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Ventilation and Airtightness, different relationship for different quality of buildings

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- **Future of Construction and Ventilation R&D: China
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History of Building Ventilation and Air Tightness in China

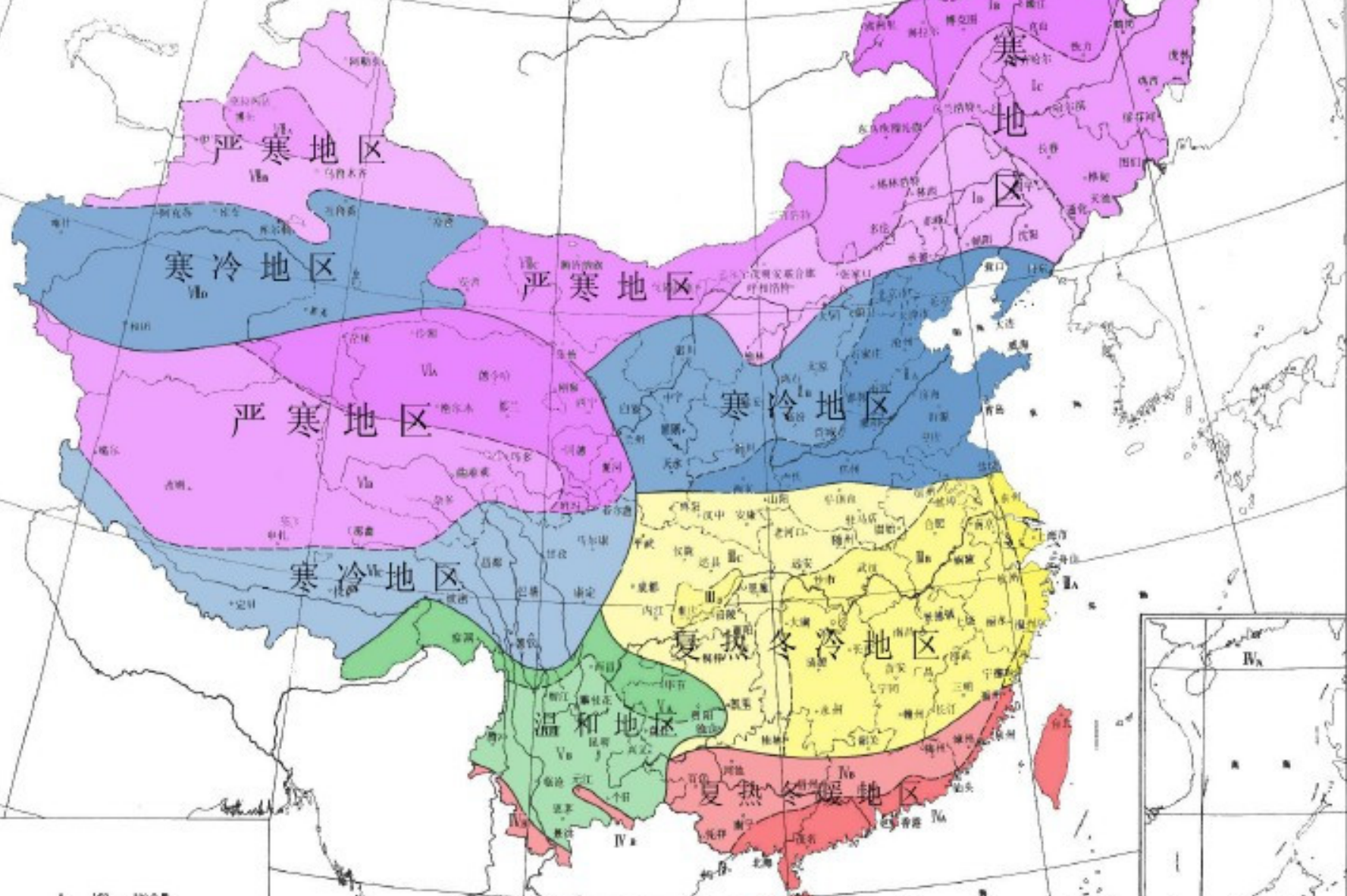
Climate Zones of China for Building Design

