Comparative Benchmark of Limix and marble tiles

Test Item	Applicable Standard / Test Location	Test Methodology	Standard Value	Results	Comparative Results (Marble)	Comments
Specific Gravity	Internal	The numerical value of the dry weight divided by the volume	–	1.9–2.2g/cm^3	2.7	The specific gravity varies depending on the type of aggregate. About 25% lighter than granite or marble
Water Absorption Ratio	JIS A 5209 Japan Tile Testing and Engineering Association	The numerical value of the amount of water absorbed in 24 hours divided by the dry weight	–	About 0.5–10%	0.5–5%	Can be controlled to a certain extent by mixture and surface coating.
Bend Breaking Load (10mm thickness; for interior and exterior walls of lower and middle floors)	JIS A 5209 Japan Tile Testing and Engineering Association	As measured by the testing method for ceramic tiles	12N／cm	90N／cm (Present mixture) (120Kg/cm2)	110Kg/cm^2	About the same value as marble. Standard strength for exterior wall use is 100N/cm. The mixture for exterior use is currently being prepared for testing.
Bend Breaking Load (15mm thickness; for floor usage)	JIS A 5209 Japan Tile Testing and Engineering Association	the same as above	120N／cm	280N／cm	–	–
Compressive Strength	JIS R 1250 Japan Testing Center for Construction Materials (JTCCM)	As measured by the test methodology for normal brick	As various standards were used, this has been omitted.	360Kg/cm^2	1200Kg/cm^2	Concrete: 150–250Kg/cm^2 For building stone, a semi-soft stone was used. For brick, a product comparable to Types 3 and 4 brick was used.
Abrasion Resistance Test (Abrasion Test with Grit)	JIS A 5209 Japan Tile Testing and Engineering Association	The test body was set at an angle and abrasives were dropped on it. The amount of abrasion resulting was then measured.	0.1g以下	0.016g	0.028g	Results varied depending on the mixture, casting pressure and curing time.

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Abrasion Resistance Test (Olsen's Method: Test Method using Plastic Abrasives)	JIS K 7205 Japan Testing Center for Construction Materials (JTCCM)	Abrasives were dropped on the test body and a rotating disc was used to grind the material into the surface, after which the amount of abrasion was measured. Generally, the amount of abrasion is measured after 1,000 revolutions of the disc, but this time, measurement also occurred after 500 revolutions.	−	After 500 revolutions 1. 29mm of surface reduction After 1000 revolutions 4. 7mm of surface reduction	After 500 revolutions 1. 0.2mm of surface reduction After 1000 revolutions 2. 11mm of surface reduction	The amount of abrasion was about the same up through 500 revolutions. The increased amount after that is probably attributable to the fact that the carbonised layer had been worn off, producing a new surface more prone to abrasion.
Hardness Test (Moh's Hardness Test)	BS 6431 U.K. Standards Japan Tile Testing and Engineering Association	The tiles were scratched with stones of varying hardness. The hardness of the stones ranged from 1 to 10, with 1 being the softest and 10 being the hardest. The highest number of stone (i.e., the hardest stone) to not produce a mark was recorded.	6 (unglazed tile)	7	Results ranged from 3 to 7.	①talc ②plaster ③calcite ④fluorite ⑤apatite⑥feldspar⑦quartz⑧topaz⑨corundum⑩diamond
Slip Resistance Test Tokyo Institute of Technology Slip Test (O-Y・PSM) (CSR)	JIS A 1454 Japan Tile Testing and Engineering Association	The prescribed slider materials were placed in the bottom of the slider and set to a vertical load of 785N. When the slider materials came in contact with the test body, they were pulled at a load speed of 785N per second at an upward angle of 18 degrees.	Special Reference Table1 All Japan Tile Association Reference Value=0.37	Floor Specifications*1 0.38 Non-slip Specifications*2 **0.42**	0.33 (finished surface was polished)	Both floor specification and non-slip specification Shikkui tiles were judged as "Neither safe nor dangerous." Anything below 0.37 being less than "Neither safe nor dangerous", is considered "Somewhat dangerous" and is thus unsuitable for floor usage.

