EVALUATING THE PERFORMANCE OF ULTRA LOW FLUSH TOILETS IN FIELD APPLICATION

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Abstract

Water closets represent a big percentage of the domestic water consumption and have a great potential for water savings. This paper presents a field investigation that has been conducted by professionals of the State University of Campinas (UNICAMP) and University of Sao Paulo (USP) with ultra low flush toilets (6.0 liters per flush). The field investigation was developed in 24 low-income houses in Pindamonhangaba, a city of Sao Paulo State, and contemplates overall and toilet water consumption monitoring with a telemeter system. Also, a questionnaire was developed to survey user's opinion concerning the water closets performance. A comparison between results of the water consumption metering and the questionnaire is shown. Conclusions of the study, which had also contemplated laboratory investigation, are presented.

Keywords

Low flush toilet, water conservation, water closet, toilet.

1 Introduction

In 1998, Brazilian Government launched the National Program of Quality and Productivity of residence construction -PBQP-H, whose purpose is going against the non-conformity of the construction materials, including building systems components MPO/SEPURB-PBQP (1998).

Inside the PBQP-H, there is a Sectorial Program of vitreous china plumbing fixtures, which has a specific goal concerning toilets (and discharge appliances) in such a way that, until 2002 the flush volume of the toilets that will be manufactured will be limited to approximately 6 liters.

Inserted in this Program, a study was developed to define the adequate volume for Brazilian low flush toilets and the laboratory tests to evaluate the performance of these

fixtures. In GONÇALVES et al (2000), it was described the methodology and preliminary results of this study.

A laboratory investigation was conducted, with help of the Stevens Institute of Technology, Hoboken, NJ, USA, which has developed a series of studies concerning water closets performance evaluation. Also, a field investigation was developed in twenty-four low-income houses.

This paper presents the final results and conclusions of the investigation, including recommendations for the Brazilian Standardization.

2 Field and Laboratory Investigations

Field investigation was composed by measurement of consumed volume in water closets and total water consumption in brand new low-income houses located in Pindamonhangaba, a city of Sao Paulo State, located near to Sao Paulo city.

The monitoring was completed in two phases. In the first phase, conventional water closets (9 and 12 liters) were installed in 18 homes and low flush water closets (6 liters) were installed in 6 homes. Total and WC water consumption were monitored and these data were used to find out the number of single and double flushes, ratio between total and WC volume and savings.

Phase two contemplated conventional water closets replacement by saver ones in 12 homes. The fixtures models tested in field investigation were the same in the laboratory investigation, but the units were different.

A questionnaire was used to survey users' opinion in both phases.

Laboratory investigation was developed at the Escola Politécnica da Universidade de Sao Paulo and had as main purposes the evaluation of the performance of the water closets under different conditions and the definition of test methods to evaluate these fixtures. The activities developed were, essentially: laboratory setup assembly, survey of different test methods for evaluating the performance of ultra low flush toilets, performance evaluation of toilets from seven different Brazilian manufacturers and evaluation of the influence of the supply pressure and flow in the units' performance.

2.1 Performance evaluation in the field

For this analysis, two parameters were considered: questionnaire answers and *fail factor* of the WC, which is defined here by the relation between the number of double flushes and the total number of flushes of each WC.

So, if users said something bad about the performance of the one WC in the questionnaire, that unit was considered not acceptable and, also, if the *fail factor* was greater than 1:7 (one double flush in seven flushes), the unit was considered not acceptable. Table 1 shows the results of the field evaluation.

Three of seven close-couple toilets (42.85%) had good performance in the field (both criteria); one unit (14.3%) had bad performance (rejected in both criteria) and three had good performance only in one of the criteria.

On the other hand, three toilets with elevated tank (42.85%) were accepted (good performance in both criteria), two units (28.55%) were rejected (in both criteria), and one (14.3%) was rejected by one criterion and the last one by another criterion.

Finally, all valve-operated toilets were accepted based on both criteria.

Table 1- Field investigation: performance evaluation.

