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Capillarity-Induced Rising Damp

Highlights

Assessment of Risk Management

Finite Element Model for Prediction

Discovering Thoughts, Inventing Future

VOLUME 26 ISSUE 1 VERSION 1.0

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By Mtaver Gwaza

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I. Introduction

Moisture ingress through building envelopes remains a prominent challenge for building performance and occupant comfort, particularly when driven by capillary action in low-level walls—a phenomenon commonly referred to as rising damp. When capillary forces transport groundwater or soil-moisture upward into porous masonry, the resulting elevated moisture content can degrade material durability, promote mould growth, and alter thermal behaviour of the envelope (Hall & Hoff, 2007). In tropical and humid climates, where groundwater levels are often high and rain-driven wetting intense, the consequences of rising damp may extend beyond durability to affect energy performance, but this linkage remains under-explored.

The town of Makurdi (LGA), in Benue State, Nigeria, presents a relevant case for investigating such interactions. Situated in the lower Benue River valley, Makurdi lies within a low-relief flood-plain environment where large portions of the built area become water-logged during heavy rainfall and exhibit high groundwater recharge. For example, geotechnical and hydrological studies indicate the town's drainage is dominated by the river and tributary system, the elevation ranges from approximately 64m to 167m above sea level, and rainfall totals range between roughly 1,190 to 1,792 mm annually. The building stock in Nigeria, and by extension in Makurdi, often uses sandcrete block wall assemblies, which research shows may suffer from high water-absorption coefficients and sub-standard quality under local production practices (Odeyemi, Akinpelu, Atoyebi, & Orire, 2018). Together, the combination of high moisture hazard (through rainfall and groundwater) and commonly used porous wall assemblies create conditions that are likely conducive to capillarity-driven moisture ingress.

Despite this plausibility, there is a paucity of studies that explicitly examine how rising damp and capillary moisture movement within wall assemblies affect building thermal behaviour and cooling energy demand in humid tropical residential settings. Most research has focused on material durability (e.g., absorption, strength of sandcrete blocks) or indoor thermal comfort for various wall materials (e.g., Okereke & Ike, 2025) but stops short of linking moisture ingress to energy performance. Therefore, this study seeks to bridge that gap by investigating the relationship between capillarity-induced wall moisture and energy performance of residential buildings in Makurdi LGA. The specific objectives are: (1) To quantify differences in wall moisture content, indoor thermal/humidity conditions, and cooling energy use between buildings exhibiting evident rising damp and those with minimal or

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no damp manifestations. (2) To analyse how increased wall moisture alters the thermal conductivity and envelope behaviour of sandcrete-block walls. (3) To identify construction typologies and maintenance-history factors most vulnerable to moisture ingress and consequent energy penalty.

The paper contributes new empirical evidence to an under-researched interface of building pathology and energy performance in tropical architecture. Practically, it offers insights for architects, builders and policymakers on designing, constructing and maintaining more energy-efficient, resilient housing in humid zones. Socially, the findings draw attention to how effective moisture control can influence occupant comfort, building energy use and ultimately quality of life in tropical urban settings. The remainder of the paper is structured as follows: Section 2 presents the conceptual and theoretical framework linking capillary moisture movement and envelope thermal/energy performance; Section 3 reviews relevant literature; Section 4 describes the study area, research design and methods; Section 5 presents results and analysis; Section 6 discusses the implications; and Section 7 concludes with summary, contributions and recommendations.

II. Conceptual and Theoretical Framework

Moisture movement in building envelopes, particularly via capillarity, and its subsequent effect on the thermal and energy performance of residential buildings can be understood through a multi-layered conceptual model. First, porous wall materials in contact with moist soil or groundwater absorb liquid water driven by capillary forces. Second, the increased liquid water content and associated vapour processes within the material's pore network modifies its hygrothermal (i.e., combined heat and moisture) behaviour. Third, these modifications alter the envelope's heat transfer characteristics (in conduction, convection, and latent heat terms), thereby influencing indoor thermal/humidity conditions and, ultimately, cooling (or heating) energy demand.

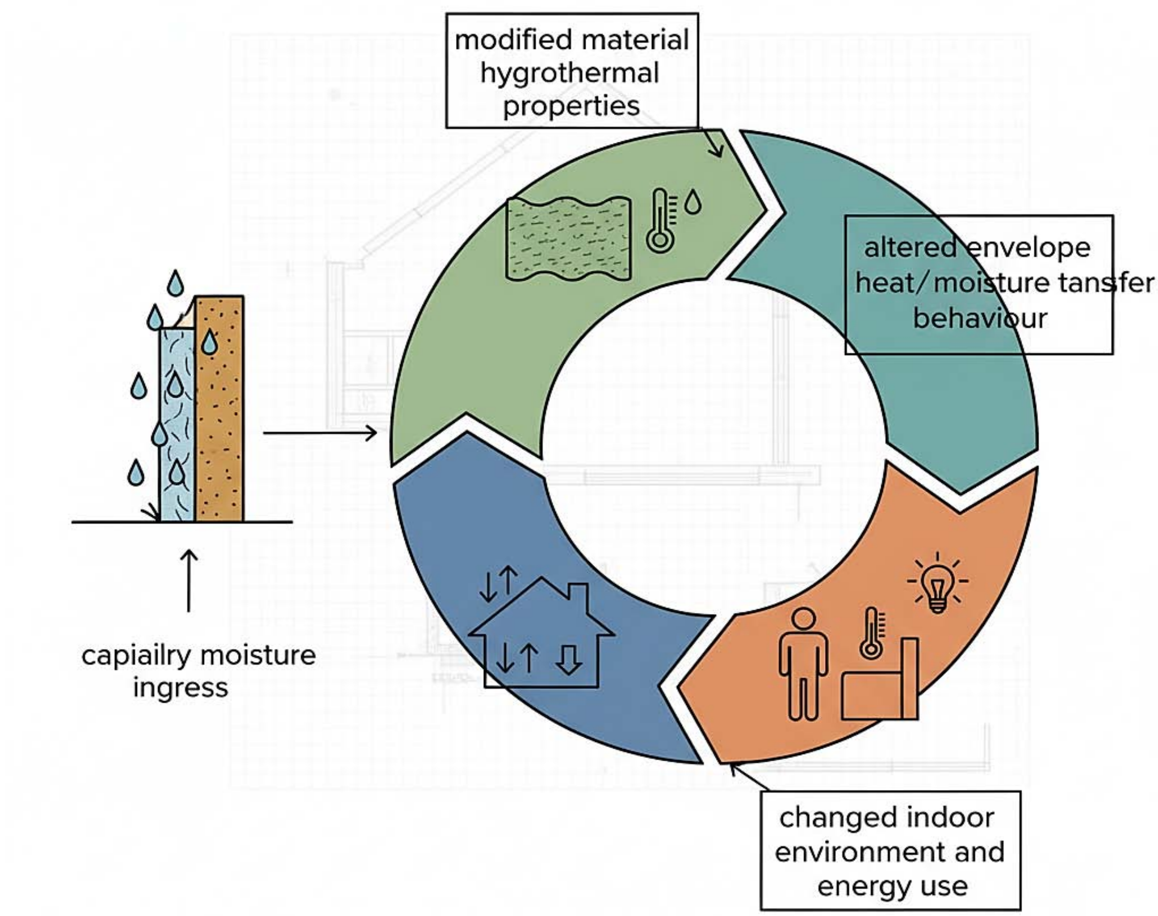

Figure 1: Capillary moisture ingress → modified material hygrothermal properties → altered envelope heat/moisture transfer behaviour → changed indoor environment and energy use

a) Capillary Rise in Porous Building Materials

Capillary rise is the mechanism by which liquid water from a wet substrate (soil, groundwater) is drawn upward into porous masonry or block work due to surface tension and adhesive forces overcoming gravity. In a simplified cylindrical pore, Jurin's law describes the height of rise *h* as:

$$h = \frac{2\,\gamma\,cos\theta}{\rho g r}$$

where γ is the surface tension of water, θ the contact angle, ρ the density of water, g gravitational acceleration, and r the effective pore radius. Fine-pore materials (small r) are therefore more prone to higher capillary rise. (See *Figure 2*.)

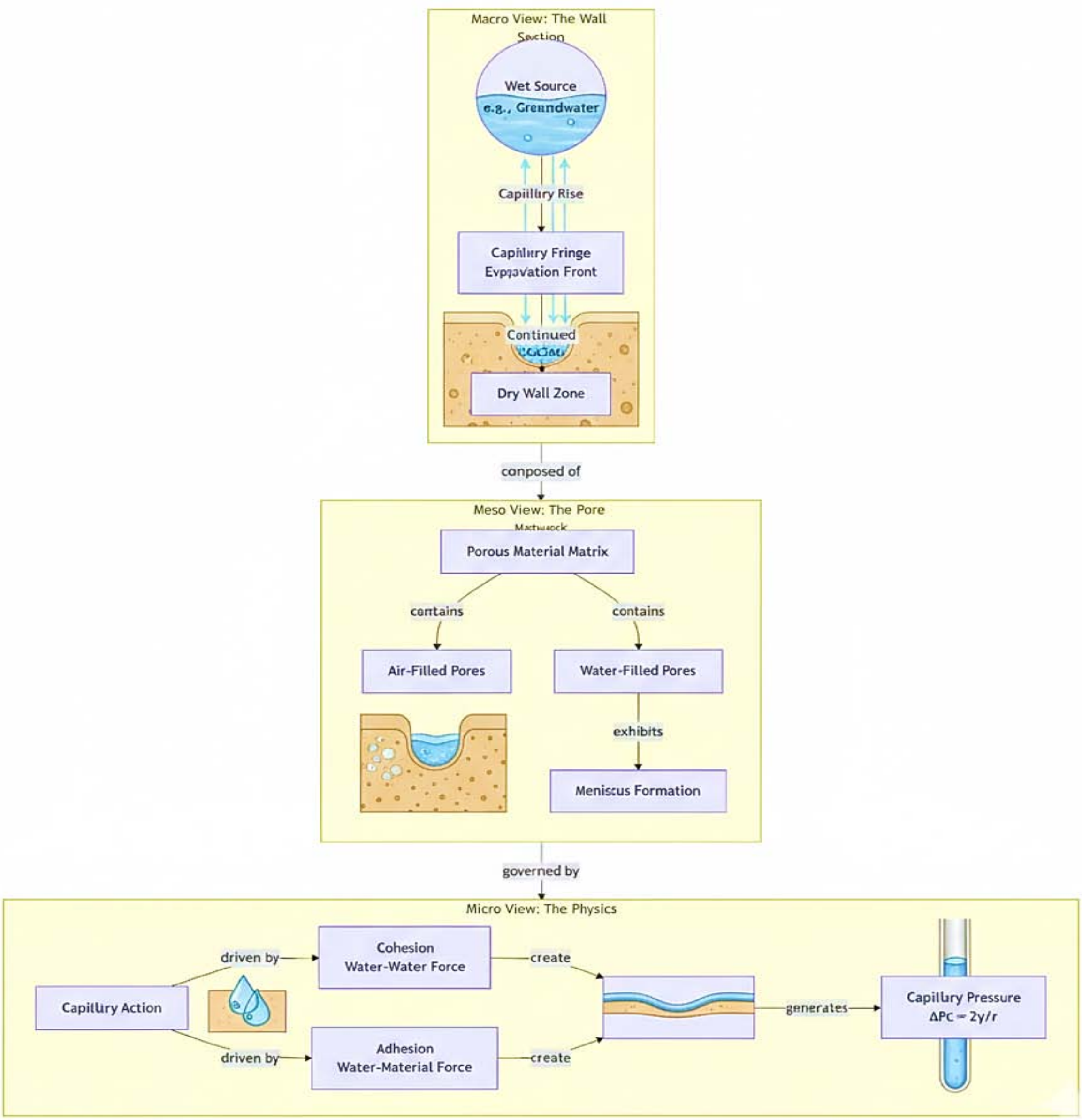

Figure 2: Conceptual model of capillary moisture transport in porous wall material

Within building physics literature, classic works emphasise that porous materials like concrete, brick or sandcrete-block walls include a network of inter-connected pores where moisture transport is governed by both hygroscopic uptake and capillary suction (Hall & Hoff, 2007). Moreover, as moisture content increases, the dominant transport mechanisms shift — in very wet zones capillary flow dominates, in less wet zones vapour diffusion is more significant (Hens, 2017).

b) Moisture-induced Changes in Hygrothermal Properties

When a porous wall absorbs moisture, the hygrothermal (heat + moisture) transport behaviour changes stage by stage in the following ways:

- *Increased thermal conductivity (λ):* Water has a much higher thermal conductivity than air; thus replacing air-filled pores in a material with liquid water increases λ and lowers the thermal resistance (U-value) of the wall. Several authors confirm that the effective thermal conductivity of porous building materials increases significantly with liquid moisture content. (e.g., Alsabry, Backiel-Brzozowska, Nikitsin, & Nikitsin, 2022).
- *Increased heat capacity (c) and latent heat effects:* Moisture present can lead to latent heat absorption/ release during phase changes (e.g., condensation/ evaporation inside the wall), which alters the transient response of the wall assembly. Dynamic models show that ignoring these effects can misrepresent real behaviour.
- *Modified moisture transport behaviour:* The wall assembly now undergoes a coupled heat–moisture transfer (HAM) scenario rather than simple steady-state conduction. Equations describing this coupling include time-dependent conservation of mass and energy and account for vapour diffusion, liquid flow, capillary suction and heat flow. For example:

$$(\rho c + \frac{\partial Hw}{\partial \theta})\frac{\partial \theta}{\partial t} = \nabla \cdot (\lambda \nabla \theta) + hv\nabla \cdot (\delta p \nabla (\varphi psat))$$

$$\frac{dw}{d\varphi}\frac{\partial \varphi}{\partial t} = \nabla \cdot (Dw\frac{dw}{d\varphi}\nabla \varphi + \delta p \nabla (\varphi psat))$$

where θ = temperature, ϕ = relative humidity, λ = thermal conductivity, Hw = moisture enthalpy, hv = latent heat, dw = liquid diffusivity, $d\varphi$ = vapour permeability, and $\varphi psat$ = saturation vapour pressure.

Furthermore, simulation studies show that for wall assemblies in humid climates, running standard heat-only models (i.e., ignoring moisture) under-estimates cooling load and mispredicts indoor humidity behaviour. For instance, a study using the HAM algorithm found increases in cooling/heating energy consumption when moisture accumulation was considered.

c) Envelope Performance and Cooling Energy Demand in Tropical Settings

In hot, humid climates such as those found in sub-Saharan Africa, cooling loads are often the dominant component of residential energy use. In such a setting, wall assemblies with elevated moisture content due to capillary rise pose multiple threats:

1. *Reduced thermal resistance* → Increased heat gain through external walls → Higher cooling demand. When moisture is present in wall materials, it fills the air voids that normally act as insulators. Since water has a much higher thermal conductivity than air, the wall's overall thermal resistance (R-value) drops.
2. *Delayed thermal response (increased inertia)* → Slower heat release at night, possible higher night-time indoor temperature. Moisture-laden walls have a higher thermal mass (heat storage capacity) because water can store more heat than dry building materials.
3. *Elevated indoor humidity levels* → Moisture absorbed by walls during humid daytime conditions can migrate inward when indoor air is drier which over time, results in moisture release into the indoor air.
4. *Potential latent heat loads* → Inside the wall assembly: moisture evaporation during warmer hours can add latent heat to the indoor space or force the cooling system to offset added moisture loads.

Given these mechanisms, the conceptual link can be drawn: when individuals' dwell in homes where rising damp raises wall moisture content, the wall behaves less like a dry thermal resistor and more like a semi-conductive/hygroscopic conduit for heat and vapour, the cooled indoor space must work harder to maintain comfort, thus raising energy consumption and reducing efficiency. This leads us to the following framework:

d) Integration of Theoretical Models: from Pathology to Energy Performance

While moisture ingress (rising damp) has traditionally been treated as a building pathology issue (durability, aesthetics, indoor air quality), this research positions it as also a building-energy issue. Theoretical models such as the HAM coupling model, moisture potential theory, and dynamic hygrothermal simulation underline that moisture transport and storage cannot be separated from heat transfer in a saturating wall. For example, Zubarev (2024) introduces a moisture-potential theory for multi-layer envelopes allowing for calculation of transient moisture regimes in single- and multi-layer structures. Homogenisation studies (Sýkora, Šejnoha, & Šejnoha, 2014) show that moisture gradients across material interfaces significantly affect macro-scopic hygrothermal performance.

From a practical architecture/engineering lens, this means that design details such as provision of capillary break layers, specification of low-absorption masonry, adequate ventilation at the wall base, and maintenance of damp-proof courses are not just durability measures but integral to preserving envelope thermal performance and reducing cooling energy loads. Furthermore, policy and practice must recognise that rising damp is not only a comfort and mould risk but a climate-adaptation and energy-efficiency issue in humid tropical housing.

