Consideration of revision for the method of calculating the installation number of a sanitary fixture

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Abstract

In the Workers of Heating, Air-conditioning & Sanitary Engineers of Japan, the sub-committee about the installation number manual preparation of a sanitary fixture was established from the 2010 fiscal year to the 2012 fiscal year, and examination for making the present technical guideline easier to use was performed. In Japan, although "The determination of the installation number of a sanitary fixture" is widely used for SHASE-S206 technical guidelines, expansion of the building use applied, the correspondence to change of a life style, and the correspondence to enlargement of a building have been called for. This paper considers the determinant of the installation number of a sanitary fixture among the researches done to these problems. Moreover, the questionnaire result about use and lifetime of a sanitary fixture is shown. Furthermore, the calculation method of a sanitary fixture is compared and it is shown in a graph.

Keywords

Sanitary fixture; Installation number; Questionnaire; Calculation method.

1. Introduction

"The determination of the installation number of a sanitary fixture" on SHASE-S206-2009 (Plumbing code)[1] technical guidelines by the Workers of Heating, Air-conditioning & Sanitary Engineers of Japan and the description is widely used focusing on the designer as the calculation method of the number of a sanitary fixture.

However, the building use shown in the technical guidelines is restricted to an office, a department store and a volume retailer, a dormitory, a hospital (ward), a theatre, and a school. The designer has to presuppose "It shall be the target range and shall predict appropriately of the number of users and the sex ratio of the sanitary fixture installed in

a rest room." It is required to show the method of calculating the number of proper fixtures general-purpose based on the present calculation method.

In the subcommittee for the installation number of sanitary fixtures, which worked from the 2007 fiscal year to the 2009 fiscal year, report SHASE-R 2014-2010 "Present condition about the determination of the installation number of a sanitary fixture and subject" was summarized. "The subcommittee for preparation the manual on installation number of the sanitary fixture" established from the 2010 fiscal year in the 2012 fiscal year analysed further the lifetime investigation carried out in the old subcommittee.

Moreover, the scope of the graph on proper number of sanitary fixtures (the number of users) was expanded and shown. Furthermore, the data to the building characteristic and user density were collected. Re-arrangement of the view of the arrival rate, which becomes important in the number of proper fixtures, was also performed. And the report was compiled in the form where presentation of a concrete calculation procedure and presentation of the case study were added.

This paper introduces the examination result about re-examination of the lifetime survay which the writer took the lead and summarized among the contents of the report[2] [3], the excretion place drawn from the result, the number of times of excretion, an excretion interval, and the method of calculating the number of proper fixtures.

2. The element in connection with the determination of installation number of a sanitary fixture

Various elements are related in order to determine the installation number of a sanitary fixture. Although this is summarized also in the technical guidelines, it is re-arranged and shows Table-1.

Although the building characteristic serves as an important element which has determined the number of proper fixtures according to a building use in technical guidelines, when there are still more guests, conditions of location become a major factor which specifies the building characteristic.

It is necessary to take into consideration the user who stops at buildings, such as a guest and a regular employee, for a long time about the number of users. A setup of the cover area, which is the use range of each toilet, needs to become important, and this needs to take into consideration duplication (overlap) of the toilet and utility area. Moreover, in the building where users density or the capacity is set up, number of users is set based on these. Furthermore, since it is necessary for that a toilet is installed according to sex, men and women's percentage (sex ratio) serves as an element. Also about this ratio, overlap a little over 100% which is the number of users, and it may ask for it, for example man: woman =80% : 40% etc.. Furthermore, a station, a service area, etc. have many passing persons, and the number of users may not become settled according to a building type.

Moreover, use conditions are greatly related to arrival of the user to a toilet. In the technical guidelines, the calculation method is divided according to two forms of use, "arbitrary use" used at any time and "intensive use" with the peak used for time for recess. Moreover, in the case of the forms of intensive use, it is necessary to assume the existence and the time zone during the peak hour, which the restraint to the room produces and entrance and exit concentrate. Since the use number of times of each user's toilet increases when the length of stay to a building is long, the arrival rate per

users becomes high. These will be synthesized and arrival users will become settled. It is thought that fixture occupancy time changes with evaluations of the fixtures with which the congestion degree or a user age, the toilet bowl, or the booth was equipped, a smell, cleanliness, etc.

And technical guidelines define some of numbers of fixtures as a service level based on the length of waiting time. Although the final factors which determine the installation number of a sanitary fixture are an arrival rate and fixture occupancy time, it depends on judgment which finally has the room of the number of fixtures of installation personnel.

