



Bamboo-based packing products for cooling tower

International center for bamboo and rattan

Xinxin Ma

CONTENTS

- 1、 The necessity, feasibility, applicable scope of the project
- 2、 Project type (for major projects), budget
- 3 、 The advancement, innovation and industrialization status of technology
- 4、 Coordination and support with existing laws, regulations, mandatory national standards and related standards



1.1 The necessity of this project

- The global market size of cooling towers in 2021 was 3.2431 billion US dollars. It is expected that the global market size of cooling towers will reach 5.3342 billion US dollars by 2030.
- The market for cooling tower fillers, which account for 60% to 80% of the cooling capacity for cooling tower, is huge, reaching a scale of 2.5 billion US dollars in 2023.
- For every 1°C decrease in the tower water temperature, the coal consumption rate of the 200MW unit decreases by 1.11 grams per kilowatt-hour, which is approximately equivalent to 0.2558 million US dollars per year.



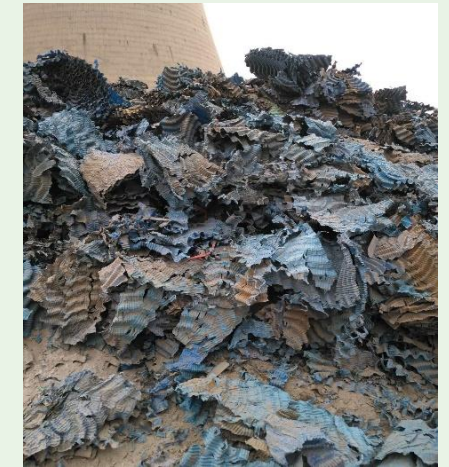
The type of cooling packings

Packings type	Enterprise type	Application ratio	
PVC packings	State-owned enterprises and a small number of private enterprises	85%	
Bamboo packings	private enterprises	1/3	15%
Cement mesh packings	private enterprises	2/3	
Ceramic packings	private enterprises		

PVC packings

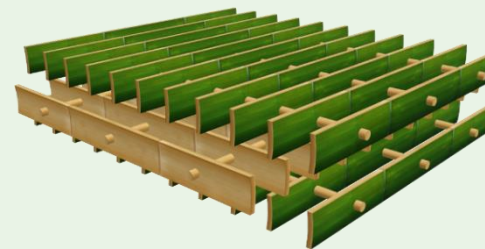


Annual replacement
1.5-1.8 million m³



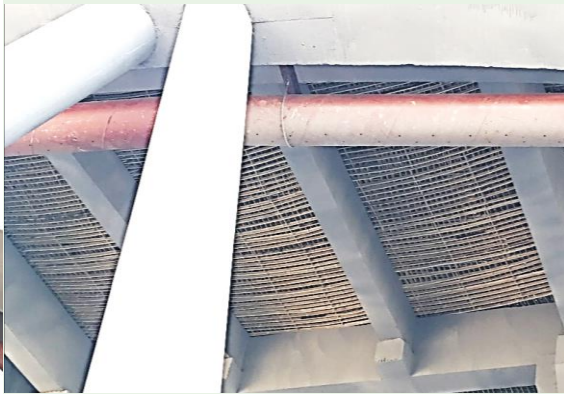
Life expectancy 3-5 year

Bamboo packings



Life expectancy 10-15₄year





Production process of bamboo based packings



Bamboo cutting



Splitting



Drying



Sliver making



Transportation



Bamboo packing manufacturing



Installation in cooling tower



Waste disposal (landfill)

The current annual sales volume of bamboo based packing materials is approximately several hundred million yuan, but there is a huge potential for replacement, and the potential market size could reach tens of billions of yuan.

- **Bamboo Substitutes Plastic:** Using carbon-negative resources instead of plastic to enhance the carbon reduction effect in power plants
- **Recyclability:** Used bamboo grid packing can be recycled as biomass fuel for secondary use.
- **Cross-disciplinary Integration and Innovative Collaboration:** The integration of the power industry and forestry can further promote the application of ecological resources like bamboo to achieve carbon neutrality.