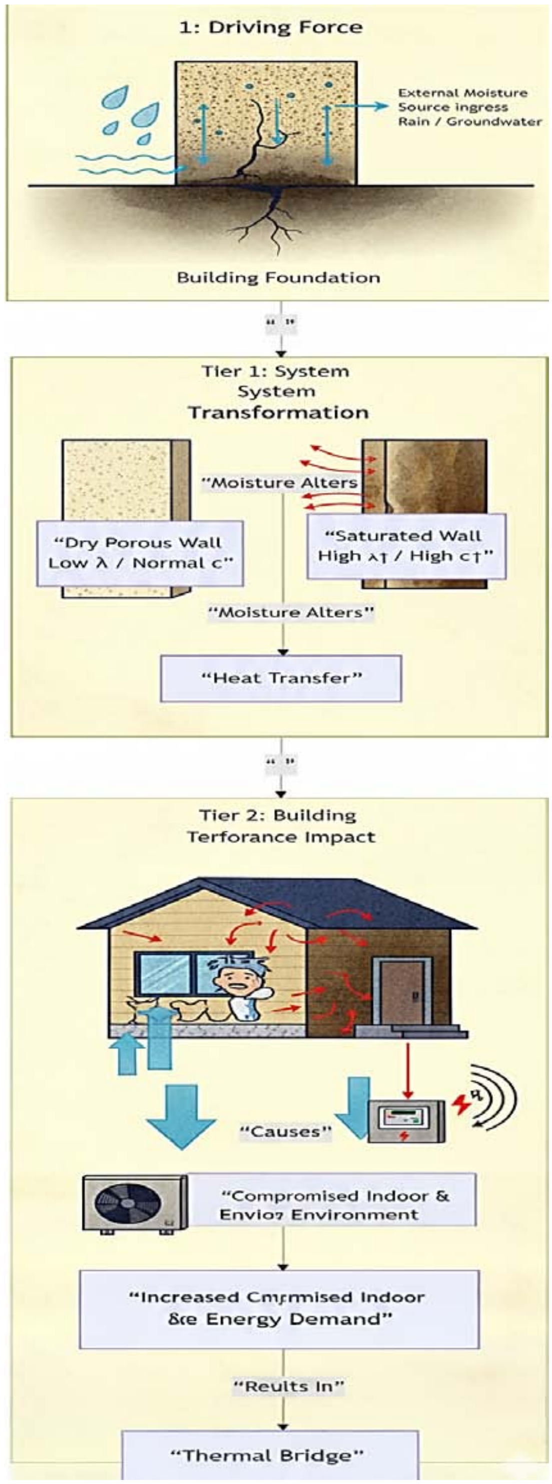

Figure 3: Framework linking capillary moisture ingress to altered wall hygrothermal properties to increased cooling energy use

III. Literature Review

a) *Moisture Movement in Building Envelopes*

Moisture transfer through the building envelope has long been recognized as a critical factor influencing structural durability, thermal comfort, and overall energy performance. Building materials are porous to varying degrees and can absorb, retain, and transmit moisture through diffusion, surface adsorption, capillary suction, and liquid transport (Hall & Hoff, 2007). Among these mechanisms, capillarity-induced rising damp—the vertical migration of groundwater through pore spaces—remains one of the most destructive forms of moisture ingress in low-rise residential buildings. The effect is particularly significant in masonry structures composed of high-porosity materials such as sandcrete blocks and fired clay (Olutoge & Olawale, 2010). In humid tropical regions, persistent rainfall, high groundwater levels, and poor damp-proofing practices amplify this problem. Makurdi, situated in Nigeria's middle belt, experiences annual rainfall exceeding 1,200 mm and shallow groundwater tables that heighten susceptibility to rising damp (Nigerian Meteorological Agency [NIMET], 2020). When moisture penetrates wall assemblies, it alters both the hygric and thermal properties of materials, increasing thermal conductivity and reducing insulation efficiency (Steeman, De Paepe, & Janssens, 2010). These coupled processes directly influence the energy balance of buildings by raising indoor humidity and cooling loads.

b) *Hygrothermal Interaction and Capillarity Models*

The theoretical understanding of rising damp and its thermal consequences draws upon classical and modern hygrothermal models. Jurin's Law explains the height of capillary rise as inversely proportional to pore radius, meaning that fine-pored materials like sandcrete or laterite exhibit greater capillary potential (Hall & Hoff, 2007). However, contemporary models recognize that real-world moisture behavior is dynamic and involves coupled heat and mass transfer. Künzel (1995) proposed the Heat, Air, and Moisture Transfer (HAMT) model, which simulates transient moisture migration in wall assemblies by coupling heat flow with vapor diffusion and liquid transport equations. Similarly, Mendes, Philippi, and Lamberts (2017) advanced a dynamic hygrothermal framework that integrates the sorption isotherm of materials and latent heat effects, allowing for more accurate prediction of wall temperature and humidity gradients. These theoretical frameworks underscore the critical feedback between moisture accumulation and thermal energy transfer—a relationship central to understanding the energy implications of rising damp in tropical housing.

c) *Rising Damp in Nigerian Tropical Construction*

Empirical studies reveal that rising damp is particularly pervasive in sub-Saharan Africa due to inadequate damp-proof detailing and the extensive use of sandcrete blocks in wall construction (Gassa, Kwaji, & Bilham, 2025). Laboratory investigations by Olutoge and Olawale (2010) reported that sandcrete blocks in humid regions exhibit porosity levels between 32–36%, almost double those of comparable masonry in temperate climates. This high porosity, coupled with limited quality control in block production, accelerates capillary uptake and long-term moisture retention. Field observations by Ogedengbe, Ede, and Ikponmwosa (2018) confirmed that over 60% of sampled residential structures exhibited signs of rising damp, including paint peeling, plaster decay, and salt efflorescence. Such conditions not only compromise durability but also alter indoor thermal behavior. The recurrent wetting and drying cycles modify the wall's effective thermal conductivity, causing the envelope to absorb and release heat more rapidly—thereby intensifying cooling energy demand during hot periods.

d) *Moisture–Thermal Coupling and Energy Performance*

Moisture presence within building walls significantly impacts energy efficiency by increasing thermal conductivity and lowering resistance to heat transfer. Experimental results by Odeyemi, Akinpelu, Atoyebi, and Orire (2018) showed that thermal conductivity of sandcrete walls nearly doubled—from 0.46 to 0.82 W/mK—when moisture content rose from 0 to 10%. This increase amplifies conductive heat flow, resulting in higher indoor heat gains and elevated energy consumption for cooling. Globally, Künzel and Kiessl (1996) observed that a 20% increase in wall moisture could raise total envelope heat flux by 15–30%, depending on material composition and boundary conditions. In the humid tropics, these effects are magnified by high ambient temperatures and relative humidity levels. Ojeh, Balogun, and Adebayo (2015) reported indoor air temperatures 2–3°C higher in damp-walled Nigerian dwellings compared with those with dry envelopes. Consequently, energy demand for mechanical cooling rose by 18–25%, highlighting the synergistic relationship between dampness and energy inefficiency.

e) *Moisture Control, Damp-Proofing, and Energy-Efficient Design*

Damp-proofing strategies in modern building science aim to minimize capillary suction and facilitate controlled vapor permeability. Traditional methods—such as bituminous damp-proof courses and cementitious coatings—are often poorly implemented in Nigeria, particularly in low-income or informal housing sectors (Gassa, Kwaji, & Bilham, 2025). Recent innovations include hydrophobic admixtures, silane–siloxane sealants, and capillary-breaking membranes, all of which reduce moisture absorption without compromising vapor diffusion (Yari et al., 2025). Beyond material science, architectural design strategies such as elevated plinths, cross-ventilation, and breathable wall finishes also contribute to passive moisture control while enhancing indoor thermal performance. The integration of these strategies not only mitigates damp-related deterioration but also contributes to overall energy efficiency. Udeaja, Dada, and Wahab (2020) demonstrated that moisture-controlled dwellings in tropical climates exhibited 10–15% lower annual energy expenditures compared with damp-affected buildings, underscoring the economic value of preventive damp management.

f) Research Gaps and Emerging Perspectives

The literature collectively confirms that rising damp, driven by capillarity, deteriorates both the physical and thermal performance of building envelopes. Theoretical models (Jurin's Law, HAMT) provide the foundation for understanding moisture transport, while empirical studies highlight its quantifiable impact on energy demand. However, limited contextual evidence exists for humid tropical regions such as Makurdi, where environmental conditions, material properties, and construction practices converge to exacerbate moisture-related inefficiencies. While the literature establishes clear theoretical and empirical links between wall moisture and thermal performance, most research has been conducted in temperate climates. Few studies quantify this relationship under the hydrometeorological conditions typical of Nigeria's humid tropics. Moreover, existing research tends to treat rising damp as an issue of material durability rather than energy efficiency. There remains a paucity of field-based studies that combine in-situ moisture measurement, thermal profiling, and energy-use monitoring within the same framework. Addressing this gap—particularly within the context of Makurdi's sandcrete-dominated housing stock—represents a novel contribution to tropical building pathology and performance science. This gap validates the need for the present research, which empirically examines the relationship between wall moisture and energy performance in residential buildings of Makurdi LGA.

IV. Methodology

a) Research Design

This study adopts a mixed-method research design, integrating *quantitative field measurements* and *qualitative surveys* to examine the relationship between capillarity-induced rising damp and the energy performance of residential buildings in Makurdi Local Government Area (LGA), Benue State. The design is structured around three interconnected components: (1) in-situ moisture assessment of wall assemblies; (2) monitoring of indoor environmental parameters and energy use; and (3) documentation of construction details and occupant practices. The triangulation of these data sources enhances validity and allows for a comprehensive evaluation of both the physical and behavioral determinants of damp-related energy inefficiency (Creswell & Plano Clark, 2018). The analytical framework builds upon established heat–moisture transfer models (Künzel, 1995; Mendes, Philippi, & Lamberts, 2017) but grounds them empirically through field measurements specific to Makurdi's humid tropical climate. Figure 4 presents the overall methodological workflow linking data collection, variable measurement, and analytical correlation.

b) Study Area and Building Selection

Makurdi LGA, the administrative capital of Benue State, lies within latitude 7°43'N and longitude 8°32'E, characterized by a tropical wet-and-dry climate with mean annual temperatures of 27–30°C and rainfall exceeding 1,200 mm (Nigerian Meteorological Agency [NIMET], 2020). The local geology is dominated by alluvial soils with high capillary potential, and the building stock is largely composed of sandcrete block masonry structures with plastered finishes. These conditions provide an ideal setting for investigating capillarity and its influence on thermal performance. The sampling frame comprised 40 residential buildings, selected through purposive stratified sampling to capture variations in construction age, material quality, and location relative to groundwater proximity. The sample included 20 buildings exhibiting visible signs of dampness (peeling paint, efflorescence, or wet walls) and 20 apparently dry buildings serving as controls. Each building was geo-tagged, documented photographically, and categorized by wall type, foundation detail, and damp-proof provision.

c) Moisture Measurement and Data Collection Instruments

In-situ wall moisture content was measured using a Tramex CMEX II non-destructive concrete moisture meter, calibrated for sandcrete material properties. Readings were taken at three vertical heights (150 mm, 600 mm, and 1200 mm above ground level) on both interior and exterior wall faces, following the sampling procedure of Ogedengbe, Ede, and Ikponmwosa (2018). To corroborate instrument readings, gravimetric analysis was performed on small extracted samples from a subset of test walls, following ASTM D2216-19 (ASTM International, 2019). Ambient environmental parameters—temperature, relative humidity, and wall-surface temperature—were monitored using Testo 160 data loggers installed in representative rooms of each building. Monitoring spanned a four-week period during the wet season (July–August), capturing diurnal variations and peak moisture accumulation cycles. Electricity consumption was concurrently recorded through plug-in energy meters for buildings using mechanical cooling systems.

d) Survey and Documentation of Construction Practices

Complementary to physical measurement, a structured questionnaire survey was administered to occupants and builders. The survey captured information on construction history, wall material composition, damp-proofing methods, maintenance frequency, and indoor cooling behavior. A total of 120 respondents participated, including 80 household occupants and 40 artisans/builders. Qualitative responses were coded thematically to contextualize field data and identify behavioral patterns contributing to dampness and energy use. The inclusion of stakeholder perspectives ensures that the research bridges theoretical modeling with practical construction realities, fulfilling the study's applied dimension (Creswell & Plano Clark, 2018).

e) Data Analysis Procedures

i. *Moisture Index and Thermal Relationship*

Wall moisture readings were normalized into a Moisture Index (MI) representing the ratio of measured moisture content to material dry weight. Mean MI values were computed for each building category and correlated with indoor temperature and relative humidity averages. The thermal performance of the walls was further analyzed by estimating apparent thermal conductivity (λ_a) using a simplified empirical relationship derived from Odeyemi, Akinpelu, Atoyebi, and Orire (2018):

$$\lambda_a = \lambda_0[1 + \beta(MI)]$$

where λ_0 is the dry-state conductivity and β represents the moisture correction factor determined experimentally (typically 0.02–0.05 for sandcrete).

ii. *Energy Performance Analysis*

For buildings using air-conditioning, daily energy consumption (kWh/day) was regressed against corresponding indoor humidity and MI values using multiple linear regression (MLR). The regression model took the form:

$$Ec = \alpha + \beta 1(MI) + \beta 2(Ti) + \beta 3(RHi) + \varepsilon$$

where Ec = cooling energy consumption, Ti = indoor temperature, and RHi = relative humidity. Statistical analysis was performed using SPSS v.28, and results were validated for multicollinearity, normality, and significance ($p<0.05$). This quantitative approach enabled empirical verification of the hypothesized link between capillarity and elevated energy demand.

iii. *Qualitative Integration and Interpretation*

Survey results were analyzed thematically to identify patterns such as lack of damp-proof courses, improper ground drainage, or use of non-hydrophobic plaster materials. These findings were integrated with quantitative data to provide a holistic explanation of observed performance differentials between damp and dry dwellings. The integration followed a convergent mixed-methods framework, where quantitative and qualitative insights were merged at the interpretation stage (Creswell & Plano Clark, 2018).

f) Validity, Reliability, and Ethical Considerations

To ensure reliability, instrument calibration was carried out before and after field deployment. Each measurement was repeated thrice, and outlier readings exceeding two standard deviations were excluded. Data triangulation across moisture readings, environmental monitoring, and occupant reports improved internal validity. Ethical clearance was obtained from the Benue State Urban Planning Research Ethics Committee, and participants provided informed consent. Data were anonymized to protect privacy, and all results are reported in aggregate form. The methodological framework integrates quantitative precision with qualitative insight to examine how capillarity-driven wall moisture affects building energy performance. By combining empirical field measurements, theoretical hygrothermal modeling, and occupant feedback, the study establishes a rigorous foundation for understanding rising damp as both a material pathology and an energy-performance issue. The next section presents the results and analysis derived from this comprehensive methodological approach.

V. Results and Discussion

a) Findings

The investigation reveals that capillarity-induced rising damp significantly affects wall moisture content, thermal performance, and indoor environmental conditions in residential buildings across Makurdi LGA. As summarized in Table 1, dwellings with damp walls exhibit markedly higher wall moisture indices, indoor relative humidity, and cooling energy use than buildings with dry walls.

Table 1: Summary of measured parameters for damp and dry buildings (mean values)

Building Type	Moisture Index (MI, %)	Indoor Temp (°C)	Relative Humidity (%)	Cooling Energy Use (kWh/day)
Damp	7.8 ± 2.1	30.2 ± 0.6	71.4 ± 3.2	6.8 ± 1.1
Dry	2.1 ± 0.9	29.1 ± 0.5	61.5 ± 2.8	3.9 ± 0.7

Source: Author's field data (2025).

These differences substantiate the hypothesis that rising damp undermines envelope performance, leading to higher indoor humidity and cooling loads.

b) Moisture Distribution and Capillarity Patterns

Vertical moisture profiles show the classic exponential decay associated with capillary rise. Table 2 illustrates moisture gradients measured at 150 mm, 600 mm, and 1200 mm above ground level for both categories.

Table 2: Vertical moisture gradient in damp and dry buildings

Height Above Ground (mm)	Damp Buildings (MI %)	Dry Buildings (MI %)
150	9.8 ± 2.3	3.5 ± 0.8
600	6.2 ± 1.6	2.2 ± 0.5
1200	4.1 ± 1.1	1.2 ± 0.3

Note: Error bars represent ± 1 SD.

These results validate the findings of Künzel (1995) and Ogedengbe et al. (2018), confirming that moisture propagates vertically through pore suction, particularly in buildings lacking effective damp-proofing.

c) Influence of Moisture on Wall Thermal Properties

Moisture content strongly influences the thermal conductivity of sandcrete masonry. Table 3 presents experimental conductivity data and derived regression equations.

Table 3: Relationship between wall moisture index (MI) and apparent thermal conductivity (λ_a)

MI (%)	λ_a (W/m·K)	Increase from Dry State (%)
0	0.85	—
2	0.89	4.7
5	0.94	10.6
8	0.99	16.5
10	1.03	21.2

Source: Author's field data (2025).

Regression equation:

$$\lambda_a = 0.85 + 0.018(MI), R2 = 0.92$$

This finding aligns with dynamic hygrothermal theory (Mendes et al., 2017), indicating that moisture elevates conductivity by filling air voids, thereby facilitating conductive heat transfer.

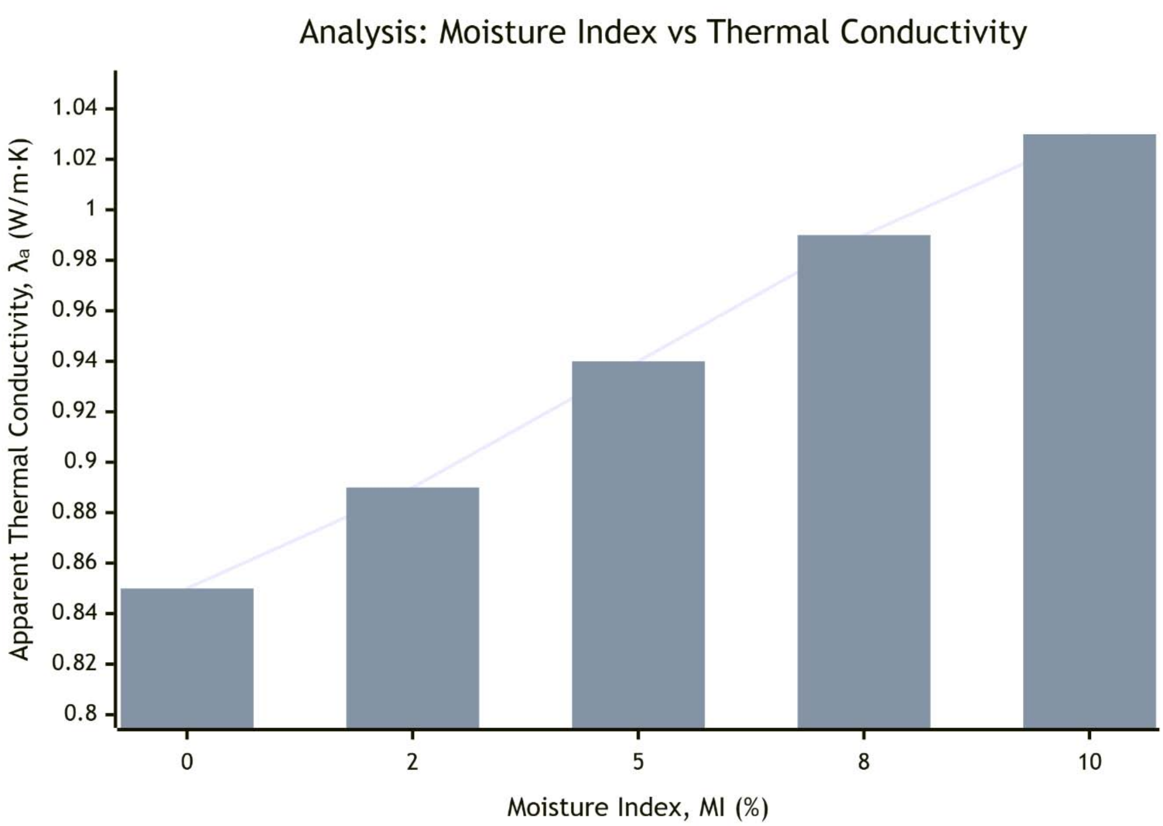

Figure 4: Relationship between moisture index and thermal conductivity of sandcrete walls (A graph showing linear increase of λ_a from 0.85 to 1.03 W/m·K as MI rises from 0 to 10 %.)

d) Indoor Environmental Conditions

Damp buildings recorded higher mean indoor relative humidity (RH) and slightly higher temperatures, which affect occupant comfort and cooling demand.

Table 4: Indoor temperature and humidity profiles

Parameter	Damp Buildings	Dry Buildings	Difference
Mean Indoor Temp (°C)	30.2 ± 0.6	29.1 ± 0.5	+ 1.1°C
Mean RH (%)	71.4 ± 3.2	61.5 ± 2.8	+ 9.9%
Nighttime Temp (°C)	29.8 ± 0.5	28.9 ± 0.4	+ 0.9°C

Note: Comfort limit of ≤ 65 % RH for tropical

The comparative analysis between damp and dry buildings reveals notable differences in indoor environmental conditions. On average, damp buildings recorded a mean indoor temperature of 30.2 ± 0.6°C, which is 1.1°C higher than the 29.1 ± 0.5°C observed in dry buildings. Similarly, relative humidity levels were substantially greater in damp buildings (71.4 ± 3.2%) compared to dry ones (61.5 ± 2.8%), showing a 9.9% increase. Even during nighttime, when temperatures typically drop, damp buildings remained warmer (29.8 ± 0.5°C) than dry buildings (28.9 ± 0.4°C), with a 0.9°C difference. These results suggest that moisture accumulation in building materials contributes to elevated indoor temperatures and humidity, reducing nighttime cooling and overall thermal comfort. These elevated humidity levels surpass ASHRAE's (2017) comfort limit of ≤ 65% RH for tropical interiors, indicating the need for greater dehumidification effort and increased cooling energy use.