Table-1 The element in connection with the installation number determination of a sanitary fixture

Building characteristics
Building use (concerned with the forms of use)
Conditions of location (concerned with the number of visitors)
Number of users (actual existence number)
Cover area (usable area)
Existence of overlap area
Users density
Capacity (the number of seats)
Sex ratio
Existence of overlap ratio
A passing person's use
Use conditions
Forms of use
Arbitrary use (no restraint, not wait, can escape)
Intensive use (with restricted, kept waiting, cannot escape)
Peak hours (entrance and exit, Before or after a restraint)
Existence of a peak
Time zone of a peak
Length of stay (frequency in use)
Arrival number of user (Average length of stay is related in arbitrary use.
Staffs and actual restricted time is related in intensive use.)
Fixture exclusive time
Congestion degree (Utility time will become short if waiting occurs.)
Age (frequency is high and elderly people's occupancy time is long)
Attachment equipment (changing one's clothes multiuse, such as a diaper substitute)
Evaluation (smelling, cleanliness)
Service level
Waiting time
Level 1: Upper limit (the generous number of fixtures)
Level 2: Standard value (the standard number of fixtures)
Level 3: Minimum value (the number of fixtures at its minimum)

3. Use and lifetime of sanitary fixtures other than housing

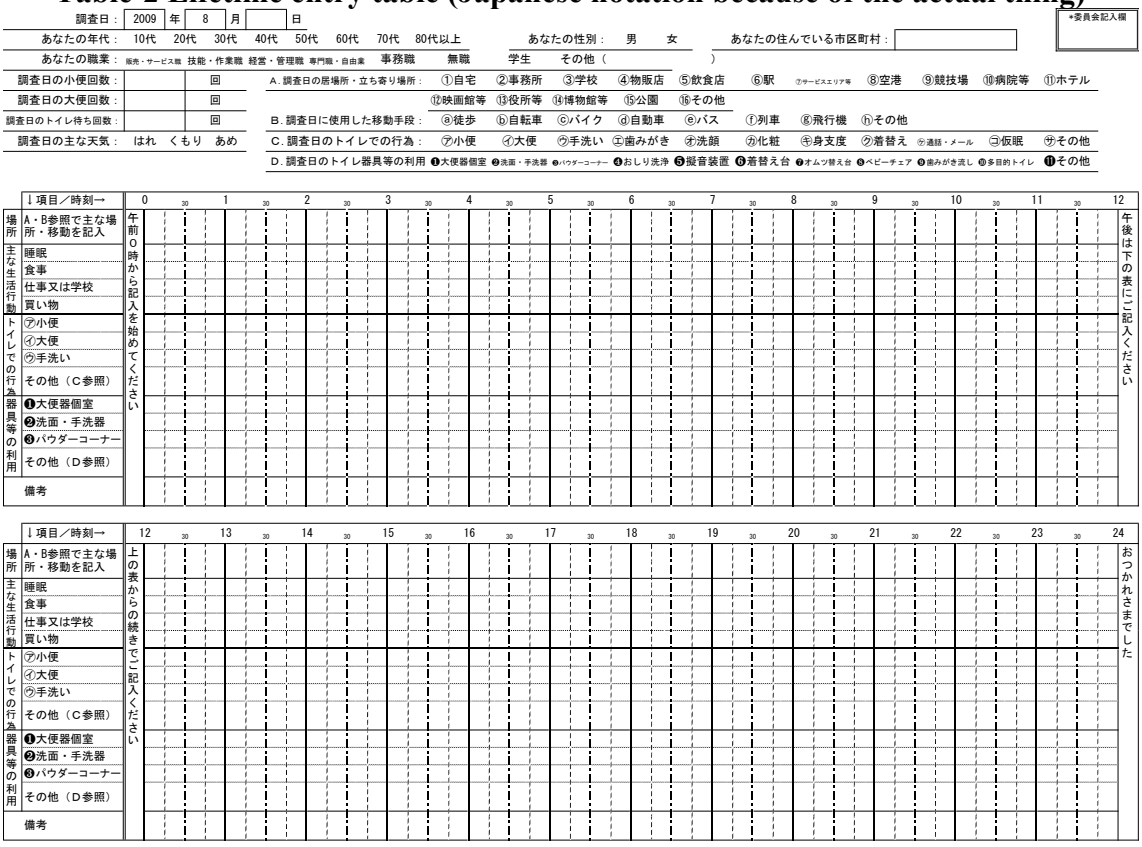
3.1 Outline of the lifetime investigation

In order to bring the number of sanitary fixtures close to a more suitable thing, it is necessary to grasp how a life and toilet use are in people. Then, lifetime investigation was carried out in the old subcommittee for the installation number of sanitary fixtures. From the result, it was quantitatively analysed in the day how, when and where people would use the toilet.

The distributed entry table is shown in Table-2 (it publishes with Japanese for a questionnaire). The number of effective replies was 340 copies including the unentered person in part. An investigation outline is shown below.

a) Investigation period: arbitrary the day in from August to September, 2009
b) Sample: the constituent and family (however, more than the high school student) of the organizations (six company and an organization) with which the subcommittee for the installation number of sanitary fixtures belongs
c) Investigation method: distribute the questionnaire created in the subcommittee to the organizations with which a committee belongs, and collect them.
d) Investigation content: entry of an age, sex, an occupation, and the number of times of urine and the number of times of feces of an investigation day. And an investigation day room - Drops in and it fills in each act for the use situation of the act in a place and the toilet of an investigation day, and the toilet fixture of an investigation day, etc. at intervals of 15 minutes.

Table-2 Lifetime entry table (Japanese notation because of the actual thing)



3.2 Result and consideration of lifetime investigation

Five items of "sale and a service industry", "technology and a work job", "management ", "a speciality and a free job", and "clerical work" of the career choice column of a investigation form were collectively made into the member of "workers".
The number of respondents for every attribute is shown in Table-3.

