

# A COMPARATIVE STUDY OF THE MECHANICAL PROPERTIES OF A CONSTRUCTION TOOL HANDLE

*Badania porównawcze właściwości mechanicznych uchwytu ręcznego narzędzia budowlanego*

Сравнительные исследования свойств механического захвата ручного строительного инструмента

Stanisław KOZIOŁ, Tomasz SAMBORSKI,  
Andrzej ZBROWSKI

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**Abstract:** The article presents a method and the results of a comparative study related to the mechanical properties of a construction manual tool handle, namely, the mason trowel. The study was conducted on behalf of Comensal, a tool manufacturer, and it was a part of the process to improve and modernize the construction and manufacturing technology of the product. In the study, strength tests were conducted for three different constructions of the handles, which were made of different materials, and for the connections between the handles and the working plate of the tool. The results of the study and the manufacturer's information on the production cost and manufacturing conditions became the basis in the decision making process to implement the most advantageous solution and to purchase appropriate manufacturing equipment.

**Keywords:** manual construction tools, destructive tests, strength tests, strength

**Streszczenie:** W artykule przedstawiono metodykę oraz wyniki badań porównawczych właściwości mechanicznych uchwytów rękojeści ręcznego narzędzia budowlanego - packi tynkarskiej. Badania wykonane na zlecenie firmy Comensal - producenta narzędzi, były częścią procesu doskonalenia i modernizacji konstrukcji i technologii wytwarzania produktu. Przeprowadzono badania wytrzymałościowe trzech różnych konstrukcji uchwytu wykonanych z różnych materiałów oraz wytrzymałości ich połączenia z płytą roboczą narzędzia. Wyniki badań oraz posiadane przez producenta dane dotyczące kosztów i warunków wytwarzania, stały się podstawą do podjęcia decyzji o wdrożeniu najbardziej korzystnego rozwiązania i zakupie odpowiedniego wyposażenia technologicznego.

**Słowa kluczowe:** ręczne narzędzia budowlane, badania niszczące, badania wytrzymałościowe, wytrzymałość

## Introduction

The aim of the studies was to analyze the possibility of replacing the plastic or mixture of plastics which would allow replace the aluminum alloy, used for manufacture of supporting parts of construction tools. The range of the work included determination of the strength parameters of the tool elements, manufactured from the selected materials and a comparative analysis of the obtained results of the tests [5, 6].

The object of the tests concerned the handles of the mason trowels, produced by Comensal company. The mentioned trowel consists of a flat working plate, made of stainless sheet, the fixed holder of the handle and the handle. The holder of the handle is fixed with the application of press-fitting connection on four pegs welded to the working plate (Fig.1). The handle is pressed into the end of the holder with the appropriate pressure as to ensure the carrying over of the work loads.

Comensal Company, the Orderer of the tests, is a producer of mason trowels, in which there are employed the holders of the handle, which are pressure die cast of aluminum alloy (Fig.2 a) or, alternatively,



Fig. 1. Using welded pegs for a press-fitting connection of the handle with the plate

Rys. 1. Zastosowanie kołków zgrzewanych do wciskowego połączenia uchwytu z płytą

made of pressed polystyrene (Fig.2 b). In commercial practice of Comensal, the aluminum holders are characterized by high manufacturing costs that make the market competition difficult. Their replacement with

the polystyrene pressed holders has caused a significant change in a shape, resulting from the necessity of ensuring the required strength of the tool. The new shape, in spite of the approvable manufacturing costs, does not find, however, the recognition of the customers due to insufficient stiffness and strength, making the effective and comfortable work of the craftsman difficult.