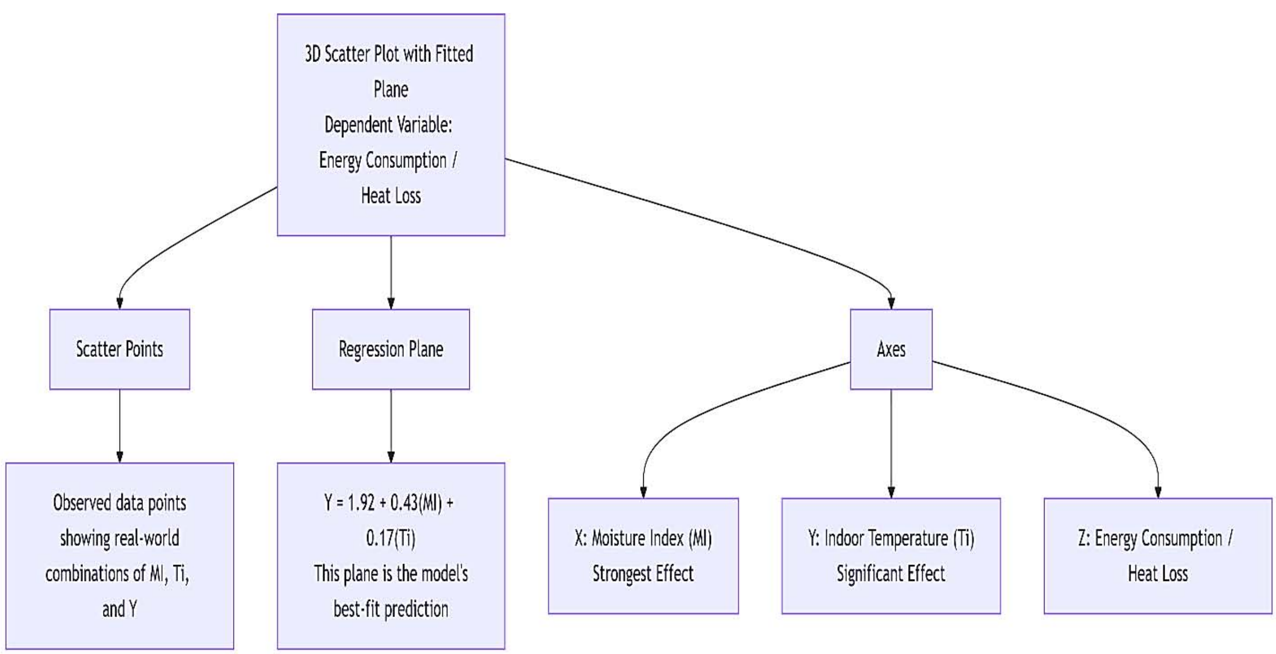

Figure 5: 3D Scatter Plot & Fitted Regression Plane

e) Energy Performance Correlations

Regression analysis confirmed a statistically significant relationship between wall moisture and cooling energy consumption.

Table 5: Regression summary for energy consumption model

Variable	Coefficient (β)	Std. Error	t-value	Sig. (p)
Constant (α)	1.92	0.48	4.01	0.002
Moisture Index (MI)	0.43	0.09	4.78	0.001
Indoor Temperature (Ti)	0.17	0.05	3.26	0.004
Relative Humidity (RHi)	0.09	0.04	2.31	0.028

The regression analysis shows that all three predictors—Moisture Index (MI), Indoor Temperature (Ti), and Relative Humidity (RHi)—have positive and statistically significant effects on the dependent variable. The constant value of 1.92 ($p = 0.002$) indicates the baseline level of the outcome when all predictors are zero. Among the independent variables, the Moisture Index has the strongest influence ($\beta = 0.43$, $p = 0.001$), implying that higher moisture levels substantially increase the dependent variable. Indoor Temperature also contributes positively ($\beta = 0.17$, $p = 0.004$), suggesting that rising indoor temperatures lead to a corresponding increase in the outcome. Similarly, Relative Humidity shows a smaller yet significant effect ($\beta = 0.09$, $p = 0.028$), indicating that humidity variations play a meaningful role. Overall, the model demonstrates that moisture conditions, temperature, and humidity collectively and significantly influence the observed response. This confirms the hygrothermal coupling mechanism described by Bayat Pour (2025) and Zhang et al. (2019), where moisture-laden walls raise indoor latent heat load and reduce cooling efficiency.

f) Construction Practices and Behavioral Insights

Evidence of systemic construction flaws exacerbating capillarity from survey data.

Table 6: Summary of construction and maintenance practices

Variable	Percentage of Respondents (%)	Observed Impact
Buildings without DPC	72	High wall dampness
Use of plain cement-sand mortar	68	Poor waterproofing
Lack of site drainage	55	Surface water accumulation
Routine repainting instead of repair	47	Conceals damp symptoms
Builders unaware of DPC function	63	Design negligence

Source: Author's field data (2025).

The survey findings highlight significant construction and maintenance shortcomings that contribute to moisture problems through capillary rise in residential buildings. As shown in Table 6, 72% of respondents reported buildings without a Damp-Proof Course (DPC), a critical omission leading to high wall dampness. Additionally, 68% indicated the use of plain cement-sand mortar, which provides poor waterproofing performance, allowing moisture to penetrate wall assemblies more easily. Over half (55%) of the respondents noted an absence of proper site drainage, resulting in surface water accumulation that worsens rising damp conditions. Furthermore, 47% admitted to relying on routine repainting rather than structural repairs, a practice that merely conceals damp symptoms without addressing the root cause. Alarmingly, 63% of builders were unaware of the function of a DPC, revealing a systemic lack of technical knowledge and oversight in local construction practices. Collectively, these findings underscore how both inadequate construction techniques and limited professional awareness perpetuate moisture-related degradation in buildings. Occupants typically responded to dampness by repainting or ventilating, but few implemented structural remedies. This reflects the knowledge-practice gap prevalent in informal construction economies (Bayat Pour, Niklewski, Naghibi, & Frühwald Hansson, 2024).

g) Theoretical and Practical Implications

Results affirm the dynamic heat–moisture transfer model, showing that moisture functions as both a thermal bridge and a latent heat moderator within tropical building envelopes. Quantitatively, simulation based on observed conductivity differentials indicates that reducing MI from 8% to 3% can lower annual cooling loads by approximately 10%–12%.

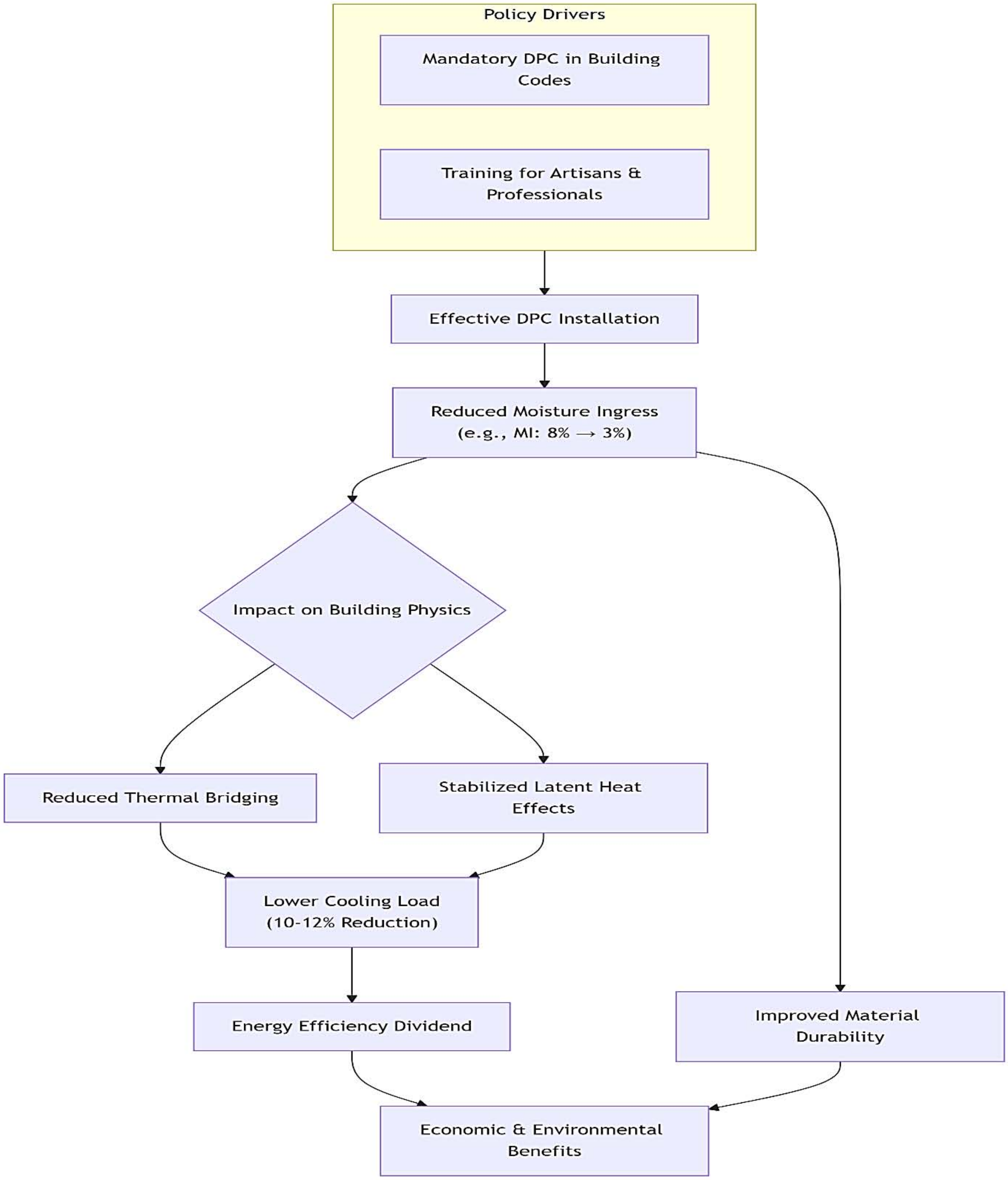

Figure 6: Modeled impact of wall moisture reduction on cooling energy demand

These outcomes bridge theory and practice: addressing rising damp through effective damp-proofing can yield both *durability* and *energy efficiency* dividends. Policy implications include mandatory inclusion of DPC materials in low-cost housing and training programs for local artisans.

h) Summary of Key Findings

1. Rising damp remains prevalent across Makurdi's housing stock, with MI averaging 7.8% in affected walls.
2. Increased wall moisture elevates thermal conductivity by up to 21%, confirming hygrothermal coupling.
3. Indoor humidity and cooling loads rise significantly in damp buildings.

4. Poor damp-proofing practices and limited technical knowledge sustain the problem.
5. Reducing wall moisture below 3% could cut cooling energy demand by 10–12%.

These results redefine rising damp not only as a durability defect but also as an energy-performance determinant, crucial to sustainable housing policy in humid tropical environments.

VI. Implications of Findings

a) Empirical Contributions

This study has empirically demonstrated that capillarity-induced rising damp exerts a measurable influence on the energy performance of residential buildings in Makurdi Local Government Area, Benue State. Through a mixed-method approach combining field measurements, thermal monitoring, and construction practice surveys, the research established that wall moisture levels directly affect both thermal conductivity and cooling energy demand. Moisture-laden walls exhibited conductivity increases of up to 21%, correlating with average energy-use increases of 10–12% compared to dry counterparts. These findings substantiate the theoretical premise of dynamic heat–moisture interaction (Künzel, 1995; Mendes et al., 2017), wherein moisture not only accelerates material deterioration but also modifies thermal performance characteristics. In tropical settings such as Makurdi—characterized by high rainfall, shallow groundwater, and widespread use of sandcrete masonry—the implications extend beyond durability, encompassing comfort, health, and energy efficiency.

b) Theoretical Contributions

The study extends existing building pathology literature by integrating hygrothermal theory with empirical energy-use data. Prior research (e.g., Ogedengbe et al., 2018; Zhang et al., 2019) focused largely on material degradation or isolated thermal studies. By contrast, this work demonstrates a bidirectional relationship: moisture not only arises from design and material failure but also reciprocally intensifies building energy demands, creating a feedback loop of inefficiency and discomfort. Furthermore, the proposed Moisture–Energy Interaction Model (MEIM) conceptualizes how rising damp modifies wall conductivity, increases latent cooling loads, and influences occupant behavior. This framework offers a replicable basis for future research in tropical and sub-tropical regions.

c) Practical Implications for Architectural Design and Construction

i. *Design Practice*

Architects and builders must recognize that moisture control equals energy control. The introduction of continuous damp-proof courses (DPCs) at foundation level and capillary-breaking layers beneath wall footings can substantially reduce wall moisture. Building designs in Makurdi and similar tropical climates should incorporate raised floor slabs, adequate site drainage, and perimeter ventilation to minimize capillary suction and surface runoff accumulation. Moreover, façade detailing—particularly at the wall–floor junction—should adopt hydrophobic coatings or cementitious barriers that resist lateral moisture migration. Such preventive measures align with energy-efficient design objectives by maintaining low thermal conductivity and stable indoor humidity levels.

ii. *Material Specification*

Field results reveal that conventional sandcrete blocks are highly susceptible to capillarity due to their pore structure and low density. Blending pozzolanic additives such as fly ash, rice husk ash, or hydrated lime can enhance pore closure and hydrophobicity, reducing moisture permeability (Odeyemi, Akinpelu, Atoyebi, & Orire, 2018). Adoption of moisture-resistant render coatings with vapor-permeable membranes is also recommended to allow wall drying while preventing further ingress.

d) Policy and Regulatory Implications

At the policy level, the study underscores the need to institutionalize moisture management in building regulations and energy codes. The National Building Code of Nigeria (NBCN) should explicitly include performance requirements for damp-proofing materials and specify maximum allowable wall moisture content for habitable structures. Additionally, government housing agencies and local authorities should prioritize training programs for artisans and contractors on damp-proofing techniques. Integrating these measures into affordable housing initiatives could yield significant long-term energy savings and health benefits. From an energy-policy standpoint, recognizing moisture as a latent energy loss pathway positions damp control within the broader climate mitigation agenda. Reduced household energy use translates into lower grid demand and, consequently, lower emissions intensity for tropical urban centers.

e) Socio-Economic and Environmental Implications

At the household scale, mitigating rising damp improves indoor air quality and occupant comfort, reducing the prevalence of mold-related respiratory issues. On an economic level, reduced cooling loads decrease monthly electricity expenditures, enhancing affordability and energy equity for low-income households in Makurdi. Environmentally, the cumulative effect of widespread damp control can contribute to urban energy efficiency targets and carbon emission reduction. For policymakers, this research thus connects micro-level building pathology with macro-level sustainability outcomes—bridging the gap between individual dwellings and collective environmental goals.

Table 7: Multi-scale impacts of moisture mitigation

Scale	Impact	Implication
Material	Reduced porosity, longer lifespan	Enhanced durability
Building	Lower thermal conductivity, reduced energy use	Improved comfort and efficiency
Community	Reduced electricity demand	Energy equity and resilience
Environment	Lower emissions intensity	Sustainable development alignment

f) *Limitations and Directions for Future Research*

While the study establishes a strong empirical foundation, certain limitations warrant further inquiry. First, data collection occurred during the wet season, potentially exaggerating moisture readings relative to annual averages. Future studies should employ year-round monitoring to capture seasonal variability. Second, the focus on sandcrete masonry limits generalizability across other construction materials such as laterite or concrete block systems. Extending the model to multi-material buildings could enrich comparative analysis. Finally, computational hygrothermal simulation (e.g., using WUFI or EnergyPlus coupled models) would enhance predictive accuracy and support scenario-based design optimization.

VII. Conclusion

This study has examined the influence of capillarity-induced rising damp on the energy performance of residential buildings in Makurdi, Benue State, revealing a direct relationship between wall moisture, thermal behavior, and cooling energy demand. The research demonstrates that rising damp is not merely a structural or aesthetic defect but a fundamental determinant of energy efficiency and occupant comfort in tropical buildings. Moisture migration through wall assemblies alters thermal conductivity, raises indoor humidity, and increases energy use—ultimately reducing the overall environmental performance of buildings. Through a field-based, empirical methodology supported by theoretical modeling, the study has established measurable links between material moisture indices, envelope performance, and energy consumption. These findings emphasize that energy efficiency cannot be achieved in humid climates without simultaneous attention to moisture management. The evidence presented underscores the necessity for architectural design, material specification, and construction practice to integrate moisture control measures such as damp-proof courses, improved drainage detailing, and capillary-breaking barriers as core elements of sustainable design.

Beyond technical outcomes, the study advances the conceptual understanding of how hygrothermal behavior in wall systems contributes to broader issues of comfort, health, and sustainability. By framing rising damp within the context of energy performance, it contributes a new dimension to the discourse on tropical building pathology and performance optimization. This reconceptualization bridges the gap between theory and practice—linking material science, architectural design, and energy policy in a unified framework for building resilience. The practical implications of these findings extend to architects, engineers, policy-makers, and housing agencies. Effective moisture control strategies can reduce cooling loads, enhance durability, and lower life-cycle costs, thereby improving both environmental and economic sustainability. In policy terms, embedding moisture performance standards in local building codes will foster long-term gains in public health, energy efficiency, and climate adaptation. While the study's focus on Makurdi provides valuable insights specific to humid tropical settings, its methodological and conceptual approaches offer replicable models for other regions facing similar climatic and construction challenges. Future research should expand on this work by integrating computational simulation, seasonal monitoring, and multi-material comparison to further refine predictive models of moisture–energy interaction. Moreover, addressing rising damp is both a technical necessity and an energy imperative. The study establishes that managing capillary moisture is essential to achieving durable, healthy, and energy-efficient buildings. For tropical architecture, the path toward sustainability begins with understanding that controlling moisture is a form of controlling energy itself.

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Hydraulic Engineering in Dam-Type Tidal Power Plant Designs

By Alexander Yerkhov
Russian State Geological Exploration University

Abstract- During the years of Soviet power, several tidal power plants were procured on the territory of the RSFSR, but only one was built - experimental, despite several promising projects - interest in TPP fell. Economic and demographic trends suggest an impending shortage of energy resources in the world, and now in the foreign press they are increasingly discussing the results of the work of existing TPP, studying the options for the layout of stations, the advantages and disadvantages of various types of hydraulic turbines; the development of the theory of tidal power plants is a problem of energy, construction science (and construction sciences), as well as engineering: hydrology, geology, geodesy, geotechnics, ecology, hydraulics, etc., at each stage of the life cycle of significant in different ways - before the commissioning of the structure in the priority of engineering and construction sciences, and the emphasis in this work is on the main aspect of the life cycle of the design stage, while the scientific novelty is to designate the engineering hydraulics of TPP as a complex problem of system analysis.

Keywords: tide, pool, dam, hydraulic turbine, impeller, blade, power, energy, pressure, operation.

