) |
|--------------------|-------------|-------------|-------------|-------------|-------------|
| 1 | 2501 | 0,19 | 0,16 | 0,33 | 0,44 |
| 2 | 2233 | 0,19 | 0,13 | 0,33 | 0,39 |
| 3 | 2133 | 0,19 | 0,13 | 0,31 | 0,36 |
| 4 | 2161 | 0,19 | 0,15 | 0,31 | 0,37 |
| 5 | 2259 | 0,19 | 0,13 | 0,67 | 0,81 |
| 6 | 2116 | 0,16 | 0,12 | 0,65 | 0,78 |
| 7 | 2376 | 0,18 | 0,18 | 0,67 | 0,94 |
| 8 | 2361 | 0,18 | 0,18 | 0,66 | 0,95 |
| 9 | 2250 | 0,17 | 0,12 | 0,66 | 0,79 |
| 10 | 2444 | 0,18 | 0,13 | 0,30 | 0,36 |
| Average | 2283 | 0,18 | 0,14 | 0,49 | 0,62 |
| Standard deviation | 133 | 0,01 | 0,02 | 0,18 | 0,26 |



Table 5 – Puncture impact behaviour [ISO 6603-2:2023] of the *StudioNaves* stoneware plates

| Specimen | F_M (N) | l_M (mm) | E_M (J) | l_p (mm) | E_p (J) |
|--------------------|-------------|-------------|-------------|-------------|-------------|
| 1 | 2827 | 0,43 | 0,74 | 0,62 | 1,17 |
| 2 | 2981 | 0,47 | 0,76 | 0,62 | 1,16 |
| 3 | 2640 | 0,17 | 0,14 | 0,52 | 0,84 |
| 4 | 3293 | 0,51 | 0,90 | 0,62 | 1,21 |
| 5 | 3310 | 0,41 | 0,75 | 0,71 | 1,45 |
| 6 | 3257 | 0,17 | 0,19 | 0,46 | 0,75 |
| 7 | 2934 | 0,38 | 0,60 | 0,51 | 0,92 |
| 8 | 2983 | 0,43 | 0,75 | 0,66 | 1,30 |
| 9 | 3399 | 0,17 | 0,21 | 0,63 | 1,25 |
| 10 | 2706 | 0,17 | 0,15 | 0,66 | 1,10 |
| Average | 3033 | 0,33 | 0,52 | 0,60 | 1,12 |
| Standard deviation | 268 | 0,14 | 0,31 | 0,08 | 0,22 |

Table 6 – Puncture impact behaviour [ISO 6603-2:2023] of the *StudioNeves* bioplastic plates

| Specimen | F_M (N) | l_M (mm) | E_M (J) | l_p (mm) | E_p (J) |
|--------------------|------------|--------------|-------------|--------------|-------------|
| 1 | 501 | 9,69 | 3,01 | 9,93 | 3,12 |
| 2 | 535 | 11,42 | 3,52 | 11,74 | 3,65 |
| 3 | 482 | 9,23 | 2,80 | 9,56 | 2,95 |
| 4 | 512 | 9,59 | 3,11 | 10,02 | 3,32 |
| 5 | 569 | 11,44 | 3,88 | 11,74 | 4,03 |
| 6 | 590 | 11,23 | 3,83 | 11,35 | 3,90 |
| 7 | 475 | 8,15 | 2,54 | 8,35 | 2,63 |
| 8 | 557 | 11,46 | 3,80 | 11,78 | 3,96 |
| 9 | 594 | 11,75 | 4,14 | 12,14 | 4,34 |
| 10 | 519 | 10,71 | 3,38 | 10,93 | 3,48 |
| Average | 533 | 10,47 | 3,40 | 10,76 | 3,54 |
| Standard deviation | 43 | 1,22 | 0,52 | 1,23 | 0,54 |

