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Community Response to Construction Noise in Three Central Cities of Zhejiang Province, China

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[Abstract]: As a common source of environmental noise in China and many developing countries worldwide, construction work provokes many complaints and deterioration in acoustic climate quality. This paper describes research to obtain an improved understanding of people's community response to, and evaluation of, construction noise in three central cities of Zhejiang province, China. This involved carrying out a social survey using standard questionnaires developed by the International Commission on Biological Effects of Noise (ICBEN). A dose-response relationship model is established using a quadratic polynomial regression analysis based on construction noise exposure measurements from 40 construction sites in Hangzhou, Ningbo and Wenzhou.

The results of the study indicate that the majority of people have a negative attitude to construction noise; the noise ranges between 60 dB to 80 dB (compared with 50 dB to 70 dB traffic noise in Tianjin), with the percentage of highly annoyed people affected increasing from 15%-20% to 30%-40% over the range. There also different levels of annoyance depending on the time of day, and the location and activities of those affected. Other cultural differences are also apparent both between Ningbo/Wenzhou and the more urbane citizens of Hangzhou, and the Chinese people and their more noise-tolerant EU and Vietnam counterparts.

The findings of this study provide a new perspective for the study of construction noise that can help local governments have an improved understanding of how residents react to construction noise for the purpose of selecting construction noise-mitigation projects and introducing construction noise-control regulations.

Capsule: The results of the study indicate that when L_{Aeq} of construction noise increases from 60 dB to 80 dB, HA% increases from 15%-20% to 30%-40%.

[Keywords]: Construction Noise; Dose-Response relationship; Social Survey; community annoyance

1. Introduction

As one of the critical environmental factors affecting quality of life (Seidman et al., 2010), environment noise is responsible for such adverse effects as hearing loss, annoyance, cardiovascular disease and efficiency loss (Fernandez et al., 2009; Lee et al., 2015 and Li et al., 2016). Complaints relating to environmental noise issues, however, are increasing worldwide (Shane, 2010; Lee et al., 2015; Xiao et al., 2015). According to the *China Environmental Noise Prevention and Control Annual Report 2016*, for example, more than 354,000 complaints related to noise issues were received by China's Environmental Protection Department in 2015, accounting for 35.3% of all environmental complaints (Ministry of Environmental Protection of China, 2016).

Environmental noise analysis and control has gradually become popular in both research and practice, with studies covering such topics as the effects of noise on individuals (Fyhri et al., 2010; Montazami et al., 2012; Torija et al., 2014); measurement of occupational noise exposure (Chung et al. 2012; Caciari et al., 2014; Jang et al., 2015); noise prevention and control (Huang et al., 2015; Castiñeira-Ibañez et al., 2015; Kwon et al., 2016); and socio-acoustic investigation such as community response to different noise sources (Fields et al., 2001; Yano et al., 2004; Gille et al., 2016). Community response analysis is used to help understand how people react to specific noise levels and is crucial for defining problem areas and severity, and estimating the likely efficacy and benefits of noise abatement measures (Klæboe et al., 2004).

The main theme of social acoustic research noise to date has been to evaluate the characteristics of community *annoyance* by establishing the *dose-response* relationship of different noise sources through examining either exposure or annoyance/sleep disturbance (Yano et al., 2012). Since 1978, when Schultz (1978) proposed the famous Schultz's synthesized curve, hundreds of community response analyses have been conducted worldwide. These characterize the impact of noise (e.g., for traffic facilities planning and site selection of noise mitigation projects) and introduction of noise regulations (e.g., for traffic noise, aircraft noise, railway noise or even combined noise) (Schultz, 1978; Miedema, 1998; Fields et al., 2001; Nguyen et al., 2011 & 2015). The main instrument for this now is a high quality survey questionnaire established by the International Commission on Biological Effects of Noise (ICBEN) that assembles those of different countries and regions into a unified framework. This follows a standardized empirical study protocol to select annoyance scale words (Fields et al., 2001; Jeon et al., 2003; Yano et al., 2004). It exists in nine languages and can facilitate international comparable measures of community response to environment noise sources.

Noise from construction activities is a worldwide problem, particularly in China, where it is the most serious form of acoustic pollution (Liu et al., 2015; Xiao et al., 2015; Li et al., 2016). Construction noise-related complaints grew quickly both relatively and absolutely from 2013 to 2015 (Ministry of Environmental Protection of the People's Republic of China, 2016), for instance, when 50.1% of complaints associated with acoustic pollution were attributed to construction noise. Environmental noise studies, however, mainly focus on traffic noise and real-life background noise, with few studies of construction noise (Ballesteros et al., 2010; Lee et al., 2015), especially in terms of community response. This is because, on the one hand, compared with traffic noise and real-life background noise, construction noise is usually generated only during limited periods (Lee et al., 2015; Li et al., 2016), whereas community response analysis usually focuses on the long-term impact of different noises. On the other hand, construction noise is relatively easy to mitigate and control by regulation, and it may be less of a problem in developed countries because of adequate legislation and enforcement. In developing countries such as China, however, the situation is completely different. First, due to its rapid industrialization and urbanization, a vast number of construction projects have taken place - emitting considerable noise to their local communities (Li et al., 2016). Second, with the continuous increase in the size of projects, the construction period – and hence construction noise - for a single project has been greatly extended. For example, it is very common in China for a single project to have a construction period of 3 years or more, which clearly has a long-term impact on the local community. Moreover, compared with developed countries, developing countries also lack an efficient and effective law enforcement system for adequate noise control.