GJRE-E Classification: JEL Code: Q25

HYDRAULICENGINEERINGINDAMTYPETIDALPOWERPLANTDESIGNS

Strictly as per the compliance and regulations of:

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ИНЖЕНЕРНАЯ ГИДРАВЛИКА В ПРОЕКТАХ ПРИЛИВНЫХ ЭЛЕКТРОСТАНЦИЙ ПЛОТИННОГО ТИПА

Alexander Yerkhov

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Аннотация- **В годы советской власти на территории РСФСР было запроектировано несколько приливных электростанций, но построена только одна – опытная, несмотря на несколько перспективных проектов, – интерес к ПЭС упал. Экономико-демографические тенденции наводят на мысль о предстоящем дефиците энергоресурсов в мире, и уже сейчас в зарубежной печати всё больше обсуждают результаты работы действующих ПЭС, изучают варианты компоновок станций, достоинства и недостатки разных типов гидротурбин; развитие теории приливных электростанций – проблема энергетики, строительной науки (и строительных наук), а также инженерных: гидрологии, геологии, геодезии, геотехники, экологии, гидравлики и т.д., на каждом этапе жизненного цикла значимых по-разному, – до ввода сооружения в эксплуатацию в приоритете инженерные и строительные науки, и акцент в данной работе делается на основном аспекте жизненного цикла этапа проектирования, научная же новизна – обозначить инженерную гидравлику ПЭС как комплексную проблему системного анализа.**

Ключевые слова: прилив, бассейн, плотина, гидротурбина, рабочее колесо, лопасть, мощность, энергия, напор, эксплуатация.

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I. Введение

Ограничение ресурсов по ископаемому топливу и глобальное потепление, вызванное эмиссией парниковых газов [1], заставляют бедные ресурсами и социально ответственные страны обращаться к альтернативным природным энергетическим источникам: солнечной радиации, ветровым потокам, морским волнам, однако сила их действия носит вероятностный характер, поскольку определяется погодными условиями, – морской прилив предсказуем относительно – наступает периодически два раза в сутки в большинстве регионов и один – в некоторых, при этом суммарная энергия приливов составляет 3 ТВт[2] при КПД преобразования 35 %, что способно удовлетворить часть мирового спроса на электричество, однако, хотя глобальный приливной потенциал значителен, лишь в нескольких районах задействован [1]. Морская энергия заключена не только в приливах в виде потенциальной энергии разных уровней воды, но и в поверхностных волнах ветрового воздействия, а также включает термальную энергию температурных полей различных глубинных зон, – отраслевое значение имеют приливы. Энергию приливам даёт асимметрия гравитационных возмущений и океанические течения: 1) согласно модели Ньютона-Лапласа, лунная гравитация из-за значительного диаметра Земли не одинакова в ближних и дальних точках и неравномерно воздействует на её поверхность, и такое притяжение образует перемещающиеся за движущейся Луной (и Солнцем) горбы и спады поверхности водных масс, которые у материковых берегов создают приливы и отливы; 2) по динамической модели вращение планеты создаёт в океанах обратно-встречные течения из-за возникающего в результате действия силы Кориолиса инерционного движения водных масс, образуя водоворотные зоны

[1] Увеличение выработки электроэнергии в мире более чем в два раза за последние 30 лет с преобладанием доли горючих ископаемых связано исключительно со странами Азии, где наиболее ощутим и ожидаемо прогнозируем рост численность населения; за тот же период концентрация диоксида углерода в атмосфере воздухавозросла на 25%.

[2] Европа: 12 ГВт – от Норвежского и Северного до Средиземного и Эгейского морей, Китай: 13,9 – от Жёлтого до Восточно- и Южно-Китайского морей, Индия: 8 – от Аравийского моря до Бенгальского залива, РФ: 90 – Баренцево и 20 – Белое моря и т.д.

размером, определяемым орографией – береговым и донным рельефом, и поскольку морские берега России воспринимают приливную волну в двух точках – географических регионах: на побережье Баренцева и Белого морей, куда волна доходит от вихря северной части Атлантики, и на протяжённой береговой линии от Берингова до Охотского морей – от двух совместно действующих вихрей Тихого океана, есть только два экономических района РФ – Северный и Дальневосточный, где проектирование ПЭС целесообразно (при условии, что здесь сохранится дефицит электроэнергии при вы соком экономическом

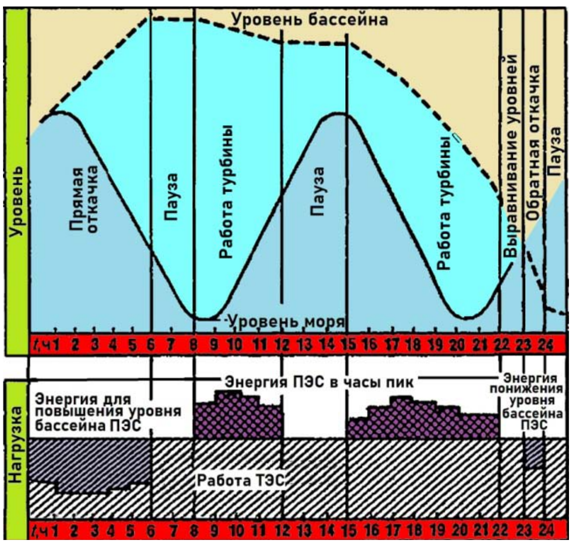


Рис. 1: Энергетические диаграммы ПЭС

уровне, и они будут работать в составе единой энергосистемы (рис. 1)). При приливно-отливном движении воды образуется солитон с амплитудой прилива до 6 м на Севере и 13 на Дальнем Востоке, что соответствует низконапорным ГЭС, однако, поскольку сейчас в приоритете атомные проекты, даже низкая себестоимость производства энергии и безопасность для окружающей среды, в сравнении с углеродной энергетикой, не стали аргументом для разработки новых проектов строительства приливных станций. И, казалось бы, в таком контексте, актуальность темы должна определяться выявлением преимуществ сравнения с АЭС (плавучего или иного типа), но важно заглянуть и в будущее, поскольку ископаемое топливо небезгранично, и кризис природных ресурсов станет отправной точкой возврата интереса к ПЭС; мировой нефтяной кризис 1970-х гг. открыл эпоху приливной энергетики, но только сейчас гидротурбины с горизонтальной осью диаметром 5-8 м стали настолько совершенны, что наряду с ветроэнергетическими появились в многочисленных зарубежных проектах ПЭС – ни что так не способствует научному обоснованию, как коммерциализация ВИЭ.

Главными достоинствами ПЭС являются низкая стоимость обслуживания – <0,5%, высокая эксплуатационная готовность – >95%; основные недостатки: очень высокая стоимость установленной мощности – в десять-сто раз выше других источников, долгий срок строительства – 5-15 лет, низкий коэффициент нагрузки – 22-35% [2], – проблемы инженерно-технического и проектно-технологического характера рассматриваются ниже.

II. Материалы и Методы

Приливная энергия используется по всему миру, но неравномерно: в Австралии, Великобритании, Канаде, Китае, США, Франции. В РФ проекты экспериментальных ПЭС рассматривали с 1930-х гг., причём Кислогубская опытная малая мощностью 1,7 МВт была построена (в 1968 г. первоначальной мощностью 0,4 МВт); другие проекты не были реализованы [3]: Северная в Баренцевом море, Лумбовская и Мезенская в Белом, Пенжинская и Тугурская в Охотском (таблица 1), – на исходе СССР в 1990 г. автор данной статьи в составе солнечногорской изыскательской экспедиции Гидропроекта проводил сейсморазведочные работы по исследованию скального основания под плотину проектируемой ПЭС Северная и геофизические исследования на Шантарских островах под проект Тугурской станции, но случившиеся за этим в стране социально-экономические неурядицы прервали ход работ[3]; для реализации проектов, помимо главных экономических, должны быть решены частные инженерные задачи.

Таблица 1: Проекты ПЭС РСФСР

Станция	Прилив ср. (м)	Площадьбассейна (км^2)	Установленная мощность (МВт)	Годовойобъем электроэнергии (ТВтч/г)	Годовой Коэффициент загрузки(%)
Северная	4,2	5,6	12	0,024	24
Лумбовская	4,2	70	320	0,7	24
Тугурская	4,7	1800	8000	27,6	24
Мезенская*	10	2640	11400	39	34
Пенжинская**	11 и 13,4	20530	108500	250	25

**В том же заливе проектировались Кулойская и Беломорская станции.*

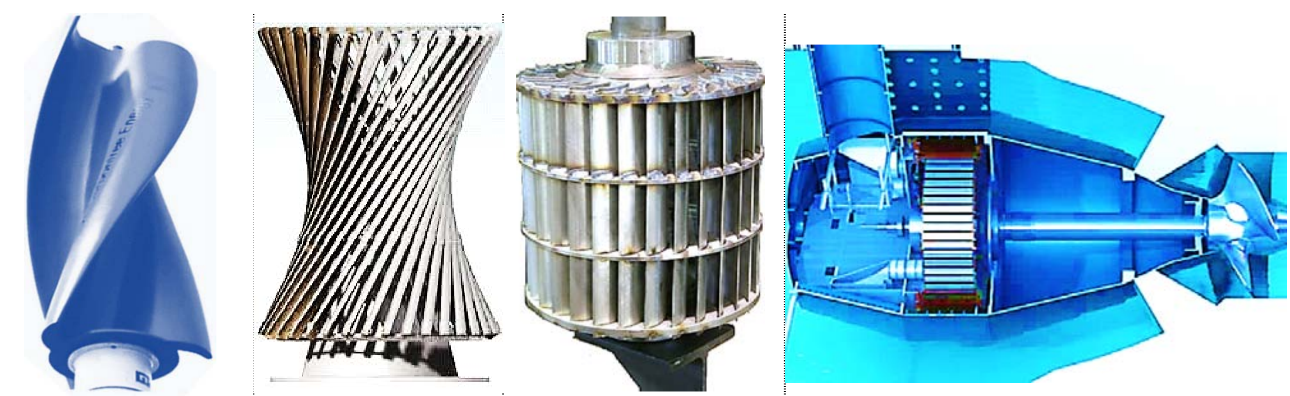
***Суммарно два бассейна.*

[3] И сохранились ли отчёты о результатах изысканий доподлинно не известно: государственные проектные институты распадались или перепрофилировались, их имущество по большей части ликвидировалось.

Проблема 1 – устойчивость плотины

Безотказность конструкции плотины при постоянных и временных нагрузках определяется силами сопротивления материалов и конструкций, не допускающими предельных состояний: 1) разрушения, потерю устойчивости формы, 2) предельных деформаций, колебаний, трещин и их раскрытия в конструкциях. Расчёт напряжённо-деформированного состояния (НДС) тела плотины при воздействии на неё внешних нагрузок, а также температурных волн и солнечной радиации, химических веществ и соединений в виде действия реакций, определяемых составом внешней среды и изменением свойств частиц конструкций при старении материалов, биологических процессов в виде биодеградации из-за действия грибов, водорослей, микроорганизмов, определяется совокупностью напряжений и деформаций, целиком характеризующих напряжённое состояние частиц тела плотины, – эту совокупность записывают в виде тензоров напряжений и деформаций конкретной конструкции и решают с применением средств вычислительной техники. Инженерная гидравлика напрямую не связана с методами компьютерного 3-D моделирования НДС численными методами, но ассоциируется с гидростатическими задачами ГТС, при этом в составе расчёта могут использовать отдельные решения: на сдвиг, напряжений по горизонтальному сечению и т.д.; методику гидростатических расчётов можно применять и для других элементов ГТС ПЭС: подпорных стенок, устоев... Наиболее актуальны и имеют принципиальное значение расчёты по определению устойчивости плотины на сдвиг и напряжения в основании. Исходные данные в расчёте: высота плотины $H_{пл}$ [м], глубина H, плотность бетона γ [кг/м^3], предел прочности грунта основания [Мпа], коэффициент трения бетона о грунт f, удельное сцепление грунта c [кПа], заложение откосов m, класс сооружения [КС]; искомая характеристика – ширина плотины B [м]. Расчёт сил и их плеч ведут относительно середины основания на основе действия группы сил: *вертикальных*: *а*) собственный вес плотины, определяемый по площадям плоских геометрических фигур, получаемым разбивкой её поперечного профиля, умноженным на плотность бетона, *б*) составляющие сил гидростатического давления воды, действующий на подводные грани плотины (с обратной стороны на подошву плотины действует сила фильтрационного противодавления – площадь эпюры, умноженная на объёмную массу воды), и *горизонтальных*: суммарное гидростатическое давление со стороны моря и бассейна (особым вопросом является расчёт флютбета проточной части ПЭС для защиты основания от размыва под действием скоростного напора и предупреждения фильтрационных деформаций, а также наличия и глубины противофильтрационной и дренажной завесы $h_{зав}$). В решении составленного уравнения необходимо учитывать нормативные показатели коэффициентов устойчивости и минимальные значения главных напряжений у верха плотины.

Особенности конструкции плотин ПЭС раскрыты в следующем разделе.

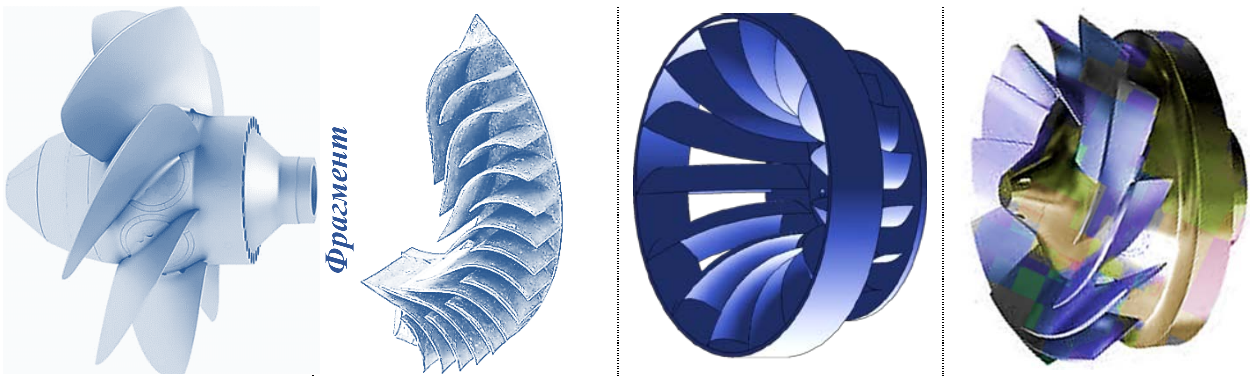


Савониуса(ортогональная)–от1,2м–от15кВт	Горлова (геликоидная) – эффективность 35 %	Банки(ортогональная)–от 2 м–1кВт-15кВт	Колбовая(капсульная, грушеобразная, трубчатая)– от 3 до 10м

Рис. 2: Низконапорные гидротурбины

Проблема 2 – необходимость эффективного управления скоростным напором

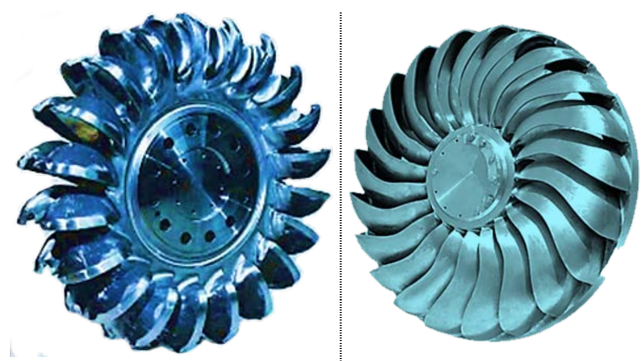
Рабочие скорости приливного течения – 2-3 м/с (дают 4-13 кВт/м^2), бóльшие (>3,0) оказывают чрезмерную нагрузку на оборудование – на рабочее колесо, меньший напор – экономически неэффективен, – напор определяет тип роторной турбины с характерным рисунком гидродинамического профиля лопатки; применение средне и высоконапорных требует конструкторских доработок, экономических обоснований. Таким образом, первую проблему можно интерпретировать как создание эффективных, надёжных приливных агрегатов и их совершенствование: 1) турбина Савониуса (рис. 2) с рабочим колесом обычно 2-4 лопасти отличается от колбовой ротором двигателя на внешнем контуре рабочего колеса и статором в центре, что имеет преимущества при переменном напоре, дешевле и проще в монтаже и обслуживании[4], – теоретически имеет бóльшую инерцию , и, значит, более устойчива, но может работать только в отлив, и не может применяться для накачки[5]; 2) в турбине Банки вода ударяет в лопасти, поступая поперечно оси, поворачивает относительно её и выходит, то есть лопасть воспринимает воздействие дважды, – эффективность невысока, подходят для небольших станций до 300 кВт, и имеют проблемы с вибрацией; 3) колбовую турбину, названную из-за формы гидроагрегата, на ПЭС применяют чаще из-за высокого КПД при низком напоре (до 90%), малого размера, низкой стоимости и реверсивности, позволяющей вырабатывать энергию как в прилив,



Каплана(радиально-аксиальная)– от 3 м–600кВт-2МВт	Томсона(радиально-аксиальная)– от 6 м–15кВт-4МВт	Фре(э)нсиса(радиально-аксиальная)–от7м–250кВт-2,5МВт	Дериаз(ис)а(диагональная)– от 4 м–до215МВт

Рис. 3: Среднескоростные типы рабочих колёс

так и в отлив, они отличаются надёжностью и высокими рабочими характеристиками, имеют низкие эксплуатационные затраты, – технология колбовых турбин хорошо отработана; 4) турбины средней скорости вращения[6] (рис. 3) можно адаптировать под различные гидравлические характеристики, однако они малопроизводительны в режиме насоса, потому что относительно короткие лопасти, расположенные под большим углом, создают нестабильное течение и приводят к чрезмерному замедлению потока (что видно по несовпадению рабочих точек режимов турбина/насос), однако конструкция турбины Дериаза, как разновидность Каплана с лопастями не перпендикулярно направленными к оси, а под углом, направляет поток диагонально – по образующей к вершине конуса, и несоответствие между прокачкой и генерацией решает, поскольку не возникают пульсации давления и кавитация [4]; турбина/насос Дериаза способна работать также при переменных скоростях вращения, что позволяет иметь в 1,5 раза бóльшую входную мощность, чем у турбин Френсиса; пропеллерная турбина Каплана с возможностью поворота лопасти относительно своей оси ранее (в СССР) называли по конструкции «поворотно-лопастной»; 5) высоконапорные (рис. 4) отличаются высокой скоростью при низком расходе: если удельная скорость выходит за критический диапазон, вращение замедляется и мощность падает [5].



Пел(ь)тона (ковшовая) – от 40 м – 30 кВт-4 МВт;	Тюрго – от 35 м – 30 кВт-2 МВт.

Рис. 4: Типы высоконапорныхгидротурбин

[4] Первоначально Кислогубская ПЭС работала на колбовой турбине мощностью 400 кВт, но в 2006 г. была модернизирована до экспериментальной ортогональной Савониуса 1,7 МВт (два агрегата), причём эффективность турбины Савониуса признаётся ниже колбовой.

[5] Самая большая диаметром 8,2 м и мощностью 17,8 МВт при КПД 89% работает на канадской ПЭС Аннаполис (зал. Фанди).

[6] Скорость вращения зависит от удельной скорости гидротурбины, частоты и числа пар полюсов генератора, при этом удельная скорость должна обеспечивать такую же скорость генератора.