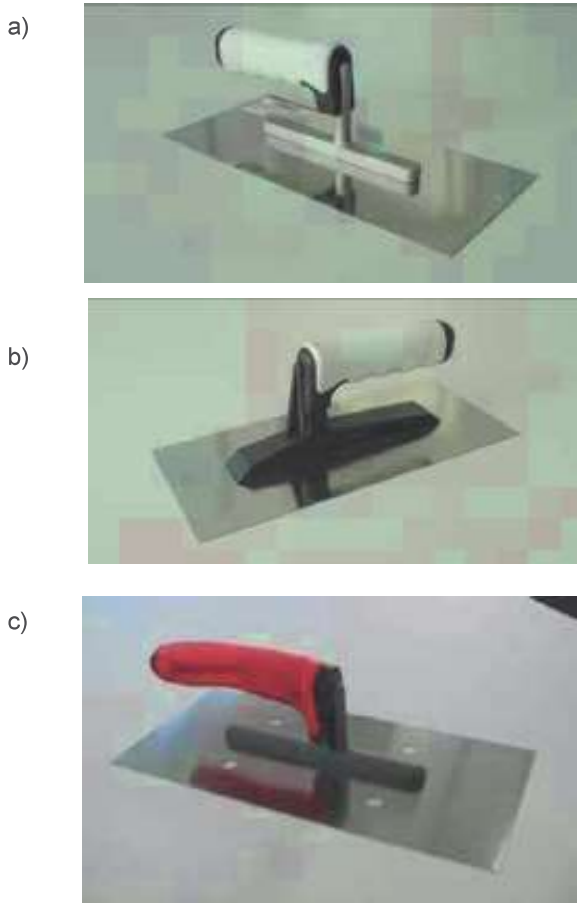


Fig. 2. Mason trowels: a) with the handle made of aluminum alloy, b) with the handle made of pressed polystyrene, c) with the handle made of polyamide  
Rys. 2. Packa tynkarska: a) z uchwytem rękojeści wykonanym ze stopu aluminium, b) z uchwytem prasowanym z polistyrenu, c) z uchwytem prasowanym z poliamidu

When bearing in mind the market requirements, Comensal Company decided to consider the possibility of replacing the so-far employed solutions by the handle, made of pressed polyamide (Fig 2 c). The trowel with the polyamide handle has a shape and construction traditionally approved by the market, similarly as in the case of aluminium handle.

The main purpose of the tests was to compare the strength parameters of the handle, as being performed using three mentioned above technologies. The results of the tests were the basis for undertaking the decision on the change of the technology producing the handles, employed in the Comensal Company.

## The research method

The strength tests of the handles of the mason trowels were carried out with the utilization of the strength testing machine INSTRON 5582 which facilitates:

- Performance of the tests with the application of measuring heads, range : 2 kN and 100 kN,
- Measurement of load and elongation in accuracy class 0.5

In the trials, the following measuring procedures, reproducing the working loads of the tool, were employed:

- Bending and compression trials with the load, directed perpendicularly to the working surface of the trowel (Fig.3),

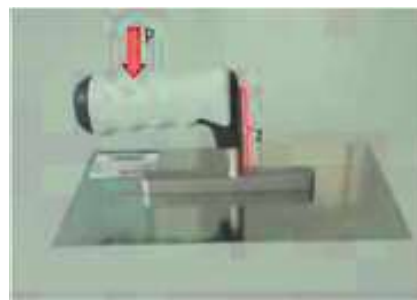


Fig. 3. A diagram of the load during a bending and compression trial with the load directed perpendicularly to the working surface of the trowel: P - load, z –the fragment of the handles with normal stress [2, 4].

Rys. 3. Schemat obciążenia podczas próby zginania ze ścisaniem przy obciążeniu skierowanym prostopadłe do płaszczyzny roboczej packi: P - siła obciążająca, z - fragment uchwyty, w którym występują naprężenia normalne [2, 4]

- Bending and torsion trial with the load directed parallel to the working surface of the trowel (Fig.4)

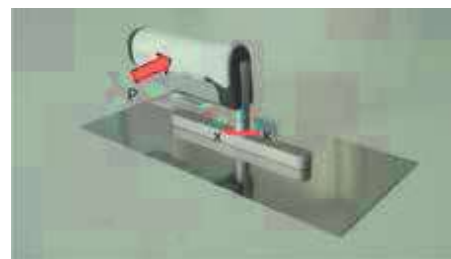


Fig. 4. A diagram for the load during a bending and torsion trial with the load parallel to the working