Against this background, the present study aimed to investigate the community response to construction noise as well as understand people's response to, and evaluation of, construction noise in three central cities of Hangzhou, Ningbo and Wenzhou in Zhejiang, an east coast province in China. The next section describes the method used, involving a social survey with the ICBEN standard questionnaires to evaluate the levels of annoyance of those affected and the use of sound level meters to measure noise exposure. The results are then provided in terms of dose-response curves established by quadratic polynomial regression analysis. Finally, the exposure-response relationships between different cities and different noise sources are discussed together with some concluding remarks on the likely implications for practice and future research.

2. Methodology

2.1 Surveyed Cities and Site Selection

The survey was conducted in Zhejiang province on the east coast of China. Adjacent to Shanghai, Zhejiang is one of China's most developed and well-governed provinces. The eastern part of China is suffering the most serious construction noise pollution of the country with, according to the *China Environmental Noise Prevention and Control Annual Report 2016*, 59.3% of complaints related to environmental noise issues in 2015 being from this region, 42% of which were caused by construction noise (Ministry of Environmental Protection of China, 2016).

In 2015, Zhejiang's GDP was CNY 4.29 trillion, with fixed assets investment of CNY 2.67 trillion. Driven by its rapid industrialization and urbanization, tens of thousands of construction projects - including public buildings, real estate projects and urban infrastructures such as viaducts and metro - are simultaneously under construction, with more than 880 million m^2 under construction and 191 million m^2 completed in 2015. The three cities for the survey are Zhejiang province's regional central cities of Hangzhou, Ningbo and Wenzhou, chosen mainly based on the cities' level of economic development, population, location and acoustic environment, as shown in **Fig.1**. Hangzhou is the capital of Zhejiang, with a population over 5 million, and considered one of the top 10 most largest and prosperous cities in China. Ningbo is the second center of politics, economics, culture and transportation in Zhejiang and is known as a township of the construction industry. It is famous worldwide for its developed economy and commercial culture, Wenzhou is beset by urban noise problems. In 2009, the average environmental noise exposure of Wenzhou was 71.6 dB, with the highest value reaching 78.9 dB, which led to public criticism from the Ministry of Environmental Protection of China.

In contrast with road traffic or aircraft noise, construction noise affects only people living or working adjacent to construction sites and the survey was therefore concentrated on these areas. The procedure used to select the survey sites for each city was: 1) to identify all the candidate construction sites in the city; 2) determine the number of survey sites needed according to the population and number of construction sites for each city; 3) to randomly choose a preliminary list of sites from the candidate construction sites; 4) to conduct a site inspection and modify the list of survey sites by considering the location, project type and construction stage of the sites. Finally, as shown in **Fig.1**, 40 construction sites were chosen, comprising 18 in Hangzhou, 12 in Ningbo and 10 in Wenzhou. The selected survey sites comprise 8 public buildings, 6 commercial buildings, 20 residential buildings and 6 infrastructure projects.

