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Corrective Methods for Pressure Calculation Procedures in Drinking Water Supply for High-Rise Buildings (S+R+6) in Bamako

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Abstract

The drinking water supply (DWS) of high-rise buildings represents a major technical challenge in many African cities, particularly in Bamako. The pressure deficiencies observed in S+R+6 type buildings result not only from the limitations of the public distribution network but also from design, calculation, and execution errors in internal water supply installations. This paper analyzes conventional pressure calculation methods used in building drinking water supply networks and highlights their shortcomings in the Malian context. A corrective approach to pressure calculation at the most unfavorable draw-off point is proposed, incorporating the actual pressure downstream of the water meter, underestimated linear head losses, and hydraulic constraints specific to local networks. In addition, special emphasis is placed on the impact of the lack of qualification of workers and technicians involved in sanitary installations, a frequently overlooked but decisive factor in system failures. The results show that adjusting calculation parameters, combined with improved technical skills of installers, can ensure sustainable, comfortable, and economically efficient operation of drinking water supply systems in high-rise buildings in Bamako.

Keywords: Drinking Water Supply; Pressure; High-Rise Buildings; Head Losses; Bamako; Workers' Qualification

1. Introduction

Water is an essential resource for life and socio-economic development. Its availability, quality, and accessibility directly influence public health, population comfort, and the sustainability of urban environments (Cissé, 2006; Fischer et al., 2011). Although the Earth is often referred to as the "blue planet" due to the global abundance of water, a significant proportion of the world's population still lacks reliable access to safe drinking water (Belhadji, 2017).

In Mali, despite the existence of exploitable water resources, drinking water supply remains insufficient in both quantity and quality. This situation is particularly acute in rapidly densifying urban areas, where the construction of multi-storey buildings exceeds the hydraulic capacity of public distribution networks. In Bamako, water pressure becomes insufficient as early as the second or third floor, leading to frequent shortages, equipment degradation, and persistent discomfort for users.

The difficulties in supplying drinking water to high-rise buildings in Bamako arise from multiple combined factors. The public distribution network, generally limited to pressures around 3 bar, is not designed to efficiently supply buildings exceeding R+2 or R+3. In addition, design practices are often based on foreign standards without sufficient adaptation to local conditions.

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Furthermore, the sanitary plumbing sector is characterized by a high proportion of unskilled or poorly trained labor. Installations are frequently carried out without strict adherence to calculation rules, recommended pipe diameters, or allowable flow velocities, thereby increasing head losses and reducing pressure at the most unfavorable draw-off points.

In this context, the present study aims to critically analyze classical pressure calculation methods used in building drinking water supply networks and to propose methodological adjustments adapted to local conditions, while emphasizing the central role of workforce qualification in installation performance.

2. Methodology

2.1. Presentation of the Study Area

Bamako, the capital of Mali, is located in West Africa at approximately 12°40′ north latitude and 7°59′ west longitude. Crossed by the Niger River, the city extends over a varied relief characterized by plateaus, hills, and extensive plains, with an average altitude of about 330 m. Its tropical climate, marked by a long dry season and a concentrated rainy season, combined with strong demographic and urban growth, places significant pressure on drinking water infrastructure. The concentration of high-rise buildings along the river, often beyond the hydraulic capacity of the public network, exacerbates pressure and water distribution problems. In this context, mastering hydraulic calculations, adapting design methods, and ensuring proper installation quality are crucial to achieving reliable drinking water supply in multi-storey buildings in Bamako.

2.2. General Approach

The adopted methodology is based on a critical analysis of classical pressure calculation formulas, followed by a proposal for adjustment that takes into account the actual operating conditions of drinking water supply networks in Bamako. The approach includes:

- Estimation of users' water demand;
- Selection of an appropriate distribution system;
- Pipe sizing based on peak flow rates;
- Verification of flow velocities and pressure at the most unfavorable point.

2.3. Conceptual and Normative Framework for Pressure Calculation

Conventional methods for sizing building drinking water supply networks rely on normative documents such as DTU 60.1 and DTU 60.11, primarily developed in the European context. These documents propose a general formula to estimate available pressure at a draw-off point by considering meter pressure, head losses, elevation difference, and in-line equipment.

However, several authors have noted that while these approaches are theoretically robust, they exhibit limitations when applied without adaptation to contexts where supply pressure is unstable and workmanship quality is variable (Nya, 2020; Rony, 2021).

