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Comparative Analysis of Existing Frameworks Used for the Selection of Sustainable Building Materials in High-Rise Construction

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Abstract

A recently created framework is presented that offers a reasoned framework for evaluating technology in advance in terms of performance, sustainability principles, and applicability to the building and operation phases of a project. The framework is intended to help policymakers and project stakeholders systematically identify and assess the relative benefits and consequences of various alternative sustainable technologies. This article proposes a multi-objective optimal fuzzy control system for tall building response reduction. High-rise structures present distinct design challenges for structural and geotechnical engineers, particularly when they are situated in seismically active regions or have soil underneath with high compressibility or other geotechnical risk factors. The best fuzzy logic control approach for building vibration reduction with magneto-rheological (MR) dampers is presented in this research. Since MR dampers are semi-active, an external voltage supply is used to monitor them. Lastly, the study assesses how well the optimised off-line fuzzy controller performs on a multi-story building model when subjected to seismic excitations. The primary benefit of employing FLC to drive the voltage of the MR damper is that the voltage shift is gradual and seamless. As a result, the current method offers improved vibration control for buildings subjected to seismic shocks.

Keywords: *Construction Materials; High-Rise Building; Sustainable Design; Fuzzy Logic Control System; Optimum Design.*

1. INTRODUCTION

A multistory structure that requires the use of an elevator or other mechanical equipment to move vertically is referred to as a high-rise building. The first tall buildings in the United States were built in the 1880s [1]. They originated in urban areas when there was a need for buildings that ascended vertically rather than horizontally, occupying less valuable real estate, due to high population concentrations and growing land costs. Buildings with multiple stories were constructed possible by the combination of glass exterior covering and steel structural frameworks. These buildings were a typical feature of most countries' architectural landscapes by the middle of the 20th century [2]. In order to sustain exceptionally high gravity loads, high-rise building foundations are sometimes constructed using concrete piles, piers, or caissons that are buried in the ground. Even on fairly soft ground, there are ways to evenly distribute pressures, even though solid rock beds are preferred. Their frames are composed of beams, which are horizontal support components, and columns, which are vertical support elements. The bundled-tube technique, which creates incredibly rigid columns or tightly spaced columns at the building's perimeter, is used to create even more robust frameworks [3].

In a high-rise, the elevator serves as the primary means of vertical mobility. For structural

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and geotechnical engineers, high-rise buildings pose unique design issues, especially when they are located in seismically active areas or have highly compressible soil beneath them or other geotechnical risk factors. High-rise buildings can confront firemen with substantial challenges in the event of an emergency. Both modern and traditional building designs have significant problems, as do building systems like fire sprinklers, HVAC, and other things. In order to ensure that concerns regarding pedestrian wind comfort and wind risk are addressed, research is usually required [4]. Setbacks are a common architectural feature in high-rise buildings; they minimise wind exposure, boost ground-level daylighting, and provide the illusion of the structure being thinner.

2. THE DEVELOPMENT OF HIGH-RISE BUILDINGS

Many people believe that the 10-story Home Insurance Building, which was built in Chicago in 1885, was the first skyscraper ever built [5]. According to the Architectural Record, the Marshall Field Estate appointed a committee consisting of architects and other experts to determine whether the Home Insurance Building could rightfully claim the title of being the world's first skyscraper before it was demolished to make way for the construction of the New Field Building.

High-rise buildings have emerged as a result of developments concerning construction technology, building materials, and structural systems. High-rise structures have encountered serious issues with serviceability and safety because of lateral weights that generate lateral displacements [6]. One method that is now in use is the outrigger system, which has been installed in many high-rise buildings all over the world and is excellent at controlling the lateral displacement of these structures [7]. The overall cost of land, preliminary construction, and roofing for high-rise buildings is substantially cheaper than for projects of the same size that are horizontal and single-story. Renters in high-rise buildings are much better protected than those in ground-level complexes, where potential criminals have multiple points of entry. Single-story buildings frequently require extra security.

High-rise buildings reduce travel times within a given area by making more space available for additional CBD developments. The outer columns and core walls of outrigger systems are connected by rigid beams. The purpose of building these beams is to limit lateral displacements by spanning one or two storeys. It has also been said that when magnetorheological dampers are positioned between outside columns and outrigger walls, outrigger damping systems can be them as an efficient smart control system. The development of structural systems, building materials, and construction technology has led to the creation of high-rise structures. Lateral displacements, such as wind or earthquake pressures, have a severe negative impact on the serviceability and safety of high-rise buildings and grow with building height. Structures that are sensitive to seismic activity and white noise stimulation require fluid visco-elastic dampers of a particular size to control their response. Currently, available methods for enhancing human comfort include semi-active magnetorheological (MR) dampers, active devices, and structures equipped with friction dampers.

Steel-Framed Core Construction:

These buildings have external curtain walls made entirely of glass and are constructed with lightweight steel or reinforced concrete frames. According to Salvadori, "The massive glass panels that make up much of the wall surface of our high-rise buildings are enclosed by thin, vertical metal struts called mullions, which are dubbed "curtain walls." Because it lacks

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the strength to maintain itself, the curtain wall which was designed to regulate temperature and lighting is supported by the steel or concrete frame that makes up the building's structure.