Table-3 The number of respondents for every attribute (unit: person)

	Men	Women	Unknown	Total
Workers	155	89	1	245
Students	63	8		71
10s	1	1		2
20s	87	1		88
30s	38	34		72
40s	56	52		108
50s	35	24	1	60
60s	7	3		10
Total	224	115	1	340

3.2.1 The number of times of excretion according to the sex and age by number-of-times entry

The average number of times of the excretion per day entered in "the number of times of urine of an investigation day" or "the number of times of feces of an investigation day" of the entry table was calculated. A male is 5.26 times and a woman is 6.32 times in urine. On the whole, more female persons than a male use (Figure-1). Moreover, it was in the tendency whose number of times increases as age went up man and woman, and it especially applied to his 50-60's, and use frequency was high. A male is 1.36 times, a woman is 0.92 times, and male persons use many feces through the whole contrary to urine (Figure-2). In feces, the use change by an age was not seen like urine, but the member of workers in his 30-40's used most males.

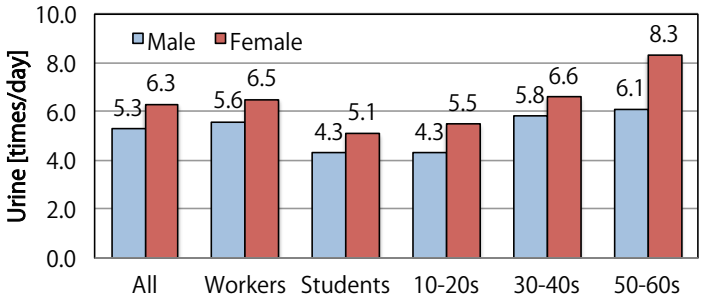


Figure-1 Number of times of the average urine classified by sex, age and occupation per one day and one person

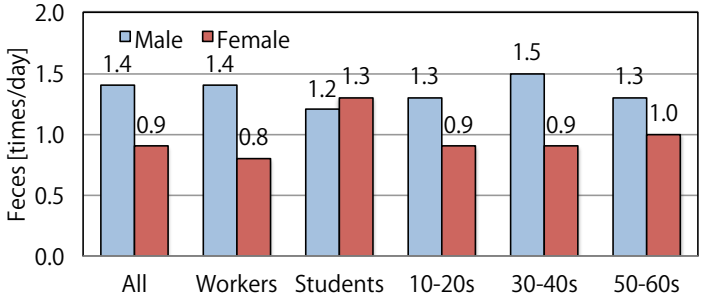


Figure-2 Number of times of the average feces classified by sex, age and occupation per one day and one person

3.2.2 Number of times of excretion classified by sex, occupation and place by time entry

The number of times of excretion and the time interval classified by sex, occupation and place were calculated by having totaled the number of times of the urine and feces entered in the time column of the entry table. The length of stay according to place as which the same entry table was filled in is shown in Table-4. Moreover, the result of the number of times of excretion and an excretion interval is shown in Table-5. Since entry parts differ, some difference is seen at a result.

Length of stay has many students about a house, and there are more members of workers about an office/school. The station serves as the same time mostly and the member of workers is long going-out time. There are many members of workers among men and women, the student of the number of times of urine has decreased, and the woman is more frequently-used except for a station. The number of times of feces is in a tendency with more male. Although a member-of-workers male has much number of times also in an office, there are few other attributes. The feces interval of the member-of-workers woman is one day or more.

3.2.3 Room and the excretion situation for every time zone

Room and the excretion situation for every time zone according to attribute are shown in from Figure-3 to Figure-6 about urine, and are shown in from Figure-7 to Figure-10 about feces.

When the time which used the toilet among one day was divided at intervals of 30 minutes, over morning 5:00 to 8:00, in the act of both urine and feces, use frequency is high and each attribute's suited to the tendency to mainly perform an act at the house before commuting attending school. Change of use was seen with the cycle of about 4 to 5 hours after that. Although as for a member of society it gathered in the office around 9:00 and students began to gather in school around 11:00, the at-home rate did not become 0%. Use became high, having applied urine around 13:00 from noon, and some members of workers were moving to the restaurant from the office. Each act once went up around 15:00 around 17:00 which hits clocking-off time. Those who go home from an office after it began to increase in number, and use decreased in 18:00 to 19:00. Use of the restaurant was around 19:00, and toilet use fell and it attached it. The student of the at-home rate continues increasing after 13:00, and its member of society continued increasing intermittently after 17:00. The use at a house of each act was increasing before the sleeping hours at 22:00 to 23:00. Almost all women were going to stool at the house.

3.2.4 Length of stay and the number of times of excretion

The data used by this clause made the reply the unentered thing which is not with the effective reply among 340 copies obtained by lifetime survay, and totaled further about the office which were among sojourners for the building use which is forms of arbitrary use. The used data is 184 copies of males, and 98 copies of women.