Manufacturer	*Fail Factor*	Questionnaire's Answers
Close-coupled toilets		
A	a	r
B	**r**	**r**
C	a	a
D	a	r
E	a	**r**
F	a	a
G	a	a
Toilets with elevated tank		
A	a	a
B	r	r
C	**r**	a
D	**r**	r
E	a	a
F	a	a
G	a	r
Valve operated toilets		
A	a	a
F	a	a

Note: a – accepted **r** - rejected

2.2 Performance evaluation in the laboratory

Several tests for performance evaluation were made in the laboratory. From them, mixed bulk media test (sponges [S] and Kraft paper [P]), and the polypropylene balls test was chosen for the analysis presented in this paper. Since other tests (surface wash - ink test, water change - dye test, trap seal restoration test, seat fouling test and transport test) are already contemplated in the Brazilian Standard, the units were previously submitted to these tests by the manufacturers before going to the University laboratory.

Four units (two close-coupled and two for valve and/or elevated tank) of seven Brazilian manufacturers were tested with the following testing loads: 10S & 6P (Test 1), 15S & 10P (Test 2), 15S & 15P (Test 3), 12S & 10P (Test 4), 7S & 4P (Test 5).

Test 1 was chosen for these analysis, because is more representative of the residential load, based on physiological data on colonic functions as shown in ILHA; KONEN (2000)

The acceptance criterion used is the removal of twelve media (sponges and/or paper Kraft sheets) on the first flush of the four best results of five runs (worst result is discarded).

For the ball test, the acceptance criterion is the removal of seventy-five balls of one hundred balls put inside the bowl. Averages of WC flush volumes used are shown in Table 2. These values represent the total flush volume, including refill volume for water seal restoration. Table 3 shows the results of performance evaluation.

Table 2 - Laboratory investigation – flush volumes.

Manufacturer	Average flush volume (liters)		
	Close-coupled WC	WC with elevated tank	Valve operated WC
A	6.22	5.79	6.64
B	6.15	6.93	5.78
C	6.28	5.95	7.24
D	6,41	5.76	6.72
E	5,81	5.95	5.81
F	5,71	5.97	7.33
G	5,43	6.25	5.65

Table 3 -Laboratory investigation: performance evaluation - waste removal.

Manufacturer	Waste removal test	
	Mixed bulk media	Polypropylene spheres
Close-coupled toilets		
A	**r**	a
B	**r**	**r**
C	**r**	a
D	a	a
E	a	a
F	**r**	a
G	a	a
Toilets with elevated tank		
A	a	a
B	a	a
C	**r**	**r**
D	a	a
E	a	a
F	r	a
G	a	a
Valve operated toilets		
A	a	a
B	a	a
C	a	a
D	a	a
E	a	a
F	**r**	a
G	a	a

Note: a – accepted **r** - rejected

Analysis of Table 3 indicates the following aspects:

- three of seven (42,85%) close-coupled toilets had bad performance in the bulk media test and good performance in the ball test, one unit (14,3%) had bad performance in both tests and three units (42,85%) had good performance in both tests,

- one of seven toilets with elevated tank (14,45%) had bad performance in the bulk media test and good performance in the ball test; one unit (14,3%) had bad performance in both tests and five units (71,4%) had good performance in both tests,
- one of seven valve operated toilets (14,3%) had bad performance in the bulk media test and good performance in the ball test and six units (85,7%) had good performance in both tests.

2.3 Performance evaluation - laboratory *versus* field investigation

This analysis was made to compare the performance in both investigations (laboratory and field), in order to propose adjustments in the tests used, based on field performance. Table 4 summarizes the obtained results.

Table 4 - Field and laboratory investigations – performance evaluation.