Steel-Framed Tube Construction:

The design of steel-framed buildings was altered to allow for the construction of taller buildings while maintaining structural integrity against potential seismic activity and wind-induced lateral pressures. This was known as the tube structure. Load-bearing outside or perimeter walls were employed in tube construction to sustain the building's weight.

Steel-Framed Reinforced Concrete Construction: The term "steel-framed reinforced construction" refers to the combination of steel-framed and reinforced concrete construction in these structures. One example would be a steel-framed building with composite floors made of steel decking and a concrete shear core. **This kind of high-rise building is commonly referred to as mixed construction.**

Framework for evaluating technologies: The framework, which was first presented by Nelms et al. [8], was created to take into account a variety of stakeholder performance criteria and operate with different kinds of buildings and technology.

3. PRINCIPLES AND STRUCTURE OF THE FRAMEWORK (ASSESSING THE PERFORMANCE OF SUSTAINABLE

Table 1 presents a comparison of the linguistically and quantitatively reported discrepancies among performance measure estimations in a low-rise and high-rise construction scenario. According to estimations from local design pros, the low-rise structure would likely incur greater startup expenditures, and yearly operations for the deployment of green roof technology due to its larger area coverage. High-rise building foundations are occasionally built utilising concrete piles, piers, or caissons that are buried in the ground to support unusually high gravity loads. Although solid rock beds are desired, there are ways to transmit stresses evenly even on very soft ground. In the case of an emergency, firefighters may face significant problems while responding to high-rise buildings. There are serious issues with both conventional and modern building designs, as well as with building systems like HVAC and fire sprinklers. High-rise buildings frequently use setbacks as an architectural element because they reduce wind exposure, increase ground-level daylighting, and give the impression that the building is thinner.

Table 1: Performance metrics for both low- and high-rise building types to assess green roof technologies

Performance measure	High-rise	Low-rise	Remark
Moisture protection	Low	High	When moisture seeps into a low-rise wood construction, it is more vulnerable to degradation than a concrete one.
Air quality	Low	High	Comparative estimate derived from the useful "green" area
Personal protection against bodily harm	Equal	Equal	Considering the same amount of space is used by both structures, the same value is provided.
Energy use	15167 W	71201 W	Comparing the areas of the green roofs led to the relative estimate.

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The physical and thermal properties are shown in Tables 2–4 based on the various building material typologies. The impact of cement which is primarily used to make clinker, is larger than that of cement mortar (cement and sand) and concrete (cement, gravel, and water), as Table 2 illustrates. However, the impact can be lessened by combining cement with less impactful materials like sand, gravel, or water.

Table 2: Properties of cement and concrete [9]

Building product	**Density (kg/m3)**	**Thermal conductivity (W/mK)**	**Primary energy Demand (MJ-Eq/kg)**	**Global Warming Potential (kg CO_2-Eq/kg)**
Cement	3150	1.4	4.235	0.819
Cement mortar	1525	0.7	2.171	0.241
Reinforced concrete	2546	2.3	1.802	0.179
Concrete	2380	1.65	1.105	0.137

Table 3: Various properties of wood products [9].

Building product	**Density (kg/m3)**	**Thermal conductivity (W/mK)**	**Primary Energy demand (MJ-Eq/kg)**	**Global Warming Potential (kg CO_2-Eq/kg)**
Sawn timber, softwood, planed, kiln dried	600	0.13	20.996	0.3
Sawn timber, softwood, planed, air dried	600	0.13	18.395	0.267
Glued laminated timber, indoor use	600	0.13	27.309	0.541
Particle board, indoor use	600	0.13	34.646	0.035
Oriented strand board	600	0.13	36.333	0.62

Table 4: Physical and thermal properties of several common building products [9]

Building product	**Density (kg/m3)**	**Thermal conductivity (W/mK)**	**Primary energy Demand (MJ-Eq/kg)**	**Global Warming Potential (kg CO_2-Eq/kg)**
Reinforcing steel	7900	50	24.336	1.526
Aluminium	**2700**	**239**	**136.803**	**8.571**
Polyvinylchloride	**1400**	**0.17**	**73.207**	**4.267**
Flat glass	**2500**	**0.95**	**15.511**	**1.136**
Copper	**8920**	**380**	**35.586**	**1.999**

4. EXAMPLE OF A BUILDING'S CONSTRUCTION AND PERFORMANCE STANDARDS

The benchmark structure, studied by the researcher Kim et al. [10], a 76-story, 306-meter-tall concrete office skyscraper planned for Melbourne, Australia, served as the study's structural model [11]. This structure is made of reinforced concrete and has a concrete frame and core. The structure is narrow, having a 7.3 height-to-width ratio. It is wind-sensitive as a result. With the large machinery in the plant rooms included, the building's overall mass is 153,000 tonnes. The 76-story structure is designed to resemble a Bernoulli–Euler beam, a type of vertical cantilever beam. Then, the static condensation has eliminated each of the 76 rotating degrees of freedom. As a result, there are 76 degrees of freedom (DOF), which indicate how far each floor may move laterally. Building response amounts owing to a cross-winds and along-winds may be estimated individually as the benchmark. Therefore, in the benchmark problem, only the controller design that uses across-wind loading is taken into account [12].