2.4. Limitations of the Classical Formula

The conventional pressure calculation formula considers the pressure at the water meter as a quasi-constant parameter. In practice, however, this pressure often corresponds to a nominal value provided by the manufacturer and does not reflect the actual pressure under flowing conditions. This approximation can lead to significant errors, particularly in high-rise buildings.

2.5. Proposed Corrective Method

To overcome these shortcomings, a corrective method is proposed. It introduces the actual pressure downstream of the meter and more accurately accounts for linear and local head losses. The objective is not to replace the classical formula but to pragmatically adjust it in order to improve the reliability of results under local conditions.

2.6. Consideration of the Human Factor

A fundamental aspect of the methodology is the consideration of the human factor. The lack of qualification among workers and installers frequently leads to execution errors such as inappropriate pipe diameters, defective assemblies, or non-compliance with allowable flow velocities. These practices increase head losses and compromise overall system performance, regardless of the theoretical accuracy of calculations.

3. Results

3.1. Application of the Classical Pressure Calculation Formula

The application of the main formula classically used to calculate the pressure at the most unfavorable draw-off point, given by Equation (1):

$$P_r = P_{co} - \Delta P - P_h - P_z \qquad \text{(Eq. 1)}$$

was carried out on S+R+6 type buildings located in Bamako and directly supplied by the public distribution network. The pressure values at the water meter P_{co} observed in the field range between 2.5 and 3.0 bar, in accordance with the data provided by the distribution service.

Linear head losses were calculated using the following expression:

$$\Delta P = 1.25 \times \sum(R_i \cdot L_i) \qquad \textit{(Eq 2)}$$

where R_i represents the unit head loss and L_i the length of the considered pipe section.

The results show that, for the upper floors (R+5 and R+6), the calculated residual pressure P_r becomes lower than 0.3 bar, which is the minimum threshold required for the normal operation of sanitary appliances. In some cases, the calculated pressure even becomes negative, indicating a theoretical impossibility of supply.

By spreading over the surface of a pipe (which is solid), the flow generates head losses that constitute an omnipresent phenomenon in the daily practice of fluid mechanics, whose control is a major challenge (R. L. Lhermerout, 2016).

These results confirm a clear inadequacy of the classical formula when applied without adjustment in the context of Bamako.

3.2. Introduction of the Actual Meter Pressure and Corrected Head Losses

In order to overcome the observed shortcomings, the proposed adjusted formula was applied:

$$P_r = P'_{co} - \Delta P' - P_h - P_z \qquad \text{(Eq.3)}$$

with:

$$\Delta P' = 1.25 \times \sum(R_i \cdot L_i) + PDCL \qquad \text{(Eq.4)}$$

and the actual meter pressure given by:

$$P'_{co} = \frac{(P_{ref} - P_{real})}{P_{real}} \times 100 \qquad \text{(Eq.5)}$$

Field measurements revealed an average pressure loss of 0.3 bar at the main meter, a value that is not explicitly taken into account in the classical method.

After integrating this correction, the calculated pressures at the most unfavorable draw-off points range between 0.4 and 0.7 bar. These values are compatible with acceptable equipment operation, although they remain marginal in terms of optimal user comfort.

These results demonstrate that adjusting the reference pressure significantly improves the consistency between theoretical calculations and real observations.

Logically, pressure and flow rate remain directly related, since the pipe cross-section increases the flow rate Qduring flow; therefore, the larger the pipe, the higher the pressure, while velocity decreases. However, the adopted approach, which assigns a permissible velocity range for each diameter Ddepending on the pipe material, is justified by the need to integrate these three fundamental flow parameters.

As flow spreads over the internal surface of a pipe, it generates head losses that represent an omnipresent phenomenon in fluid mechanics, whose control remains a major technical challenge (R. L. Lhermerout, 2016).

3.3. Flow Velocity and Workers' Qualification

The peak flow rate was calculated using Equation (6):

$$Q_p = \sum q \cdot k \qquad \text{(Eq.6)}$$

and pipe sizing was performed using:

$$Q = v \cdot S \qquad \text{(Eq. 7)}$$

Velocity verification was carried out considering the maximum allowable velocity:

$$\omega = \begin{cases} 7d & \text{for } 10 \leq d \leq 16 \text{ mm} \\ 6.6d & \text{for } 17 \leq d \leq 22 \text{ mm} \\ 6.3d & \text{for } 23 \leq d \leq 33 \text{ mm} \\ 6.2d & \text{for } 34 \leq d \leq 40 \text{ mm} \\ 2.5 & \text{for } d \geq 40 \text{ mm} \end{cases} \qquad \text{(Eq.8)}$$

The results show that, in several inspected installations, the actual velocities $v_c$exceed the admissible limits ($v_c > \omega$), mainly due to undersized pipe diameters.

