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Muslim Women's Studies

Journal homepage: <https://womenstudy.abu.ac.ir/>



International Journal of Muslim Women Studies

The Evolving Role of Women in Civil Engineering and Architecture

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ARTICLE INFO

Article history:

Received: 13 April 2024

Revised: 15 April 2024

Accepted: 8 may 2024

Keywords:

Women in Engineering, Gender Inclusion in Civil Engineering, Women Architects and Engineers, Barriers to Female Participation in Engineering, Gender-Responsive Urban Development.

ABSTRACT

Women have long faced structural and cultural barriers in civil engineering and architecture, traditionally male-dominated fields. Despite these challenges, they have made significant contributions to innovation, sustainability, and the transformation of the built environment. In recent decades, greater access to higher education and professional opportunities has increased women's visibility in these disciplines. In Iran, for example, women account for over 55% of civil engineering graduates but occupy less than 20% of positions in the professional workforce. Using a mixed-method approach—including case studies, statistical analysis, and literature review—this study examines women's role in advancing sustainable structures, technological progress, and inclusive urban development. Findings highlight that women's participation enhances creativity, problem-solving, and resilience in engineering teams, leading to more effective outcomes. Historical and contemporary figures such as Emily Warren Roebling, Zaha Hadid, and Patricia Galloway illustrate how women have driven breakthroughs in leadership, design, and policy. Nevertheless, persistent obstacles—including gender stereotypes, workplace discrimination, limited leadership opportunities, and work-life balance pressures—continue to hinder women's full integration. Case studies from countries such as Sweden, India, and Rwanda demonstrate that gender-responsive policies, mentorship programs, and family-friendly workplace reforms can significantly improve women's retention and advancement. This paper argues that integrating women into civil engineering and architecture is not only a matter of gender equity but also a strategic necessity for innovation, sustainability, and global development. Encouraging greater female participation ensures more diverse perspectives and inclusive solutions to 21st-century challenges such as climate change, urbanization, and infrastructure resilience.

E-ISSN: 000-000

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How to cite this article:

P. Tarighi 1, (2024). The Evolving Role of Women in Civil Engineering and Architecture.

Muslim Women's Studies, 1(2), 43-56. <https://doi.org/10.22034/mws.2024.729885>



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1. Introduction

Civil engineering and architecture have long been regarded as male-dominated professions, with women facing significant structural, educational, and cultural barriers to entry and advancement [1]. Despite comprising nearly half of the global population, women remain underrepresented in these fields, particularly in leadership positions and technical roles requiring high expertise [2]. However, over the past three decades, increasing global emphasis on gender equity and diversity in STEM fields has prompted substantial changes in the demographics and culture of engineering and architecture [3].

Research underscores that gender-diverse teams contribute to improved innovation, communication, and decision-making capabilities—qualities that are especially crucial for addressing 21st-century challenges such as climate change, urban resilience, and infrastructure sustainability [4-5]. Institutions and professional bodies are gradually recognizing the importance of inclusivity, not just as a matter of equity but as a strategic advantage.

This paper explores the historical and contemporary contributions of women in civil engineering and architecture, with an emphasis on leadership, innovation, and systemic challenges. Using peer-reviewed literature, institutional reports, and illustrative case studies, the study also investigates how social norms, educational access, and workplace dynamics continue to shape women's participation. Finally, it proposes evidence-based strategies to foster gender inclusiveness and equitable professional advancement.

2. Historical Perspective

2.1. Early Contributions of Women in Civil Engineering and Architecture

Despite being historically excluded from formal education and professional recognition, numerous women played pivotal roles in the early development of civil engineering and architecture. These early pioneers made remarkable achievements despite prevailing gender biases and restrictive societal norms.

One prominent historical figure is Emily Warren Roebling (1843–1903), who assumed supervisory responsibilities during the construction of the Brooklyn Bridge in New York after her husband's illness. She coordinated communications between the chief engineer and on-site workers and managed technical challenges, making her one of the earliest known female field engineers in a large-scale infrastructure project [6].

