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The Enlightenment on Urban Ecological Construction by Research Progress of Sponge City in China Based on Literature Analysis

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Abstract To quantitatively analyze main figure, field, agency and level of sponge city research in China, and clear research focus and hot spot in each year, by using the Full Text Database of Chinese Sci-tech Periodicals and other retrieval tools, the statistics and analysis of 3152 research literatures on sponge city published in domestic academic journals of 2004–2016 are conducted based on bibliometrics. It is found that since the concept of "sponge city" was firstly proposed in 2012, development research of sponge city involves 40 subject fields and is mainly published in 32 kinds of journals, which is dominated by natural science research (1427 literatures). Researchers are mainly from each college and university, some design institutes and Chinese Academy of Sciences. The research could play certain guidance significance for further research and construction of ecological city construction in China.

Key words Literature analysis, Sponge city, Retrieval tool, Bibliometrics, Ecological construction

1 Introduction

Since proposed "vigorously impelling eco-civilization construction" in the Eighteenth National Congress of the CPC of 2012, people's ecological civilization consciousness to respect, conform to and protect the nature enhances increasingly. As a kind of national policy, sponge city construction opens an important milestone of Chinese ecological city construction. In the *Technical Guidelines of Sponge City Construction—Construction of Low-impact Development of Rainwater System*, sponge city is defined that the city could be like a sponge to have good "elasticity" at the aspect of adapting to environmental change and responding to natural disaster. It could absorb, store, penetrate and purify water in rainfall day, and the stored water could be "released" and used when needed. At the macro level, sponge city construction is the research on ecological security strategy of water, terrain, surface soil and vegetation in urban development at a large scale. At the micro level, sponge city construction is the research on rainfall flood resource utilization, thereby building ecological safety pattern of the city and creating the city space of harmonious coexistence of man and nature, suiting for residence and sustainable development^[1–4]. Taking the Network Publication Library of Chinese Academic Periodicals of CNKI as literature source and using bibliometric analysis, publication decade, included number, research filed, journal distribution, publication year, research lev-

el, author information and research agency of the domestic literatures on urban agriculture published in the past 12 years are analyzed, in order to provide the scientific reference for continuous improvement and further practice of the sponge city construction theory.

2 Research methods

2.1 Data source Using retrieval tools and decade of Table 1, related bibliographic data of literature are searched, and total recorded content is analyzed by statistics.

2.2 Method and data treatment Analytic method and data treatment refer to the literature^[5]. According to retrieval decade and collection situation, all theses published in 7 databases (academic periodical, papers, conference thesis, master and doctor thesis, characteristic periodical and international conference thesis) are searched. The theses of journal distribution, publication year, research level, author information, research content, research agency and fund source are only from Network Publication Library of Chinese Academic Periodicals.

2.3 Analytic index and content Analytic index and content refer to the literature^[5].

3 Research content and analysis

3.1 Retrieval decade and included situation Seen from the retrieval, theoretic research result of sponge city in China is analyzed from macro concept, and the research started from 2004. There are 7 included databases, with 3152 literatures in total. Among them, included number of Network Publication Library of Chinese Academic Periodicals is 1643 and is the most, accounting for 52.1%; Full Text Database of Chinese Important Newspaper includes 1058 literatures, accounting for 33.6%; 202 literatures

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are included in Characteristic Periodicals, accounting for 6.4% ; Full Text Database of Chinese Excellent Master's Thesis includes 120 literatures, accounting for 3.8% ; 86 literatures are included in Full Text Database of Chinese Important Conference Thesis, ac-

counting for 2.7% ; Full Text Database of Chinese Doctor's Dissertation and Full Text Database of International Conference Papers respectively include 22 and 21 literatures, both accounting for 0.7% (Fig. 1).

Table 1 Retrieval database

Ranking	Retrieval tool	Retrieval decade	Included quantity	Included percentage//%
1	Network Publication Library of Chinese Academic Periodicals	2011 –2016	1643	52.1
2	Full Text Database of Chinese Important Newspaper	2013 –2016	1058	33.6
3	Full Text Database of Chinese Important Conference Thesis	2004 –2016	86	2.7
4	Full Text Database of Chinese Excellent Master's Thesis	2009 –2016	120	3.8
5	Characteristic Periodicals	2014 –2016	202	6.4
6	Full Text Database of Chinese Doctor's Dissertation	2008 –2016	22	0.7
7	Full Text Database of International Conference Paper	2007 –2016	21	0.7
Total			3152	

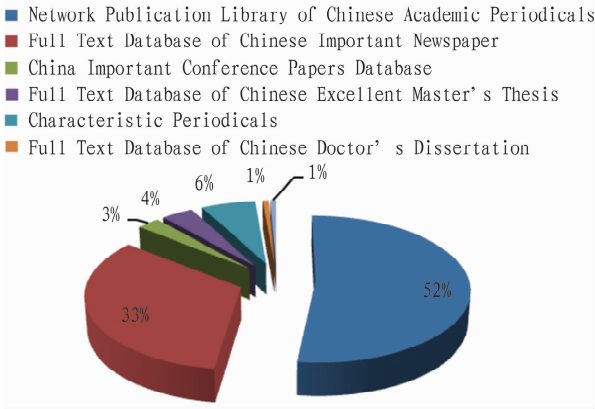


Fig. 1 Retrieval result of the database

3.2 Research field and publication result 3679 literatures on

sponge city are searched in the database, involving 40 subject fields. According to publication number in each field, the top ten are construction science and engineering, water conservancy and hydropower engineering, macroeconomic management and sustainable development, Chinese politics and international politics, highway and waterway transportation, environmental science and resource utilization, forestry, finance, finance and taxation, industrial economy (Table 2). It is clear that there are more researches on sponge city in the field of construction science and engineering, accounting for 46.5% ; water conservancy and hydropower engineering accounts for 23.3% ; macroeconomic management and sustainable development accounts for 19.4% ; Chinese politics and international politics accounts for 2.1% ; highway and waterway transportation accounts for 1.4% ; it is less than 1% in other subject fields.