These errors are strongly correlated with the lack of worker qualification, as installers often favor empirical choices over hydraulic calculation rules. Observed consequences include increased head losses, noise, and premature equipment wear.

Moreover, the intrinsic behavior of flow in a pipe resulting from a thermal activation phenomenon follows a logarithmic trend, which directly affects flow force (T. D. Blake et al., 2002; M. Ramiasa et al., 2013). This major observation emphasizes that workforce quality and thermal factors remain decisive elements.

4. Discussion

4.1. Application of the Classical Pressure Calculation Formula

The results obtained from the classical formula (Eq. 1) highlight its limitations in an urban context characterized by low service pressures. Considering a nominal and constant meter pressure leads to an overestimation of the available downstream pressure.

For S+R+6 buildings in Bamako, this assumption proves to be unsuitable, as cumulative head losses and geometric height almost completely eliminate residual pressure. These observations confirm that the unadjusted application of normative methods, without local adaptation, may lead to technically unviable designs.

Razaki B. (1889), in his work on the drinking water supply of a building in Dakar, already demonstrated that in cases of insufficient pressure, the network layout should be revised to reduce head losses. When the layout is optimal, a pump should be selected to supply a storage tank whose useful volume is calculated based on the number of occupants and daily per-capita domestic water demand.

Debacq M. (2019), in his publication *Mechanical Fluid/Solid Separation*, emphasized that for each pipe material and type of water supply system in a building, a detailed calculation report specifying dimensions is required.

4.2. Introduction of the Actual Meter Pressure and Corrected Head Losses

Introducing the actual meter pressure and explicitly adding corrected linear head losses constitutes a major methodological improvement. The results show better agreement between calculations and the actual operation of installations.

This corrective approach not only anticipates pressure deficits but also technically justifies the use of alternative solutions such as booster pumps or autonomous systems. It follows a pragmatic logic of adapting international standards to local hydraulic realities.

D. Seveno et al. (2009), in *Dynamics of Wetting Revisited*, showed that detailed calculation notes must be produced during the concrete design of building distribution networks, not only to protect users from water shortages but also to better preserve materials.

These findings are consistent with those of H. Vasilchina and J. G. Petrov, who stated that pressure and flow rate must always be linked by applying at least two calculation methods for each parameter and then combining them for adjustment.

4.3. Flow Velocity and Workers' Qualification

The observed exceedances of allowable velocities underline the decisive role of installation execution. Even when theoretical calculations are correct, poor workmanship cancels out the benefits of proper sizing.

The lack of worker qualification thus appears as an aggravating factor in drinking water supply problems in high-rise buildings. Insufficient technical training leads to inappropriate diameter selection and poor understanding of velocity criteria, thereby increasing head losses and reducing available pressure.

These results corroborate those of Thomas Grillot (*Study of the Dynamic and Two-Phase Behavior of a Fluidized-Bed Classifier*), who highlighted the role of bulk viscosity in expressing the resistance of particles to expansion or compression. This bulk viscosity, still insufficiently understood, is the subject of ongoing research and must be continuously adjusted.

Such adjustments should focus on the following parameters:

(i) pipe material type, (ii) building climatic conditions et (iii) qualification and technical mastery of installation personnel.

Overall observations confirm that sustainable improvement in hydraulic performance depends as much on rigorous calculations as on the professionalization of field actors.

5. Conclusion

This study highlights the need to adapt classical pressure calculation methods to the local realities of African cities, particularly Bamako. The proposed corrective approach enables a more realistic estimation of available pressure and contributes to more reliable sizing of drinking water supply installations in high-rise buildings.

However, these technical improvements must be accompanied by:

- training and certification of sanitary plumbing workers and technicians;
- improved supervision and quality control of construction works;
- adoption of autonomous distribution solutions for buildings exceeding the capacity of the public network.

The combined implementation of these measures will ensure user comfort, reduce operating costs, and extend the service life of drinking water supply equipment.

Compliance with ethical standards

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No conflict of interest to be disclosed

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