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These structures are formed of lightweight steel or reinforced concrete frames with external curtain walls composed entirely of glass. Our high-rise buildings' vast glass panels, which make up a large portion of the wall surface, are surrounded by mullions—thin, vertical metal struts that are also known as curtain walls. The curtain wall, which was intended to control lighting and temperature, is supported by the steel or concrete frame that makes up the building's structure because it is too weak to maintain itself. In these constructions, the combination of steel-framed and reinforced concrete construction is referred to as "steel-framed reinforced construction". A steel-framed building with composite floors composed of shear-core concrete and steel decking would be one example. Mixed construction is the term often used to describe this type of high-rise structure.

5. THE NEED OF HIGH RISE BUILDINGS

First, there is a growing need for tall structures due to the world's fastest-growing population, which is mostly urban. Global urbanisation and the growth in population density in urban areas are being caused by the world's largest cities' ever-growing populations and expanding economies. Urban sprawl through suburban developments is steadily consuming arable land regions. On a smaller plot of land, a tall building can house a lot more people than a low-rise one would be able to.

There is more traffic and longer travel times as a result of cities spreading outside into the suburbs. When tall buildings are grouped together in highly populated locations, ground level space may be freed up to create open spaces such as parks, plazas, playgrounds, and other communal areas [13]. Tall structures thus affect the city fabric where they touch the ground, in addition to their effect on the skyline. Planning officials in large cities are now forced to prioritise improving the "public realm."

One of the biggest benefits that customers derive from high-rise buildings is their propensity to have established occupier profiles or customised neighborhoods. For high-rise structures, the total price of land, preliminary work, and roofing is significantly less than for horizontal, single-story projects of the same size. Tenants in high-rise buildings have far greater protection than those in ground-level developments, where there are several entry opportunities for would-be burglars. A single-story complex often needs more protection. By creating more room for more CBD constructions, high height structures shorten commute times within a given area.

Rigid beams are used to link the exterior columns and core wall of outrigger systems. These beams are built to span one or two stories to minimise lateral displacements. It has also been said that outrigger damping systems can effectively employ magnetorheological (MR) dampers as a smart control system when they are placed in between outside columns and outrigger walls. Several analytical studies [14] have demonstrated the successful operation of outrigger systems as structural systems for a high-rise buildings. The optimal location of the outriggers in the outrigger system was determined using an approximation analysis method.

This is crucial for producing an ideal design since it guarantees structural efficiency and validates the outrigger system's applicability [15]. Before it was destroyed to make room for the New Field Building, the Building had a legitimate claim to be the first skyscraper in history. Advances in structural systems, building materials, and construction technology have led to the emergence of high-rise buildings. Taranath's study [16] examined the ideal locations for outrigger installation. It was demonstrated that, under the assumption that the outrigger exhibits

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continuously high flexural rigidity the best location for an outrigger in a structure with one outrigger is at 0.455H (H: building height) from the top). The best place for a multi-outrigger system has also been the subject of several studies [17, 18].

High-rise structures are a result of advances in structural systems, building materials, and construction technology. The serviceability and safety of high-rise buildings have been severely hampered by lateral displacements, such as stresses from wind or earthquakes, which increase with the height of the structure. Fluid visco-elastic dampers of a specific size are needed to regulate the response of structures that are susceptible to seismic activity and white noise stimulation. To improve human comfort, current solutions have included buildings with fitted friction dampers, active devices, and semi-active magnetorheological (MR) dampers.

Current designs have suggested buildings with installed friction dampers, semi-active magnetorheological (MR) dampers, active devices, and fluid visco-elastic dampers (VEDs) for human comfort [19]. Control systems that are enhanced by applying the methods outlined in previous research might lessen the structure's reactivity. One such innovative device is the magnetorheological (MR) damper, which provides control capabilities through the use of MR fluids. A MR damper offers a very trustworthy method of response reduction at a cheap cost, making it fail-safe in the event that the control hardware breaks [20].

When designing civil engineering buildings, it is crucial to take into account the reduction of reaction quantities brought on by dynamic loadings from the environment, such as wind and earthquake. These values include velocities, deflections, and forces. Structural control approaches which fall into the categories of active, semi-active, passive, and hybrid control systems are the most recent strategies for accomplishing this aim [21]. Recent years have seen a rise in interest in the research of active tuned mass damper (ATMD) systems, and significant progress has been achieved in this area [22]. The literature has several papers on different active control systems [23].

Fuzzy neural networks have been used in a number of research to produce fuzzy rules. Fuzzy neural network systems require actual operational data in order to determine the control rules. In certain situations, getting the actual information ahead of time might be difficult. The authors suggested altering the association functions of fuzzy control rules. One of the key features of the CA, which is that the algorithm could discover unforeseen and valuable directions, was not utilised by Karr's approach. GA was simply used to amend the fuzzy rules designer's membership function settings.

His approach worked very well when the systems historical control data sufficed. Stated differently, it is beneficial when the controller's performance may be enhanced by the adjustment of the membership function parameters. Developing new fuzzy control rules in his manner with only the membership function parameters is difficult. For example, the instruments are designed to assess different building types, highlight different life cycle phases, and use different databases, regulations, and questionnaires.

Clearly, a user survey is required. Disclosure of the factors that affected the choice of tool is required. The methodology may be swiftly implemented to provide a preliminary assessment of the potential for urban wind energy over large geographic areas, such as many cities, a region, or a country. A method to estimate the yearly mean wind speed distribution is provided inside the framework, which makes it relevant to urban areas where the only available parameters are turbulence intensity and/or annual mean speed data.

