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FIBER CEMENT BOARDS PERFORMANCE REQUIREMENTS AND IMPROVEMENT

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ABSTRACT
After nearly 20 years of development in China, the non asbestos fiber cement board has been recognized and adopted by more and more designers, and constantly applied in a variety of construction projects and parts. In addition to being used as indoor decorative board, in view of the excellent performance and structural properties of fiber cement board, outdoor application is favored by more and more architects, and has achieved good results. In this paper, the performance requirements of the fiber cement board are analyzed, performance improvement method are put forward, and some typical examples are listed.

KEYWORDS:
Light weight board for construction; fibre cement board for outdoor use; weathering performance; Elkem microsilica.

1. INTRODUCTION
Light weight board for construction generally refers to boards formed with some cementitious and auxiliary materials reinforced by fiber and can be used in many parts of the building, such as wall, roof and floor etc., The building material is not only decorative, but also functional. Many types of light weight board are commercially available, including gypsum board series, cement board series, magnesium oxide board series, mineral wool board series, wood board series and so on.

2. PERFORMANCE REQUIREMENTS AND PRODUCT DESIGN OF FIBER CEMENT BOARDS FOR OUTDOOR USE
The environment of outdoor application is much more complex than that of indoor. Therefore, the requirements of the board are much higher.
In terms of mechanics, architectural designer should consider wind pressure, rain-snow dynamic loading, so the board should at least guarantee the following mechanical performance: bending strength, MD/CD strength ratio, elasticity modulus, shear strength, compressive strength, and

impact strength.

Outdoor humidity and temperature will have a greater change, so the water absorption, temperature expansion coefficient, humidity expansion coefficient of board must be controlled, also the mechanical properties under extreme environment must be controlled.

The weather resistance and durability of board are most critical for the outdoor application of the product, these performances can be evaluated by laboratory tests such as freeze-thaw test, carbonation experiment and heat-rain test. And the test process should be multicycle, and some physical and mechanical properties changes of board are measured after each cycle.

When determining the technical indexes of mechanical properties and dimensional stability of board, the coordination of whole application system parameters including thickness of plate, maximum elongation or maximum distention of fasteners and so on must be considered. In determining the said technical indexes, we could have different emphasis according to the application environment, such as freeze-thaw resistance of plate should be emphasized in some areas, and damp-heat resistance of plate should be emphasized in other areas.

Table 1 and table 2 show the requirements on the related performance of fiber cement board for external wall in Chinese construction industrial standard JC/T396-2012 "Non-bearing fiber reinforced cement board for external wall"

Table 1 Requirements on the performance of fiber cement board for external wall in Chinese construction industrial standard JC/T396-2012

Item		Specification
Apparent density D/（g/cm3）		≥1.2
Water absorption /%		≤22
Water impermeability		24h after the test, the reverse side of the board is allowed to appear wet mark, but the water drop should not appear.
Moisture deformation /%		≤0.07
Thermal conductivity λ		Production enterprises should give a λ value
Durability	Freezing resistance	After freeze-thaw cycles, rupture stratification of surface should not appear. The ratio of rupture strength in water-saturated state of freeze-thaw cycle specimen and contrast specimen should be ≥ 0.80
	Heat-rain resistance	After 50 times of heat-rain cycle, surface shall show no visible cracks, delamination or other defects.
	Heat-water resistance	After immersion in 60℃ water for 56d, the ratio of rupture strength in water-saturated state of test specimen and contrast specimen should be ≥ 0.80
	Dry-wet resistance	After 50 times of immersion-drying cycle, the ratio of rupture strength in water-saturated state of test specimen

		and contrast specimen should be≥0.75
Combustion performance		not lower than the non flammable A2 level requirements in GB 8624-2006
Radioactivity		Internal exposure indexIRa≤1.0 External exposure indexIγ≤1.0
Note: Freezing and thawing cycles are 100 times in severe cold regions, 75 times in cold regions, 50 times in regions with hot summer and cold winter, 25 times in regions with hot summer and warm winter.		

Table 2 Rupture strength in water-saturated state

Strength grade	Rupture strength in water-saturated state
Ⅰ	≥7MPa
Ⅱ	≥13MPa
Ⅲ	≥18MPa
Ⅳ	≥24 MPa
Note 1: The value of the rupture strength listed in the table is the vertical and horizontal arithmetic mean value. Note 2: When the length-width ratio of plate is ≤7, the rupture strength of weak direction of plate should be not less than 70% rupture strength.	