1. Severe Cold
2. Cold
3. Hot Summer and Cold Winter
4. Hot Summer and Warm Winter
5. Temperate

1-2. heating is required in standards

3-5, ventilation required in standards considering energy

中国建筑气候区划图



本图上中国国界系按照地图出版社1998年出版的1:400万
《中华人民共和国地图》绘制。

Hot Summer and Cold Winter Zone

1. The most developed zone in China currently
2. The most tough climate zone
3. Opening window is a typical habit of residents in this climate zone from ancient times
4. Heating is more and more needed now
5. Energy consumption of this zone will be an important challenge for total energy consumption of the whole country

We take it as an example to discuss in this presentation

Traditional Folk Houses till 1970's

Ventilation, for hot summer

- Old architects practiced with good architectural design to implement sunshading, natural ventilation etc.
- Different arrangement for different climate zones

Traditional Folk Houses till 1970's

Air Tightness, for cold winter

- The importance of air tightness was aware by people from ancient times:

There is a proverb: A needle size hole causes a bowel size wind

- Most of buildings were constructed mainly to benefit natural ventilation in summer
- Some measures were taken to resist excessive ventilation in winter as the special layout of buildings
- To enhance air tightness in winter with temporary measures as using paper/plastic film to seal leakages of windows and doors



Traditional Folk Houses till 1970's

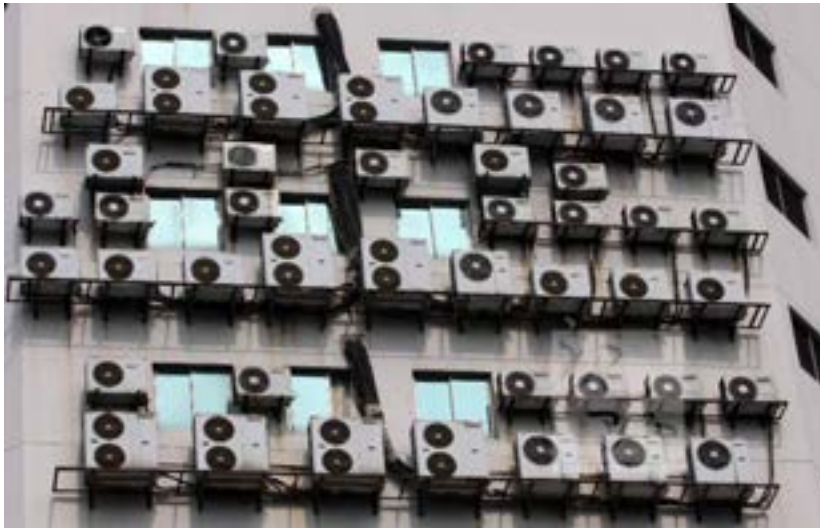
Summary

Ventilation: well designed for promoting natural ventilation in summer and transition seasons and preventing excessive NV in winter. Movable control with wood windows and doors with relatively high quality

Air Tightness: preliminary measure to enhance in winter

From 1980's to 2000

- New architects handed the duty of indoor environment to HVAC engineers
- Only AC and mechanical ventilation
- Natural Ventilation was mainly promoted in industry buildings



From 1980's to 2000

Summary

- Habits of residents to open windows for ventilation persisted
- Design of NV did not persist/AC consumed excessive energy and degraded IAQ
- The windows were not easy to open and close due to low quality steel windows
- The air tightness of products as windows and doors were not promoted because of the low quality windows and window frames

From 2000 especially from 2006

Situation: policy and standards

- Green/intelligent building was highly promoted from 2016
- NV was advocated for both energy conservation and IAQ
- AT was mainly for energy conservation .