In architecture, Ethel Charles became the first female member of the Royal Institute of British Architects (RIBA) in 1898. Despite being barred from major commissions due to her gender, her entry into RIBA marked a significant institutional milestone [7]. Similarly, Sophia Hayden Bennett, the first female graduate from MIT's architecture program, gained recognition for designing the Women's Building at the 1893 World's Columbian Exposition in Chicago—an emblem of early feminist architectural expression [8].

Moreover, Byzantine Empress Theophanu (d. 991) is credited with initiating and sponsoring architectural projects across the Holy Roman Empire, demonstrating how women in positions of

influence contributed to urban form and civic structures centuries prior to the professionalization of the field [9].

These examples illustrate that those women, even when marginalized, have long contributed to civil society's built environment. However, their stories were often omitted from mainstream academic narratives, underscoring the need for re-evaluating history through a more inclusive lens.

2.2. Societal Barriers and Gender Roles

The underrepresentation of women in civil engineering and architecture is closely linked to longstanding societal norms and gender roles that have historically excluded women from technical and leadership professions. These fields have been culturally constructed as masculine domains, reinforced by education systems, media portrayals, and family expectations [10].

During much of the 20th century, women faced restricted access to engineering education due to institutional discrimination. For example, prominent universities in North America and Europe either barred women entirely or implemented restrictive policies that marginalized their participation [11]. Even after admission, female students often encountered unwelcoming academic environments characterized by gender stereotyping and isolation [12].

The perception that engineering requires traits stereotypically associated with men—such as physical endurance, assertiveness, and spatial reasoning—continues to impact female participation in these fields [13]. Such stereotypes are internalized at a young age, discouraging girls from pursuing STEM disciplines and limiting their confidence and career aspirations [14].

In addition, professional workplaces have historically been structured around a “male breadwinner” model that disadvantages women. Rigid hierarchies, inflexible schedules, and lack of mentorship limit career advancement for women in both the public and private sectors of engineering and architecture [15]. The phenomenon of “leaky pipelines”—where women enter technical education but later leave the profession—is a direct consequence of these exclusionary structures [16].

Institutional practices such as informal hiring networks and opaque promotion criteria often exacerbate gender inequity. Studies indicate that women engineers are more likely to be assigned lower-visibility projects and are underrepresented in high-impact, high-budget developments [17]. Additionally, the absence of gender-sensitive policies, such as parental leave, childcare support, and anti-harassment protocols, further reinforces inequality in career progression.

Furthermore, cultural expectations assign women primary responsibility for domestic and caregiving roles, creating an added burden in managing work-life balance [18]. These societal norms contribute to career interruptions, part-time work, or complete attrition from the profession, disproportionately affecting women compared to their male counterparts. Breaking these entrenched barriers requires a holistic approach that addresses both cultural perceptions and institutional norms. Educational reform, inclusive policy-making, and visible female leadership can collectively shift perceptions and support long-term gender equity.

2.3. Modern Contributions and Breakthroughs

In the 21st century, women have increasingly played pivotal roles in driving innovation and excellence in civil engineering and architecture. No longer confined to support or administrative roles, many women now lead major infrastructure projects, champion sustainable design strategies, and influence global engineering standards. Studies confirm that gender-diverse engineering teams tend to outperform homogeneous teams in creativity, risk management, and overall project outcomes [19].

2.4. Technological Innovation and Leadership

Women engineers and architects are leading the implementation of smart technologies in construction, including Building Information Modeling (BIM), modular construction systems, and adaptive infrastructure design. Dr. Maria Lehman, the 2023 president of the American Society of Civil Engineers (ASCE), has emphasized resilience-based digital solutions in infrastructure policy and design [20].

Architectural firms like Zaha Hadid Architects exemplify the transformative role of female leadership in parametric design, digital modeling, and structural aesthetics, merging technological advancement with cultural expression [21].

2.5. Sustainability and Environmental Advocacy

Women in the field are advancing regenerative design and ecological sustainability. Research indicates that women engineers often prioritize social and environmental impacts, advocating for community-based and low-carbon design approaches [22]. Professor Taryn Mead, for example, promotes biodiversity-conscious urban planning, integrating nature-positive metrics into infrastructure systems [23]. Institutional efforts such as the “Women in Green Building Leadership” initiative by the U.S. Green Building Council highlight how women are driving sustainability leadership across industries [24].

