How Does China Achieve a 95% Compliance Rate for Building Energy Codes?: A Discussion about China's Inspection System and Compliance Rates

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ABSTRACT

In order to improve the building energy efficiency of its fast-growing stock of new buildings, the Chinese government has vigorously promoted the implementation of building energy codes. According to China's official inspection data, the compliance rates at both design and construction stages have improved from 53% (design) and 21% (construction) in 2005 to 100% and 95.5%, respectively, in 2011.

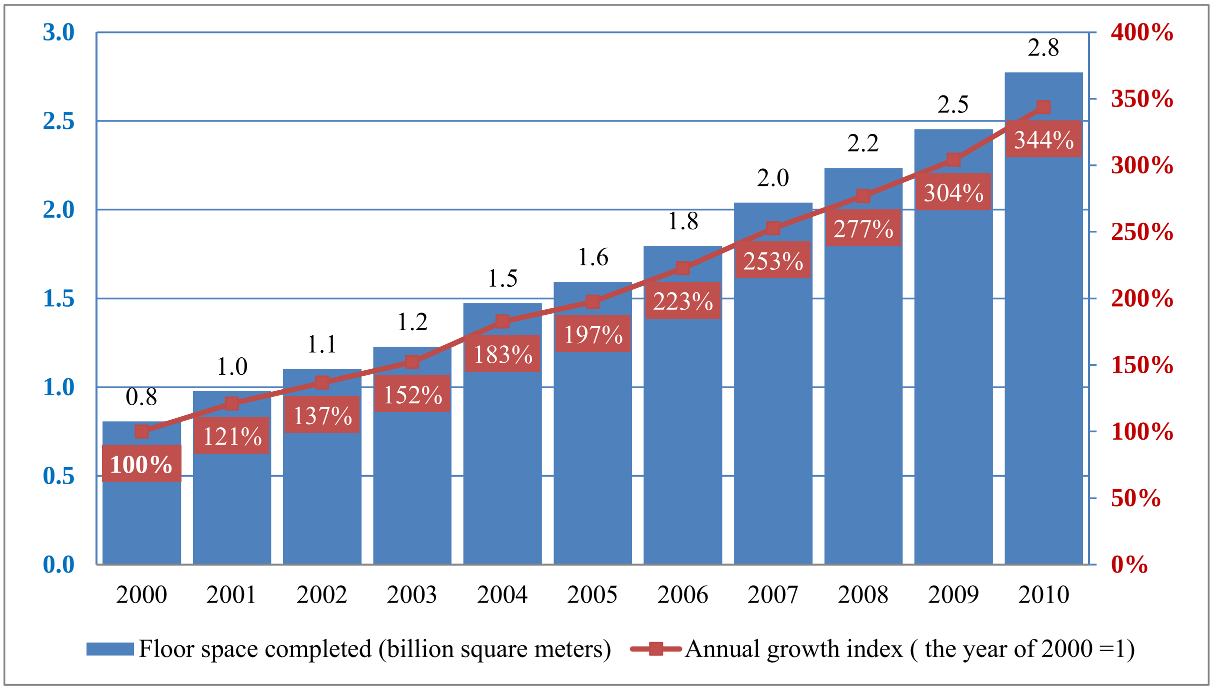
Are these numbers credible? If so, how is it that China has been able to bring about such improvements in only six years? This paper provides a discussion and analysis of a unique, three-level inspection system that carries out the enforcement of building energy codes in China, and offers a discussion of the claimed compliance rates.

The authors suggest that China's official compliance rates can mislead observers to infer that the compliance system is near perfection, while in fact they indicate the need for a clearer definition of the compliance rates and for an improvement in the quality of data collected. The current compliance statistics should be regarded as an indicator of the compliance status of new medium and large building construction projects located exclusively in urban areas. Nevertheless, China has established a functioning inspection system. The Chinese approach provides an interesting case study of how a well-designed compliance framework can play an active role in promoting the enforcement of building energy codes.

Introduction

Construction in China has been a major contributor to the country's rapid economic growth: the industry accounted for 6.7% of China's gross domestic product in 2010, with a labor force numbering 41.6 million (China State Statistics Bureau 2012). The total area of new buildings has increased from 1 billion square meters (10.8 billion square feet) in 2005 to 2.8 billion square meters (30.1 billion square feet) in 2010 (Figure 1). China is thus the world's largest market for new construction (Hammond and Anderlini 2011).

