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Strategies For Combating Urban Floods In Bengaluru

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ABSTRACT

In the recent years, urban flooding is a menace caused by heavy rainfall overwhelming drainage capacity in urban areas. These are likely to increase if no changes are attempted for the management of urban storm water. Then, if an intense rainfall occurs, within a brief period (as the 14th August 2017 rainfall event), flash flooding may occur with little or no warning. In present study, a systematic approach has been attempted to analyse the cause for urban floods in Bengaluru and strategic solution has been suggested to combat this issue. Since 1990, Bengaluru is passing through the peak process of urbanization, because of IT invasion. In the future, the urban development is expected to add more people, hence we are likely to face the risks of flood in our city. We initiated the work with understanding the hydrological characteristics like precipitation, infiltration capacity, evapotranspiration and after removing the losses the excess runoff of 983.84mm was determined. On the other hand, the change in land use and land cover of the built-up area in the city has increased from 341.91km^2(2001) to 568.37km^2(2013), then the slope, waterbodies, etc. were mapped using geo-informatic techniques.Due to the increase in rate of floods, the strategies for combating urban floods is done by providing a smart and permanent solution to manage the excess runoff occurring in the low-lying areas of Bengaluru through GIS-RS. After all the geological, geotechnical and hydrological data regarding the SMART tunnel was collected, it is designed in one of the flood prone area, Nayandahalli for a length of 12km to carry to excess water in the tunnel that also has transportation facility during the non-monsoon periods. The tunnel is designed with all the hydrological inputs for withstanding the maximum discharge in monsoon period and the structure is designed considering all the necessary precautionary measures.Thus, new strategies designed and implemented in fast growing cities like Bengaluru to solve the emerging disaster like urban flood and the ever-increasing traffic congestion will help in making Bengaluru a smart city.

INTRODUCTION

Flood is defined as a high stage of water course i.e. river, drain or their tributary or in a water retaining body i.e. lake, pond, reservoir, seas, ocean or other low-lying areas- the level at which water over flows over its banks and inundating the adjoining areas.

fig 1.10 nayandahalli

fig 1.20 btm layout

Urban flooding is caused by heavy rainfall overwhelming drainage capacity. It already has large economic and social impacts. These are very likely to increase if no changes are made to the management of urban drainage. Urban floods are a great disturbance of daily life in the city blocking and has a large impact on economy. Though the economic damages are high, the number of casualties is usually very limited, because of the nature of the flood. The water slowly rises on the city streets. When the city is on flat terrain the flow speed is low and you can still see people driving through it. The water rises relatively slow and the water level usually does not reach life endangering heights (Aggarwal, 2014). Then, if an intense rainfall burst occurs, causing a large amount of rain within a brief period, flash flooding may occur with little or no warning.

DESCRIPTION OF THE STUDY AREA – BENGALURU

Bengaluru is situated in the southeast of the South Indian state of Karnataka. It is positioned at 12.97° N 77.56° E and covers an area of 2,190 square kilometres. According to data contained in the Bangalore Mahanagara Palike Master Plan, 40.4% of the land in the city is used for residential purposes. Transport uses 24.3% of the land, while land used for industrial, and commercial purposes comprise 6.9% and 2.7% respectively. The Pedi plains form the major part of the district underlain by granites and gneisses. Major part of the Pedi plain constitutes low relief area having matured dissected rolling topography with erosional land slope covered by a layer of red loamy soil of varied thickness. The soils of the districts can be grouped into red loamy soil and lateritic soil. The population of the city is about 1.23 crores according to 2017 census. The elevation is about 920m above sea level.

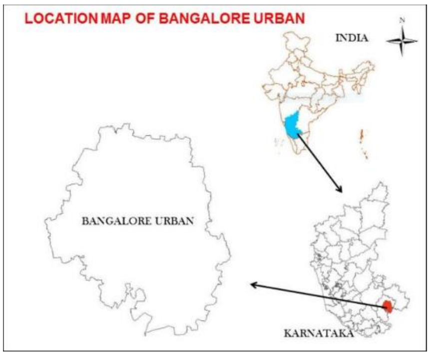

Fig 1.30 Location map of Bengaluru Urban

MATERIALS AND METHODS:

The rainfall pattern of Bengaluru urban area was studied and the data was received from KSNDMC(Karnataka State Natural Disaster Monitoring Centre) and thus it was determined that the change in rainfall pattern over the years is one of the reasons for urban flooding and which has occurred in the year 2002, 2009, 2013 and as well in 2017.