In addition, "Non-bearing fiber reinforced cement board for external wall" requires the impact-resistance strength of the fiber cement plate shall meet: No through crack in plate surface after 5 times of falling ball impact test.

Due to asbestos has been prohibited or limited, now the autoclaved fiber cement board generally uses wood pulp fiber as a reinforcing material, non-autoclaved (atmospheric steam curing) fiber cement board generally uses wood pulp fiber mixed with some chemical fiber as reinforcing material. Many physical and mechanical properties of wood pulp fiber are inferior to asbestos, which is mainly due to the combustibility, strong moisture absorption and poor durability of wood pulp fiber. So during producing process improvement is needed.

2.1 Improvement of Microsilica on the Performance of Non-autoclave d Product

Micro silica is a by-product of ferrosilicon alloy factory, a gray spherical particle powder. The basic particle shape is spherical, ultra-fine, with an average particle size of 0.15μm. In the production of non-autoclave d fiber cement products, micro silica is a good material to improve product mechanics and durability.

Micro silica has a good effect on enhancing and improving the performance of non-autoclave d fiber cement products, in terms of hydration mechanism of base material, micro silicon has high pozzolanic activity, namely reacting with $Ca(OH)_2$ generated by cement hydration and producing more hydrated calcium silicate gel, led to an increase in intensity. In terms of fiber-reinforced effect, after incorporation

of micro silica, the bond strength between the fiber and cement matrix has been significantly improved, so that the fiber reinforced effect of final product is significantly improved.

Elkem Material Fiber Cement Laboratory studies on the using of micro-silica in fiber cement products and concludes:

（1）For the production of non-asbestos fiber cement products, micro-silica is a kind of very effective auxiliary material is added.

（2）Micro silicon powder can significantly improve the final strength, freeze-thaw resistance and anti-humid hot property of non asbestos fiber cement products;

（3）Micro silicon can effectively improve the layering problem existed in the production of non asbestos fiber cement products with Hatschek process.

In actual use, micro silica particles should be fully dispersed, otherwise the effect will decline.

Table 3 shows the freeze-thaw conditions of products with or without micro silica tested by us. It suggests that the freeze -thaw resistance of fiber cement board has been greatly improved with the use of micro silica.

Table 3 Freeze-thaw test

Test specimen without micro silica	Test specimen with 8% of micro silica(replace cement)
Pulverization occurs from the 8th day	Pulverization occurs from the 28th day
Note: Product is produced in pulp flow on production line, specification for freeze thaw specimen is 100×100×12mm, the surface is treated with mat-finish to destroy the protective layer and placed in the water, then it into the freezer together with water, keep at -25℃ for 16h, after taking out, keep at room temperature for 8h, that is a cycle, and pulverization of surface of test specimen is observed in each cycle.	

2.2 Improvement of the Performance of Autoclave d Product by Wollastonite

Wollastonite is a fibrous mineral of calcium, the crystals can be leaf shaped acicular, radial, fibrous and massive aggregates. It can not only play an enhanced role in the board as auxiliary fibers, but also can improve the dry-wet dimensional stability and water saturated strength retention of board.

In terms of moisture expansion, although autoclaved product can generally maintain at a lower level, but because of the fiber orientation in manufacturing process, the difference of moisture expansion between horizontal and vertical direction is unavoidable, and may have an impact on the application process of board. The use of wollastonite can reduce the moisture expansion of the plate. In addition, it has a significant effect on maintaining the low temperature expansion coefficient of the plate.

After water absorbing ,the water saturated strength of board can be improved through the use of wollastonite.

In practice, the purity, the draw ratio and the size distribution of wollastonite should be controlled. The wollastonite data from one factory located at Jiangxi Province, China at following:

length-diameter ratio 14:1, sedimentation value 55ml/30g， particle size distribution 80~200mu.

Table 4 shows the comparison of some physical and mechanical properties of the fiber cement board produced by the formula with wollastonite or without wollastonite. The value in the table is the statistical value in a production period. In actual production, the product control process is not simply a process of

adding wollastonite, so the improvement of the physical and mechanical properties of the product is not entirely the result of addition of wollastonite. However, the relevant numerical value in Table 4 can still prove that it can improve many performances of fiber cement board by improving other processes with wollastonite.