Table-4 The length of stay, the number of times of excretion, the excretion interval according to sex and attribute

		Workers Male	Workers Female	Students Male	Students Female
Length of stay (hours/day)	Home	10.63	11.63	15.97	16.81
	Office/School	9.55	8.71	4.27	4.84
	Restaurant	0.54	0.41	0.07	0
	Station	1.46	1.46	1.56	1.44
	Others	1.82	1.79	2.13	0.78
	Outdoors total	13.37	12.37	8.03	7.06

		Workers Male	Workers Female	Students Male	Students Female
Number of times of urine (times/day)	Home	2.02	2.76	2.62	3.38
	Office/School	2.89	3.10	1.02	1.25
	Restaurant	0.17	0.15	0.02	0.00
	Station	0.17	0.16	0.03	0.00
	Others	0.30	0.07	0.46	0.13
	Outdoors total	3.53	3.47	1.52	1.38
	Total	5.55	6.24	4.14	4.75

		Workers Male	Workers Female	Students Male	Students Female
Number of times of feces (times/day)	Home	0.79	0.57	0.95	1.00
	Office/School	0.59	0.19	0.21	0.13
	Restaurant	0.03	0.01	0.00	0.00
	Station	0.05	0.00	0.02	0.00
	Others	0.02	0.03	0.08	0.00
	Outdoors total	0.68	0.25	0.30	0.13
	Total	1.47	0.82	1.25	1.13

		Workers Male	Workers Female	Students Male	Students Female
Urine interval (hours)	Home	5.26	4.21	6.10	4.98
	Office/School	3.30	2.81	4.20	3.88
	Restaurant	3.22	2.79	4.50	
	Station	8.69	9.27	49.13	
	Others	6.01	26.63	4.64	6.25
	Outdoors total	3.79	3.56	5.27	5.14
	Total	4.33	3.85	5.79	5.05

		Workers Male	Workers Female	Students Male	Students Female
Feces interval (hours)	Home	13.50	20.29	16.77	16.81
	Office/School	16.27	45.60	20.67	38.75
	Restaurant	16.75	36.25		
	Station	32.29		98.25	
	Others	94.17	69.55	26.90	
	Outdoors total	19.55	50.05	26.63	56.50
	Total	16.32	29.26	19.14	21.33

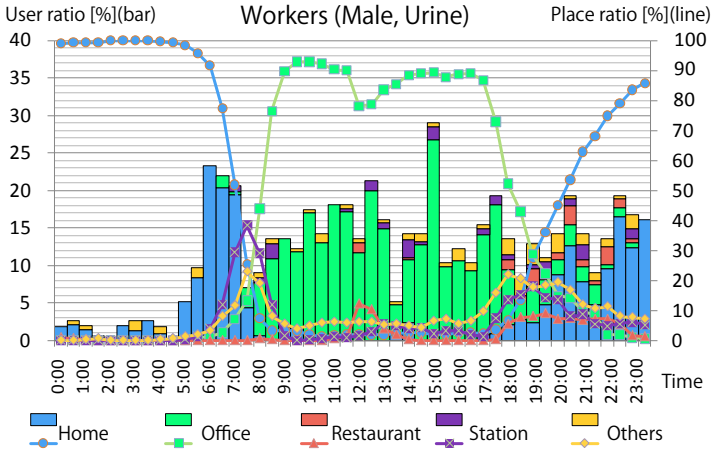


Figure-3 Use frequency for every time zone (workers, male, urine)

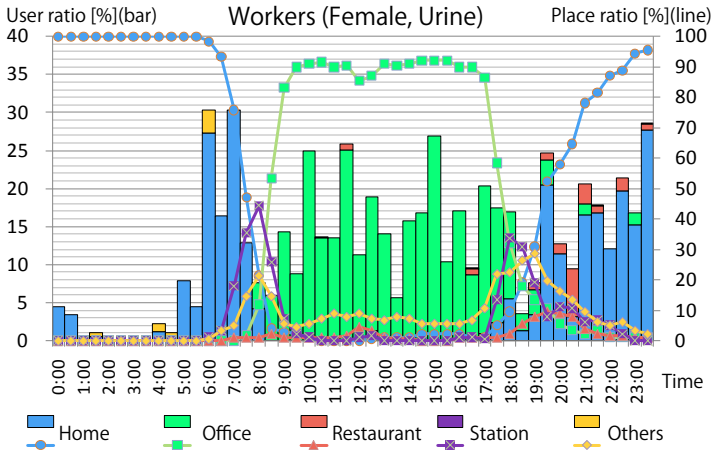


Figure-4 Use frequency for every time zone (workers, female, urine)

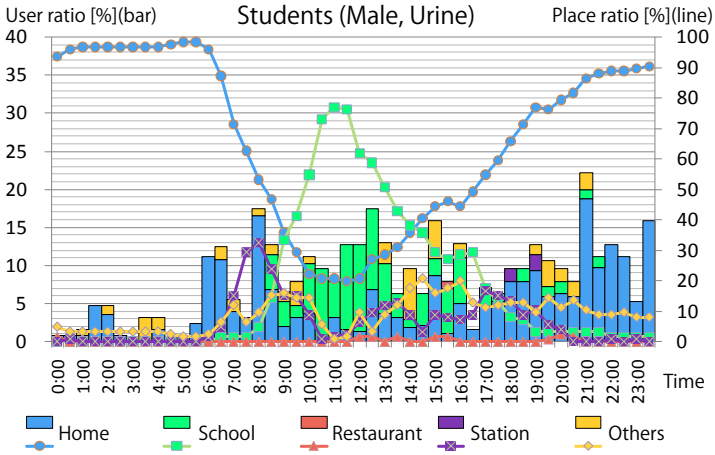


Figure-5 Use frequency for every time zone (students, male, urine)

