Road Side Drains in Urban Areas

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Abstract— Urbanization is pervasive global trend. Nearly half the world's population now resides in urban areas and that percentage is expected to increase to 60% by the year 2030. The effect of urban development has increased flood frequencies in area due to imperviousness. However, drainage infrastructure has not kept pace with the rate of population growth. In addition, studies in climate change and global warming, have led conclusion that extreme event rainfall events are likely to become more frequent in future. This has resulted in increased incidences of urban flooding followed by epidemics not only disrupting the daily life during monsoons but also affecting the overall quality of life in most of the metros in India as well as around the world. To overcome flooding problems, the design of drainage system should be effective. The study area selected is the metropolitan city, Mumbai (India). The city experienced the unpredicted rainfall of 944.2 mm in 24 hours on 26th July 2005. Extensive floods were experienced in low lying areas in Mumbai. The current paper describes the Mumbai's drainage system, design criteria and practices for effective design of road side drains for Mumbai area and presents specific management practices to handle the high monsoon discharges in metros.

Key words: Urbanization, Storm Water Runoff, Global Warming

I. INTRODUCTION

In India, out of total population of 1027 million, about 285 million live in urban areas. With increasing urbanization and the pressures of the population, the impervious areas in the metropolitan cities are increasing. Urbanization increases runoff quantity and degrades surface water quality.

The effect of suburban development on runoff characteristics are widely acknowledged to include:

- Decreased low flow and ground water discharge.
- Increased surface runoff in annual stream flow.
- Increase magnitude of peak runoff.
- Decreased lag time between rainfall and runoff response.
- Increased rate of hydrograph rise and recession.
- Decreased mean residence time of stream flow.

Thus, the quantity and quality of surface runoff are of great concern in the catchment area properties. The effect of urban development has increased flood frequencies in area due to impervious areas such as paved roads. Urban runoff also elevates levels of toxic metals and when discharged directly into water bodies, these pollutants degrade water quality and impact aquatic life and human health.

To design the actual drainage system, to avoid the flooding problem, the detailed hydrologic analysis should be carried out. In hydraulic analysis the main objective should be to estimate the maximum quantity of water expected to reach the element of the drainage system under consideration. The surface drainage system should be designed to drain away this surface runoff water safely.

The study area selected is the metropolitan city, Mumbai (India). Mumbai city having an area of 437 sq km with a population of 12 million to a complete halt owing an area to the unprecedented rainfall of 944 mm during the 24 hours starting 08.30 on 26 July 2005. At least 419 people (and 16000cattle) were killed as a result of the ensuing flash floods and landslides in Mumbai Municipal area, and another 216 as a result of floods-related illnesses. Over 100000 residential and commercial establishments and 30000 vehicles were damaged. If we exclude the area of forest and lakes, about 22% of Mumbai's land was submerged in rain waters on 26th and 27th July[6]. The current paper describes the Mumbai's drainage system, design criteria and practices for effective design of road side drains for Mumbai area and presents specific management practices to handle the high monsoon discharges in metros.

II. IMPACT OF CLIMATE CHANGE ON MUMBAI AREA

Mumbai city having an area of 437 sq km with a population of 12 million to a complete halt owing an area to the unprecedented rainfall of 944 mm during the 24 hours starting 08.30 on 26 July 2005. At least 419 people (and 16000 cattle) were killed as a result of the ensuing flash floods and landslides in Mumbai Municipal area, and another 216 as a result of floods-related illnesses. Over 100000 residential and commercial establishments and 30000 vehicles were damaged. If we exclude the area of forest and lakes, about 22% of Mumbai's land was submerged in rain waters on 26th and 27th July. According to an earlier estimate of a study conducted 10 years ago, the economic damage to Mumbai, the country's financial capital, as a result of climate change could amount to over Rs 2 lakh crore. However, since then, urbanization and investments have only gone up in Mumbai.

According to the Intergovernmental Panel on Climate Change (IPCC), the sea level is expected to rise at the rate of 2.4 millimeters (mm) per year in India. By the middle of the century the rise will be 38 centimeters (cm). This would inundate low lying areas, drown coastal marshes and wetlands and erode beaches.

It has been observed that till 1989 the average rainfall of Mumbai was 2129 mm. However, in 2005-2006 the average annual rainfall was found to be of 3214 mm, an increase of 50%. Besides the rainfall related issue, energy consumption will also be a major issue. Increase in rainfall and rise in the mean sea level (MSL), in addition to the poor drainage of the city will increase the frequency of floods. Almost one fourth of Mumbai comprises low-lying areas (below or at MSL). Therefore low-income groups and poor residents living in vulnerable locations (accounting for nearly 50% of Mumbai's population) will be affected more. A conservative estimate shows that about 40% population will be affected in the city of Mumbai. Frequent floods and salt-water intrusion will affect the structural stability of high-rise buildings, which are mushrooming at an increasing rate.

Floods, especially in the low-lying areas of the city, will result in dislocation of people and also deaths.

