Stormwater Measures using Rooftop Greenings

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# Table of Contents

1. **Background**
   Environmental improvement effect of rooftop greenings

2. **Methods**
   Simulation condition and calculation formula

3. **Results**
   Stormwater runoff and characteristics

4. **Conclusion and future plan**
   Delay effect of stormwater runoff
Green Roof Construction Area (m²) from 2000 to 2007

- Single-year area
- Accumulated area

<table>
<thead>
<tr>
<th>Year</th>
<th>Single-Year Area (m²)</th>
<th>Accumulated Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>3,000,000</td>
<td>400,000</td>
</tr>
<tr>
<td>2001</td>
<td>200,000</td>
<td>600,000</td>
</tr>
<tr>
<td>2002</td>
<td>300,000</td>
<td>900,000</td>
</tr>
<tr>
<td>2003</td>
<td>400,000</td>
<td>1,300,000</td>
</tr>
<tr>
<td>2004</td>
<td>500,000</td>
<td>1,800,000</td>
</tr>
<tr>
<td>2005</td>
<td>600,000</td>
<td>2,400,000</td>
</tr>
<tr>
<td>2006</td>
<td>700,000</td>
<td>3,100,000</td>
</tr>
<tr>
<td>2007</td>
<td>800,000</td>
<td>3,900,000</td>
</tr>
</tbody>
</table>
Environmental improvement effect

Horizontal network

Vertical network

Urban heat island reduce

stormwater runoff delay

Comfort, landscape and attracting
Stormwater runoff delay effect

Introduction

Reservoir-system

Permeation-system
Typhoon
2,500.0
1,000.0
200.0
50.0
0.0

(2002~2006)

Typhoon
59 (25.21%)
Torrential rain
156 (66.67%)

Introduction

Torrential rain

Source of flood disaster in Tokyo
(1974~2006)

Rain total (mm)

Number of rainfall of over 50 mm/hour

Number of rainfall of over 100 mm/hour

Ave. 200
Ave. 234
Ave. 313

Ave. 2.2
Ave. 2.4
Ave. 5.1

Ave. 2.2
Ave. 2.4
Ave. 5.1

Ave. 2.2
Ave. 2.4
Ave. 5.1
Comprehensive flood management measures

Introduction

River improvement
- Channel improvement
- Construction of retarding basins, floodways
- Maintenance of controlled urbanization districts
- Conservation of nature
- Construction of reservoirs and regulating basins
- Installation of permeable pavements and seepage sumps
- Preservation of urbanization control zones
- Control of landhill
- Promotion of conditions favorable to agricultural activities
- Development of interior drainage facilities
- Construction of storage facilities

Runoff control
- Encouragement of use of flood-proof buildings
- Establishment of warming and evacuation system
- Augmentation of flood-fighting management system
- Promotion of conditions favorable to agricultural activities
- Development of interior drainage facilities
- Construction of storage facilities

Damage Mitigation measures
- Encouragement of use of flood-proof buildings
- Establishment of warming and evacuation system
- Augmentation of flood-fighting management system
- Promotion of conditions favorable to agricultural activities
- Development of interior drainage facilities
- Construction of storage facilities
- Encouragement of use of flood-proof buildings
- Establishment of warming and evacuation system
- Augmentation of flood-fighting management system
- Promotion of conditions favorable to agricultural activities
- Development of interior drainage facilities
- Construction of storage facilities
Seepage sumps
Storage facilities → Rooftop greening
Using some rainfall pattern, analyzing the current situation of stormwater, simulating a stormwater with rooftop greening, we could be made some conditions of land suitability forward creating “rooftop greening suitable area map”.
Case study areas are 17 blocks; Iidabashi 1, 2, 3, 4. Misaki-cho 1, 2, 3. Kudan-kita 1, 2, 3, 4. Kanda-jimbocho 1, 2, 3. Nishi-kanda 1, 2, 3.
Torrential rain

Rainfall intensity (mm/hr)

Duration of total rainfall (mm/day)

Methods

Rainfall intensity

Duration of total rainfall

4th July, 2000  78.0 mm/hr

27th August, 1993  234.5 mm/day

Average of water inundation disaster

Rainy season

Rain-intensity

Duration of total rainfall

4.2 mm/hr

100.4 mm/day
### Coefficient of discharge

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Land Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20</td>
<td>Rice field</td>
</tr>
<tr>
<td>0.50</td>
<td>Parks and greenery spaces</td>
</tr>
<tr>
<td>0.80</td>
<td>Parks and greenery spaces</td>
</tr>
<tr>
<td>0.90</td>
<td>Road</td>
</tr>
<tr>
<td>0.95</td>
<td>Other community-public facilities</td>
</tr>
<tr>
<td>1.00</td>
<td>Rivers and lakes</td>
</tr>
<tr>
<td>0.20</td>
<td>Dry field</td>
</tr>
<tr>
<td>0.50</td>
<td>Under developed land</td>
</tr>
<tr>
<td>0.80</td>
<td>Open spaces</td>
</tr>
<tr>
<td>0.90</td>
<td>Mid-to-high-rise housing area</td>
</tr>
<tr>
<td>0.95</td>
<td>Commercial-business area</td>
</tr>
<tr>
<td>1.00</td>
<td>Industrial area</td>
</tr>
</tbody>
</table>