2.6. Inclusive Urban Planning and Social Equity

Female architects and planners contribute unique perspectives in the design of inclusive, accessible, and people-centered cities. Research by Sánchez de Madariaga illustrates how women emphasize spatial justice, including better access to transportation, childcare, and public safety in urban planning [25]. Projects rooted in “Feminist Urbanism” in Spain and community co-design in Kenya have resulted in more resilient, inclusive environments tailored to diverse users [26].

2.7. Academic and Research Contributions

The presence of women in scholarly research within civil engineering and architecture is steadily increasing. Their contributions include advancements in seismic design, sustainable materials, and AI-driven modeling. Data from Scopus (2022) show that women now make up over 30% of lead authors in top-tier journals in engineering and environmental design—an increase from 12% in 2005 [27]. This shift indicates growing influence in defining the intellectual and methodological future of these disciplines.

3. Notable Women Pioneers

The history of civil engineering and architecture, though traditionally male-dominated, has been continually shaped by pioneering women whose contributions laid the foundation for innovation, resilience, and inclusive design.

3.1. Emily Warren Roebling (1843–1903)

Often regarded as the first recognized woman field engineer, Emily Warren Roebling played a central role in completing the Brooklyn Bridge project after her husband, the chief engineer, became incapacitated. She mastered technical communication, materials science, and project supervision in an era when women were largely excluded from formal engineering practice [28]. Scholars now recognize her as an early example of leadership under constraint, showcasing women's capability in high-pressure engineering contexts [29].



Fig1. Brooklyn Bridge (1883) – One of the first large-scale infrastructure projects completed under the supervision of a woman (Emily Warren Roebling).

3.2. Sophia Hayden Bennett (1868–1953)

The first female graduate of MIT's architecture program, Bennett designed the Women's Building at the 1893 World's Columbian Exposition in Chicago. Her work blended Beaux-Arts principles with symbolic feminist aesthetics, offering a critical entry point into professional architecture for women at the time [30]. Her design is now considered a landmark in feminist architectural history, reflecting women's aspirations for public and cultural representation [31].



Fig.2 The Woman's Building at the 1893 World's Columbian Exposition in Chicago

3.3. Zaha Hadid (1950–2016)

Iraqi-British architect Zaha Hadid became the first woman to win the Pritzker Architecture Prize in 2004. Her signature works—such as the MAXXI Museum in Rome and the London Aquatics Centre—demonstrate groundbreaking formal complexity and the use of parametric technologies. Hadid's career redefined architectural aesthetics and opened space for global women leadership in high-concept architecture [32].

She was also instrumental in proving that large-scale urban commissions could be led by women, breaking longstanding gender exclusivity in elite architectural competitions [33].



Fig.2 MAXXI Contemporary Arts Center in Rome – A symbol of parametric architectural innovation led by Zaha Hadid.

3.4. Patricia Galloway (1957-2024)

Patricia Galloway was the first woman president of the American Society of Civil Engineers (ASCE), serving in 2004. She is widely credited with advocating for ethics, project governance, and the integration of risk management in infrastructure systems [34]. Galloway's leadership brought national attention to the need for greater inclusivity in engineering organizations, promoting transparent hiring and advancement policies for women [35].



Fig.3 Panama Canal Plans

3.5. Ethel Charles (1871-1962)

As the first woman admitted to the Royal Institute of British Architects (RIBA) in 1898, Ethel Charles paved the way for women's entry into formal architectural practice in the UK. Though denied major commissions due to gender bias, her admission marked a critical institutional shift [36]. Her legacy has been re-evaluated in modern architectural discourse as symbolic of resistance and institutional change [37].