Figure 1. New Floor Space Constructed in China, 1996-2010



Source: China State Statistics Bureau (2011)

Improving the energy efficiency of this huge and growing stock of new buildings is a daunting challenge facing China, and in response the Chinese government has been actively developing and deploying an array of related policies and projects to promote building energy efficiency at local and national levels. One of the government's efforts is the enforcement of compliance with building energy codes. In 2012, China claimed that the 2011 compliance rates were 100% at the design stage and 95.5% at the construction phase. These extremely high rates do raise questions: How are compliance rates measured? How reliable are these statistics? What can account for such rapid progress in such a relatively short period?

Several papers and reports have helped to shed light on the efforts of the Chinese government to promote building energy code compliance. Zhou et al. (2010) gave a nice overview of energy efficiency policies in China including building energy efficiency. Shui and Li (2012) provided a comprehensive documentation on the development history, deployment and implementation status of a variety of building energy efficiency policies and projects in China. Both studies offered a big picture on how the development of building energy codes has been taken place in China.

Earlier studies on China's building energy codes focus on reviewing the development history of China's building energy codes and the technical contents of China's major design standards[1] (Huang and Deringer 2007; Shui et al. 2009). A few of them briefly mentioned the Acceptance Codes as part of China's building energy codes system, and described the national annual inspection of building energy efficiency as part of the national government's enforcement efforts (Shui et al. 2009).

Two comparative studies exist focusing on issues surrounding building energy codes in different countries (including China). Evans et al. (2009) not only presented the development history of building energy codes in seven key Asian-Pacific countries, but also discussed enforcement and compliance issues in these seven countries, including enforcement frameworks, testing and rating, and compliance software and tools. Liu et al. (2010) described the experiences of both developed and developing countries with regard to code compliance, and suggested that developing countries need to enhance governmental oversight of building construction.

More recent studies have shown increasing interest in China's compliance process. Evans et al. (2010) provided a comprehensive assessment of the compliance process and issues related to the enforcement of building energy codes in China, drawing policy recommendations for both China and the United States. They concluded that "China has dramatically enhanced its enforcement system for building energy codes in the past two years, with more detailed requirements for ensuring enforcement and new penalties for non-compliance," and "the U.S. and other developed countries could benefit from learning about the multiple checks and the documentation required in China." Shui and her colleagues (2011a) examined the challenges to building energy code implementation by means of focus group interviews with key stakeholders, thereby revealing the major factors in decision making and common compliance difficulties facing key stakeholders. Price et al. (2011) provided quantitative and qualitative evaluations of the level of compliance with building energy codes in China. Shui (2012) discussed the role of third parties in the enforcement of building energy codes in China, stating that "strong governmental support and effective employment of third parties, coupled with strict quality control and supervision are the key factors" in China's progress in enforcement of building energy codes.

Building upon the previous studies and by means of ongoing exchange of information with building energy code experts in China, this paper provides a summary of China's current compliance process (a three-level inspection system consisting of project level, local level and national level), and discusses factors in this inspection system that influence compliance with building energy codes in China. This paper also attempts to examine issues related to compliance rates through a discussion on the data collection process. Several policy suggestions are then put forward concerning the next steps China should consider, such as re-defining the building eligibility criteria for construction inspection, publicizing inspection data and results, and providing access to inspection data in greater detail to researchers and policy decision makers.

[1] China's building energy codes include design standards and acceptance codes. Design standards address compliance with building energy codes at the design stage. China has one design standard for public buildings (issued in 2005) and three design standards for residential buildings, each covering a different climate zone, including a heating zone standard (issued in 1986, updated in 1995 and 2010), a hot-summer and cold-winter zone standard (2001, 2010), and a hot-summer and warm-winter zone standard (2003). Note that the definition of public building in China includes structures that would be categorized as commercial buildings in other countries.

The Compliance Process: A Three-Level Inspection

Buildings Subject to Inspection

The inspection system in China does not apply to every new building. MOHURD requires any new residential community with an area of 50,000 square meters or more to undergo a local construction inspection. Local construction departments (or local MOHURD branches) at the provincial and municipal level will determine whether a residential project under 50,000 square meters should be subject to construction inspection. New public buildings with a total investment over RMB 30 million (US$4.8 million[2]) are subject to a local construction inspection. Any schools, cinemas and stadium buildings, as well as construction projects supported by foreign aid and loans are required to undergo construction inspection (MOHURD 2001).