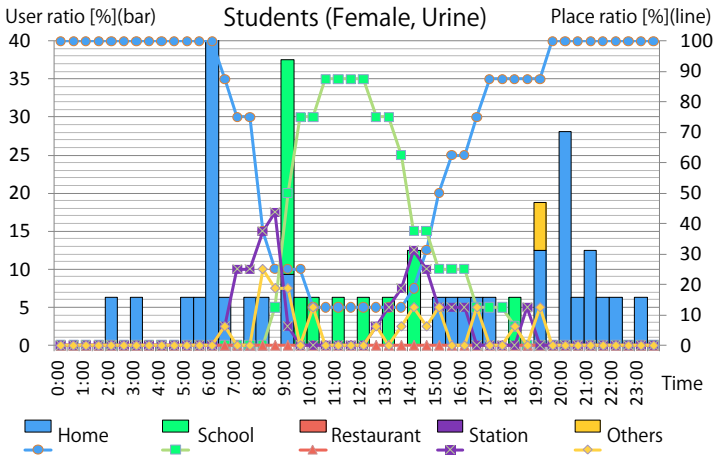


Figure-6 Use frequency for every time zone (students, female, urine)

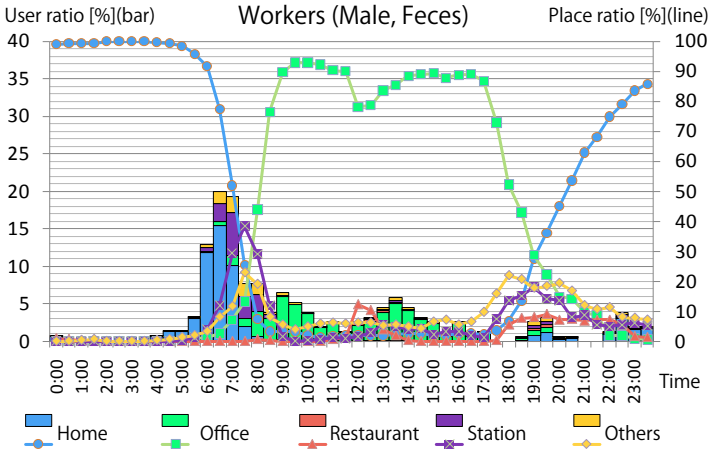


Figure-7 Use frequency for every time zone (workers, male, feces)

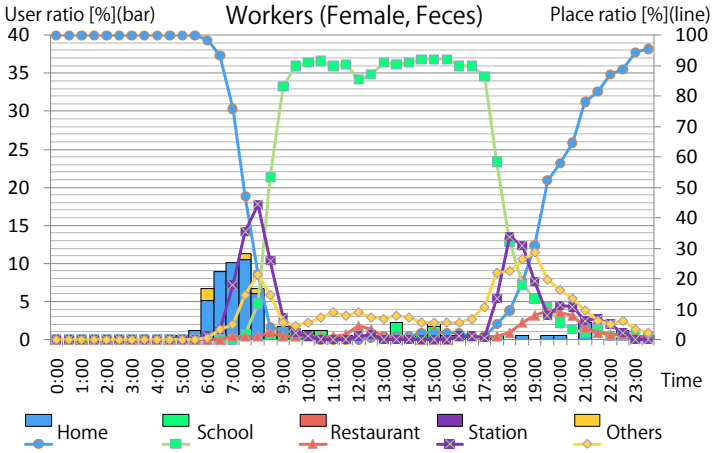


Figure-8 Use frequency for every time zone (workers, female, feces)

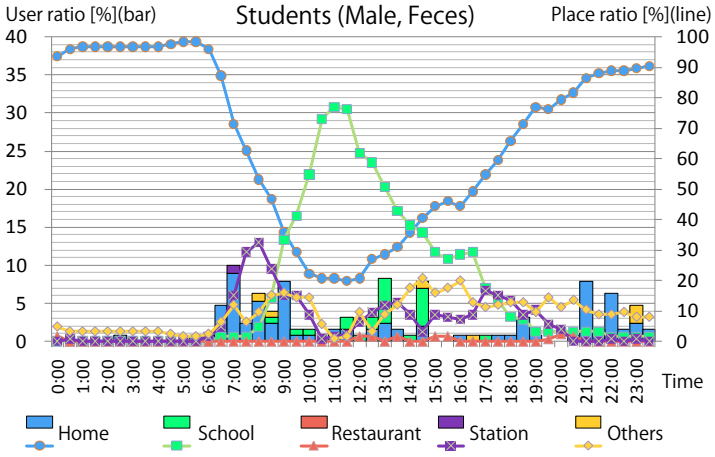


Figure-9 Use frequency for every time zone (students, male, feces)