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6. RELATED WORK

Mitigating the dynamic reactions of tall building structures subjected to wind loads is one of the most difficult challenges for structural engineers since, in some cases, doing so can increase structural safety and integrity while also reducing motion sickness and human discomfort. Tuned mass dampers (TMDs) are among the most popular and extensively utilised wind response control devices for tall structures. Because it doesn't require external power, traditional passive TMD is trustworthy and doesn't make the structure unstable. Holland [24] introduced fuzzy logic control, MR dampers, and the experimental setup is followed by a discussion of GA optimisation. To produce the ideal fuzzy logic controller (FLC), an automated optimisation procedure is required due to the possible complexity of the input and output interactions. Evolutionary algorithms known as genetic algorithms use generational cycles and fitness-based improvement to simulate natural selection. In order to advance the generation cycle, genetic algorithms frequently employ a population of solutions that are prone to crossings and mutations.

Ever since their development and early application, genetic algorithms have been widely applied. The findings of Johnson et al. [25] have shown that a structure may be protected against powerful earthquakes with intelligent base separation while still being able to function normally during more frequent, moderate earthquakes. However the application of sophisticated controllers, like fuzzy logic controllers (FLC), has received less attention. Fuzzy logic-based vibration control has recently piqued the curiosity of structural control experts. Karr [26] claimed that innovative attempts to improve fuzzy logic controllers via GA techniques were fruitful when paired with the optimisation of a single impartial. In the future, popular optimisation problems will be successfully resolved by Pareto-based multi-objective optimisation algorithms.

Unlike what is often done, the current use of genetic algorithms for structural control takes into account four structural response targets. The FLC is often represented by a vector of values called a chromosome when fuzzy logic is encoded in a genetic algorithm. Real operational data is usually needed in fuzzy neural network systems to identify control rules. In certain situations, getting the actual information ahead of time might be difficult [27, 28]. A tall building can accommodate far more people than a low-rise building on a smaller area of ground. Cities are expanding out into the suburbs, which results in more traffic and lengthier commute times.

Ground level space may become available for the creation of open spaces like parks, plazas, playgrounds, and other community places when tall buildings are clustered together in densely populated areas. As a result, tall buildings affect more than just the backdrop; they also affect the urban fabric where they touch the ground. Large-city planning officials are currently compelled to give priority to enhancing the public domain. "Via a battery of performance testing, various combinations of displacement, velocity, and voltage were used to create a neuro-fuzzy model that represents the dynamic behaviour of the MR damper. The FPS is modeled using neuro-fuzzy training and a nonlinear analytical equation. The efficacy of the proposed GA optimised FLC is compared with a human-designed FLC, a passive damping method, and a conventional semi-active controller [29].

The nation's earthquake-prone zones have been identified using scientific data on seismicity, past earthquakes, and the geological structure of the area. The Bureau of Indian Standards [IS 1893 (Part I):2002] classified the country into four seismic zones, corresponding

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to Zones II, III, IV, and V, based on these inputs. Of all the zones, Zone V has the most seismic activity, while Zone II has the lowest. All of northeastern India, as well as parts of Uttaranchal, Himachal Pradesh, North Bihar, are included in Zone V. It was anticipated that different swing angle-clearance combinations would be employed for each wind zone in order to obtain optimal designs when six wind zones were established in India in the late 1990s [30]. Research has shown that although conductor swing angles vary greatly based on the local wind speed circumstances in each zone, a change in conductor clearances substantially offsets the effect on tower configuration and cost. In order to minimise extra costs, construction delays, and other problems that may have arisen from the adoption of alternate tower layouts, the designers of India's transmission lines decided to utilise the same tower configuration for each voltage class in all wind zones.

7. INSTRUMENTATION

The dSPACE platform's fuzzy logic-based boost converter is used and tested by the researchers Shook et al. [31] under a wide range of load conditions. The experiment setup of the authors [] is shown in Figure 1. Superior steady-state performance and swift transient response are offered by fuzzy logic driven boost converters. Furthermore, the dSPACE program includes a graphical object-oriented package called the Control Desk that allows the creation of simple and user-friendly graphical user interfaces (GUI) for online monitoring and control. Through the dSPACE system, the FLC provides each MR damper with a particular voltage that fluctuates between zero and the saturation voltage. Variations in current continually modify the force of each MR damper.