Note that the compliance rates only reflect medium and large-scale buildings inspected in urban areas. Buildings in rural areas are not subject to construction inspection (Evans et al. 2010; Price et al. 2011; Shui et al. 2011b). However, if a construction project in a rural area is funded by foreign aid or loans, such a construction project would be subject to construction inspection (Shui et al. 2011b).

Project-Level Inspection

China's enforcement framework can be described as a three-level inspection system: project level, local level and national level (Figure 2). This system, which involves the participation of a variety of key stakeholders, plays an important role in the implementation of building energy codes at both local and national levels.

The purpose of a project-level inspection is to ensure that new buildings are compliant with building energy codes at both design and construction stages. The inspection involves two inspection activities carried out by two third parties: drawing inspection companies and construction inspection companies.

The *Rules on Energy Conservation in Civil Buildings*, released by the Ministry of Housing and Urban-Rural Development (MOHURD) in 2008 – national administrative rules focused solely on building energy efficiency – define the responsibilities of each third party company. In particular, these *Rules* provide "sticks" (see Box 1 for examples of specific penalties for violations) that can be applied by drawing inspection and construction inspection companies when they conduct inspection activities. Currently, there are no data reporting how often these penalties are applied.

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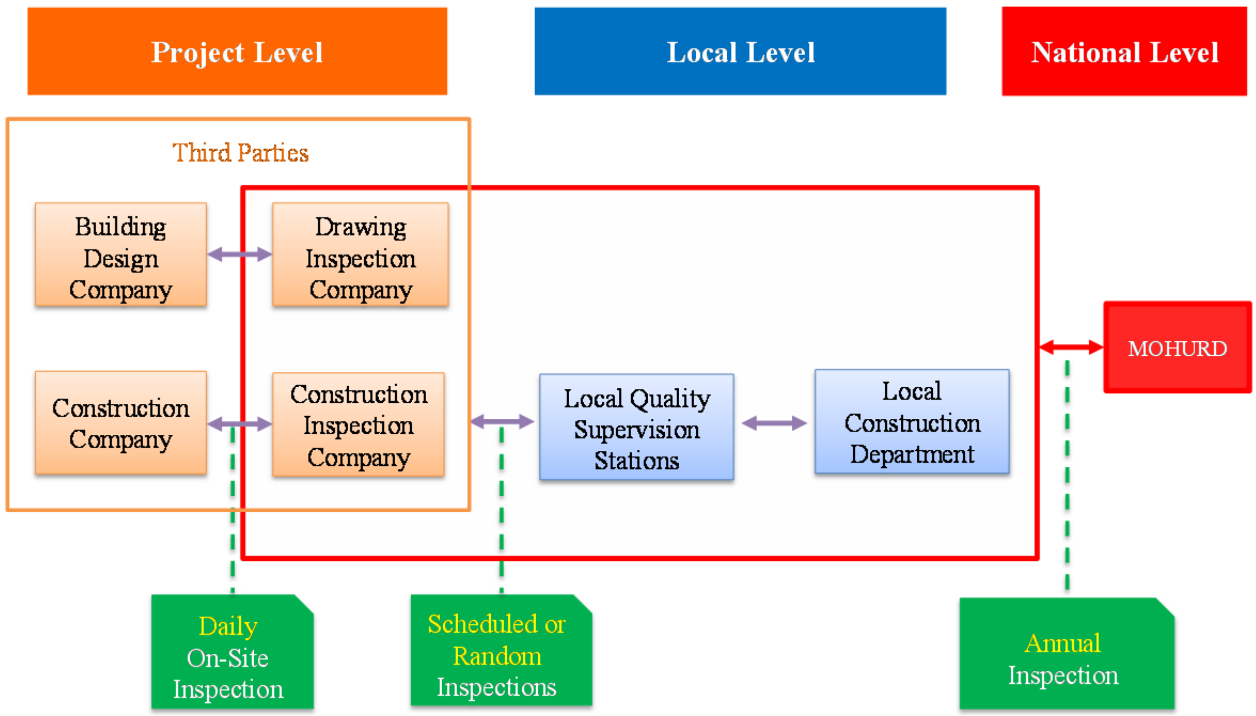
[2] 1 RMB = US$ 0.1586, according to the exchange rate on May 2nd, 2012.

