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Iterative Methodology In the Proprtionate 'Design' Flow-Kinetics of Water Supply Network of Distribution Zones

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ABSTRACT

With the growth of infrastructure, development is now-a-days' common point of discussion. Preparation of suitable land-scape is seen here & there, everywhere; be it plateau or long terrain of varieties, it's irrespective. It's very particular when the rural places are brought to under developmental infrastructure. Design & its subsequent implementation often gets trouble over the several information of the sites under construction – it's here to be pondered on designing the distribution of the flow into the network of pipes of the urban life. This paper has explained a procedural methodology in determining the corrected flows & its distribution in designing the water supply scheme of infrastructure sector, especially the distribution network of township. There may be several methods available in the regard, but this study's method has demanded the level of precision based upon the designer's expectancy. This method has shown itself to be as flexible as modest in its handling estimation. Not only the flow-distribution be done by it, it has also the ability of finding out the efficacy of dimensional magnitudes such as length, diameter, velocity etc. With such scope of vision, this study has ended here with various cross-checks which have made the methodology discriminately more realistic & reiiable.

Keywords: Pipe flow, pressure distribution, Head loss, Hardy-cross method, Hazen-William equation, Flow optimization, Iteration procedure, Water supply, Distribution network design.

I. INTRODUCTION

In the present periods of twenty-first century, developments are a rapidly growing concern, everywhere. With the journey from our independence from the British reign, various upliftments in the sector of infrastructure have shown continuously to becoming more & more delicious & advanced. Over the years it has improved & run in a rapid pace to remain 'on the news' always with other country of this planet 'earth'. Several yojanas & planning (short-term & long-term) have been pervading over the encast valley of india's development scenario & are lighting to that at what we are today. Change is constant. Like every field the water supply sector of the infrastructure has also shown its necessity so far as the rate of development of land is concerned. Open lands, be it plain water-body or open rustic fields, are becoming a scarce source of citeful sites – it's just because of engulfment of urban over its rural adjacent. This is going to be huge in the near future showing its drastic looks.

In result of the urbanization, present cities shall reach to its capacitative saturation & by very natural cause, it then protrudes itself to its nearby rural places to accommodate its future land-scape of lives in order to become more relaxed, even for at its least magnitude.

Yearly budgeting, especially reimbursement of loan, keeps its amount to higher owing to this particular

increase of city-life. Growth-rate of urban development for the country India is rapid & it's not be of quite so unclear to grasp the hugeness & impact of development on all around. Following is the realistic data of urban growth for the country India -
Population residing in urban areas in India, according to 1901 census, was 11.4%. This count increased to28.53% according to 2001 census, and crossing 30% as per 2011 census, standing at 31.16%. According to a survey by UN State of the World Population report in 2007, by 2030, 40.76% of country's population is expected to reside in urban areas. Witnessing the fastest rate of urbanisation in the world, as per 2011 census, Delhi's population rise by 4.1%, Mumbai's by 3.1% and Kolkata's by 2% as per 2011 census compared to 2001 census[1].

In all, the progress or growth of urban as well as rural developments together are going to pamper on & engulf the most of the open lands available at present so as to meet the requirements of future lives.

Despite the fact of water-level (Ground water table) condition below the ground surface, it may now thereby be presumed that it's seldom to be on towards of fulfilling/obeying the prescribed limitation/guideline of its use authoritatively due to the rapid growth of urbanization unless the strictness be applied & enforced on all across the inhabitants on the use of groundwater. Due to the increasing population in the country, the national per capita annual availability of water has reduced from 1,816 cubic metre in 2001 to 1,544 cubic metre in 2011. This is a reduction of 15%[2].

In the 21st century & beyond, it is thereby hoped, or rather, should be hoped that the use of groundwater shall never be used after a while & much before that the authority should take steps to make regulation for each of the urban place to have their own system of water supply. It's only a small glimpse of the future demand of the infrastructure & the urban places might have already started to make themselves well equipped in advance. So, a flexible kind of water supply system is required to be necessitated to take the infrustucture to be well-capable.
In this study, the flow-kinetics required to design the distribution network of water supply have been studied. Conventionally general physicality has also been found as its crude principle as any derived mechanism always has. Subjective method in finding out the discharge, head loss etc. discussed & subsequently given is the fundamental basis of this study. Methodology of this study has its own level of usefulness towards fulfilling the subjective goals of the corresponding behaviour of flow dynamics through the water supply pipes.

GOALS OF STUDY

Followings are the basic objectives of this study -

1) Determination of the corrected flow parameter such as discharge, velocity, roughness, head-loss etc. of the flow-distribution loops.
2) Examination of the flow dynamics as described by this study through the pipe flow with regards to effectiveness.
3) Satisfactory implementation of the pipe's dimensional parameter such as diameter, velocity etc. with validity of the methodology so initiated, introduced & used in this study.