Manufacturer	Laboratory evaluation		Field evaluation	
	Mixed bulk media test	Polypropylene balls test	Fail factor (double flushes)	Questionnaire's answers
Close-coupled water closets				
A	r	a	a	r
B	**r**	**r**	**r**	**r**
C	**r**	a	a	a
D	a	a	a	r
E	a	a	a	**r**
F	r	a	a	a
G	a	a	a	a
Water closets with elevated tank				
A	a	a	a	a
B	a	a	**r**	**r**
C	**r**	**r**	**r**	a
D	a	a	**r**	r
E	a	a	a	a
F	r	a	a	a
G	a	a	a	r
Valve operated water closets				
A	a	a	a	a
B	a	a	----	----
C	a	a	----	----
D	a	a	----	----
E	a	a	----	----
F	r	a	a	a
G	a	a	----	----

Note: a – accepted **r** - rejected

Considering close-couple toilets, one unit (14.3%) had good performance both in the laboratory and in the field investigation and one unit was rejected in the same criteria.

Two toilets (28.55%) with elevated tank were accepted based on laboratory and field investigation criteria.

One valve operated toilet (50%) had good performance in the laboratory and in the field.

3 Proposals

Based on field and laboratory investigation results and in the operational conditions of Brazilian building systems, the hydraulic parameters and the tests for performance evaluation of ultra low flush toilets in the laboratory were proposed, which are described in following sections.

3.1 Supply Characteristics

For all tests, except for the maximum volume test, pressure and flow measuring apparatus employed for testing shall be:

- Close-couple and WC with elevated tank tests- flow rate: (0.20 ± 0.01) l/s,
- Valve operated WC tests - dynamic pressure: 12 kPa, flow rate: (1.50 ± 0.05) l/s

3.2 Performance Tests

The following tests shall be done for the performance evaluation of Brazilian ultra low flush toilets:

- water consumption,
- maximum flush volume,
- waste removal - polypropylene balls and bulk media (sponges and Kraft paper),
- drainline transport,
- surface wash- ink test,
- water change,
- trap seal restoration, and
- seat fouling test.

3.2.1 Test Procedures and Perfo rmance Criteria

Some of these procedures are already contemplated in Brazilian Standards (ABNT, 1997a, 1997b) and others have been described in GONÇALVES et al (2000).

a. Water Consumption Test

Apparatus and procedure test: a receiving vessel, with 20 liters (minimum) and a scale. Other apparatus, shown to be capable of measuring volumes to within 0.1 liters shall be acceptable. The dynamic pressure shall be recorded, before the flush release device is activated. When the flush is completed, as indicated by cessation of the trailing flow, which occurs at the end of the discharge, the volume received in the vessel shall be recorded. This completes one test run. The procedure shall be repeated until three runs are performed.

Performance criteria: the average water consumption of water closets shall not exceed 6.8 liters, with a tolerance of 5%.

b. Maximum Flush Volume

Apparatus and procedure test: the test apparatus shall be as specified for the water consumption test. The water closets components shall be adjusted for the maximum volume and the dynamic pressure shall be adjusted to 300 kPa.

Performance criteria: the average water consumption of water closets shall not exceed 8.0 liters for this pressure.

c. Polypropylene Ball Test

Apparatus and procedure test: this test is the same that is already contemplated in the Brazilian Standards, with a little modification: After the adjustment of the dynamic pressure, the 100 balls shall be dropped in the bowl and the flush release device shall be activated. After completion of this initial flush, balls passing completely out of the fixture shall be counted. This completes one test run. . The procedure shall be repeated until five runs are performed.

Performance criteria: for acceptance, 80 balls per initial flush shall be flushed out of the bowl, based on the average of five initial flushes. This is a tighter criterion than the one already contemplated in the Brazilian Standards.

d. Bulk Media Test (sponges and Kraft paper)

This test is not contemplated in current standards. After the adjustment of the dynamic pressure, twelve new conditioned sponges shall be placed in the test bowl and squeezed under water to remove air, saturating the media. The sponges should be floating with the top of each sponge even with the water surface. The well shall be slowly refilled with water to ensure a full depth of seal. The six paper balls shall be dropped into the well, and the unit flushed. After the flush cycle is completed, the number of sponges and paper balls discharged through the fixture shall be counted and recorded. This completes one test run. The procedure shall be repeated until five runs are performed.

Performance criteria: for acceptance, in four of the five runs (the worst result is discarded) an average of fourteen (14) media (sponges and/or paper balls) shall be flushed out of the fixture on the initial flush. Additionally, in each of the four best runs, twelve (12) media (sponges and/or paper balls) shall be flushed out of the fixture on the initial flush.

