# 既有居住区海绵化改造条件调查与措施研究 ——

# 以天津市为例

# Conditions Investigation and Measures Research on Sponge Transformation of Existing Residential Areas —A Survey of Tianjin

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**摘要：**国务院办公厅提出城市建成区面积 80%以上需达到海绵建设要求的目标，给既有居住区海绵化改造提出了要求，也带来了挑战。通过对天津中心城区 32 个居住区的调研发现，虽建成年代不同，但均存在雨洪管理欠缺、雨水资源利用不足的问题，具有明显的海绵化改造需求和潜力。本文首先对天津既有居住区不同产流空间雨洪管理的现状及存在问题进行了梳理，提炼现阶段雨洪管理存在的共性问题，并以此为基础提出了相应的更新改造措施，为我国既有居住区海绵化更新建设提供有价值的参考。

**关键词：**海绵城市；既有居住区；雨洪管理；改造；天津

**Abstract:** The target of sponge city construction proposed by General Office of the State Council makes a clear request and brings challenges to sponge transformation of existing residential areas that 80%

urbanized district meets the target of sponge city construction. Based on the surveys of 32 existing residential areas from 1980to 2010 located in Tianjin center area, this paper carries out a comparative analysis on stormwater management of different residential areas. The surveys reveal the common problems that lack of stormwater management and insufficient utilization of rainwater resources, which leads to a widespread demand of sponge transformation in all residential areas from different periods. This paper firstly clears the current situations and common problems on stormwater management in different runoff spaces of existing residential areas, Tianjin. Then authors propose the corresponding transformation measures to provide valuable reference information for the sponge transformation of existing residential areas in China.

**Key words:** sponge city; existing residential area; stormwater management; transformation;Tianjin

## 1 调查研究背景分析

2015 年 11 月，国务院办公厅《关于推进海绵城市建设的指导意见》【国办发（2015）75 号】明确，通过海绵城市的建设，最大限度地减少城市开发建设对生态环境的影响，将 70 %的降雨就地消纳和利用。到 2020 年，城市建成区 20 %以上的面积达到目标要求；到 2030 年，城市建成区 80 %以上的面积达到目标要求[1]。以天津市为例，根据《2015 年城市建设统计年鉴》，以天津市建成区面积为 885 $km^2$ 计，到 2030 年牵涉的海绵城市改造面积近 700 $km^2$。区别于新区在规划建设阶段便对海绵措施应用与落地予以考虑不同，既有居住区海绵化改造存在更多难点与挑战。

既有居住区在建设之初没有考虑海绵城市建设内容，排水防涝单纯依靠市政管网，加之经过二三十年的使用，大部分管网存在排水能力不足、老化破损等问题，这直接给居住区的排水安全带来隐患。基于当今我国城市发展模式已迈入存量更新发展阶段，针对我国海绵城市建设目标，如何进行既有居住区的海绵化改造已经成为迫切需要解决的问题。本文试图从实态调查研究的角度出发，结合海绵城市建设的基本原则和策略，深入调研既有居住区排水防涝的问题，识别既有居住区能够实现“自然积存、自然渗透、自然净化”雨洪管理目标的空间条件，从而为全国更多既有居住区的海绵化改造项目提供理论和数据参考。

## 2 调查实施基本情况

### 2.1 调研对象选取

本次调查对象集中于天津市解放南路和小白楼片区的 32 个居住区，包括 20 世纪 80 年代建设的居住区 5 个；90 年代居住区 13 个；2000 年～2005 年的居住区 14 个；居住区规模从 14 000 m2～200 000 m2 不等（图 1）。调研中发现，所调研的居住区均或多或少存在着因雨洪管理欠缺所导致的建筑基础结构浸水受潮、开裂，以及场地局部积水乃至内涝等问题（图 2）。

### 2.2 调查方法确定

通过实地调研，首先，按照雨水径流产生的下垫面不同对场地空间进行分类考察和整理，将居住区室外空间分为建筑雨落管下方空间、道路和停车场空间以及绿地空间；其次，这些空间因雨洪管理欠缺所产生的问题，并通过拍照等方式记录场地现状；然后，对 32 个居住区相同类型空间的照片进行比对，提取某类空间在雨洪管理方面的共性问题；最后，对调研信息进行总结，深入探究解决相应雨洪管理问题的可能性及方式。