Figure 2. A Three-Level Inspection System



Source: Authors

Note: MOHURD refers to Ministry of Housing and Urban-Rural Development

Box 1: Penalties for Violation

If a building design company fails to correct a flawed building design inspected by a drawing inspection company, the building design company shall be warned and fined between RMB 100K (US$ 15K) and RMB 300K (US$ 46K). A building design company that fails to correct flaws three times over the course of two years shall be suspended until rectification, and their qualification certificates will be downgraded or revoked.

A construction company is required to correct any flawed construction activities detected by a construction inspection company. Construction companies shall be responsible for any rectification costs attributable to necessary corrections. In the event of a serious violation, the construction company will pay as much as two to four percent of the construction contract cost as a penalty for its violation. The violating company also faces the possible downgrading of its certification, or even its suspension.

Source: *Rules on Energy Conservation in Civil Building, 2008*

Local-Level Inspection

A local-level inspection is conducted by local quality supervision stations on behalf of local construction departments. The local quality supervision stations supervise the quality of third parties' work, in particular any work that is carried out by construction companies and construction inspection companies. The stations also help to collect, review, and approve documents related to construction and code compliance in reference to both the approved drawings and the Acceptance Codes. A local construction department is in charge of local compliance and enforcement activities, such as the issuing of permits for construction and occupancy, organizing training and outreach activities for local stakeholders, and developing local policies and regulations to promote building energy codes (Evans et al. 2010; Price et al. 2011; Shui 2012).

In order to reduce potential conflicts of interest, local construction departments obtain their budgets from both regional construction departments and local governments. For example, a city construction department is funded by both its provincial construction department and by its city government. The salaries of employees of local construction departments are not related to fees collected from the compliance and enforcement process, such as construction permit fees and occupancy permit fees (Shui 2012).

National-Level Inspection

MOHURD is a national governing entity responsible for construction-related issues, such as the development, supervision and management of building energy efficiency policies and projects at the national level.

Since 1994, MOHURD has been actively establishing a regulatory environment for the implementation of building energy codes in China, including development and deployment of the design standards that apply to residential and public buildings[3]. The release of the Acceptance Codes (2007) has proved to be vital to the implementation of building energy codes during the construction phase. The Acceptance Codes not only integrate compliance with building energy codes into the existing construction acceptance process, but also raise building energy codes to equivalent importance with safety-related building codes (such as fire codes and structure codes) (Evans et al. 2010; Shui et al. 2011; Shui 2012).

Since 2005, MOHURD has conducted national inspections of building energy efficiency at a small sample of locations and buildings (as discussed in more detail below). An annual inspection focuses on implementation issues related to a wide range of national and local building energy efficiency policies and practices, such as heat reform, green buildings, residential building retrofits, government building energy efficiency, and the application of renewable energy in buildings. Compliance with building energy codes is one of the focal points of these inspections.

After each inspection, MOHURD *publicly* announces the inspection results on its website, naming those provinces that have done an excellent job. Unlike national inspections conducted by other ministries, the MOHURD annual inspection comes with the authority for enforcement. If a construction project receives a notice from the inspection team for correction, the construction project must rectify the problem identified within a stipulated period.

[3] In China the term *public buildings* refers to government office buildings, commercial buildings, buildings used in the service industries, buildings used for educational purposes, and hospitals.

Discussion

Within the three-level inspection system, at each level of inspection a different party acts as a primary "enforcer" to "push" compliance with building energy codes.

MOHURD plays the role of "enforcer" by means of national-level inspections. Through annual inspections, MOHURD evaluates the development and deployment of building energy efficiency policies and practices at a local level (i.e., provinces and cities). In order to better prepare for the annual national inspection, many local governments also conduct their own scheduled and random inspections (Evans et al. 2010; Shui et al. 2011b).