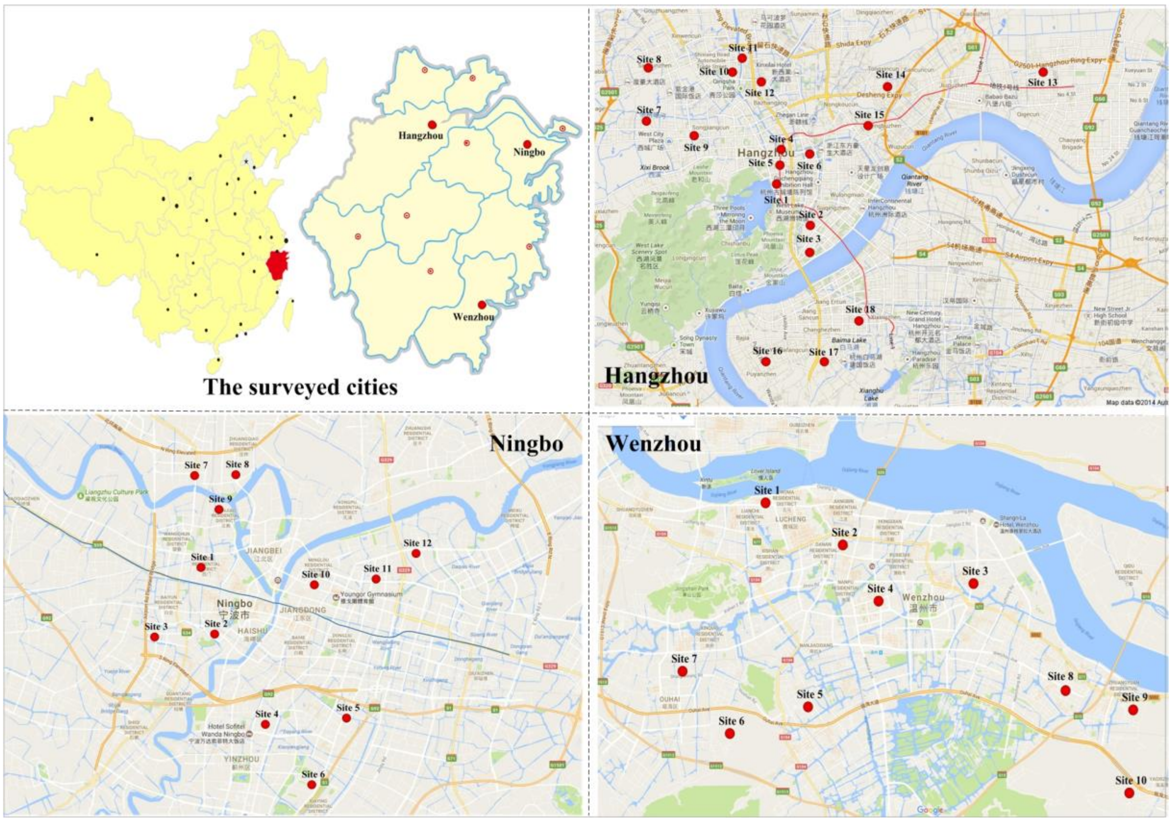

Fig. 1. Maps of surveyed cities and sites

2.2 Social Survey

The survey was conducted from 10 July to 30 August 2012 in Hangzhou, 21 June to 9 July 2014 in Ningbo and 12 to 25 July 2015 in Wenzhou. Residents or employees surrounding the selected construction sites (within 100 m) were identified as potential target respondents as they were directly exposed to construction noise.

A self-administered questionnaire comprising 17 questions was prepared, divided into three main sections. The first section contains general socio-demographic questions concerning the respondent's age, gender, etc. The second section focuses on the respondents' response to construction noise pollution in their urban lives, such as the potential impact and hazard to human health and impact on specific activities, and the respondents' evaluation and attitudes towards construction noise in their living or working environment. The self-reported attitudes and dissatisfaction with the construction noise environment are gauged on a five-point scale from 1="extremely" to 5="not at all". The third section of the questionnaire contains construction noise-annoyance related questions from the ICBEN instrument (Fields et al., 2001; Ma et al., 2003 and Yano et al., 2004) with a 5point verbal scale and an 11 numerical scale. The exact wording of the key questions (in both Chinese and English) using both the 5 point verbal scale and the 11 numerical scale in the ICBEN standard questionnaires is provided in **Appendix A**.

From the 1600 questionnaires (including 720 in Hangzhou, 480 in Ningbo and 400 in Wenzhou) dispatched to randomly selected respondent, 1027 valid responses were obtained, comprising 407 from Hangzhou (response rate of 56.53%), 330 from Ningbo (response rate of 68.75%) and 290 from Wenzhou (response rate of 72.50%). The total response rate of 64.19% is high for a survey of this kind but commensurate with some similar social surveys reported in the literature (Sato et al., 2002; Nguyen et al., 2011 &2016). Survey respondents had a mean age of 41.8, and 52.97% were male. All respondents were over 18 years of age while 63.49% were over 35. About 64.36% of participates are residents living around some survey site while 35.64% are employees working around the survey site.

2.3 Noise Measurement

To obtain the dose-response relationship, construction noise exposure was measured by an AZ® 8928 Digital Sound Level Meter. Measurements were taken at eight reference points set up inside residential buildings and workplaces around each survey site. Two measuring points randomly positioned within a 100m radius in each of the four directions of each selected construction site were set as reference points to measure the construction noise accurately. The mean of eight measured values from reference points were used to represent the construction noise exposure for every survey sites.

The current study chose the strategy named "real environment measurement" to truly assess the respondents' construction noise environment, which means no changes on both environmental conditions and respondents. The 12-hour construction noise (L_{Aeq}) was obtained by measuring the 10-minute equivalent continuous A-weighted sound pressure level every 2 hours for 12 hours (from 08:00 to 20:00). Since all respondents live or work within approximately 100 m of the measurement points, the values obtained in this way provide a good representation of the exposure values from the site.

3. Results

3.1 Characteristics of Construction Noise Exposure

Table 1 shows the fluctuation of the average A-weighted sound pressure level for every 2 hours from 08:00 to 20:00 in the three cities. This shows the L_{Aeq} of the construction noise to be higher than the traffic noise reported in the literature (Ma et al., 2008; Shimoyama et al., 2014; Nguyen et al., 2016). The respondents in all cities are generally exposed to very high noise levels not only during the day but also at night, as the lowest nighttime construction noise exposure levels in Hangzhou, Ningbo and Wenzhou were 67dB, 63dB and 64dB respectively. The construction noise is high around 10:00 and between 14:00 to 18:00, and low between 12:00 to 14:00 as well as around 20:00. Overall, construction noise in Hangzhou is slightly lower than Ningbo and Wenzhou, while it decreases quicker in Ningbo and Wenzhou than Hangzhou from 18:00 to 20:00.