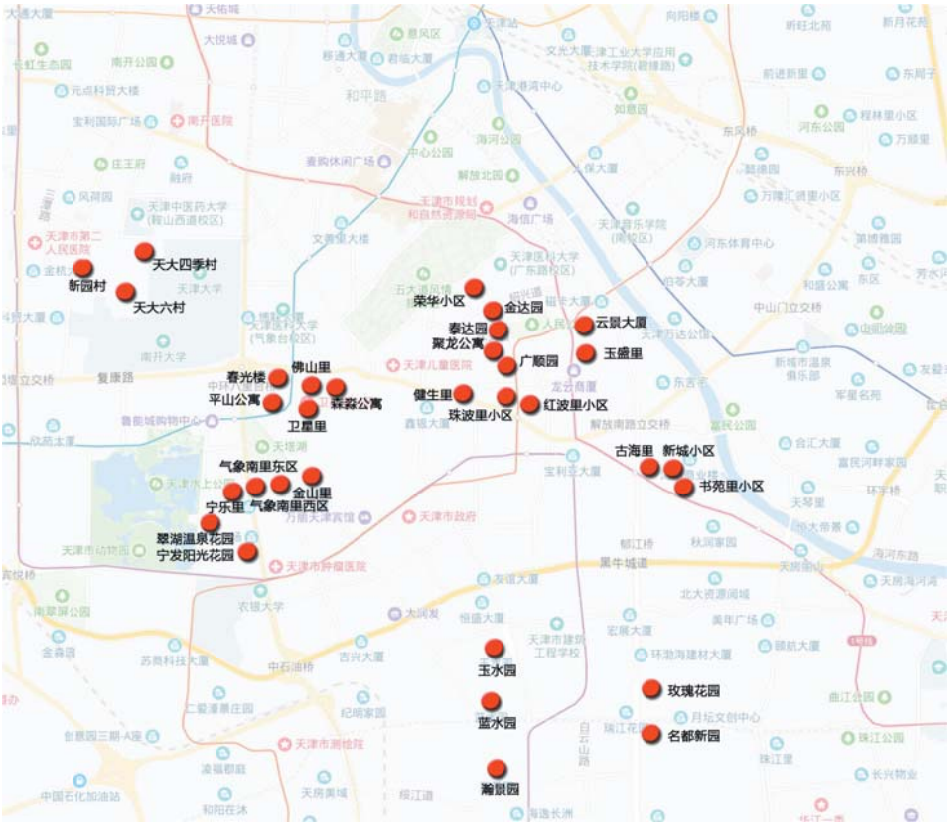
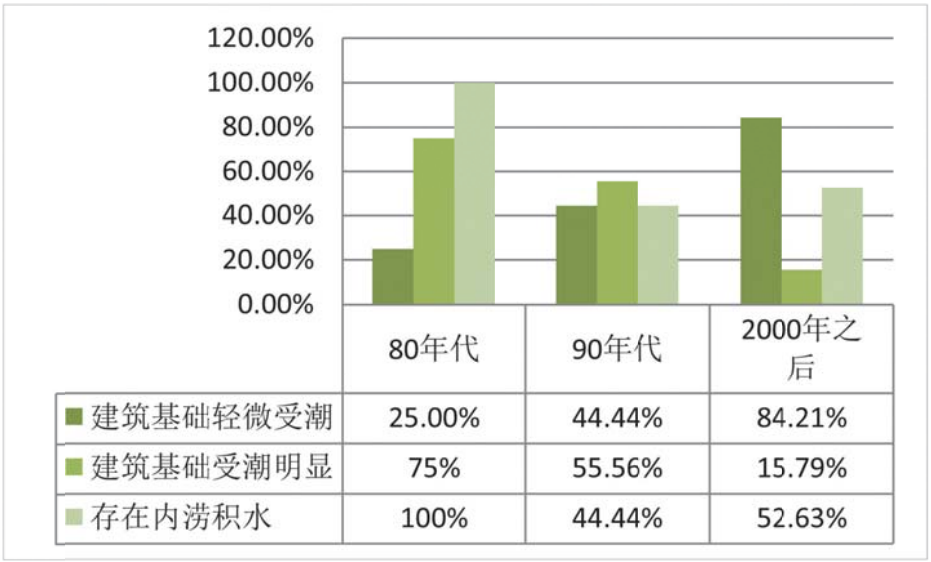



图 1 调研对象及其分布

Figure 1 Research Objects and their Distribution




| | 80年代 | 90年代 | 2000年之后 |
|---|---|---|---|
| 建筑基础轻微受潮 | 25.00% | 44.44% | 84.21% |
| 建筑基础受潮明显 | 75% | 55.56% | 15.79% |
| 存在内涝积水 | 100% | 44.44% | 52.63% |

图 2 调研居住区的雨洪管理现状

Figure 2 Current Problems of the Communities Investigated

## 3 既有居住区雨洪管理现状调查分析

### 3.1 居住区建筑屋顶雨洪管理现状调查分析

调查显示，各类居住区对建筑屋顶雨水径流的管理模式相近，即利用雨落管将建筑屋顶产生的雨水径流导流至地面。雨落管末端一般位于建筑散水上方 15 cm～20 cm 处，雨水径流从雨落管流出后，直接漫流在散水上。调查发现，这种雨洪管理方式对建筑、道路以及居民出行均产生了普遍性的负面影响。主要表现为：（1）受雨落管涌出水流长期冲刷影响，散水出现破损、开裂甚至局部塌陷等问题（图 3A）；（2）雨落管末端周围的建筑墙角乃至建筑基础受潮，呈现墙体表皮开裂等现象（图 3B）；（3）调查对象中，有 17%的建筑出入口附近设有雨落管，受雨水长期冲刷导致出入口区域地面凹陷，雨季积水问题突出，给居民出入带来不便（图 3C）。常规建筑散水修补方法为对开裂、塌陷处进行水泥砂浆灌缝或填补处理。虽处理工艺简单，但据房管部门反映，该方法时效性短。

调研过程中发现，建筑雨落管下方散水旁用地有三种类型（图 4、图 5）：

（1）小区道路用地；（2）自行车/机动车停放用地。这两种情况下，径流从雨落管中流到路面后，由于流速突然放缓，水流中所携大颗粒固体污染物沉积，极易出现路面局部淤黑现象。对于面包砖铺砌的路面，该现象尤为明显；（3）宅旁绿化用地。宅旁绿地多高于散水，被路缘石分隔，雨水径流积滞在建筑墙角，难以排出。上述三种用地类型分别占调查样本中的 17 %、57 %及 26 %。