AT values of outer windows in Chinese standards

For Public Buildings:

- **GB50189-2005:** $1.5 \geq q_1 > 0.5 \text{ m}^3/\text{m} \cdot \text{h}$ (per window crack length)
 $4.5 \geq q_2 > 1.5 \text{ m}^3/\text{m}^2 \cdot \text{h}$ (per window area)
- **GB50189-2015:** $1.0 \geq q_1 > 0.5 \text{ m}^3/\text{m} \cdot \text{h}$ (per window crack length,
10th and above floor)
 $3.0 \geq q_2 > 1.5 \text{ m}^3/\text{m}^2 \cdot \text{h}$ (per window area, 10th and above floor)
 $1.5 \geq q_1 > 0.5 \text{ m}^3/\text{m} \cdot \text{h}$ (per window crack length, under 10th floor)
 $4.5 \geq q_2 > 3.0 \text{ m}^3/\text{m}^2 \cdot \text{h}$ (per window area, under 10th floor)

AT values of outer windows in Chinese standards

For Residential Buildings (for Hot Summer and Cold Winter):

- **JGJ134-2001:** $4.0 \geq q_1 > 2.5 \text{ m}^3/\text{m} \cdot \text{h}$ (per window crack length, 7th and above floor)
 $12 \geq q_2 > 7.5 \text{ m}^3/\text{m}^2 \cdot \text{h}$ (per window area, 7th and above floor)
 $2.5 \geq q_1 > 1.0 \text{ m}^3/\text{m} \cdot \text{h}$ (per window crack length, under 7th floor)
 $7.5 \geq q_2 > 4.5 \text{ m}^3/\text{m}^2 \cdot \text{h}$ (per window area, under 7th floor)
- **JGJ134-2010:** $1.5 \geq q_1 > 1.0 \text{ m}^3/\text{m} \cdot \text{h}$ (per window crack length, 7th and above floor)
 $4.5 \geq q_2 > 3.0 \text{ m}^3/\text{m}^2 \cdot \text{h}$ (per window area, 7th and above floor)
 $2.5 \geq q_1 > 2.0 \text{ m}^3/\text{m} \cdot \text{h}$ (per window crack length, under 7th floor)
 $7.5 \geq q_2 > 6.0 \text{ m}^3/\text{m}^2 \cdot \text{h}$ (per window area, under 7th floor)

Clauses related to NV in Chinese standards

1. Although having several values about window ratios to floor, there lack of proofs and calculation from references.

- **General civil design standard:** 5.1.2 The window-opening ratios to floor should be not less than 1/20.
- **Design criteria for energy conservation of residential buildings in hot-summer and cold-winter:** 4.0.11 The openable window ratios to floor should be not less than 0.08.
- **Design codes for residential buildings:** 7.2.4 :The opening area to floor should be higher than 5%.
- **Design specification for dormitory building:** 5.1.5 The openings area to floor in bedroom, living room, toilet should be not less than 1/20.
- **Design Standard for Energy Efficiency of Public Buildings:** 4.2.8 The openable area needs to be higher 30% of whole window.

2. Despite the suggestion to design natural ventilation in the standards, no specification has been given.

- **Design codes for residential buildings:** 5.1.4 In the bedroom room or living room, it needs to design natural ventilation. Buoyance should be considered in single-sided opening house.
- **General Civil Design Documents:**7.2.1 In residential building, natural ventilation should first be considered, otherwise make use of mechanic ventilation.
- **Evaluation standard for green building:** 8.2.10 For public building, the air change rate ought to be higher than 2 times per hour.
- **Design code for heating ventilation and air conditioning of industrial building:** 6.1.5 The cross ventilation's direction should coincide with local predominant wind direction.

6.4.1 The sectional design should be able to make use of buoyancy force. It should use software to simulate and make optimization on natural ventilation system.

6.4.2 The plan design should be opt for cross ventilation.

6.4.5 Following components could be applied for natural ventilation.

- (1) Wind-inducing wall, wind-catcher, stack tower, tromp wall is suggested to be employed.
- (2) Atria could be made for buoyancy ventilation
- (3) Use ventilator in residential buildings for inducing outside wind.

3.As lots of factor such as climate, terrain,internal obstacle and openings, the contents in those standards are difficult to be implemented since no systemic knowledge with principles, guidelines and specification in design this passive technology.