METHODOLOGY

To meet requirements at the upper floors of multi-rise or at the dead-end, it is always desirable to design the water supply network system accordingly. It's become like challenges to provide sufficient pressure heads to the far ends as the water goes away from its source of supply/storage. Head loss is always given attention to have its desired minimum design value at the most, especially at the upper floors or so.

Cost feature has its own variation on availability of several factors. Land-topography is one of the factor in the design consideration of distribution pipe network of a water supply scheme. Gravitational

nature of pipe-flow is indeed of the best priority of design engineer & is always searched of. Keeping all the related factors into consideration, the methodology described in this paper applies the general physicality & necessary dimension of use of different variables in determining the stated goals. The basic aim of this methodology is not to include all the factors specifically, but it gives knowledge & concept of how the distribution as well as the design of pipe network of a city/town under a water supply scheme/project can be well gathered & applied in ways of variety as shown by this study. There may also be inclusion and/or exclusion of one or more parameters of flow-kinetics in developing its subsequent methodology. So in general, this study has brought an insight vision regarding the correct distribution of flow & its (effective) pattern, hydraulic energy lines, velocity etc., suitably. In doing the correctness in the flow-distribution of pipe, a methodology has been described here which follows certain assumption given in the following. The conventional equation $H_L=KQ^z$ used here is a prime base to generate the methodology; where, H_L=Head-loss, Q= Discharge, z = constant, K = dimensional factor, a function of length & pipe diameter.

Besides the assumption so stated here, the common & basic know-how of conventional type remains the same & is having quite less space to get them introduced & told here. Let's start it with the discussion of the assumption & later on with its overlying methodology which is core body of this journal paper as well -

ASSUMPTION

i. The flow pipe may be flexible or rigid.
ii. Materialistic properties of the pipe, like elastic modulii, bulk modulii, temperature coefficients etc. remain constant so far a particularity of pipe-flow is concerned.
iii. The flowing fluid is incompressible – in this study, it's water flowing through the pipe.
iv. Hazen-William's equation may be used for the value of K owing to the evaluation of K, if necessary.
v. The common form $H_L=KQ^z$ has been considered for the formulation of this study's methodology.
vi. The value of the K & z is kept as conventional as used in the Darcy-Weisbach equation for the pipe network design.
vii. In the methodology, the value of H_L has been recognised as a desirable parameter – it value may be zero or anything of expected by designer's (prescribed) limits of the entire distribution network. Therefore there shall be no strictness in keeping the H_L value zero or else of fix type, on all over the pipe network anywhere or on a whole.
viii. The term 'Loop' is herein defined as a framework of pipes consisting of number of pipe-lines.
ix. The incoming flow, after getting distributed with the proportion suitably (on desired 'design' basis) into its adjoining pipes in a loop, shall tend to go to satisfy the particular condition to be fulfilled as stated in (vii) earlier – this procedure is entirely iterative till the satisfactory guideline of the design basis.

METHODOLOGY

The flow-distribution is a dutiful task of a water supply engineer. The correct & stable magnitude of the various flow-kinetics such as discharge, velocity, pipe diameter, roughness etc. express the status & life-style of the entire distribution of network of pipes for a township/metropolitan. If not properly designed, it often requires maintenance as well as renovation. In fact, the distribution of flow is the very beginning step in the design of pipe-line network of distribution zones of urban life. The distribution zones generally comprise of the area between the treated water reservoir (grounded/underground/overhead) upto the tail-ends of the domestic/industrial basin-taps of the population under the service of a water supply scheme. This entire 'design' area may be sub-divided

into various sub-areas / sub-zones. The planning of the urban life concerned is although its background basis in design. However in the design stage of the distribution network for the pipeline, it is customary to meet the sufficient pressure heads at dead-ends of the zone. In doing so, the distribution of the design flows is a matter of such task that finalises the future of the pipes as well as the status of urban life.

The distributed flows in conformance with its overburden duty of service are required to be designed in a very realistic & needful way. Also, the anticipated pressure/demand of water must be the designing criteria indeed. Keeping the entire factor in accordance, this study has described a typical procedure to have a method to design the water supply pipes of distribution network in a better of provision.

For a loop of pipe network, the total flow(Q), coming into the loop through different corners of the loop, is divided into different sub-flows of pipes using their subsequent ratios. These flows are hereby termed as distributed flows. Thereby, the equation of the Q may be given as for the n-th pipes in the loop, $Q = Q_1 + Q_2 + Q_3 + ... + Q_n$ which is also $(Q_1/Q) + (Q_2/Q) + (Q_3/Q) + ... + (Q_n/Q) = 1$. The value of Q_1 , Q_2 , Q_3 , ... , Q_n be the pipe-flows & Q be the total flow coming into the loop from various places of the loop of the pipes as inflow.