By mapping the temporal change of land use or land cover over the years it was know that the rate of unrbanization in Bengaluru has increased drastically from the year 2001 to 2013 and this change was mapped using QGIS open software data along with additional inputs like toposheets, district resource maps etc.

Finally the designing of a Smart Tunnel in one of the flood prone areas of Bengaluru i.e Nayandahalli was delineated for easy storm water disposal.

RESULTS AND DISCUSION

Hydrometeorological Studies

In this study,the hydrological investigations for the proper assessment of following factors are necessary;

- The magnitude of flood flows to enable safe disposal of the excess flow.
- The minimum flow and quantity of flow available at various seasons.
- The interaction of the flood wave and hydraulic structures, such as reservoirs, bridges and tunnels.

The estimation of annual run-off occurring in Bengaluru was carried by using the following method.Flows from several small channels join bigger channel and flows from these in turn combine to form a larger stream, and so on, till the flow reaches the catchment outlet.

This is calculated using Khosla's formula.

$$R_m = P_m - L_m$$

And $L_m = 0.48Tm$ for $Tm > 4.5°C$

Where R_m = monthly runoff in cm and $R_m \geq 0$

P_m = monthly rainfall in cm

L_m = monthly losses in cm

T_m = mean monthly temperature of catchment in °C

Monthly Temperature (T_m)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	22	24.5	26.5	28	27.5	24.5	24	24	24	24	22.5	21.5
L_m	10.56	11.76	12.72	13.44	13.2	11.76	11.52	11.52	11.52	11.52	10.8	10.32

The runoff calculation is shown in the table below:

Runoff (R_m)													
Sl.no.	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	2009	0.0	0.0	172.7	651.9	1675.2	1008.9	459.1	1260.9	2987.8	325.6	772.1	98.6
2	2010	37.4	30.1	64.2	654.3	815.3	641.5	1170.8	985.5	1221.9	815.7	1462.4	77.9
3	2011	0.0	125.0	47.3	1106.3	1506.1	511.5	945.8	2132.3	800.2	1604.9	388.7	57.6
4	2012	0.0	0.0	13.2	231.0	847.7	122.1	659.4	1129.7	351.1	836.4	1028.3	181.2
5	2013	0.0	39.4	15.2	377.1	1151.2	968.8	851.4	840.5	2505.8	1122.9	484.5	4.1
6	2014	0.0	0.0	147.9	100.1	927.4	832.9	631.7	768.5	1366.4	2400.8	313.0	36.7
7	2015	119.4	0.0	309.0	1450.7	1426.2	1021.5	519.1	1280.0	2233.5	955.8	2173.6	85.6
8	2016	58.0	0.0	34.9	53.9	1266.5	1548.2	2034.7	428.8	396.1	334.1	25.7	664.4
9	2017	0.0	0.0	181.8	258.9	2088.5	444.6	302.6	2495.0	3393.5	2447.1	95.0	178.4

Landuseand Landcover changes:

The widespread use of GIS in land management and planning and the increasing demands for land use and land cover pay attention to these differences and the need to overcome them.This software gives visual representation of statistical analysis of data in the form of thematic maps.All the thematic maps are prepared using QGIS(64bit) data along with additional inputs like toposheets, district resource maps etc.,The present study is concentrated on land use /land cover classification and its changes in Bengaluru urban area. It aims at providing land use/land cover changes over the periods of 2001-2013.

LAND USE/LAND COVER CHANGE (2001 -2013):

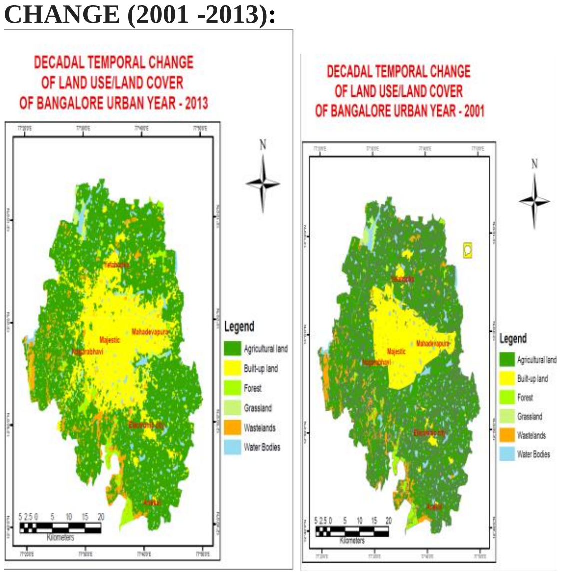

Fig.1.40Change Rate of LU/LC Since 2001 to 2013

The change is represented in the form of a table below:

These changes in land use and land cover category effect the land surface temperature pattern on the study area

Classes	Year 2001	Area in Sq. Km Year 2013	Changes	Change rate in Percentage
Water body	159.79	150.68	-9.11	-5.70
Forestland	218.75	299.77	81.028	37.04
Agriculture	2053.95	2871.72	817.76	39.81
Fallow land	1923.55	2895.10	971.55	50.50
Wasteland	4030.51	2163.41	-1867.10	-46.32
Settlement	74.54	85.20	10.66	14.30
Industry	8.04	13.11	5.06	62.96

from 2001 to 2013.

STRATEGIES FOR COMABTING URBAN FLOODS:

SMART: Managing environmental disaster requires the use of technology and how technology is used to minimize the causalities and the losses incurred when disaster strikes. This is done based on the role of smart tunnel plays as tool in flood prone areas. Here, the 'SMART' is the acronym for 'STORM WATER MANAGEMENT AND ROAD TUNNEL '. It also plays a vital role in flood disaster management and traffic congestion management. Tunnels are solution to problems of road crossing, road traffic, railway lines and canals.

Geotechnical Design Considerations: It is evident that the type and dimensions of a tunnel lining in most of civil engineering tunnels will be decided upon by the factors prior to any consideration being given to the geotechnical environment. The first point to be established is that the design of a tunnel lining cannot be considered as a structure being subjected to well-defined values of loading as there is no absolute certainty of the actual ground behavior following excavation. Thus, the problem should be considered as one related to ground and structural behavior rather than simply one governed entirely by structural features.

Hydrological Design General Considerations:

- factors which combine to determine the nature of flow in tunnels like, pressure head, shape, size, length, surface roughness of tunnel etc.
- obligatory levels of tunnels,
- cross sections: area, tunnel dimensions
- cavitation

Cross-Section: Area of cross section of a tunnel shall be of sufficient size 'to carry the maximum required flow on the head available and in addition shall conform to construction requirements.Tunnel dimensions and shape should be decided based on economic studies to obtain a most economical section. The following should be considered:

a) Velocity requirements,
b) Loss due to tunnel friction,
c) Interest charges on capital cost of tunnel,
d) Annual maintenance charges,
e) Whether lined or unlined, and
f) Cost of gates and their hoists.

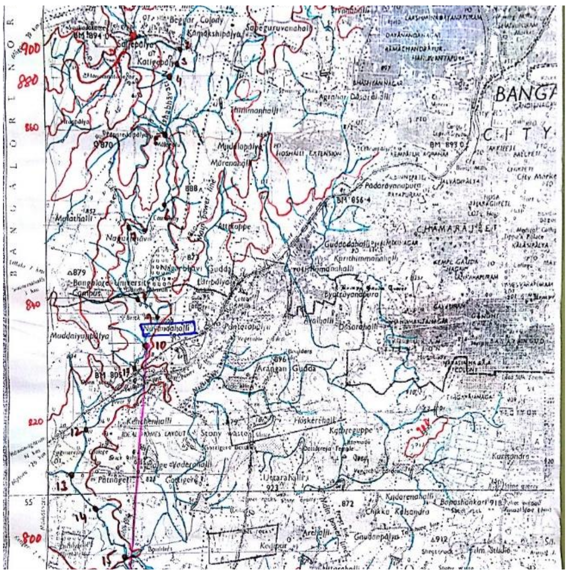

Fig.1.50 Toposheet of Nayandahalli

For our study we have selected one of the flood prone areas Nayandahalli located in south of Bengaluru. We have selected the water channels of Vrushabhavti and determined the discharge occurring in each stream that includes the sewage and domestic water. The hydraulic design was further carried out according to the procedure considering maximum rainfall, Manning co-efficient, runoff co-efficient of covered and open area.

Design Considerations

	S	1 IN 167
MANNINGS CO. EFF.	N	0.018
	1/N	55.55
	RADIUS OF TUNNEL	6m

Dimensions of Tunnel:

By calculating the wetted area and wetted perimeter the hydraulic gradient was known. Thus, the velocity at each depth and the total discharge occurring at the every 1m depth was calculated.