Table 2 Retrieval results of research field

Ranking	Literature amount	Subject field	Percentage//%
1	1712	Construction science and engineering	46.50
2	858	Water conservancy and hydropower engineering	23.30
3	715	Macroeconomic management and sustainable development	19.40
4	77	Chinese politics and international politics	2.10
5	52	Highway and waterway transportation	1.40
6	31	Environmental science and resource utilization	0.80
7	30	Forestry	0.80
8	29	Finance	0.80
9	24	Finance and taxation	0.70
10	20	Industrial economy	0.50
11	13	Investment	0.40
12	12	Secondary education	0.40
13	12	Resource science	0.40
14	9	Reform of economic system	0.20
15	9	Negotiable securities	0.20
16	8	Inorganic chemical industry	0.20
17	8	Administration and state administration	0.20
18	7	Meteorology	0.20
19	6	The party and mass organizations	0.20
20	5	Information economy and postal economy	0.10

(to be continued)

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Ranking	Literature amount	Subject field	Percentage//%
21	4	Economic law	0.10
22	4	Administrative law and local legal system	0.10
23	4	Tourism	0.10
24	3	Market research and information	0.09
25	3	Agronomy	0.09
26	3	Agricultural basic science	0.09
27	3	Higher education	0.09
28	2	Gardening	0.06
29	2	Sociology and statistics	0.06
30	2	Organic chemical industry	0.06
31	2	Trade economy	0.06
32	2	Geophysics	0.06
33	1	Legal principle and history	0.03
34	1	Culture	0.03
35	1	Audit	0.03
36	1	Culture economy	0.03
37	1	Biology	0.03
38	1	Ideological and political education	0.03
39	1	Vocational education	0.03
40	1	Metallurgical industry	0.03
Total	3679		

3.3 Periodical distribution Seen from Table 3, 504 theses are respectively published in 19 kinds of periodicals. By searching the 2016 edition of Peking University core journal catalog, there are 3 core journals: *Water and Wastewater Engineering*, *China Water and Wastewater*, and *Chinese Landscape Architecture*. Among them, the prior two kinds are double core journals, and they respectively include 33 and 26 theses on sponge city, accounting for 6.5% and 5.1%. According to included number, the two journals ranked in the fourth and the seventh. 14 literatures are from *Chinese Landscape Architecture*, accounting for 2.8%, with the highest influence factor of 0.956. There are 16 kinds of general jour-

nals, and 8 kinds of journals are ranked in top 10 (Table 3). Among them, the most literature (76) is from *Construction Science and Technology*, followed by the *Urban Planning Newsreport* (43); *Shanxi Architecture* (35); *Water and Wastewater Engineering* (33); *Xiandai Horticulture* (31) and *Jiangxi Building Materials* (31); *China Water and Wastewater* and *Building Block and Block Construction* (26); *Urban and Rural Development* (24); *Urban Roads Bridge and Flood Control* (23) and *Construction Materials and Decoration* (23); *Cities and Towns Construction in Guangxi* (20); *China Water Resources* (19), accounting for 81.4%.

Table 3 Statistics of publication journal

Ranking	Literature quantity	Journal name	Host unit	Influence factor	Publication category	Percentage %
1	76	<i>Construction Science and Technology</i>	Science and Technology Development Promotion Center of Ministry of Construction	0.173	General journal	15.1
2	43	<i>Urban Planning Newsreport</i>	Chinese Academy of Urban Planning and Design	—	General journal	8.5
3	35	<i>Shanxi Architecture</i>	Shanxi Academy of Building Research	0.091	General journal	6.9
4	33	<i>Water and Wastewater Engineering</i>	Asia Pacific Construction Science and Technology Information Research Institute; China Architectural Design and Research Institute	0.528	Core journal CSCD	6.5
5	31	<i>Xiandai Horticulture</i>	Jiangxi Economic Crops Bureau; Jiangxi Shuangjin Orange Test Station	—	General journal	6.2
6	31	<i>Jiangxi Building Materials</i>	Jiangxi Building Material Research and Design Institute	—	General journal	6.2
7	26	<i>China Water and Wastewater</i>	North China Design and Research Institute of Municipal Engineering; Chinese Cities	0.762	Core journal CA JST PK(AJ) CSCD	5.1
8	26	<i>Building Block and Block Construction</i>	China Building Block Association	0.092	General journal	5.1
9	24	<i>Urban and Rural Development</i>	Architectural Magazine	0.143	General journal	4.8