Comprehensive Comparison of Bamboo and Plastic packings

	Bamboo packing	PVC packing cooling tower
Function unit	One cubic meter	One cubic meter
Mass per function unit	175 kg packing	24 kg PVC corrugated sheet packing
Bamboo cutting	<ul style="list-style-type: none"> One-ton bamboo trunk was produced by 1.4 tons of bamboo plants. The chainsaw was used for cutting bamboo with rate of 42 min per ton (10-ton bamboo per person per day. Cutting 1.4 tons bamboo needed 58.8 min of chainsaw use. 	<p>The inventory data for the production of PVC corrugated sheet packing were from SimaPro database and are presented as follows:</p> <p>3.12-ton water, 1.2 GJ energy from gas, 1.02 GJ energy from oil, 867.35 MJ energy from coal, biomass and from wood, 114.73 kg Carbon dioxide, etc.</p>
Transportation from the bamboo cutting place to the sliver mill.	Transport distance of 5 km using the Tractor, $5 \times 175 / 1000 = 0.875$ tkm	
Production of bamboo slivers for cooling tower	<ul style="list-style-type: none"> Bamboo slivers with green skin part, 25% of the output Bamboo sawdust, 75% of the output 	
Electricity, low voltage, for the manufacturing of bamboo slivers	15 kwh per function unit	
Raw materials for one function unit of cooling tower packings	169.6 kg/m ³ bamboo slivers 4.2 kg/m ³ bamboo rods 1.2 kg/m ³ PP pipe	22.4 kg/m ³ S-type PVC 1.6 kg/m ³ U-PVC glue
Electricity, low voltage, for the treatment of bamboo slivers	25 kwh per function unit	10 kwh per function unit
Transportation from the bamboo sliver mill to cooling tower site	500 km, >32-ton lorry. The bamboo slivers were 175 kg, it was calculated as $500 \text{ km} \times (175 \text{ kg}/1 \text{ ton}) = 87.5$ tkm	500 km, >32-ton lorry. The PVC packing was 24 kg, it was calculated as $500 \text{ km} \times (24 \text{ kg}/1 \text{ ton}) = 12$ tkm
Transportation from the cooling tower place to the landfill site	$50 \text{ km} \times (175 \text{ kg}/1 \text{ ton}) = 8.75$ tkm	$50 \text{ km} \times (24 \text{ kg}/1 \text{ ton}) = 1.2$ tkm

Thermal and resistance characteristics of bamboo grid packing and PVC packing

Packing type	Height (m)	$\Omega=A\lambda^m$		$A=A_xq^2+A_yq+A_z$			$m=m_xq^2+m_yq+m_z$		
		A	m	A_x	A_y	A_z	m_x	m_y	m_z
Bamboo grid packing	1.5	1.52	0.64	0.0038	0.1252	0.7254	0.0033	0.0712	2.0172
PVC packing	1.5	2.35	0.65	0.0004	0.0329	1.1867	0.0001	0.0018	1.9974

Notes: Ω is the cooling number; λ is mass ratio of dry air to water; A and m are the indexes of the test. A_x , A_y , A_z , m_x , m_y , and m_z are coefficients relating to the pour water density.

Coal Saving Benefits: :

Calculation based on: Power generation $N_j=7 \times 10^9$ kWh; Standard coal price at $\$dj=800$ yuan/ton.

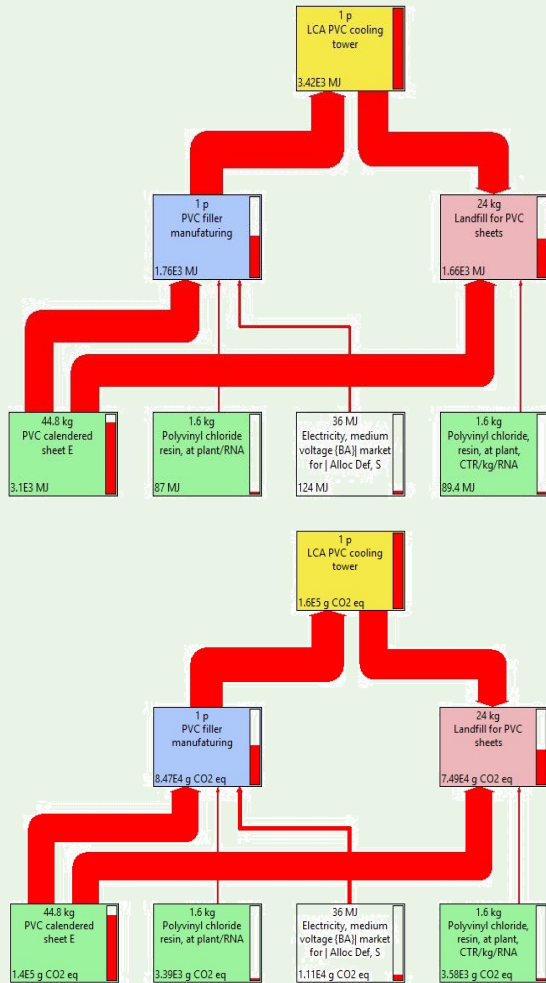
	Area of cooling tower	Packings used before	Reason for replacement	Type of replacement	Coal consumption rate	Total 4-11 month coal consumption	Annual savings of RMB
Case 1	4000m ²	PVC composite wave	Severe aging, average annual filler damage: 120-160 m ³	Bamboo and PVC packings	Reduction: 2.76g/kW.h	5796t	4.6368 million CNY
Case 2	9600m ²	PVC (S-wave packings)	Comparison only: PVC has better thermal performance but poor resistance	-	-	-	
Case 3	399.84m ²	Polypropylene Corrugated packings	Packings collapse and blockage	Bamboo packings	Inlet~outlet temp.diff.:~6-10°C	~600t	0.45-0.50 million CNY
Case 4	2000m ²	Cement Grid	Increased load after unit expansion	Bamboo packings	0.9g/kwh	630t (Power gen. × coal rate / 10%)	0.504 million CNY