- ***Design Standard for Energy Efficiency of Public Buildings:***

- 4.1 Design of outdoor airflow should concern the local prevailing wind, layout of buildings and each of their facade.

Design criteria for energy conservation of residential buildings in hot-summer and cold-winter:

- 4.0.1 Layout of buildings needs considering the cross ventilation

- 4.0.2 Facade the building should face the north as much as possible.

- 4.0.5 Casement window is recommended in the multi-story building

- ***Urban residential thermal environment design standard:***

- 4.1.3 In China's Architectural Zone of I、II、VI、VII, the residential building with high dense needs to place on the upstream of wind to have more natural ventilation, but for Zone of III、IV、V it should place at downstream region.

- 4.1.8 In zone of III、IV、V, the fence surrounding building is ought to have 40% openable area when its height is more than 1m.

- ***Green building design standards:***

- 6.4.4 The window's position, direction and opening approach needs to be reasonable for better natural ventilation.

- 6.4.7 When low wind velocity outsides, ventilators are suggested and ought be controlled, noise-proof, maintained and fixed.

4. No specification for ventilative cooling techniques given in the standards

- *Green building design standards:*

6.4.5 Following means could be considered for cooling,

- (1) Underground tunnel cooling
- (2) Semi-underground cooling
- (3) Ground cooling

Existing Chinese design standards concerning NV

Conclusions

- There are conceptual clauses related to NV and window area values in different standards
- No clear principles for the design of NV
- No database and no exact calculating methodology
- No methods for evaluating energy consumption of NV
- No guidelines for CFD simulation around or inside building
- No scientific evidences about window area

From 2000 especially from 2006

Situation-designers and environment

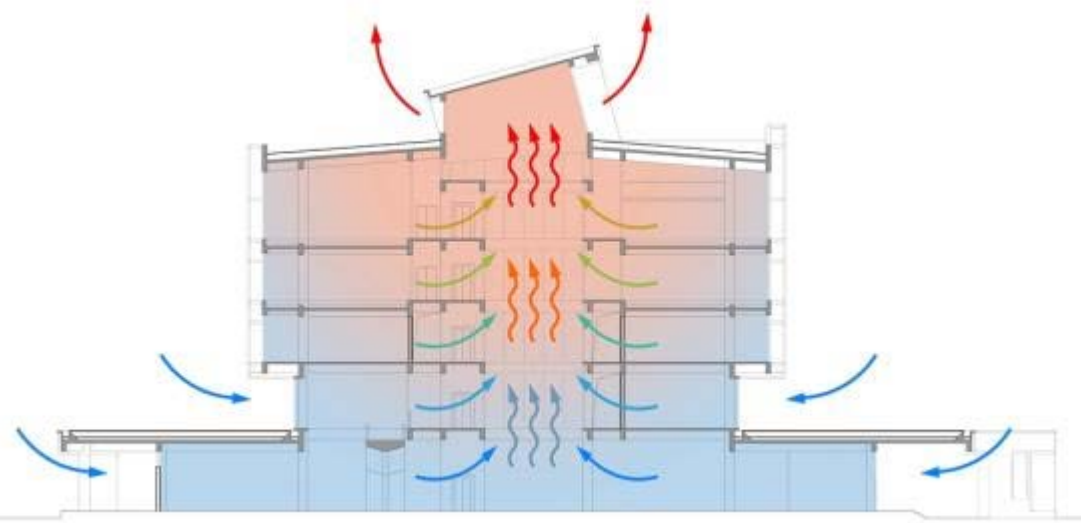
- Modern architects started to have the willing to do well ventilated building design but do not know how.
- They still expected that modern energy and environment engineer as HVAC engineer would give them solution.
- Outside air were severely polluted, NV is difficult to use.
- Quality of products as windows was still low.