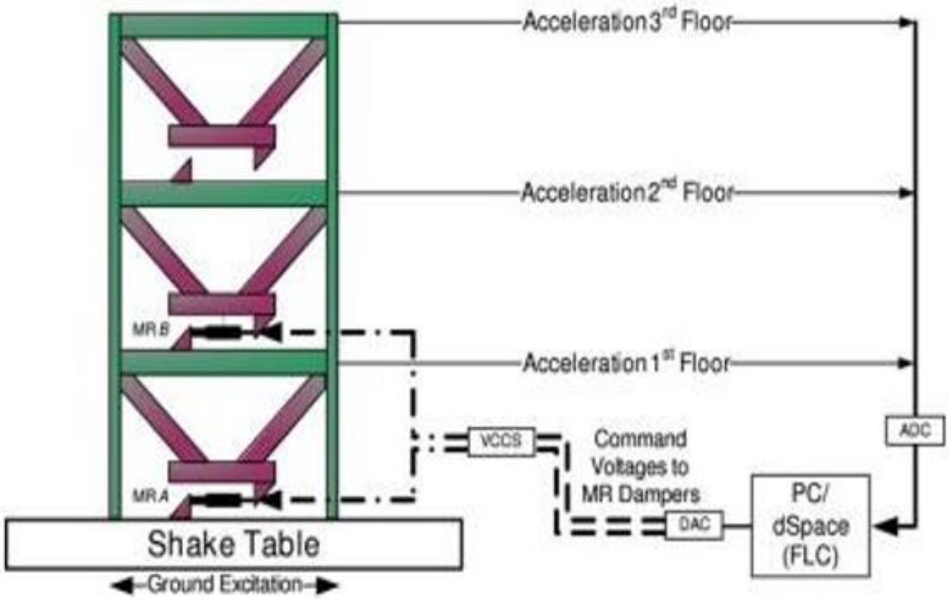

Figure 1: Shake table and experimental set-up [31]

7.1 Magnetorheological dampers

When electricity is applied to the damper, iron particles in the MR fluid are oriented to alter the force resistance. A change in the resistance force of the piston may be observed up to a voltage of 1.2 V. It follows that this value is thought to indicate the saturation or "passive-on" voltage. When the controller sends a signal with zero voltage, which is at the other end of

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the spectrum of important voltages, it is referred to as "passive off." This is comparable to the case where each damper has a very low resistance and no current is applied to it as shown in the setup of Figure 2. Reducing inter-storey drift defined in the study as the relative displacement between two subsequent floors is the primary objective of using dampers. A recently developed framework is presented, which provides a rational framework for pre-evaluating a technology with respect to sustainability principles, performance, and suitability for the project's building and operation phases. The goal of the framework is to systematically identify and evaluate the relative advantages and disadvantages of different alternative sustainable technologies for use by project stakeholders and policymakers.

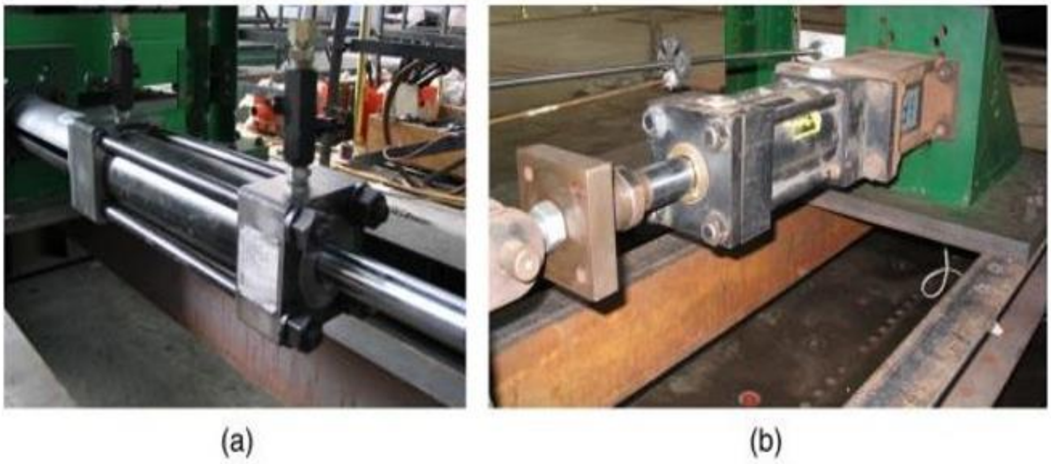

Figure 2: MR dampers: (a) and (b) [31]

7.2 MR damper model

The class of controlled fluids includes MR fluids. The main property of MR fluids is their reversible transformation from free-flowing, linearly viscous Newtonian fluids to semi-solid, controlled yield strength Bingham fluids in the presence of a magnetic field. This function offers an easy-to-use, quiet, and responsive interface between the electrical control and the mechanical system. MR fluid dampers are lightweight, affordable, dependable, stable, and portable. The gadget can only produce regulated force when it is powered by a battery. Viable MR dampers come with a Wonder Box, which is a tool for adjusting the magnetic flux across the device. It is reasonable to use voltage over current as the input variable for the MR damper since Wonder Boxes may take external voltage as input [32].

Since the semi-active device can only respond to the motion of the structure in order to collect vibratory energy, it is considered steady. Semi-active devices should function effectively over a wide range of frequencies and amplitudes. To save space, just two fuzzy surfaces are presented for each MR damper; however, three fuzzy surfaces might be exhibited to fully capture each damper's characteristics. An example of the neuro-fuzzy force prediction for MR damper A based on specific validation data [33]. The neuro-fuzzy model demonstrates the damper's ability to absorb energy by capturing hysteretic activity.