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Ranking	Literature quantity	Journal name	Host unit	Influence factor	Publication category	Percentage %
10	23	Urban Roads Bridge and Flood Control	Shanghai Municipal Engineering Design and Research Institute	0.095	General journal	4.6
11	23	Construction Materials and Decoration	Chengdu Kitchen Sanitation Industry Association; Chengdu Press and Publication Development Center	–	General journal	4.6
12	20	Cities and Towns Construction in Guangxi	Construction Technology Exchange; Guangxi Civil Engineering; Guangxi Urban Construction	0.090	General journal	4.0
13	19	China Water Resources	China Water Conservancy Press	0.468	General journal	3.8
14	18	China Engineering and Consulting	China Association of Survey and Design	0.150	General journal	3.6
15	16	China Municipal Engineering	Shanghai Urban Construction Design Research Institute	0.147	General journal	3.1
16	16	China Construction	Policy Research Center, Ministry of Housing and Urban-rural Development	–	General journal	3.1
17	15	Journal of Beijing Forestry University	Beijing Forestry University	0.563	General journal	3.0
18	15	China Economic Guide	National Development and Reform Commission	–	General journal	3.0
19	14	Chinese Landscape Architecture	Chinese Landscape Architecture Society	0.956	Core journal	2.8
Total	504	–	–	–	–	–

Note: Influence factors are all composite influence factor inquired in CNKI, and "–" shows that the journal does not have influence factor.

3.4 Published year Seen from the retrieval, the research on sponge city theory started from 2011, and one thesis was received respectively from 2011 to 2013, showing that theoretic research on sponge city is still at exploratory research phase. In 2014, 35 literatures on sponge city were included, which was at initial stage of sponge city research. In 2015, 777 literatures on sponge city were included, which increased by 22 times than that in 2014. In 2016, 1609 literatures on sponge city were included, which increased by 46 times than that in 2014 and 2 times than that in 2015. In January of 2017, 37 literatures on sponge city were included. The research on sponge city construction in the past three years corresponds with basic national policy of ecological city construction in China, and meets historical period of key decision making of

sponge city construction(Table 4).

Table 4 Statistics of publication year

Ranking	Literature quantity	Publication year	Percentage//%
1	37	2017	1.50
2	1609	2016	65.38
3	777	2015	31.60
4	35	2014	1.40
5	1	2013	0.04
6	1	2012	0.04
7	1	2011	0.04
Total	2461	–	–

Table 5 Statistics of research level

Ranking	Research level	Literature quantity	Percentage//%
1	Engineering technology (natural science)	1124	51.2
2	Industry guidance (social science)	531	24.2
3	Industry technique guidance (natural science)	150	6.8
4	Basic and application basic research (natural science)	110	5.0
5	Policy research (social science)	89	4.1
6	Mass culture	39	1.8
7	Economic information	25	1.1
8	Gazette, bulletin, announcement, proclamation	23	1.0
9	Basic research (social science)	20	0.9
10	Policy research (natural science)	18	0.8
11	Popular science popularization	17	0.8
12	Elementary education and secondary vocational education	16	0.7
13	Professional practical technology (natural science)	13	0.6
14	Advanced science popularization (natural science)	12	0.6
15	Literary works	2	0.1
16	Vocational guidance (social science)	2	0.1
17	Higher education	2	0.1
18	Party construction and party member education	1	0.1
Total	–	2194	–

3.5 Research level Seen from Table 5, theoretic research of sponge city involves 18 research levels. In published 2194 theses, 1124 literatures belong to engineering technology research; 531 literatures belong to industry guidance; 150 literatures belong to industry technique guidance; 110 literatures belong to basic and application basic research. In top 4 research levels, 3 research levels belong to natural science research, and 1384 research theses account for 63%; residue belongs to social science research level, and there are 531 theses, accounting for 24.2%.

3.6 Author information and direction of research content

The research of sponge city is mainly from research results of 11 colleges, 7 scientific research institutes, 4 enterprises and 1 relevant functional department. Research results of college are the most (117), accounting for 62.8%. Among them, there are 5

colleges ranked in the top three, and two colleges are simultaneously list in the second and third positions, and they are Beijing University of Civil Engineering and Architecture, Peking University, China University of Geosciences, Beijing Forestry University, and Anhui University of Science and Technology, with the thesis number of 65, 8, 8, 7 and 7, accounting for 34.7%, 4.3% and 3.8%. 46 theses are from scientific research institute, accounting for 24.8%; there are 18 enterprise's research theses, accounting for 9.7%; Jiujiang Hydrological Bureau of Jiangxi Province issues 5 literatures, accounting for 2.7%. Theoretic research on sponge city mainly concentrates in the interpretation of relevant state policies, the problems existing in sponge city construction at home and abroad, solution channel and method^[6-26] (Table 6).