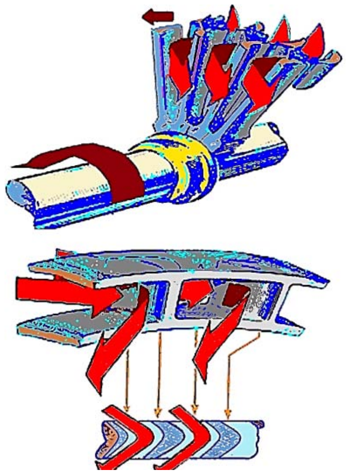


Рис. 5: Реактивный и импульсный потоки

Проблема 3 – необходимость выверенной ориентации рабочего колеса турбины в водоводе

Общее наблюдение – вертикальная ориентация вала гидротурбины большого диаметра лучше подходит для реактивных – Каплана, Дериаза, горизонтальное – импульсных – Пелтона (рис. 5); впрочем, изменение формы лопасти по длине – от центра к переферии – способно обеспечивать в одном колесе оба режима, что для требующих повышенных технических характеристик турбин, работающих в составе современного технологичного оборудования необходимо. *а*) Турбины с горизонтальной осью ориентированы валом ротора параллельно потоку, и поскольку, коэффициент их мощности достигает 40%, на большинстве ПЭС установлены именно они, что не означает отсутствия недостатков: стоимость турбины и конструкции выше, ортогональных, генерация энергии возможна только в одном направлении, что требует двух турбинных групп – на прилив и отлив. *б*) Турбины ортогональные с поперечно ориентированной осью: Банки-Митчелла или Особергера – при простоте конструкции, сказывающейся на стоимости, имеют высокий КПД – 80%, надёжны и просты в эксплуатации; КПД важнейший показатель турбины, в том числе, по признаку ориентации, – турбины с вертикальной осью и, например, пассивным переменным углом наклона лопасти для лучшего угла атаки (турбина Кобольда – рис. 6 – может иметь номинальную мощность >150 кВт), удерживающим аэродинамический профиль в положении наибольшей подъёмной силы, обеспечивая максимальную касательную силу для наибольшей мощности, – переменный угол добавляет 3% мощности.

Проблема 4 – неравномерность выработки электроэнергии из-за нерегулярности потока, вызванной длительными паузами прилив/отлив.

Оптимизации путём равномерного распределения выходной мощности (рис. 1) с повышением коэффициента нагрузки турбин выше 60% некоторым образом могут способствовать многоячеистые бассейны, более гибко реагирующие на изменение напора – отбор мощности должен осуществляться от отдельных турбин или их групп, и, таким образом, турбины нижних и верхних бассейнов работают синхронно-циклично по напору – море-бассейн$_1$-бассейн$_2$-море, как одна электростанция; и также станция может дооснащаться гидроаккумуляторами.

Рис. 6: Турбина Кобольда

Проблема 5 – недостаточная эффективность преобразования энергии.

Связана со второй проблемой, и решается усложнением конструкции гидротурбин – важно для оптимизации работы станции. Эффективность ПЭС определяется технико-экономическими показателями, то есть минимальными затратами на производство электроэнергии, тогда как КПД турбин – эффективностью в отношении преобразования энергии – зависит от условий работы турбин, и максимальна, если турбина работает с расчётной нагрузкой (рис. 7), – при неполной или перегрузке КПД падает, и рекомендуют турбины Дериаза или Каплана.

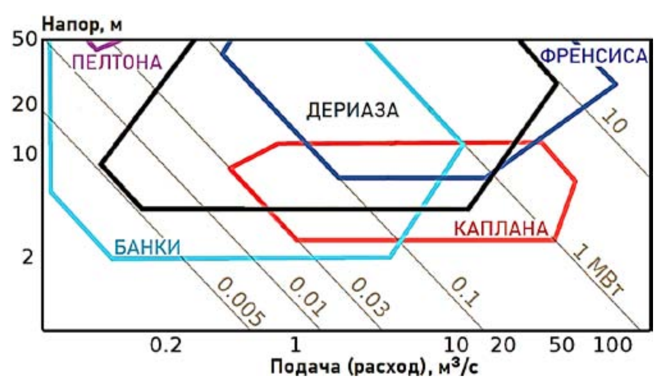


Рис. 7: Сравнение некоторых типов турбин. Эффективность

Проблема 6 – тяжёлые условия эксплуатации гидротурбин по ряду показателей, например, наличию шуги, активно идущих биологических/химических процессов.

Требует изменения свойств материалов или характера процессов путём особых технологических мероприятий – для повышения надёжности оборудования. Большинство ПЭС имеют напорные плотины для накопления и эффективной выработки энергии турбинами, работающими в одну или обе стороны, – их конструкция должна обеспечивать КПД турбин 80-90% и бесперебойную работу в течение десятилетий, для чего поверхности конструктивных элементов, соприкасающиеся с внешней средой, покрываются защитными лаками от биообрастаний, подключаются к системе катодной защиты от коррозии и т.д. [6].

Проблема 7 – изменение экологического равновесия.

Плотина ПЭС, перекрывая вход в естественную бухту/залив/фьорд/губу/лиман/эстуарий и даже лагуну, но не пролив, образует бассейн, отделённый от моря, и имеющий различный с ним гидрологический режим (рис. 1), нарушая сложившуюся экосистему и в определённых случаях вызывая социальные проблемы, поскольку ограничивается доступ к лежбищам и ареалам обитания держащихся у берега морских животных – млекопитающих, моллюсков и др., изолируются места нереста и пути миграции ихтиофауны, а также сужаются возможности судоходства, – и тем не менее, последствия преодолимы, что должно отражаться в проектах, при этом учитывать надо то, что воздействия на дикую природу могут быть прямыми и косвенными.

Проблема 8 – влияние на прибрежно-морской наносный режим и переформирование дна за счёт отложений твёрдого стока рек.

Седиментация уменьшает приливную зону (площадь и объём) бассейна; в зависимости от источника аккумуляция донных отложений и эрозия способны оказать негативное воздействие как на работу сооружений ПЭС, так и на окружающую среду.

Эти проблемы с разной степенью важности определяются потоками отно сительно плотины и в рабочей зоне гидротурбин, – в проектах ПЭС гидравлика сооружений (плотины (потенциальная энергия прилива/отлива), турбинного водовода (кинетическая энергия скоростного напора), а также механических машин (механическая работа гидротурбин)) с вопросами электроэнергетики взаимосвязана: плотина – главное сооружение ПЭС с решающей долей инвестиционных затрат – имеет в теле на турбинном водоводе работающую на перепаде давлений горизонтально или вертикально ориентированную турбину, соединённую посредством вала с коротким и большим в диаметре электрогенератором (рис. 8 [7]), индуцирующим ЭДС, и имеющим, ввиду низкой частоты вращения, несколько пар полюсов, соединённых через трансформатор с сетью. И, следовательно, концепция с анализом и техническое обслуживание с эксплуатацией в жизненном цикле станции имеют приоритетное научно-теоретическое и утилитарно-прикладное значение.

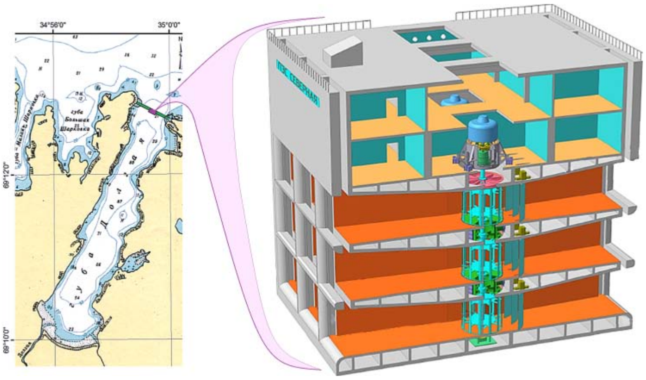


Рис. 8: Многоярусный ортогональный гидроагрегат диаметром рабочих колёс 5 м на примере проекта ПЭС Северная

Для каждого сооружения ПЭС важны, но рутинны конкретные технические параметры: размеры, тип грунта, используемый строительный материал, особенности конструкции, – они общедоступны и не обсуждаются.

III. Результаты

a) Решение проблемы 1 – расчёт конструкции плотины

В зарубежной литературе плотину ПЭС чаще называю «заграждением», вкладывая в это понятие значение несущественности сил давления воды со стороны «бьефов» – гидростатический напор воды настолько мал и одинаков в противофазе с обеих сторон, что в максимуме Δh составляет считанные метры, поэтому от речных плотин их отличает кубоидная форма (рис. 9), а по конструктивному исполнению – это ячеистые плотины с плоскими перекрытиями, в гидротехнике обычно называемые «облегчёнными»; по материалу – бетонные/железобетонные сооружения.

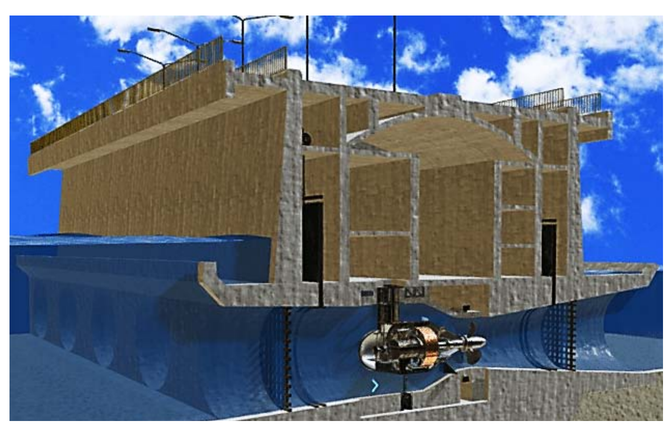


Рис. 9: 3-Dмодель saVRee обычного заграждения ПЭС с в ряд расположенными турбинами

Ячеистые низконапорные плотины стали разрабатывать в СССР с середины 30-х годов; размеры ячеек – 1,5×1,5-6×6 м, толщина стенок – 0,1...0,6 м, способ монтажа – монолитный или сборно-монолитный железобетон (с расходом арматуры – 20...30 кг на м^3

бетона) с соединением элементов сваркой и бетонированием. Положение и форма ячеек сказывается на напряженном состоянии конструкции плотины, что позволяет корректировать напряжения в теле и основании, методом предварительного напряжения повышать сжимающие напряжения у напорных граней. Верхнюю часть такой плотины рассчитывают, как гравитационную, нижнюю – как массивную раму с жёсткими узлами и заделкой в основании[7].

Помимо экономии бетона, ячеистая плотина имеет ряд других достоинств: удобные цементация швов, сбор и отвод инфильтрационной воды, управление температурным режимом, возможность коммуникации.

b) Решение проблемы 2 – расчёт турбинных агрегатов

1. *Энергетический потенциал прилива в исходных данных расчёта водовода гидротурбин.*

Разница уровней закладывает в приливную волну потенциальную энергию, которая в прилив выше, чем в отлив, поэтому в оценке приливной энергии следует рассматривать два случая: вращение турбины за счёт падающей воды, и поднимающейся. Энергию приливного цикла в работе ПЭС определяет инженерное решение по размещению плотины; приняв амплитуду – напор на плотину – как разницу уровней Δh ($-\Delta h$), а площадь бассейна обозначив как A [м^2], потенциальную энергию прилива выражают в виде E=mgΔh2=AρΔhgΔh2=AρgΔh22 [Дж], и мощность приливной энергии – N=EΔt=12AρgΔh2Δt [Вт], а если предположить полный переход потенциальной энергии в кинетическую, скорость приливного течения из N=12mu2=12ρHlu3 равна u=32NHl, где H – глубина прилива, l – пройденное приливной волной расстояние в пределах ПЭС,Δ t – продолжительность падения или подъёма уровня, то есть половина приливной фазы. Вес поднятой и опущенной приливом воды составляет G=γHA, где γ – удельный вес морской воды, равный 1025 [кг/м^3], и максимальная расчётная мощность ПЭС P=280AH2 [кВт], то есть накопленная энергия пропорциональна квадрату глубины прилива, высоты плотины.

Пример расчёта бассейна Пенжинской ПЭС:

определить теоретическую запасённую энергию и среднюю мощность при средней высоте прилива по северному и южному бассейнам 12,2 м, площади бассейнов 20 530 000 000 м^2 и времени прилива 6 ч, – $E = 0{,}5A\rho gh^2 = 0{,}5\cdot 20\ 530\ 000\ 000$ [м^2]·1025 [кг/м^3]·9,8 [м/с^2]·12,2^2 [м] = 1,53472·10^{16} [Дж], $P = E/t$ = 1,53472·10^{16} [Дж]/6 [ч]/3,6·10^6 [кВт·ч/Дж] ≈ 710 517 [МВт], при том что плотинные гидроагрегаты по проекту должны производить 108 500 МВт.

Турбина с генератором – наиболее чувствительная критически значимая составляющая ПЭС.

2. *Кинетическая энергия турбинного водовода в энергии осевых турбин.*

В водоводе, соединяющем море и бассейн, устанавливают турбину, мощность потока в которой Nп=gQHт [кВт], где Hт=C1ucos1gη – рабочий напор турбины, позволяет турбине развить мощность Nт=Mω, где M=ρQC1cos1R1-C2cos2R2 – момент количества движения и ω – угловая скорость рабочего колеса, C_1, C_2 – абсолютные скорости на входе и выходе [м/с], u – окружная скорость на внутренней окружности рабочего колеса, R_1, R_2 – размеры окружностей рабочего колеса (рис. 10), α_1, α_2 – углы между касательными и кривой лопасти к наружной окружности на входе и выходе [°], η=NтNп – гидравлический КПД, – и при низком напоре турбины с пропеллерными лопастями, как, например, Каплана, не могут обеспечить высокую мощность, Q – расход через гидротехническое сооружение: Q = CdA2gHт , где C_d – коэффициент расхода, A – площадь проходного сечения через сооружение.

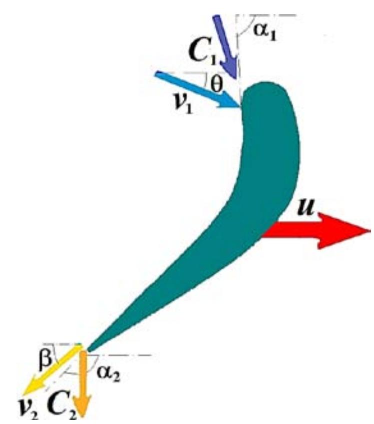


Рис. 10: Схема к расчёту скорости лопатки

3. *Гидравлические характеристики осевой гидротурбины в конструктивных параметрах мощности.*

Сегодня «испытания» концепта начинают с компьютерной модели, выполняя структурный анализ (ставшим ведущим методом конечных элементов – FEA, широко применяющимся в расчёте плотин) весовых характеристик конструкции, отдельных деталей и элементов, например, лопастей, и применяя вычислительную гидродинамику (CFD) для оценки набегания и взаимодействия потока с граничными поверхностями. Кинематическая характеристика движения потока и рабочего колеса описывается производными физическими величинами передачи скорости потока – скорости на входе лопатки – скорости на выходе – скорости самой лопатки, – лопатка, таким образом, определяет диаметр колеса и размер турбины вне зависимости импульсная/реактивная, – лопасти колеса неподвижные, то есть угол их наклона не может изменяться (на рис. 10 показана изогнутая лопасть с входом и выходом струйного потока под заданными

[7] Методика расчёта изложена в Рекомендациях по конструированию сборно-монолитных ячеистых конструкций и организации изготовления их элементов. М.: Союзгипроводхоз, 1983. – С. 36.

углами, векторно представляющего треугольники скоростей). Чтобы рассчитать крутящий момент, действующий на водяную турбину, необходимо оценить обмен импульсом, то есть обмен импульсом происходит за счёт изменения направления вектора скорости. Мощность турбины определяется силой на входе, скоростью вращения лопастей, выходной мощностью и скоростью потока на выходе. Сила, по второму закону Ньютона – это изменение количества движения F=dm,vdt [Н], то есть определив его получают силы на лопатках, – методика расчёта представляет алгоритм: 1) для расчёта эффективной силы, действующей на лопатки, необходимо рассчитать величину и направление относительной скорости набегающей струи; определение компонент *x* и *y* вектора относительной скорости на входе: vx1=$v_1$cos, vy1=$v_1$sin и на выходе: vx2=-$v_2$cos , vy2=v_2·sinβ, где v_1 и v_2 – относительные скорости входящего и выходящего потока струи, представляющие сумму векторов скоростей лопасти *u* (окружная составляющая скорости $u = \pi \cdot d \cdot n$, где *d* – диаметр [м], *n* – частота вращения [$с^{-1}$]) и абсолютной на входе C_1 и выходе C_2 [м/с], *θ*, *β* – углы между соответственно v_1, v_2 и *u* [°]; 2) сила, передаваемая реактивным потоком лопатке в направлении *x*, равна массовому расходу *Q* [кг/с], который равен плотности жидкости *ρ* [кг/$м^3$] на площадь поперечного сечения струи A_c [$м^2$] и на скалярное значение скорости набегания v: Q=ρAcv; сила, передаваемая реактивным потоком лопатке в направлении оси *Y*: Fy=ρAcvvy2-vy1=ρAcv$v_2$sin +$v_1$cos; полная сила, приложенная к лопатке, равна результирующей: F=Fx2+Fy2, а угол равнодействующей силы – =FyF; выходная мощность: движущая сила турбины равна Fx=ρAcvvx2-vx1=ρAcv-$v_2$cos -$v_1$cos; 3) КПД водяной турбины – отношение выходной мощности к кинетической энергии движения: *η*=Acvvx2cos +vx1cos ·uAcv·v·a·i22.

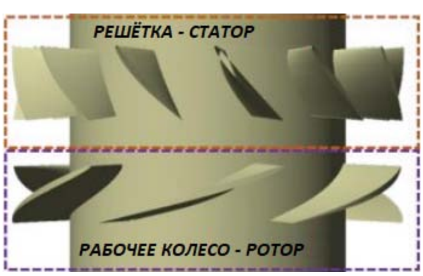


Рис. 11: Принцип передачи количества движения с решётки на лопасти рабочего колеса

4. *Совмещение турбинного водовода со средненапорной гидротурбиной.*

Совмещение посредством рабочей (направляющей) решётки – статора, формирующего направленный на лопасти поток как из диффузора (рис. 11), требует отдельного расчёта, и после определения C_1 и *u*, выбора угла α_1, вычисляют относительную скорость W_1 на входе в рабочую решётку: W1=C12+u2-2C1ucos 1 , и определения угла β_1 по формуле 1=sin 1 cos 1 -uC1 , – после оценки относительной скорости на выходе W_2 и определения угла β_2 (для активных ступеней $\beta_2 \approx \beta_1$ – (2…4°)) абсолютная скорость C2=W22+u22-2W2ucos 2 , а угол α_2 – 2 =sin 2 cos 2 -uW2.

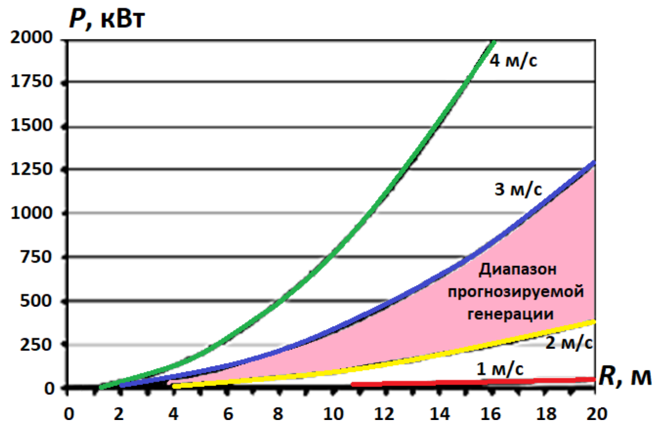


Рис. 12: Выработка электроэнергии в зависимости от диаметра ротора и скорости потока

Решение проблемы 3 – принципиальное решение по ориентации в потоке рабочего колеса, то есть выбор типа турбины.