Progress of the research

Synthesis and comparison

Performances	Bamboo shower packing	PVC packing
Thermal properties	Good $\Omega=2.06\lambda^{0.63}$	Better $\Omega=2.16\lambda^{0.66}$
Resistance characteristics	Good	Good
Mechanical property	GB/T 15780	GB/T 13022/GB/T 1130
Anti-fouling properties	Good	Worse
Ageing resistance	Good	Worse
Service life	15 years	5 years

Comparison of Total Energy Consumption and Carbon Emissions over the Life Cycle



- The total energy consumption (CED) of PVC filler is 3420 MJ, while the total energy consumption of bamboo packing is only 561 MJ, which is 6 times less than PVC packing. Among them, fossil energy, biomass fuel, wind energy and solar energy consumed by bamboo filler were 6.8-19.8 times lower than that of PVC packing, but the amount of water consumed was 1.4 times higher.
- After replacing PVC packing with bamboo packing in the same volume, the emission of CO₂ is reduced by 6.1 times. PVC packing's 'Global Warming', 'Acidification', 'HH-Cancer', 'HH-Non-Cancer', 'HH-Criteria Air Pollutant', 'Eutrophication' and 'Smog', 'HH-Non-Cancer', 'HH-Criteria Air Pollutant', 'Eutrophication' and 'Smog'. indicators are 6.1, 3.2, 10.5, 6.4, 4.7, 2.9 and 1.5 times higher than those of bamboo lattice packing, respectively.

Economic benefit

1. Direct economic benefits from lower consolidated costs

Taking the 300MW unit 5,500m² cooling tower as an example, the life extension will result in an annual saving of \$198,000/year in the scope of the project.

2. Direct economic benefits from mechanised processing

As an example, the price of a 2000 m²cooling tower is reduced by approximately 3-5 labour productivity.

3. Indirect economic benefits

The temperature of effluent is reduced by 1°C, the bamboo lattice packing will save 529.2t standard coal than PVC packing.