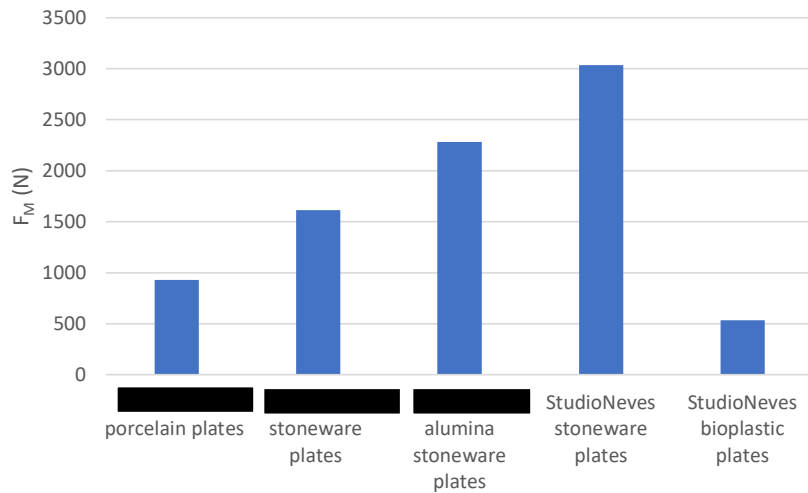


Figure 8 - Maximum impact force (F_M) obtained for samples analysed

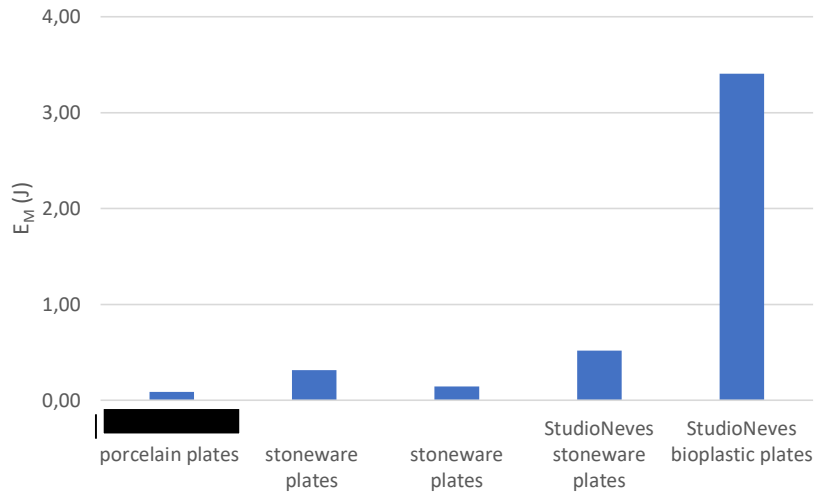


Figure 9 – Energy at maximum impact force (E_M) obtained for samples analysed

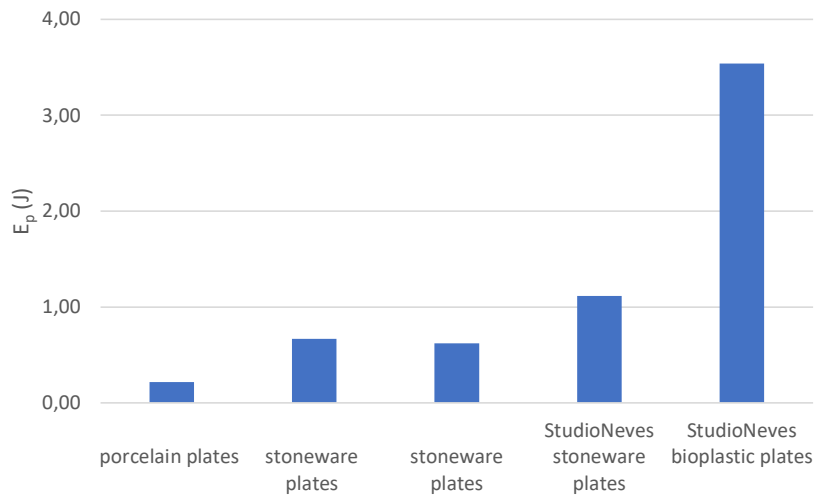


Figure 10 – Puncture energy (E_P) obtained for samples analysed

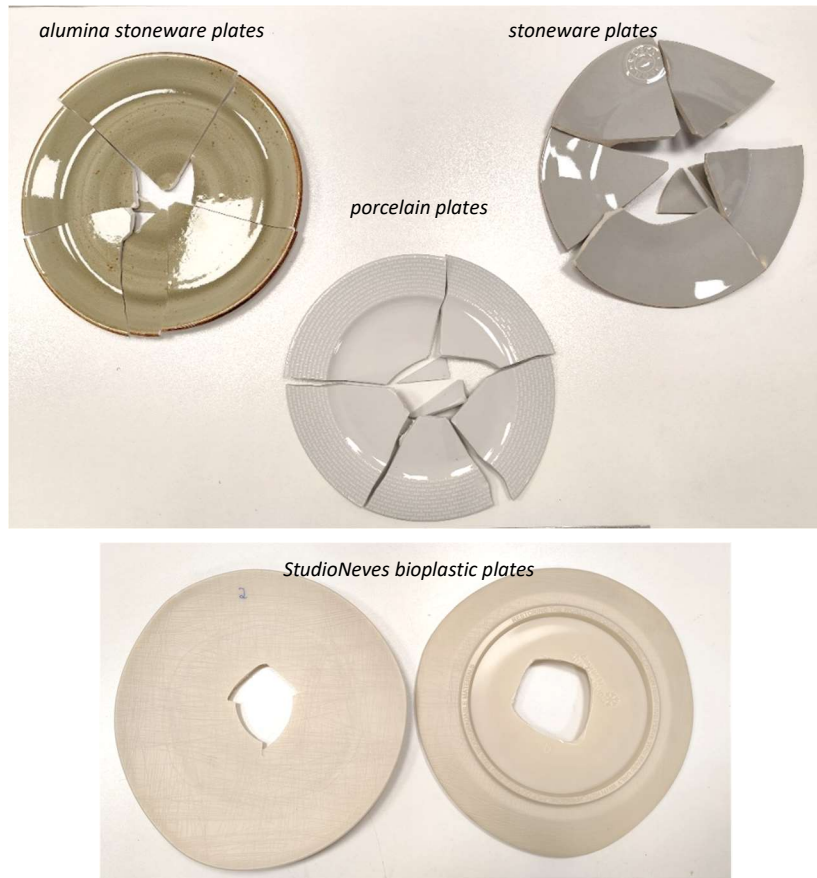


Figure 11 - Failure mode observed in plate samples subjected to multi-axial impact tests

Report approved by:



Paula Peixoto

Tests and Failure Analysis | Coordinator