Для ПЭС инженерная гидравлика может рассматривать турбины двух типов: *а*) с горизонтальной осью, ориентированной вдоль потока, диаметром 10-20 м и мощностью 200-700 кВт могут иметь лопасти с регулируемым шагом, подстраиваемым под скорость потока (рис. 12); *б*) с ортогональной осью и перпендикулярно ей направленным потоком способны извлекать из потока до 35% энергии (для примера, с горизонтальной осью турбины извлекают от 20%); другие преимущества: конструкция низкой материалоёмкости; недостатки: стоимость изготовления на 20% выше турбин со спиральными лопастями (при равной стоимости монтажа), конструкция прямолинейной лопасти (например, вертикальной 3-лопастной турбины Кобольда (рис. 6)) из-за неустойчивости течения с предрасположенностью к разрыву потока приводит к вибрации, но многочисленные лабораторные испытания показывают, что геликоидные лопасти турбины Горлова (рис. 2) решают проблему, и кроме того, в сравнении с прямолинейными лопатками, извлекаемая энергия на 12% больше (согласно другим данным коэффициент мощности прямолинейных лопастей на 5% выше спиральных).

Решение проблемы 4 – неравномерность выработки электроэнергии.

Получение электроэнергии ТЭС (рис. 1) при низкой цене на газ является предпочтительней ПЭС как по финансовым, так и техническим соображениям, а также по воздействию на окружающую среду, но КПД ПЭС при мощности 20-250 МВт может быть в 4 раза больше, – важнейшим фактором, снижающим экономическую эффективность ПЭС, являются паузы в работе из-за периодичности приливов/отливов. В традиционном исполнении ПЭС – *однобассейное* гидротехническое сооружение с отгораживающей плотиной, и работа электростанции возможна в трёх режимах: 1) Генерация в прилив; заполнение бассейна морской водой начинается не сразу: некоторое время затворы турбинных водоводов закрыты, пока не возникнет достаточный гидростатический напор (в ночное время при низких спросе и тарифе вода пропускается в бассейн через дополнительные отверстия, наполняя его). 2) В отлив при минимальном напоре со стороны моря вода из бассейна выпускается через турбинные водоводы, вырабатывая электроэнергию пока гидростатический напор в бассейне не упадёт до минимального уровня, позволяющего турбинам работать эффективно. 3) Двунаправленная генерация – метод использует как фазы прилива, так и отлива: затворы турбинных водоводов остаются закрытыми до конца прилива (рис. 1), после чего воду направляют в турбины – наступает фаза генерации, длящаяся до минимального гидростатического напора – фазы отлива, – двусторонняя генерация сокращает долю пауз и снижает количество агрегатов, то есть стоимость оборудования. *Двухбассейные* ПЭС – основной бассейн может работать как один; второй предназначен для закачки и аккумуляции воды в процессе фазы откачки из первого бассейна, при этом используется часть электроэнергии, генерируемой турбинами, и такая система способна регулировать подачу электроэнергии потребителю, – преимущество систем с двойным бассейном – способность генерировать электричество в период повышенного спроса, недостатки: низкая эффективность работы турбин при низком напоре и увеличение затрат на строительство из-за удлинения плотины. Хотя неравномерность выработки ПЭС не только суточная, но и месячная, но проблема 4 определяется изменением напора в результате приливно-отливного действия волны.

Решение проблемы 5 – недостаточная эффективность преобразования энергии и оптимизация – проблема тоже инженерной гидравлики. Экономическая и энергетическая эффективности требуют оптимизации – компьютерного моделирования выработки электроэнергии от изменений уровня воды в бассейне на основе конкретных аналитических подходов, что даёт, прежде всего, оптимальное время начала и окончания генерации каждой фазы. Именно этим – нелинейной зависимостью уровня напора и мощностью определяется проблема возможности выхода станций на проектную мощность. Целью оптимизации эксплуатационных мероприятий является, в первую очередь, определение количества турбин и единых оптимальных эксплуатационных характеристик для одинаково результативной работы во время всех фаз всех приливных циклов. Заданное количество турбин заданной мощности должны обеспечить предполагаемую установленную мощность станции в заданном диапазоне; при моделировании исследуют два режима работы: двухсторонняя генерация без насосных станций и двухсторонняя с накачкой. Для улучшения оперативного управления силовыми установками во времени каждого приливного цикла в качестве исходного параметра применяют одно общее значение, и далее оптимизация моделируемой станции продолжается с последних параметров предыдущего цикла, – последовательность операций по управлению режимами работы ПЭС: 1) откачка воды в отлив (опорожнение бассейна), 2) пауза при минимальном уровне отлива (задержка в ожидании), 3) начало прилива (фаза перед наполнением бассейна), 4) начало пропуска воды через затворы, 5) наполнение бассейна, 6) накачка воды в прилив, 7) пауза на максимуме приливного уровня, 8) начало отлива (перед опорожнением), 9) пропуск воды в отлив через затворы, 10) откачка воды в отлив (опорожнение бассейна). Эффективная эксплуатация на основе целевой функции каждого цикла максимизирует выход энергии, и добавление прокачки повышает выход электричества на ≈15-20% [8], а в целом оптимизированное управление циклами приводит, за счёт более гибкого управления турбинами и затворами, к увеличению выхода электроэнергии на ≈30-35% (оптимизация повышает КПД модели четырехлопастной турбины на 5,5 и трёхлопастной на 4,5%). Полностью оптимизированный процесс управления в решении инженерных задач включает большое число переменных (начиная с гидродинамических характеристик прибрежной зоны), требующих повышенных вычислительных ресурсов.

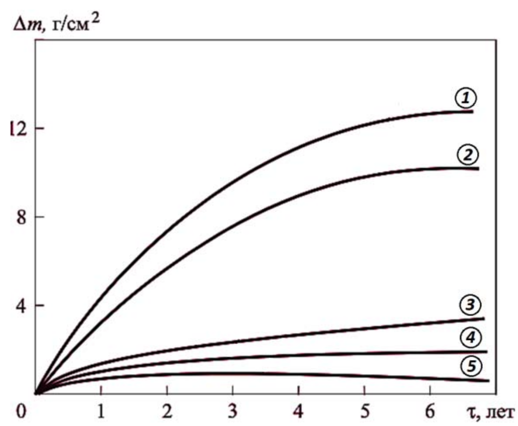


Рис. 13: Интенсивность коррозии конструкций в воде разных морей: 1 – Северном; 2 – Средиземном; 3 – с высоким содержанием Са и загрязнённая сточными водами; 4 – без загрязнений; 5 – Чёрном[9]

Решение проблемы 6 – особые условия эксплуатации и технического обслуживания отражаются на расходах, и стоимость эксплуатации и мероприятия по техническому обслуживанию обычных ПЭС самая низкая в сравнении с другими станциями генерации энергии моря. Из всех возможных осложнений в эксплуатации, связанных с задачами инженерной гидравлики, три наиболее острые – волны, ледовые явления, коррозия. Традиционными для ГТС методами, описанными в СП (38.13330.2018), рекомендациях, справочниках являются: для снижения силы воздействия волн – волнорезы, берегоукрепление, для ледовых нагрузок – ледорезы, для защиты сороудерживающих решёток от обмерзания – антиобледенители в виде, например, гидрофобных покрытий, для защиты за кладных частей затворов – электрообогрева, борьбы с внутриводным льдом и шуговыми коврами – запани и шугосбросы, – целесообразно гидравлическое лабораторное моделирование. Электрохимическая коррозия металлических конструкций, исполнительных механизмов, деталей турбинных агрегатов в морской воде высока из-за наличия в ней растворённых солей – катионов активных металлов: хлоридов и сульфатов натрия, магния, кальция, калия; кроме того, в морской воде высока и депассивность. Кинетика процессов определяется составом и концентрацией электролита (рис. 13): больше солёность – выше скорость коррозии и ниже надёжность, а также активностью металла конструкции в виде простого вещества или соединения (таблица 2).

Таблица 2: Электрохимический ряд активности металлов

активные	***средней активности***		***неактивные***
Li → K → Na → Ca → Ba →	Mg → Al → Mn → Zn → Cr → Fe → Ni → Sn → Pb →	H_2	Cu → Hg → Ag → Pt → Au

К примеру, высокий потенциал медных сплавов в электролитическом контакте со сплавами железа создаёт поток электронов от Fe к Cu, корродируя первый, а это требует специальных методов защиты: легирования, ингибиторов, изолирующих покрытий, электрохимической защиты; выбор метода, предотвращающего окислительно-восстановительную реакцию, определяет стоимость строительства и эксплуатационные издержки.

Сейчас накоплен достаточный опыт работы приливных электростанций, вырабатывающих электричество в сеть на протяжении многих десятилетий.

Решение проблемы 7 – воздействие на окружающую среду.

Приливная станция – вредная технология электрогенерации: ПЭС нарушает сложившуюся экосистему географического региона, формировавшуюся тысячелетиями, – наиболее показательные примеры с крупными млекопитающими[8]: в августе 2004 г. на ПЭС Аннаполис в зал. Фанди (рекордные приливы – до 18 м) взрослый горбатый кит в слабый прилив проплыл через открытые ворота шлюза в бассейн, и на несколько дней застрял в верхней части р. Аннаполис, но самостоятельно нашёл выход, однако уже весной 2007 г. там же, у г. Бриджтауна, найдено тело неполовозрелого горбатого кита, и причина гибели осталась неизвестной; впрочем, роль заграждений в данных случаях скорее положительная. ПЭС также могут стать определённой угрозой экономического развития, если в ограждаемой зоне активно развито судоходство, но и данная проблема решается при помощи инженерной гидравлики. И вместе с тем, традиционные приливно-отливные электростанции вряд ли будут иметь широкое распространение из-за критических недостатков: дороговизны, длительного срока строительства, ограниченного числа мест с высоким приливом и подходящей береговой линией, непреодолимой угрозы окружающей среде. Поиск новых технологически совершенных подходов в развитии энергетики формирует в среднесрочной перспективе политику поддержки возобновляемых источников энергии, главным образом солнечных и ветровых, а в долгосрочной – атомных реакторов на быстрых нейтронах (ядерного топлива замкнутого цикла) и ядерного синтеза (термоядерного цикла), а также производства водорода.

Решение проблемы 8 – влияние на прибрежно-морской наносный режим.

Блокирование приливно-отливного течения плотиной способно вызвать увеличение эрозии берегов как со стороны моря, так и бассейна, усилить подводные течения с подмывом сооружений. Инженерная гидравлика открывает широкие возможности в проектировании специальных сооружений, меняющих наносный режим водных объектов: методом лабораторного моделирования участков в пределах акватории можно определять параметры и строить в натуре на дне пороги, на берегах – шпоры, то есть возводить простые сооружения, изменяющие сложным образом характер течений, и формирующие отложения твёрдого стока в пределах безопасных и целесообразных, согласно проекту с учётом батиметрических особенностей бассейна.

IV. Заключение

1. Альтернативная энергетика, построенная на возобновляемых источниках, предполагает прекращение в процессе преобразования энергии выработки парниковых газов, – также немаловажным является переориентация поставок ископаемого сырья с энергетического на перерабатывающий промышленный сектор и снижение стоимости получения электроэнергии.
2. Тело плотины ПЭС отлично от устраиваемых на реках и по поперечному профилю, и по конструкционному исполнению, поскольку предназначено для одинаковых с обеих сторон гидростатических напоров, – плотина ПЭС – низконапорная, железобетонная, целесообразна – кубоидной формы, ячеистая.
3. Трёхмерные информационные модели потока проточной части гидротурбины позволяют судить о вибрации и кавитации с учётом изменения

[8] Исследования – количественные данные о передвижениив зоне заграждения иуровне гибелирыб, связанной с проходом через прямоточные турбины большого диаметра,отсутствуют.

параметров главных характеристик, например, при большем напоре – меньше вибрация и ниже вероятность возникновения усталости металла; сравнения колебаний сил и моментов, развиваемых в различных турбинных установках, позволяют проектировать конструкции с минимальными колебаниями. Структурный анализ твёрдого тела конструкций гидротурбины направлен, помимо конструкторской проработки геометрии деталей и основных элементов, таких как форма лопастей, на изучение механических свойств металла и выбор конструкционной стали.

4. Оптимизация работы ПЭС направлена не только на совершенствование течения в турбинном колесе с целью роста КПД, снижения вибрации и шума, но и решения других вопросов инженерной гидравлики: расчёт многобассейных систем, определение оптимального количества турбин, определение оптимального времени начала и окончания генерации каждой фазы, единых оптимальных эксплуатационных характеристик для одинаково результативной работы во время всех фаз всех приливных циклов.
5. Осложнения в эксплуатации, связанные с задачами инженерной гидравлики – волны, ледовые явления, коррозия. Традиционными для ГТС методами, описанными в СП, рекомендациях, справочниках являются: для снижения силы воздействия волн – волнорезы, берегоукрепление, для ледовых нагрузок – ледорезы, для защиты сороудерживающих решёток от обмерзания – антиобледенители в виде, например, гидрофобных покрытий, для защиты закладных частей затворов – электрообогрева, борьбы с внутриводным льдом и шуговыми коврами – запани и шугосбросы, – целесообразно гидравлическое лабораторное моделирование. Для предотвращения электрохимической коррозии металлических конструкций, исполнительных механизмов, деталей турбинных агрегатов в морской воде используют методы: легирования, ингибиторов, изолирующих покрытий, электрохимической защиты.
6. Системный анализ проблем, по сложности сопоставимых с ПЭС, невозможен без колоссальных вычислительных мощностей ЭВМ, поэтому стал широко доступен лишь в последние годы, и целесообразен не только в задачах КИВР, но и в проектах ПЭС, где учтены оптимизация работы электростанции, вопросы эксплуатации, охраны водных ресурсов и др.

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Evaluation and Design of Improvement of Al-Jbeiha Signalized Intersection Traffic Operation

By Batool Alaraj & Hana Naghawi

Abstract- The main objective of this paper is to design Al-jubha intersection and the Roadways approaches optimized to better level of service. Traffic design for this intersection include evaluation the current LOS for the intersection and design all possible solutions to reduce congestion, delay and low level of service in this intersection. This design will absolutely save time and money.

An intersection is a shared space that is used by more than one approach at a time. A signalized intersection is one where the shared space is used alternatively by a fixed number of approaches for a predefined time interval as per the phasing scheme used for the intersection.

In this paper, we made unconventional ideas to improve the intersection of the aljabaha signal. the intersection is analyzed as an isolated intersection in this study, using Synchro 8 and HCM 2010 standards. The simulation results the median U-Turn and signal optimization improve the intersection level of service from E-B. The delay for this intersection was reduced to 48.8%, 11.8.

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EVALUATIONANDDESIGNOFIMPROVEMENTOFALJBEIHASIGNALIZEDINTERSECTIONTRAFFICOPERATION

Strictly as per the compliance and regulations of:

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Batool Alaraj [α] & Hana Naghawi [σ]

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I. Introduction

The traffic performance of a roadway network is greatly influenced by the traffic flow through intersections. Many types of traffic control are being used worldwide at intersections such as yield signs, stop signs, roundabouts and signals. Similar to other countries, many traffic signals are installed in Jordan at intersections with moderate and heavy traffic volumes.

Traffic signals ensure safe and efficient traffic flow at intersections, along routes, and in street networks. They improve intersection capacity, minimize traffic delays, enhance safety by reducing specific accidents like right-angle collisions, promote orderly traffic movements, allow safe passage for minor amidst heavy traffic, and aid in establishing a signal system. Transportation professionals primarily measure the performance of signalized intersections based on vehicle delay, a crucial parameter (David 2013).

Vehicle delay is the most important parameter used by transportation professionals in evaluating the performance of a signalized intersection. This is perhaps because it directly relates to the time loss that a vehicle experiences while crossing an intersection (though we have not considered other problems like congestion due to queuing, extra fuel loss due to vehicle ignition etc.) Determining delay at intersections is challenging due to the unpredictable nature of arrival and departure processes. However, extensive research has been conducted to define delay using various analytical models, including deterministic queuing, steady state stochastic, and time dependent stochastic models. These models make assumptions that simplify the complex flow conditions, providing an approximate measure of the average delay experienced by vehicles crossing an intersection. Some studies have also aimed to predict the variance in overall delay for individual vehicles, considering the significant variations and randomness in traffic arrivals and interruptions caused by traffic signal controls (Gupta, 2005).

Vehicles exert a substantial environmental influence through emissions and the consumption of fossil fuels. The burning of gasoline and diesel generates CO_2, a greenhouse gas that contributes to climate change. Additionally, vehicles release pollutants like NOx and particulate matter, negatively impacting both air quality and human health. The extraction, refining, and transportation of fossil fuels also lead to habitat destruction and water pollution. To address these issues, there is a strong focus on developing electric vehicles, enhancing fuel efficiency, and investing in alternative transportation options such as public transit and cycling infrastructure. These measures are essential for reducing emissions, improving air quality, and safeguarding the environment for future generations.

a) Project Description

Yajouz road is located in Amman, and it is considered one of the most important dynamic sites which links Amman and Zarqa. In a map is displayed which demonstrates the location of Yajouz road within the districts of Amman.

In this study, a part of the Yajouz road is considered which is Al Jubaiha intersection. The intersection has four legs and connects Yajoz street with Abdullah Al-Lawzi Street. The intersection is signalized, and it is selected because it is considered one of the most important dynamic sites. Jubaiha Intersection has a heavy daily volume of traffic, which leads to a traffic problem represented by delay,

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especially during peak hours. It is located in the north of the Jordanian capital.

Fig. 1: Aljbaha intersection

b) Problem Statement

The increase in road network by widening roads, building new tunnels and other infrastructure is costly and limited by the available spaces in Amman, therefore, the other solution is to decrease the travel demand, especially within the peak hours. The long-term solution requires developing a reliable and comprehensive transportation system and encouraging people to use it instead of private cars. However, the current situation of congested traffic requires immediate solutions with minimal costs, time, and effort. In this project, a micro-scale solution to the delay problem at the intersection is proposed. More than one alternative will be considered (including a signal optimization, median U-Turn and signal optimization with median U-turn), and then the best alternative will be selected. Although, a long-term macro scale solution is required on a network-wide level which considers the interactions between different elements of the roadway. However, the scope of this project is limited to a micro-scale solution.

c) Project Objectives

This project aims to improve the level of service at Al-Jbeiha intersection. The objectives can be summarized as follows:

1. Assessing the existing level of service at the intersection: Evaluate the current traffic conditions and determine the performance of the intersection.
2. Developing alternative solutions for improved traffic conditions: Propose various strategies and measures that can enhance the traffic flow and alleviate congestion at the intersection. Use simulation models to estimate the resulting level of service for each alternative.
3. Selecting the optimal solution: Analyze and compare the proposed alternatives based on their predicted level of service and feasibility. Determine the best alternative for implementation at the intersection.

d) Project Constrains

The main constraints involved in this project are economic and ethical. First, the selected alternative should be economically justified by considering a sequential evaluation process starting from the least disruptive option to the most disruptive option which would be more costly. Furthermore, the design follows all local and international ethical code requirements.

e) Project Standard and Codes

- Highway Capacity Manual) HCM)
- American Association of State Highway and Transportation Officials (AASHTO) 2011

II. Literature Review

Hussein (2023) conducted a study to evaluate and enhance four three-leg intersections controlled by STOP signs in various locations within Amman City. The evaluation and improvement processes utilized Highway Capacity Software (HCS-2010) and Synchro-10 software. The validation and simulation were performed using VISSIM-11 software. The evaluation with HCS-2010 and Synchro-10 indicated that the left-turn movements from the minor streets experienced significant delays and operated in a breakdown traffic condition (Level of Service LOS-F). The application of Warrant-3 (Peak Hour Volume) determined that three of the selected intersections warranted signalization under existing conditions, while the fourth intersection did not meet the requirements. For short-term conditions with a growth rate of 5.5%, both software tools indicated that all four selected intersections warranted traffic signals. The optimal cycle length for the traffic signals was determined for each intersection, considering two operation modes for the left-turn movements on the major streets: Protected and Protected-Permitted phase. The HCS-2010 and Synchro-10 software were used for this analysis, and the results were validated using VISSIM-11. The improvements in traffic and geometric conditions resulted in a reduction in vehicle delays, with improved Level of Service (LOS-C or LOS-D) at the minor approaches and the entire selected intersections (LOS-B or LOS-C).