### 3.2 居住区道路及停车场雨洪管理现状调查分析

被调查的所有居住区道路均采用灰色的雨洪管理方式，即通过道路找坡将道路雨水径流直接排放至道路沿线的市政管网中。我国居住区道路、雨水管线与建筑的平面布局关系以“楼北入户、路北排管”为主要特点，即两栋南北向住宅楼之间的空间被 2.5 m～3 m 宽的宅间小路分隔。因为绝大多数的住宅以北入口为主，所以宅间小路位于南北两楼间的南侧，并为北侧争取到了较大面积的楼间绿化。小区雨水排水管网的集水口位于宅间小路的近绿地侧，距离建筑 6 m～8 m[2]（图 6）。本次调研对象中，有 74%居住区采用这种布局模式。由此可知，雨中及雨后一段时间内，道路上的雨水除其自产径流外，还包括从建筑雨落管末端流出，漫流到道路上的雨水径流。由于既有居住区，特别是老旧小区路面破损、局部凹陷现象较多，以及路口竖向在最初施工过程中的问题，导致既有居住区路面积水点较多，给居民出行带来不便。这亦与居民访谈所了解到的积水情况相符。

此外，既有居住区由于在建设之初对机动车饱有量估计不足，导致停车位占用小区道路、公共空间、活动场地等情况严重，从而使得居住区用地紧张，这也给海绵城市雨洪管理措施的增建和改造带来难度。

### 3.3 调研结论

通过以上调研发现，既有居住区雨洪管理模式单一、缺少源头减排方式，而且存在很多共性问题，如雨落管下方缺乏源头雨洪管理措施；绿地设计缺少雨洪管理的功能设计；未能充分利用绿地、公共空间进行地上有组织排水等。这些问题不仅增加了我国居住区

的防洪排涝压力，降低了雨水资源利用率，而且也给居住区的使用年限和环境品质带来了负面影响。

调研中发现，一些住在一层的居民针对雨落管出水冲刷破坏散水以及屋顶雨水未得到充分利用的问题，采取了若干自发性改进措施。如在玫瑰花园、玉水园、星图公寓中发现，一楼住户通过接管将雨落管末端延伸至宅旁绿地中，减少对散水的冲刷，以便保护建筑墙体（图 7）；在玫瑰花园、名都新园、气象南里、平山公寓、兴军公寓等居住区中发现，住户将自家废弃的澡盆、塑料桶、油漆桶等放在雨落管下方，收集雨水，并利用其进行植物灌溉、洗车等（图 8）。这些现象不仅体现了住户对小区雨洪管理模式改造的诉求，而且其虽质朴甚至简陋的源头式雨洪管理模式给海绵化改造与建设工作带来启发。


图 3 居住区中散水、雨落管下缘排水中的现状问题

Figure 3 The Current Situation of the Building Apron and Downspout in Tianjin Community


图 4 建筑散水旁为停车空间

Figure 4 Parking Space next to the Building Apron


图 5 建筑散水旁为绿地空间

Figure 5 Green Space next to the Building Apron

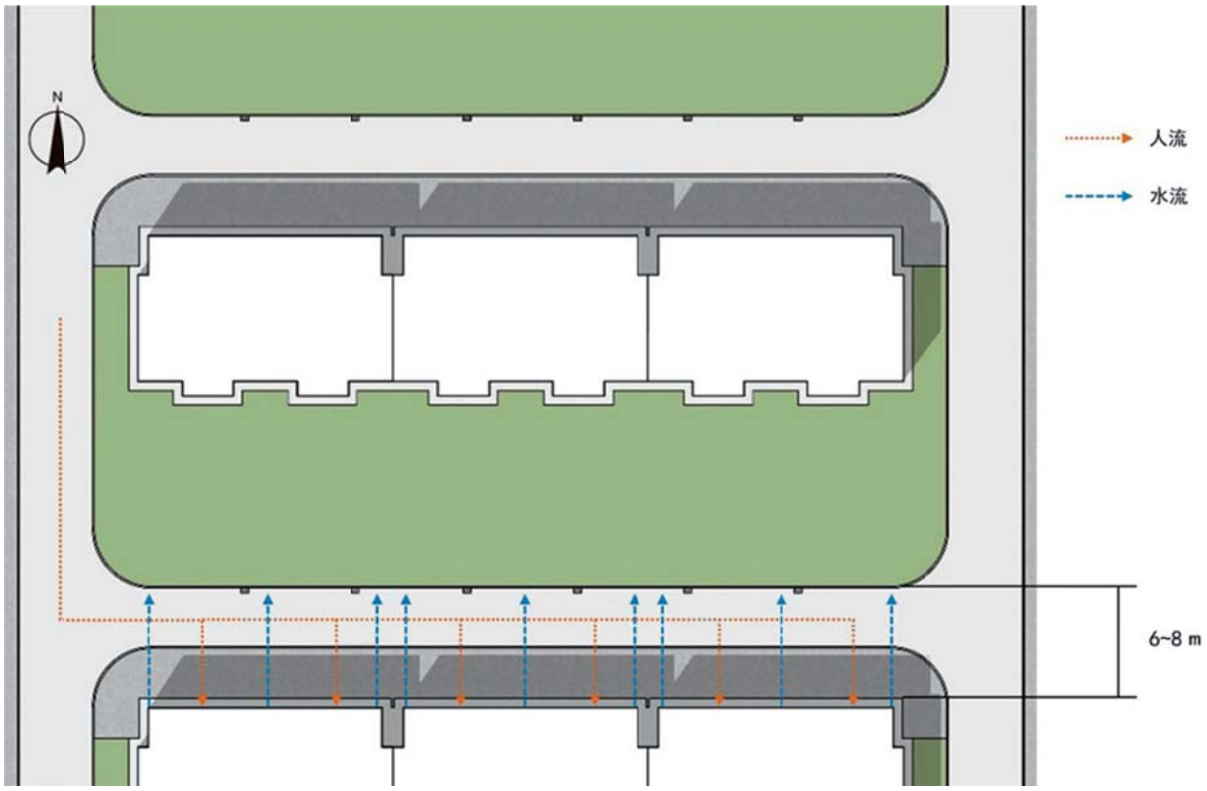



图 6 居住区建筑排水与绿地、市政管网典型布局平面示意图

Figure 6 the Typical Layout of Building Drainage, Green Space and Municipal Pipe Network in Communities