From 2000 especially from 2006

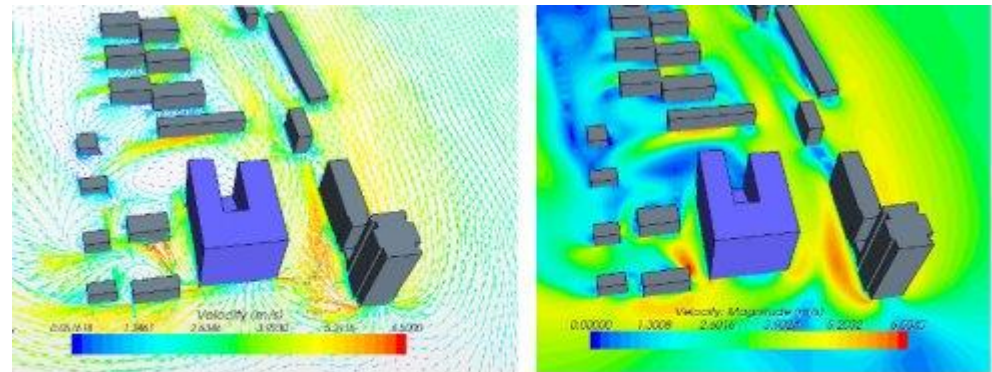
Summary

- NV: was highly advocated but difficult to promote, due to low quality of design, construction and products.
- AT: was highly promoted but difficult to control, due to low quality of construction and products and/or budget limitation

While much focusing on promoting Sustainable and intelligent buildings



so:
Ventilation by Simulation
but many cases:
Ventilation on Simulation



夏季场地范围1.5m人行高度处风速矢量图及风速云图

From 2017

Development Trends

As important part of China Construction 4.0 Platform

- NV: **firstly high quality** of design, construction and products.
- AT: **firstly high quality** of construction and products.

Well NV/AT, Build Tight Ventilate Right, itself is sustainable
and intelligent

Ventilation Research in Hunan University

1980's, Industry Ventilation.

the only text book of China was edited by Hunan University

2001, IAQ-NV-EC concepts introduced to China

host the first international conference in China:

The 4th International Conference on IAQ, Ventilation and Energy Conservation in Buildings

2005, Sustainable Education

the first green building education system

EU Asia-Link: A Multidisciplinary Approach on Curriculum Development on Sustainable Built Environment

2014,2018, International Way of Research

International Cooperation: Representing China to join IEA Annex 62, Annex 5

2017, New Platform for Construction Quality and Sustainable Cities

China Construction 4.0 Platform

From 2005, about 20 natural ventilation articles published in international journals, mainly on NV cooling

- 1. Airflow model of natural ventilation**
- 2. Natural ventilation considering thermal mass**
- 3. Adaptive thermal comfort in natural ventilation mode**
- 4. Assessment model of natural ventilation**
- 5. Architectural design for natural ventilation**

Research Projects of National and International Level

1. National natural science foundation of China

- 2006, Guoqiang zhang. Coupling of thermal mass and natural ventilation
- 2012, Mingjing Xie . Natural ventilation design in rural residential in Hunan province of China
- 2012, Junli Zhou. Thermal mass in unsteady wind pressure
- 2013, Shuanping Duan . Use solar energy to support fan to enhance natural ventilation
- 2014, Yin Wei. Airflow model in corridor by heat and wind

2. National projects sponsored by the Ministry of Science and Technology

- 2006, Guoqiang Zhang. Natural ventilation design and related measuring technique
- 2014, Guoqiang Zhang. Ventilative cooling technology integration and demonstration

3. International cooperation project

- 2014, IEA-Annex62-Ventilative Cooling
- 2018, IEA-Annex5-AIVC

The first Natural Ventilation Standard of China

The first project of *Natural Ventilation Design Standard of China* was launched in 2015.

First expert meeting with **30 participating institutions** was held Dec. 19, 2016.



Outline of the Draft of Natural Ventilation Design Standard of China

1. Principles
2. Climate potential
3. Airflow around buildings
4. Cross and Buoyance design in a Building
5. Passive Cooling for Air
6. Ventilative Components
7. Hybrid Cooling
8. Calculation

Join ISO/TC205 WG2 representing China

Design process of natural ventilation for reducing cooling demand in energy-efficient non-residential buildings

From 2017

As important part of China Construction 4.0 Platform

- NV: **firstly high quality** of design, construction and products.
- AT: **firstly high quality** of construction and products.