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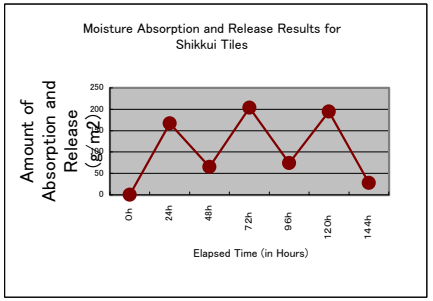
Slip Resistance Test British Portable Skid Resistance Tester (BPN)	ASTM E 303 U.S. Standards Japan Tile Testing and Engineering Association	A pendulum equipped with a rubber slider was allowed to contact the test surface while swinging and the drag produced due to friction was given a numerical value.	Special Reference Table 2	Floor Specifications*1 Dry 62 Wet 41 Non-slip Specifications*2 Dry 80 Wet 52	7 (finished surface was polished and wet)	A score of 40 or more indicates a surface that is safe for both normal walking. Also, at low speed, a car may be driven on such a surface.
Shock Test (Hard Ball Drop Test)	BS 1281 U.K. Standards Japan Tile Testing and Engineering Association	A hard ball having a diameter of 19 mm, specific gravity of 7.85 and a mass of 28.35 was dropped on the test body from a height corresponding to the thickness of the test body (741mm for this test) and the test body was then checked for any resulting damage.	–	No damage indicated	–	–
Heat Conduction Test (Guarded Hot Plate Method、GHP Method)	JIS A 1412-1 Japan Testing Center for Construction Materials (JTCCM)	Conducted in accordance with thermal resistance and thermal conductivity measurement techniques for heat insulating materials.	–	1.84 kcal/m·h·℃	1.96 kcal/m·h·℃	Results about the same as that of marble. Indication are that it is suitable for usage with floor heating. Reference data: lime plaster 0.64kcal/m·h·℃ , mortar 1.3kcal/m·h·℃ .
Thermal Expansion Test	Saga Ceramic Research Laboratory (conducted August, 2000)	–	–	4.0–5.0×10^{-6}/℃	7.0×10^{-6}/℃	Thermal expansion is about the same as that for porcelain (3–6×10^{-6}/℃) and brick (3–9×10^{-6}/℃).

Test Item	Applicable Standard・Test Location	Test Methodology	Standard Value	Results	Comparative Results (Marble)	Comments
Frost Damage Resistance Test (porcelain tile)	JIS A 5209 Japan Tile Testing and Engineering Association	One cycle consisted of eight hours at -20℃, six hours in water at a normal temperature and then another eight hours at -20℃. This was repeated for ten cycles after which the test body was checked for the presence of any cracks or peeling.	10cycles	No abnormalities detected.	−	Testing carried out as per external surface coating specifications.
Frost Damage Resistance Test (Construction-grade Exterior Wall Materials Frost Damage Resistance Test Method)	JIS A 1435 Japan Tile Testing and Engineering Association	An air-freezing, water-thawing method. One cycle lasted between three and six hours and involved freezing at −20℃ and thawing out at ＋20℃. Three hundred cycles were performed.	−	No abnormalities detected up through fifty cycles.	−	**Currently being tested.**
Dowel Area Fixed Physical Strength Test (30mm thick)	JASS 9T 201 Japan Testing Center for Construction Materials (JTCCM)	A dowel pin was embedded in the side of the test body tile with the use of an adhesive and a plate was connected to the dowel pin. The plate was then pulled and the amount of load which produced failure was recorded. The strength of both formed (i.e., hardened) and freshly cut surfaces was measured.	−	Both formed and freshly cut surfaces showed failure at a load of about 100Kgf /dowel pin.	−	**Reference data:** The breaking load of the dowels on the sandstone tiles from company A (made of concrete, 600 x 600 x 30 mm, approx. 22kg) is 110 kgf per dowel, so when supported by four dowels, these tiles can withstand a wind load of 440 kgf each. When installed on an exterior wall at a height of 30 meters, a 600 mm tile is subjected to a wind load of 90 kgf, so its safety rating is thus about 5 (440/9 = 4.9).

Test Item	Applicable Standard・Test Location	Test Methodology	Standard Value	Results	Comparative Results (Marble)	Comments
Adhesive Qualities	JIS A 5548 Tilement Co., Ltd.	Bonds manufactured by Tilement Co., Ltd. were used for the test. For exterior use, a metamorphic silicon epoxy was used, while for interior use an epoxy and an acrylic resin-type emulsion adhesive was used. After allowing for the drying time prescribed for each product and subjecting the bonded areas to unfavorable conditions (hardening at low temperatures, exposures to warm alkaline water, repeated immersion in hot and cold water, degradation by heat), adhesive strength was measured. Testing of exterior use adhesive products conformed to the test methods used by the Ministry of Construction's Public/Private Collaborative Research on Development of Tile and Building Stone Systems which Utilize Organic Elastic Adhesives.	Standard ($6Kgf/cm^{2)}$ Immersion in alkaline water・drying・repeated immersion in water・ heat degradation・hardening at low temperatures ($3Kgf/cm^{2)}$	If the adhesive chosen for exterior and interior use has the same constituents as the products tested here, the adhesive strength provided should be sufficient. However the use of only bond is to be limited to use up through the lower-middle floors (2nd and 3rd floors); on construction higher up, dead weight becomes an issue and adhesives must be used in unison with hardware clips or dry construction techniques must be employed.		In evaluating the performance of the adhesives, the main factors were adhesive strength and failure conditions. The first standard of evaluation was whether an acceptable minimum level of adhesive strength corresponding to actual usage and work environment could be demonstrated. However, recently there has been in increase in assessments of, and discussions regarding, failure conditions after adhesive strength measurement is completed. The ideal failure condition is either surface material (tile, etc.) failure or substrate material (mortar, etc.) failure with the next favorable condition being cohesive failure (CF) of the adhesive. In this test, Shikkui tiles for internal walls displayed surface material failure, while external wall tiles displayed cohesive failure of the adhesive. According to a representative of Tilement Company Ltd., after demonstrating the prescribed adhesive bonding strength, if the adhesive demonstrates cohesive failure, the adhesive's bond with the materials has been demonstrated to be effective.