The average intensity for a given period is simply the rainfall depth divided by the time over which the rainfall occurs.

Rainfall data is fundamental building block for determining the amount of storm water generated during a particular event.

For the design purpose, the most important characteristics of rainfall are:-

- The depth or volume of a rainfall during a specified time interval.
- The duration of the rainfall.
- The area over which the rainfall occurs
- The temporal and spatial distribution of rainfall within the storm.
- The average recurrence interval of rainfall amount.

Rainfall data was collected from the Santacruz IMD station. The rainfall data consists of hourly rainfall in mm and peak rainfall intensity at 15 minute interval. Also maximum hourly rainfall data from the year1969 to till year 2005 was also collected from Santacruz IMD station (Table 1).

A. Rainfall Intensity

Year	Max. Rainfall mm/hr	Year	Max. rainfall mm/hr	Year	Max. rainfall mm/hr	Year	Max. rainfall mm/hr
1969	93.0	1978	43.8	1987	48.0	1996	44.9
1970	45.0	1979	45.5	1988	46.7	1997	93.0
1971	58.1	1980	60.8	1989	43.5	1998	153.0
1972	57.5	1981	43.0	1990	55.3	1990	60.9
1973	27.0	1982	47.0	1991	92.5	2000	67.5
1974	57.3	1983	42.5	1992	41.0	2001	52.0
1975	63.5	1984	67.5	1993	94.0	2002	45.0
1976	43.1	1985	63.7	1994	70.0	2003	43.5
1977	68.9	1986	36.0	1995	80.0	2004	51.4

Table 1: Measured Hourly Rainfall at Santacruz airport from 1969 to 2004

Source: ISH Symposium on cities and floods, CWPRS.

B. Recurrence Interval

The probability that a rainfall event of a certain magnitude will occur in any given year is expressed in terms of recurrence interval (also called return period or event frequency).

The relationship between recurrence interval and exceedance probability is given by:

$T = 1/P$;

Where;

T= Return period (Years);

P= Exceedance probability.

Although different design philosophies are applied in different countries, they show one common feature: storm sewers are expensive, and it is desirable to minimize the cost while maintaining a low frequency of urban flooding causing disruption to services and property damage. A risk based design, based on the probability of occurrence of a state variable (such as flow, discharge, water level) grater than the design magnitude during a specified period of time, is not yet fully developed for storm sewer design. Until now the optimization of sewer system has been expressed by the choice of the design return period.

C. Runoff / Discharge

Aspect of storm water management is estimation of urban runoff, as the urban runoff estimation plays important role in the design of storm water sewer system. First the runoff is estimated, proper design of the drainage system can be worked out by using various standard design methods to avoid floods. Also to estimate the pollutant impact estimation of the runoff is very essential as the maximum pollutants are carried away with surface runoff.

The hydrologic discharge to be drained by the system under consideration is estimated using two methods, 'Rational method' and by using the 'SCS method'.

D. Design of Drainage System

Once the design run-off is determined, the next step is the hydraulic design of drains. Assuming uniform flow in the drains, the discharge capacity of the channel has been worked out by using the Manning's Equation as follows:

$Q = A \times V = A \times 1/n \times R^{(2/3)} \times S^{(1/2)}$ Where;

Q = the quantity of runoff to be removed by the drains (m^3/s),

V = Average velocity in m/s;

A = Area of cross section of the drainage system (m^2).

n = Manning's roughness coefficient; R = Hydraulic radius (A/P);

P = Wetted perimeter;

S = Longitudinal slope of drain

E. Techniques to be used for effective SUDS and BMPs for Controlling Runoff and Storm Water Quality

Sustainable Drainage Systems (SUDS) are designed to reduce the potential of flooding on new and existing urban developments. Unlike traditional urban storm water drainage systems, they also help to protect and enhance ground water quality. SUDS use the following techniques:

- Source control
- Permeable paving
- Storm water detention
- Storm water infiltration
- Evapo-transpiration (e.g. from a Green roof)

III. CONCLUSION

Storm Water Management's (SWM) objective is essentially to safeguard health, safety and property of the citizens/ residents and to reduce inconvenience to them by having an integrated approach for developing and maintaining a system for storm water runoff which will provide better quality of life for the society. To save metro cities like Mumbai, the detailed study to provide the systematic new holding ponds/ spaces at critical locations to treat them as a part of urban space and as an integral part of the land use plans can be carried so that runoff can be controlled, the tidal effects can be sustained and flooding can be avoided, also the impacts of solids and other pollutants can be reduced in urban drainage system. Sustainable urban drainage systems should be adopted to reduce the potential of flooding on new and existing urban developments which helps to protect and enhance ground water quality. Best management practices such as porous pavements, grass buffers and swales, stream buffers and greenways, extended detention basins, wet detention ponds, constructed wetlands, spill containment facilities should be adopted to reduce flow rates and constituent concentrations in Mumbai area.

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