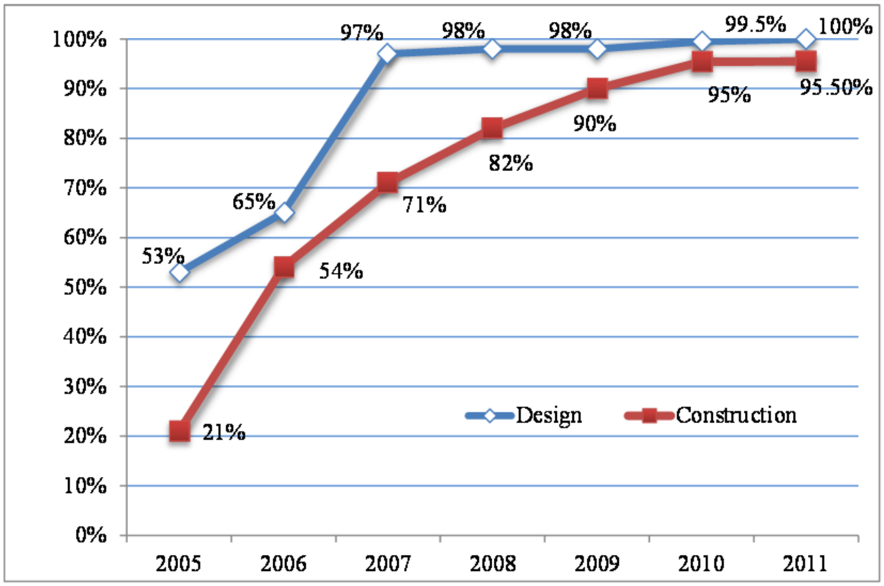
Local construction administrations, through the local quality supervision stations, carry out enforcement by means of local-level inspections. In some cities, local construction administrations integrate the inspection results from the national-level inspections into employees' performance evaluations, a practice that aims to motivate local construction administrations to be more engaged in the promotion of compliance with building energy codes under their jurisdiction.

Two parties act as key "enforcers" during project-level inspections. *Construction inspection companies* are hired by developers and under the direct supervision of the local quality supervision stations. As an enforcer, construction inspection companies must ensure that: the construction process meets the requirements of the acceptance codes, which will facilitate the developer's acquisition of an occupancy permit. *Drawing inspection companies* also play a role in enforcement at the project level. These companies' principal function is to make certain that the building energy efficiency requirements are satisfied or exceeded through the use of appropriate materials and technology as specified in design codes of building energy efficiency and the Acceptance Codes

The Compliance Rate: Data Collection and Quality

How well has China's three-level inspection system performed? Based on the national inspection results from MOHURD, the building energy code compliance rates have improved from 53% (design stage) and 21% (construction stage) in 2005 to 100% and 95.5%, respectively, in 2011 (Figure 3). Thus it would appear that China's compliance rates have gone from notoriously problematic to almost perfect within just six years, which does lead to various questions. For example, how are these compliance rates actually measured and what do they really indicate?

Figure 3. Building Energy Code Compliance Rates in Urban Areas



Source: MOHURD (2006, 2007, 2008, 2009, 2010, 2011 2008, 2009, 2010, 2011 #84)

Data Collection and Sample Size

The annual national inspection by MOHURD typically takes place in late November or in December, requiring roughly two or three weeks to complete. MOHURD usually assembles approximately ten inspection teams, with each team inspecting two to three provinces (including autonomous regions and very large municipalities not located within provincial boundaries).

Each annual inspection covers the majority of 31 provincial territories.[4] By default four large municipalities and the capital city of each provincial division are selected for annual inspection. In addition, two cities – or districts in the case of municipalities – in each provincial territory, representing prefecture-level and county-level respectively, are randomly selected for inclusion in the annual inspection (Price et al. 2011; Shui 2012).

The cities to be inspected are required to provide an inventory of the construction projects that have completed the drawing inspection stage (and been approved), and of projects that are already in the construction stage that are subject to ongoing inspection by construction inspection companies.

The inspection teams randomly select a number of construction projects for documentation evaluation and for onsite inspection. For example, during the course of a 2011 prefecture-level city inspection, an inspection team would select six construction projects for documentation evaluation (four public construction projects and two residential construction projects) and another six construction projects for onsite construction inspection (Table 1).

[4] China has 22 provinces, four “autonomous” municipalities (Beijing, Shanghai, Tianjin, and Chongqing), and five autonomous regions.