Table 1. Average sound level from 08:00 to 20:00

Cities	L_{Aeq}	08:00	10:00	12:00	14:00	16:00	18:00	20:00
Hangzhou	Mean (dB)	69.66	70.08	70.86	70.87	71.43	71.14	66.98
	Std (dB)	6.39	6.00	4.40	5.07	5.40	5.69	5.99
Ningbo	Mean (dB)	67.62	71.04	65.82	72.38	76.05	75.50	62.90
	Std (dB)	7.24	4.27	5.95	5.82	5.07	5.93	6.92
Wenzhou	Mean (dB)	71.09	71.49	70.15	15.30	77.00	74.47	63.94
	Std (dB)	5.35	6.06	5.55	5.91	4.77	6.22	4.71

3.2 Awareness on the construction noise

The local people's awareness on potential consequences of environment noise reveals their environmental awareness, as well as the performances of the local government in spreading knowledge and controlling noise pollution related to environmental noise. **Table 2** summarizes the responses of the survey. Although almost all the respondents (roughly 96%) have heard of construction noise pollution, and many were annoyed by it, there is a clear lack of understanding of the specific consequences involved, especially in terms of hearing loss and other afflictions, e.g. hypertension, negative effects on cardiovascular, endocrine, and immune function.

Table 2. Respondents' awareness of the consequences of construction noise

Locations	Awareness of consequences				Have you ever heard of construction noise pollution?
	Annoyance increasing	Efficiency loss	Hearing loss	Other afflictions	
Hangzhou	53.32%	58.23%	23.83%	9.34%	93.86%
Ningbo	77.58%	51.82%	22.73%	14.85%	96.06%
Wenzhou	77.93%	59.31%	24.83%	13.79%	98.97%

A five-point verbal scale, from 1="not at all disturbed" to 5="extremely disturbed", was used to evaluate the impact of construction noise on such daily activities as watching TV/listening to music, conversation, sleep and concentration levels. As shown in **Figure 2**, construction noise affects activities such as studying/mental activities and sleeping more than watching TV/listening to music and conversation, with house working the least. Statistical analysis indicates impact of construction noise on all these activities to be significant at the 0.05 level.

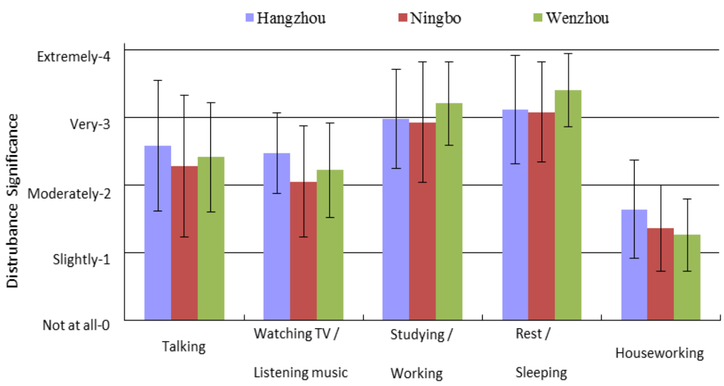

Fig. 2. Disturbances on various daily activities of the respondents

Table 3 shows the average daily times most disturbed by construction noise over the previous 12 months in the three cities. More than 50% respondents in all the cities reported they are seriously disturbed by construction noise during working hours (08:00–11:30 and 13:30–18:00). Approximately 18% of respondents in Ningbo and Wenzhou are seriously disturbed by construction noise at night (21:00-08:00+1), but only 7.8% in Hangzhou. However, 22.3% of Hangzhou respondents are disturbed at noon naptime (11:30-13:30) compared with 16.0% and 11.3% in

Ningbo and Wenzhou respectively.

Table 3. Time distribution of construction noise pollution

Location	Which time did the construction noise annoy you mostly?			
	Working time	Noon nap time	Evening	Night
	08:00–11:30 & 13:30–18:00	11:30-13:30	18:00-21:00	21:00-08:00+1
Hangzhou	50.81%	22.31%	19.09%	7.80%
Ningbo	56.68%	16.02%	8.90%	18.40%
Wenzhou	58.28%	11.38%	12.76%	17.59%

3.3 Response to, and evaluation of, construction noise

Table 4 summarizes the dissatisfaction levels of construction noise measured by a 5-point verbal scale, and levels of annoyance caused by construction noise measured using the ICBEN standard 5-point verbal scale from three surveyed cities. In terms of dissatisfaction evaluation, less than 15% of the respondents in each city are satisfied or very satisfied with the construction noise environment, which is far lower than the combined proportion of dissatisfied and very dissatisfied (highest of 67.7 % in Wenzhou and lowest of 53.9% in Ningbo). More than half the respondents in each city have a negative attitude towards their surrounding construction noise environment.