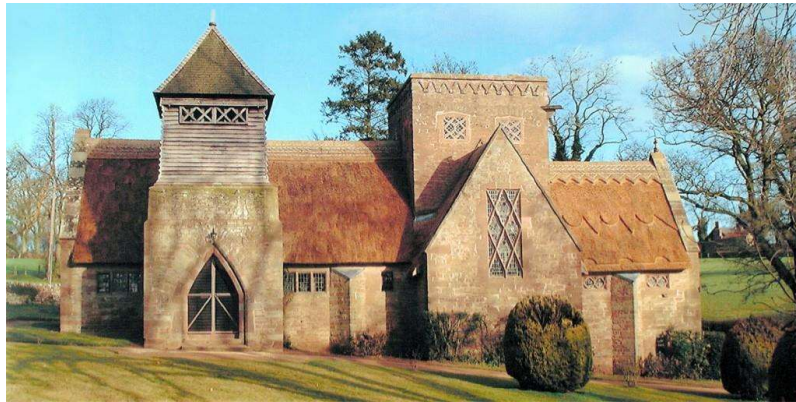


Fig.4 The All Saints' Church in Brockhampton.

3.6. Jane Jacobs (1916–2006)

Though not formally trained as an architect or engineer, Jane Jacobs profoundly impacted urban planning through her writings, activism, and critiques of modernist planning. Her book *The Death and Life of Great American Cities* (1961) reshaped urban theory, emphasizing mixed-use development, pedestrianism, and community participation [38]. She inspired a generation of planners and urban designers to reconsider human-scale infrastructure and grassroots urbanism [39].

4. Current Challenges

Despite significant progress in education and increased visibility of women in civil engineering and architecture, persistent barriers continue to hinder their full participation in the profession. These challenges are multidimensional, encompassing cultural, institutional, structural, and personal dimensions.

4.1. Gender Stereotypes and Cultural Norms

Deeply ingrained gender stereotypes continue to frame engineering as a masculine domain, especially in regions where traditional gender roles are dominant. Women engineers often face skepticism regarding their technical competence and leadership potential, particularly in construction site management or structural analysis roles [40]. These perceptions can lead to diminished confidence and reduced opportunities for advancement.

Studies in the Middle East and South Asia indicate that family expectations, societal pressures for early marriage, and caregiving responsibilities contribute to the attrition of women from the engineering workforce [41]. These factors disproportionately affect women's ability to stay in long-term, project-based roles, especially in infrastructure sectors that demand mobility and extended site presence.

4.2. Workplace Discrimination and Pay Gaps

Women in engineering still face significant discrimination in hiring, promotion, and salary negotiations. A global survey by the World Federation of Engineering Organizations (WFEO) found that women engineers earn 20–30% less than their male counterparts with similar qualifications and experience [42]. Furthermore, informal workplace cultures often exclude women from decision-making networks, technical mentoring, and leadership pipelines [43].

The "glass ceiling" effect remains prevalent in many firms, where women are underrepresented in upper management and technical leadership, despite performing on par with male colleagues.

4.3. Lack of Mentorship and Networking Opportunities

Mentorship and sponsorship play a critical role in career advancement, yet many women engineers report the absence of female mentors or role models within their organizations. This lack of representation contributes to feelings of isolation and limited access to informal learning opportunities that often occur through professional networks [44].

Organizations that actively promote mentorship, such as Women in Engineering (WIE), Society of Women Engineers (SWE), and Engineers Without Borders, have demonstrated improvements in retention and career satisfaction for women [45].

4.4. Work-Life Balance and Institutional Inflexibility

Balancing work and family remains a central challenge for many women engineers, especially in cultures where domestic duties fall disproportionately on women. Long working hours, inflexible schedules, and the absence of parental leave policies exacerbate career dropouts or transitions to part-time or administrative roles [46]. Despite the growing availability of remote work in design and modeling, field-based and managerial engineering roles often lack the flexibility necessary for women to thrive equally.

4.5. Underrepresentation in Decision-Making and Research Leadership

Women are significantly underrepresented in research councils, editorial boards, and national engineering policy bodies. A bibliometric analysis published in *Engineering Education Review* showed that only 17% of grant recipients in civil engineering research were women, and women authored less than 15% of papers in top-tier engineering journals as lead investigators [47]. Without equitable representation in research and policy-making, gender-specific issues—such as inclusive infrastructure planning or maternal health in design—remain under-addressed.