Test Item	Applicable Standard・Test Location	Test Methodology	Standard Value	Results	Comparative Results (Marble)	Comments
Moisture Absorption and Release Test	Internal Test	The test body was kept in an environment with a constant temperature and humidity of 20℃ and 50% respectively until its weight stopped fluctuating. After the true test body weight was verified, it was kept at 20℃ with a humidity of 95% for 24 hours, after which it was weighed. It was then kept at a temperature of 20℃ with a 50% humidity for another 24 hours and then weighed again. This process was repeated once and through the variances in weight produced, moisture absorption and release were measured.	−	The test body absorbed and released about twice as much moisture as cedar, which absorbed and released about 100g/m2. This might be able to be altered by varying the mixture and casting pressure.	−	
Soiling Resistance Test *3 (finger marks, magic marker, grease)	Internal Test	The surface coating treated-test body was soiled with a magic marker and then additional grime was applied with unwashed hands.	−	Grease should be cleaned up as soon as possible.	−	The removal of grease is especially problematic. It is advised to wipe up grease as quickly as possible. If a stain develops, apply water to a commercial water-resistant sandpaper (#240 - #400) and buff it out. This will tend to remove a portion of the coating so, after the surface has dried (or one full day and night later), apply a coating agent with a brush.

Test Item	Applicable Standard・Test Location	Test Methodology	Standard Value	Results	Comparative Results (Marble)	Comments
Soiling Resistance Test *3 (Soy sauce, Worcestershire sauce, coffee, Japanese green tea, etc.)	Internal Test	Soy sauce, Worcestershire sauce, coffee and Japanese green tea was dripped on the surface coating treated-test body, where it was allowed to remain.	−	Areas soiled with these items can be effectively cleaned with a damp cloth if done so before permeation of the soiling agent. If permeation has already taken place, clean with Kabi Killer or a similar chlorine-based bleaching agent.	−	If Kabi Killer or similar cleaning agents are not effective, apply water to a commercial water-resistant sand paper (#240 - #400) and buff the stain out. This will tend to remove a portion of the coating so, after the surface has dried (or one full day and night later), apply a coating agent with a brush.
Soiling Resistance Test *3 (mud)	Internal Test	The coating treated-test body was stepped on with muddy shoes.	−	Light washing with water and a nylon scrubbing pad or sponge is effective in removing mud.	−	If mud has penetrated deeply into the small surface holes, complete removal may be impossible.

*1 Special Aggregate Mixture　*2 Special Aggregate Mixture with Uneven Surface Specifications　*3 Test was conducted on a tile surface to which a coating agent had been applied.

Table1 CSR Reference Values and Evaluation Graph

Product Type	CSRValue
Terrazzo Block	0.44
Interlocking	0.8
Flat Concrete	0.52
Asphalt	0.75
Marble (Polished)	0.33

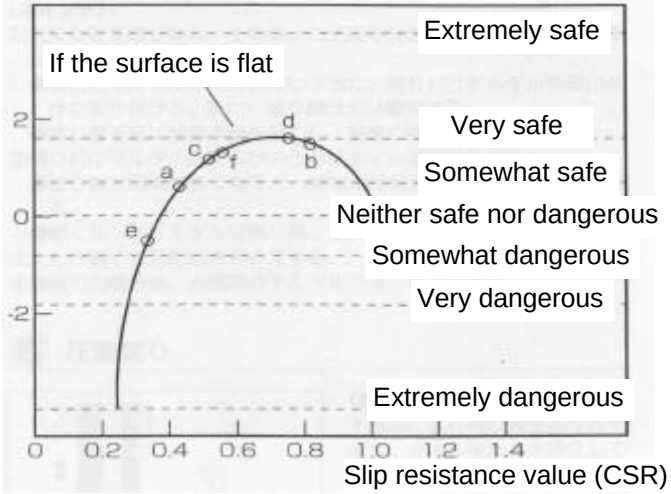


Table 2　Slip Resistance Standards

Slip Resistance Value (BPN)	Slip Resistance Standard
024BPN	Easy to slip.
2539BPN	Safe if the area is flat and the walking speed is moderate.
40−46BPN	Even with a grade, safe at a moderate walking speed. An automobile may be driven slowly.
4754BPN	Depending on the walking speed, no slipping whatsoever. An automobile may be easily driven.
55BPN以上	Safe even with violent or sudden movements. General travel by automobile also safe.