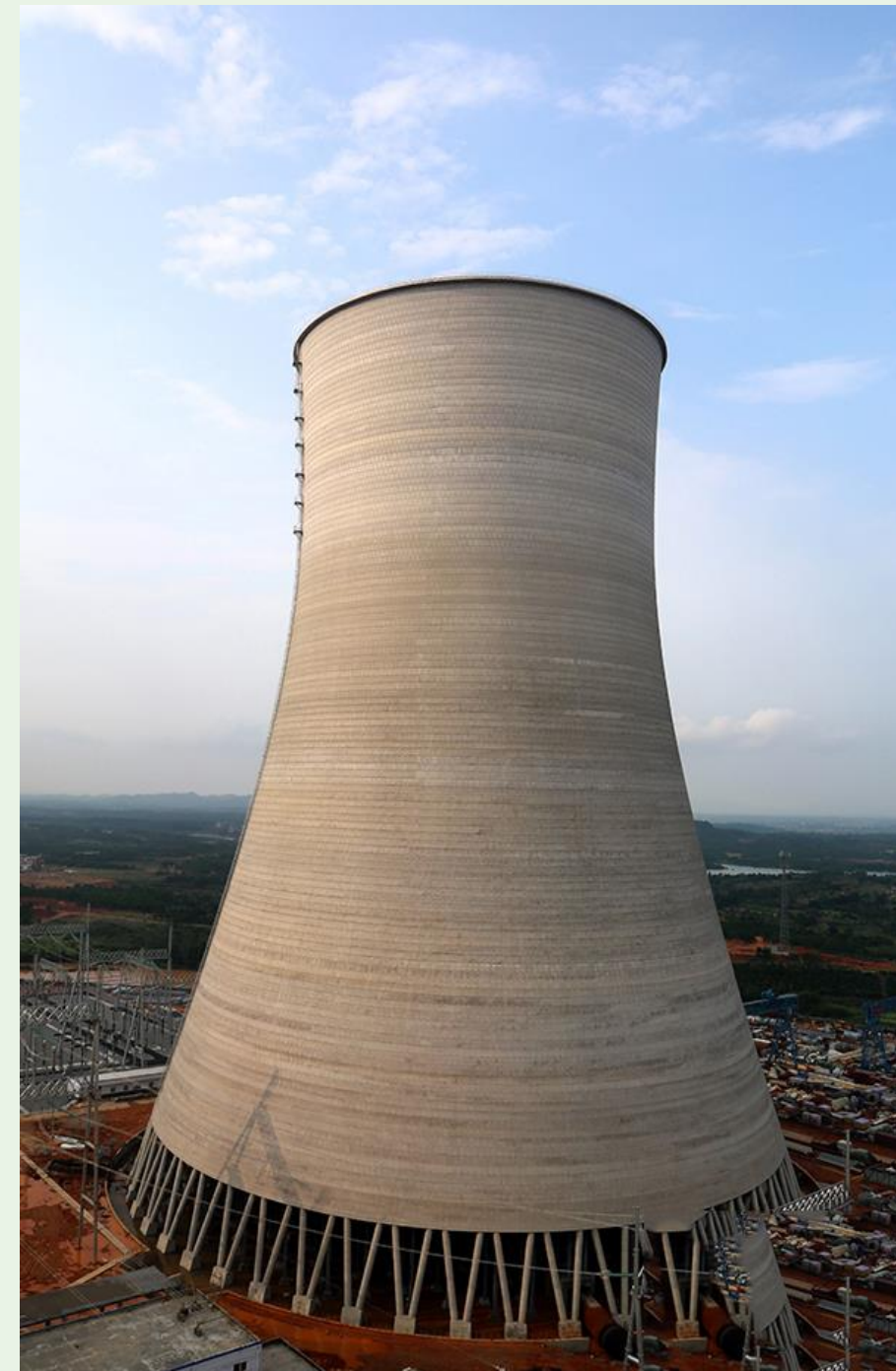
projects	Bamboo Lattice Shower Packing	Plastic Drip Packing
Service life	15 years	5 years
Cost of materials	360RMB/m ³	240RMB/m ³
Transport costs, installation costs	50RMB/m ³	30RMB/m ³
One-time installed cost	460RMB/m ³	420RMB/m ³
5500m ² average annual amortisation	\$198,000	\$396,000

1.2 Feasibility of the project

- **Research and Development:** Industry standard ‘Thermal power plant cooling tower bamboo drip filler technical conditions’ for the development of this standard has accumulated a good foundation; research in recent years in the bamboo unit performance and drip filler thermal resistance performance, service life and carbon emissions and other aspects of significant development. It provides a good practical foundation and basis for improving and upgrading the standard technical index system.
- **Undertaking unit:** The International Centre for Bamboo and Rattan (ICBR), the project undertaking unit, is professionally engaged in the research on the basic and application system of bamboo and rattan materials, and has rich experience in the application of bamboo materials in the fields of construction, household and energy, etc. It has presided over and participated in the formulation of a number of international and national standards, which has provided the basis and conditions for the successful completion of the present standard.

1.3 Scope of application

- It is suitable for the cooling tower in thermal power generation industry with bamboo as the main raw material of bamboo drenching filler;
- Provides for the cooling tower bamboo drenching filler design, manufacture, quality inspection, installation, shutdown maintenance and other basic requirements.



1.4 Main issues to be addressed

➤ **Current problems:**

Moisture absorption and deformation, detachment of nodes, uneven and easy to detach at the edges of the laying and discolouration.