Rys. 4. Schemat obciążenia podczas próby zginania ze skręcaniem przy obciążeniu skierowanym równoległe do płaszczyzny roboczej packi: P - siła obciążająca, x-x - przekrój uchwyty, w którym występują największe naprężenia zredukowane [2, 4]

The trials consisted in the application of the load  $P$  (Fig. 3 and 4) with preliminary value equal to 30 N and its increasing at the speed of deformation amounting to 10 mm/min. The software of the testing machine registered the diagram of relationship of the load and the sample deformation. The trial was stopped at the moment of damage of the sample (breaking of the holder of the handle) or obtaining the highest possible deformation, resulting from the construction conditions.

The first trials were conducted when applying the load to the handle of the trowel, as it was illustrated in Fig.3 and 4. It was found that it caused the uncontrolled changes in a real load, resulting from the destruction of the material of the handle due to a high stress concentration in the site of the quasi-point application of strength and instability of the contact of the loading element and surface of the handle at the great deformations of the sample.

As a result of the conducted preliminary trials, the research procedure was changed. The change consisted in the removal of the handle from the handle and application of the load directly to the mandrel on which it was mounted. To ensure the stability of the contact of the loading element connected with the testing machine and the surface of the sample, a special mandrel with the fork-shaped termination was performed (Fig.5).

For the both measuring procedures, three series of the tests for each procedure were carried out; the trials included three mason trowels in each series, with the handles made from the particular materials.

## The run of the trials and the recorded results

Fig. 5 shows the photographs of the illustrating the method of loading and mechanism of destruction of the handle holders during the bending and compression trial, with the load directed perpendicularly to the working surface of the trowel.

The tested tool was mounted on the table of the testing machines in a strictly determined position, ensuring the repeatable distance of the point of the load application from the neutral axis of vertical segment of the bent cross-section of the handle.

Fig.6 shows the example of the diagram of the relationship between the load of the tested handles and the deformation. The vertical segment of the diagram is the end of the trials as a result of the destruction of the tested sample.

Fig.7 presents the photographs showing the way of loading, mounting of the samples and Fig.8 contains the images of destruction of the handles during bending and torsion trial, with loading directed parallel to the working surface of the trowel. The tested tool was mounted on the vertical surface of a special holder, combined with the table of the testing machine in a strictly determined position, ensuring the repeatable distance of the point of the load application from the neutral axis of the segment of cross-section of the handle perpendicularly directed to the working surface.