Quantity of (1/Q) is same but when it's distributed it's to be formed into (wQ_1), (xQ_2), (yQ_3), ... (uQ_n) using the certain ratio/factor & this factor is herein called as the proportionate ratio, such as w, x, y,...,u etc. This ratio may be required to be differed or of varying magnitudes amongst the pipes in order to bring the design more pragmatic & realistic. Its selection also requires experience hand or makes one experienced with the nature of urban life. In this study the application of these ratios has made the design emphasis.

Thereby, incorporation of the ratios gives the following equation of Q

$Q = (wQ_1) + (xQ_2) + (yQ_3) + ... + (uQ_n)$; subject to change of sign of each proportionate flows, depending on each pipe's flow direction considered. Here, it's to be mentioned that the direction of the flow in any pipe may be changed if the necessity on design demands & subsequent estimation of it follows accordingly.

Now, the loop is to be given the flexibility of designing mechanism for its better service to the urban life. In doing so, the sum of head-losses, H_L, around a loop should be conferred with a designed value of guidance so that each pipe of the loop bears with the contributory head-loss (or the value of KQ^z) in maintaining the design head-loss, as a whole. The sum-value of this head-loss (loop head-loss) may be zero or anything as to be desired of, as said in the assumption. In this study this value has been kept as zero. It means around a loop of the n-th pipes, $\sum H_L = 0$ which signifies $K_1(wQ_1)^z + K_2(xQ_2)^z + K_3(yQ_3)^z + ... + K_n(uQ_n)^z = 0$; where, K_1, K_2,K_3, ..., K_n be the K-value for the n-th pipes in the loop. The conditional expression of H_L is always to be after incorporating the design/desired ratios into its subsequent flows as the estimation factor of KQs, indeed. The basic aim of the methodology of this study is to reach at the desired condition ($\sum H_L = 0$) for loop system of pipe network. This is the way of the methodology said which finally fixes the ultimate values of the proportionate ratios. The result & estimation has been shown in Table 1 on how the entire determination as said here may be tabulated & defined.

The term 'loop' is a framework of pipes of the different dimension. Each pipe-flow should be estimated after giving due consideration to the direction of flow in the pipes & this shall create the +ve or -ve sign convention in the flow-estimation owing to the direction considered.

Two consequent or adjacent loops may have common pipes in between themselves; but, the design or

corrected flow for this common pipe should be first estimated loop-wise as well as by the flow-direction indeed & then determined by the iteration procedure through checking the entire pipes of the loop whether those are thoroughly meeting the criteria of the methodology stated in this study or not. This iteration procedure is first to be done for the considered direction of the pipe-flows in a loop & then adjusted & kept under alternate checking procedure as discussed in this study till the satisfaction of the reliable flow in pipe(Table 1).

Table 1. Iteration Format† of the Corrected Flow-kinetics of Pipe

Sl.	Ratios			Pipe constant			Distributed quantity of flow (sign +/-)			Head-losses (distributed)			Corrected head-loss# (designed) H_L
	w	x	y	K_1	K_2	K_3	wQ_1	xQ_2	yQ_3	$K_1(wQ_1)^z$	$K_2(xQ_2)^z$	$K_3(yQ_3)^z$	
1	1st round of estimation based on the given data(or design data)												
2	2nd iteration may start from right to left												
3	3rd iteration may start left to right & say this is the final defining stage.												

†iteration continues for subsequent loops till satisfactory attainment of the H_L.

#pipes to be checked on both sides of the common pipe simultaneously during iteration.

The entire procedural steps required in furnishing the iteration process are given as follows step-wise -

Procedure of the iteration format:

i. First select loop of pipe-flow.
ii. Assume the ratio of the total flow to be distributed, proportionately, to each pipe of the loop.
iii. Selection of these ratios at the beginning stage may be kind of childish learner; but later such preliminary 'learning' data makes the learner quite experienced.
iv. As said, the basic feature of this method follows the general equation $H_L=KQ^z$ it thereby is required to have a perspective of this while assuming the ratios.
v. The selection of the constant, say K & z, is on the designer's choice.
vi. Estimate the values of KQ^z for the different pipes/loops – after 1st round of estimation justification to be decided & determined for the common pipe, if any, in order to make the entire loops under equillibrium/stable stage.
vii. Now, determine the sum of all the values of KQ^z for the loop. Verify the equation of head-loss which may be of desired kind.
viii. It is now required to select the philosophy to bind the value of the head-loss H_L.
ix. Check the step (vi) with the step (vii) & make the balance or the equilibrium to bring the estimated H_L to its 'designed/desired' H_L - at this stage, the justification as said in step (iv) should actually start.
x. The balancing or the equilibrium determination may be forward (left to right) or backward (right to left).
xi. The number of iteration depends on the flexibility the designer wants to offer. Although the experience in doing such iteration shall not be so tough to find the ball.
xii. Evaluate the various cross-checks in order to validate & make the flow-justification more reliable & realistic. These have been termed as 'Methodology of discrimination'.