## 4 天津市既有居住区海绵化改造策略

基于对现有调研对象的分析总结，及天津既有居住区在雨洪管理方面存在的共性和个性问题，将改造策略分为通用性策略和针对性策略两类。通用性策略适用于各种居住区，

而针对性策略则需根据居住区的具体情况和改造定位制定相应的改造方案。

**4.1 针对性策略**

4.1.1 构造更新：改变传统散水模式

（1）在建筑雨落管外置的情况下，即雨落管出口高度可调节时，增设与建筑散水、结构墙合二为一的高位植台设计，使屋面雨水径流流出后直接导入种植池（图 9）。

（2）在建筑雨落管内置的情况下，即雨落管下部空间高度受限时，可采用沿散水外侧边缘设置砾石浅沟的做法（图 9），将散水上漫流的雨水径流进行集中收集，减缓流速，实现源头管理。类似做法在成都、长沙、重庆等南方城市早有使用，对于保护散水及建筑结构基础均有较好效果（图 10）。但该方式虽实现了建筑基础周围的有组织排水、短时储存径流，但是无法对径流的汇集速度加以缓滞，对于减轻市政排水管压力作用较小。通过在沟槽中置石的简单处理，便可起到减缓径流汇集速度，对径流进行前处理预沉淀的作用。

（3）采用雨落管下端设置雨水桶或混凝土砾石池的做法（图 9）。

4.1.2 就近原则：充分利用宅旁绿地进行雨洪管理

选择性去掉散水、道路等硬质铺装与绿地间的路缘石，将雨落管流出的雨水径流、道路雨水径流通过浅沟、砾石槽、暗槽以及豁口等方式导流至宅旁绿地，阻断其从屋顶、道路直排到市政管网的通道。

当宅旁绿地较宽时，特别是宽度大于 5 m 时可采取的方法：（1）可在绿地中距离建筑基础大于 3 m 远处设置下凹绿地、生物滞留池或雨水种植池等。（2）在强调景观品质营造的居住区，亦可设计带状雨水湿地式宅间绿地。（3）当宅旁绿地宽度较窄时，建议沿宅旁绿地长边及垂直绿地长边等间距设置排水浅沟或砾石沟，并通过浅沟或砾石沟将径流导流至集中的下凹绿地或地下储存设施中（图 11）。

4.1.3 建立联系：实现绿色基础设施与灰色基础设施的多级排水

秉承源头治理、灰绿耦合的基本思想，改造后居住区新的雨洪管理模式首先是截断屋面和道路径流与市政管网的直接联系，优先就地处理；如有溢流径流，再有组织地传输至绿色基础设施；最终，将仍超过调蓄容积的径流排送至市政管网系统，即实现海绵城市低影响开发雨水系统和市政排水系统的双级管理。因此，建议在居住区内增加明沟或暗槽的规划布局。最简易的方式是，

在道路两侧布设宽 50 cm～100 cm，下凹 3 cm～5 cm 的浅沟，也可根据实际情况，沿道路走向等间隔布设横向浅沟，加强地面雨水径流的有组织管理，强化源头管理与末端管理的连续性。这种模式在荷兰阿姆斯特丹、瑞典斯德哥尔摩等欧洲城市的道路排水中较为常见。此类做法既可利用预制混凝土结构单元，预留缝隙形成排水线，也可利用植物、砾石、块石铺设出浅沟。另外，由于居住区交通强度较小，根据实际情况，纵、横向浅沟也可隐藏于贯穿道路的地表雨篦之下（图 12）。

**4.2 针对性策略**

4.2.1 2000 年之前的居住区

春光楼、荣华小区、兴军公寓等居住区的特点是：道路铺装破损较为严重，且由于规划

设计之初对机动车拥有量估计不足，居住区道路两侧停车需求突出。因此，对该类居住区的海绵化改造要兼顾社区修复更新的需求，建议在对居住区路面进行整修提升时，采用透水铺装，增设生态停车场。

常用地面透水铺装主要有透水混凝土、透水砖和透水沥青三种。相关研究显示，三者透水性由好到差依次是透水混凝土、透水沥青、透水砖。在耐久性方面，透水混凝土路面的使用年限一般在 15 年～30 年，而沥青路面由于夏季容易软化、冬季容易脆裂，使用年限一般是 5 年～15 年，透水砖由于易断裂、破损且较难维护，因此其耐久性最差，其使用年限一般在 2 年～5 年。对既有居住区道路铺装进行改造时，建议根据交通强度、透水性能以及降温性能需求选择相应的透水材料[3][4]。