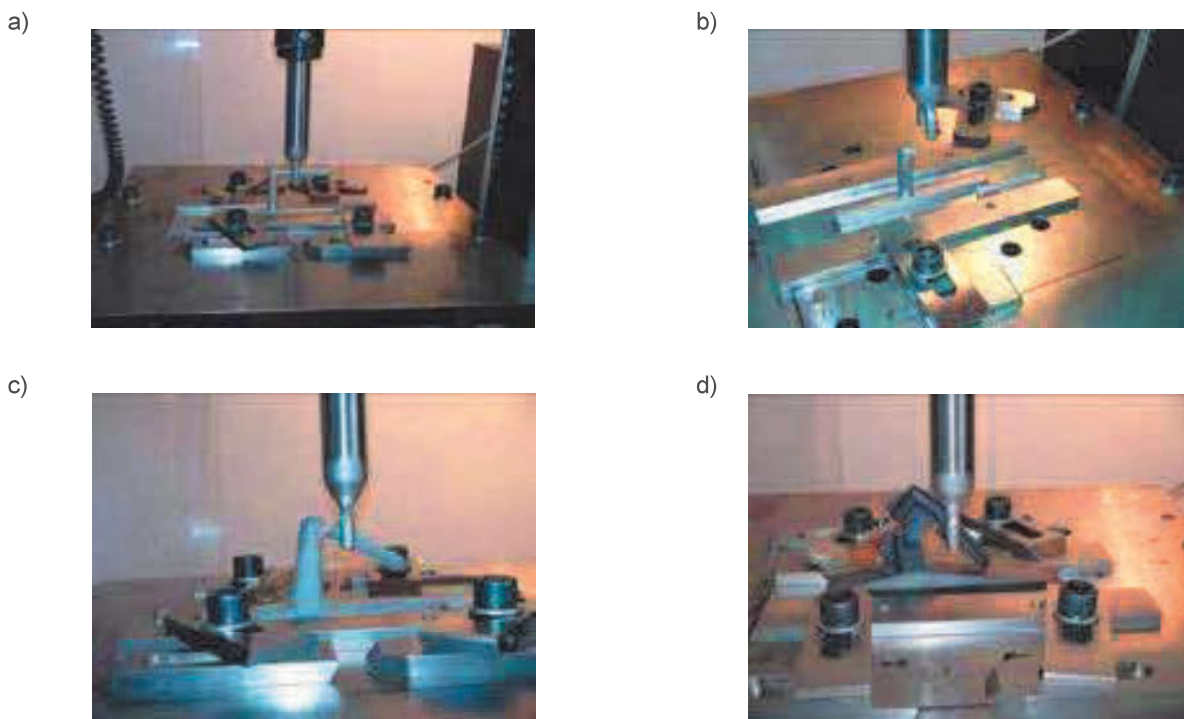


Fig. 5. The bending and compression trial with the load directed perpendicularly to the working surface of the trowel: a) the mounting of the trowel and load application, b) the destruction image of the aluminum handle, c) the destruction image of the polyamide handle, d) the destruction image of the polystyrene handle

Rys. 5. Próba zginania ze ściskaniem przy obciążeniu prostopadłym do płaszczyzny roboczej packi: a) sposób zamocowania packi i przyłożenia obciążenia, b) obraz destrukcji uchwytu ze stopu aluminium, c) obraz destrukcji uchwytu poliamidowego, d) obraz destrukcji uchwytu polistyrenowego

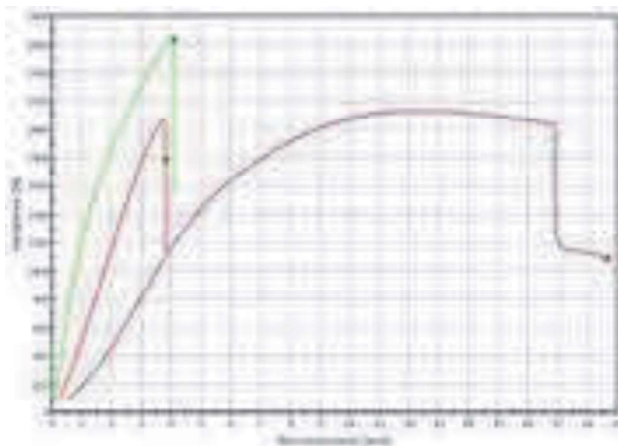


Fig.6. Diagram of the relationship between the load in the tested handles and the deformation registered for the load perpendicular to the working surface of the trowel  
 Rys.6. Wykresy zależności obciążenia badanych uchwytów od odkształcenia zarejestrowane przy obciążeniu prostopadłym do płaszczyzny roboczej packi



Fig. 7. Bending and torsion trial with a load parallel to the working surface of the trowel (polyamide handle): a) the mounting of the trowel and the load application, b) termination of the trial – handle breaking

Rys. 7. Próba zginania ze skręcaniem przy obciążeniu równoległym do płaszczyzny roboczej packi (uchwyt z poliamidu): a) sposób zamocowania packi i przyłożenia obciążenia, b) koniec próby - złamanie uchwytu



Fig. 8. Images of the trowel handle destruction during the bending and torsion trial with the load parallel to the working area of the trowel: a) and b) aluminum alloy handle, c) polyamide handle, d) polystyrene handle

Rys. 8. Obrazy destrukcji rękojeści packi przy próbie zginania ze skręcaniem przy obciążeniu równoległym do płaszczyzny roboczej packi: a) i b) uchwyt ze stopu aluminium, c) uchwyt poliamidowy, d) uchwyt polistyrenowy