Table 6 Author information

Ranking	Literature quantity	Author information	Percentage %	Direction of research content
1	19	Li Junqi, Beijing University of Civil Engineering and Architecture	10.1	Exploring the channel of trans-boundary planning in sponge city construction; solving planning idea of urban water environment problem from city construction source; the interpretation on basic concept and comprehensive target, target area division of total amount control of rainfall runoff, and total amount control index of urban runoff in the guideline for sponge city construction; analyzing and exploring misunderstanding and perplexity of sponge city construction and its countermeasures; exploring acceptance assessment methods of main targets of sponge city construction and simply analyzing the planning and design point of sponge city construction; analyzing the function of low-influence development technology based on sponge city construction and the obfuscation of low-influence development rainwater system construction; exploring related concept and connotation of sponge city and urban rainwater management; simulation evaluation and optimization of rainfall-flood control use case of one vehicle section in Beijing City; application case research of low-influence development technology in TCF Bank Stadium; the threatening of climate change to urban water safety and the construction of adaptation ability in China; test research on adsorption effect of runoff pollutant by river sand; test research on adsorption performance of runoff pollutant by common materials for pervious concrete pavement; case research of multi-target rainwater system in one slope district of Beijing; control test of runoff pollutant by permeable concrete pavement with pipe guiding permeation and drainage
2	14	Che Wu, Beijing University of Civil Engineering and Architecture	7.4	Exploration of urban planning method based on sponge city idea; rational thought on basic concept and comprehensive target, target area division of total amount control of rainfall runoff, and total amount control index of urban runoff in the guideline for sponge city construction and several problems of sponge city construction, the interpretation on reasonable construction of urban rain flood storage regulation system; cold thinking under the upsurge of sponge city construction, exploring acceptance assessment methods of main targets, connection and breakthrough with "three lines of the city", survey on pollution problem of urban runoff; the relationship between initial rainfall and runoff total amount control and its application analysis; time delaying adjustment facility and its application in urban waterlogging and runoff pollution control; urban rainwater control and use standard system and problem analysis; vulnerability assessment of rainstorm waterlogging in international city and adaptive strategy research
3	8	Yu Kongjian, Peking University	4.3	Based on today, China is just facing many kinds of water problems; water resource shortage, water contamination, flood disaster and aquatic habitat loss, and proposes the theory of "sponge city" and practice case; ancient "sponge city" idea—experience enlightenment of water suitability landscape; three key strategies of sponge city: consumption, deceleration and adaption; the practice of "sponge city": control planning and landscape planning of Ecological Development Demonstration Area of Beijing Yanqi Lake; relieving waterlogging needing to create "sponge city"; constructing urban green sponge—planning research of ecological rain flood storage regulation system; green sponge creating water suitability city; Harbin Qunli Stormwater Park; key technology of water ecological infrastructure construction

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Ranking	Literature quantity	Author information	Percentage %	Direction of research content
4	8	Wu Lianfeng, Xiamen Urban Planning and Design Institute	4.3	Sponge city construction of Xiamen——practice and thinking of scheme programming, key analysis of implementing case programming, thinking and optimization of urban water system; taking Gulangyu of Xiamen City as an example, the construction of sponge city system and water safety system in historical cultural block; establishment of water safety system of sponge city in coastal region——taking pilot area of Xiang'an sponge city of Xiamen City as an example; planning effect analysis of sponge city in building area based on SWMM model; some reference of Melbourne water sensitive city design on sponge city planning of Xiamen
5	8	Wang Ziliang, China University of Geosciences	4.3	The interpretation on basic concept and comprehensive target, target area division of total amount control of rainfall runoff, and total amount control index of urban runoff in the guideline for sponge city construction; several obfuscations of sponge city construction and countermeasure analysis; exploring related concept and connotation of sponge city and urban rainwater management; application case research of low-influence development technology in TCF Bank Stadium; analyzing the obfuscation of low-influence development rainwater system construction; case research of multi-target rainwater system in one slope district of Beijing
6	6	Wang Sisi, Beijing University of Civil Engineering and Architecture	3.2	Based on today, China is just facing many kinds of water problems: water resource shortage, water contamination, flood disaster and aquatic habitat loss, and proposes the theory of "sponge city" and practice case; The interpretation on basic concept and comprehensive target in the guideline for sponge city construction; studying flexible infrastructure construction of sponge city and the enlightenment on sponge city construction by urban planning thought in ancient China; vulnerability assessment of rainstorm waterlogging in international city and adaptive strategy research; vegetation selection and design of low-impact development rainwater facility
7	6	Wang Zeyang, Xiamen Urban Planning and Design Institute	3.2	Construction of sponge city system in historical cultural block——taking Gulangyu of Xiamen as an example; establishment of water safety system of sponge city in coastal region——taking pilot area of Xiang'an sponge city of Xiamen City as an example; planning effect analysis of sponge city in building area based on SWMM model; some reference of Melbourne water sensitive city design on sponge city planning of Xiamen; the construction of water safety system in historical cultural block based on sponge city——taking Gulangyu of Xiamen City as an example; thinking and optimization of urban water system——taking Xiamen as an example
8	6	Ren Xinxin, Urban Planning and Design Institute of Shenzhen	3.2	Studying construction strategy of sponge city in Shenzhen City based on the investigation on historical waterlogging, decomposition mechanism of regional sponge city establishment target and construction of sponge city index system, application and simulation evaluation of low-impact development system in one sport center; exploring the application of total amount control rate of annual runoff in sponge city and acceptance assessment methods of main targets of sponge city construction; top-level design of sponge city construction in Fushan City
9	5	Lv Lanjun, Jiujiang Hydrological Bureau of Jiangxi Province	2.7	Hydrology's effect in the construction of sponge city and thinking; exploring sponge city construction and hydrological services, sponge city construction and hydrological services in Jiujiang City of Jiangxi Province; support study of hydrological station network planning and water conservancy technology based on sponge city construction
10	5	Zhang Qingping, College of Landscape Architecture of Nanjing Forestry University	2.7	Application study of urban permeable pavement under sponge city idea; studying design strategy of road greenbelt under the background of sponge city construction, urban rain flood landscape security pattern, general situation and progress of sponge city; multi-field fusion strategy in rain flood management planning in New Orleans, USA
11	5	Gong Yongwei, Beijing University of Civil Engineering and Architecture	2.7	Exploring the channel of trans-boundary planning; the interpretation on basic concept and comprehensive target by the guideline for sponge city construction; exploring acceptance assessment methods of main targets of sponge city construction; simulation evaluation and optimization of rainfall-flood control use case of one vehicle section in Beijing City; application case research of low-influence development technology in TCF Bank Stadium
12	5	Wang Junling, Beijing University of Civil Engineering and Architecture	2.7	Progress research of permeable pavement system based on the idea of "sponge city"; Function analysis of low-impact development technology based on sponge city construction; test research on adsorption effect of runoff pollutant by river sand, test research on adsorption performance of runoff pollutant by common materials for pervious concrete pavement; control test of runoff pollutant by permeable concrete pavement with pipe guiding permeation and drainage