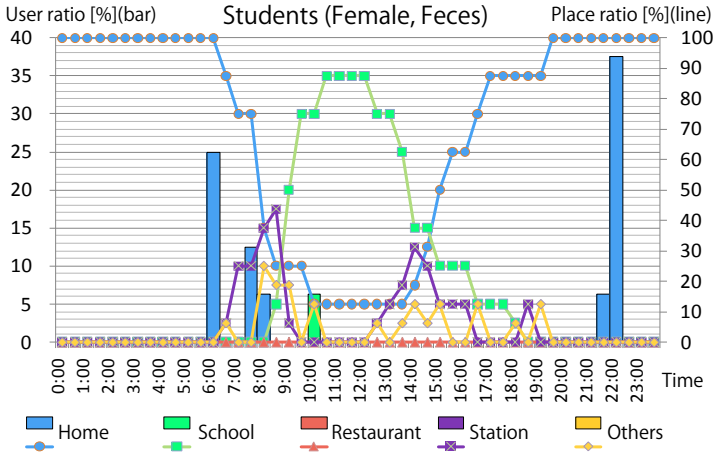


Figure-10 Use frequency for every time zone (students, female, feces)

This data is divided according to sex, a relation with the number of times of excreting within the length of stay which was present in the office, and the time is made into a scatter diagram, a male shows figure-11 and a woman shows figure-12. In addition, since male feces had the number of times of an average as small as about 1 time which lets one day pass, it is not taken up here, but female excretion is mixed in order to perform urine and feces within the same fixture.

It asked for the regression line in each scatter diagram. R^2 is set to about 0.3-0.4, and it can be said that there is both positive correlation of a medium degree. Moreover, one use is seen for man and woman in length-of-stay about 3 hours. When it thinks to 100 persons' use number, from 100 persons arriving in 3 hours, this becomes a part for 100 / 180 = 0.56 person per minute, and is mostly in agreement with a part for 0.6 arrival rate of a male urinal and a female toilet bowl in calculation conditions of the present technical guidelines.

A male shows the number of times of average use for every length of stay to figure-13, and a woman shows it to figure-14. By both the male and a woman, while length of stay increases, there is a tendency for the number of times of average use and the maximum number of times of use to increase. Moreover, in male urine, while length of stay increases, the difference of the number of times of the maximum use and the minimum use is large.

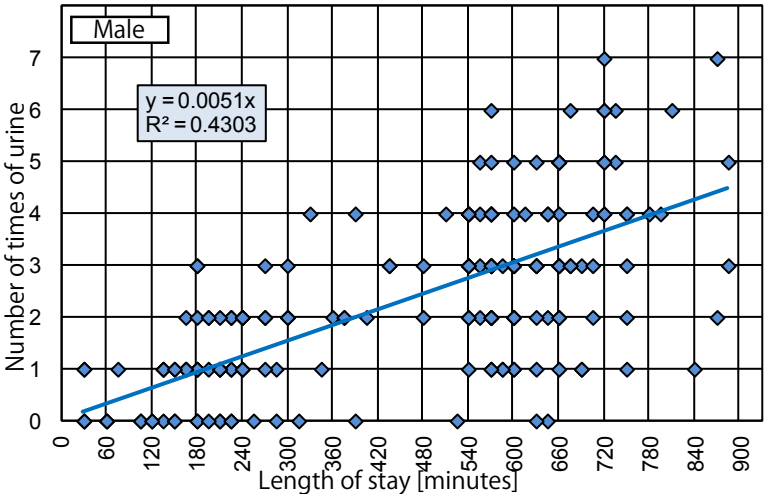


Figure-11 The scatter diagram of the number of times of use to length of stay (male, urine)

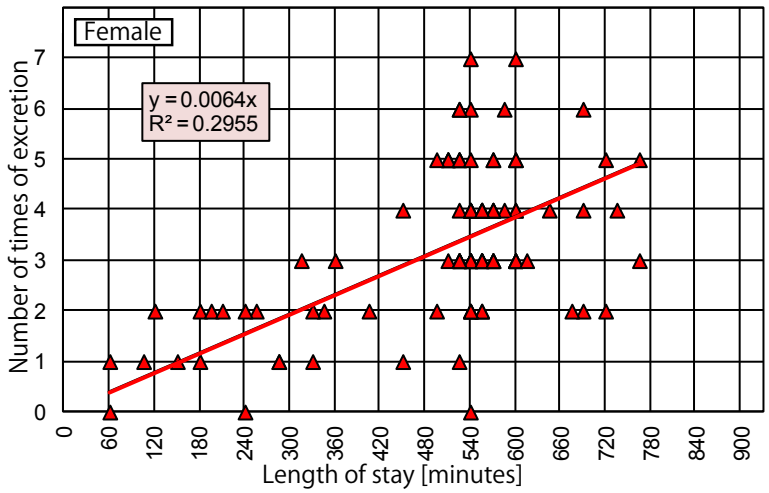


Figure-12 The scatter diagram of the number of times of use to length of stay (female, excretion)