Well NV/AT, Build Tight Ventilate Right, itself is sustainable and intelligent

China Construction 4.0 (CC4.0) Platform

www.construct4.cn

A China Based International Knowledge and Innovation Platform
for High Quality Construction and Sustainable Cities

China Construction 4.0(CC4.0):Definition

CC1.0: Construction: Folk House

NV&AT: Relatively good NV and AT

CC2.0: Construction: Modern high rise Buildings

huge amount+ complicated technologies

A fatal defect: No quality assurance system,
while discard advantages in CC1.0

NV&AT: Bad NV and AT

CC3.0: Construction: Green and Intelligent Building

NV&AT: NV on simulation

CC4.0: Construction: Quality first, while green and intelligent

NV&AT: Quality assurance of NV and AT

Different from
Industry 4.0=Cyber + Physical System

CC4.0 = CC2.0_{+quality} + CC3.0

CC2.0_{+quality} = Mechanism + Technology+...

CC4.0 is much more than a technology issue, but strongly related to management of the society and thinking way of people(professionals, users, decision makers)

CC4.0 Platform: Mission

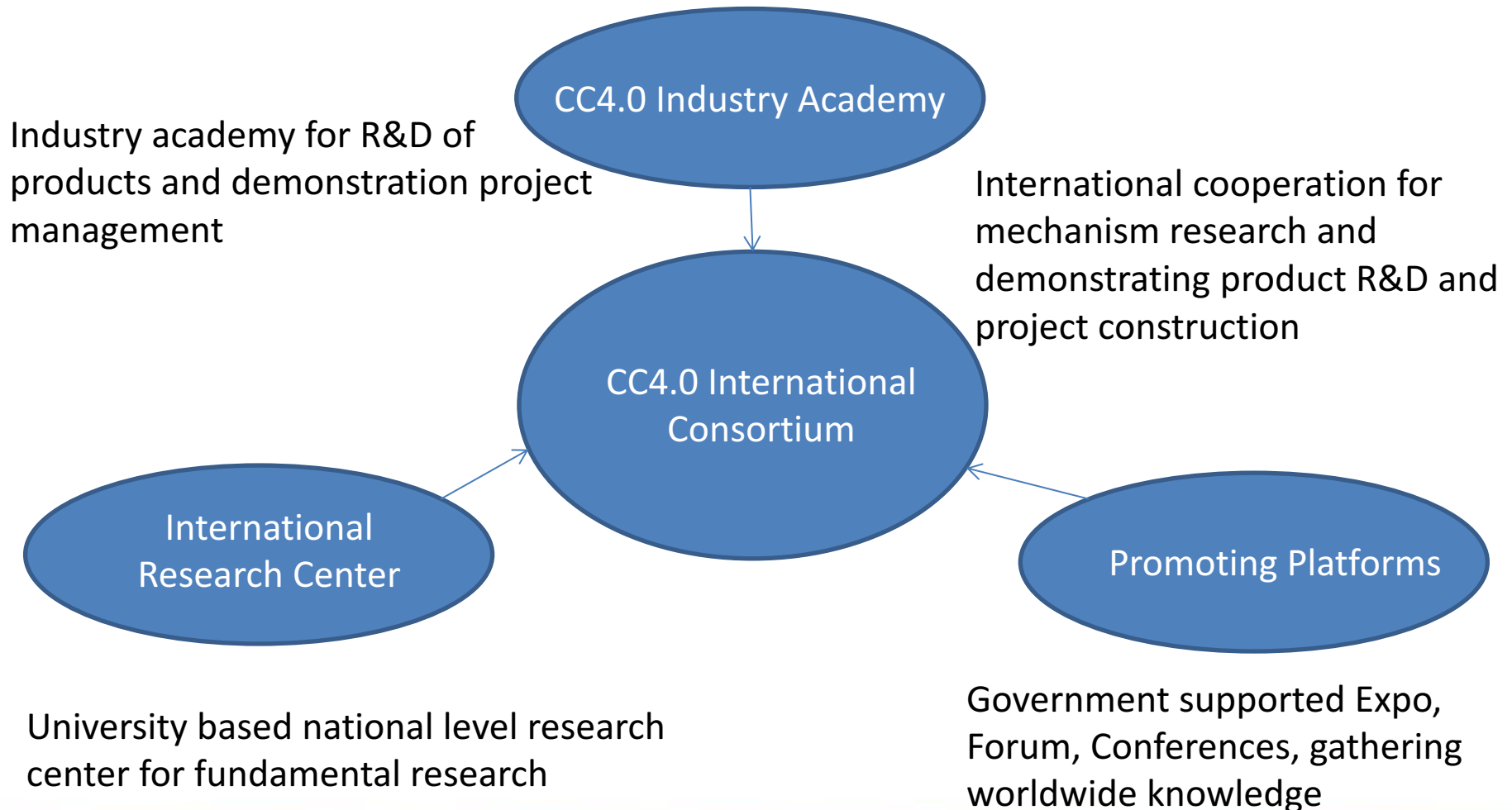
To Promote High Quality Construction and Sustainable Cities for a huge urbanization market in China (and Developing Countries)