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Ranking	Literature quantity	Author information	Percentage %	Direction of research content
13	5	Xu Zhenqiang, Institute of Resources and Environment, Ecological City Planning and Construction Center of China City Council	2.7	Establishment and application of evaluation concept mode of demonstration performance in Chinese characteristic sponge city pilot—simultaneously discussing the construction of innovation system platform of sponge city in China; policy evolution and local practice of Chinese characteristic sponge city; declaration strategy research and ability construction suggestion of sponge city pilot demonstration in China; facing "the 13th five-year" to cultivate Chinese characteristic sponge city industry system—based on initial exploration on overall status of enterprise in sponge city; expert's opinion on water storage and pollution discharge of sponge city construction, green sponge city and ecological equilibrium
14	5	Zhang Chen, Shanghai Municipal Engineering Design Institute (Group) Co., Ltd.	2.7	Studying construction index system of sponge city in Shanghai City, pilot planning and applicable technology; sponge city construction and comprehensive corridor technology; studying the construction of standard service of sponge city and systemic construction of ecological new town
15	5	Wang Ning, Xiamen Urban Planning and Design Institute	2.7	Practice and thinking of construction scheme programming of Xiamen sponge city; planning effect analysis of sponge city in building area based on SWMM model; exploring design scheme of urban road based on sponge city idea; analyzing implementation scheme programming point of sponge city construction—taking Xiamen as an example; studying scheme design of sponge type of wetland park based on MIKE model
16	5	Yang Yifu, Xiamen Urban Planning and Design Institute	2.7	Construction of sponge city system in historical cultural block—taking Gulangyu of Xiamen as an example; establishment of water safety system of sponge city in coastal region—taking pilot area of Xiang'an sponge city of Xiamen City as an example; planning effect analysis of sponge city in building area based on SWMM model; some reference of Melbourne water sensitive city design on sponge city planning of Xiamen; systemic research on Xiamen urban road rainwater LID based on sponge city; thinking and optimization of urban water system—taking Xiamen as an example
17	4	Lin Weibin, College of Horticulture, Fujian Agriculture and Forestry University	2.2	The enlightenment on sponge city construction of China by GI construction of New York City; rain flood management planning based on SUSTAIN model; application of low-impact development mode in landscape garden site design; planning research of campus rain flood management measure based on SUSTAIN model—taking Xiamen Campus of Fujian Agriculture and Forestry University as an example
18	4	Zhang Yajun, Beijing University of Civil Engineering and Architecture	2.2	Function analysis of low-impact development technology based on sponge city construction; test research on adsorption effect of runoff pollutant by river sand; test research on adsorption performance of runoff pollutant by common materials for pervious concrete pavement; control test of runoff pollutant by permeable concrete pavement with pipe guiding permeation and drainage
19	4	Gao Feng, Chinese Academy of Science	2.2	The construction of "sponge city" should avoid "scattered point" thinking research; resilient city is future development direction; concerning urban water eco-system; studying the waterlogging
20	4	Qiu Baoxing, Chinese Society for Urban Studies	2.2	Introducing basic connotation of sponge city and the channel of realizing sponge city, and looking ahead new technology of deepening sponge city construction
21	4	Zhao Yang, Beijing Yuren Runke Ecological Technology Co., Ltd.	2.2	The interpretation on the guideline for sponge city construction—basic concept and comprehensive target; the interpretation on the guideline for sponge city construction—target area division of total amount control of rainfall runoff; the interpretation on the guideline for sponge city construction—total amount control index of urban runoff; the interpretation on the guideline for sponge city construction—rational construction of urban rain flood storage regulation system
22	4	Che Shengquan, Shanghai Jiaotong University	2.2	Development evolution and construction channel of sponge city theory and technology; green space construction index of Shanghai sponge city and low-impact development technology demonstration; exploring application mode of "sponge city" of village along Dianshan Lake; the impact of rainwater garden structure in Shanghai region on hydrographic features of rainfall runoff
23	4	Ge Xiaoyu, Beijing Forestry University	2.2	Change because of water—rational cognition on sponge city system from the view angle of urban green system; initial exploration on construction strategy of Qian'an City rainwater harvesting type of green infrastructure system based on the guidance of sponge city construction; planning response research of urban green space system under the background of sponge city construction; landscape practice and enlightenment of American city transportation infrastructure updating