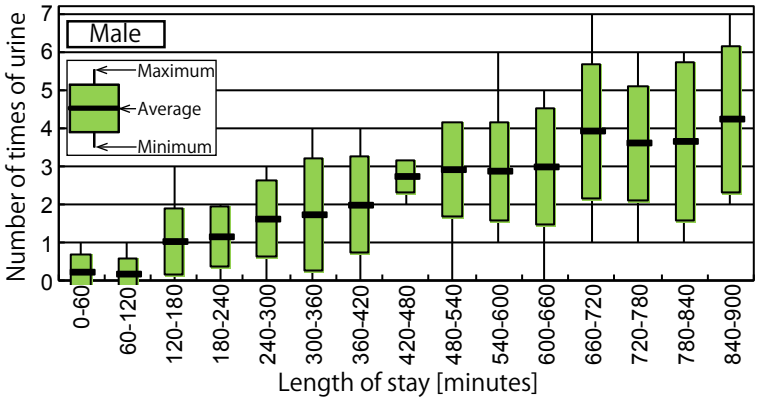


Figure-13 The number of times of use for every length of stay (male, urine)

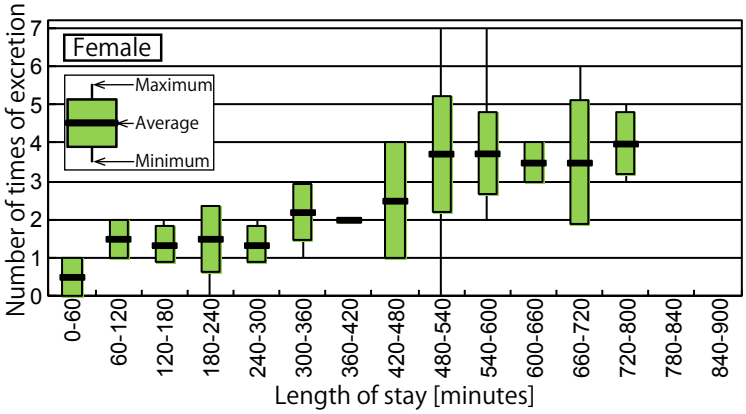


Figure-14 The number of times of use for every length of stay (female, excretion)

4. The examination matter about calculation of the installation number of a sanitary fixture

4.1 Outline

As for the installation number of the sanitary fixture, six building uses are only shown in the technical guidelines. Moreover, only the number with which the use number, and the number of seats and the number of students were restricted is shown. However, in the actual design, there are various building uses and also extension of the figure shown so far is called for with the increase in the floor area per story.

A number of users and occupancy time are various also in the building where a use is the same. At the society, an arrival rate and occupancy time are found for every building use based on various results of an investigation, an arrival rate is converted into a number of users, and the graph of the installation number is shown. When repair of the existing building, etc. examine the number of instruments, it is possible to compute the more suitable installation number by finding an arrival rate and average occupancy time by survey beforehand.

Here, the two calculation methods shown in technical guidelines about the installation number at the time of extending the number of users who made the woman toilet bowl of the office the example are compared and shown. In addition, the number calculation program of sanitary fixtures created in the old subcommittee is used for calculation.

4.2 **Comparison of the calculation method and the installation number at the time of extending a number of users**

The woman toilet bowl of an office is assumed about the two calculation methods, the queueing theory in the forms of arbitrary use used and the Monte Carlo simulation in the forms of intensive use in the technical guidelines. The result by which it might be calculated on the same conditions [the arrival rate 0.6, 90s of occupancy time, and rate scale of waiting time: $P(>10) < 0.01$ (level 1)] is shown in figure-15. In addition, although the calculation method of the Monte Carlo simulation is proportionate to the technical guidelines, it is premised on the waiting for one row, and movement of the

sequence is omitted. Moreover, the number of users of the office converted as 0.6 person / (minute * 100 persons) is also shown in the horizontal-axis upper part. In addition, in the case of a department store and a volume retailer, it is 0.3 person / (minute * 100 persons), and also is the same as that of the above-mentioned conditions, and can convert it as the 100 number of users by the arrival rate 0.3. In the technical guidelines, although the maximums number of users which can be assumed was 300, they are calculated by having expanded to 900 persons here.

If two results are compared, when an arrival rate is small, many numbers of fixtures will be calculated for the direction of a simulation. When an arrival rate is large, many numbers of fixtures are calculated for the direction of a queueing theory. For example, although the arrival rate 4.2 assumes 700 number of users in an office, the difference in the calculation number is two pieces at the maximum, and it does not have a big difference.

In intensive use, comparison in the case of a theater was performed. Figure-16 is the result of computing the number of proper fixtures on three conditions of fixture users ratio 0.30 to number of visitors (number of seats) and average fixture occupancy time 75 second and, and 15 minutes between the last arrival time. The number of fixtures when a queueing theory (the calculating method A) sets to P(>40) < 0.01 (level 1), and the simulation (the calculating method B) asked for the minimum number of fixtures that becomes lower than 40 seconds of the maximum waiting time which is the level 1 in 10 times of the number of times of trial. Moreover, when average fixture occupancy time was made into 75 seconds and waiting for one row was carried out, the minimum number of fixtures (the calculating method C) in which all fixture users finish use in 20 minutes of the end time limit (it cannot be concerned with waiting time but can deal with people at an intermission) was computed. In the case of the theater, the number of instruments changes greatly with calculating methods.