4.2.2 2000 年之后的居住区

2000 年之后建成的泰达园一期、玉水园、金海湾等 9 个居住区，均设有小区公园，绿地面积较大，约在 1000 m2～5000 m2。现有小区公园中的绿地具有进行集中式海绵化改造的条件和潜力。如兼顾居住区居民的活动需求进行集中式雨水花园的规划设计。典型的案例有如美国俄勒冈州波特兰市的唐纳泉社区、Hoyt 公寓区、德国柏林伦多夫区 88 号居住区、汉堡市的 Trabrennbahn Farmesen 居住区[5]等。另外，针对目前多个居住区网球场、篮球场被长期废弃，亟待整修的问题，可根据实际需求，综合考虑改造经费和成本，利用这类废弃运动场地增设地下储水设施。将居住区夏季过量雨水径流储存，供植物灌溉、社区清洁等用。但是该方式可能产生较多工程费用，并且后期需要制定规范的管理维护方法和守则。

图 7 住户自发将雨落管末端延伸至宅旁绿地

Figure 7 The Residents Spontaneously Extend the end of the Downspout to the Surrounding Green Space

图 8 住户自发对雨水径流进行收集再利用

Figure 8 The Residents pontaneously harvest rainwater to irrigate vegetable or garden


图 9 基于源头管理思想的建筑散水改造模式

Figure 9 the Retrofit Mode of Building Apron basing on the Principle of Source Stormwater Management

## 5 结语

在全国范围内积极推行海绵城市建设的大背景下，由于我国城市中既有居住区在城市中心城区中占比较大，因此，关注点不应只放在新建区的海绵性规划设计上，既有居住区的海绵化改造并兼顾不同建设年代居住区改造的通用性设计方法就显得十分重要。此外，对于既有居住区海绵化改造而言，基于大量调研所制定的系统性改造策略仅是中心城区海绵化改造策略的一个方面，相关规划设计的规范标准和执行政策亦要与时俱进，积极补充完善。

## 1 Analysis of Investigation and Research Background

In November 2015, Guiding Opinions of the General Office of the State Council on Advancing the Construction of Sponge Cities【issued by General Office of the State Council (2015) No.75】states clearly that the construction of sponge city can minimize the impact of urban development and construction on the ecological environment, and absorb and utilize 70% of the rainfall on the spot. By 2020, more than 20% of the urban built-up areas will meet the target requirements; by 2030, more than 80% of the urban built-up areas will meet the target requirements [1].

Taking Tianjin as an example, according to the 2015 Statistical Yearbook of Urban Construction, according to the construction area of 885 square kilometers in Tianjin, the area of sponge city transformation will be nearly 700 square kilometers by 2030. Different from the new area in the planning and construction stage to consider the application and landing of sponge measures, there are more difficulties and challenges in the spongy transformation of existing residential areas.

When the existing residential area was just built, the construction content of sponge city was not taken into account, and the drainage and waterlogging prevention could only rely on the municipal pipe network. In addition, after 20 or 30 years of use, most of the pipe network drainage capacity is insufficient, aging damage and other problems, which directly bring hidden dangers to the drainage safety of residential areas. Based on the current urban development model in China has entered the stock renewal development stage, in view of the goal of sponge city construction in China, how to carry out the spongy transformation of existing residential areas has become an urgent problem to be solved.

From the point of view of actual investigation and research, combined with the basic principles and strategies of sponge city construction, this paper deeply investigates the problems of drainage and waterlogging prevention in existing residential areas. Thus, this paper identifies the spatial conditions that the existing residential areas can achieve the goal of "natural accumulation, natural infiltration, natural purification", so as to provide theoretical and data reference for more spongy reconstruction projects of existing residential areas in the country.

## 2 Basic Situation of Investigation and Implementation

### 2.1 Research Object Selection

The subjects of this survey are concentrated in 32 residential areas of Jiefang South Road and Xiaobailou District in Tianjin, including 5 residential areas built in the 1980s, 13 residential areas in the 1990s, and 14 residential areas from 2000 to 2005. The size of the residential area ranges from 1.4 to 20 hectares (figure 1). It is found that the residential areas investigated are more or less due to the lack of rain and flood management caused by the building infrastructure flooding moisture, cracking, as well as local water and even waterlogging and other problems, as detailed in figure 2.

### 2.2 Determination of Investigation Method

Through the field investigation, first of all, according to the different underlying surface produced by rain water runoff, the space of the site is classified and sorted out. The outdoor space of residential area is

divided into building rain pipe space, road and parking space and green space. Secondly, it focuses on the problems caused by the lack of stormwater management in these spaces, and records the current situation of the site by taking pictures and so on. The photos of the same type of space in 32 residential areas were compared to extract the common problems in stormwater management of a certain kind of space. Finally, the paper summarizes and deals with the research information, and deeply explores the possibility and way to solve the corresponding stormwater management problems.

图 10 成都的建筑散水做法

Figure 10 The Building Apron in Chengdu

## 3 Investigation and Analysis on the Present Situation of Stormwater management in Existing Residential Areas

### 3.1 Investigation and Analysis on Stormwater Management of Building Roof in Residential Area

The investigation shows that the management mode of rain water runoff on building roof in all kinds of residential areas is similar, that is, using rain pipe to diversion rain water runoff from building roof to the ground. The end of the rain pipe is generally located at the 15-20cm above the apron of the building. After the Rain water runoff flows out of the rain pipe, it flows directly on the apron. The survey found that this kind of stormwater management has a universal negative impact on buildings, roads and residents' travel. The main manifestations are as follows: (1) Due to the long-term scour of the rain pipe, the apron is damaged, cracked and even partially collapsed (figure 3A). (2) The corner of the building wall and even the building foundation around the end of the rain pipe are wet, showing the phenomenon of wall skin cracking (figure 3B). (3) Among the subjects surveyed, 17% of the building entrances and exits were arranged with rain pipes, and the ground depression in the entrance area was caused by rain water's longterm scour. The problem of stagnant water in the rainy season was prominent, which caused inconvenience for residents to enter and leave the house (figure 3C). Generally speaking, the method of repairing building apron is to seal or fill the cracks and collapses with cement mortar. The treatment process is not difficult, but according to the housing management department, the timeliness of this method is short.