The optimisation technique, which seeks to maximise system performance by minimising control energy under firm restrictions or by decreasing the reaction measures of the structures, forms the basis of most control design methodologies. Optimisation is the process of fine-tuning the controller system's settings. Genetic algorithms (GAs) effectively extract the optimal solution from the complicated and perhaps intermittent resolution space, in contrast to the

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conventional optimisation approach. Numerous optimisation issue domains have been successfully searched using genetic algorithms [33]. Although a great deal of research has been done on actively controlling vibrations in buildings, very few studies have combined evolutionary algorithms with fuzzy logic controllers (GFLC) Kumar and Garg [48]. Thus, more work needs to be done before scientists can properly comprehend how the GFLC system lessens structural vibrations. A GFLC, a cross between fuzzy logic and genetic algorithms, has been presented. The purpose of this is to guarantee structural safety, which is mostly dependent on the response of the structure to displacement. It is discovered that the ATMD system's response reduction performance is enhanced by the combination of fuzzy logic and evolutionary algorithms. Relationships between variables such as displacement, velocity, applied voltage, and resistive force are among the distinctive features of an MR damper. The 300 kN MR damper is described using the three input and force output parameters below since it has been shown that this model is sufficient for control purposes and offers sufficient information for damper operation. For MR damper modeling, there are two types of experimental data: (1) training and checking, and (2) validation. Training data is used to learn and fine-tune fuzzy rules, while testing data is used to ensure that the model is not overfit [34].

7.3 Semi-active MR dampers

A number of large-scale structures have received extra dampening technology in recent years in an effort to reduce the reactions. Given the rising sophistication of MR damper use in civil engineering structures, the optimal design plan ought to be recommended. Since alternative damper layouts might offer superior control levels, the optimal damper placement should be chosen [37]. Minimising the costs related to semi-active system installation and upkeep is also essential. Conversely, the lowest vibration magnitude plays a crucial role in assessing the efficacy of a control system. While several studies have examined damper placement, none have precisely examined the optimal sites for MR sensors and dampers as two distinct concerns. A modified binary particle swarm optimisation (BPSO) is used to place MR dampers and sensors in the optimal positions with the least amount of MR dampers. Both instantaneous and classical optimum control have been used in constructions that have known structural properties. Furthermore, control techniques such as Linear Quadratic Gaussian (LQG) optimal control need answers for severely constrained optimisation issues [38]. Many research efforts have focused on addressing these issues through the use of soft computing techniques such as neural networks and fuzzy logic. Recent research indicates that adaptive controllers are more trustworthy and efficient.

7.4 Encoding Fuzzy Logic Structure

Fuzzy logic may be used to develop simple control algorithms, but fine-tuning a fuzzy controller for a particular application is difficult and requires a more involved procedure than with a regular controller. This is explained by the fact that the MFs and inference procedures are characterised by an enormous number of parameters. This means that the MF and/or scaling factors must be changed dynamically throughout the defuzzification process. Prior research has employed techniques such as neural networks and neuro-fuzzy algorithms to maximise FLC [39]. A fuzzy logic controller and conventional controllers are integrated to create a closed-loop control system, as shown in Figure 3. The most often used fuzzy control inference (Ri) is the "if-then" rule. The following parts make up the basic makeup of a typical FLC, as shown in Figure 4.

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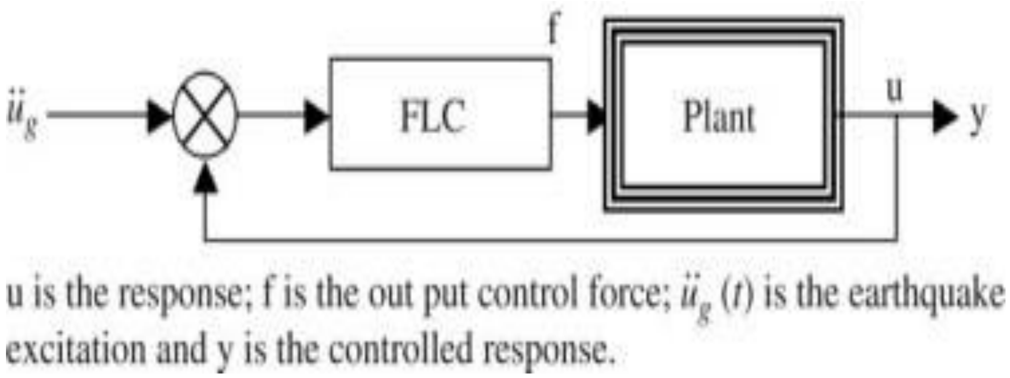

Figure 3: Block diagram of the fuzzy logic controller [40]

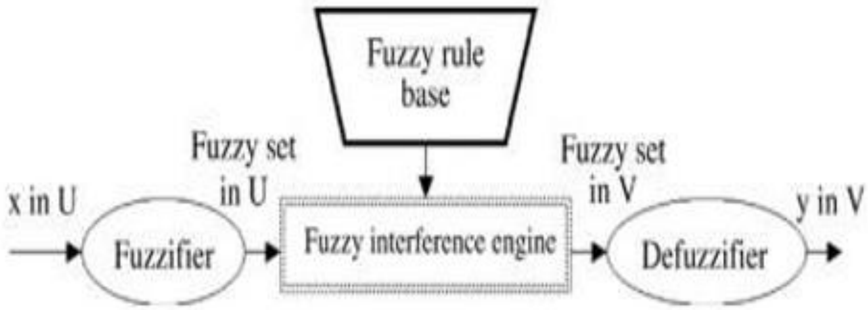

Figure 4: FLC components [40]

- Fuzzifier: Measurable inputs for the control process, which might be in the form of crisp values, are converted into fuzzy language values using a fuzzy reasoning mechanism.
- Fuzzy rules: These are a collection of the astute control rules needed to accomplish the control goal. The fuzzy reasoning mechanism, also known as the fuzzy interference engine, deduces the control action for a given fuzzy input by applying a range of fuzzy logic operations.
- Defuzzifier: This unit converts the required crisp control value from the inferred fuzzy control action.