Structural Design: Structural design of tunnel lining requires a thorough study of the geology of rock mass, the effective cover, results of insitu tests for modulus of elasticity, Poisson's ratio, state of stress and other mechanical characteristics of the rock. The assessment of rock load on the lining and portion of the internal pressure which should be assumed to be transmitted to the rock mass will have to be done by the designer based on the results of these investigations.It is essential to have accurate idea of the seepage, and the presence or absence of ground water under pressure to be met with. Where heavy seepage of water is anticipated, the design shall make provisions for grouting with cement and/or chemicals or extra drainage holes, and consider the feasibility of providing steel lining, if necessary. It is recommended that such designs of alternate use of steel lining be made along with the design of plain or reinforce lining.

DEPTH OF FLOW		ANGLE		AREA	PERIMETER	HYDRAULIC GRADIENT	VELOCITY	DISCHARGE
h	c	ɵ	radian	A	P	R	V	Q
(m)					R*ɵ	A/P	(1/N) *R $^{(2/3)}$ *s$^{(1/2)}$	V*A
1	6.63	33.54	0.59	10.34	3.51	2.95	8.83	91.30
2	8.94	48.16	0.84	14.85	5.04	2.95	8.83	131.13
3	10.39	60.00	1.05	18.52	6.28	2.95	8.83	163.53
4	11.31	70.47	1.23	21.73	7.37	2.95	8.77	190.57
5	11.88	81.89	81.89	25.27	8.57	2.95	8.85	223.64
6	12.00	180.00	180.00	55.54	18.46	3.01	8.975	498.47
7	11.88	81.89	81.89	86.53	29.54	2.93	8.83	764.06
8	11.31	70.47	70.47	90.07	30.64	2.94	8.85	797.12
9	10.39	60.00	60.00	90.07	31.88	2.83	8.82	794.42
10	8094.00	48.16	48.16	96.95	33.41	2.90	8.77	850.25
11	6.33	33.54	33.54	101.46	36.92	2.75	8.46	858.35

The portions of a tunnel which should be reinforced, and the amount of reinforcement required depends on the physical features of the tunnel, geological factor and internal water pressure, for a free-flow tunnel normally no reinforcement need be provided, However, reinforcement shall be provided where required to resist external loads due to unstable ground or grout or water pressures.

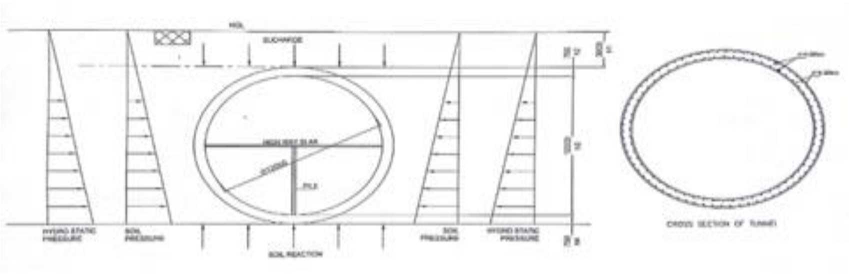

Fig.1.50 Cross section of the tunnel

CONCLUSION

The present study has been carried out to decrease the ocuurance and also effects of urban flooding in smart city like Bengaluru located at an elevation of 920m. A city with many lakes and gardens has been undergoing changes drastically over the years and this has led to enchroachments and unplanned development in the city. To overcome the effects, a systamatic approach is done, thus analysing strategies for combating urban floods. For planning requirements, it is very much essential to have knowledge about the stability of each soil that is enough to cope with the anticipated surface runoff loads was determined and thus the control of excess runoff was done.Climate change is expected to affect flooding through changes in rainfall, temperature, sea level and river processes climate change may change flood risk management priorities and may even increases the risk from flooding to unacceptable levels in some places, also due to acquizition of flood planes, improper and poor management of drainage system. Digital supervised clarification technique using QGIS has found effective for the preparation of LU/LC maps with good accuracy and thus an increase of approximatey 70% is seen in the landuse and land cover from 2001 to 2013.The LU/LC predictive modelling technique is very useful tool for planning. sustainable management strategies based on model predicted future LU/LC change scenario.Thus by analysing all the causes for urban flooding a SMART Tunnel was designed to carry forward the excess runoff which also plays a vital role not only in flood disaster management but also solves the traffic congestion.During the monsoon season, the upper layer is also used for storm water movement which is then cleaned and reused for transportation within 48 hours. Thus, the design and implementation of this type of tunnel will be promising to solve the urban floods issue and also the ever increasing traffic congestion in the metropolitan cities like Bengaluru.

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