In the course of the investigation, it is found that there are three types of land next to apron under the

building rain pipe (figure 4 and 5). (1) Road land in residential area. (2) Bicycle / car parking space. In these two cases, after the runoff flows from the rain pipe to the road surface, due to the sudden slowdown of the flow velocity, the large particles of solid pollutants deposited in the flow, it is very easy to appear the local silting phenomenon of the road surface. This phenomenon is particularly obvious for bread brick pavement. (3) Green land next to the house. The green space beside the house is higher than apron, separated by curbstone, because the runoff of rain water is stagnant in the corner of the building wall, it is difficult to discharge. The above three types of land use accounted for 17%, 57% and 26% of the survey samples, respectively.

### 3.2 Investigation and Analysis on Stormwater Management of Roads and Parking Lots in Residential Areas

All the residential roads surveyed adopted grey stormwater management, that is, through the road to find slope, the road rain water runoff directly to the municipal pipe network along the road. The plane layout relationship between roads, rain water pipelines and buildings in residential areas in China is mainly characterized by "entering the house in the north of the building and arranging the pipe in the north of the road", that is, the space between the two north-south residential buildings is separated by a 2.5 to 3 m wide interhouse path. Since most of the houses are north entrance, the interhouse path is located on the south side between the north and south buildings, and has won a larger area of interbuilding greening for the north side. The water collecting port of Rain water drainage pipe network in the residential area is located near the green space side of the interhouse path, which is 6 to 8 m away from the building [2](figure 6). In this survey, 74% of the residential areas adopt this layout model. It can be seen that in the rain and a period of time after the rain, in addition to its own runoff, Rain water on the road also includes Rain water runoff flowing out from the end of the building rain pipe and overflowing to the road. Due to the existing residential areas, especially the old residential areas, there are many phenomena of pavement damage and local depression, as well as the vertical problems of the intersection in the initial construction process, resulting in more water accumulation points on the pavement of the existing residential area, which brings inconvenience to the residents to travel. This is also consistent with the situation of stagnant water found in interviews with residents.

In addition, due to the insufficient estimation of the number of cars at the beginning of construction, the parking spaces occupy the roads, public space and activity space in the residential area, resulting in the shortage of land in the residential area. This also brings difficulty to the construction and transformation of stormwater management measures in sponge cities.

### 3.3 Investigation Conclusion

Through the above research, it is found that the existing residential stormwater management model is single, lack of source emission reduction. There are many common problems, such as lack of source stormwater management measures under rain pipe, lack of functional design of stormwater management in green space design, failure to make full use of green space and public space for organized drainage on the ground, and so on. These problems not only increase the pressure of flood control and drainage in residential areas in

China, reduce the utilization rate of rain water resources, but also have a negative impact on the working life and environmental quality of residential areas.

In the investigation, it is found that some residents living on the first floor have taken some spontaneous improvement measures to solve the problems that the rain pipe water scour destroys apron and the roof rain water is not fully utilized. For example, in Rose Garden, Yushui Garden and Xingtu apartment, it is found that the residents on the first floor extend the end of the rain pipe to the green space next to the house by means of water pipes, so as to reduce the scour of apron to protect the building wall (figure 7). In residential areas such as Rose Garden, Mingdu New Garden, Qixiang Nanli, Pingshan apartment, Xingjun apartment, and so on, it is found that residents put their abandoned bathtubs, plastic buckets, plant irrigation, car washing, etc. (figure 8). These phenomena not only express the residents' demand for the transformation of the stormwater management mode in the residential area, but also the simple and even crude source stormwater management mode brings inspiration to the spongy transformation and construction work.