Prior to starting the control process, decisions regarding a number of important design elements related to fuzzy controller design must be made. These variables consist of the rules themselves, the fuzzy sets.

7.5 Fuzzy Logic Control

Complex structural systems are characterised by nonlinearities and uncertainty in the loading magnitude and structural features. It is difficult to find a trustworthy dynamic model on which to construct the typical controller. The novel control method can lower modeling mistakes and inaccuracies without presenting any severe optimisation problems. The basis of fuzzy logic control, or FLC, is fuzzy set theory. In order to mimic human reasoning, FLC is essentially divided into four sections [41].

Consequently, the input variables are the sensor's displacement and velocity. Inducing current is the FLC's output variable that controls the MR damper control force. For the input

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variables, the membership functions' range is [-1, 1], and for the output variables, it is [0, 1]. The rule-bases use a large current to produce a strong regulating force when the damper's displacement and velocity are pointed. If they are heading in different directions, no substantial regulating force is required. The Gaussian curve membership function was utilised. The sensor signal is fuzzified that is, transformed into linguistic fuzzy values [42].

Structural control approaches which are further subdivided into active, semi-active, passive, and hybrid control systems are the most recent strategies for accomplishing this objective. Although active control systems have been developed and used in large-scale structures, the robustness problems still require attention. While passive devices effectively lessen structural responses, one of their resilience's problems is that they can't adapt to shifting vibratory circumstances. A semi-active control system is one that has parts that aren't able to supply energy to the system.

8. CONCLUSION

The aim of the present study is to provide clarity on the broad subject of constructing environmental assessment tools by assessing and classifying the already available tools. Comparing the instruments and their output is challenging, if not impossible. For instance, the instruments are made to evaluate various building kinds, highlight various life cycle stages, and make use of various databases, policies, and surveys. A user survey is obviously necessary. It is necessary to disclose the considerations that influenced the tool selection.

The framework may be quickly put into practice to offer an initial evaluation of the potential for urban wind energy across broad geographic areas, such as several cities, a region, or an entire nation. In order to make this framework applicable to metropolitan regions where turbulence intensity and/or annual mean speed data are the only accessible parameters, a technique is described inside the framework to estimate the yearly mean wind speed distribution. The purpose of this study is to examine how well a semi-active TMD with an MR damper (MR-STMD) controls the excitation of wind in a multi-story structure. In this work, a fuzzy logic controller is used to regulate the MR-STMD efficiently.

Additionally, the benchmark problems sample passive TMD and ATMD are cited in comparison analyses. Although the MR-STMD's control power is far less than the ATMD's, its control performance is often equivalent to that of the ATMD. More work is needed to improve the framework and provide associated tools, such as a full range of user-friendly order-of-magnitude estimate models that offer insight into technology performance that is important for policymakers and project stakeholders. The framework's main purpose is to offer an unbiased evaluation of the advantages and disadvantages of various technologies as well as the construction settings in which they perform best.

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References

1) Kontokosta, C. E. (2013). Tall buildings and urban expansion: Tracing the evolution of zoning in the United States. *Leadership and Management in Engineering*, *13*(3), 190-198.
2) Smith, I., & Frangi, A. (2014). Use of timber in tall multi-storey buildings. International Association for Bridge and Structural Engineering.
3) Ali, M. M., & Moon, K. S. (2007). Structural developments in tall buildings: current trends and future prospects. *Architectural science review*, *50*(3), 205-223.
4) Alianto, B., Nasruddin, N., & Nugroho, Y. S. (2022). High-rise building fire safety using mechanical ventilation and stairwell pressurization: A review. *Journal of Building Engineering*, *50*, 104224.
5) Turak, T. (1985). Remembrances of the Home Insurance Building. *The Journal of the Society of Architectural Historians*, *44*(1), 60-65.
6) Coull A, Subedi N. Framed-tube structures for high rise buildings. J Struct Div1971; 97:2097–105.
7) Grossman J, Cruvellier M, Stafford-Smith B. Braced-tube concrete structure. Concr Int 1986; 8(9):32–42.
8) Nelms, C. E. (2005). *A framework for assessing the performance of sustainable technologies for building projects* (Doctoral dissertation, University of British Columbia).
9) Bribián, I. Z., Capilla, A. V., & Usón, A. A. (2011). Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential. *Building and environment*, *46*(5), 1133-1140.
10) Kim, H. S., & Kang, J. W. (2012). Semi-active fuzzy control of a wind-excited tall building using multi-objective genetic algorithm. Engineering Structures, 41, 242-257.
11) Pinkaew T, Fujino Y. Effectiveness of semi-active tuned mass dampers under harmonic excitation. Eng Struct 2001; 23:850–6.
12) Ahlawat AS, Ramaswamy A. Multi-objective optimal fuzzy logic controller driven active and hybrid control systems for seismically excited nonlinear buildings. J Eng Mech 2004; 130(4):416–23.
13) Asai T, Chang CM, Phillips BM, Spencer Jr BF. Real-time hybrid simulation of a smart outrigger damping system for high-rise buildings. Eng Struct 2013; 57:177–88.
14) Fan Z, Long Y. Linear analysis of tall buildings using spline elements. Eng Struct 1991;13:27–33
15) Smith BS, Salim I. Formulae for optimum drift resistance of outrigger braced tall building structures. Comput Struct 1983;17(1):45–50
16) Taranath BS. Optimum belt truss location for high-rise structures. Struct Eng 1975; 53(8):345–7.