Note: This study was developed only in residential units. For other applications, it shall be developed specific investigations to establish the usage conditions and the loads for the tests.

e. Drainline Transport Test

Long drainlines, with more than 4.0 m and with only one toilet, is an unusual and extreme situation. Also, the polypropylene balls have a tendency to roll down in the drain, even with no water, due to the slope. Water volume, in turn, shall be able not only to remove the wastes from the toilet, but also to transport them for any distance. Therefore, the transport test has been changed as described in sequence.

Apparatus and procedure test: an assembly shall be made using a minimum of 6.0 m of 100mm transparent plastic or glass pipe connected directly to the toilet. The pipe shall be adequately supported to provide a straight run having a 1% slope. After water supply and general conditions have been adjusted, twelve polyurethane sponges shall be placed in the test bowl and squeezed under water to remove air, saturating the media. The sponges should be floating with the top of each sponge even with the water surface. The well shall be slowly refilled with water to ensure a full depth of seal and the flush release device shall be activated, observing the distance of travel of each

exiting sponge. This completes one test run. . The procedure shall be repeated until three runs are performed. All test media shall be removed from the fixture and the pipe before beginning the next run.

Performance criteria: the weighted carry distance (total carry of all sponges divided by the total number of sponges) shall be 5.0 m or greater.

f. Surface Wash- Ink Test

Apparatus and procedure test: this test is already in the Brazilian Standards. Here, there are some changes, based on ASME proposals: the flushing surface shall be scrubbed clean to remove any deposits on the walls of the test bowl. The surface shall be dry. Two lines shall be inked around the circumference of the *flushing surface* of the test bowl at levels of 25 mm and 50 mm below the rim roles. The flush device shall be activated and the lines shall be observed during and after the flush. When the flush cycle is complete, the lengths of the unwashed line segments where the ink has remained on the flushing surface shall be measured. This completes one test run. The procedure shall be repeated until three runs are performed.

Performance Requirement: the line drawn at 50 mm below the rim holes shall be completely washed away from the flushing surface.

Note: After three years from this date, the performance criteria will be: the line drawn at 25 mm below the rim holes, the total length of ink line segments remaining on the flushing surface after each flush shall not exceed 50 mm as averaged over three test runs, and the average of individual segments remaining on the flushing surface after each flush shall not exceed 12 mm. Also, the line drawn at 50 mm below the rim holes shall be completely washed away from the flushing surface.

g. Water Change – Granule Test

Apparatus and procedure test: based on ASME proposals: the test media (100 ml of disc-shaped high density polyethylene granules of 0.170 +/- 0.010 in. (4.32 mm +/- 0.25 mm) diameter and an average bulk density of 0.94 – 0.95 Kg/m^3 shall be added to water in the bowl. The flush release device shall be tripped and released. Three sets of data shall be obtained.

Performance Requirement: not more than 125 granules (5%) shall be visible in the bowl after each initial flush.

h. Trap Seal Restoration Test

This test is already contemplated in Brazilian Standards. The procedure and the performance criteria have no changes.

i. Set Fouling Test

This test is already contemplated in Brazilian Standards. The procedure and the performance criteria have no changes.

Table 5 summarizes the main changes in the performance tests for evaluating water closets.

Table 5 - Summary of proposals.

Test	Changes proposed
polypropylene balls Test	performance criteria
bulk media (sponges and Kraft paper)	inserted
drainline transport	media, procedure and performance criteria
surface wash-ink test	procedure and performance criteria
water change	media, procedure and performance criteria

4 Conclusions

Since the beginning of this year, when the analysis of the data from field and laboratory investigations was finished, Brazilian manufacturers have been developed some individual tests to evaluate the proposals in their plants. From this, maybe some adaptations will be performed in the procedures. Afterwards, the next step will be to adapt the current Brazilian standard.

Also, it is necessary to find a local manufacturer for the sponges and the Kraft paper, since those used are from the USA.

Brazilian manufacturers worked together in this study and this demonstrates their commitment towards better products and concern with water conservation.

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