➤ **Currently in the traveller's standard:**

Mechanical strength only at 12% moisture content, mechanical properties under no water saturation conditions;
Characteristics of bamboo material after aging without moisture and heat, such as water-absorbing thickness expansion rate, water absorption rate, low-temperature cold resistance;


➤ **Technical elements to be added to the international standard:**

- (1) Mechanical properties, deformation characteristics, and wet weight characteristics of bamboo after moisture-heat ageing;
- (2) Regulate the paving programme at the edges;
- (3) Standardise the way nodes are connected in the current line standard;
- (4) Addition of factory inspection item list for unit and formed sheets.

2.1 Technological advancement and innovation


This standard is based on many years of scientific research results and the promotion and application of practice development, is the organic combination of theoretical research, application results, technically advanced, innovative.

Unique physical properties




Utilising the unique heat and mass transfer properties of bamboo for thermal power generation applications

Design improvements



Design of new connection nodes; design of paving schemes at edges;

Parameter optimisation



The parameters in the current standard are further optimised to provide a basis for their application in cooling towers of large thermal power plants (300MW units and above).

2.2 Industrialisation

It has been applied in thousands of thermal power plants or steel mills, with an application area of more than 1.5 million square metres and 350,000 tonnes of bamboo material.

The formulation of international standards is of great significance in promoting the application of bamboo filler on a large scale and the cross-fertilisation of the power industry and forestry.

Shandong Yang Coal Hengtong Chemical Co.	1000m ³
Xuzhou Baofeng Special Steel Co.	2500m ³
Shandong Haihua Group thermal power three plants	4900m ³
Shandong Xinhua Special Steel Group Co.	3000m ³
Hebei Construction Renqiu Thermal Power Co.	5500m ³
Guangdong Guoyue Shaoguan Comprehensive Utilisation Power Generation New Project	22700m ³
Jining Jinwei Thermal Power Co.	3000m ³
Hebei Huaqiang Science and Technology Development Co.	1000m ³
Suzhou Wuhan Iron & Steel Co.	1000m ³
Hebei Tangshan Tangshan Steel Plate Co.	1350m ³
Hebei Shijiazhuang Xinji Oriental Thermal Power Co.	7000m ³
Shanghai GCL Group Xuzhou Fengxian Thermal Power Plant	2500m ³
Shanxi Xiangyuan Huaneng Coking Co., Ltd Gas Power Plant 2×12.5WM Unit Project	2250m ³
Jiangsu Lianyungang Mitsubishi Group	1000m ³
Repair of cooling tower at the oxygen plant of Benxi Beiyang Iron & Steel (Group) Co.	5000m ³
Fugu Yuanye Coke Power Generation Co.	2400m ³
Qinhuangdao Baigong Iron & Steel Company Limited 45 Gas Power Generation Project	3000m ³
China Energy Conservation (Shijiazhuang) Environmental Protection Energy Co.	1800m ³
Hebei Nanjing Coal Fuzhou Cogeneration Co.	15000m ³
Ordos Shuangxin Power Co.	6000m ³

2.2 Industrialisation

- The International Centre for Bamboo and Rattan (ICBR) has cooperated with Jiangsu Hengda Bamboo Grid Filler Co., Ltd, China Institute of Water Resources and Hydropower Research, China Electricity Federation, State Electricity Investment Group Research Institute, China Railway 18th Bureau Group and other units to carry out cooperative research and development, and there have been relevant theses, appraisal results, and relevant test reports.
- Industrialisation and promotion model: State-owned enterprises as the base to achieve carbon neutrality in the thermal power generation sector.



This item can be used in coordination with other standards:

- 1、 ISO 22157:2019 Bamboo structures — Determination of physical and mechanical properties of bamboo culms —
Test methods
- 2、 GB/T 50102 - 2014 Code for design of cooling for industrial recirculating water
- 3、 EN 14705 Heat exchangers-Method of measurement and evaluation of thermal performances of wet cooling
towers
- 4、 DL/T 1361-2014 Thermal power plant cooling tower bamboo drench packing technical conditions;
- 5、 GB/T 2828.1 Counting Sampling Procedures Part 1: Lot-by-Lot Inspection Sampling Plans for Retrieval by
Accepted Quality Limits (AQL);
- 6、 GB/T 15780 Test Method for Physical and Mechanical Properties of Bamboo;



Thank You