In terms of community response, the respondents from different cities have different response modes to construction noise. As shown in **Table 4**, more than 95% of the respondents are annoyed at different levels by the construction noise in each city, but the degree of "annoyance" is significantly different. In the "extremely annoyed" category, the proportion is more than 12% in both Hangzhou and Ningbo, but less than 8% in Wenzhou. More than 40% of the respondents in Hangzhou are "very annoyed" by the construction noise, while more than 40% of the respondents in Wenzhou are "moderately annoyed". In Ningbo, there is little difference between the proportion of respondents who are "very annoyed (23.03%)", "moderately annoyed (28.18%)" or "slightly annoyed (28.48%)".

Table 4. Dissatisfaction/Annoyance with the surrounding construction noise environment

Location	Category	Level of dissatisfaction[1] / Level of annoyance[2]					
		1	2	3	4	5	Average

Hangzhou	Dissatisfaction	0.78%	8.36%	27.68%	50.39%	12.79%	3.66
	Annoyance	4.61%	20.87%	20.87%	40.92%	12.74%	3.36
Ningbo	Dissatisfaction	1.52%	13.03%	31.52%	41.21%	12.73%	3.51
	Annoyance	4.85%	28.48%	28.18%	23.03%	15.45%	3.16
Wenzhou	Dissatisfaction	0.34%	9.66%	22.41%	53.79%	13.79%	3.71
	Annoyance	3.44%	29.21%	41.58%	17.87%	7.90%	2.98

[1] Level of dissatisfaction: 1= Very satisfied, 2= Satisfactory, 3=Average, 4= Unsatisfactory, 5= Very dissatisfied.

[2] Level of annoyance: 1= Not at all, 2= Slightly annoyed, 3=Moderately annoyed, 4= Very annoyed, 5= Extremely annoyed.

It is worth noting that differences between the respondents' response to, and evaluation of, construction noise can be seen from **Table 4** by comparing the respondents' levels of dissatisfaction and annoyance. On the one hand, the average levels of dissatisfaction in Hangzhou, Ningbo and Wenzhou (3.66, 3.51 and 3.71 respectively) are all higher than the levels of annoyance (3.36, 3.16 and 2.98 respectively) caused by construction noise. On the other hand, specific to each of the 5 categories, large differences appear in category 2 and category 4, where the former proportion of the "Slightly annoyed" category in annoyance evaluations (highest of 29.21% in Wenzhou and lowest of 20.87% in Hangzhou) is significantly higher than the proportion of the "Satisfactory" category in dissatisfaction surveys (highest of 13.03% in Ningbo and lowest of 8.36% in Hangzhou). The latter the proportion of the "Unsatisfactory" category (highest of 53.79% in Wenzhou and lowest of 41.21% in Ningbo) is also significantly higher than the proportion of the "Very annoyed" category (highest of 40.92% in Hangzhou and lowest of 17.87% in Wenzhou). This may be the main cause of differences between the respondents' average levels of dissatisfaction and annoyance.

3.4 Dose-response relationships

According to the ICBEN's Guidelines (Fields et al., 1997; 2001), the dose-response curve, which places specific noise exposures and residents' annoyance (normally highly-annoyed %) on the horizontal and vertical axes of the rectangular plane coordinate system respectively, is centered on understanding how residents' reactions to the specific noise, as reported through the fixed-format questionnaires, are related to the specific acoustical noise environment measured or estimated using a variety of noise indices. In the current study, Fields's (1997) quadratic polynomial regression analysis is used to investigate the dose-response relationship between construction noise exposure and community response. The 12-hour equivalent continuous A-weighted sound pressure level is the independent variable and the percentage of highly annoyed respondents taken from the top two categories of the 5 point verbal scale as well as the top three points of the 11 numerical scale is the dependent variable in the dose–response relationship. **Figs. 3** and **4** show the relationship between L_{Aeq} and the highly annoyed percentages for the two scales.

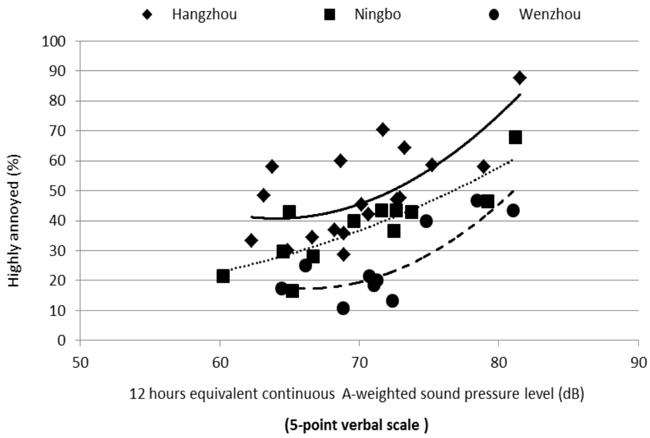

Fig. 3. Construction noise dose-response curves
(counted by the two top categories of the 5-point verbal scale)