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Ranking	Literature quantity	Author information	Percentage %	Direction of research content
24	4	Fang Tao, Anhui University of Science and Technology	2.2	Design research of sunken green space under the idea of "sponge city"; exploring sunken green space design based on the idea of "sponge city"; research summary of rainwater harvesting type of sponge city construction; challenge strategy proposed by establishing rainwater harvesting type of sponge city on the teaching of landscape architecture major in the college
25	3	Xu Ping, Beijing University of Civil Engineering and Architecture	1.6	Function analysis of low-impact development technology based on sponge city construction; test research on adsorption effect of runoff pollutant by river sand; test research on adsorption performance of runoff pollutant by common materials for pervious concrete pavement
26	3	Liu Song, Tongji University	1.6	Landscape approach of sponge city based on low-impact development; transition process of Australian water sensitive city and its enlightenment; LID's application in planning and design of residential district
27	3	Li Bing, Shanghai Urban Construction Design Research Institute	1.6	Experimental study on rainwater seepage storage based on the idea of "sponge city"; studying the relationship between rainfall control rate and precipitation in sponge city construction; the thinking on special planning programming of sponge city
28	3	Zhang Yi, Northwest A & F University	1.6	Evaluation on drought resistance performances of 11 kinds of urban forest plants in Xi'ning City based on leaf anatomical structure; studying drought and cold resistance performances of 22 kinds of urban forest plants in Xi'ning City; analyzing drought resistance performance of leaf anatomical structure from 22 kinds of urban forest plants in Xi'ning City
29	3	Gao Xiaokang, Nanjing University	1.6	Smart city construction: fractal, open source and sponge; how Chinese city to go toward ecological optimization during the era of GDP increasing velocity reaching "6"; smart city: technology, function and scene
30	3	Zhang Yi, Beijing University of Civil Engineering and Architecture	1.6	Several obfuscations of sponge city construction and countermeasure analysis; exploring related concept and connotation of sponge city and urban rainwater management; obfuscation analysis of low-impact development rainwater system construction
31	3	Zhang Wei, Beijing University of Civil Engineering and Architecture	1.6	The relation and breakthrough between sponge city construction and "urban three lines"; the relationship between initial rainwater and runoff total amount control and its application analysis; rational thought on several problems of sponge city construction; standard system of urban rainwater control and use and problem analysis
32	3	Liu Yu, Beijing University of Civil Engineering and Architecture	1.6	Construction of flexible infrastructure of sponge city—taking ecological flood detention pond of Taiwan as an example; the relation and breakthrough between sponge city construction and "urban three lines"; standard system of urban rainwater control and use and problem analysis
33	3	Wang Hong, China Institute of Water Resources and Hydropower Research	1.6	Hydrological control index system of rain flood management in American city and its reference significance; basic principle of green infrastructure construction and case analysis of combining grey and green; historical evolution of deep tunnel of rain and sediment storage in American city
34	3	Li Xiong, Beijing Forestry University	1.6	Studying systemic planning of urban green space under the background of sponge city construction, and construction strategy of rainwater harvesting type of green infrastructure system in Qian'an City; rational cognition of sponge city system from the view angle of urban green space system
35	3	Bai Xue, Anhui University of Science and Technology	1.6	Challenge strategy proposed by establishing rainwater harvesting type of sponge city on the teaching of landscape architecture major in the college; studying sunken green design and sunken green space design under the idea of "sponge city"
36	3	Bian Huaying, Henan Building Materials Research and Design Institute Co., Ltd.	1.6	Talking about the technique guideline for sponge city construction; studying greening technology of building roof and utilization technology of rainwater resource in development processes of ecological city and sponge city
37	3	Hu Qingfang, Nanjing Hydraulic Research Institute	1.6	Discussing related problems of sponge city construction and thinking 5-point technology; flood problem of Chinese city and cause analysis
Total	186			

3.7 Research institutions Seen from the statistics, 40 research institutes have research result of sponge city, such as college, research institute, central functional department, design institute and enterprise. The institutes with the most research result are

Beijing Forestry University and Beijing University of Civil Engineering and Architecture, and both have 37 literatures, accounting for 8.3%. In the research institutes, there are 27 colleges (4 science and engineering 211 and 985 colleges; 4 comprehensive 211

and 985 colleges; 1 agriculture and forestry 211 and 985 colleges; 3 agriculture and forestry 211 colleges; 3 science and engineering 211 colleges; 1 comprehensive 211 college; 7 science and engineering colleges; 3 agriculture and forestry colleges and 1 comprehensive college), accounting for 70.1% ; 9 scientific research in-

stitutions, 2 central functional departments, 1 enterprise and 1 design institute, accounting for 2% , 0.4% , 0.2% and 0.2% . Seen from Table 7, main research institution of sponge city is college, involving each subject area and inducing attention of each industry.