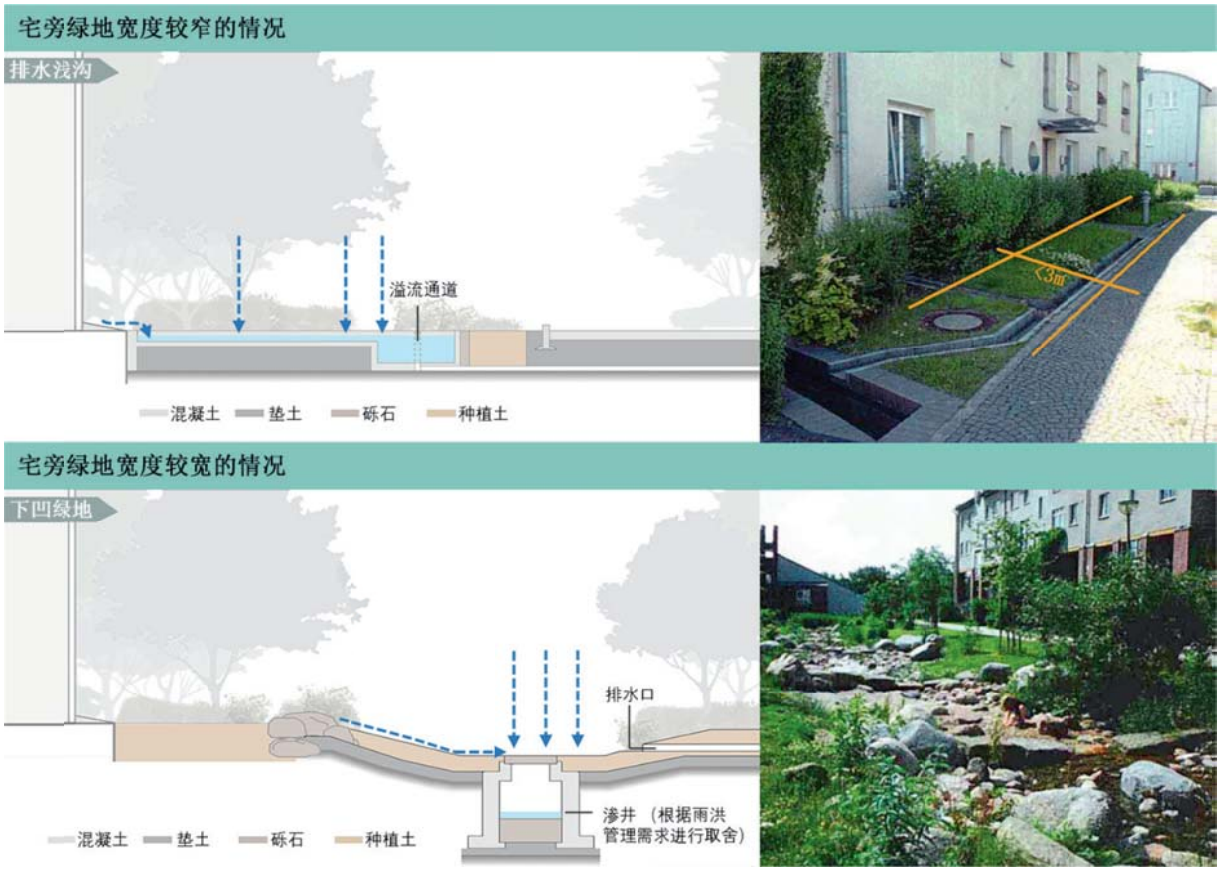



图 11 宅旁绿地改造模式

Figure 11 The Retrofit Mode of the Green Space next to the Building

## 4 Spongy Transformation Strategy of Existing Residential Areas in Tianjin

Based on the analysis and summary of the existing research objects, and based on the common and individual problems in stormwater management in existing residential areas in Tianjin, the transformation strategy is divided into two categories: universal strategy and targeted strategy. The universal strategy is

suitable for all kinds of residential areas, and the targeted strategy needs to formulate the corresponding transformation plan according to the specific situation and transformation orientation of the residential area.

### 4.1 Targeted Strategy

4.1.1 Structural Updates: Changing Traditional Apron Patterns

(1) In the case of the external placement of the building rain pipe, that is, when the outlet height of the rain pipe is adjustable, a high planting platform design which is integrated with the building apron and the structural wall is added to make the roof rain water runoff flow directly into the planting pool (figure 9).

(2) When the building rain pipe is built in, that is, when the space in the lower part of the rain pipe is limited, a gravel shallow ditch can be set up along the outer edge of the apron (figure 9). The rain water runoff on the apron can be collected centrally to slow down the flow rate, which realizes source management. Similar practices have long been used in southern cities such as Chengdu, Changsha, Chongqing, and so on, which have a good effect on the protection of apron and building structural foundation (figure 10), which realizes organized drainage and short-term storage of runoff around the building foundation. However, it is impossible to slow down the collection speed of runoff, which has little effect on reducing the pressure of municipal drainage pipe. Through the simple treatment of placing stone in the trench, it can slow down the collection rate of runoff and preprecipitate the runoff.

(3) The practice of setting up rain water bucket or concrete gravel pool at the lower end of the rain pipe (figure 9).

4.1.2 The Principle of Proximity: Making Full Use of the Green Space Next to the House for Stormwater Management

The kerb between apron, road and other hard pavement and green space can be selectively removed, and the rain water runoff and road rain water runoff from rain pipes can be directed to the green space next to the house through shallow trenches, gravel grooves, dark grooves and gaps. At the same time, it is necessary to block the access from the roof and the road to the municipal pipe network.

When the green space next to the house is wide, especially when the width is more than 5 m, (1) the concave green space, biological detention pool or rain water planting pool can be set up in the green space more than 3 m away from the building foundation. (2) in the residential area which emphasizes the construction of landscape quality, the banded rain water wet house green space can also be designed. When the width of the green space next to the house is narrow, (3) it is suggested that the drainage shallow ditch or gravel ditch should be set up along the long side of the green space next to the house and the long side of the vertical green space. Rain water runoff is directed through shallow or gravel ditches to concentrated concave green spaces or underground storage facilities (figure 11).

4.1.3 Establishing Links: Realizing Multi-level Drainage of Green Infrastructure and Grey Infrastructure

Adhering to the basic idea of source control and the combination of gray and green, the new rain and flood management mode in residential area has been reformed. The first is to give priority to local treatment to cut off the direct connection between roof and road runoff and municipal pipe network. If there is overflow runoff, it is then transmitted to a centralized green infrastructure in an organized manner. In the end, the

runoff which still exceeds the storage volume is sent to the municipal pipe network system, that is, to realize the twolevel management of sponge city low impact development rain water system and municipal drainage system. Therefore, it is suggested that the planning layout of open or dark trenches should be added in the residential area. The easiest way is to set up shallow ditches with a width of 50-100 cm and a depression of 3-5 cm on both sides of the road. According to the actual situation, horizontal shallowditches can also be arranged at equal intervals along the road direction, so as to strengthen the organized management of surface rain water runoff, while the continuity of source management and end management. This model is common in road drainage in European cities such as Amsterdam in the Netherlands and Stockholm in Sweden. The method can not only make use of precast concrete structural units, reserve cracks to form drainage lines, but also use plants, gravel and blocks to lay shallow ditches. In addition, due to the small traffic intensity of residential areas, according to the actual situation, vertical and horizontal shallow trenches can also be hidden under the surface rain grate that runs through the road (figure 12).