5. Case Studies

To better understand the role and impact of women in engineering and architecture, it is essential to examine successful case studies across different socio-economic and cultural contexts. These

examples highlight how policy frameworks, institutional support, and individual leadership have converged to foster gender inclusivity in the built environment professions.

5.1. Sweden: Systematic Policy and Infrastructure for Gender Equality

Sweden is frequently cited as a global benchmark for gender equity in engineering. Through government-led initiatives such as the “Gender Mainstreaming in Academia” (GEM) project, female participation in engineering faculties and research programs has significantly increased. The country has implemented family-friendly work policies, mentorship programs, and gender quotas on public boards [48].

Swedish engineering firms like Sweco and Skanska have integrated gender-sensitive policies into corporate governance, leading to greater inclusion in project leadership roles. According to Statistics Sweden (2021), women now represent over 30% of engineers in the country [49].

5.2. India: Female Leadership in Emerging Technology Sectors

India has seen notable progress in women’s engagement in technical disciplines, especially in urban infrastructure and information technology. A standout case is the Delhi Metro Rail Corporation (DMRC), where women engineers have been instrumental in planning, designing, and operating metro systems [50]. Notably, Mangu Singh, former DMRC Managing Director, championed hiring policies that favored diversity and meritocracy. The tech-driven city of Bengaluru has also witnessed the emergence of women-led architecture and design startups, many of which focus on green urbanism and inclusive housing models [51].

5.3. Iran: Quiet Transformation Through Higher Education

In Iran, while cultural and structural challenges persist, higher education has been a powerful driver of female empowerment in STEM. Women constitute over 55% of university students in civil engineering programs at leading institutions such as Sharif University of Technology and Tehran University [52].

Although labor market absorption remains low, several women have broken barriers. One example is the all-female team of civil engineers who led the 2019 rehabilitation of historical structures in Yazd, integrating seismic retrofitting with heritage conservation [53].

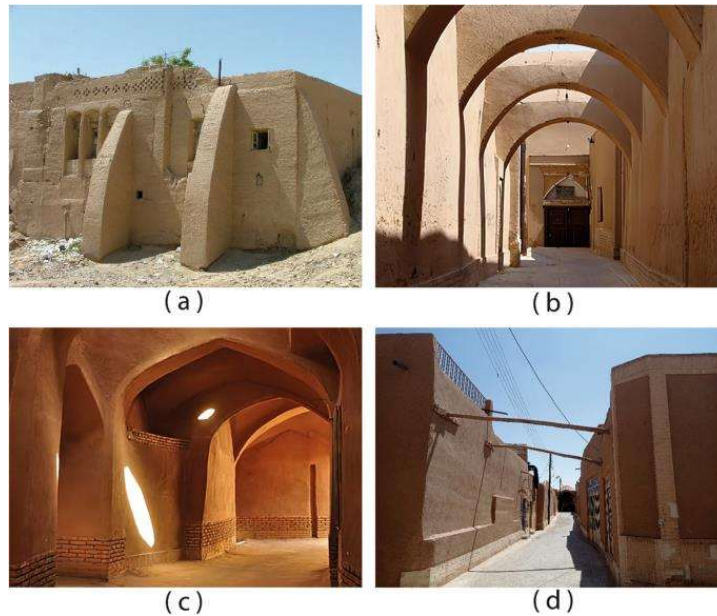


Fig.3 Historic restoration project in Yazd – An example of women engineers leading the integration of seismic retrofitting with heritage conservation.

This case reflects how technical expertise combined with cultural sensitivity can yield innovative outcomes, especially in contexts where female engineers navigate social resistance.



Fig.4 Tabiat (Nature) Bridge in Tehran – A user-centered, sustainable urban design project led by Iranian architect Leila Araghian.

5.4. Rwanda: Post-Conflict Reconstruction with Gender Focus

Rwanda presents a compelling model where post-conflict rebuilding efforts included deliberate policies to involve women in infrastructure and planning. The Rwanda Women Engineers Association (RWEA), founded in 2004, has been instrumental in placing women in leadership roles across national and municipal infrastructure projects [54].