Table 7 Statistics of research institution

Ranking	Literature quantity	Research institution	Institution type	Percentage %
1	37	Beijing Forestry University	Agriculture and forestry 211 college	8.3
2	37	Beijing University of Civil Engineering and Architecture	Science and engineering college	8.3
3	18	Tongji University	Science and engineering 211 and 985 college	4.0
4	18	Shanghai Municipal Engineering Design Institute (Group) Co. , Ltd.	Research institution	4.0
5	17	Chongqing University	Comprehensive 211 and 985 college	3.8
6	16	Peking University	Comprehensive 211 and 985 college	3.6
7	15	Shenyang Urban Planning and Design Institute	Research institution	3.4
8	14	Chinese Society for Urban Studies	Research society	3.1
9	14	China Academy of Urban Planning and Design	Research institution	3.1
10	13	Nanjing Forestry University	Agriculture and forestry college	2.9
11	12	Fujian Agriculture and Forestry University	Agriculture and forestry college	2.7
12	11	Xi'an University of Architecture and Technology	Science and engineering college	2.5
13	11	Nanjing University	Comprehensive 211 and 985 college	2.5
14	11	China Economic Herald Agency	Enterprise	2.5
15	11	Tianjin University	Science and engineering 211 and 985 college	2.5
16	10	Chang'an University	Science and engineering 211 college	2.2
17	10	Urban Planning & Design Institute of Shenzhen	Research institution	2.2
18	10	Xiamen City Planning and Design Institute of Fujian Province	Research institution	2.2
19	10	Wuhan University	Comprehensive 211 and 985 college	2.2
20	9	Ministry of Housing and Urban-rural Development of the People's Republic of China	Central ministry and commission	2.0
21	9	Southwest Forestry University	Agriculture and forestry college	2.0
22	9	Harbin Institute of Technology	Science and engineering 211 and 985 college	2.0
23	9	Northwest A & F University	Agriculture and forestry 211 and 985 college	2.0
24	9	Tsinghua University	Science and engineering 211 and 985 college	2.0
25	9	Southwest Jiaotong University	Science and engineering 211 college	2.0
26	8	Nanchang University	Comprehensive 211 college	1.8
27	8	Nanjing Tech University	Science and engineering college	1.8
28	7	General Office of the State Council of the People's Republic of China	Central authority	1.6
29	7	Tianjin Urban Planning and Design Institute	Research institution	1.6
30	7	Jiangsu Institute of Urban Planning and Design	Research institution	1.6
31	7	Lanzhou Jiaotong University	Science and engineering college	1.6
32	6	Northeast Forestry University	Agriculture and forestry 211 college	1.4
33	6	Shenyang Jianzhu University	Science and engineering college	1.4
34	6	Kunming University of Science and Technology	Science and engineering colleges	1.4
35	6	Guangxi University	Agriculture and forestry 211 college	1.4
36	6	Hohai University	Science and engineering 211 college	1.4
37	6	China Institute of Water Resources and Hydropower Research	Research institution	1.4
38	6	Dalian Polytechnic University	Science and engineering college	1.4
39	5	Shenzhen University	Comprehensive college	1.1
40	5	Zhuzhou Planning and Design Institute of Hunan Province	Design institute	1.1
Total	445			

3.8 Fund project Seen from Table 8, research theses on sponge city are from 159 fund projects (35 kinds), in which research amount of the Natural Science Foundation of China is 84,

which is the most and accounts for 52.8% , followed by Shanghai Science and Technology Development Fund Project, which is 8 and accounts for 5.1% . National Fund Project involves 101 items of 7

subjects; natural science, social science, science and technology support, science and technology project, high technology research and development program, key basic research development program, and study abroad fund, accounting for 63.5%. Beijing Fund Project is divided into four classes; natural science, science and technology development fund of education commission, technology plan and excellent talent fund, accounting for 6.9%; Shanghai Fund Project is divided into two classes; science and technology development, key project of science and technology promoting agriculture, accounting for 5.7%. Science and Technology Plan Project of Ministry of Construction contains 6 items,

accounting for 3.8%. Fund Project of Henan Province involves 4 items of two classes; science and technology project and soft science research, accounting for 2.5%. Besides State Ministry and Commission, China Postdoctoral Science Foundation, Special Science Research of Doctor Subject in Higher School, Changjiang Scholar Award Scheme, Transformation Fund of Agricultural Science and Technology Result, Shanghai, Beijing, Tianjin, Chongqing, Yunnan, Shaanxi, Henan, Hunan, Jiangsu, Jiangxi, Sichuan, Anhui, Heilongjiang, Guangdong, Fujian and Hongkong also have related funds on sponge city.