In their study, Khalifate (2021) aimed to improve the capacity and level of service at the sixth circle in Jordan by implementing traffic signals and a roundabout metering approach. The VISSIM software and a C++ program were utilized for this purpose. The sixth circle, situated near Crown Plaza and the Jordan Gate Towers project, experiences congestion due to heavy traffic flow. The study focused on assessing the traffic situation at the sixth circle and proposed potential solutions to reduce daily traffic flow for circle users. In the second scenario, four signals were placed at the roundabout, interconnected with different cycle lengths. A 90-second cycle length resulted in a level of service rating of D. The third scenario involved the use of adaptive signals on the roundabout, which were connected to ground detectors placed before the signals. These adaptive signals operated based on the queue length of approaching vehicles detected by the ground detectors. The opening and closing of the signals were designed using simulation and implemented through the C++ programming language. The first two signals were opened for 45 seconds, prioritizing Swefieh road with reference to King Faisal, and then closed for 45 seconds to open the signal for the next street from the fifth circle, specifically Zahran street.

III. Methodology

The methodology is summarized as follows:

1) Collecting data for the intersection; traffic volumes, geometric components, and traffic signal system.
2) Analysis of the current situation for the intersection, by finding the level of service and delay for the intersection using the Synchro software.
3) Provide solutions for the intersection.
4) Evaluate the performance of the intersection after applying the solutions, in term of level of service and delay, with the help of the Synchro software.

a) *Traffic Volumes*

Aljbaha intersection located at the Amman, the key traffic data were taken from the department of traffic operations at GAM. Traffic data was collected on April 4th, 2022, with attention to the 15-min peak hour volumes that happened in the morning peak from 7-8 am.

b) *Model Development*

SYNCHRO8 which is a microscopic level analysis software was used to analyze and evaluate.

i. *Current Situation*

The current Volumes of the current Volumes values Based on the analysis of data above, the total intersection control delay was found to be 62.1 seconds, under those circumstance the level of service was E. Moreover, the maximum volume to capacity ratio (V/C) was 1.94.

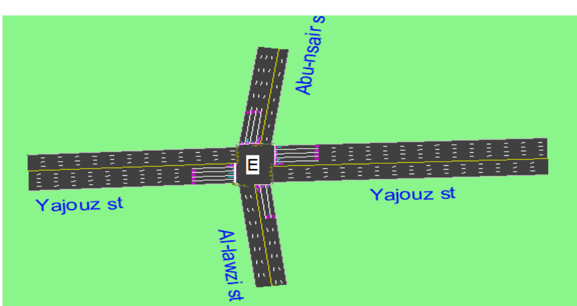

Fig. 2: Level of service

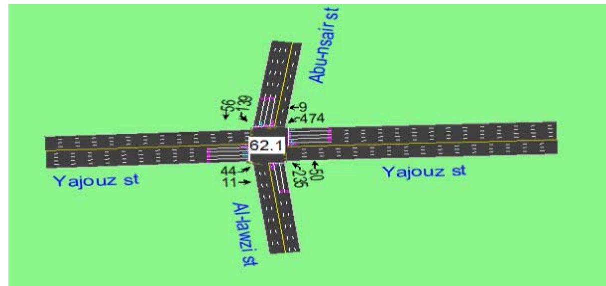

Fig. 3: The total intersection delays

IV. Project Design

The main objective of this paper is to design Al-jubha intersection and the Roadways approaches optimized to better level of service.

Traffic design for this intersection include evaluation the current LOS for the intersection and design all possible solutions to reduce congestion, delay and low level of service using Synchro 8.

a) *Signal Optimization: (The FIRST Alternative)*

Traffic signal optimization is one of the most cost-effective ways to improve traffic movement and make our streets safe and efficient. Signal optimization is performed for the following reasons: To adjust signal timing to account for changes in traffic patterns due to new developments and traffic growth.

LOS (D) Steady Traffic at High Density. The speed and the maneuverability are severely reduced. Low level of comfort for drivers, as collisions with other vehicles, must constantly be avoided. A slight increase in the traffic risks causing some operational problems and saturating the network.

Under the same phasing and geometric conditions, Synchro 8 results show that the cycle length has decrease to 45 seconds. Furthermore, the total intersection delay has decreased to 48.8 seconds, and the maximum volume to capacity ratio has decrease to 1.8. However, the service level turned into D.

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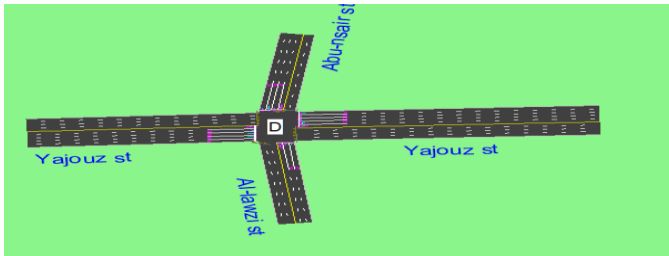

Fig. 4: Level of service

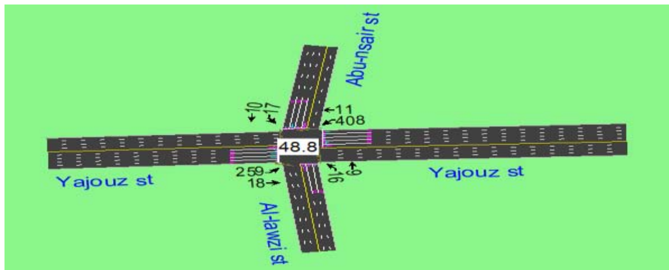

Fig. 5: The total intersection delays

b) Median U-Turn (The Second Alternative)

Median U-Turn: The main disadvantage is the added stopping and delay impact on left turning traffic. Although despite this fact, this design has been shown to improve total intersection delay and travel time conditions under certain volumes. It requires larger R.O.W. along the major roadway ¬ AASHTO recommends a 60ft to accommodate large trucks, from a non-motorized user standpoint, this design presents fewer threats to crossing pedestrians (longer time, refuge area). Level of service LOS (C) Steady Traffic but Limited. The presence of other vehicles affects drivers. The choice of the speed is affected and maneuvering requires vigilance. The level of comfort decreases quickly at this level, because drivers have a growing.

Fig. 6: Level of service

Fig. 7: The total intersection delays

c) Signal Optimization a Median U-turn (Third Alternative)

LOS (B) Steady Traffic: The presence of other vehicles begins to affect the behavior of individual drivers. The choice of the speed is free, but the maneuverability has somewhat decreased. The comfort is excellent, as drivers simply need to keep an eye on nearby vehicles. Intersection delays 11.8s.

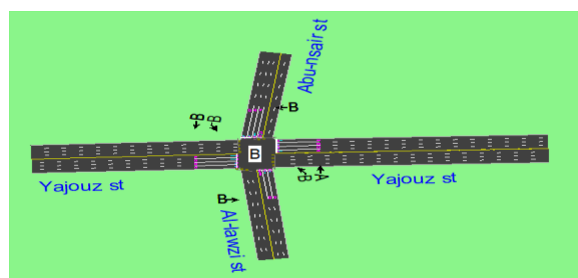

Fig. 8: Level of service

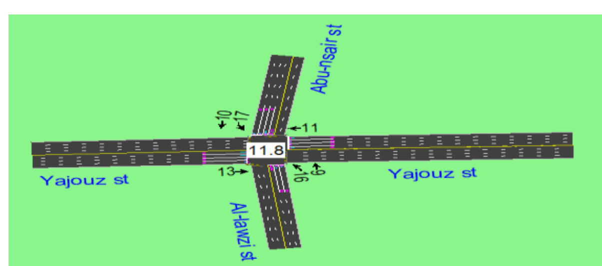

Fig. 9: The total intersection delays

V. Results

Table 1: Summary of result

	Cycle length	Maximum v/c ratio	Intersection delay	Level of service
Current situation	158	1.94	62.1	E
Signal optimization	45	1.8	48.8	D
Median U-turn	158	0.61	30.5	C
Signal optimization +Median U-turn	45	0.67	11.8	B

VI. Conclusion

1. The main object of this study is to evaluate the effect of implementing unconventional arterial intersection design.
2. These designs are regarded to be unconventional because they incorporate geometric features or movement restriction that would be accepted at 4 leg intersection.
3. Aljbaha intersection was selected to perform this study. in the final analysis, results showed a different level of improvement according to the UAID model chosen, to sum up, the level of service of Signal optimization, median U-turn and single optimization + median U-turn enhanced from E to D, C, B respectively. Moreover, the intersection delay was reduced by 48.8, 30.5, and 11.8 respectively.
4. Since the median U-turn + single optimization which improved the LOS from E to B on the main intersection the use of median U-turn + single optimization will decrease the delay by 11.8%.

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Assessment of Risk Management at the Design Stage of Construction Projects in Afghanistan

By Mohammad Alem Wardak & Engineer Madiha Salangyar
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Abstract- In this study, as identified above, the identification of the critical factors afterwards how the management and prevention of possible risks in the design phase of the construction project are investigated, rather than the problems and shortcomings encountered in this phase of the project. Successful completion of this research will help us identify hazardous items in the design phase of construction projects, and what steps should be taken to eliminate or minimize these risks.

Keywords: risk, construction, risk management, afghanistan, risk control, riskology.

GJRE-E Classification: FOR Code: 090599

ASSESSMENTOFRISKMANAGEMENTATTHEDESIGNSTAGEOFCONSTRUCTIONPROJECTSINAFGHANISTAN

Strictly as per the compliance and regulations of:

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Mohammad Alem Wardak [α] & Engineer Madiha Salangyar [σ]

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I. Introduction

The importance of this issue is heightened when the Afghan government has prepared long-term plans for the development of approximately one million affordable housing units with appropriate living standards. Due to the findings of the Ministry of Urban Development and Independent Bureau of Local Authorities, Kabul Municipality and UN Habitat Research, Afghanistan's urban population has been increasing from 20% to 24% due to urban migration in the past two years. In the absence of housing, about 1.5 million have been observed over the years. Kabulas the largest center of internal migration represents 10% annual growth over the past decade, also, sources indicate that 78% of citizens seeking housing are in critical condition, according to the above report, housing problems are one of the most serious social issues in Afghanistan, especially in Kabul. So it is imperative that you pay close attention to this issue and develop comprehensive plans for addressing and resolving this issue and manage it properly. In Afghanistan, risk management will be one of the steps that will help to make these programs a reality. Given the importance of this issue, it requires a comprehensive research to identify the sources of risk and how to manage it realistically, the questions of this research are divided into two types of open and closed questions. These two types of questions are considered as questionnaire and interview form. The questions addressed in the questionnaires are quantitative and closed-ended questions that were scored by the participants. Points are given, that is, by choosing 1 of 5 options, From 1 to 5, respectively, from 5 to 1 enormous.

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a) Research Goals in Brief

Identifying the sources of risk
Get comprehensive solutions
Prevent similar occurrences in future projects
Accelerate the design phase of future construction projects

b) When is Risk Analysis needed?

Risk assessment is useful in many situations.

For example:

1. When planning a project, to help predict and neutralize potential problems.
2. When you are deciding to go with a project.
3. When you plan to increase the level of safety and potential risk management in your workplace.
4. Be prepared for events such as equipment and technology failure, theft, employee illness, or natural disasters.

c) How to use Risk Analysis?

To apply the risk analysis, follow these steps:

1. Identify threats

1:1 the first stage of risk analysis is to identify existing and occurring risks. Risks that may be encountered.
1:2 Prepare a list briefly to check that there is a threat or not?
1:3 what are some issues that may harm you?
1:4 Ask people who have different views

2. Risk Assessment

2:1 once you have identified the threats, it is necessary to calculate the probability of the two cases: Threats and their impact. One solution is this: Find the accurate estimate of the probability of occurrence of event, and then multiply this value to the expense of occurrence of the event and doing it right, this will give you a risk value.
2.2 Value of risk = probability of occurrence x cost of occurrence.

As a simple example: Imagine you have identified the risk that rent accommodation to substantially increase: You think that there is 80% chance of this happening next year, because your landlord has recently increased rentals for other businesses. If this happens, next year your business will cost extra $ 500,000.

So the value of the risk of increased rent equals: 0.8 (probability of occurrence) × 500000 (fee happen) = 400000 (Risk value).

3. How to manage risk

3:1 once you have identified the value of the risk you are facing; you can look for a way to manage it. (Mehta Arjmand, 1396).

4. Divide the risk

4:1 You can also divide the risk with people, Groups, Organizations or other third parties as a result of the possible risks.

For example: When you cover your office building or company property list with insurance of the third party, or when you partner with another organization at the beginning of product development, you have shared the risk with them (Mehta arjmand, 1396).

5. Accept risk

5:1 Your last choice is risk acceptance. This is usually the best option for situations where risk cannot be avoided or mitigated, When the potential risk loss is less than the cost of insurance to prevent risk, or when the potential benefit is at the risk of accepting the risk.

6. Risk control

6:1 if you have chosen a risk-taking solution, there are ways to reduce the impact. Past experiences are effective ways to reduce risk. Experienced managers do risky things in smaller and more manageable dimensions. You can use the results of previous tests to identify the location of the risk and take preventive action before performing large-scale work.

Research Methods: We are trying to clarify the facts and find ways to bring us closer to the goal. The research method of this article is divided into two sections.

1. Questionnaire
2. Interview

The two sections are divided into 5 departments and projects with 60 expert participants. Participants in the two sections of the questionnaire and interview presented their opinions separately. The data were analyzed using SPSS software. Choosing this app to get right and accurate statistics and numbers is intended to make the results work and useful.

1. *Questionnaire:* The questions raised in the questionnaires are as follows.

1. Which of the following is the main cause of the crisis (risk) in the design phase of construction projects?

Table 1

No.	Value	Very low	Low	Medium	Much	Very much
	Number	1	2	3	4	5
1	Lack of unit management in the project					
2	lack of coordination of the project team					
3	Lack of cooperation from related departments or presidency					
4	Lack of work ethics (managerial)					
5	Internal competition (Negative competition)					
6	Lack of transformation management (inability to lead new ways in the project)					
7	Appointing non-technical people in charge					
8	The planning team imbalance in knowledge					
9	Management weaknesses in not recognizing project strengths and weaknesses					
10	Appointment of people with low knowledge level					
11	Change and renewal of plan					
12	Lack of planning and communication in the project					
13	Lack of office facilities to carry out project work					
14	Sophisticated design and detail (Details) inadequate about it					
15	Delay in drawing and issuing drawings					
16	Lack of risk management in projects					
17	Conflict in project priorities					
18	Poorly organized office project					
19	Involvement in many projects at the same time					
20	Vandalism, disruption and unforeseen side effects					
21	Lack of attention to cultural issues and social norms in building design					
22	Inadequate design and plan information for accurate estimation and planning					

23	The lack of a specific timeline for the regular development of design						
24	Poor control of the design flow and its development						

2. Which of the following is the most critical factor in the risk-taking phase of project design?

Table 2

No.	Value		Very low	Low	Medium	Much
	Number	1	2	3	4	5
1	Waste of time					
2	Monetary inflation					
3	The rising prices of materials (market risk)					
4	Exchange rate fluctuations					
5	Delays in project					
6	Canceled project					
7	Poor management's perception of the country and lack of confidence from donors in the future					
8	Failure by donors to read interior design processes					
9	The emergence of the deteriorating security situation					
10	Political changes					

2. *Interview:* The questions in the interview section are as follows:

1. What causes the design process in construction projects to be compromised?
2. What suggestions do you propose to prevent or minimize the crisis during the design phase of construction projects?
3. How to manage the crisis in the design phase of construction projects?

The main research issues are as follows:

What causes the design process in construction projects to be compromised? These two divisions are made up of a total of 60 special partners.

This analysis was performed using Statistical Package for Social Science (SPSS) software. Variable statistics using SPSS software are distributed in the following table and chart.

1. Lack of Unit Management in Projects
2. The lack of coordination of the project team

Table 3

Lack of unit management in the project Lack of unit management in the project					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	1	4.3	4.3	4.3
	Medium	3	13.0	13.0	17.4
	Much	8	34.8	34.8	52.2
	Very much	11	47.8	47.8	100.0
	Total	23	100.0	100.0	

Table 4

The lack of coordination of the project team					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very low	1	4.3	4.3	4.3
	Low	4	17.4	17.4	21.7
	Medium	3	13.0	13.0	34.8
	Much	7	30.4	30.4	65.2
	Very much	8	34.8	34.8	100.0
	Total	23	100.0	100.0	

Table 5

Lack of Work Ethics (Managerial)					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very low	2	8.7	8.7	8.7
	Low	7	30.4	30.4	39.1
	Medium	8	34.8	34.8	73.9
	Much	4	17.4	17.4	91.3
	Very much	2	8.7	8.7	100.0
	Total	23	100.0	100.0	

Table 6

Internal Competition (Competition Negative)					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very low	2	8.7	8.7	8.7
	Low	5	21.7	21.7	30.4
	Medium	3	13.0	13.0	43.5
	Much	7	30.4	30.4	73.9
	Very much	6	26.1	26.1	100.0
	Total	23	100.0	100.0	

It is also considered for each factor of the table, which totals 24 tables, then check the validity of the questionnaire was using Cronbach's alpha coefficient.

$$\alpha = \frac{K}{K-1}(1 - \frac{\sum_i^k \sigma^2}{\sigma^2})$$

In this formula (k) the number of questions, and (σ^2) is the variance of each question. The Cronbach's alpha coefficient is used to measure the one-dimensionality of attitudes, judgments, and other items that are not easy to measure.