Table 1. Number and Type of Construction Projects Inspected in an Inspected City (2011)

	New public buildings		New residential buildings	
	Building drawing documents	Construction sites	Building drawing documents	Construction sites
A prefecture-level[5] city	4	4	2	2
A county-level city	1	1	2	2

Source: MOHURD (2011)

Checklists and Counting Compliance Rates

There are five checklists related to building energy codes used in the annual national inspection by MOHURD: one form each for the drawing and drawing inspection documentation of residential buildings in each of the three climate zones (Table 2 is the form that is used in the evaluation of residential buildings in severe cold and cold regions), one form for the drawing and drawing inspection of public buildings, and one form for the Acceptance Codes.

Table 2. Inspection Form for Residential Buildings in Severe Cold and Cold Regions (Partial)

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Items</th><th rowspan="2">Inspection Contents and related Standards and Codes</th><th colspan="2">Evaluation</th><th rowspan="2">Notes</th></tr>
<tr><th>Drawing Documents</th><th>Drawing Inspection Documents</th></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Window-Wall Ratio (WWR)</td><td rowspan="2">The WWR value of a residential building shall not be higher than the corresponding values listed in Table 4.1.4 in the Design Standards of Residential Buildings in Severe Cold and Cold Regions (JGJ 26 - 2010). When the WWR is higher than the default values of Table 4.1.4, a trade-off calculation for thermal engineering characteristics must be conducted.</td><td>□ Compliant</td><td>□ Compliant</td><td rowspan="2"></td></tr>
<tr><td>□ Non-Compliant</td><td>□ Non- Compliant</td></tr>
<tr><td colspan="2" rowspan="2">Comprehensive Assessment</td><td colspan="4">Drawing: □ Compliant □ Non-Compliant</td></tr>
<tr><td colspan="4">Drawing Inspection: □ Compliant □ Non-Compliant</td></tr>
<tr><td colspan="6">Inspection Team Representative Signature: Date:</td></tr>
</table>

Source: MOHURD (2011)

The other items that are evaluated in Table 2 include the thermal characteristics of the building envelope, the heating, ventilation, and air conditioning (HVAC) systems, and the lighting. The check list for public buildings includes not only the above items (with different requirements) but also an additional list of items to be appraised related to lighting in office buildings, commercial buildings, hotels, hospitals and schools.

Items that must be inspected in order to determine compliance with the Acceptance Codes include compliance with energy efficiency requirements for windows, doors, roofing, HVAC, lighting, construction planning, revised drawing, and acceptance (MOHURD 2011).

5 A prefecture is an administrative division used in China, ranking below a province and a municipality and above a county.

During the annual national inspection by MOHURD, , if a building is found to be non-compliant with the requirements in the checklists, the building is counted as non-compliant in the inspection statistics, regardless of whether the identified instance of non-compliance is immediately rectified (Shui 2012).

Data Quality

Compliance rate at the design stage. Building design in China is aided by the use of specialized software for construction design that integrates building energy efficiency information for specific building components into the building design and drawing process, and for assessing compliance with building energy codes at the design stage (Evans et al. 2010). Several Chinese building energy code experts have expressed their confidence in the credibility of the compliance data at the design stage.[6]

Compliance rate at the construction stage. According to the Acceptance Codes, on-site building materials are required to be tested for their energy characteristics at a test lab. In reality, manufacturers can send their materials to several test labs and select the best results (Evans et al. 2010). In addition, the average level of education of construction workers is elementary school. The level of understanding and knowledge of construction workers has been identified as a key weakness in ensuring compliance with building energy codes (Shui et al. 2011b; Shui 2012). Construction inspection companies have complained that a lack of standardized specifications for construction techniques hinders the improvement of construction quality (Shui et al. 2011a). Some Chinese building energy code experts have also expressed concerns with regard to the compliance rates reported at the construction stage.

Policy Implications and Suggestions

Assessment of the Compliance Rate

China has 287 prefecture-level cities (NBC 2012) and 374 county-level cities[7]. The inspected cities represent only roughly 9.4% and 7.0% of the total number of prefecture-level and county-level cities, respectively. The number of inspected construction projects as a percentage of the total number of new construction projects in an inspected city is low and varies from city to city. The relatively small sample size is thus not representative of the implementation status of the general population.

It has been observed that some inspection teams have in some instances counted a case which was rectified *after* receiving an inspection notice as one that was code compliant, while others did not.[8] Such inconsistency in data collection practices leads to questions concerning the validity of claimed compliance rates.