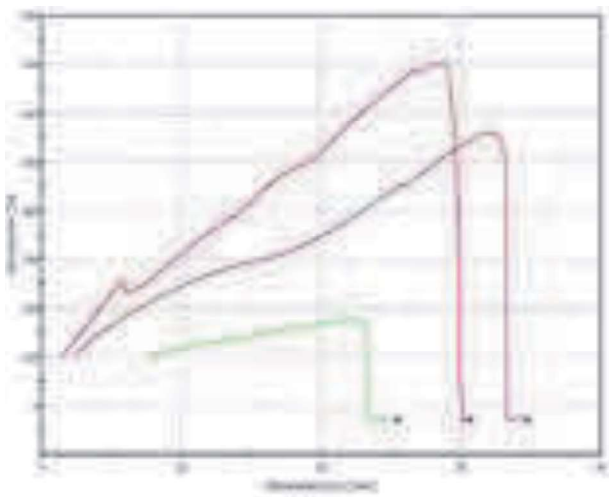


Fig. 9. Diagrams of the relationship between the load in the tested handles and the deformation registered for the load perpendicular to the working surface of the trowel  
 Rys.9. Wykresy zależności obciążenia badanych uchwytów od odkształcenia zarejestrowane przy obciążeniu równoległym do płaszczyzny roboczej packi

Fig.9 shows the examples of diagrams of the relationship between the load of the tested trowels and the deformation. The vertical segment of the diagram is the end of the trial as a result of the destruction of the tested sample.

#### The comparative analysis of the strength parameters

Table 1 and 2 contain a summary and the calculated mean values of the results of the measurements, carried out during the strength trials

When analyzing the obtained results, the run of the trials and mechanisms of destruction of the particular handles of the tested tools, the following conclusions have been formulated:

1. The handle made of aluminum alloy by the method of pressure die casting is characterized by the best strength properties. The mean destructive load in the bending and compression trials is equal to more than 3 kN what exceeds more than 3 times the load

Table 1. A summary of the measurements obtained for bending and compression trials with the load directed perpendicularly to the to the working area of the trowel  
 Tabela 1. Zestawienie wyników pomiarów otrzymanych w próbie zginania ze ściskaniem przy obciążeniu skierowanym prostopadle do płaszczyzny roboczej packi

Test with load perpendicularly directed to working surface of the trowel	Maximum load [N]	Mean maximum load [N]	Destructive displacement [mm]	Mean destructive displacement [mm]
Aluminum handle	2 661	3 136	4,1	4,8
	3 502		5,9	
	3 244		4,4	
Polyamide handle	2 068	1 915	3,8	4,0
	1 953		3,9	
	1 723		4,2	
Polystyrene handle	2 135	2 117	18,7	18,8
	2 098		20,3	
	2 118		17,3	

Table 2. A summary of the measurements obtained for the bending and torsion trial with the load directed parallel to the to the working area of the trowel  
 Tabela 2. Zestawienie wyników pomiarów otrzymanych w próbie zginania ze skręcaniem przy obciążeniu skierowanym równoległe do płaszczyzny roboczej packii

Test with load parallel directed to working surface of the trowel	Maximum load [N]	Mean maximum load [N]	Destructive displacement [mm]	Mean destructive displacement [mm]
Aluminum handle	706,1	643,8	30,7	25,8
	576,0		23,6	
	649,3		23,0	
Polyamide handle	560,8	521,0	34,7	34,9
	524,5		36,5	
	477,7		33,6	
Polystyrene handle	176,5	175,5	25,5	24,9
	172,1		24,3	
	177,8		24,9	

of average man. The destructive deformation in the discussed trial results from the limited plastic properties of the cast and is comparable with the deformation of polyamide handle. In the bending and torsion trial, the aluminum handle is also characterized by the highest strength and a big recorded destructive displacement is caused by pulling out of the pegs linking it with the sheet of the working part of the trowel (Fig.8a). The tendency to pull the pegs out during the trial results from a small width of the handle's foot adjacent to the sheet what causes the generation of a great pulling out force, caused by lateral load. Defective structure of the cast, caused most probable by utilization of a cheap, recycled alloy with non-identified composition and doubtful purity does not affect negatively the strength properties of aluminum handles as compared to the remaining constructions (Fig.10).