One notable initiative is the Kigali Housing Pilot Project, where women engineers contributed to the design and construction of climate-resilient, low-income housing units. The project

emphasized energy efficiency and community engagement, setting a precedent for gender-responsive planning [55].

6. Future Directions

As civil engineering and architecture evolve to address 21st-century challenges, such as climate change, urbanization, and technological disruption, the full integration of women into these professions becomes both a matter of social justice and a strategic imperative. This section outlines potential future directions to advance gender inclusivity, leadership, and innovation.

6.1. Embedding Gender-Inclusive Education in Early STEM Curricula

Long-term transformation begins with education. Numerous studies have shown that early exposure to hands-on STEM experiences positively affects girls' confidence and interest in technical careers [56]. Educational systems must embed gender-inclusive content, avoid implicit bias in classroom interactions, and showcase female engineering role models in textbooks and curricula. International initiatives such as UNESCO's "Cracking the Code" have demonstrated success by training educators, reforming national STEM curricula, and fostering STEM clubs for girls in secondary schools [57].

6.2. Advancing Digital Platforms for Visibility and Mentorship

The digital era offers unprecedented opportunities to overcome structural barriers. Online mentorship programs, webinars, and virtual career expos can connect women in remote areas with global professionals. Platforms such as LinkedIn, STEMConnector, and LeanIn Circles have proven effective in expanding professional networks and creating communities of support [58]. Investment in digital communities for women in engineering can increase retention, reduce isolation, and foster peer-led learning.

6.3. Promoting Intersectional Policies at the Organizational Level

The next generation of policy must move beyond general gender targets and address intersectional challenges, considering race, socioeconomic background, disability, and geographic location. Inclusive workplace policies should include transparent hiring and promotion criteria, gender audits, anti-harassment training, and paid parental leave for all genders [59].

Corporations such as Arup and AECOM have piloted "Gender Equity Certification" models, linking internal policy compliance with external accountability mechanisms [60]. In Iran, targeted policies such as flexible work arrangements, clear anti-discrimination guidelines, and stronger university-to-industry pipelines can help address the persistent gap between female graduates and their professional participation.

6.4. Gender Lens in Infrastructure and Urban Resilience Planning

Future infrastructure must be designed with a gender-sensitive lens, ensuring public safety, access, and comfort for all users. Gender-sensitive urban planning incorporates lighting, public transport access, restrooms, and breastfeeding facilities in a way that addresses women's specific needs [61]. Emerging concepts such as "feminist infrastructure" and "caring cities" emphasize empathy,

safety, and equity in the built environment and are gaining traction in European and Latin American cities [62].

6.5. Increasing Female Representation in Leadership and Policy-Making

It is critical that women are represented in engineering policy bodies, research funding committees, and urban governance councils. Without their voices, key design and planning decisions risk ignoring gendered impacts. A meta-analysis in *Leadership Quarterly* found that organizations with gender-balanced boards demonstrated stronger innovation, stakeholder trust, and long-term sustainability [63].

7. Conclusion

This research has demonstrated that the role of women in civil engineering and architecture is both historically significant and increasingly vital to the future of sustainable, inclusive development. Through a comprehensive analysis of historical contributions, current challenges, global case studies, and future directions, it is evident that while women have achieved considerable progress in education and public recognition, systemic barriers—including gender bias, limited access to leadership roles, and lack of institutional support—continue to constrain their full professional integration. The study highlights that structural reforms alone are insufficient; cultural transformation, inclusive policymaking, and proactive institutional engagement are also required. Successful international examples from Sweden, Rwanda, India, and even grassroots progress in Iran reveal that when women are meaningfully included, engineering and design outcomes become more innovative, equitable, and socially responsive. As the built environment continues to intersect with pressing global issues such as climate change, urban resilience, and digital transformation, the full empowerment of women in engineering and architecture is not only a moral imperative but a strategic necessity for advancing technological excellence and societal well-being. Therefore, multi-level, interdisciplinary efforts must continue to ensure that future infrastructure is shaped by diverse perspectives and inclusive leadership.

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