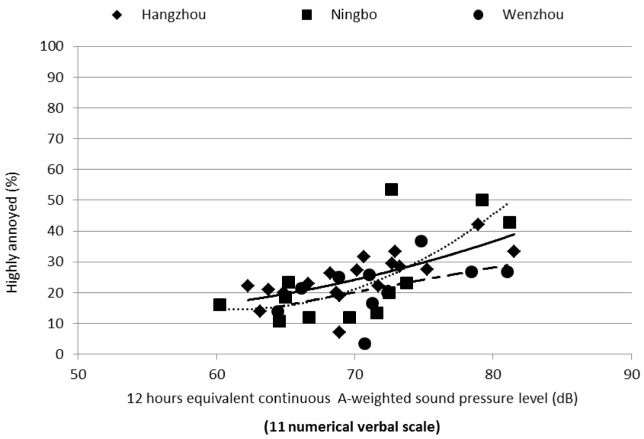

Fig. 4. Construction noise dose-response curves
(counted by the upper three steps of the 11 numerical scale)

Comparing the dose–response curves of the three cities in **Figs. 3** and **4**, respondents from Hangzhou and Ningbo appear to be more annoyed by construction noise than those in Wenzhou, even at the same noise level. It is also noteworthy that when L_{Aeq} increases from 60 dB to 80 dB, the percentage of highly annoyed respondents increases from 15%-20% to 30%-40% (counted by the upper three steps of the 11 numerical scale) or from 20%-40% to 50%-80% (counted by the two top categories of the 5 point verbal scale). The reasons for these big differences between the two dose–response curves are discussed in the next section.

4. Discussion

Similar to previous findings of traffic and aircraft noise, social survey results shown in **Fig. 2** reveal that construction noise disturbs people's various daily activities differently, with studying/mental activities and sleeping/resting being the most affected, followed by talking and watching/listening, with housework the least. Although the conclusions of previous studies are not entirely consistent (Moehler et al., 2000; Phan et al., 2010), there is sufficient research evidence to indicate that the disturbance from environmental noise caused by road traffic and aircraft is significantly annoying to people (Osada et al., 1997; Yano et al., 2002). This is especially the case with specific activities such as reading/mental work and sleeping (Sobotova et al., 2010; Shimoyama et al., 2014). According to Lam's (2009) findings, the actual noise exposure level is not very important in defining annoyance, but noise disturbance to daily activities and how noisy people feel are. It is therefore probably more effective for us to utilize strategies minimizing both the disturbance of daily activities and perceived noisiness to reduce construction noise annoyance.

Night work can have a significant impact on adjacent neighborhoods and businesses (Schexnayder et al., 2010). The survey indicates that nighttime construction noise, as one of environmental hazards in acoustic pollution, is still a serious problem in Ningbo and Wenzhou, with approximately one–fifth of respondents there being annoyed by this form of noise. This is unsurprising as, of the 452 complaints related to acoustic pollution received by Wenzhou CM&AEB during January to May 2015, 279 were related to nighttime construction noise (Wenzhou CM&AEB, 2015). The same also applies in Ningbo, where there were 388 complaints related to nighttime construction noise in October 2015 (Ningbo CM&AEB, 2015). Meanwhile, the social survey here suggests the need for the Hangzhou government to mitigate and control construction noise emitted during the noon naptime (11:30-13:30).

As **Table 4** indicates, there is a very big difference between the Hangzhou, Ningbo and Wenzhou respondents in responding the construction noise environment, even though the construction noise exposure of the three cities is very similar. Respondents in Hangzhou, where construction noise exposure seems to be less serious, are relatively more sensitive. The main reason for this difference may be attributed to differences in socio-economic conditions and lifestyles between Hangzhou, Ningbo and Wenzhou. Compared with Ningbo and Wenzhou, Hangzhou is a popular domestic and global tourism destination, and the more urbane Hangzhou residents have a higher requirement of their acoustic environment. This finding is similar to the Phan et al (2009) psychoacoustic experiment on the annoyance of horn sounds in Vietnam and Japan, and Yano and Sato's (2002) comparative investigation of Japan and Sweden, which also attributes the main difference in community response to road traffic noise to the difference in lifestyles of the two countries.

The data in **Table 4** also reveal that differences exist in reaction measures assessed with general scales of dissatisfaction and specific scales of annoyance. Similar to the current study, socio-acoustic investigations concentrate on understanding negative reactions by examining the relationships between noise exposure and noise-related reactions, attitudes and effects, and people exposed to noise (Miedema et al., 1998; Job et al., 2001). Negative reactions (dissatisfaction, annoyance, exhaustion, anger, frustration, fear and/or distress) are one of the undisputed consequences of exposure to noise, and are usually represented by such possible and important indicators as annoyance, dissatisfaction and perceived affectedness (Fields, 1997; Job et al., 1993; 2001). Compared with general dissatisfaction, annoyance from noise is more specific and limited (Job et al., 2001). Thus, the different indicators used to capture respondents' negative reactions may be the main cause of the differences between respondents' annoyance from, and dissatisfaction with, construction noise. Although the ICBEN had established a standard framework to assess the local residents' community response to noise by evaluating the level of annoyance of people exposed to noise in 2000, there is still literature recommending that general scales of dissatisfaction and perceived affectedness are more reliable than scales of annoyance (Hede et al., 1982; Job et al., 1993; 2001).