Volume 63 | Issue 06 | June 2024
DOI: 10.5281/zenodo.12721245

17) Coull A, Lau WHO. Analysis of multioutrigger-braced structures. J Struct Eng 1989; 115(7):1811–5.
18) Wu JR, Li QS. Structural performance of multi-outrigger-braced tall buildings. Struct Des Tall Spec Build 2003;12(2):155–76
19) Zhang WS, Xu YL. Dynamic characteristics and seismic response of adjacent buildings linked by discrete dampers. Earthq Eng Struct Dynam 1999; 28(10): 1163–85.
20) Kim J, Ryu J, Chung L. Seismic performance of structures connected by viscoelastic dampers. Eng Struct 2006; 28(2):183–95.
21) Datta TK. Control of dynamic response of structures. In: Indo–US symposium on emerging trends in vibration and noise engg, 1996. p. 18–20.
22) Aldawod M, Samali B, Naghady F, Kwok Kenny CS. Active control of along wind response of tall building using a fuzzy controller. Eng Struct 2001;23:1512–22
23) Yang JN. Recent advances in active control of civil engineering structures. Probab Eng Mech 1988; 3(4).
24) Holland J. Adaptation in natural and artificial system. Ann Arbor (MI): The University of Michigan Press; 1975
25) Johnson EA, Ramallo JC, Spencer Jr BF, Sain MK. Intelligent base isolation systems. In: Proc 2nd world conf on structural control, vol. 1. 1999. p. 367–76
26) Karr CL. Design of an adaptive fuzzy logic controller using a genetic algorithm. In: Proc of the 4th international conference on genetic algorithms. 1991. p. 450–57
27) Ahmed, A., Qayoum, A., & Mir, F. Q. (2021). Spectroscopic studies of renewable insulation materials for energy saving in building sector. Journal of Building Engineering, 44, 103300.
28) Karr CL, Freeman L, Meredith D. Improved fuzzy process control of spacecraft autonomous rendezvous using a genetic algorithm. In: SPIE conf on intelligent control and adaptive systems. 1989, p. 274–83.
29) Battaini M, Casciati F, Faravelli L. Fuzzy control of structural vibration. An active mass system driven by fuzzy controller. EarthqEng Struct Dyn 1998; 27 (11):1267–76.
30) Murugesha, K. M., Veerabhadrappa, B. P., & Patil, M. S. (2014). ‘Wind energy: Analysis of the technological potential and policies in India. Int. J. Eng. Res. Technol, 3(2), 90-111.
31) Shook, D. A., Roschke, P. N., Lin, P. Y., & Loh, C. H. (2008). GA-optimized fuzzy logic control of a large-scale building for seismic loads. Engineering structures, 30(2), 436-449.
32) Schurter KC, Roschke PN. Neuro-fuzzy control of structures using acceleration feedback. Smart Mater Struct 2001; 10:770–9.
33) Lin PY, Chung LL, Loh CH. Semiactive control of building structures with semiactive tuned mass damper. Comput Aided Civil Infrastruct Eng 2005; 20(1):35–51.

Volume 63 | Issue 06 | June 2024
DOI: 10.5281/zenodo.12721245

34) Kim HS, Roschke PN, Lin PY, Loh CH. Neuro-fuzzy model of hybrid semi-active base isolation system with FPS bearings and an MR damper. Eng Struct 2006; 28 (7):947–58.

35) Kim HS, Roschke PN. Design of fuzzy logic controller for smart base isolation system using genetic algorithms. Eng Struct 2006; 28 (1):84–96.

36) Kim HS, Roschke PN. Fuzzy control of base-isolation system using multiobjective genetic algorithm. Comput Aided Civil Infrastruct Eng 2006; 21(6):436–49.

37) Ahmed, A., & Qayoum, A. (2021). Investigation on the thermal degradation, moisture absorption characteristics and antibacterial behavior of natural insulation materials. Materials for Renewable and Sustainable Energy, 10(1), 1-10.

38) Samali B, Kwok KCS, Wood GS, Yang JN. Wind tunnel tests for wind-excited benchmark building. J Eng Mech 2004;130(4):437–46

39) Ali, Sk.F., Ramaswamy, A., 2006. FLC based semi-active control of buildings using magneto-rheological dampers. In: Maity, D., Dwivedy, S.K. (Eds.), Proceedings of the 2nd International Congress on Computational Mechanics and Simultion. Indian Institute of Technology, Guwahati, India. Zadeh LA. Fuzzy sets. Information Control 1965; 8:338–53.

40) Pourzeynali, S., Lavasani, H. H., & Modarayi, A. H. (2007). Active control of high rise building structures using fuzzy logic and genetic algorithms. Engineering Structures, 29(3), 346-357.

41) Fatehi A, Abe K, Lucas C. Challenges on the design of the fuzzy logic controller by the genetic algorithms. In: 2nd Int. workshop on intelligent systems of the 4th joint conf. on information systems, 1998.

42) Kumar M, Garg DP. Inteligent learning of fuzzy logic controllers via neural network and genetic algorithm. In: Proceeding of 2004 JUSFA, Japan–USA symposium on flexible automation. p. 19–21.