It is known by Chinese experts that the data validation methods used in building software are not consistent. Evans et al. (2010) pointed out that the lack of protocols to test the software

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[6] Personal communication with building energy code experts in China.
[7] http://www.chinacity.org.cn/csph/csph/58528.html
[8] Personal communications with various building energy code experts in China.

and the lack of protocols for building simulation would affect the reported compliance rates. Shui et al. (2011a) also reported that building designers often find themselves overwhelmed by the demands of dealing with time-consuming computer simulation when the shape coefficient and heat transfer coefficients of building envelopes exceed the standard limits. The reliability and the incorrect use of such software may thus lead to an inaccurate account of the compliance rates at the design stage.

Compliance rates have been compiled mainly based on new construction projects of a particular scale (i.e., medium and large construction projects) in urban areas, and they do not represent the compliance status of the general population of new buildings in China.

Compliance rates approaching 100% can mislead observers to infer that the compliance system is near perfection. These extremely high compliance rates actually indicate the need for a clearer definition of compliance rates, for additional checking of data collected throughout the process and for improvement of data quality.

We cautiously conclude that the current compliance statistics may be considered as an indicator of the compliance status of a certain building segment, i.e., new medium and large construction building projects located exclusively in urban areas. For these particular types of projects the compliance rates show dramatic improvement over the past six years.

Redefining the Building Eligibility Criteria for Construction Inspection

MOHURD currently requires construction inspections for any new residential community with an area of 50,000 square meters or more and for new public buildings with a total investment over RMB 30 million. MOHURD may wish to consider redefining the above criteria for construction inspection. For example, in future they should consider requiring construction inspection for any new residential community with an area of 30,000 square meters or more and for new public buildings with a total investment over RMB 20 million. Over time these thresholds could be reduced even further.

Utilizing Inspection Data

To date MOHURD has conducted six annual national inspections. However, the only data MOHURD has made available to the public has been the aggregated compliance rates for the provincial divisions (including municipalities) selected for inspection.

There are many interesting questions that could be answered through access to the existing inspection data. For example, it would be possible to examine any trends that are indicated by changes in compliance rates for specific checklist items by region, climate zone, building type, building size, ownership, and by type of building occupant. Analysis of the existing inspection data would thus lead to a more comprehensive understanding of the compliance status of new buildings.

Exchanging Information and Experience Related to Enforcement

China has been promoting compliance with building energy codes for many years, yet there is still a substantial need for information exchange with regard to enforcement-related issues. MOHURD should consider establishing a national platform for such a purpose, such as an annual national conference. Participants could include representatives of MOHURD, local construction departments, building design companies, drawing inspection companies, construction companies, construction inspection companies, local quality supervision stations, developers, test stations, building material manufacturers, research centers, and universities.

Conclusions

China is the world's largest market for new construction, with 2.8 billion square meters of new buildings in 2010. In order to improve the energy efficiency of its huge and growing stock of new buildings, for several years China has been actively enforcing compliance with building energy codes. For example, the use of a unique, three-level inspection system (including project-level, local-level, and national-level inspection activities) is key to the enforcement of building energy codes in China and has led to the dramatic improvement of enforcement for medium and large-scale buildings in urban areas.

The official building energy code compliance rates would seem to indicate a positive, upward trend of improvement over the past six years. However, these extremely high compliance rates can mislead observers to infer that nearly all new buildings in China have been shown to comply with current building energy codes. Instead, the high rates indicate the need for a clearer definition of compliance rates, for additional checking of data collected throughout the process and for improvement of data quality. These rates should therefore be interpreted with caution. Several factors hinder the use of the official compliance rates in the quantitative measurement of code compliance among the general population of new buildings. These factors include a relatively small sample size focused on medium and large-scale construction projects in selected cities, possible inconsistency in measuring compliance rates between inspection teams, and unregulated test stations which may pass building materials that have not complied with the Acceptance Codes.

There are several measures that the Chinese government should consider integrating into its current policy framework, such as redefining the criteria used to determine which buildings are subject to construction inspection, providing greater access to existing inspection data, and establishing a national platform for the exchange of information concerning enforcement experiences for a variety of national and local stakeholders.

Nevertheless, within the last six years, China has established a functioning inspection system in the context of its unique political, social, economic, and cultural conditions. The Chinese approach provides an interesting case study of how a well-designed, functioning compliance framework can play an active role in promoting the enforcement of building energy codes.

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