Table 4 Performance changes of board with use of wollastonite

Parameter	usage of wollastonite	Measured value	Change amount
Lateral moisture expansion	Formula without wollastonite	0.23%	43%
	Formula with wollastonite	0.13%	
Longitudinal moisture expansion	Formula without wollastonite	0.18%	33%
	Formula with wollastonite	0.12%	
Vertical and horizontal moisture expansion ratio	Formula without wollastonite	78%	Vertical and horizontal moisture expansion coefficient is basically balanced by increasing 14%
	Formula with wollastonite	92%	
Average drying intensity	Formula without wollastonite	19.7MPa	4%
	Formula with wollastonite	20.6MPa	
Average water saturation intensity	Formula without wollastonite	12.3MPa	27%
	Formula with wollastonite	15.7MPa	
Loss rate of saturation strength	Formula without wollastonite	37.6%	36%
	Formula with wollastonite	23.8%	
Note	1 Wollastonite data ： length-diameter ratio 14:1 sedimentation value 55ml/30g， particle size distribution 80~200mu (Jiangxi province factory) 2 Recipe without wollastonie: cement 39%, sand 52%, paper fiber8%, deflocculant 1% 3 Recipe with wollastonie: cement 39%, sand 44%, paper fiber8%, wollastonite 8%, deflocculant 1%		

2.3 Usage Water Absorption Reducing Agent and of Water-proofing Agent

After water absorption, many performances of the fiber cement board will decline, at least include:

（1）Reduction of mechanical properties of board;

（2）Affect the durability of material;

（3）Affect the heat transfer coefficient, which is bad for energy-saving insulation.

So, low water absorption is very important for outdoor products. Water absorption could be reduced by increasing the density of plate to reduce the porosity of plate, and adding some special water absorption reducing agent.

Table 5 shows water absorption performance changes of different types of fiber cement specimen after addition of water absorption reducing agent. It suggests that the water absorption performance of fiber cement specimen could be improved by about 50% with use of some water absorption reducing agents.

Table 5 Changes of water absorption for fiber cement specimen after addition of water absorption reducing agent

Specimen	Addition of water absorption reducing agent	Water absorption [weight ratio]	Change amount
High density non autoclaved specimen	Not added	24%	46%
	1.2% additive amount	13%	
Medium density non autoclaved specimen	Not added	36%	58%
	1.2% additive amount	15%	
Low density non autoclaved specimen	Not added	69%	52%
	1.2% additive amount	33%	

In some application systems, there are strict requirements for the water absorption of board, it needs to do waterproofing treatment on the surface of board, there is a lot of waterproof agents in the market, test and verification should be carried out before selection. Figure 1 is from Wacker Chemical Shanghai Technical Center.

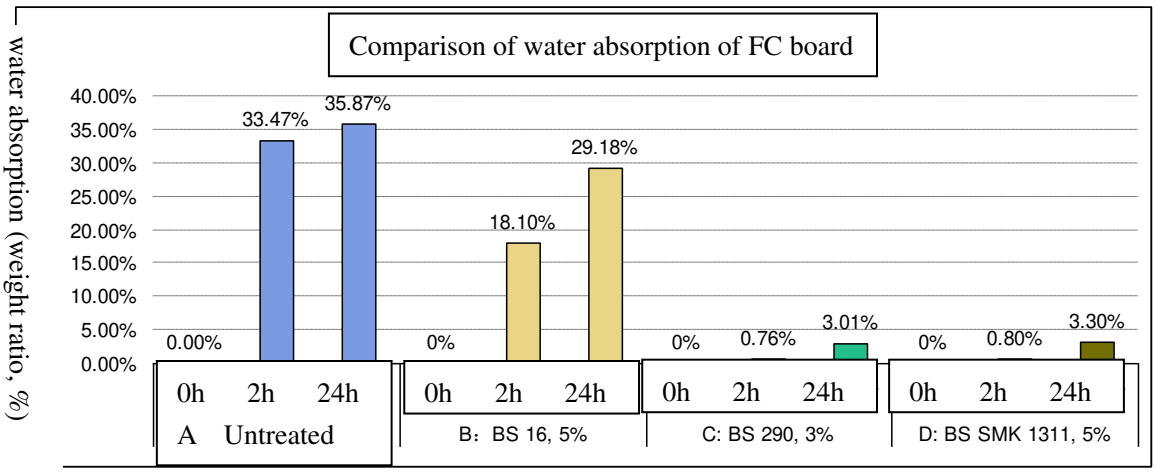

Figure 1 Water absorption of fiber cement board after treatment with different water proofing agent