Fig. 10. Internal structure of the aluminum alloy  
Rys. 10. Struktura wewnętrzna odlewu aluminiowego

The manufacturing costs are a defect of aluminum handles. Brittleness of the cast alloy [1, 3] limits also the possibility of regulating the bearing capacity of the press-fitting connection and peg connectors that could be increased by the change in pressing or imposing of plastic deformation e.g. by knurled pegs.

2. The handle made of polyamide by pressing method is characterized by good strength properties. The mean destructive strength in the bending and compression trial is equal to almost 2 kN what is value being quite sufficient for use of the trowel during typical plastering and bricklaying work. The results of the measurements of destructive load and deformation as obtained in the bending and torsion trial are very similar to the parameters of aluminum handle. The material of the handle contains filler which improves its strength what limits the susceptibility to deformations. The advantage of the handle includes the increased cross-section at the basis as marked in Fig. 4 as x-x. It causes a considerable increase of its strength in the site of incidence of the highest reduced stress, caused by operating lad. The advantage resulting from the discussed solution gives a lower cost and lower energy consumption of the process

of the manufacture of the discussed elements by the method of pressure injection of plastics.

3. The handle made of polystyrene by the pressing method is characterized by the worst strength properties. It is mainly determined by low destructive load in the bending and torsion trial. There is a concern that in the case of certain typical operations during construction work e.g. removal of dried glue remnants or of mortar, the resistance of the handle will be insufficient. The handle is characterized by a high formability on bending and compression trial what results from the application of ribs, increasing the resistance to bending in the plane of the trowel's symmetry. A high susceptibility to deformation does not give any practical advantage. The construction of the polystyrene handle indicates distinctly the action of constructor whose purpose was to stiffen the product in the plane of the tool's symmetry; it did not however bring a similar result as in the case of being endangered to other operating loads. The disadvantage of the polystyrene handle includes a higher amount of plastic being indispensable for its manufacture as compared to the polyamide handle.

### Summing up

As a result of the conducted work, the possibility of improving the innovativeness of the products, manufactured by Comensal Company and the innovative character of technological processes of their production has been confirmed.

In manual construction tools, produced by Comensal (mason trowels), the so-far applied aluminum or, alternatively, polystyrene element joining the stainless working plate of the trowel with the handle should be replaced by the handle made of polyamide. The pressed polyamide handle is characterized by good strength parameters, comparable with the parameters of the best aluminum handle. It is more resistant than the employed alternatively handle, made of pressed polystyrene.

Apart from the revealed good strength, the polyamide handle has the following advantage, being significant from the viewpoint of the tool producer and user which decide on its innovativeness:

- Smaller cost of manufacture as compared to aluminum handle;
- Shape consistent with the tradition of the market of construction tools;
- Possibility to produce the handles in the own factory;
- Positive effect of technology on implementation of the principle of the sustainable development of economy via limitation of the energy consumption in manufacture and elimination of material (Al alloy) the obtaining of which is especially burdensome for the environment.

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dr inż. Stanisław Koziół, adiunkt, Instytut Technologii Eksploatacji - PIB, ul. K. Pułaskiego 6/10, 26-600 Radom, e-mail: stanislaw.koziol@itee.radom.pl

dr inż. Tomasz Samborski Instytut Technologii Eksploatacji - PIB, ul. K. Pułaskiego 6/10, 26-600 Radom, e-mail: tomasz.samborski@itee.radom.pl

dr hab. inż. Andrzej Zbrowski, prof. ITeE-PIB - Instytut Technologii Eksploatacji - PIB, ul. K. Pułaskiego 6/10, 26-600 Radom, e-mail: andrzej.zbrowski@itee.radom.pl

properties. The steels of group III and IV are successively implemented into manufacturing and their share is steadily increasing, mainly in the passive safety elements.

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