Methodology of Discrimination (checks through iteration)

Preferably, after the determination of the stable loop by its conditional guidance of the loop head-loss as feasible & realistic, the following equation & discussion shall be used as the basis to get the design values (such as ratio, head-loss factor, the pipe-flows etc.) checked & confirmed on towards becoming more satisfactory by this section of methodology of discrimination – here how the evaluated data of the corrected flows & etc. (Table 1) to be checked are discussed. Although, these below description may be done during iteration process given by the Table 1.

By applying the ratio proportioning,

$Q = wQ_1+xQ_2+yQ_3+...+uQ_n$ …(Eq. A)

where, w,x,y,...u be the value of the proportion for the 1,2,3....,n-th pipes in a loop.

The Eq.(A) is subject to change of sign convention depending on the flow direction considered.

By the general equation of the head-loss, $H_L = KQ^z$

$Q^z = (H_L/K)$ …(Eq. B)

For a loop of n-th pipes,

$H_L = K_1Q_1^z +K_2Q_2^z+K_3Q_3^z +...+K_nQ_n^z$ …(Eq. C)

Eq.(A) is now found as using the Eq.(B) in terms of the total flow Q,

$(H_L/K)^{(1/z)}=wQ_1+xQ_2+yQ_3+...+uQ_n$

$H_L = K(wQ_1+xQ_2+yQ_3+...+uQ_n)^z$ …(Eq. D)

Again from Eq.(C) & Eq.(B) in terms of H_L

$H_L = KQ^z = K_1wQ_1^z +K_2xQ_2^z+K_3yQ_3^z +... + K_nuQ_n^z$

$Q^z = (K_1wQ_1^z +K_2xQ_2^z+K_3yQ_3^z +...+K_nuQ_n^z)/K$

$Q^z = (wQ_1^z)(K_1/K) +(xQ_2^z)(K_2/K)+(yQ_3^z)(K_3/K) +...+(uQ_n^z)(K_n/K)$

$Q = (wQ_1^z)(K_1/K)^{(1/z)} +(xQ_2^z)(K_2/K)^{(1/z)}+(yQ_3^z)(K_3/K)^{(1/z)} +...+(uQ_n^z)(K_n/K)^{(1/z)}$ ... (Eq.E)

The equation of K given in the Eq.(B), Eq.(D) & Eq.(E) is given by,

$K = K_1+K_2+K_3+...+K_n$ where, K is a function of Length, dia of pipe.

In a different way, the general equation $H_L = KQ^z$ may be expressed as, $H_L \propto Q^z$; where, the sign ∝ indicates the proportionality. Thereby from this proportional relationship it should also be conferred that the change of head-loss is proportional to the change in the flow-rates in the subsequent pipe-section. Mathematically, say for pipe A & pipe B of a loop, {(Head-loss for pipe B) minus (Head-loss for pipe A)} ∝ {(Discharge for pipe B) minus (Discharge for pipe A)} ... (Eq.F)

Thereby for any two pipes in a loop, Eq. (F) should reckon the proportional relation & related adjustments in estimation of correcting the flows or head-losses that may also have to be performed & checked simultaneously in order to have the confirmation of the estimation methodology (Table 1) more well – this may be seemed as the approximate one out of the given checking processes but it gives quite more of the most firm reliability in estimating the corrected flow-dynamics.

The equation from Eq.(B), Eq.(D), Eq.(E) & Eq.(F) may be required after the entire iteration procedure is furnished. It may so happen there might be slight to moderate changes required once browsed through this discriminative section.

II. CONCLUSION

i. The iterative procedure of the methodology may be done for the purpose of the two outcomes, primarily -

a. To determine the corrected flows for the 'needful' suitable H_L.

b. To determine the corrected dia(D) for the HL for a given discharge Q.

The first one has been explained here & the latter may be discussed in future publication relating to this.

ii. The mode of evaluation of the corrected flows as described in this paper may also be done graphically by plotting H_L vs. D (for given Q) & H_L vs. Q – both of these may aim for to attain at the desired/designed H_L value. By graphical application, the desired (derived) 'proportional' values of the various flow kinetics of distribution networking may be selected after suitable & reasonable justification of the flow-mechanism or flow-values, one of which has been discussed in the Table 1..

iii. It is evident that correction factor, as deduced in the Hardy-Cross procedure, is not needed here.

Instead, the correction here has been done by the iteration procedure as discussed in this study.

iv. Any approximation hardly appears with almost little chance of fallibility to determine the corrected flows by the procedural easeness of this study for finding more swift, flexible & precisive value of the flows.

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IV. REFERENCES

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