Table 8 Statistics of fund source

Ranking	Literature quantity	Fund source	Percentage//%
1	84	National Natural Science Foundation	52.8
2	8	Shanghai Science and Technology Development Fund	5.1
3	6	National Science and Technology Support Program	3.8
4	6	Science and Technology Plan Project of Ministry of Construction	3.8
5	6	National Social Science Foundation	3.8
6	4	Beijing Natural Science Foundation	2.5
7	3	Special Science Research of Doctor Subject in Higher School	1.9
8	3	Shaanxi Provincial Education Commission Fund	1.9
9	3	Henan Scientific and Technological Research Program	1.9
10	3	Beijing Science and Technology Plan Project	1.9
11	2	China Postdoctoral Science Foundation	1.3
12	2	National Key Technologies R & D Program	1.3
13	2	Guangdong Natural Science Foundation	1.3
14	2	Research Foundation of Humanities and Social Science of Jiangsu Provincial Education Department	1.3
15	2	Science and Technology Development Fund of Beijing Municipal Education Commission	1.3
16	2	Changjiang Scholars Award Scheme	1.3
17	2	Beijing Excellent Talent Fund	1.3
18	2	Transformation Fund of Agricultural Science and Technology Result	1.3
19	1	Research Foundation of Hunan Provincial Education Commission	0.6
20	1	Yunnan Natural Science Foundation	0.6
21	1	Key Research Fund of Sichuan Provincial Education Commission	0.6
22	1	Key Project of Shanghai City Science and Technology Promoting Agriculture	0.6
23	1	Jiangxi Natural Science Foundation	0.6
24	1	Jiangsu Natural Science Foundation	0.6
25	1	Research Foundation of Anhui Provincial Education Department	0.6
26	1	Heilongjiang Postdoctoral Research Start-up Foundation	0.6
27	1	Fujian Natural Science Foundation	0.6
28	1	National Study Abroad Fund	0.6
29	1	Research Foundation of Chongqing Municipal Education Commission	0.6
30	1	Henan Soft Science Research Project	0.6
31	1	Support Item of the Hongkong Research Grants Board	0.6
32	1	Tianjin Science Foundation	0.6
33	1	National Key Basic Research Development Plan(973 Plan)	0.6
34	1	National High-technology Research and Development Program (863 Plan)	0.6
35	1	Guangdong Soft Science Research Project	0.6
Total	159		

4 Conclusions

Seen from retrieval decade and included situation, since included theoretic research results on sponge city in 2004, there are 7 included databases in China, and Network Publication Library of

Chinese Academic Periodicals has the most included quantity. Seen from research field and publication quantity, the research on sponge city involves 40 subjects, in which the research in building science and engineering field is wide, accounting for 46.5%; en-

engineering field accounts for 69.8% ; economy field accounts for 20.29% ; agriculture and forestry field accounts for 1.04% ; higher education accounts for 0.09% . Seen from periodical distribution, 504 theses are respectively published in 19 kinds of periodicals, with 3 kinds of core periodicals, and others are general periodical. There are 4 kinds of construction periodicals, accounting for 27% ; 2 kinds of architectural periodicals, accounting for 12% ; 2 kinds of journals of water supply and drainage, accounting for 11.6% ; 2 kinds of building materials periodicals, accounting for 10.8% . The research of sponge city needs continuously deepening and widening each research field, which could promote theory's guidance on practice, and use practice to better impel theory's perfection and development. Seen from publication year, the research of sponge city theory conforms to the national policy, and the research on sponge city started to abruptly increase since 2014. But theoretic research of sponge city also needs systematism, and instructive research on ecological city construction in each site should be conducted. Seen from research layer of sponge city theory, natural science research layer has 1427 literatures (6 kinds), accounting for 65% ; social science research layer has 642 literatures (4 kinds), accounting for 29.3% ; the research on sponge city mostly focuses on engineering technology, industry and industry technique guidance. Seen from author information and direction of sponge city research result, researchers are mainly from each college, some design institutes and research institutes. Research content is wide, involving the interpretation on the guideline of sponge city construction, urban water ecological problem, related technical problems of sponge city construction, and the research has have certain depth and reference significance. Seen from the information of research agency, there are 40 research institutes with research result of sponge city, and college is main agency of sponge city research, involving forestry, architecture, traffic and water conservancy and hydropower. Seen from fund source, research theses on sponge city are from 159 fund projects (35 kinds), including national and provincial natural science fund projects, and national fund contains 101 items of 7 classes. As a basic national policy, sponge city construction is highly valued and supported by the state.

5 Discussions

Foreign sponge city construction extensively applies rain flood management in ecological landscape system, forming many advanced ideas and methods, with better reference significance for the measures and means of doing well water conservation, rain flood storage regulation, runoff pollution reduction and rain flood resource utilization in ecological construction of Chinese city. The domestic research and practice on flood, surface runoff control and pollution, rainwater resource utilization are conducted in sponge city construction are conducted. But considering the difference of Chinese society, economy, natural geographical environment and management system from abroad and other regions, a set of theory, method and mode of sponge city construction with regional feature must be systematically established in ecological city construction. In future ecological city construction, the authors think that sponge city

construction should enhance the research on the relationship among city development, site development and urban hydrological system, notice research's scale, level and systematicness, strengthen deep cooperation and communication among multiple professions, subjects and departments, strive for extensive participation and cooperation of social public, thereby playing huge impelling role in characteristic and ecological development of sponge city construction in each province and city of China. Seen from research field, periodical distribution, research level, author information and research institute of sponge city, the research and practice of sponge city construction have been implemented in each province and city of China. It should start from the idea of enhancing systemic theory of sponge city construction with regional feature, value suiting for the *Technical Guideline of Sponge City Construction—Construction of Low-impact Development Rainwater System*(Trial) issued by Ministry of Housing and Urban-rural Development and current city planning under rain flood management idea, sufficiently shift scholars from multiple fields, engineering technician, manager and various societies to actively devote themselves to the ecological construction of the city, drive wide participation of social public, and accelerate fast construction and sustainable development of ecological city in each area.

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