As shown in **Figs. 3** and **4**, the dose response curves from the 11 numerical scales and 5-point verbal scale respectively seem very inconsistent or even contradictory. In Hangzhou, for example, when L_{Aeq} is increased from 60 dB to 80 dB, the 'highly annoyed' the 11 numerical scale increased from 20% to 40% while the equivalent from the 5-point verbal scale increased from 40% to 80%. The reason for this seems to be an artifact of the analysis concerning the treatment of the 'highly annoyed' group. Schultz's (1978) original definition was the upper 28% of the scale for the sake of converting survey data from different scales to a unified annoyance scale. However, with the increased popularization of the ICBEN standardized questionnaires, the selection criteria for HA has gradually been classified into three categories, namely the upper 3 steps of the 11 numeric scale, the top category of the 5-point verbal scale and the 2 top categories of the 5-point verbal scale (Yano et al., 2004; Ma et al., 2008; Nguyen et al., 2011). In the present study, the upper 3 steps of 8, 9 and 10 for the 11 numeric scale are scored as HA in **Fig. 4**, which represents 27.3% of the total scale. For the 5-point verbal scale, the 2 top categories scored as HA in **Fig.3** include 40% of the total scale. Following Schultz(1978), i.e. treating the upper 28% of the scale as HA, means counting the upper category *plus 0.4* of the next category as HA% for the 5-point verbal scale (Gjestland, 2015). This result in a dose response curve established by the exact 28% HA that is substantially the same as **Fig. 3**.

In addition to the comparative analysis of the *same* noise source between different countries or regions, comparative analysis of dose response relationship between *different* noise sources have been reported in various studies (Fields et al., 1982; Schreckenberg et al., 1998). These typically include road traffic and railroad noise (Moehler et al., 2000; Ma et al., 2004) and road traffic and aircraft noise (Kurra et al., 1999; Nguyen et al., 2015). In order to roughly compare the difference in dose response curves between construction and traffic noise, the Miedema curve from Europe (Miedema et al., 1998), two dose response curve of traffic noise from Tianjin, China (Ma et al., 2008) and Hanoi, Vietnam (Phan et al., 2010) and the Hangzhou curve shown in Fig. 4 are put together on the same basis, as shown in **Fig. 5**.

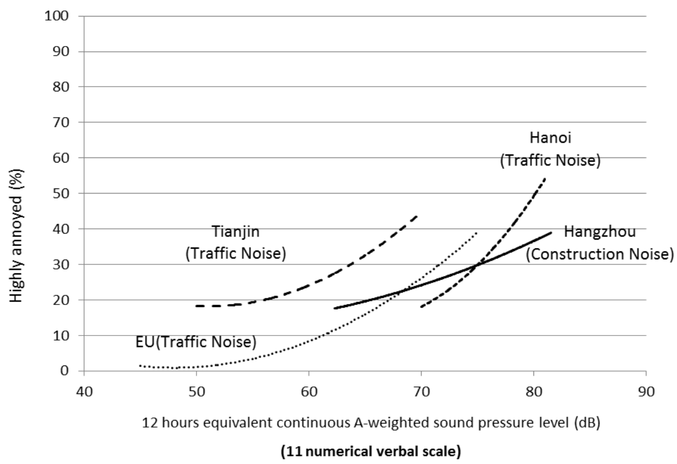

Fig. 5. Dose-response curves on the same basis
(EU Miedema and Tianjin traffic curves and the Hangzhou construction noise curve)

Except for illustrating that the average levels of noise exposure caused by construction works in all three cities was higher than traffic noise exposure in Tianjin, the comparative analysis shown in Fig. 5 indicates the HA% caused by construction noise in Hangzhou to be slightly lower than by traffic noise in Tianjin at the same noise level. In other words, there is an 8-10 dB difference between the two curves at the same HA%. When compared with the EU Miedema traffic curve, the difference still exists, but the gap is reduced to 2-3 dB. Meanwhile, annoyance caused by construction noise in Hangzhou is rising significantly slower than that caused by traffic noise in EU, Hanoi and Tianjin. These results are quite unexpected, and may be contrary to the popular belief of the public for the reason that construction noise is severely disliked by the public and the most annoying compared with other noise sources (Ma et al., 2007; Li et al., 2015; Lee et al., 2015). Previous studies show there are usually different community response patterns between different type of environmental noises, such as road traffic noise, railway noise and aircraft noise (Miedema and Vos, 1998; Lim et al., 2006). Acoustic properties, e.g., frequency and loudness, the regularity and predictability of noise event intervals, are mainly the reason for this phenomenon (Fields et al., 1982; Fastl et al., 1996; Kurra et al., 1999). Due to significant differences between construction and traffic noise on acoustic properties, it is reasonable for the existed differences in community response between construction noise and traffic noise. However, the exact mechanism by which the acoustic properties affect community response patterns is still unclear. Thus, verifying the findings, and identifying the causes of its occurrence are a priority for future studies.