2 billion square meters annually currently
About 50% of the total amount of the world

CC4.0 Platform: Challenge and Approach

- **Challenge:** whole industry chain of construction should be improved: Education, research, design, construction, products, operation and maintenance
- **Approach:** International cooperation, Mechanism + technology research, Demonstrating products, Demonstrating Projects.

CC4.0 Platform: Framework



CC4.0 Platform: Annual Promoting Activities

- **Building Expo:** Already a best well organized Expo in China from 2016
- **CC4.0 Forum:** With participants from 30 countries in 2017
- **Intel. Conference:** AsiaCity 2050, High Quality Construction and Sustainable Cities, from 2018

Scheduled on Sept. 18,19(Conference), 20-22(Expo&Forum)

CC4.0 Platform: Continuous Operation Medias

- **Chinese Journal of Building Energy and Environment:** sponsored by Chinese Society of Architecture, launched in 1982
- **ChinaHVACR.com:** the first website in China HV&AC field, established in 1998
- **Building.eser.cn:** A building technology website for green building, prefabricated building and urban energy

CC4.0 Platform: Seeking for Cooperation

- **Education:** courses development and student exchange
- **Fundamental Research:** Research on technology as well as mechanism for quality assurance
- **Knowledge transfer, Innovation and Entrepreneurship:** for high quality construction and products
- **Business:** Promoting good practice and products in China



CHINA CONSTRUCTION 4.0

China Construction 4.0 International Innovation Platform

Fundamental Research

Institutions

Institute for Sustainable Urbanization and Construction Innovation, Hunan University
National Center for International Research Collaboration in Building Safety and Environment, MOST, China

Platforms

International Conference on AsiaCity2050: High Quality Construction, Sustainable Cities
Multidisciplinary Sustainable Built Environment Education System

Achievements Transformation

Institutions

Hunan China Construction 4.0 Industry Academy
Hunan University Regal Energy Science and technology Co. Ltd.

Platforms

China Construction 4.0 International Innovation Forum
China Construction 4.0 International Innovation Consortium

Promoting&Dissemination

Institutions

Hunan China Construction 4.0 Industry Academy
Changsha RuiliNetsun Cultural Communication Co. Ltd.

Platforms

China(Changsha) Prefabricated Building and Construction Technology Expo(Changsha Building Expo)
Chinese Journal of Building Energy and Environment China Building Website

[News](#)
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Conclusions

- NV&AT developed with urbanization and building technologies in China for 3 stages.
- Quality of Construction and related products including NV&AT should call for more fundamental level attention than developed countries.
- China has about 50% global construction quantity, and its Belt & Road Strategy influences developing countries
- High quality development is a national strategy from 2018.
- CC4.0 platform was set up in 2017 to promote quality of construction, which will cooperate with international community in an international way.
- Ventilation and air tightness is one of the priorities of CC4.0.

www.construct4.cn

Thank You for Your Attention