- Rice field: Parks and greenery spaces
- Dry field: Under developed land, Open spaces
- Other agricultural land: Mid-to-high-rise housing area, Density low-rise apartment housing area
- Mountain district: Low-rise apartment housing area
- Wilderness: Commercial-business area, Industrial area, Rivers and lakes
Infiltration- impermeability distribution map
Coefficient of discharge
0.80

Efflux start time
12’37”

(Murayama et Koshimizu, 1997)

Commercial -business area
Other community-public facilities

0.95 → 0.80
Stormwater runoff

\[ Q = \frac{(C*I*A)}{3600} \quad \cdots (1) \]

Flood tide effect

\[ \bigtriangleup Q = Q_p - Q_c \quad \cdots (2) \]

Flood tide lowering ratio

\[ p = \frac{(Q_p - Q_c)}{Q_p} \quad \cdots (3) \]

\( Q \) Stormwater runoff \((m^3/sec.)\)

\( C \) Coefficient of discharge

\( I \) Average of rain intensity in arrival time \( t \) \( (mm/hr)\)

\( A \) Block area \( (ha)\)

\( \bigtriangleup Q \) Flood tide effect \((m^3/sec.)\)

\( Q_p \) Present stormwater runoff \((m^3/sec.)\)

\( Q_c \) Rooftop greening stormwater runoff \((m^3/sec.)\)

\( P \) Flood tide lowering ratio
Results

Rain intensity (mm/hr)

Rainfall finished $p$

<table>
<thead>
<tr>
<th>Elevation high</th>
<th>Elevation low</th>
<th>Building ratio</th>
<th>Rooftop area</th>
<th>time</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q$ (m³/min.)</td>
<td>8,331</td>
<td>7,805</td>
<td>6,503</td>
<td>7,988</td>
</tr>
<tr>
<td>$\Delta Q$ (m³/min.)</td>
<td>526.0</td>
<td>1,828</td>
<td>811.8</td>
<td>343.1</td>
</tr>
</tbody>
</table>

Rainfall Intensity (mm/hr)

Rainwater runoff (m³/sec.)

Stormwater runoff

Time (min.)

Elevation-high

Elevation-low

Building ratio-high

Rooftop area-large
Results

Rain intensity (mm/hr) present  elevation-high  elevation-low  building ratio-high  rooftop area-large

- Stromwater runoff (m³/sec.)
  - Elevation high: 6,942
  - Elevation low: 6,524
  - Building ratio: 5,395
  - Rooftop area: 6,297
  - Time: 780

- Rainfall intensity (mm/hr)
  - Max p: 0.120
  - AQ (m³/min.): 417.7

- Time (min)
  - Max p: 0.074
  - AQ (m³/min.): 272.5

- Stormwater runoff (m³/sec.)
  - Max p: 0.166
  - AQ (m³/min.): 644.8

- Time (min)
  - Max p: 0.388
  - AQ (m³/min.): 1,547

- Stormwater runoff (m³/sec.)
  - Max p: 0.074
  - AQ (m³/min.): 272.5

- Time (min)
  - Max p: 0.388
  - AQ (m³/min.): 1,547
Results

Rain intensity (mm/hr)
- present
- elevation-high
- elevation-low
- building ratio-high
- rooftop area-large

Stormwater runoff (m³/sec.)

Rainfall intensity (mm/hr)

<table>
<thead>
<tr>
<th>Elevation high</th>
<th>Elevation low</th>
<th>Building ratio</th>
<th>Rooftop area</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q (m³/min.)</td>
<td>995.3</td>
<td>924.8</td>
<td>837.8</td>
<td>914.5</td>
</tr>
<tr>
<td>ΔQ (m³/min.)</td>
<td>70.45</td>
<td>157.5</td>
<td>80.71</td>
<td>56.64</td>
</tr>
<tr>
<td>Time of occurrence p</td>
<td>---</td>
<td><del>240, 420</del>540</td>
<td>---</td>
<td>300~360</td>
</tr>
</tbody>
</table>
### Torrential rain
Stormwater runoff delay effect was contributed in maximum rain intensity. Due to several spatial characteristics of rooftop greening constructing conditions, the stormwater runoff was different by rainfall finished.

### Typhoon
Stormwater runoff delay effect had the greatest in maximum rain intensity. The effect was contributed at the beginning of rainfall time.

### Rainy period
Due to several spatial characteristics of rooftop greening constructing conditions, the flood tide effect and the flood tide lowering ratio showed different trends.
As results of the stormwater runoff simulation based on the several spatial characteristics, such as elevation, building ratio, and rooftop area, it was showed the rooftop greening has the stormwater runoff delay effect.

When a torrential rain, rooftop greening have a stormwater runoff delay effect at the beginning of it.
Examination of the rain intensity and the rainfall pattern to be able to expect stormwater runoff delay effect.

Setting of the coefficient of discharge and the efflux start time by the constructing rooftop greening.

Grasp the sewerage maintenance condition, the watershed features.

Forward creating “rooftop greening suitable area map”, it is necessary to the quantification of stormwater runoff delay effect by rooftop greening.
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