BS16: Methyl silicate water proofing agent,
BS290: Silane silicone mixture solvent type water proofing agent
SMK1311: Silane silicone self emulsifying agent
From Figure the SMK 1311is much better than BS 16

2.4 Tackifier and Layers binding strength

Fiber cement board is in layered structure under Hatschek or flow on process. In theory, boards in this structure will be delaminated after the freeze-thaw. So the boards are not fit to the cold exterior area. In fact, when the boards have been used at cold exterior area, there must be strict rules for anti-freeze-thaw, such as we mentioned in this papers : Freezing and thawing cycles are 100 times in severe cold regions, 75 times in cold regions, 50 times in regions with hot summer and cold winter, 25 times in regions with hot summer and warm winter in China construction industrial standard JC/T396-2012 "Non-bearing fiber reinforced cement board for external wall"
Tackifier application will improve the binding strength of layers: spray the tackifier at forming roller's layer during producing, and after press the strength between layers will be improved.
Table 6 is from R&D Center. From test result, we can find out that the boards without press without good binding effect. After press the binding strength between layers is improved. And the high density boards samples from our 100 times freezing and thawing cycles test.

Table 6 Boards produced with and without press

Item	Tackifier	Pressing to board	Bing strength MPa
1	without	without pressing	0.41
2	without	Pressure10MPa and keep15mintes	1.17
3	with	without pressing	0.46
4	with	Pressure10MPa and keep15mintes	1.63
Note	1：Products from form flow on process and forming roller line pressure is 45 kg/cm； 2：Autoclaved； 3：Binding strength test：Saturated 24 h，dry 1 h, natural cooling，use high sticking glue fix sample on iron and keep that for 4hr, then put into water for 24hr before making test 4：Tackifier (powder) is form Jiangxi Province factory, type is XCM-02 5：Binding strength have been improved about 39% after pressing with pressing , with tackifier.		

Figure 2 Effect of Tackifier

Photo set at Figure 2 is from test. The up one did not use tackifier and the below one have sprayed. Clearly the up one layers been destroyed badly and the layers are loose. The one used tackifier is slightly harmed and the layers are dense.

3 APPLICATION

Figure 3 Fuzhou Hotel

Marble-imitated exterior wall of Fuzhou Hotel is depicted in Figure 3. High density fiber cement board is used as base material, which has excellent impact resistance, flexural strength, especially suitable for the curtain wall of external wall of high upscale building in the coastal areas with frequent typhoon, its surface has been treated with marbleized finish, which can be maintained for more than 15 years.

Figure 4 Outdoor Floor

Landscape footway in Fuzhou South Riverside is shown in Figure 4. Fiber cement board with wood grain on surface is used, this board has many features such as high impact resistance, weather resistance, anti-corrosion, anti moth, mould proof, beautiful and so on. In the living environment, the mechanical properties and structure of board can maintain long-term stability, in theory, the service life only depends on the service life of coupled system. Therefore, this board can extend the service life of footway by more than 10 years, it's a good substitute for wooden trestle or wood-plastic trestle.

Figure 5 Seaside Viewing Lodge

Seaside viewing lodge in Wetland Park, Changle, Fuzhou (Figure 5), the main body uses steel-wood composite structure, the wall, roof, floor, covering material all use fiber cement products. The building is still in good condition after several years of cold and heat circulation and erosion of bad weather.

4 CONCLUSION

(1) Fiber cement board for outdoor use needs higher and more comprehensive performance requirement, it should be fully considered in product design and formula design.

(2) The adaptability of the outdoor application of fiber cement board could be improved by adding some materials.

(3) By spraying tackifier on layer during producing to improve the binding strength between layers. And this will reach 100 times freezing and thawing cycles for extreme cold area usage.

(4) It is very important to keep low water absorption for the outdoor fiber cement board. In some applications, it is necessary to make surface waterproofing treatment on fiber cement board.

REFERENCE

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