### 4.2 Targeted Strategy

4.2.1 Residential Areas Before 2000

The characteristics of Chunguang Building, Rong Hua Village, Xingjun apartment and other residential areas are that the road pavement is seriously damaged, and because of the insufficient estimation of the number of cars owned by residents at the beginning of planning and design, the parking demand on both sides of the road is prominent. Therefore, the spongy transformation of this kind of residential area should take into account the needs of community restoration and renewal, and it is suggested that when renovating and upgrading the pavement of residential area, permeable pavement should be adopted and ecological parking lot should be added.

There are three kinds of permeable pavement: permeable concrete, permeable brick and permeable asphalt. Related studies show that the three permeability from good to poor are permeable concrete, permeable asphalt, permeable brick.

In terms of durability, the service life of permeable concrete pavement is generally 15 to 30 years. Asphalt pavement is easy to soften in summer and brittle in winter, and its service life is generally 5 to 15 years. Because the permeable brick is easy to break, damaged and difficult to maintain, its durability is the worst, and its service life is generally 2 to 5 years. When reforming the road pavement in existing residential areas, it is suggested that the corresponding permeable materials [3] [4] should be selected according to the requirements of traffic intensity, water permeability and cooling performance.

4.2.2 Residential Areas After 2000

After 2000, the first phase of Taida Garden, Yushui Park, Golden Bay and other 9 residential areas, all with community parks, larger green space area, about in 1000-5000 m2. The green space in the existing community park has the conditions and potential for centralized spongy transformation. The centralized rain water garden can be planned and designed while the activities and needs of residents in residential areas are taken into account. Typical cases include Tangnaquan Community in Portland of Oregon in America, Hoyt apartment, 88 Rendoff in Berlin in Germany, and Trabrennbahn Farmesen Residential area

in Hamburg [5]. In addition, according to the actual demand, in the case of comprehensive consideration of reconstruction funds and costs, a number of abandoned sports venues such as tennis courts and basketball courts, which need to be renovated, can be used to add underground water storage facilities. These can be used for excessive Rain Water runoff storage in residential areas in summer, for plant irrigation, community cleaning and so on. However, this approach may incur more engineering costs, and later need to develop standardized management and maintenance methods and codes.

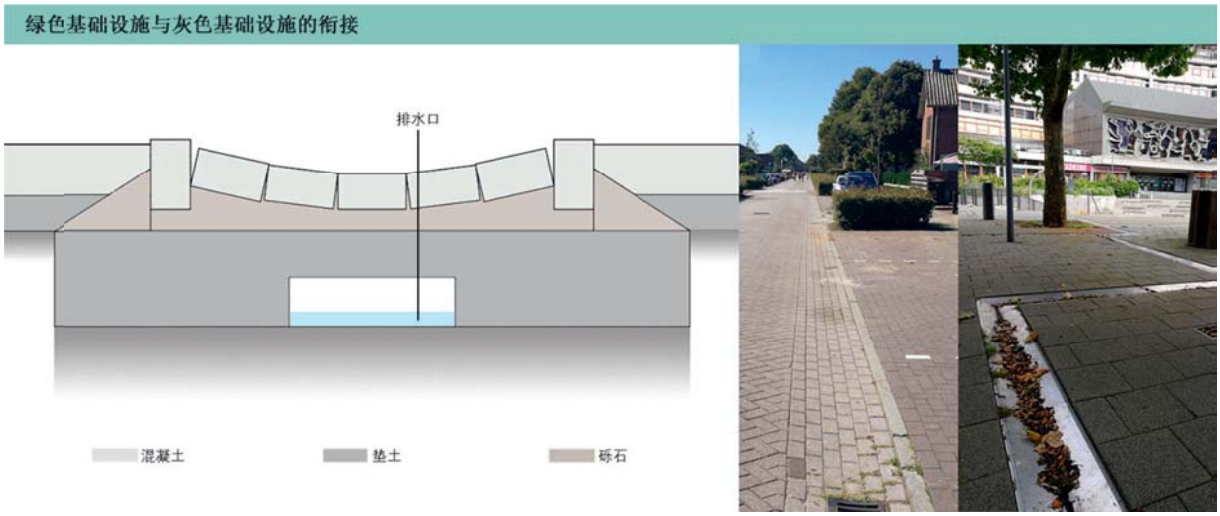



图 12 居住区道路排水改造模式

Figure 12 The Retrofit Mode of the Street Drainage in Communities

## 5 Conclusion

Under the background of actively carrying out the construction of sponge cities in the whole country, because the existing residential areas account for a large proportion in the central urban areas of our country, our attention should not only focus on the sponge planning and design of the newly built areas. It is very important that there is a universal design method for the spongy transformation of existing residential areas and taking into account the transformation of residential areas in different construction ages. In addition, for the spongy transformation of existing residential areas, the systematic transformation strategy based on a large number of investigations is only one aspect of the spongy transformation strategy in the central urban area. It is also necessary to keep pace with the times to design the relevant planning standards and implementation policies, and timely and actively supplement and improve them.

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