Internal Reliability	Cronbach's alpha coefficient
Excellent	$\alpha \geq 0.9$
Good	$0.9 > \alpha \geq 0.8$
acceptable	$0.8 > \alpha \geq 0.7$
Questioned	$0.7 > \alpha \geq 0.6$
Poor	$0.6 > \alpha \geq 0.5$
unacceptable	$0.5 > \alpha$

Case Processing Summary			
		N	%
Cases	Valid	23	100.0
	Excluded[a]	0	.0
	Total	23	100.0

a. List wise deletion based on all variables in the procedure.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Lack of unit management in the project	81.00	223.545	.042	.904
The lack of coordination of the project team	81.52	201.625	.625	.893
Lack of cooperation from related departments or projects	82.09	198.901	.745	.890
Lack of work ethics (managerial)	82.39	204.613	.622	.893
Internal competition (competition Negative)	81.83	198.877	.652	.892
Lack of transformation management (inability to lead new ways in the project)	81.09	204.174	.654	.893
Appointing non-technical people in charge	81.04	212.771	.422	.898
The scheme imbalance in knowledge	81.96	210.316	.432	.898
Management weaknesses in not recognizing project strengths and weaknesses	81.26	201.929	.692	.892
Appointment of people with low knowledge level	81.65	206.874	.537	.895
Change and renewal of plan	82.04	199.862	.589	.894

Lack of planning and communication in the project	81.39	210.794	.515	.896
Lack of office facilities to carry out project work	82.13	211.846	.385	.899
Sophisticated design and detail (Details) inadequate about it	81.78	207.178	.573	.895
Delay in drawing and issuing drawings	81.57	216.075	.276	.901
Lack of risk management in projects	81.83	214.787	.241	.903
Conflict in project priorities	81.83	203.332	.678	.892
Poorly organized office project	81.61	204.704	.495	.896
Involvement in many projects at the same time	82.52	210.715	.316	.901
Vandalism, disruption and unforeseen side effects	81.74	208.747	.545	.895
Lack of attention to cultural issues and social norms in building design	82.13	206.573	.478	.897
Inadequate design and plan information for accurate estimation and planning	81.70	200.676	.661	.892
The lack of a specific timeline for the regular development of design	81.35	213.964	.339	.899
Poor control of the design flow and its development	81.57	216.530	.367	.899

II. Conclusion

Considering the statistics of the risk among the 24 risk identified by the researcher in the design phase of construction projects and distributed to questionnaires specialists in related fields, there are 6 types of high risk that are listed below:

- Lack of unit management in the project
- Lack of transformation management (inability to lead new talents in the project)
- Appointing non-technical people at the helm
- Management weaknesses in not recognizing project strengths and weaknesses
- Office of thick organization
- Organizing team's lack of coordination

Important Factors from the Interview:

- Lack of unified management and planning
- Lack of assessment of possible risks
- Lack of detailed study of lands and topography of the area
- Failure to examine religious, cultural and climatic conditions of the country
- Lack of economic planning in projects

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Finite Element Model for Prediction of Highway Pavement Deformation

By Arinze, Emmanuel Emeka, Agunwamba, Jonah Chukwuemeka & Ezeokpube, Gregory Chukwuemeka
Michael Okpara University of Agriculture

Abstract- The determination of stresses developed in a pavement constitutes a basic prerequisite and is achieved mainly by implementation of various methods which is dependent on the number of distinct pavement layers. The need to predict the deformation of highway pavement with a precision that will aid optimal design cannot be oversized. Boussinesq's work was foundational for the development of all subsequent elasticity theories, but Boussinesq assumed one layer of uniform subgrade material. In this research, a mechanistic elastic model for obtaining deformation in road pavement was derived using Finite Element Method (FEM). This model was found to be an improvement on the Boussinesq model owing to the closeness of its result to that obtained from Plaxis software. In addition to this, it has the capability of handling deformation in both flexible and rigid pavement utilizing the dimensional similarities between unit weight and modulus of subgrade reaction of soil. A MATLAB program was also written for easy computation using the new model.

Keywords: *pavement deformation; finite element model; boussinesq's model; MATLAB program.*

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FINITEELEMENTMODELFORPREDICTIONOFHIGHWAYPAVEMENTDEFORMATION

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Finite Element Model for Prediction of Highway Pavement Deformation

Arinze, Emmanuel Emeka [α], Agunwamba, Jonah Chukwuemeka [σ] & Ezeokpube, Gregory Chukwuemeka [ρ]

Abstract- The determination of stresses developed in a pavement constitutes a basic prerequisite and is achieved mainly by implementation of various methods which is dependent on the number of distinct pavement layers. The need to predict the deformation of highway pavement with a precision that will aid optimal design cannot be oversized. Boussinesq's work was foundational for the development of all subsequent elasticity theories, but Boussinesq assumed one layer of uniform subgrade material. In this research, a mechanistic elastic model for obtaining deformation in road pavement was derived using Finite Element Method (FEM). This model was found to be an improvement on the Boussinesq model owing to the closeness of its result to that obtained from Plaxis software. In addition to this, it has the capability of handling deformation in both flexible and rigid pavement utilizing the dimensional similarities between unit weight and modulus of subgrade reaction of soil. A MATLAB program was also written for easy computation using the new model.

Keywords: pavement deformation; finite element model; boussinesq's model; MATLAB program.

I. Introduction

a) Causes of Pavement Deformation in Highway Pavement

Deformation of highway pavement can be occasioned by weak soils [1-2], frost action [3-4], expansive soils [5], Unbound aggregate material [6], seasonal drying and wetting [7]. Deformation can also result from thermal stresses [8], differential subgrade settlement [10], and aggregate morphology [11-12].

b) Methods of Analysis of Highway Pavement

Boussinesq's work was foundational for the development of all subsequent elasticity theories. Boussinesq's theory assumed one layer of uniform and homogenous subgrade material. According to [13], the stresses applied to an elastic homogenous and isotropic material extended to infinity at both directions, (horizontal and vertical) and the stress developed at any depth, z, below the surface of the pavement under the influence of a point load in Figure 1 can be calculated thus:

Vertical stress,

$$\sigma_z = \frac{3Q}{2\pi} \cdot \frac{z^3}{R^5} \tag{1}$$

After the pioneering work of Boussinesq, different methods of analysis have been used in obtaining stresses and the accompanying deformation in highway pavement. Behera (2013) [14] used linear elastic theory in analyzing the deformation behaviour of fly ash composite material in the subbase of surface coal mine haul road. Uzan (2004) [15] applied the mechanistic framework in determining the permanent deformation of flexible pavement. Du and Dai (2006) [16] utilized the dynamic stability evaluation index in analyzing permanent deformation. It was discovered that the method is not fit for evaluating permanent deformation of asphalt mixture. Tchemou et al. 2011 [17] and Qiao et al. 2015 [18] applied rutting mechanisms in predicting flexible pavement degradation, [19] used model simulation in determining permanent deformation in high-modulus asphalt having sloped and horizontally curved alignment. Du and Shen (2005) [20] applied grey modelling method, [21] used field cores, and [22] used ground-penetrating-ladar in predicting the development of irrecoverable deformation in road pavement. Sawant (2009) [23] used dynamic analysis whereas [24] used the back-calculation of the transition probability approach. Each group of researchers demonstrated the merit of their method.

Many researchers have applied finite element method (FEM) in the analysis of deformation in highway pavement [25-28]. He et al. (2008) [29] used 3D visco-elastic finite element analysis (FEA) in determining asphalt pavement rutting deformation. Kim et. al. (2014) [30] used FEM in modelling the effect of environmental factors on rigid pavement deformation. In analyzing the influence of asphalt deformation under heterogeneous settlement of roadbed whereas [31] used elastic-plastic dynamic FEM to compute the differential settlement of the half-filled and half dug embankment under axle load. The latter succeeded in deriving a model for computing critical differential settlement. Each of the models is unique depending on the assumptions made by each group of researchers. Sadek and Shahrour (2007) [32] compared Boussinesq's model with the occasional plastic nature of subgrade and pavement materials. The researchers model was shown to be an improvement on Boussinesq's model.

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II. Purpose

This work involves the finite element method for predicting pavement deformation. Each model cited is derived either for rigid pavement and flexible pavement. However, this model is also unique owing to assumptions and approach was derived to handle both rigid and flexible pavement. Secondly, according to [33], many models used in the structural design of pavements are complex and/or difficult to use in the field, making its application in pavement analysis rather difficult. This model is devoid of such complexities.

III. Methodology

a) Derivation of the New Model

i. *Model Assumption*

In the derivation of the new model for deformation behaviour, the following assumptions were made;

1. Loading is symmetrical
2. Soil is elastic, homogenous and isotropic
3. The principle of superposition is valid
4. Constitutive law is valid
5. The idealized system of pavement structure is treated as a beam on elastic subgrade
6. The UDL from asphaltic concrete is converted to point load to produce the worst deformation needed for optimal design.
7. The problem is two-dimensional.

ii. *Model Derivation*

A road of base course thickness t_b, asphaltic concrete (AC) thickness as t_p, and width l is subjected to a standard axle load P_a as shown in Figure 10.

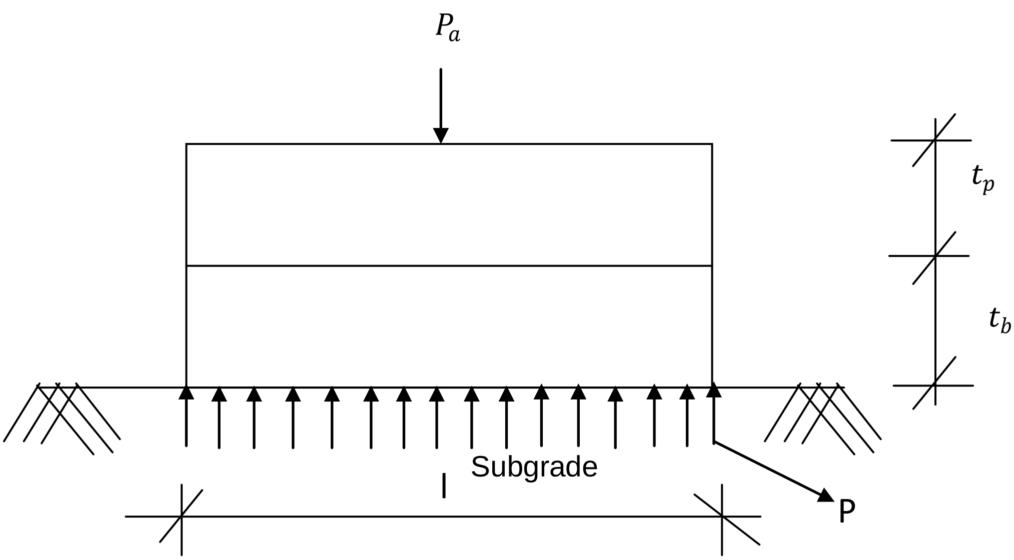

Figure 1: Simple model diagram

To convert the asphaltic concrete (AC) to a point load.

$$\text{Area of } AC = t_p . l \quad (2)$$

Let the modulus of subgrade reaction due to $AC = ƙ$

∴ Weight per unit length (UDL)

$$= l . t_p . ƙ \quad (3)$$

Converting the UDL to point load

$$P_u = (l t_p \kappa_{ac}) L = l^2 t_p \kappa \quad (4)$$

∴ Total point load on the pavement

$$P = Pa + l^2 t_b \kappa \quad (5)$$

The model diagram in Figure 1 is simplified in Figure 2.

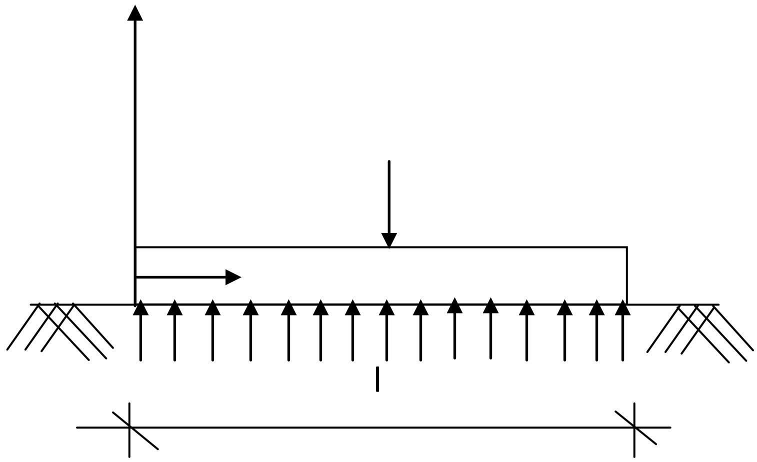

Figure 2: Model pavement with point load and moment

To determine the total stricture stiffness matrix for a spring assemblage by using the force/displacement matrix relation of FEM, the model is discretized into nodes and element as shown in Figure 3.

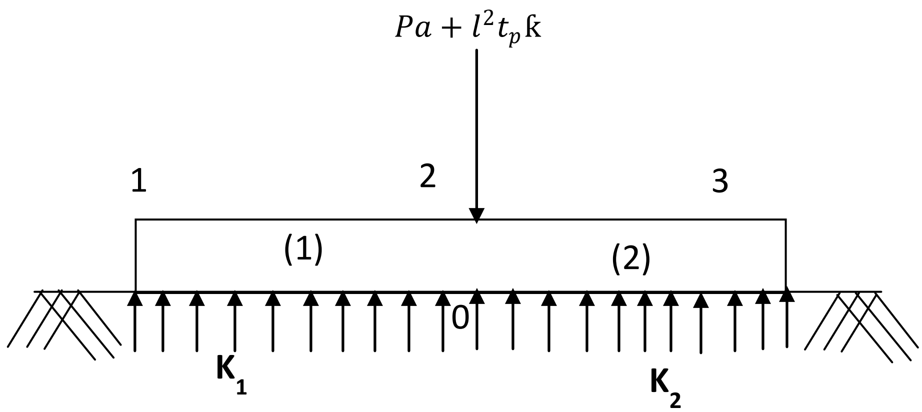

Figure 3: Pavement discretized into 2 elements and 3 nodes

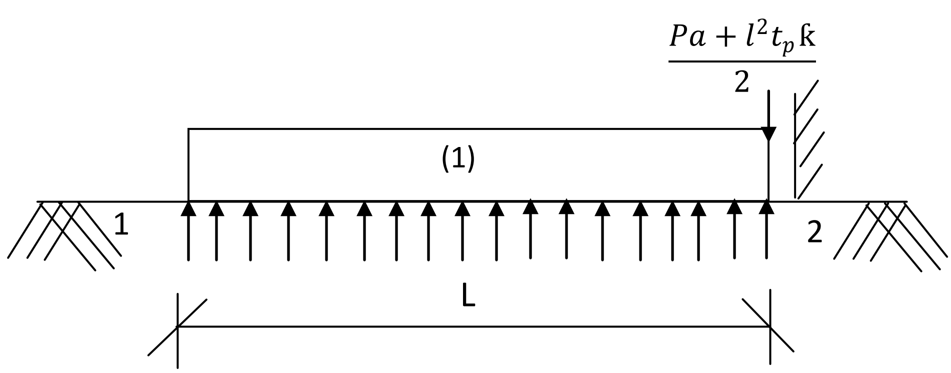

Figure 4: Symmetry of the discretized model pavement

Substituting into the Timoshenko beam element stiffness matrix, a global Equation (13) is obtained.

$$\frac{EI}{L^3(1+\emptyset_c)}\begin{bmatrix} 12 & 6L & -12 & 6L \\ 6L & (4+\emptyset_c)L^2 & -6L & (2-\emptyset_c)L^2 \\ -12 & -6L & 12 & -6L \\ 6L & (2-\emptyset)L^2 & -6L & (4+\emptyset_c)L^2 \end{bmatrix}\begin{Bmatrix} d_1y \\ \emptyset_1 \\ d_2y \\ \emptyset_2 = 0 \end{Bmatrix} = \begin{Bmatrix} F_1y \\ 0 \\ \frac{Pa+l^2 tp\ k}{2} \\ 0 \end{Bmatrix} \tag{6}$$

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Applying the boundary condition

$$d_1 y = 0 = \emptyset_2$$

$therefore$ using the 2nd and 3rd row of equation 13 whose rows are associated with the two unknowns, $\emptyset_1$ and $d_2 y$ and simplifying, we obtain;

$$d_2 y = \frac{(Pa + L^2 t_P ƙ)(4 + \emptyset_c)L^3}{24EI} \quad (7)$$

For long slender beams with L about 10 times or more, the beam depth, shear correction term $\emptyset_c$ is small and can be neglected [34].

For standard highway, L=7.4 m, d = 0.6 m [35]

$$\therefore \frac{l}{d} = \frac{7.4}{0.6} \approx 12 \quad (8)$$

$$\Longrightarrow \emptyset_c = 0$$

If l= the whole length of the beam, then l = 2L and we can substitute $L = l/2$ in equation 5.38 to obtain the deformation in terms of the whole length of the beam as;

$$=> d_2 y = \left[\frac{\left(P_a + l^2 t_p \kappa\right) l^3}{48EI}\right] \quad (9)$$

IV. Conclusion and Recommendation

Many roads fail even before their design lives, probably because of using conservative models in their design to save cost. The cost implication of early maintenance and/or rehabilitation implies that using conservative models is not economical in the real sense. This new model, being close with the result from plaxis software shows that it is an improvement on Boussinesq's model which is found to be conservative. Secondly, the dimensional uniformity between unit weight and modulus of subgrade reaction was utilized by the researchers in making it a flexible model that can handle deformation in both rigid and flexible road pavement unlike many existing models.

V. Declarations

a) Ethical Approval and Consent to Participate

The research observed all ethical codes and done with the consent of all authors involved.

b) Consent for Publication

We give our Consent for the publication of the article.

c) Availability of Supporting Data

Not applicable

d) Code Availability

Not applicable

e) Funding

Not applicable

List of Abbreviations

σ_z = Vertical Stress
Q = Vertical Load
Z = Vertical Load
R = Influence Radius
t_b = Base Course Thickness
t_p = Asphaltic Concrete/ Rigid Concrete Thickness
l = Width of Pavement
ƙ = Modulus of Subgrade Reaction
P_a = Axle Load
d_2y = Deformation
∅ = Shear Correction Factor
E = Young's Modulus of the Pavement
I = Moment of Inertia of the Pavement
d = Depth of the Pavement
e = Expected Values
o = Observed Values
V = Degree of Freedom
χ = Chi-square Value

Highlights

- The need to predict the deformation of highway pavement with a precision that will aid optimal design cannot be overemphasized.
- A mechanistic elastic model for obtaining deformation in road pavement was derived using Finite Element Method (FEM).
- The new model improved on Boussinesq's owing to the closeness of its result to that obtained from Plaxis software.
- The new model also has the capability of handling deformations in both flexible and rigid pavement.

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Career | Credibility | Reputation

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Career | Credibility | Reputation

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Financial

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Associates are authorized to organize symposium/seminar/conference on behalf of Global Journal Incorporation (USA). They can also participate in the same organized by another institution as representative of Global Journal. In both the cases, it is mandatory for him to discuss with us and obtain our consent. Additionally, they get free research conferences (and others) alerts.

Career | Credibility | Financial

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Exclusive Financial

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Preferred Author Guidelines

We accept the manuscript submissions in any standard (generic) format.

We typeset manuscripts using advanced typesetting tools like Adobe In Design, CorelDraw, TeXnicCenter, and TeXStudio. We usually recommend authors submit their research using any standard format they are comfortable with, and let Global Journals do the rest.

Alternatively, you can download our basic template from https://globaljournals.org/Template.zip

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Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

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Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

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Tips for Writing a Good Quality Engineering Research Paper

Techniques for writing a good quality engineering research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

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6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.
22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.
23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- o Explain the value (significance) of the study.
- o Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

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This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

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	A-B	**C-D**	**E-F**
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Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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