Also of note from **Fig. 5** is that the Tianjin, Hanoi and EU Miedema curves are virtually parallel, suggesting that Chinese people are less tolerant of traffic noise than their more developed European or less developed Asian counterparts. Some factors affecting the local residents' response to a specific noise source (e.g., traffic noise) were identified through a series of extensive studies, i.e., natural and economic conditions (Phan et al., 2009; Wang and Kang, 2011), perception of, and attitude to, a specific noise source (Fields et al., 1982), socio-culture factors such as lifestyle (Yano et al., 2004), policy discourse (Kroesen et al., 2011) and social conditions and habituations in relation to specific noise sources (Phan et al., 2010). Sato et al. (2002) found the main difference in community response to traffic noise between Sweden and Japan to be attributed to the difference in lifestyles of the two countries by comparing the community response to road traffic noise between Japan and Sweden. The socio-economic conditions, political system and cultural characteristics in

China are much different to Europe or even Vietnam, may offer a reasonable explanation of the emerging differences in community response to traffic noise between Europe, Vietnam and China. Consequently, this finding emphasizes the importance of establishing separate dose–response curves for each city/region/country based on their actual socio-economic conditions and cultural characteristics.

5. Conclusions

Because of rapid industrialization and urbanization, construction noise has led to many complaints, a deterioration in acoustic climate quality, and has become a common source of environmental noise in China and many other developing countries worldwide. To obtain an improved understanding of people's response to, and evaluation of, construction noise, this paper describes an investigation into community response to construction noise in three central cities of Zhejiang province, China. This involved a quadratic polynomial regression analysis of social survey data using the ICBEN standard questionnaires and the measurement of actual construction noise levels to establish the dose-response relationships involved.

The results of the study indicate that the majority of people have a negative attitude to construction noise; the noise ranges between 60 dB to 80 dB (compared with 50 dB to 70 dB traffic noise in Tianjin), with the percentage of highly annoyed people affected increasing from 15%-20% to 30%-40% over the range. There are also different annoyance levels depending on the time of day, and the location and activities of those affected. For example, studying/mental activities and sleeping are the most affected, residents of Ningbo and Wenzhou being seriously disturbed at night and those of Hangzhou at their noon naptime. Some cultural differences are also apparent both between Ningbo\Wenzhou and the more urbane citizens of Hangzhou, and the Chinese people and their more noise-tolerant EU/Vietnam counterparts.

The findings of this paper provide a new perspective for the study of construction noise and enrich the application of community response analysis to the current body of knowledge. The findings can also provide local governments with an improved understand of how people react to construction noise when choosing construction noise mitigation projects and introducing construction noise control regulations. However, additional future work is also needed. For example, the findings of this study need to be confirmed and verified by further similar surveys and studies conducted in other cities. An improved understanding of the causes of differences in behavior patterns in different cities, or annoyance differences at the same noise level between construction and other noise sources is also needed.

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Appendix A

The 5-point verbal scale:

In English:

Thinking about the last 12 months when you are here at home or workplace，how much does noise from construction bother, disturb or annoy you?

(1) Extremely; (2) Very; (3) Moderately; (4) Slightly; (5) Not at all.

In Chinese:

在过去的一年中，当您在居住/工作场所中，建筑施工噪声污染在多大程度上打扰您？

(1) 特别; (2) 相当; (3) 比较; (4) 好像有点; (5) 一点也不.

The 11 numerical scale:

In English:

Next is a zero to ten opinion scale for how much the construction noise bothers, disturbs or annoys you when are here at home or workplace. If you are not at all annoyed, choose zero. If you are extremely annoyed, choose ten. If you are somewhere in between, choose a number between zero and ten. Thinking about the last 12 months, what number from zero to ten best shows how much you are bothered, disturbed or annoyed by construction noise?

☐ 0; ☐ 1; ☐ 2; ☐ 3; ☐ 4; ☐ 5; ☐ 6; ☐ 7; ☐ 8; ☐ 9; ☐ 10.

In Chinese:

下面从0到10的数字尺度用于表示当您在居住/工作场所中，建筑施工噪声打扰、干扰或烦扰您的程度。如果您一点也不感到烦扰就选择0，如果您感到特别烦扰就选择10，如果您的感觉在两者之间就从0到10的数字中选择一个恰当的数字来表示您受烦扰的程度。

回想过去12个月，哪个数字能最好地表示当您在居住/工作场所中时，建筑施工噪声打扰、干扰或烦扰您的程度?

☐ 0; ☐ 1; ☐ 2; ☐ 3; ☐ 4; ☐ 5; ☐ 6; ☐ 7; ☐ 8; ☐ 9; ☐ 10.