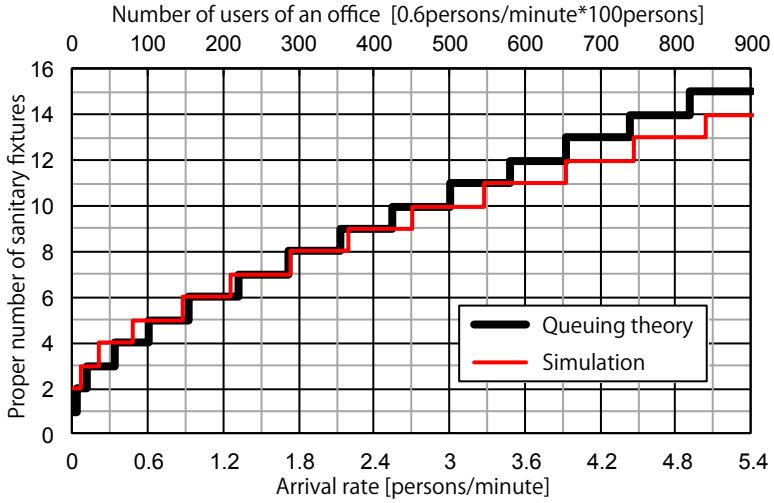


Figure-15 Comparison of the calculation method of the two numbers of proper fixtures under the same conditions (the woman toilet bowl of an office, the level 1)

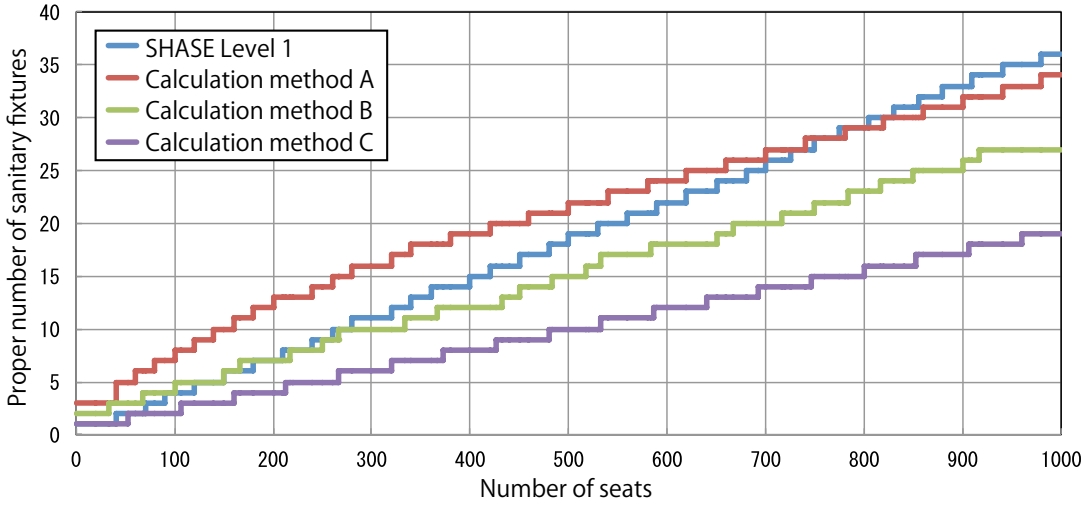


Figure-16 Comparison of the three calculation methods of proper fixtures on the same conditions (Level 1 of the woman toilet bowl in a theater or the number in which a user finishes use at an intermission)

5. Conclusions

This paper considers the determinant of the installation number of a sanitary fixture among the researches done to the present problems. Moreover, the questionnaire result about use and lifetime of a sanitary fixture is shown. Furthermore, the calculation method of a sanitary fixture is compared and it is shown in a graph.

Although the determination of the number of proper fixtures defines the number of the sanitary fixture, which constitutes the interface of plumbing sanitary fixtures, influence also attains to the design method in plumbing system. The present number of proper fixtures also needs to take into consideration the environmental side, the sanitary side, and the still more spatial side from now on, although it has been a standard, which permits waiting time.

In this research, wide use of the arrival rate was proposed paying attention to the relation between the length of stay of a building, and the number of times of excretion. On the other hand, a value was not changed about fixture occupancy time. Changing the method of calculating the number of proper fixtures has a possibility of causing social confusion. Although it is difficult to survey on the problem of privacy, about fixture occupancy time, it is necessary to collect data with backing and to check whether the present method is appropriate.

6. References

1. Workers of Heating, Air-Conditioning and Sanitary Engineers of Japan. (2000). SHASE-S206-2009 : Plumbing Code

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3. H. KOSE (2011) : Usage Behavior in the Restroom : Seen from the Questionnaire Investigation on Living Hours Examination on the Determination Method for Fixtures Requirement(Part3), *Annual meeting of SHASE* (I, A-5, pp.17-20)

7. Presentation of Author

Hiroyuki Kose is the Associate Professor at Toyo University, Faculty of Information sciences and arts from 2009. Special fields of study are plumbing engineering, water environment and reproduction of the agricultural and forestry industries by collaboration of citizens and an organization.